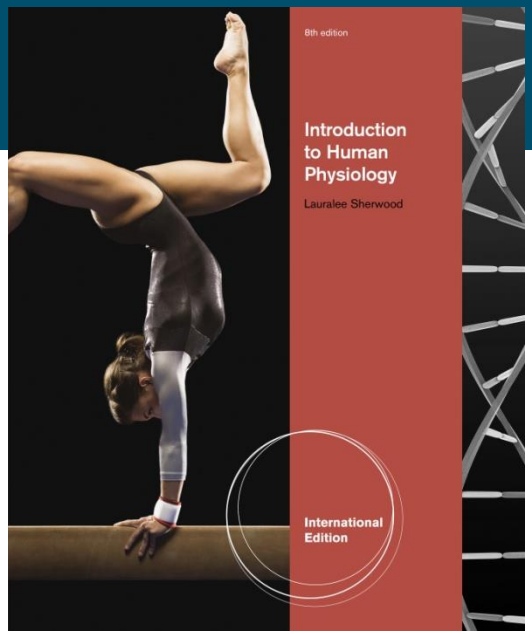


Lauralee Sherwood

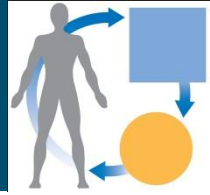
BROOKS/COLE CENGAGE Learning

The Reproductive System-Female

Warning!!!

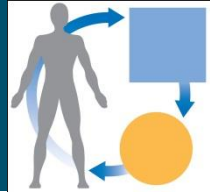
- Today's lecture materials show many pictures depicting men's and women's sexual organs. If you feel uncomfortable, you may leave.

Contents at a glance



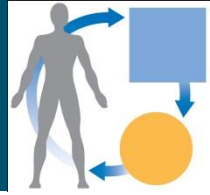
1. Uniqueness of the reproductive system
2. Male reproductive physiology
3. Sexual intercourse between males and females
4. Female reproductive physiology

20.1. Reproductive System



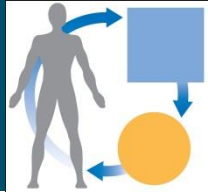
- Includes **gonads**, **reproductive tract**, and **accessory sex glands.**
- Sexual reproduction:
  - depends on union of male and female gametes (생식세포) to form new individual
  - male and female reproductive systems enable union of genetic material

Primary Reproductive Organs



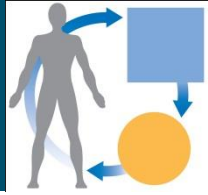
- Gonads consist of paired **testes** in male and paired **ovaries** in female.
- Functions of mature gonads:
  - produce **gametes** (sperm and egg)
  - secrete sex hormones **testosterone** in males and **estrogen** and **progesterone** in females

Other Reproductive Structures



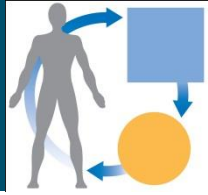
- **Reproductive tract:**
  - system of specialized ducts that transport or house gametes after they are produced
- **Accessory sex glands:**
  - empty secretions into reproductive tract
- **External genitalia:**
  - externally visible structures of reproductive system

