

Human Anatomy & Physiology

Eighth Edition



Elaine N. Marieb
Katja Hoehn

Chapter 27

The Reproductive Systems

Reproductive System

- Primary sex organs (gonads): testes and ovaries
 - Produce sex cells (gametes)
 - Secrete steroid sex hormones
 - Androgens (males)
 - Estrogens and progesterone (females)
- Accessory reproductive organs: ducts, glands, and external genitalia

Reproductive System

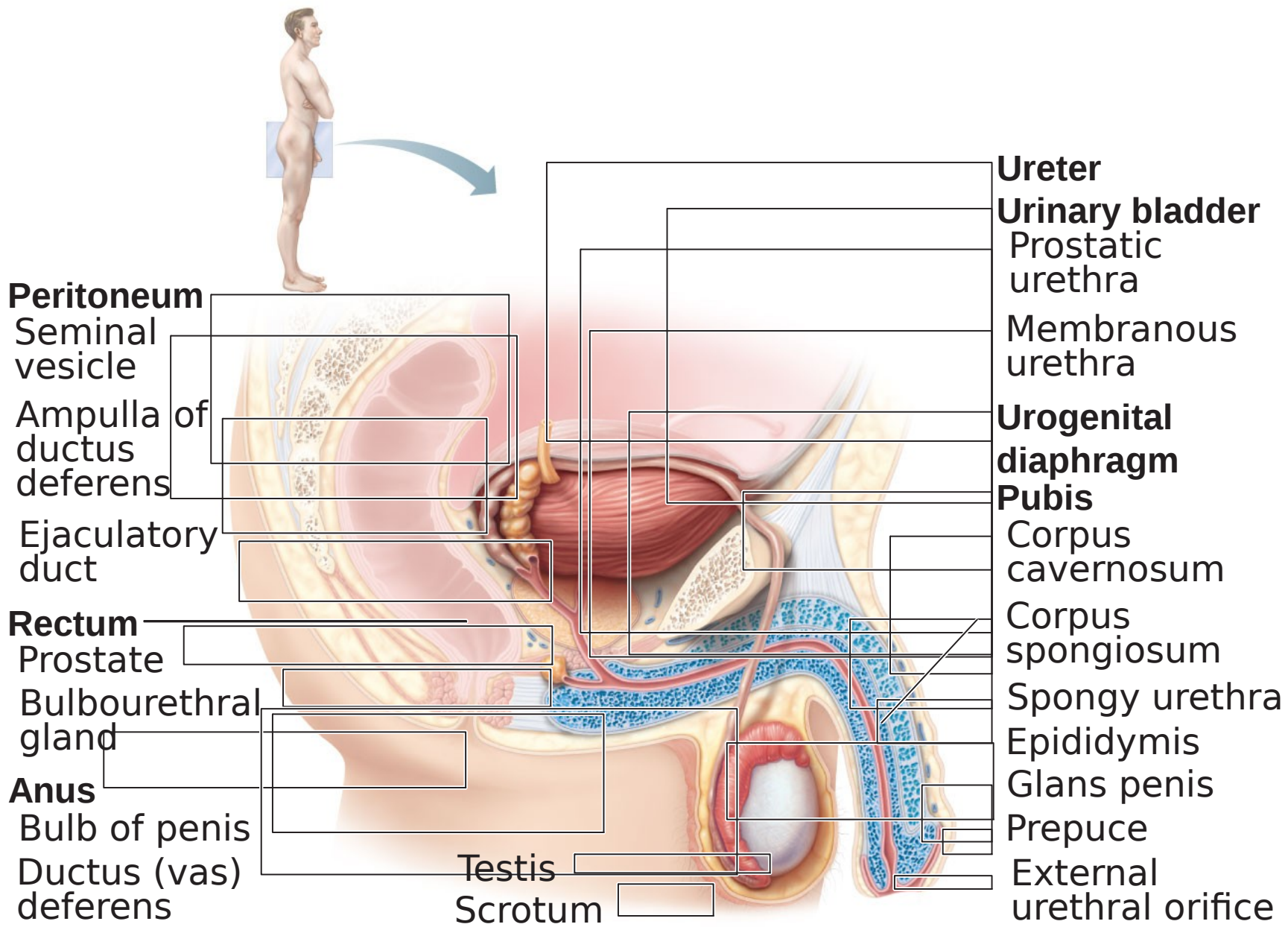
- Sex hormones play roles in
 - Development and function of the reproductive organs
 - Sexual behavior and drives
 - Growth and development of many other organs and tissues

Male Reproductive System

- Testes (within the scrotum) produce sperm
- Sperm are delivered to the exterior through a system of ducts
 - Epididymis, ductus deferens, ejaculatory duct, and the urethra

Male Reproductive System

- Accessory sex glands: seminal vesicles, prostate, and bulbourethral glands
 - Empty secretions into the ducts during ejaculation



Peritoneum

Seminal vesicle

Ampulla of ductus deferens

Ejaculatory duct

Rectum

Prostate

Bulbourethral gland

Anus

Bulb of penis

Ductus (vas) deferens

Testis

Scrotum

Ureter

Urinary bladder

Prostatic urethra

Membranous urethra

Urogenital diaphragm

Pubis

Corpus cavernosum

Corpus spongiosum

Spongy urethra

Epididymis

Glans penis

Prepuce

External urethral orifice

Figure 27.1

The Scrotum

- Sac of skin and superficial fascia
 - Hangs outside the abdominopelvic cavity
 - Contains paired testes
 - 3°C lower than core body temperature
(temperature necessary for sperm production)

The Scrotum

- Temperature is kept constant by two sets of muscles
 - Smooth muscle that wrinkles scrotal skin (dartos muscle)
 - Bands of skeletal muscle that elevate the testes (cremaster muscles)

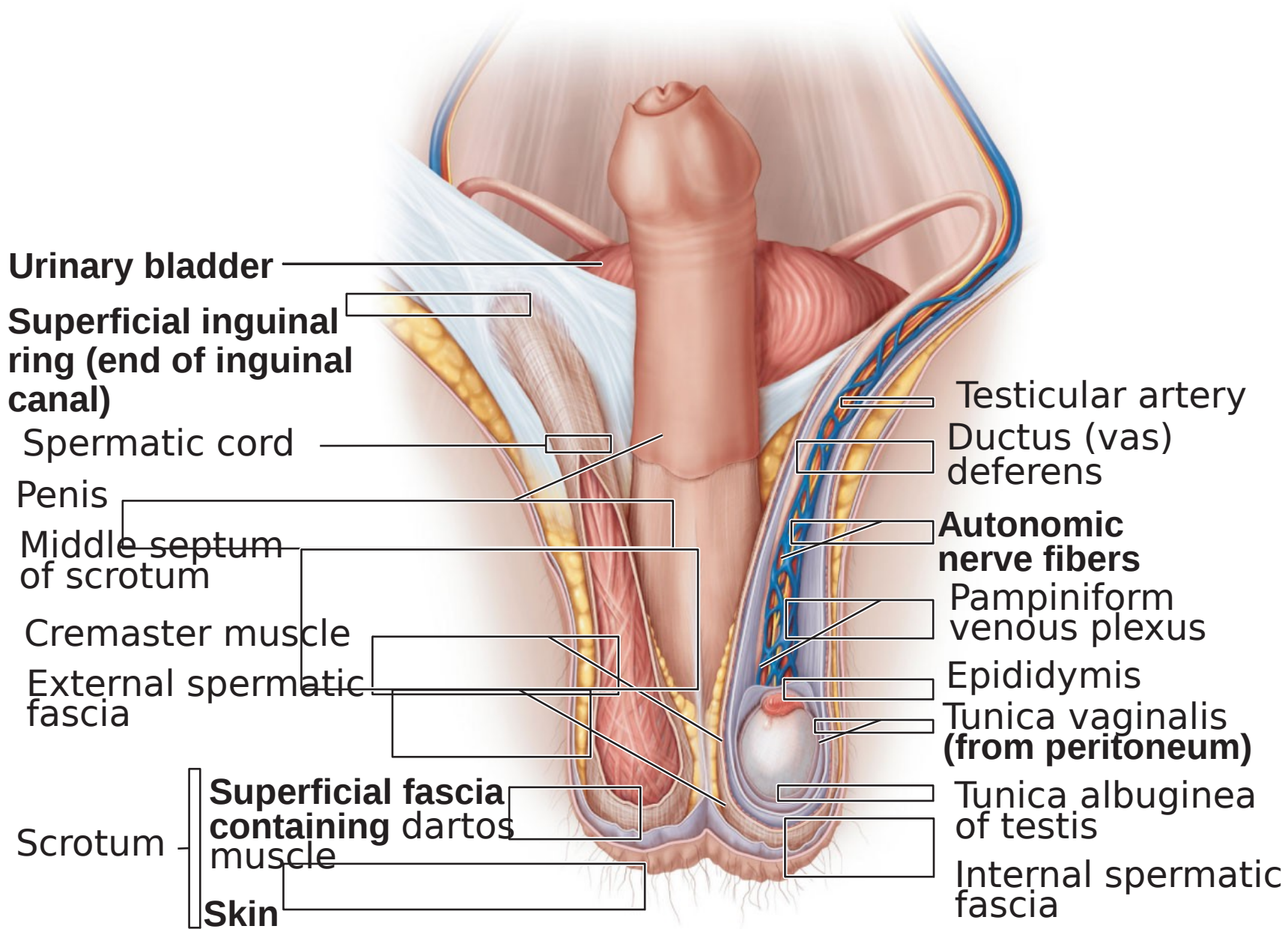


Figure 27.2

The Testes

- Each is surrounded by two tunics
 - Tunica vaginalis, derived from peritoneum
 - Tunica albuginea, the fibrous capsule
- Septa divide the testis into 250–300 lobules, each containing 1–4 seminiferous tubules (site of sperm production)

The Testes

- Sperm are conveyed through
 - Seminiferous tubules
 - Tubulus rectus
 - Rete testis
 - Efferent ductules
 - Epididymis

The Testes

- Blood supply comes from the testicular arteries and testicular veins
- Spermatic cord encloses ductus (vas) deferens, plus nerve fibers, blood vessels, and lymphatics that supply the testes

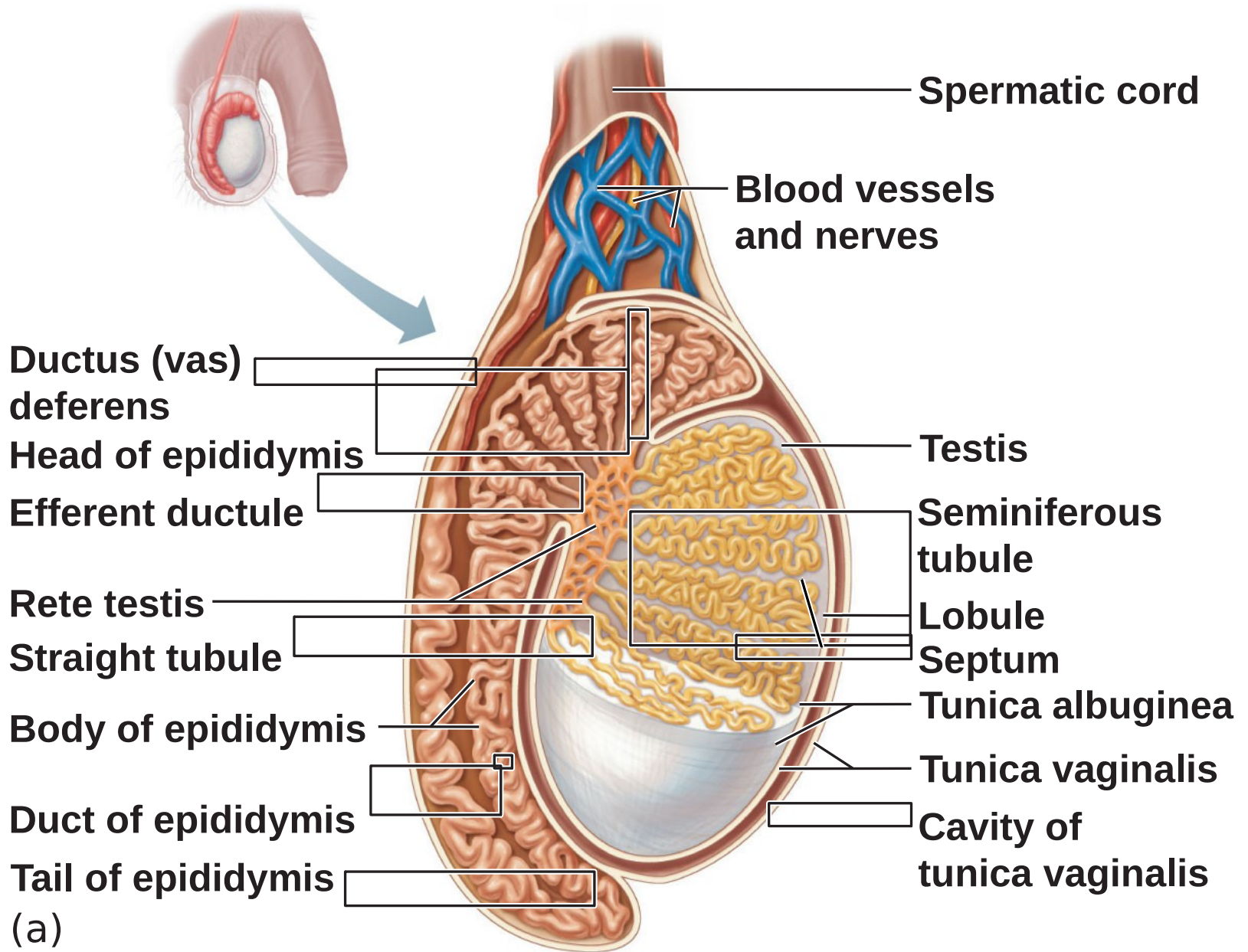
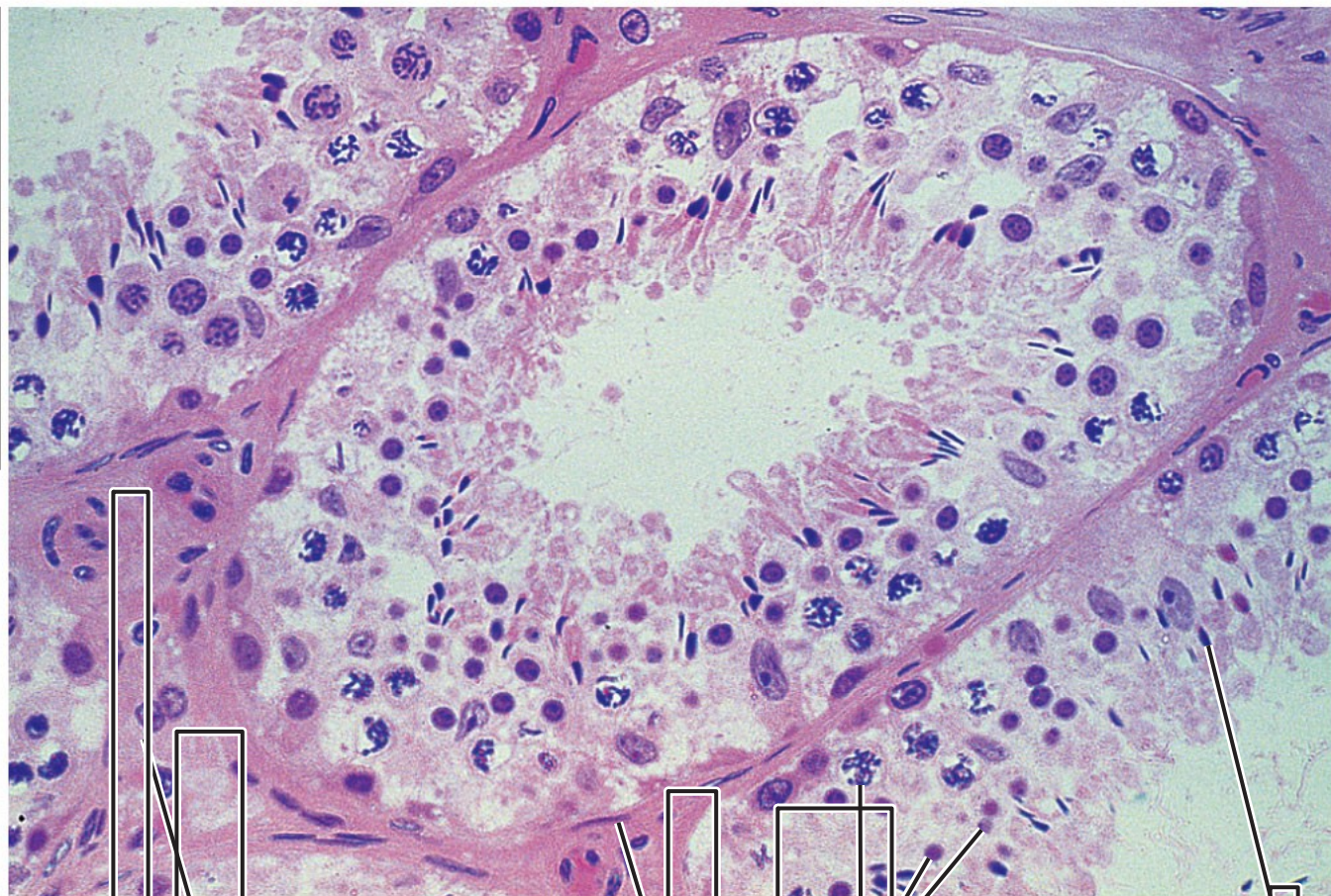


Figure 27.3a

The Testes

- Interstitial (Leydig) cells outside the seminiferous tubules produce androgens

Seminiferous tubule



(c)

Interstitial cells

Areolar connective tissue

Myoid cells

Spermatogenic cells in tubule epithelium

Sperm

Figure 27.3c

The Penis

- External genitalia are the scrotum and the penis
- Penis is the male copulatory organ

The Penis

- Penis consists of
 - Root and shaft that ends in the glans penis
 - Prepuce, or foreskin—the cuff of loose skin covering the glans
 - Circumcision is the surgical removal of the foreskin
 - Crura
 - The proximal end surrounded by ischiocavernosus muscle; anchors penis to the pubic arch

The Penis

- Spongy urethra and three cylindrical bodies of erectile tissue (spongy network of connective tissue and smooth muscle with vascular spaces)
 - Corpus spongiosum surrounds the urethra and expands to form the glans and bulb
 - Corpora cavernosa are paired dorsal erectile bodies
- Erection: erectile tissue fills with blood, causing the penis to enlarge and become rigid

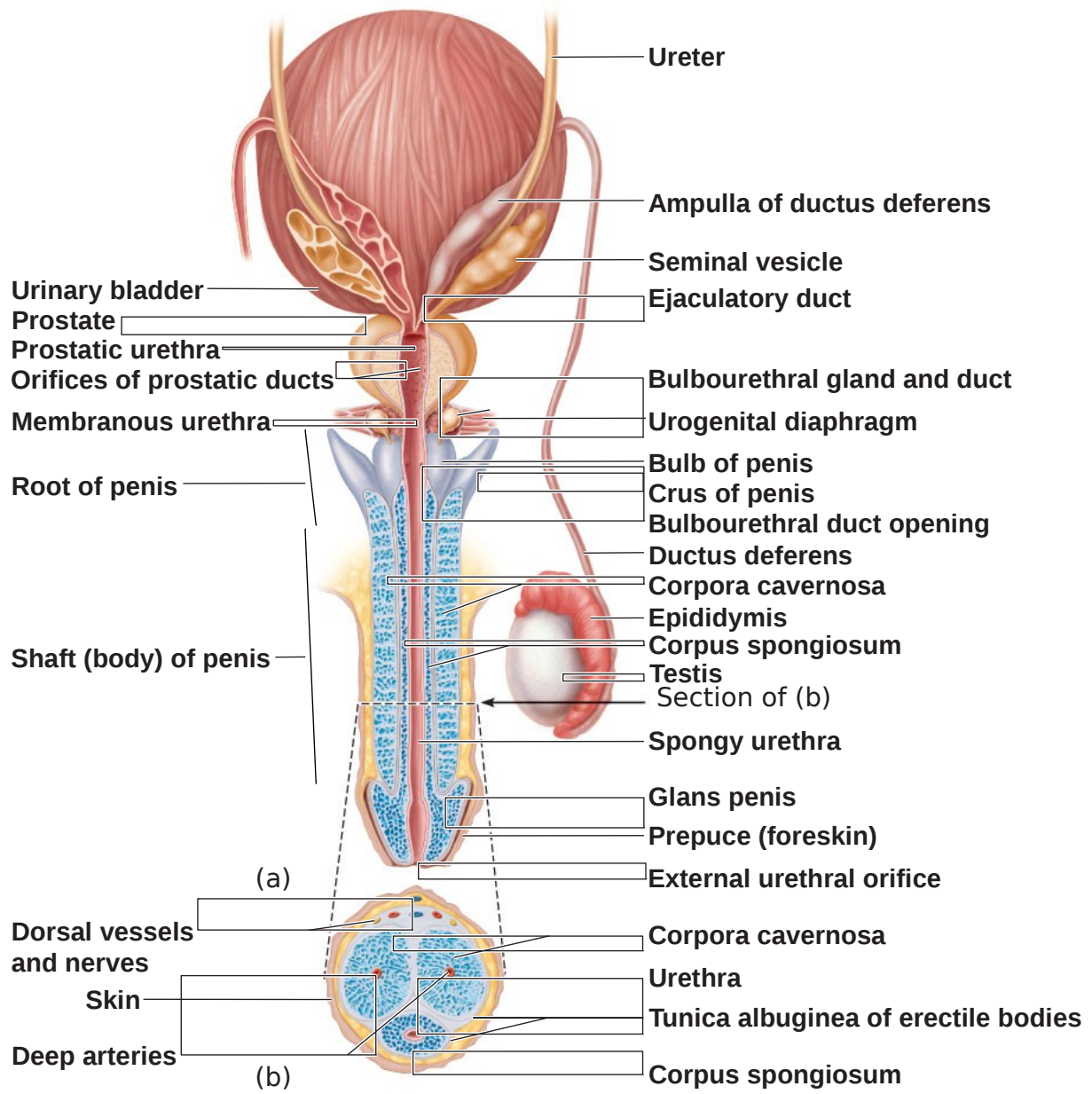


Figure 27.4

The Male Duct System

- Epididymis
- Ductus deferens
- Ejaculatory duct
- Urethra

Epididymis

- Head: contains the efferent ductules
- Duct of the epididymis
 - Microvilli (stereocilia) absorb testicular fluid and pass nutrients to stored sperm
- Immature, nonmotile sperm enter, pass slowly through, and mature to become motile
- During ejaculation the epididymis contracts, expelling sperm into the ductus deferens

Ductus Deferens and Ejaculatory Duct

- Ductus deferens
 - Passes through the inguinal canal
 - Expands to form the ampulla and then joins the duct of the seminal vesicle to form the ejaculatory duct
- Propels sperm from the epididymis to the urethra
- Vasectomy: cutting and ligating the ductus deferens, which is a nearly 100% effective form of birth control

Urethra

- Conveys both urine and semen (at different times)
- Has three regions
 1. Prostatic urethra
 2. Membranous urethra
 3. Spongy (penile) urethra

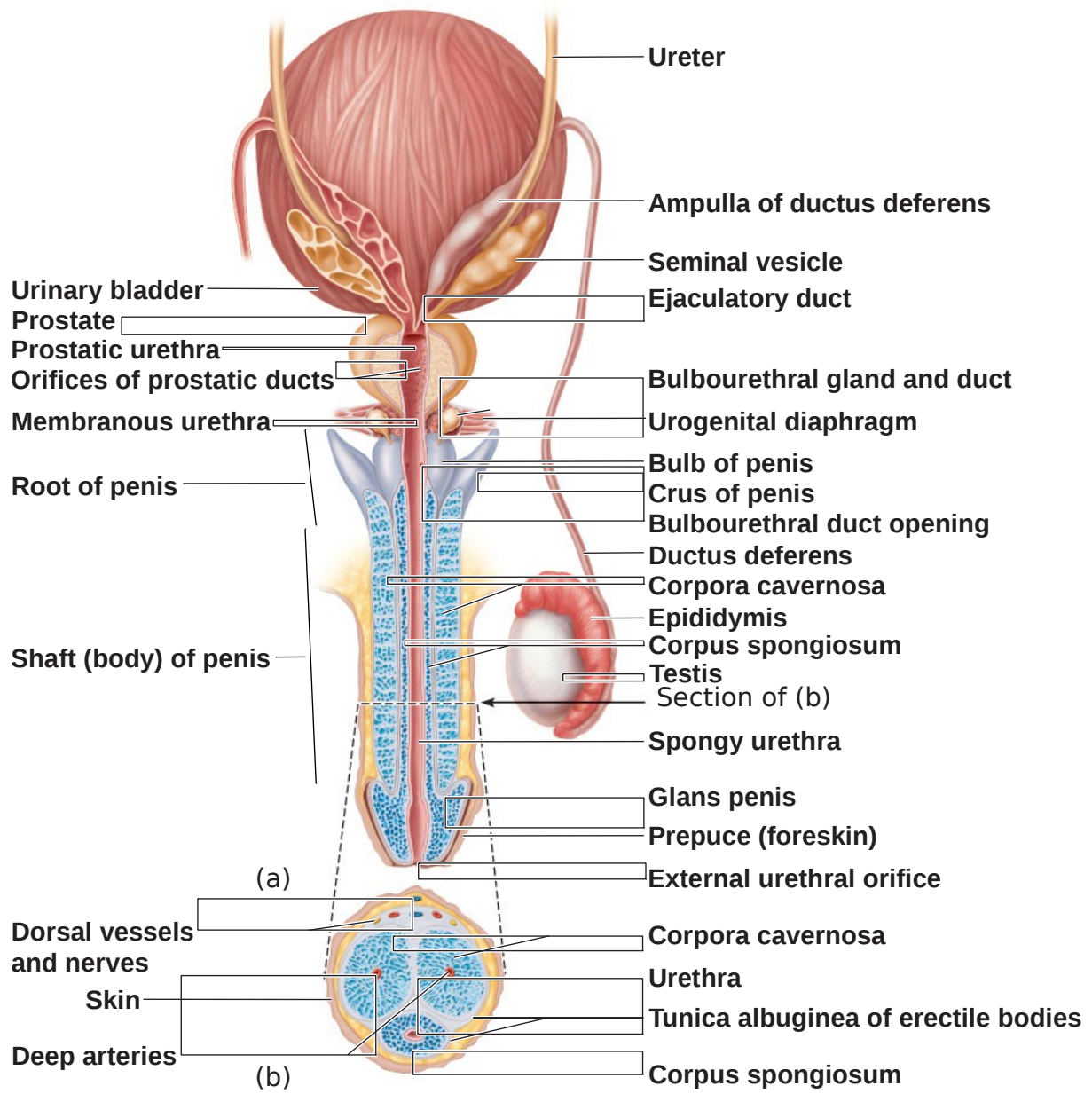


Figure 27.4

Accessory Glands: Seminal Vesicles

- Produces viscous alkaline seminal fluid
 - Fructose, ascorbic acid, coagulating enzyme (vesiculase), and prostaglandins
 - 70% of the volume of semen
- Duct of seminal vesicle joins the ductus deferens to form the ejaculatory duct

Accessory Glands: Prostate

- Encircles part of the urethra inferior to the bladder
- Secretes milky, slightly acid fluid:
 - Contains citrate, enzymes, and prostate-specific antigen (PSA)
 - Plays a role in the activation of sperm
 - Enters the prostatic urethra during ejaculation

Accessory Glands:

Bulbourethral Glands

(Cowper's Glands)

- Pea-sized glands inferior to the prostate
- Prior to ejaculation, produce thick, clear mucus
 - Lubricates the glans penis
 - Neutralizes traces of acidic urine in the urethra

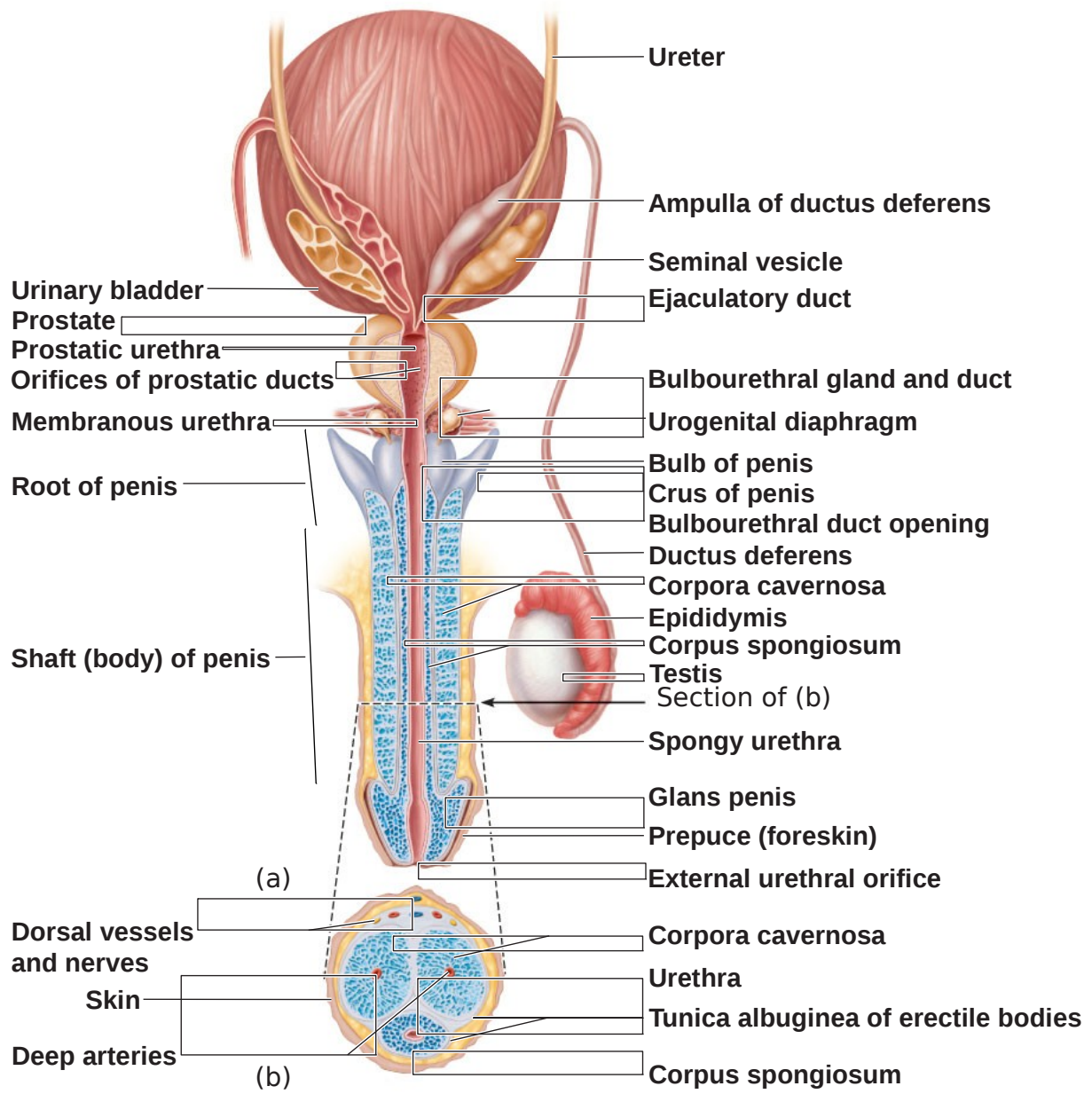


Figure 27.4

Semen

- Mixture of sperm and accessory gland secretions
- Contains nutrients (fructose), protects and activates sperm, and facilitates their movement (e.g., relaxin)
- Prostaglandins in semen
 - Decrease the viscosity of mucus in the cervix
 - Stimulate reverse peristalsis in the uterus

Semen

- Alkalinity neutralizes the acid in the male urethra and female vagina
- Antibiotic chemicals destroy certain bacteria
- Clotting factors coagulate semen just after ejaculation, then fibrinolysin liquefies it
- Only 2–5 ml of semen are ejaculated, containing 20–150 million sperm/ml

Male Sexual Response

- Erection
 - Enlargement and stiffening of the penis from engorgement of erectile tissue with blood
 - Initiated by sexual stimuli, including:
 - Touch and mechanical stimulation of the penis
 - Erotic sights, sounds, and smells
 - Can be induced or inhibited by emotions or higher mental activity

Male Sexual Response

- Erection:
 - Parasympathetic reflex promotes release of nitric oxide (NO)
 - NO causes erectile tissue to fill with blood
 - Expansion of the corpora cavernosa
 - Compresses drainage veins and maintains engorgement
 - Corpus spongiosum keeps the urethra open
 - Impotence: the inability to attain erection

Male Sexual Response

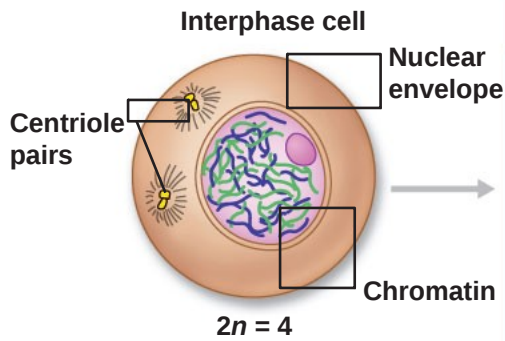
- Ejaculation
 - Propulsion of semen from the male duct system
 - Sympathetic spinal reflex causes
 - Ducts and accessory glands to contract and empty their contents
 - Bladder sphincter muscle to constrict, preventing the expulsion of urine
 - Bulbospongiosus muscles to undergo a rapid series of contractions

Spermatogenesis

- Sequence of events that produces sperm in the seminiferous tubules of the testes
- Most body cells are diploid ($2n$) and contain
 - Two sets of chromosomes (one maternal, one paternal)
 - 23 pairs of homologous chromosomes
- Gametes are haploid (n) and contain
 - 23 chromosomes

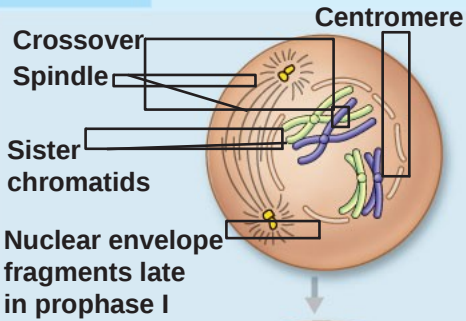
Meiosis

- Gamete formation involves meiosis
 - Nuclear division in the gonads in which the number of chromosomes is halved (from $2n$ to n)
 - Two consecutive cell divisions (meiosis I and II) following one round of DNA replication
 - Produces four daughter cells
 - Introduces genetic variation



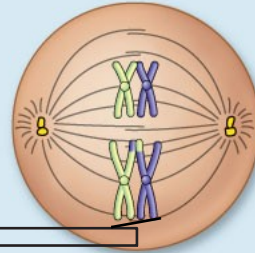
Interphase events
 As in mitosis, meiosis is preceded by DNA replication and other preparations for cell division.