Male Reproductive System

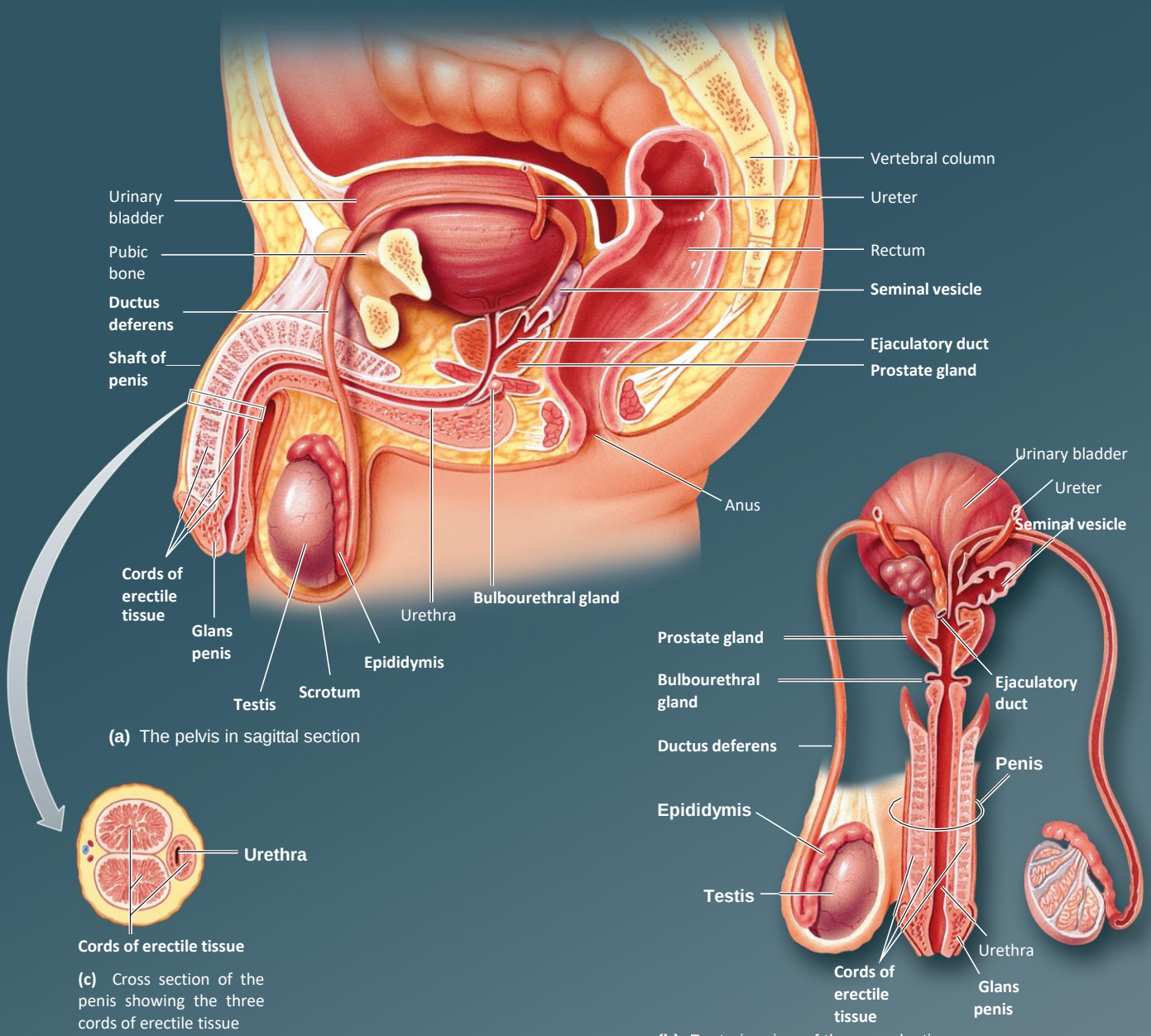


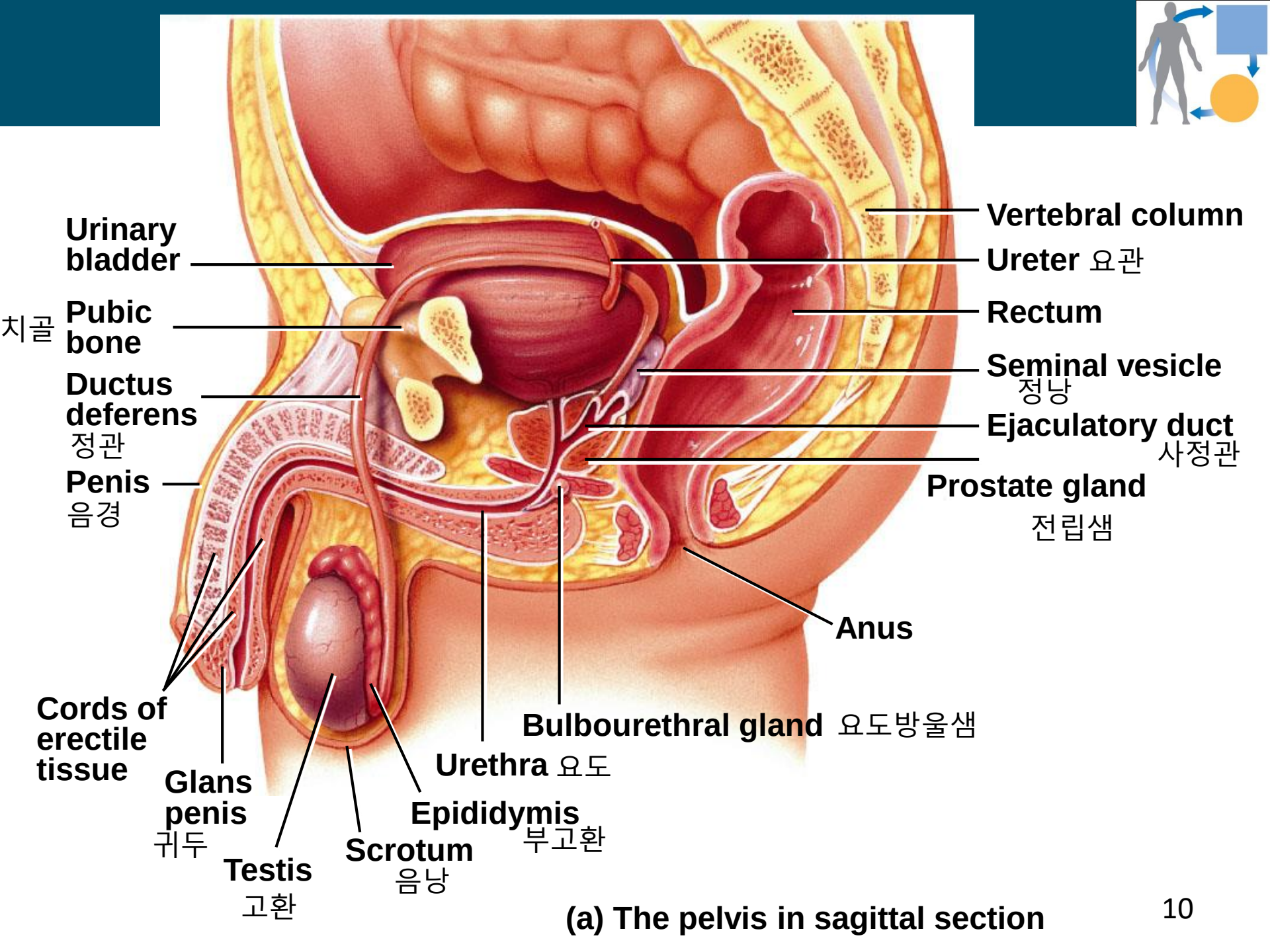
- Testes:
  - sperm-producing organs
  - suspended outside abdominal tract in **scrotum (음낭)**
- Accessory sex glands:
  - **Seminal vesicles (정낭), prostate gland (전립샘), bulbourethral glands (요도방울샘)**
  - secretions provide bulk of semen (정액)