MEIOSIS I



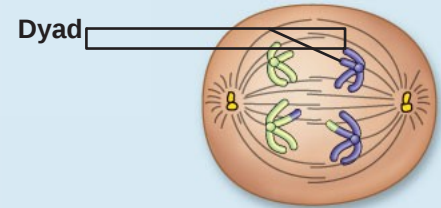
Prophase I

Prophase events occur, as in mitosis. Additionally, synapsis occurs: Homologous chromosomes come together along their length to form tetrads. During synapsis, the “arms” of homologous chromatids wrap around each other, forming several crossovers. The nonsister chromatids trade segments at points of crossover. Crossover is followed through the diagrams below.



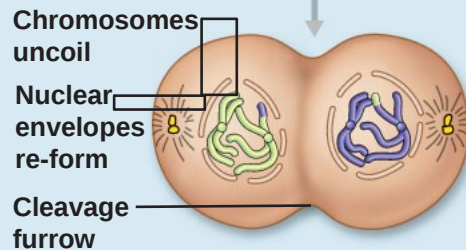
Metaphase I

The tetrads align randomly on the spindle equator in preparation for anaphase.



Anaphase I

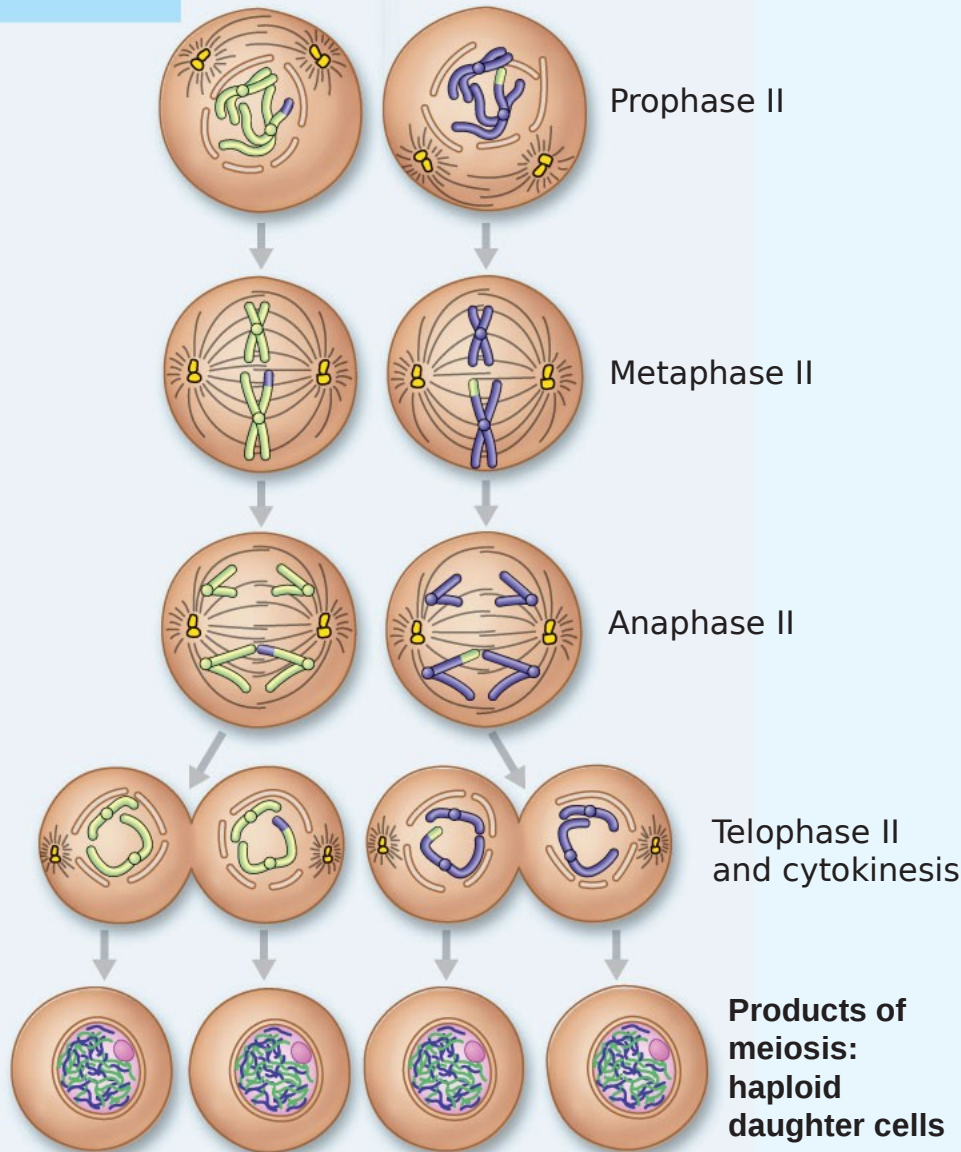
Unlike anaphase of mitosis, the centromeres do not separate during anaphase I of meiosis, so the sister chromatids (dyads) remain firmly attached. However, the homologous chromosomes do separate from each other and the dyads move toward opposite poles of the cell.



Telophase I

The nuclear membranes re-form around the chromosomal masses, the spindle breaks down, and the chromatin reappears as telophase and cytokinesis are completed. The 2 daughter cells (now haploid) enter a second interphase-like period, called interkinesis, before meiosis II occurs. There is no second replication of DNA before meiosis II.

MEIOSIS II



Meiosis II begins with the products of meiosis I (2 haploid daughter cells) and undergoes a mitosis-like nuclear division process referred to as the equational division of meiosis.

After progressing through the phases of meiosis and cytokinesis, the product is 4 haploid cells, each genetically different from the original mother cell. (During human spermatogenesis, the daughter cells remain interconnected by cytoplasmic extensions during the meiotic phases.)

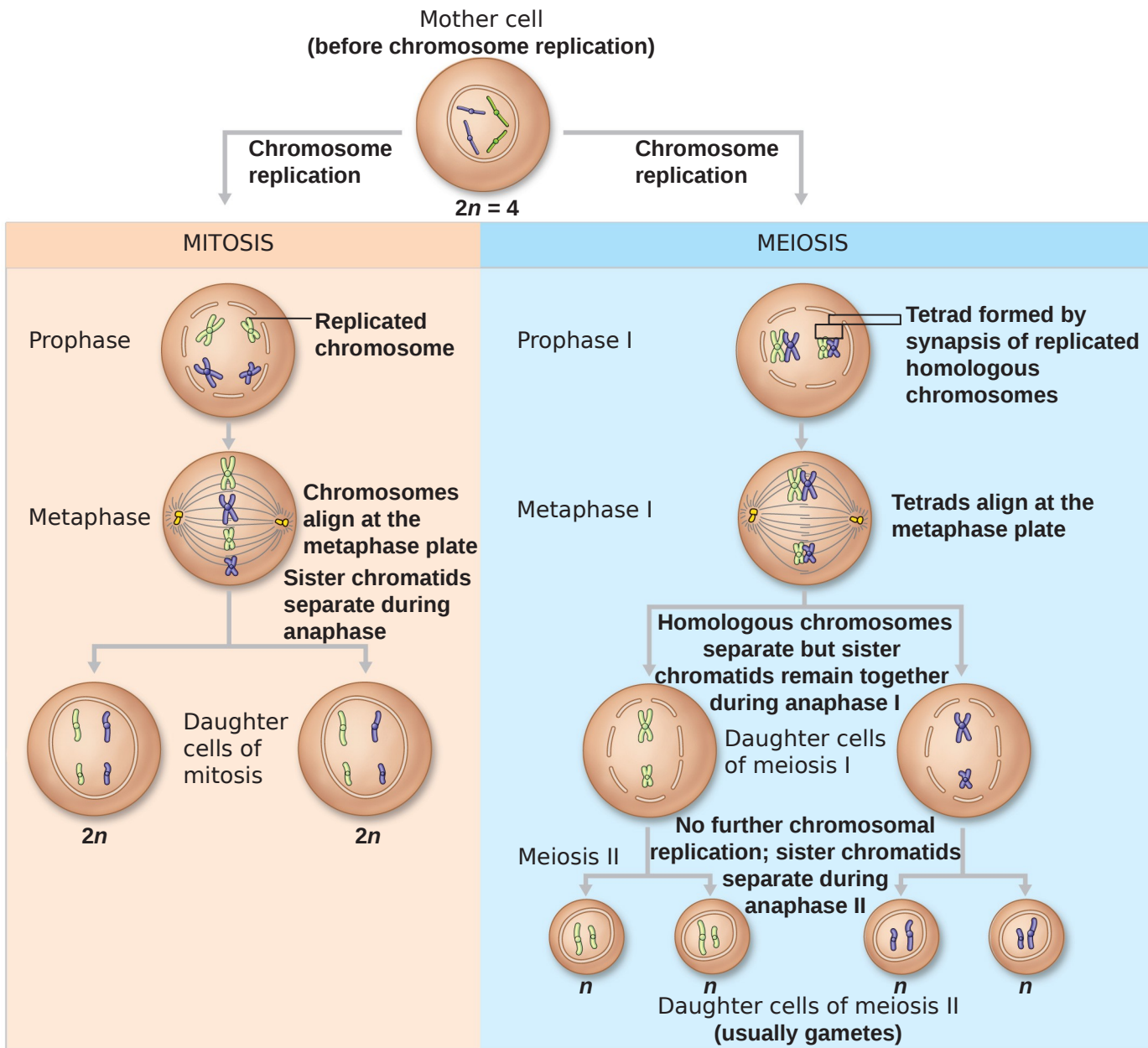


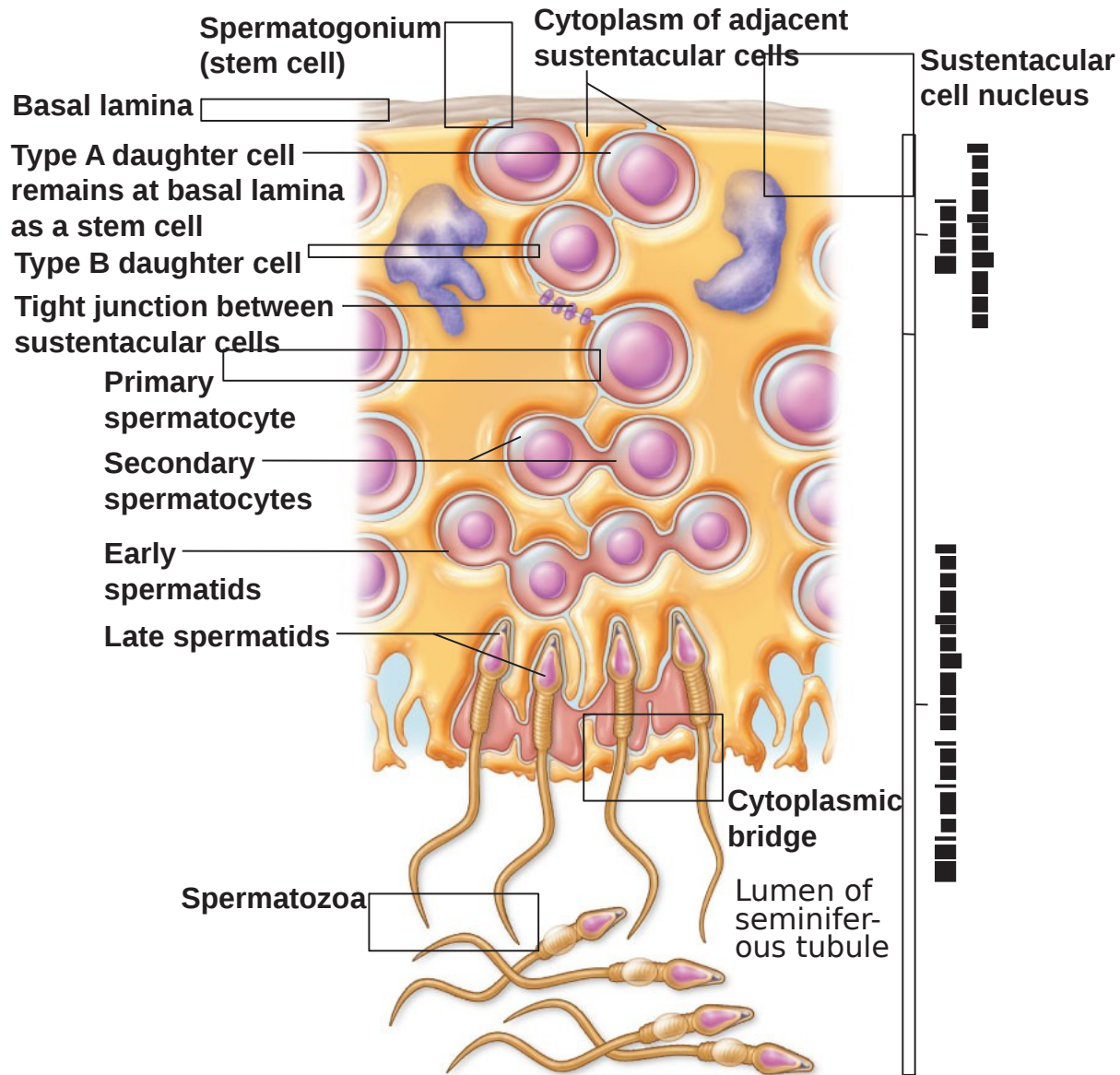
Figure 27.5 (1 of 2)

Spermatogenesis

- Spermatogenic cells give rise to sperm
 - Mitosis
 - Spermatogonia form spermatocytes
 - Meiosis
 - Spermatocytes form spermatids
 - Spermiogenesis
 - Spermatids become sperm



(a) Scanning electron micrograph of a cross-sectional view of a seminiferous tubule (225x)



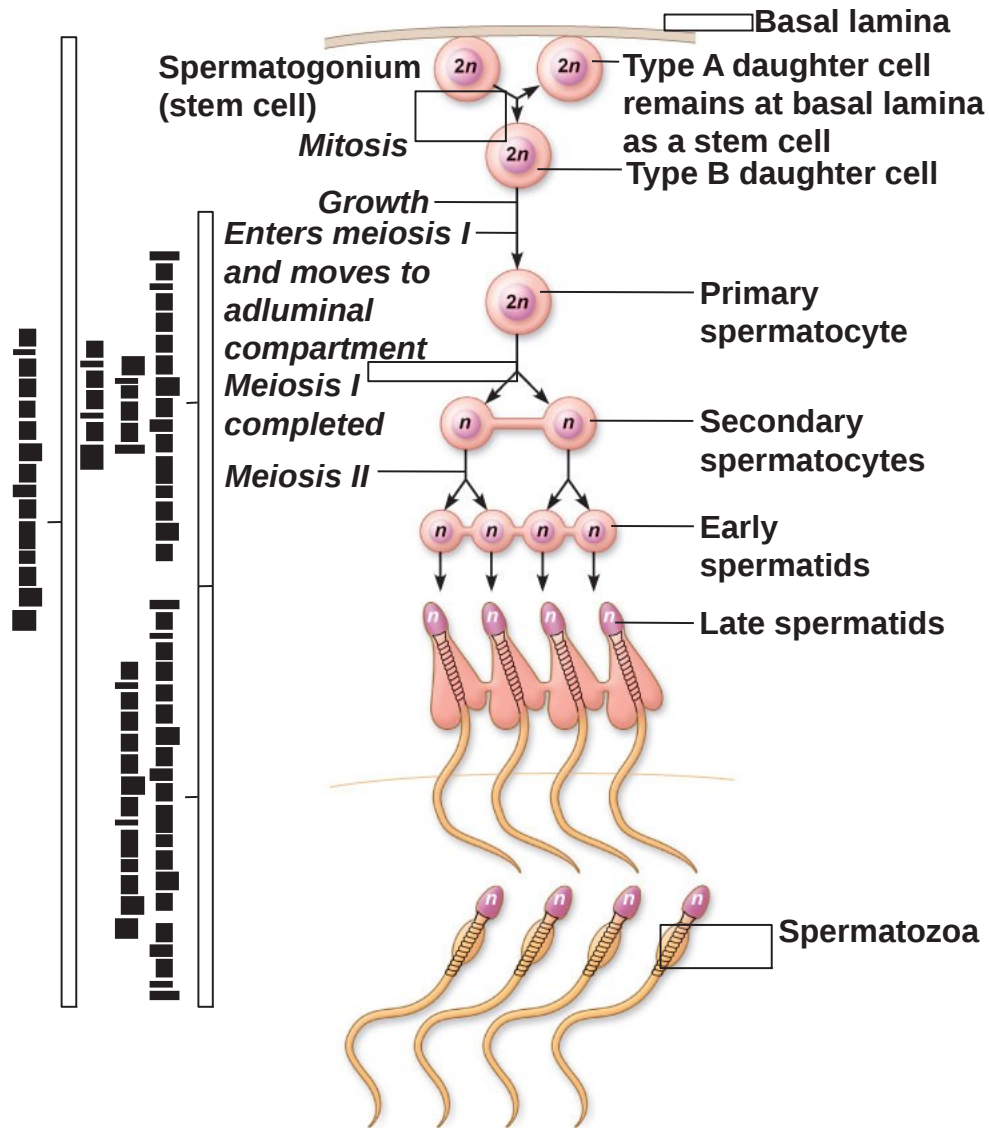
(c) A portion of the seminiferous tubule wall, showing the spermatogenic cells surrounded by sustentacular cells (colored gold)

Mitosis of Spermatogonia

- Begins at puberty
- Spermatogonia
 - Stem cells in contact with the epithelial basal lamina
 - Each mitotic division → Two cells. One differentiates into a primary spermatocyte, while the other remains a spermatogonium.

Meiosis: Spermatocytes to Spermatids

- Meiosis I
 - Primary spermatocyte ($2n$) → two secondary spermatocytes (n)
- Meiosis II
 - Each secondary spermatocyte (n) → two spermatids (n)
 - Spermatid: small nonmotile cells close to the lumen of the tubule



(b) Events of spermatogenesis, showing the relative position of various spermatogenic cells

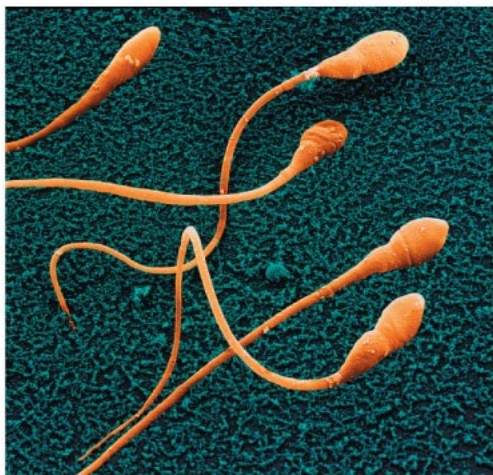
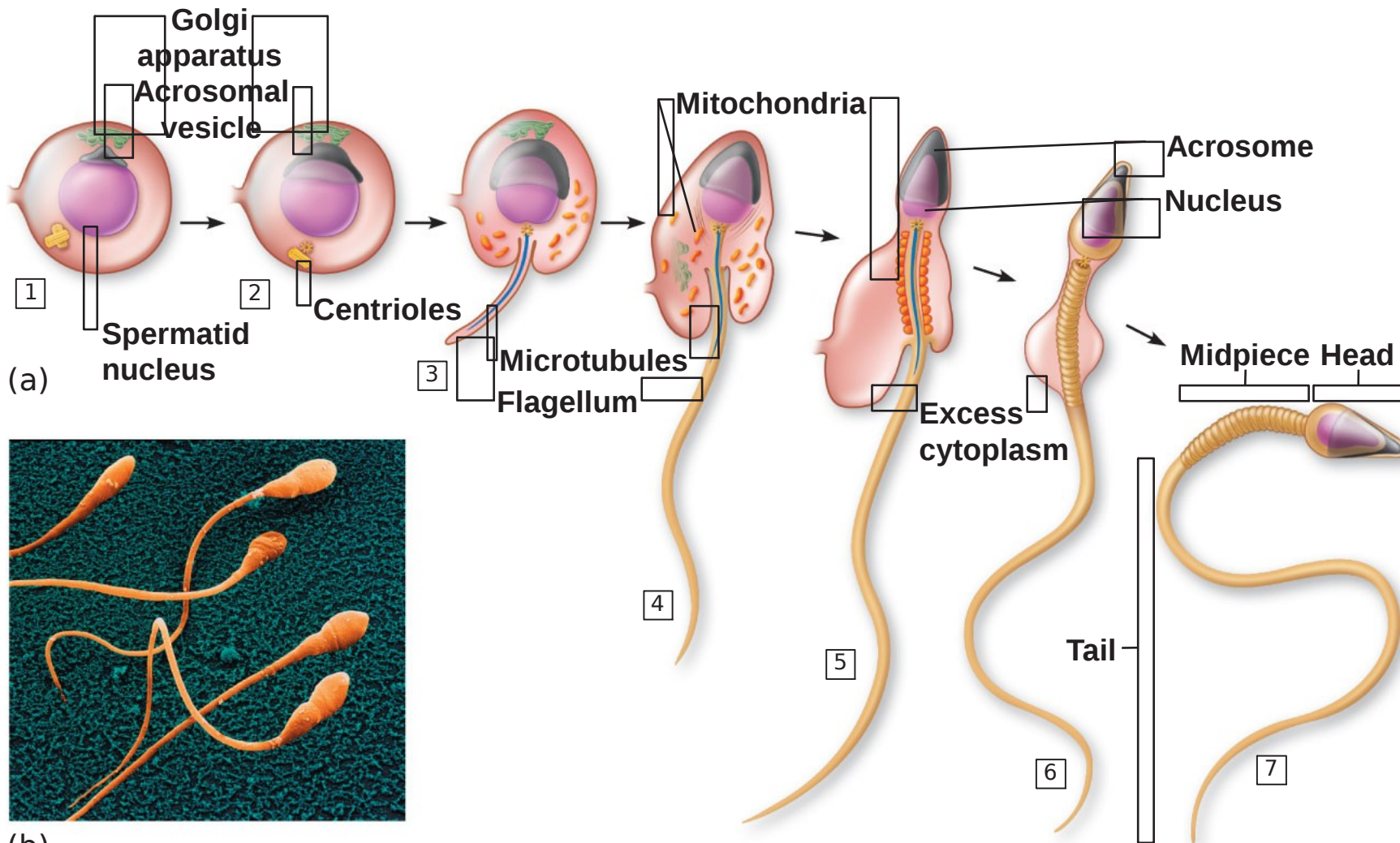
Spermiogenesis: Spermatids to Sperm

- Spermatids lose excess cytoplasm and form a tail, becoming spermatozoa (sperm)

Sperm

- Major regions
 1. Head: genetic region; nucleus and helmetlike acrosome containing hydrolytic enzymes that enable the sperm to penetrate an egg
 2. Midpiece: metabolic region; mitochondria
 3. Tail: locomotor region; flagellum

Approximately 24 days



(b)

Figure 27.8a, b

Role of Sustentacular Cells

- Tight junctions form a blood-testis barrier
 - Prevents sperm antigens from escaping into the blood where they would activate the immune system
- Because sperm are not formed until puberty, they are absent during immune system development, and would not be recognized as “self”

Male Secondary Sex Characteristics

- Features induced in the nonreproductive organs by male sex hormones (mainly testosterone)
 - 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

Female Reproductive

Anatomy

- Ovaries: female gonads
 - Produce female gametes (ova)
 - Secrete female sex hormones (estrogen and progesterone)
- Accessory ducts include
 - Uterine tubes
 - Uterus
 - Vagina

Female Reproductive Anatomy

- Internal genitalia
 - Ovaries
 - Uterine tubes
 - Uterus
 - Vagina
- External genitalia
 - Clitoris
 - Labia Majora and Minora
 - Orifices of paraurethral glands and greater vestibular glands

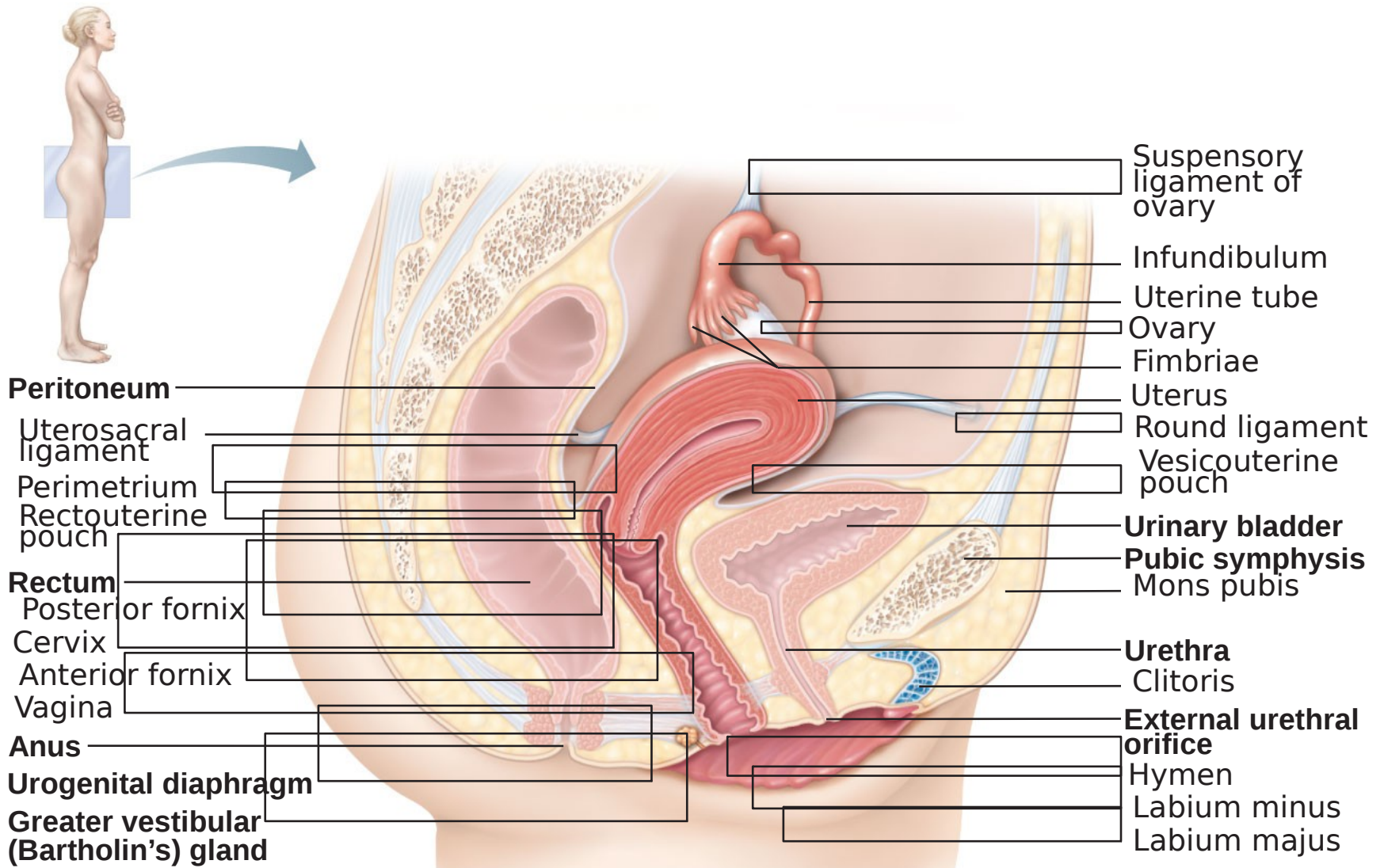


Figure 27.10

Ovaries

- Held in place by several ligaments
 - Ovarian ligament: anchors ovary medially to the uterus
 - Suspensory ligament: anchors ovary laterally to the pelvic wall
 - Mesovarium: suspends the ovary
- Broad ligament: supports the uterine tubes, uterus, and vagina; also contains the suspensory ligament and the mesovarium

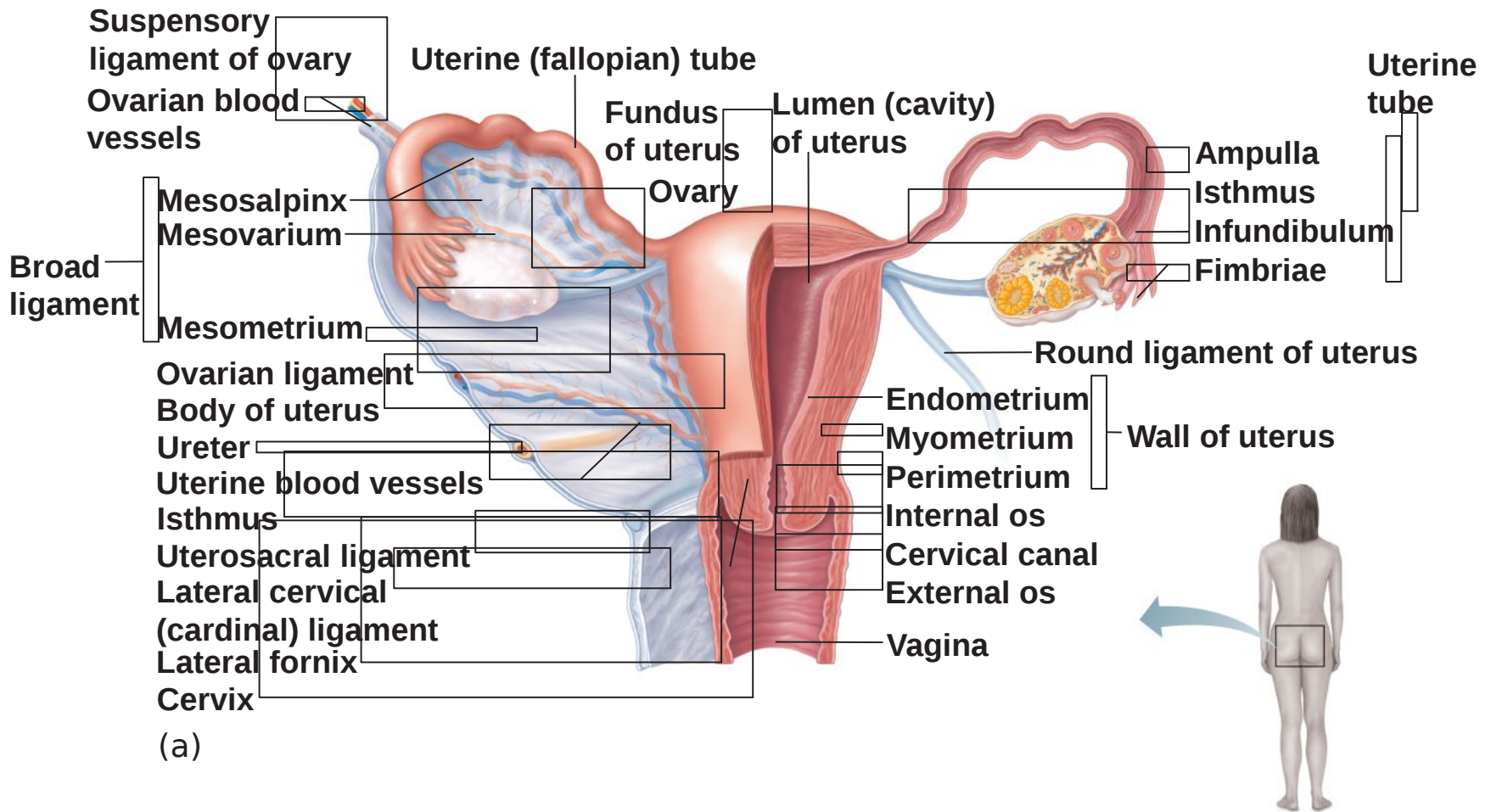


Figure 27.12a

Ovaries

- Blood supply: ovarian arteries and the ovarian branch of the uterine artery
- Surrounded by a fibrous tunica albuginea
- Two poorly defined regions
 - Cortex: ovarian follicles
 - Medulla: large blood vessels and nerves