Male Reproductive System

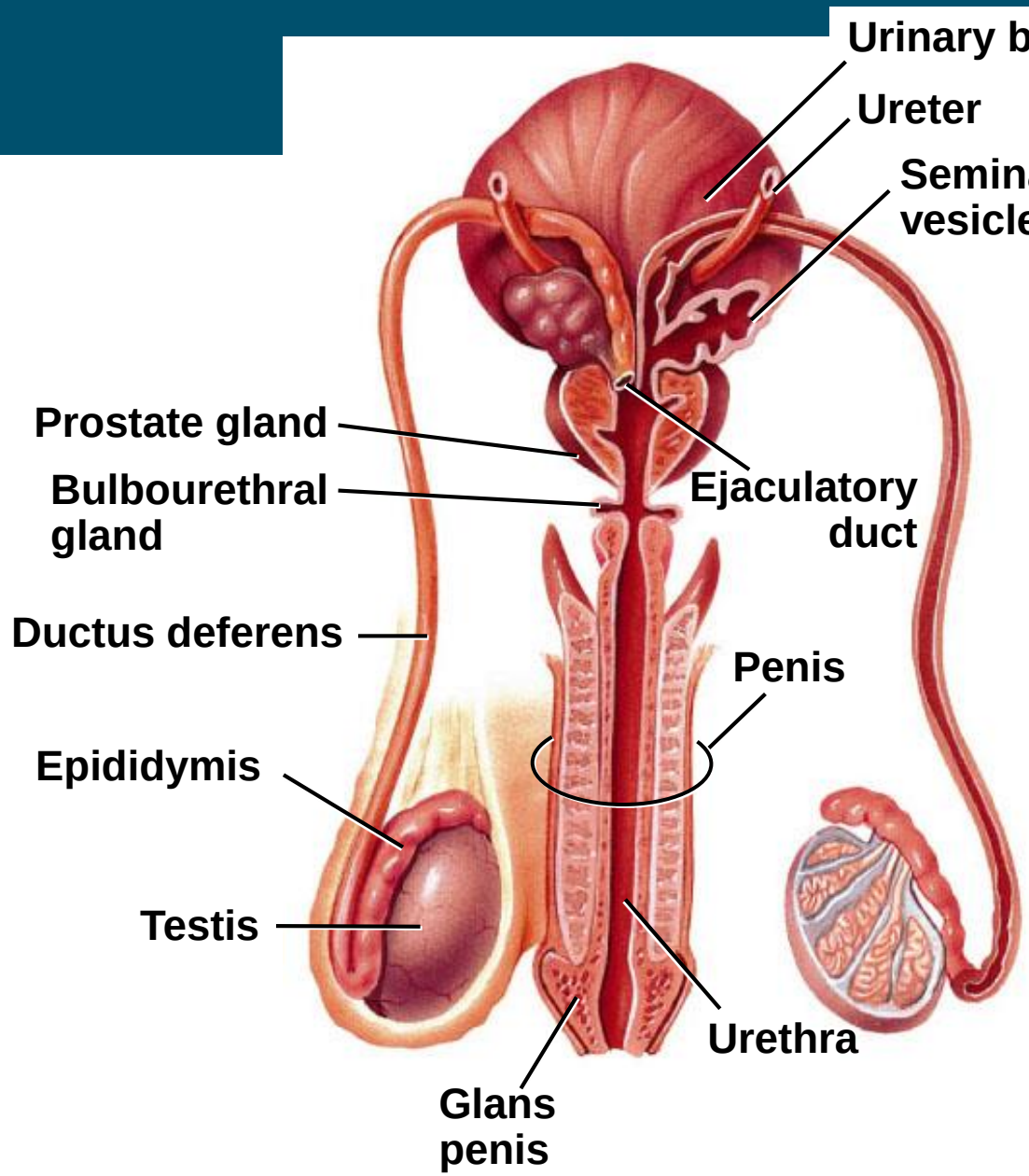


- Penis:
  - organ used to deposit semen in female
- Male reproductive tract:
  - **Epididymis (부고환), ductus (vas) deferens (정관), ejaculatory duct (사정관)**
  - Empty into **urethra (요도)**


Urinary bladder
Pubic bone
Ductus deferens
Shaft of penis
Vertebral column
Ureter
Rectum
Seminal vesicle
Ejaculatory duct
Prostate gland
Anus
Cords of erectile tissue
Glans penis
Testis
Scrotum
Epididymis
Urethra
Bulbourethral gland
(a) The pelvis in sagittal section
Urethra
Cords of erectile tissue
(c) Cross section of the penis showing the three cords of erectile tissue
Urinary bladder
Ureter
Seminal vesicle
Prostate gland
Bulbourethral gland
Ductus deferens
Epididymis
Testis
Ejaculatory duct
Penis
Urethra
Cords of erectile tissue
Glans penis
(b) Posterior view of the reproductive organs

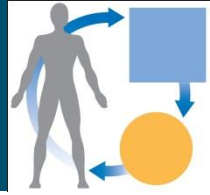


(a) The pelvis in sagittal section



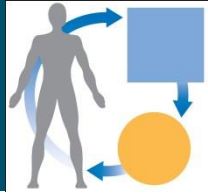
(b) Posterior view of the reproductive organs

Female Reproductive System

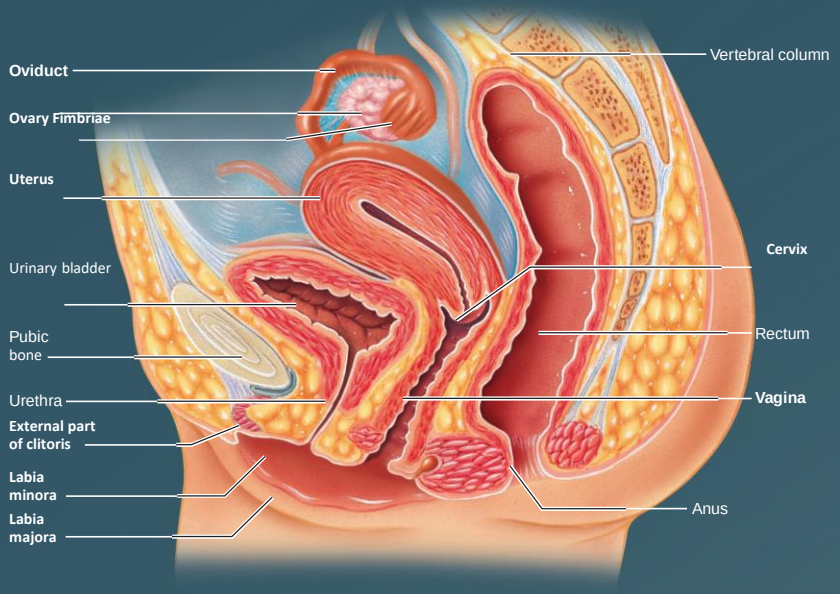


- **Oviducts (Fallopian tubes),** pick up ova on ovulation and serve as the site for fertilization.
- **Uterus** responsible for maintaining the fetus in development and expelling it during labor.
- **Vagina** is a muscular tube that connects the uterus to the external environment.
- **Cervix** is the lowest portion of the uterus that projects into vagina.

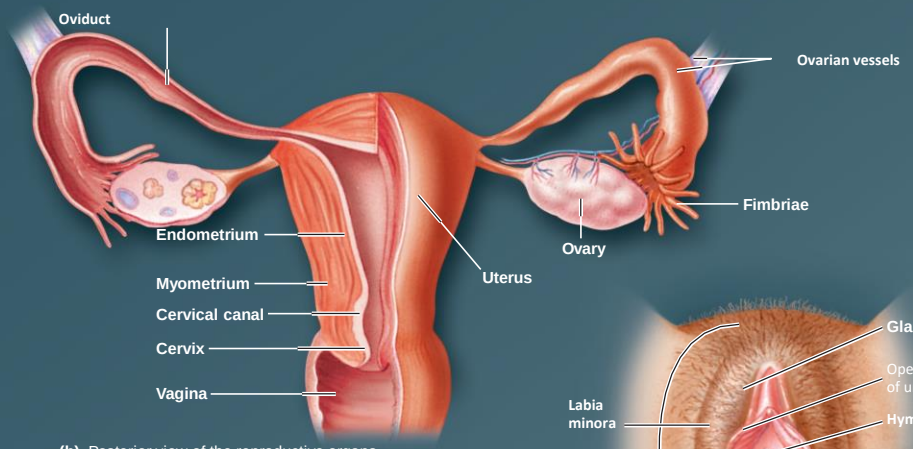
Female Reproductive System



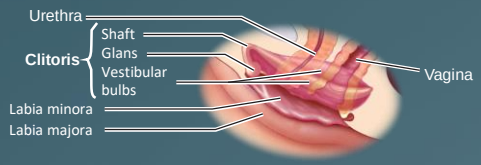
- The vaginal opening is located in the **perineal region (회음부)** between the urethral and anal openings.
- Two pairs of skin folds, the **labia minora** (소음순) and **labia majora** (대음순) surround openings.
- **Clitoris** lies at the anterior end of the folds of the labia minora.
- Female external genitalia are collectively referred to as the **vulva.**