Ovaries

- Follicle

- Immature egg (oocyte) surrounded by

- Follicle cells (one cell layer thick)

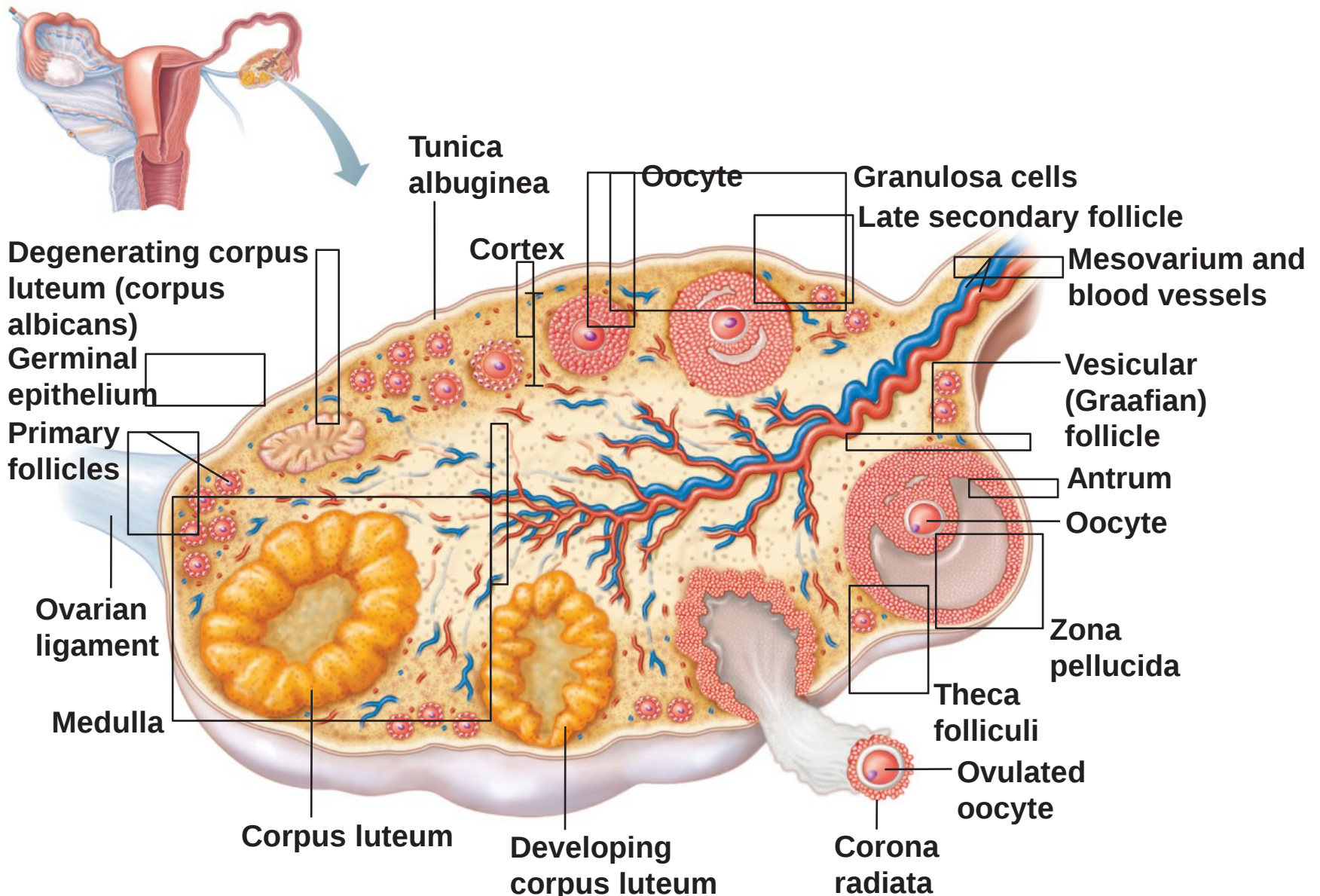
- Granulosa cells (when more than one layer is present)

Follicles

- Several stages of development
 - Primordial follicle: squamouslike follicle cells + oocyte
 - Primary follicle: cuboidal or columnar follicle cells + oocyte
 - Secondary follicle: two or more layers of granulosa cells + oocyte
 - Late secondary follicle: contains fluid-filled space between granulosa cells; coalesces to form a central antrum

Ovaries

- Vesicular (Graafian) follicle
 - Fluid-filled antrum forms; follicle bulges from ovary surface
- Ovulation
 - Ejection of the oocyte from the ripening follicle
- Corpus luteum develops from ruptured follicle after ovulation



(a) Diagrammatic view of an ovary sectioned to reveal the follicles in its interior

Female Duct System

- Uterine (fallopian) tubes or oviducts
- Uterus
- Vagina

Uterine Tubes

- Ampulla
 - Distal expansion with infundibulum near ovary
 - Usual site of fertilization
- Ciliated fibriae of infundibulum create currents to move oocyte into uterine tube
- Isthmus: constricted region where tube joins uterus

Uterine Tubes

- Oocyte is carried along by peristalsis and ciliary action
- Nonciliated cells nourish the oocyte and the sperm
- Mesosalpinx: mesentery that supports the uterine tubes

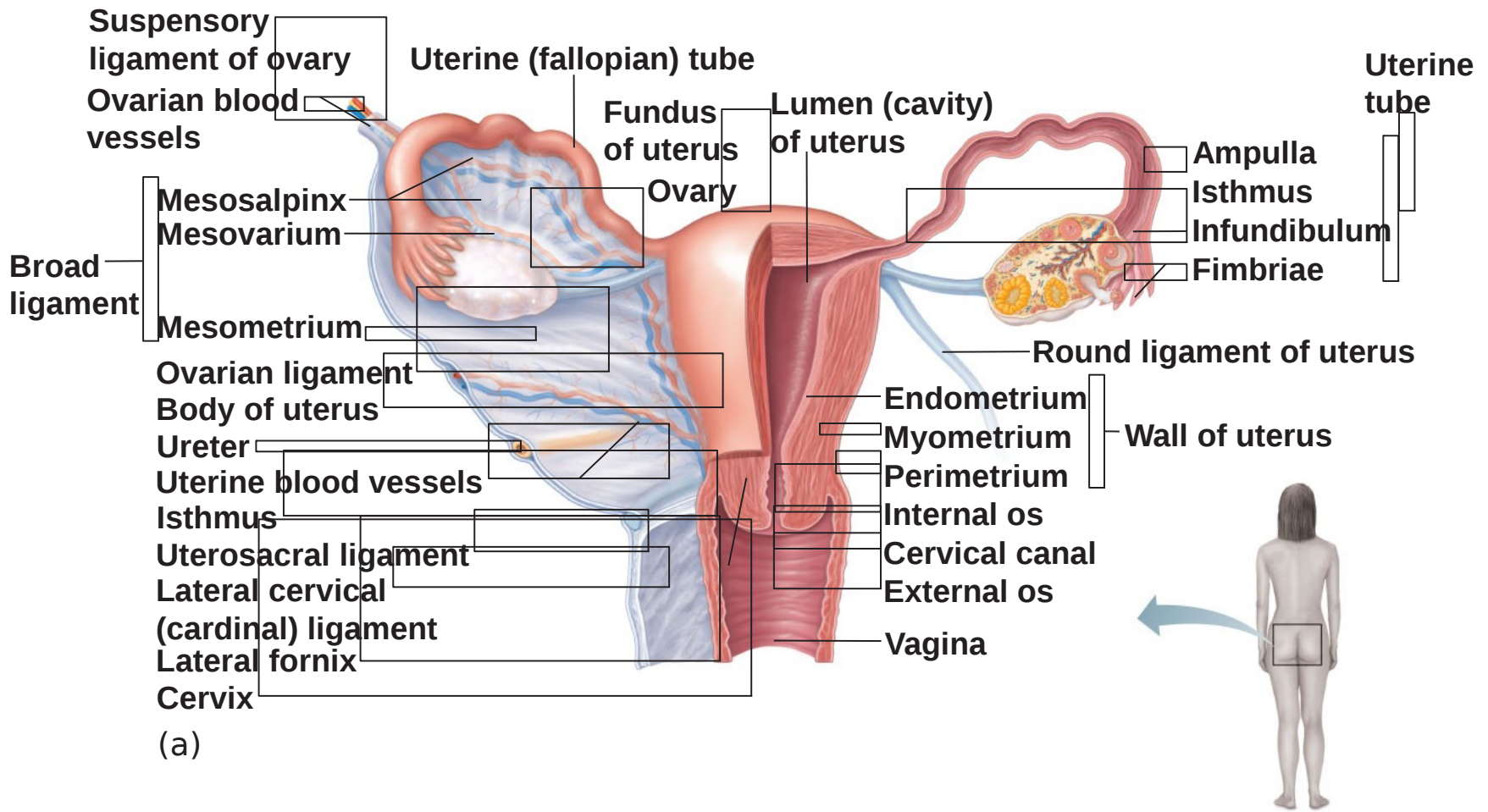


Figure 27.12a

Uterus

- Body: major portion
- Fundus: rounded superior region
- Isthmus: narrowed inferior region

Uterus

- Cervix: narrow neck, or outlet; projects into the vagina
- Cervical canal communicates with the
 - Vagina via the external os
 - Uterine body via the internal os
- Cervical glands secrete mucus that blocks sperm entry except during midcycle

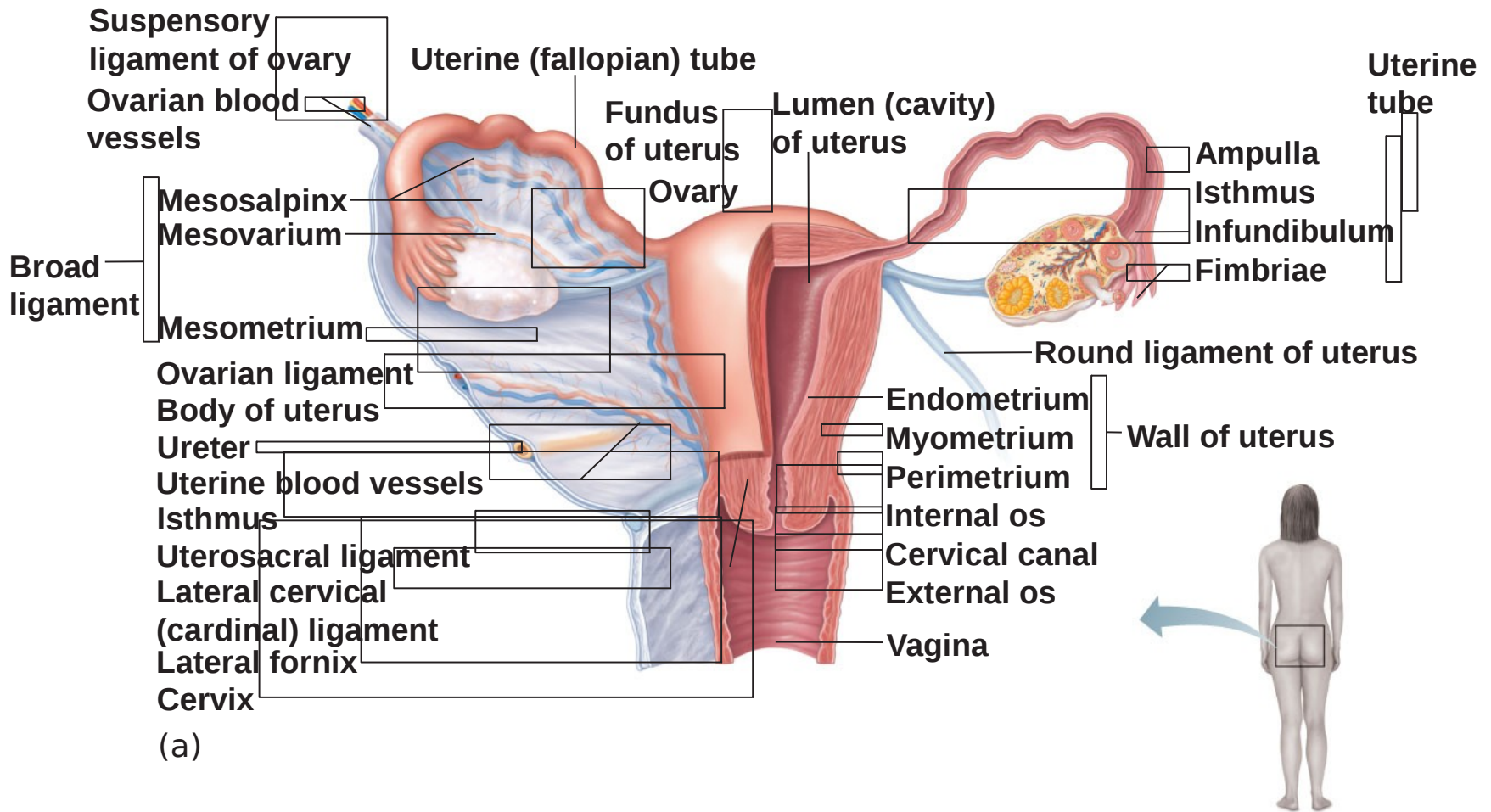


Figure 27.12a

Uterine Wall

- Three layers
 1. Perimetrium: serous layer (visceral peritoneum)
 2. Myometrium: interlacing layers of smooth muscle
 3. Endometrium: mucosal lining

Endometrium

- Stratum functionalis (functional layer)
 - Changes in response to ovarian hormone cycles
 - Is shed during menstruation
- Stratum basalis (basal layer)
 - Forms new functionalis after menstruation
 - Unresponsive to ovarian hormones

Uterine Vascular Supply

- Uterine arteries: arise from internal iliacs
- Arcuate arteries: in the myometrium
- Radial branches in the endometrium branch into
 - Spiral arteries → stratum functionalis
 - Straight arteries → stratum basalis
- Spasms of spiral arteries leads to shedding of stratum functionalis

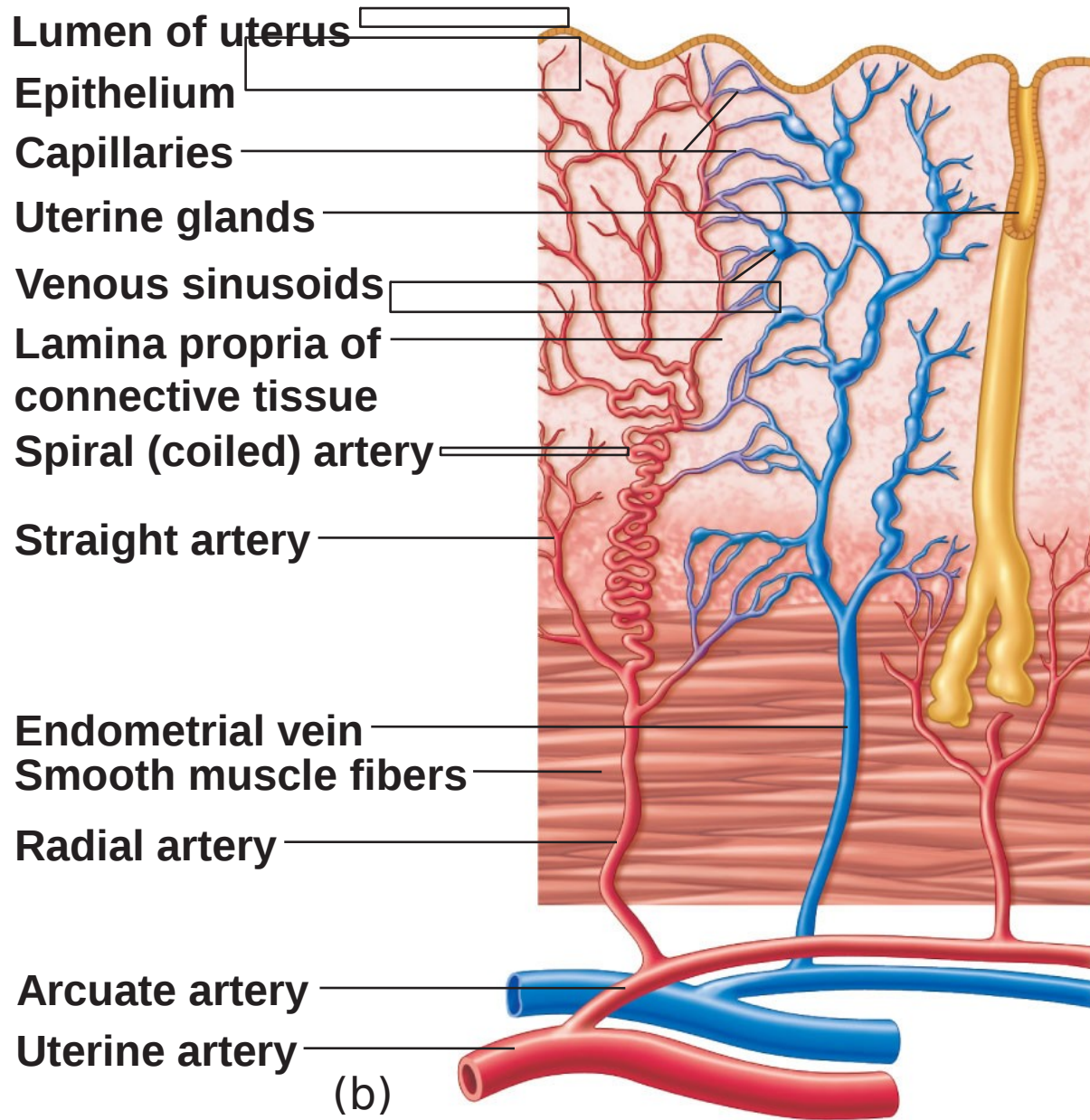


Figure 27.13b

Vagina

- Birth canal and organ of copulation
- Extends between the bladder and the rectum from the cervix to the exterior
- Urethra embedded in the anterior wall

Vagina

- Layers of wall
 1. Fibroelastic adventitia
 2. Smooth muscle muscularis
 3. Stratified squamous mucosa with rugae
- Mucosa near the vaginal orifice forms an incomplete partition called the hymen
- Vaginal fornix: upper end of the vagina surrounding the cervix

External Genitalia (Vulva or Pudendum)

- Mons pubis: fatty area overlying pubic symphysis
- Labia majora: hair-covered, fatty skin folds
- Labia minora: skin folds lying within labia majora
 - Vestibule: recess between labia minora

External Genitalia

- Greater vestibular glands
 - Homologous to the bulbourethral glands
 - Release mucus into the vestibule for lubrication

External Genitalia

- Clitoris
 - Erectile tissue hooded by a prepuce
 - Glans clitoris: exposed portion
- Perineum
 - Diamond-shaped region between the pubic arch and coccyx
 - Bordered by the ischial tuberosities laterally

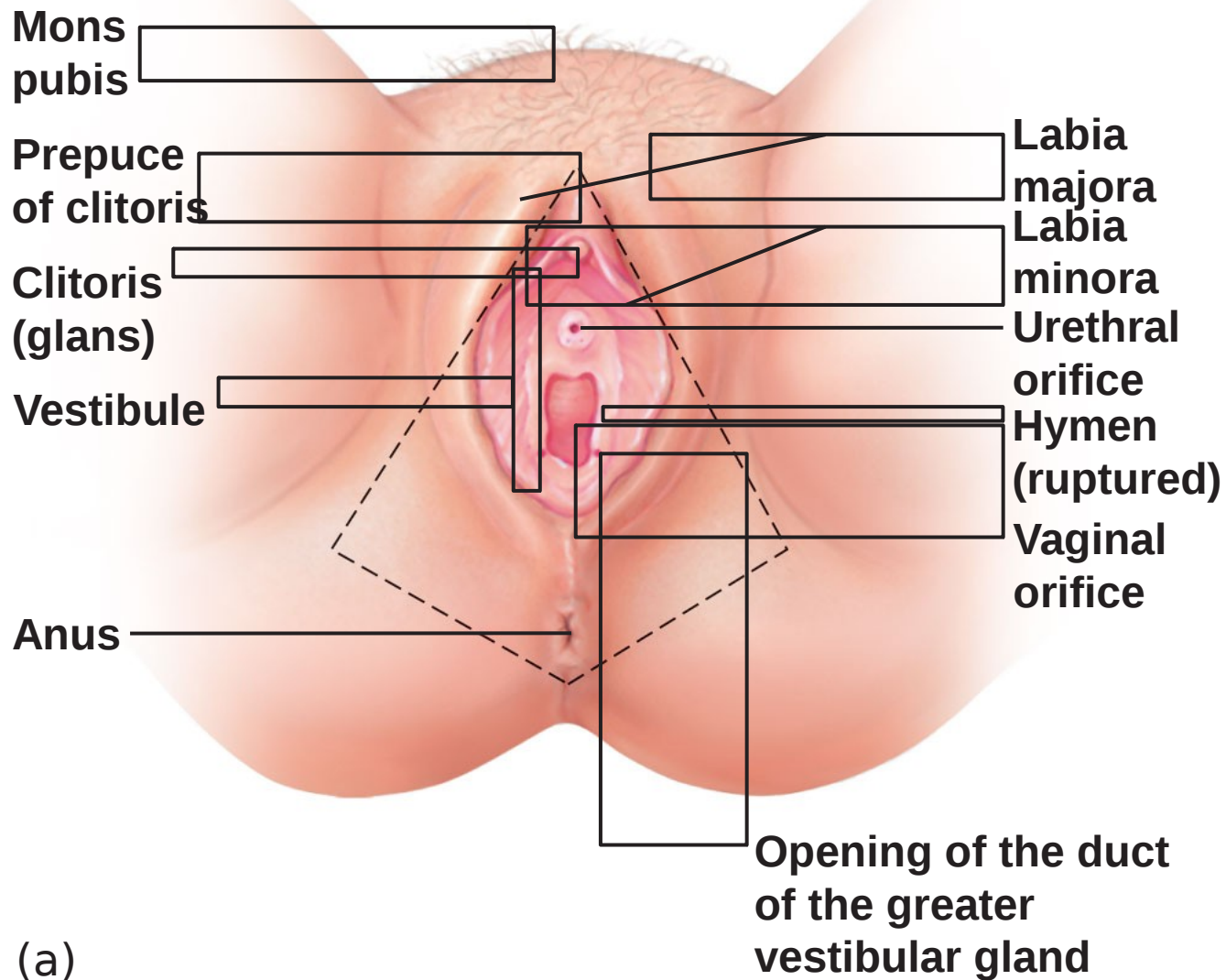


Figure 27.14a

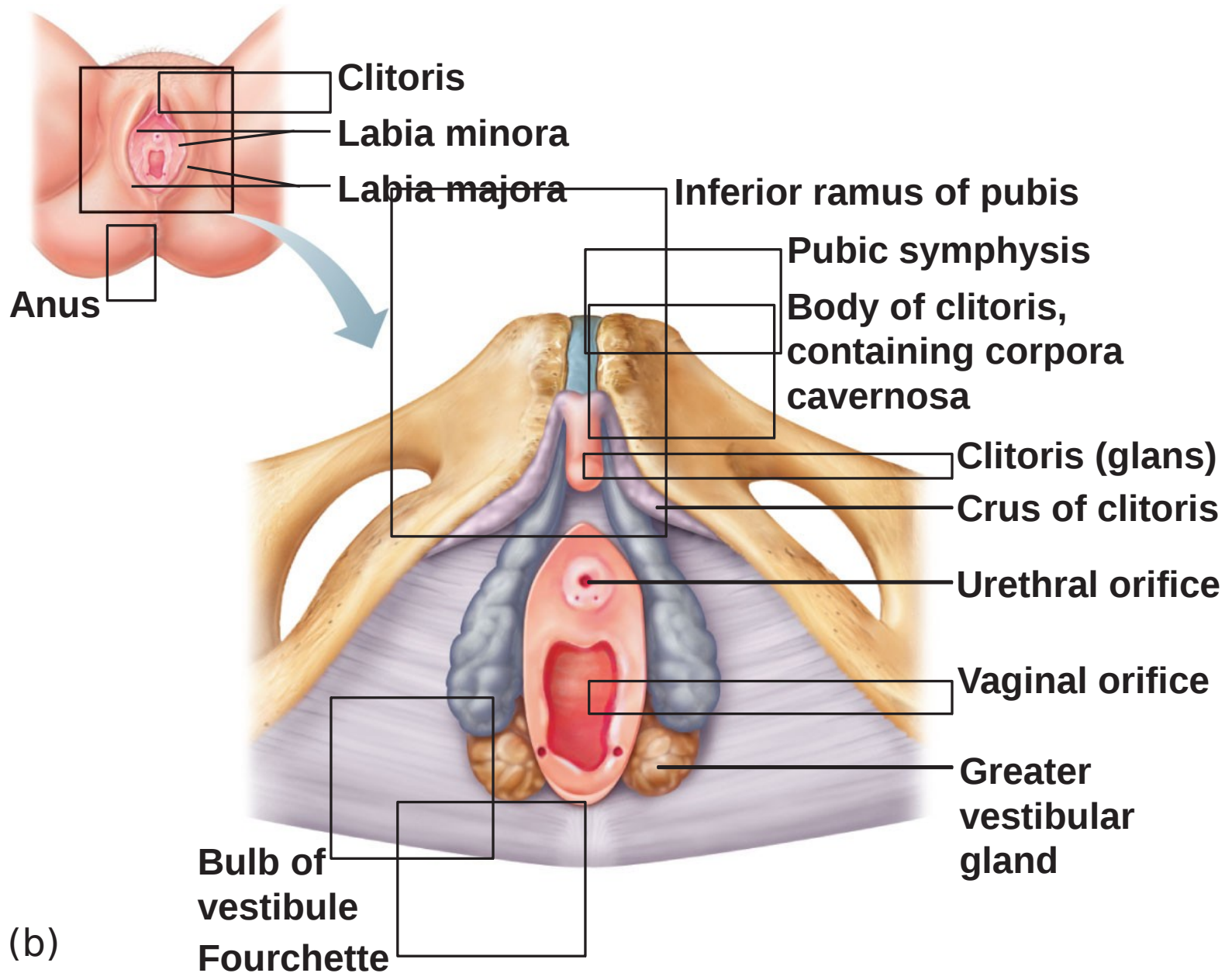


Figure 27.14b

Mammary Glands

- Modified sweat glands consisting of 15–25 lobes
- Areola: pigmented skin surrounding the nipple
- Suspensory ligaments: attach the breast to underlying muscle
- Lobules within lobes contain glandular alveoli that produce milk

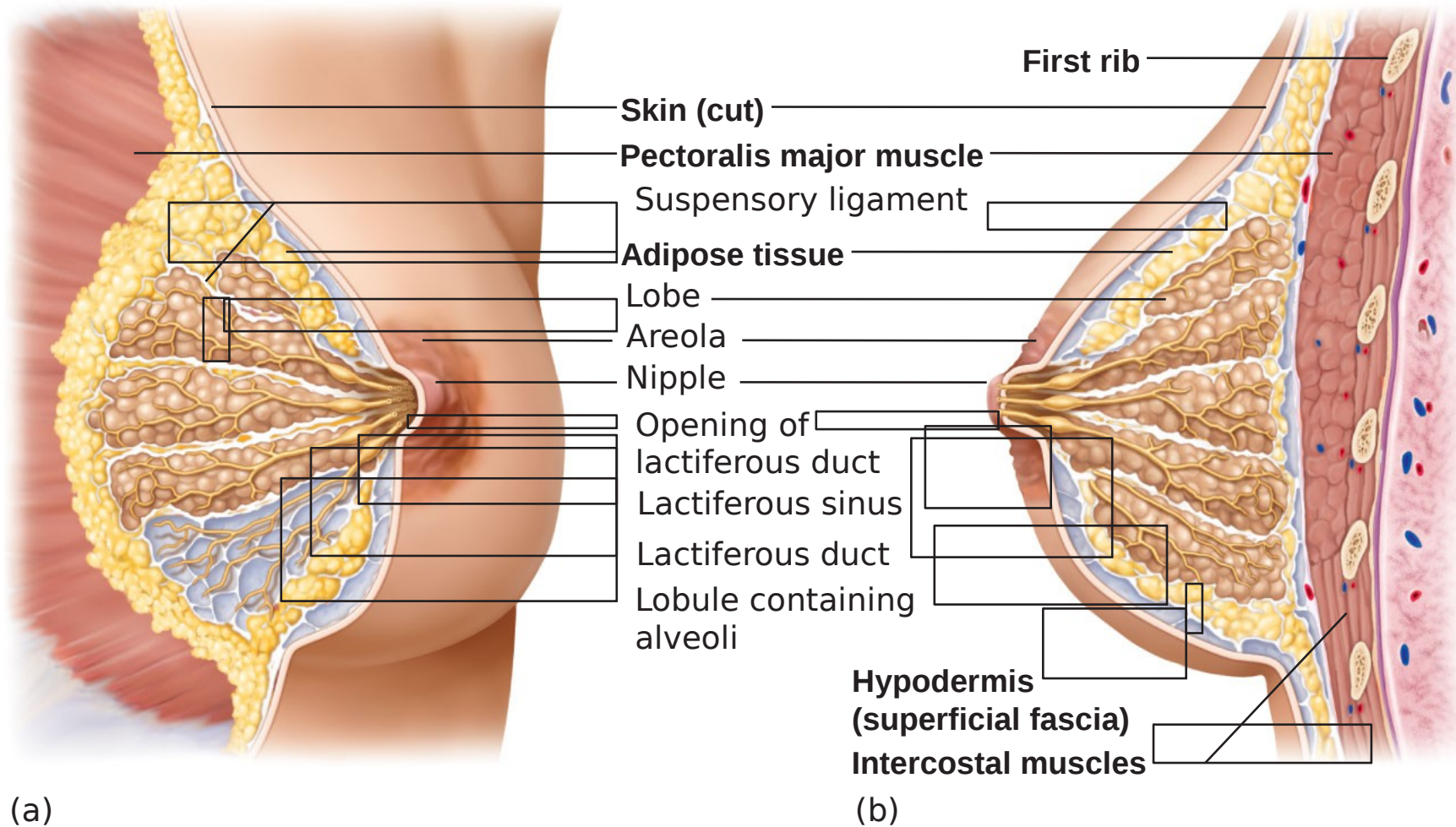


Figure 27.15

Oogenesis

- Production of female gametes
- Begins in the fetal period
 - Oogonia ($2n$ ovarian stem cells) multiply by mitosis and store nutrients
 - Primary oocytes develop in primordial follicles
 - Primary oocytes begin meiosis but stall in prophase I

Oogenesis

- Each month after puberty, a few primary oocytes are activated
- One is selected each month to resume meiosis I
- Result is two haploid cells
 - Secondary oocyte (contains most of the cytoplasm)
 - First polar body (degenerates)

Oogenesis

- The secondary oocyte arrests in metaphase II and is ovulated
- If penetrated by sperm the second oocyte completes meiosis II, yielding
 - Ovum (the functional gamete)
 - Second polar body