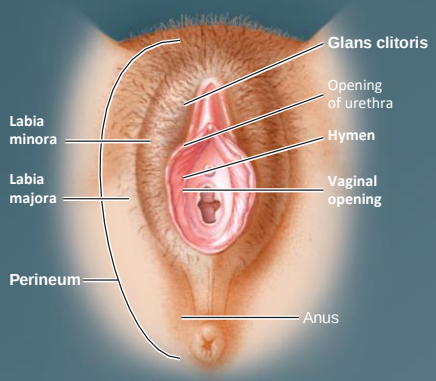
(a) The pelvis in sagittal section



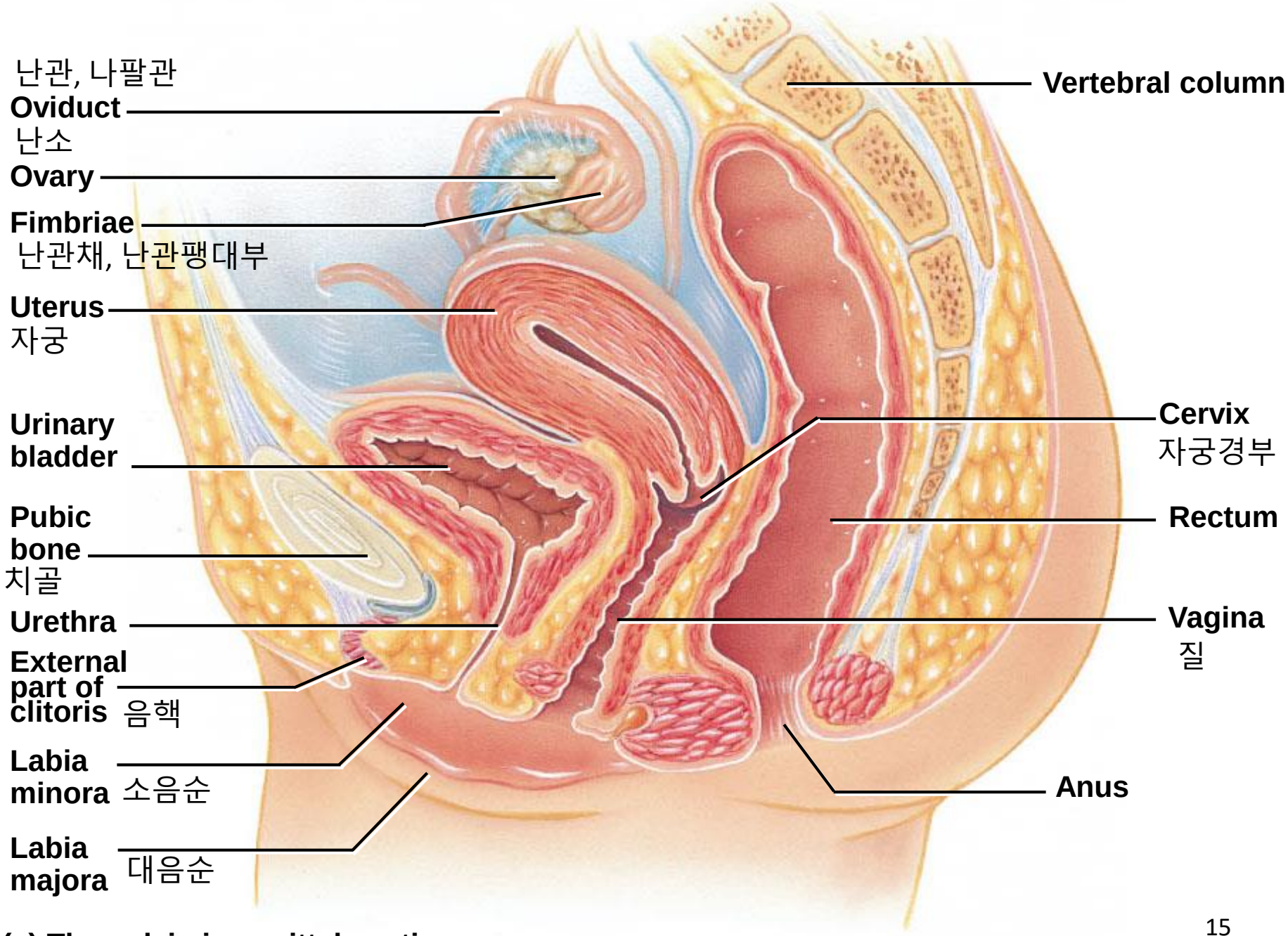
(b) Posterior view of the reproductive organs



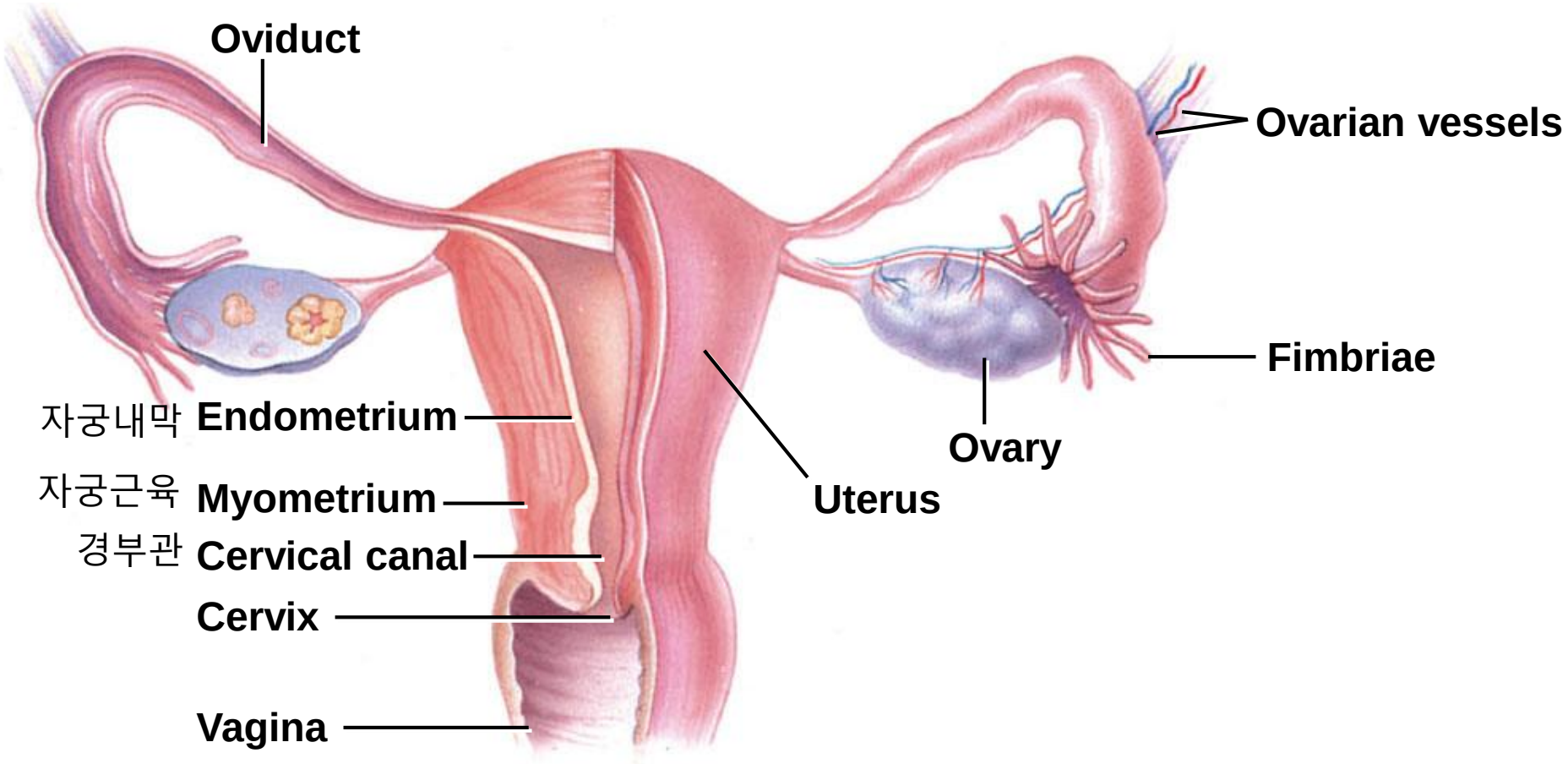
(d) Sagittal section of the internal and external parts of the clitoris