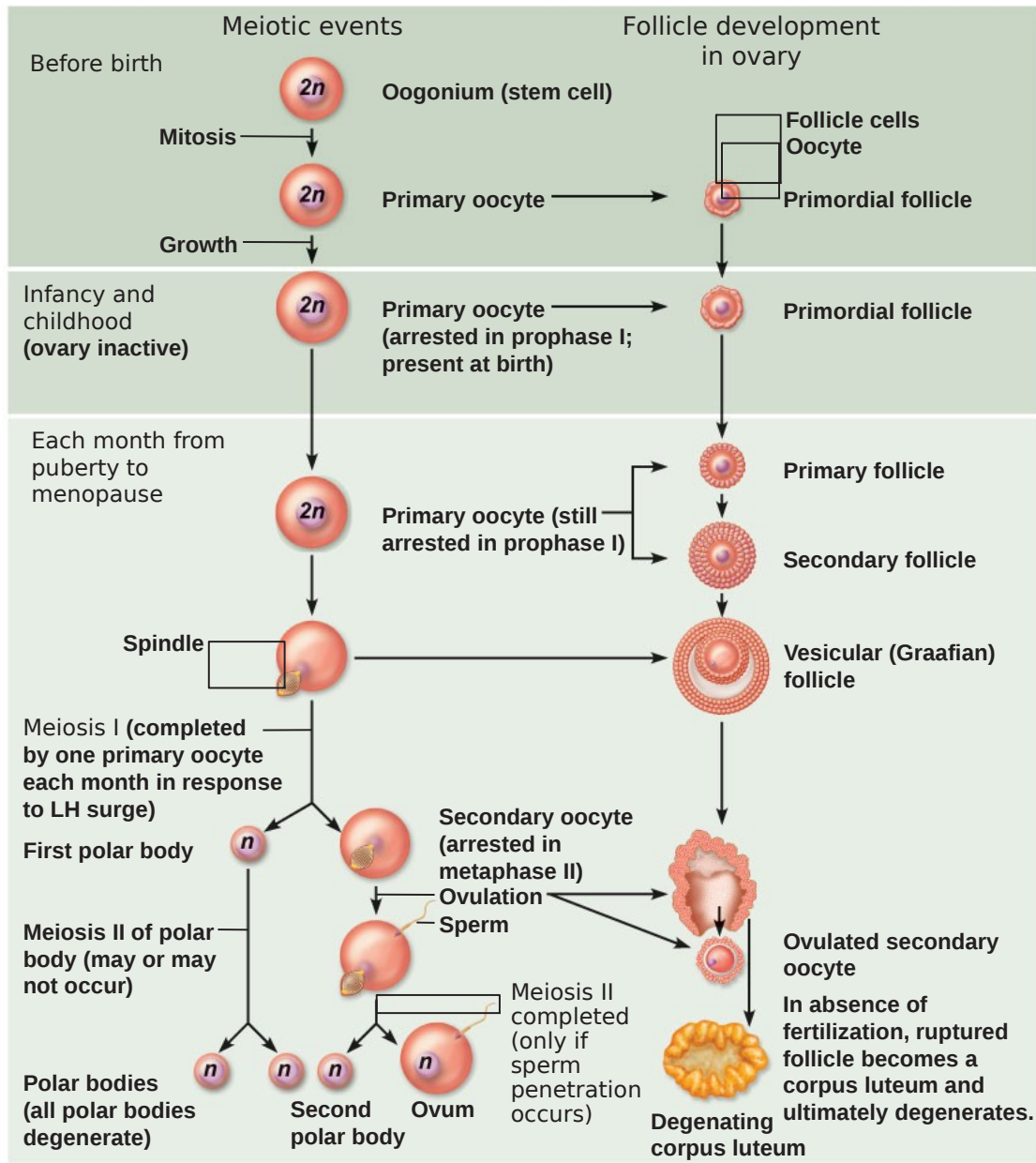


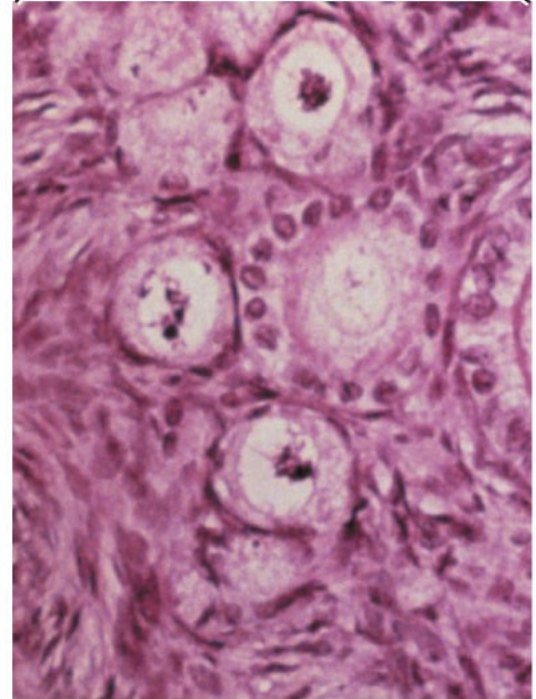
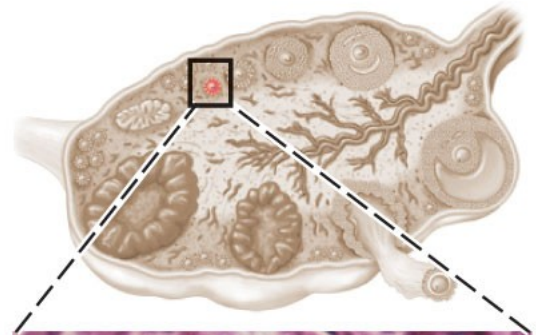
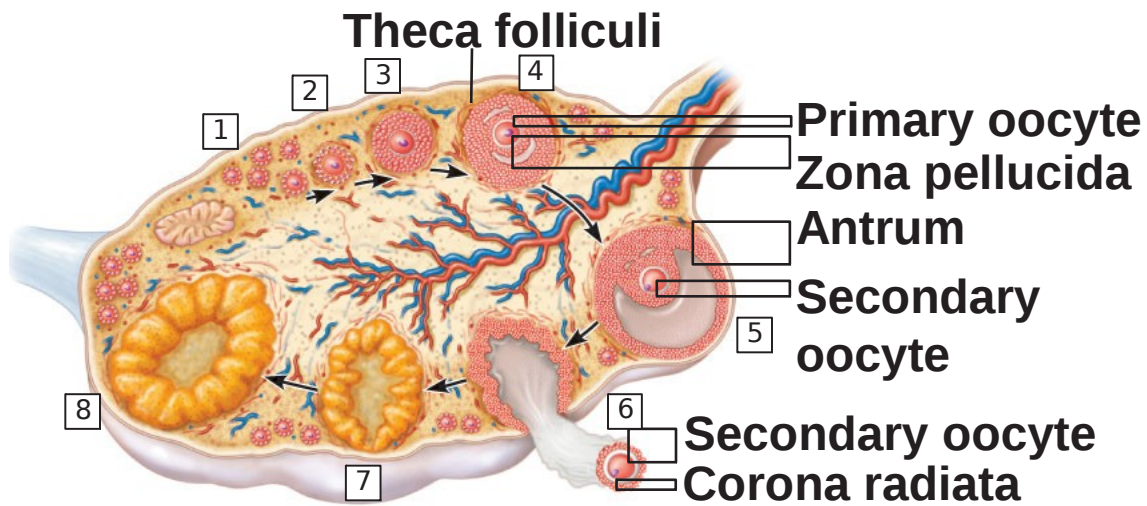
Figure 27.17

Ovarian Cycle

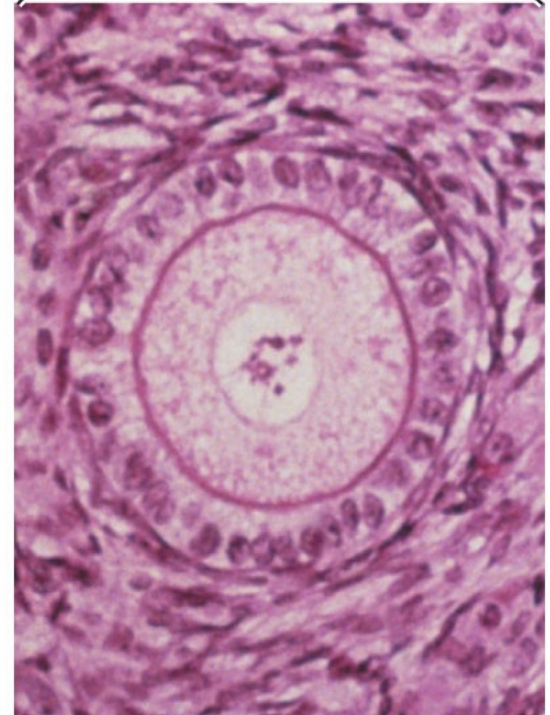
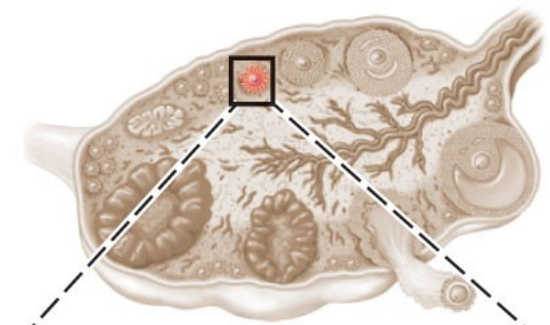
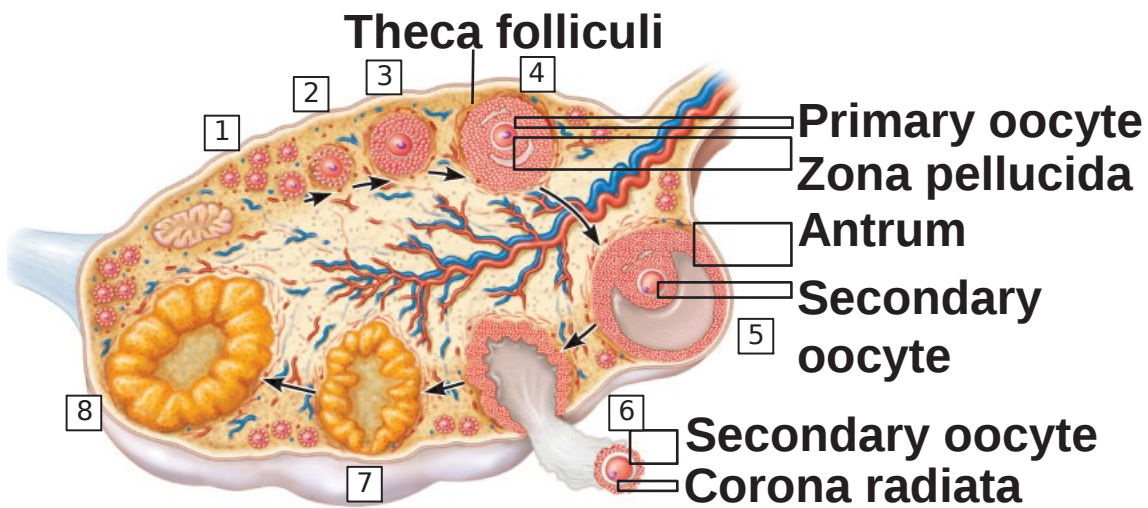
- Monthly series of events associated with the maturation of an egg
- Two consecutive phases (in a 28-day cycle)
 - Follicular phase: period of follicle growth (days 1–14)
 - Ovulation occurs midcycle
 - Luteal phase: period of corpus luteum activity (days 14–28)

Follicular Phase

- Primordial follicle becomes primary follicle
 1. The primordial follicle is activated
 - Squamouslike cells become cuboidal
 2. Follicle enlarges to become a primary (1°) follicle



1 Primordial follicles



2 Primary follicle

Follicular Phase

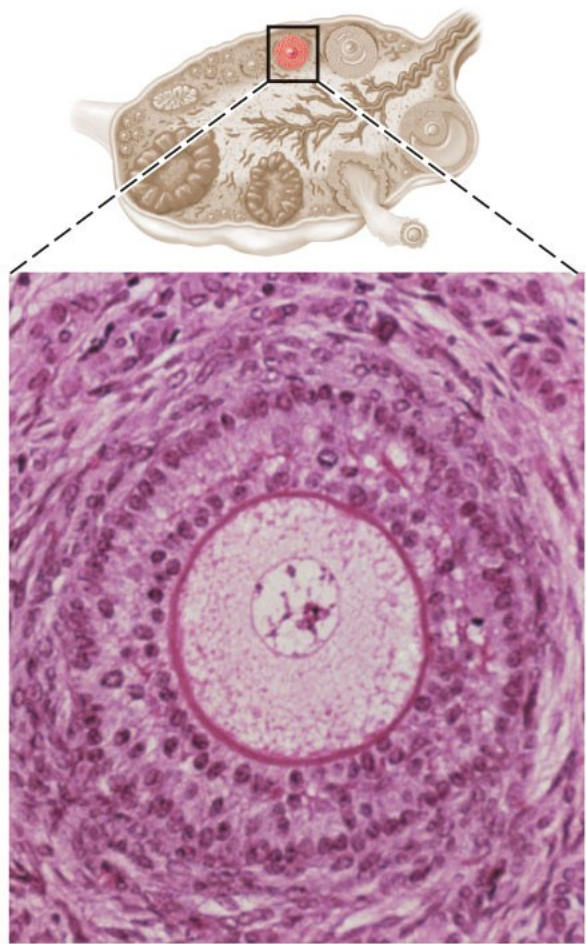
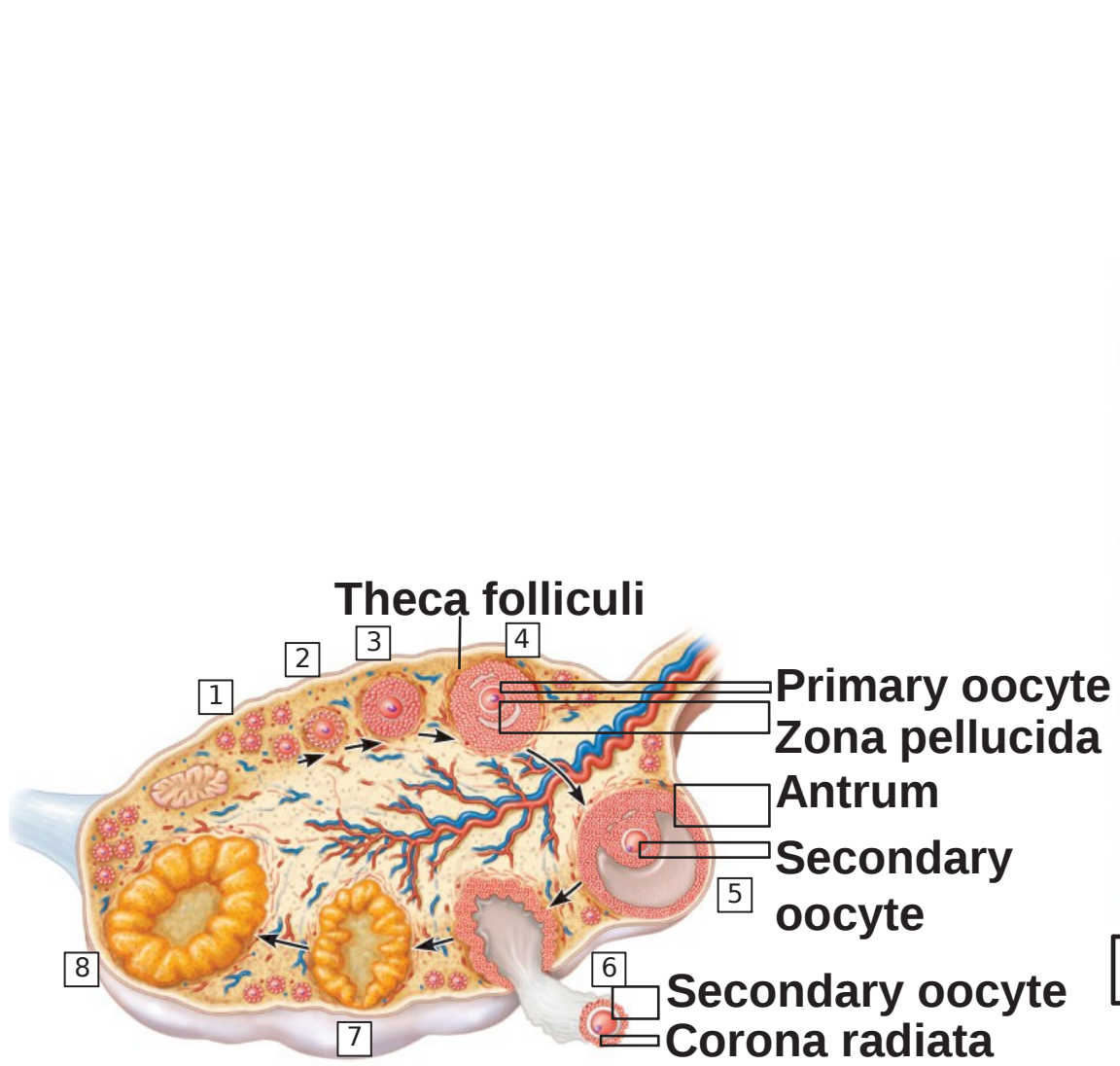
1. Primary follicle becomes a secondary follicle

- Stratified epithelium (granulosa cells) forms around oocyte
- Granulosa cells and oocyte guide one another's development

Follicular Phase

1. Secondary follicle becomes a late secondary follicle

- Connective tissue (theca folliculi) and granulosa cells cooperate to produce estrogens
- Zona pellucida forms around the oocyte
- Fluid begins to accumulate



3 Secondary follicle

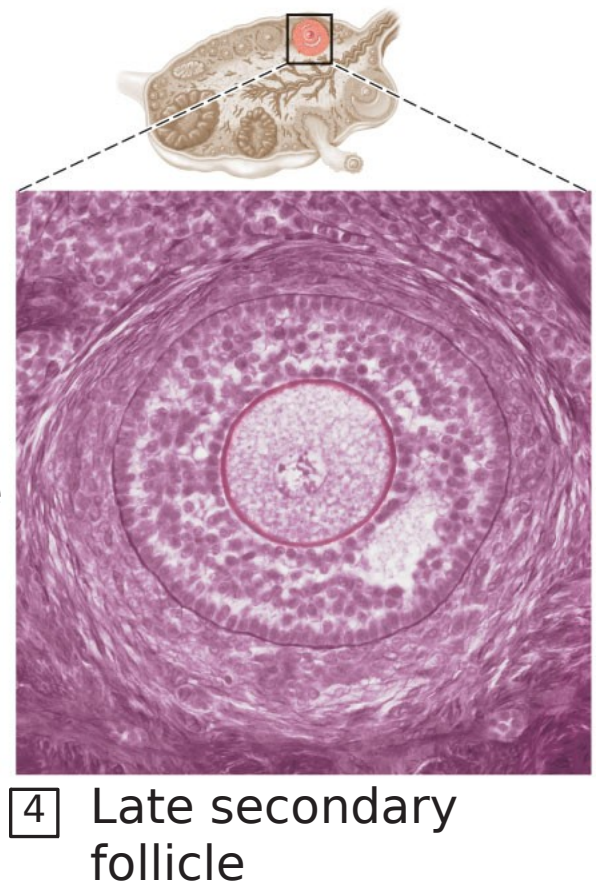
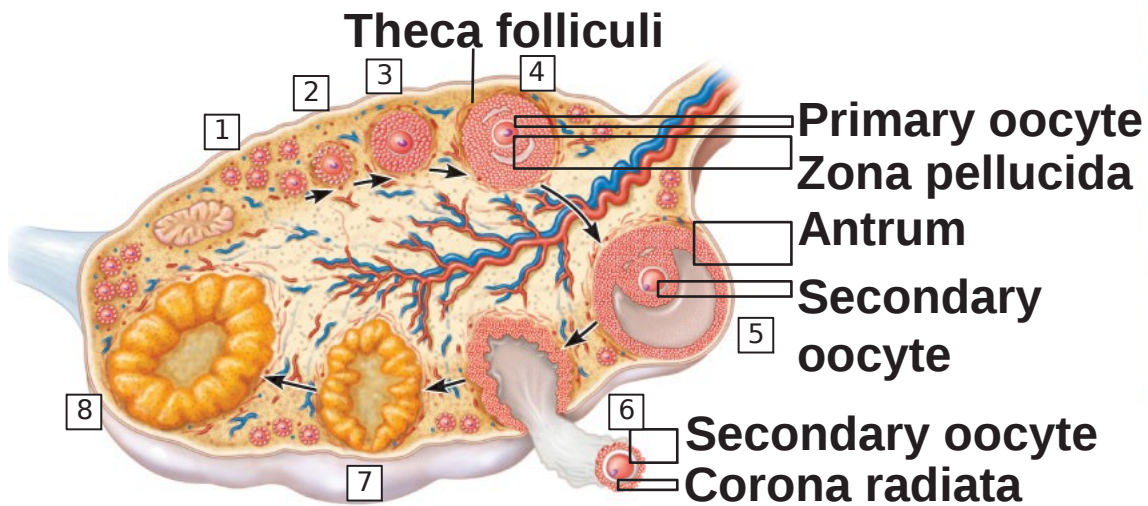


Figure 27.18 (4 of 7)

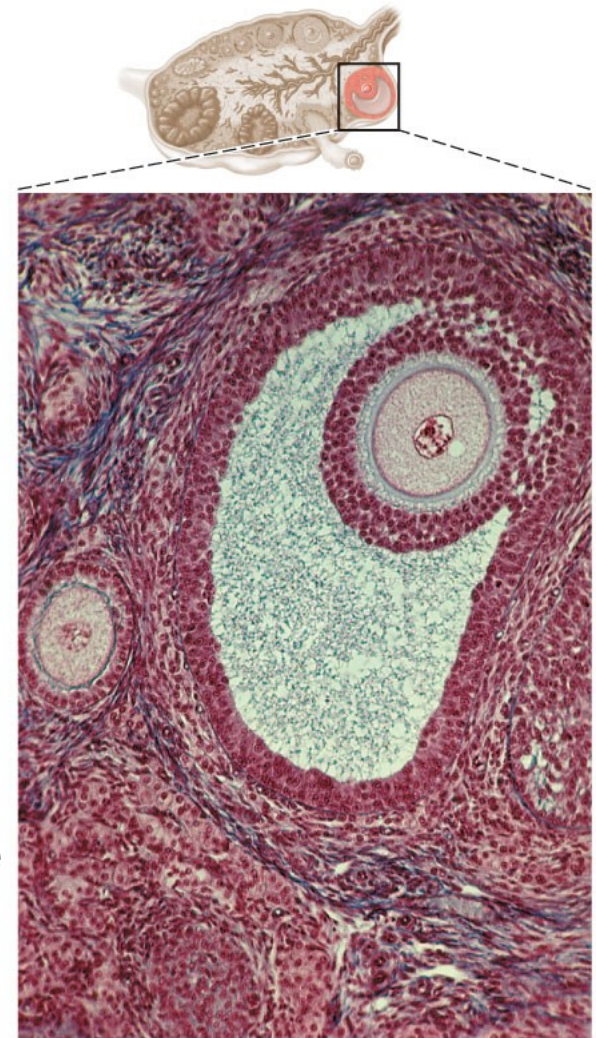
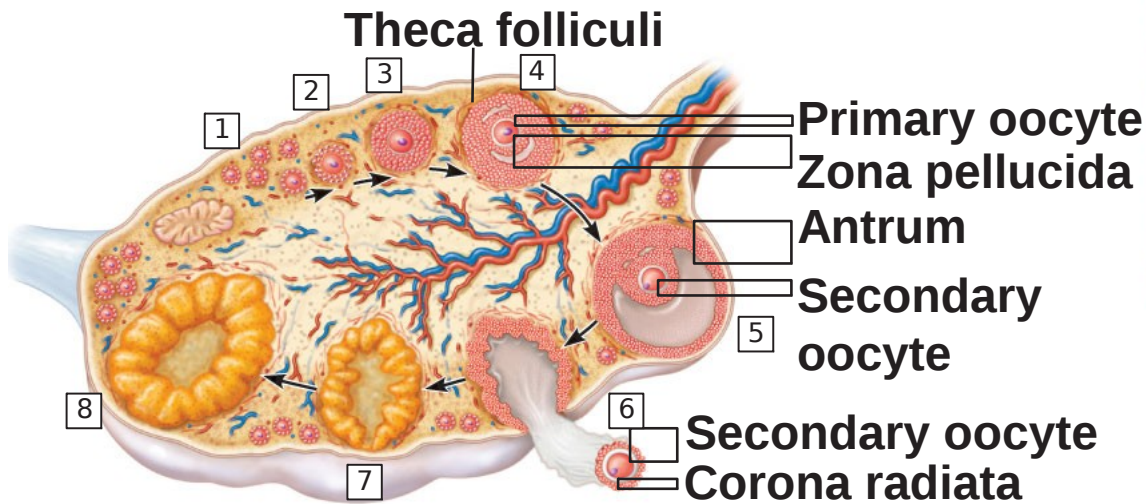
Follicular Phase

1. Late secondary follicle becomes a vesicular follicle

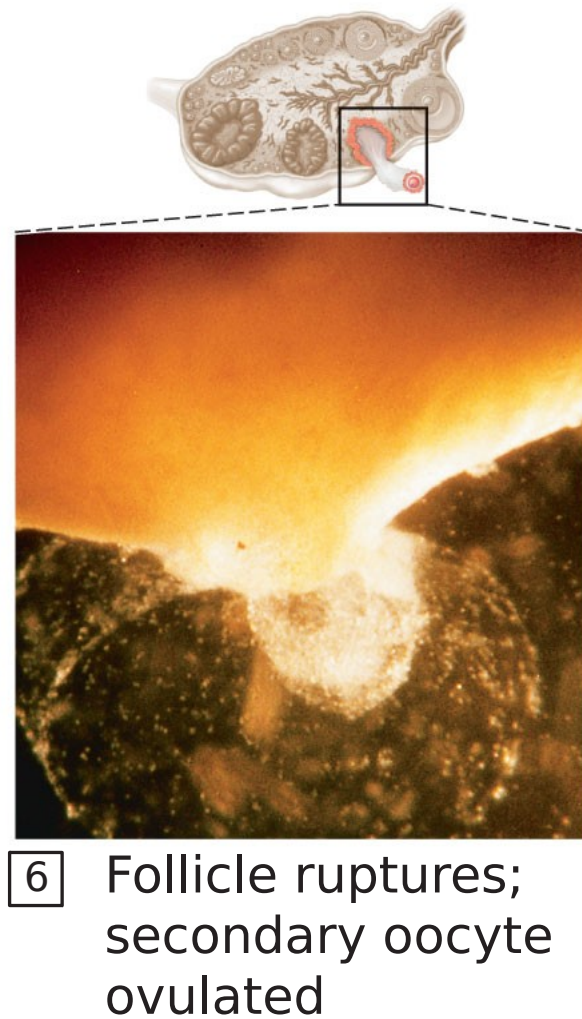
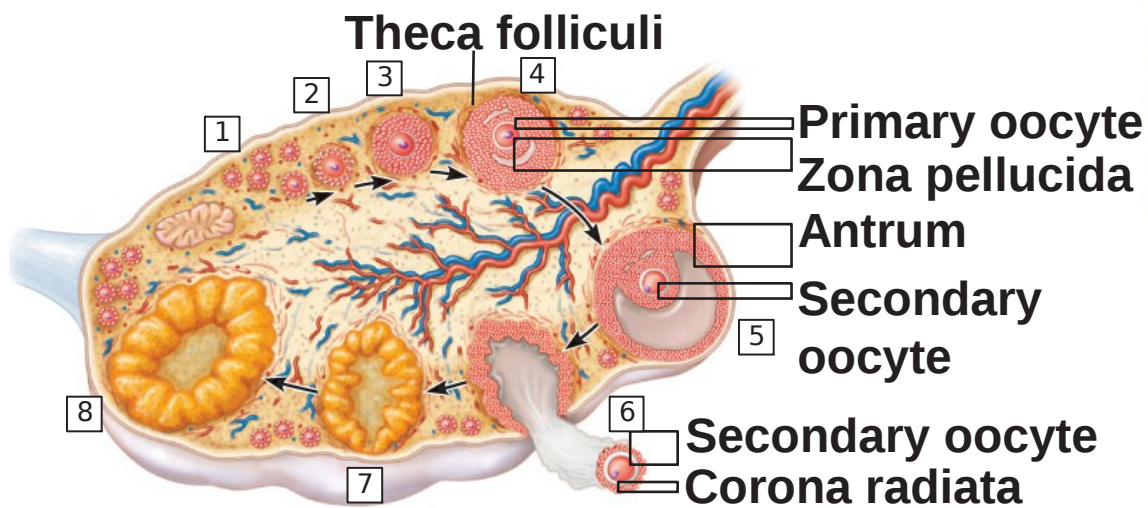
- Antrum forms and expands to isolate the oocyte with its corona radiata on a stalk
- Vesicular follicle bulges from the external surface of the ovary
- The primary oocyte completes meiosis I

Ovulation

- Ovary wall ruptures and expels the secondary oocyte with its corona radiata
- Mittelschmerz: twinge of pain sometimes felt at ovulation
- 1–2% of ovulations release more than one secondary oocyte, which, if fertilized, results in fraternal twins



5 Mature vesicular follicle carries out meiosis I; ready to be ovulated

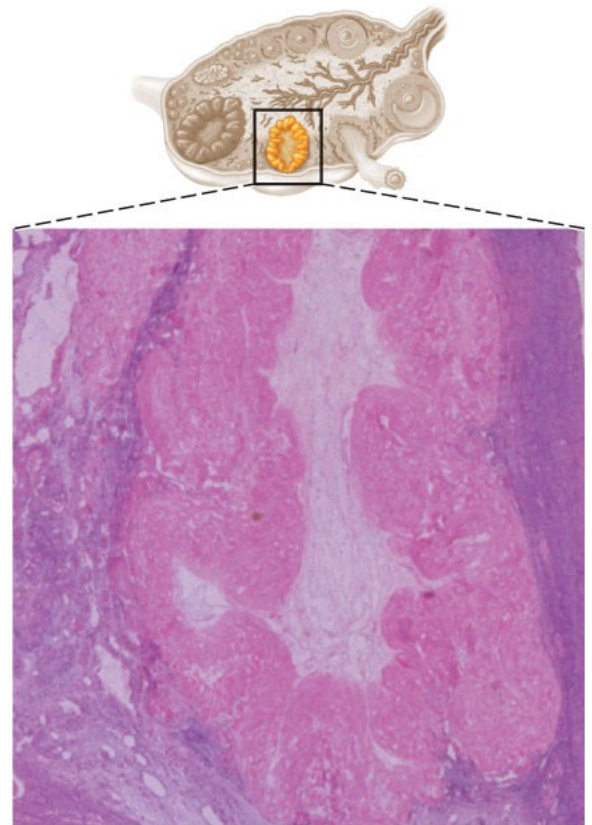
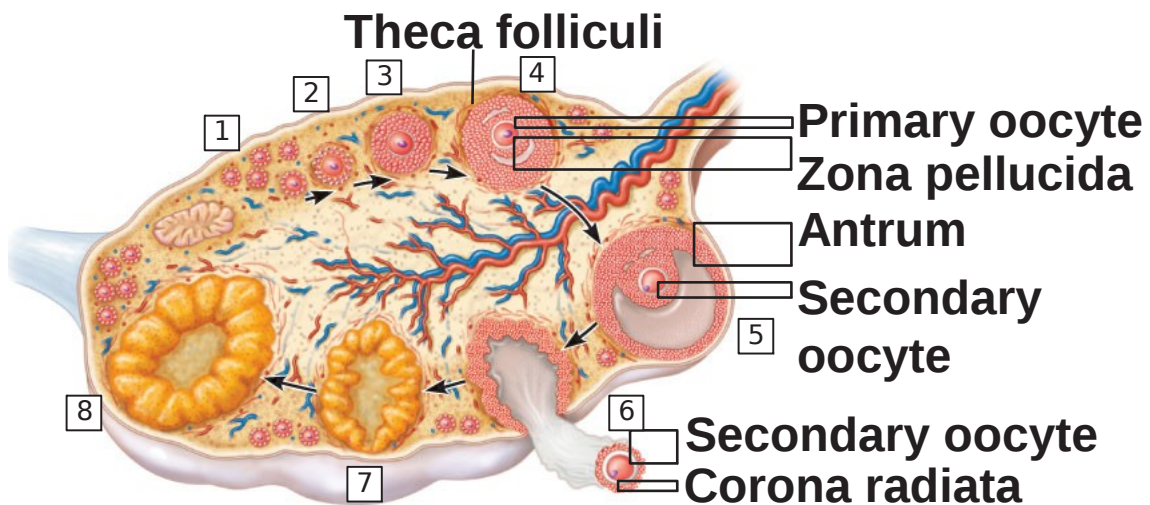


Luteal Phase

- Ruptured follicle collapses
- Granulosa cells and internal thecal cells form corpus luteum
- Corpus luteum secretes progesterone and estrogen

Luteal Phase

- If no pregnancy, the corpus luteum degenerates into a corpus albicans in 10 days
- If pregnancy occurs, corpus luteum produces hormones until the placenta takes over at about 3 months



7 Corpus luteum
(forms from
ruptured follicle)