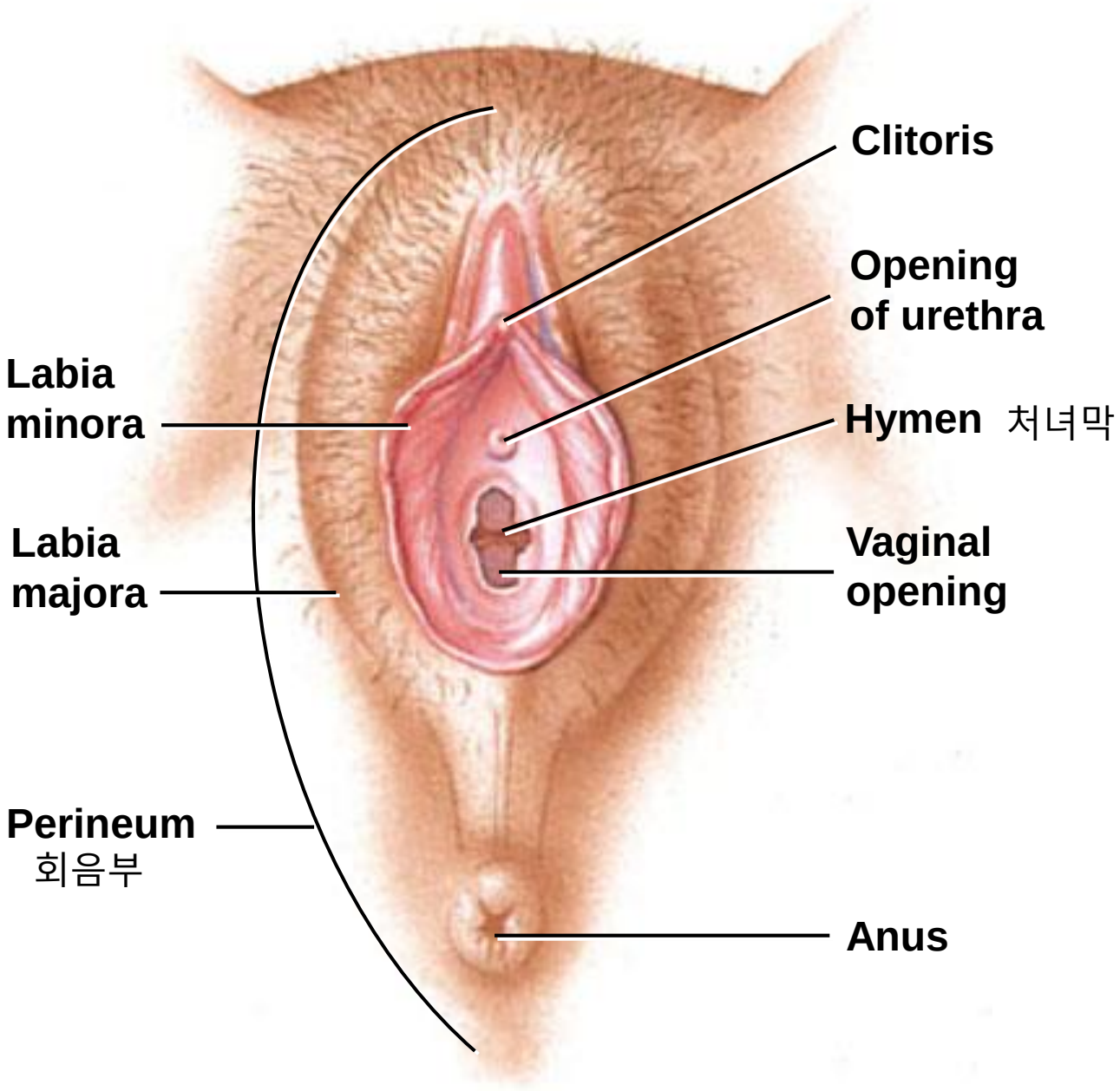
(c) Perineal view of the external genitalia



(a) The pelvis in sagittal section



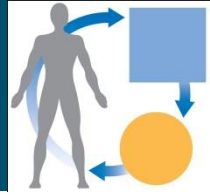
(b) Posterior view of the reproductive organs



(c) Perineal view of the external genitalia

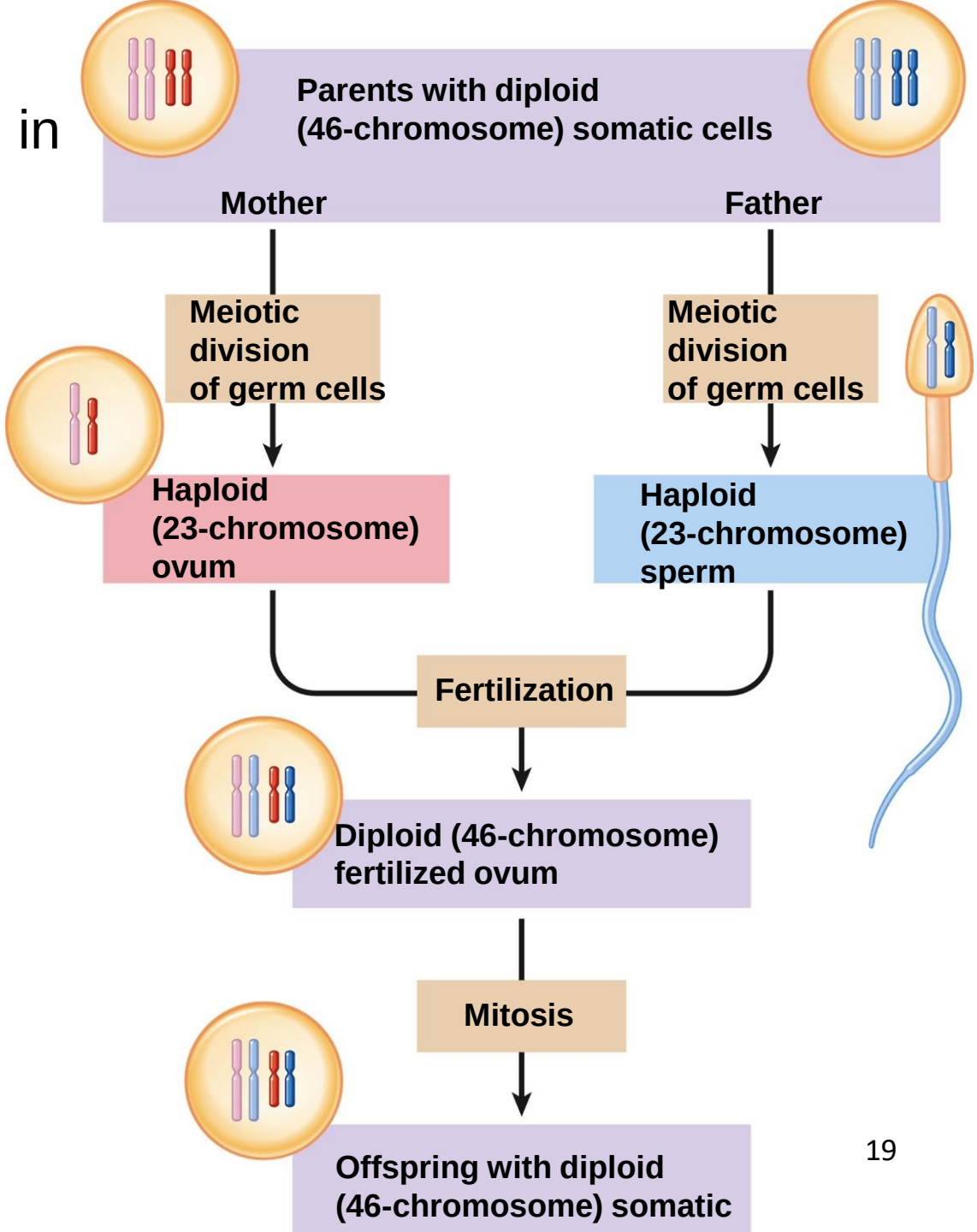
Fig. 20-2c, p. 738

Gametes

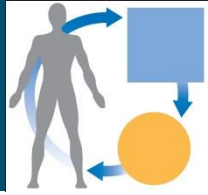


- Somatic (body) cells contain 46 chromosomes (**diploid number,** 배수체)
- Gametes (sperm and eggs) contain 23 chromosomes (**haploid number,** 반수체)
- **Gametogenesis** is accomplished by meiosis, resulting in genetically unique sperm and ova.

Fig. 20-3
Chromosomal distribution in sexual reproduction



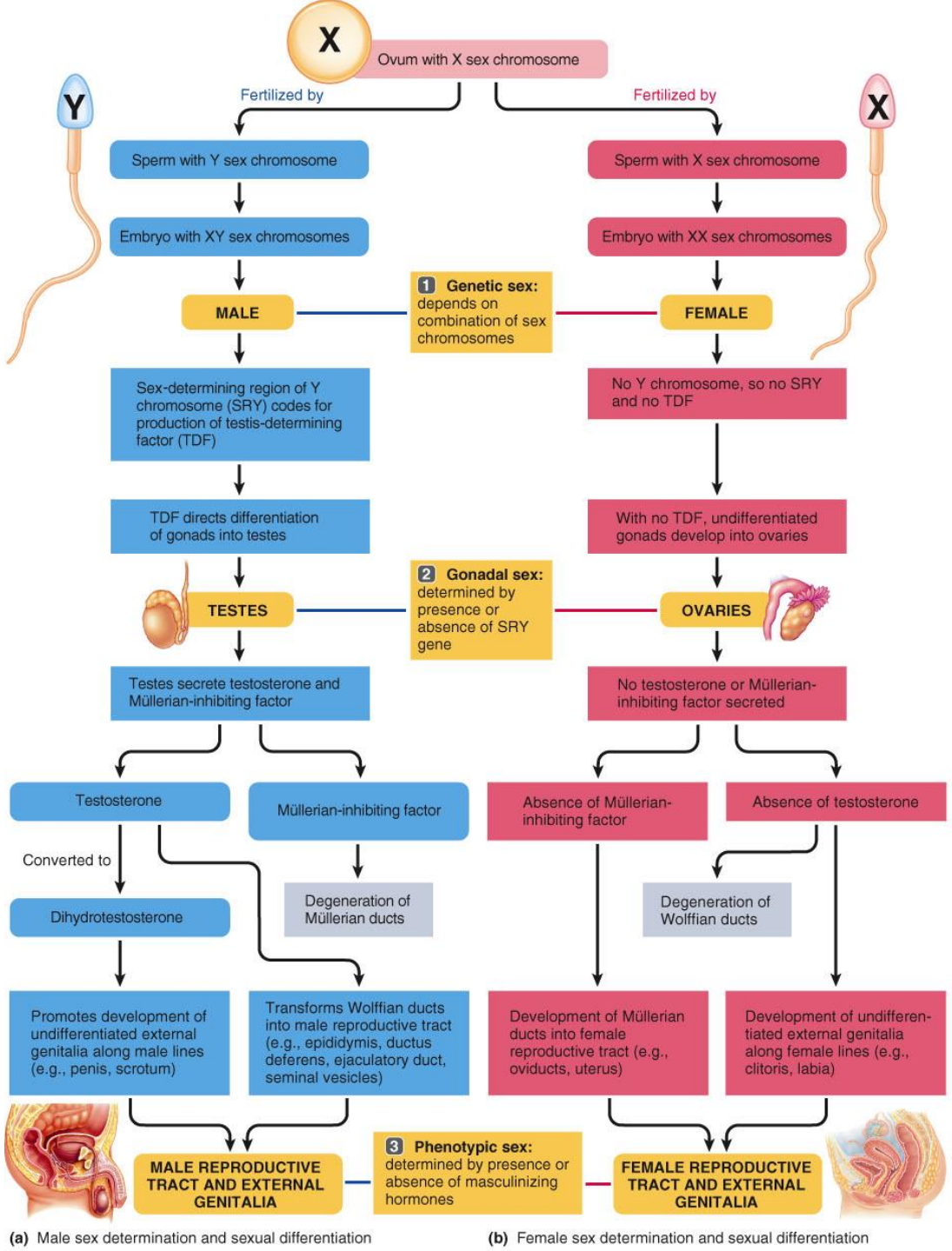
Sex Determination & Differentiation



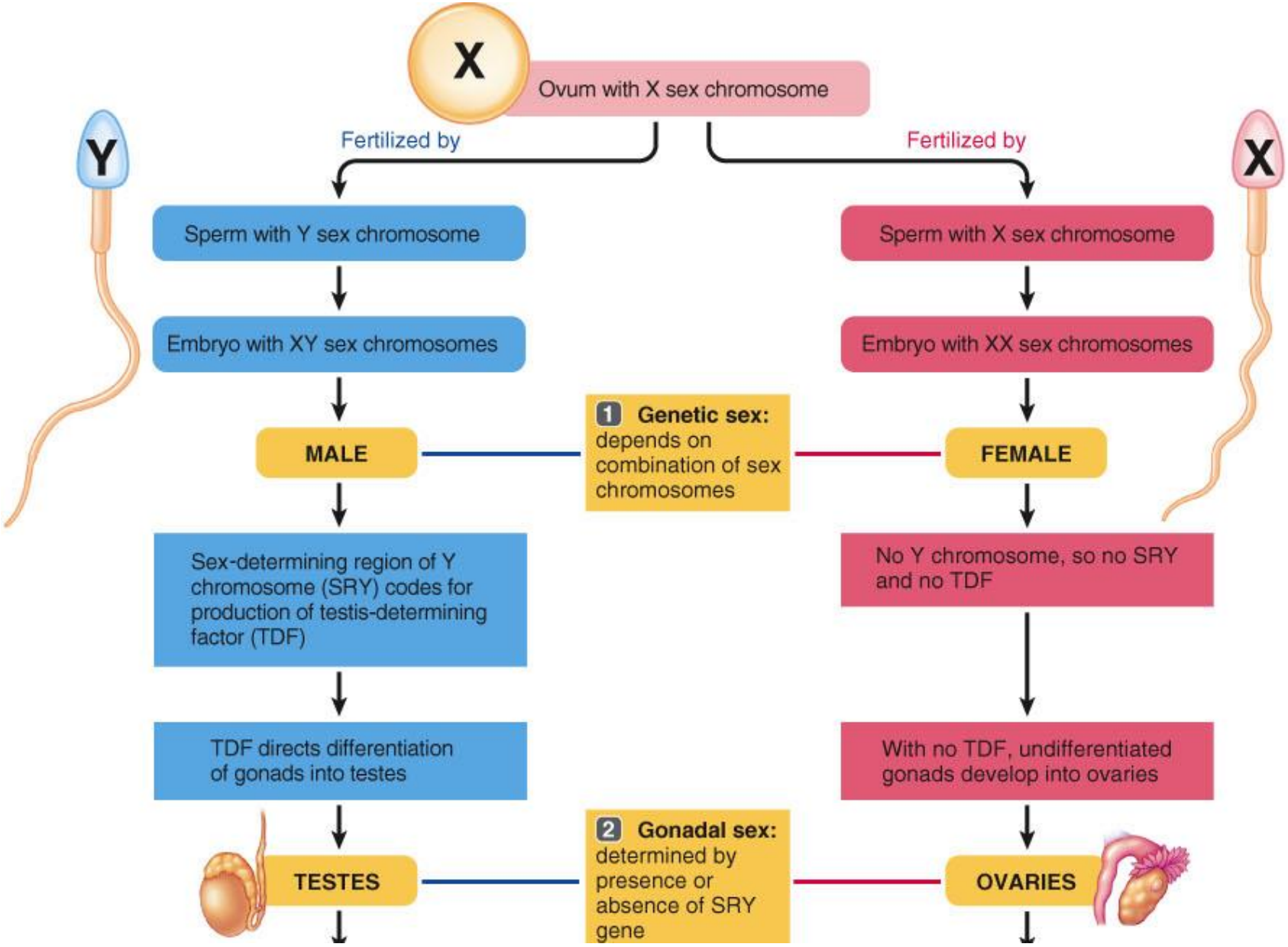
- The sex of an individual is determined by the combination of sex chromosomes.
- **Genetic males** have both an X and a Y sex chromosome; **genetic females** have two X sex chromosomes.
- **Phenotypic sex** is the apparent anatomic sex of an individual
- It is hormonally mediated and depends on the genetically determined **gonadal sex.**

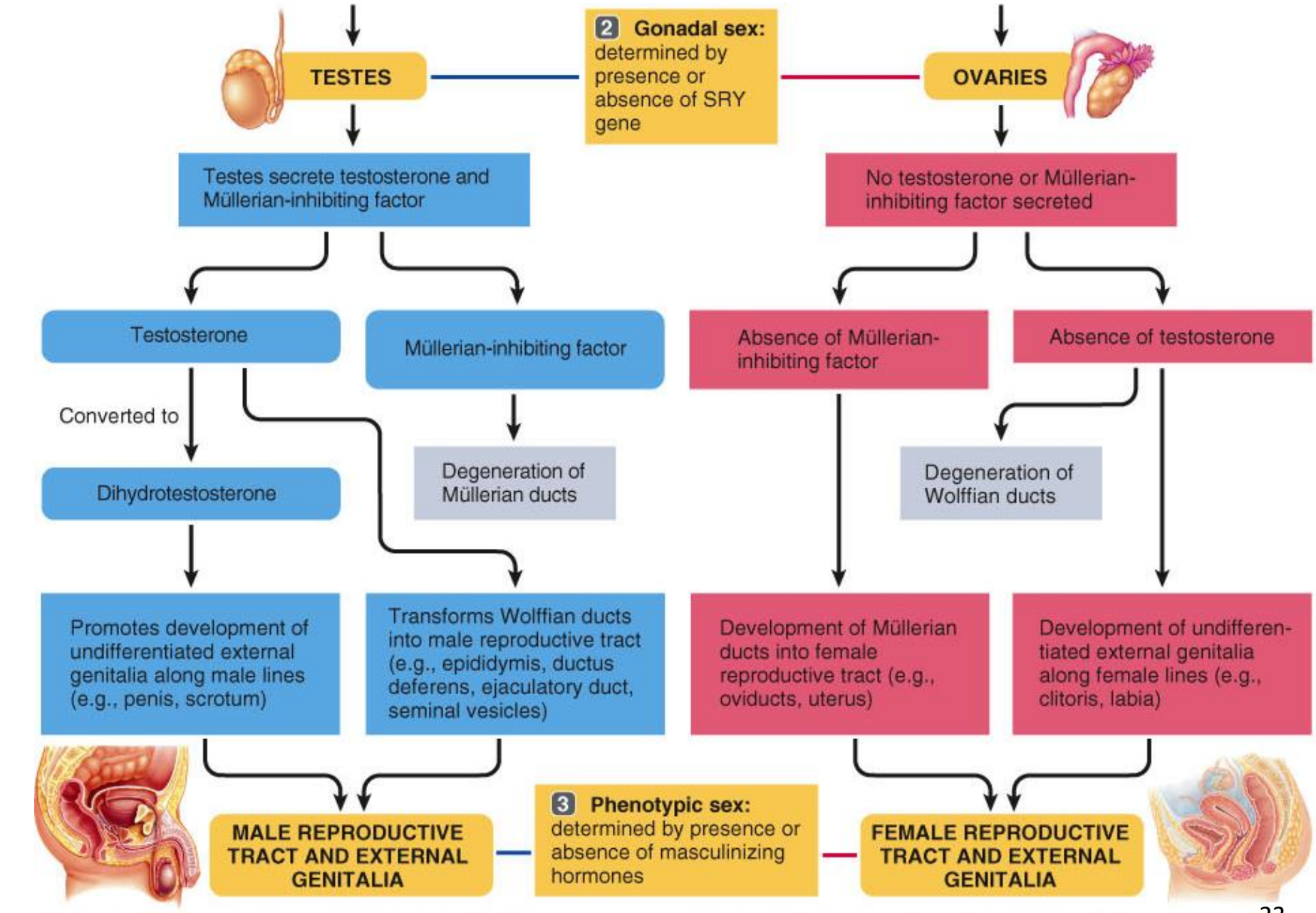
With SRY
With H-Y antigen
With TDF
Wolffian ducts

No SRY
No H-Y antigen
No TDF
Müllerian ducts



- SRY, sex-determining region (성결정인자)
- TDF, testis-determining factor

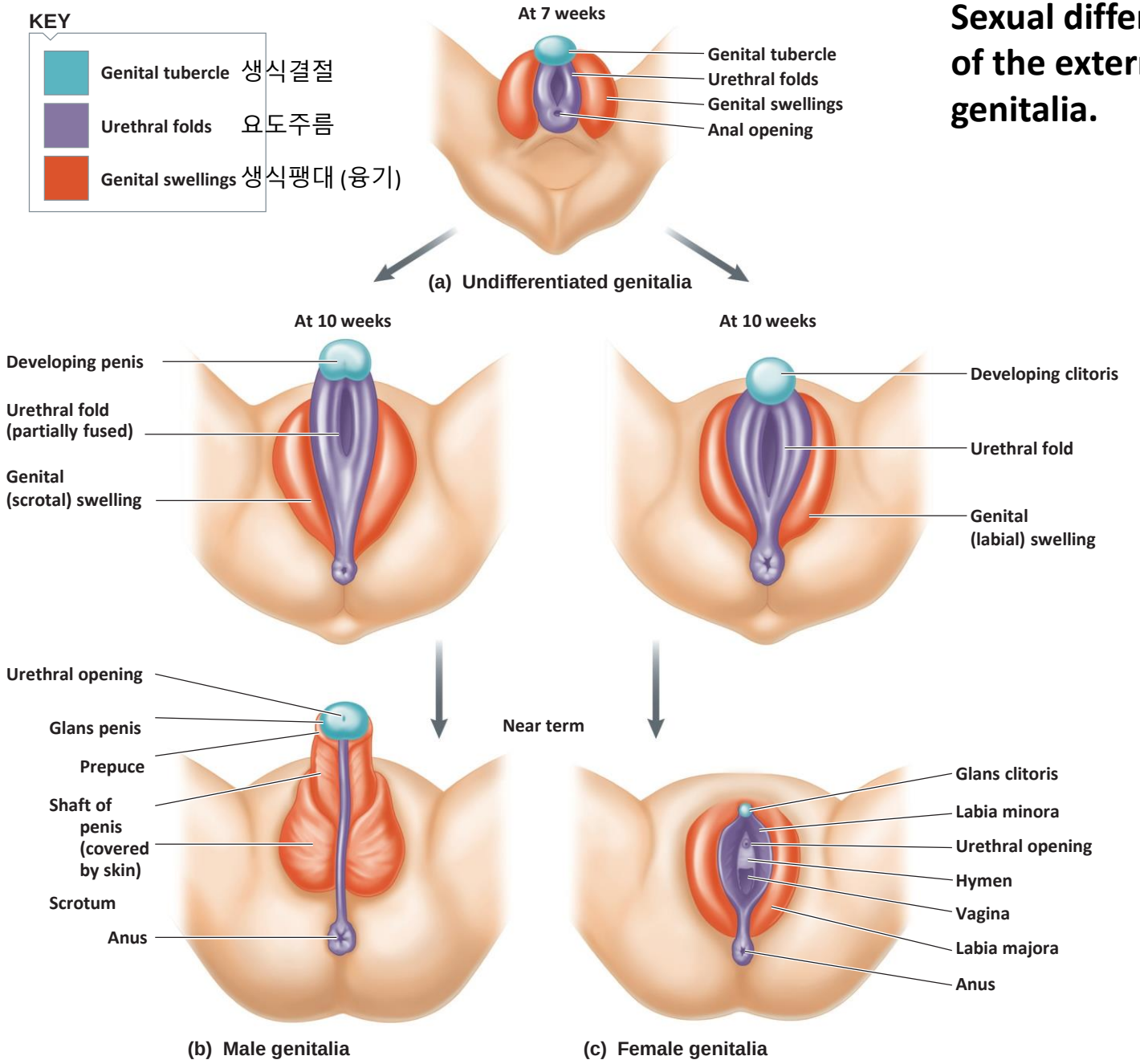

X
Ovum with X sex chromosome
Fertilized by
Fertilized by
Y
X
Sperm with Y sex chromosome
Sperm with X sex chromosome
Embryo with XY sex chromosomes
Embryo with XX sex chromosomes
1 Genetic sex: depends on combination of sex chromosomes
MALE
FEMALE
Sex-determining region of Y chromosome (SRY) codes for production of testis-determining factor (TDF)
No Y chromosome, so no SRY and no TDF
TDF directs differentiation of gonads into testes
With no TDF, undifferentiated gonads develop into ovaries
2 Gonadal sex: determined by presence or absence of SRY gene
TESTES
OVARIES



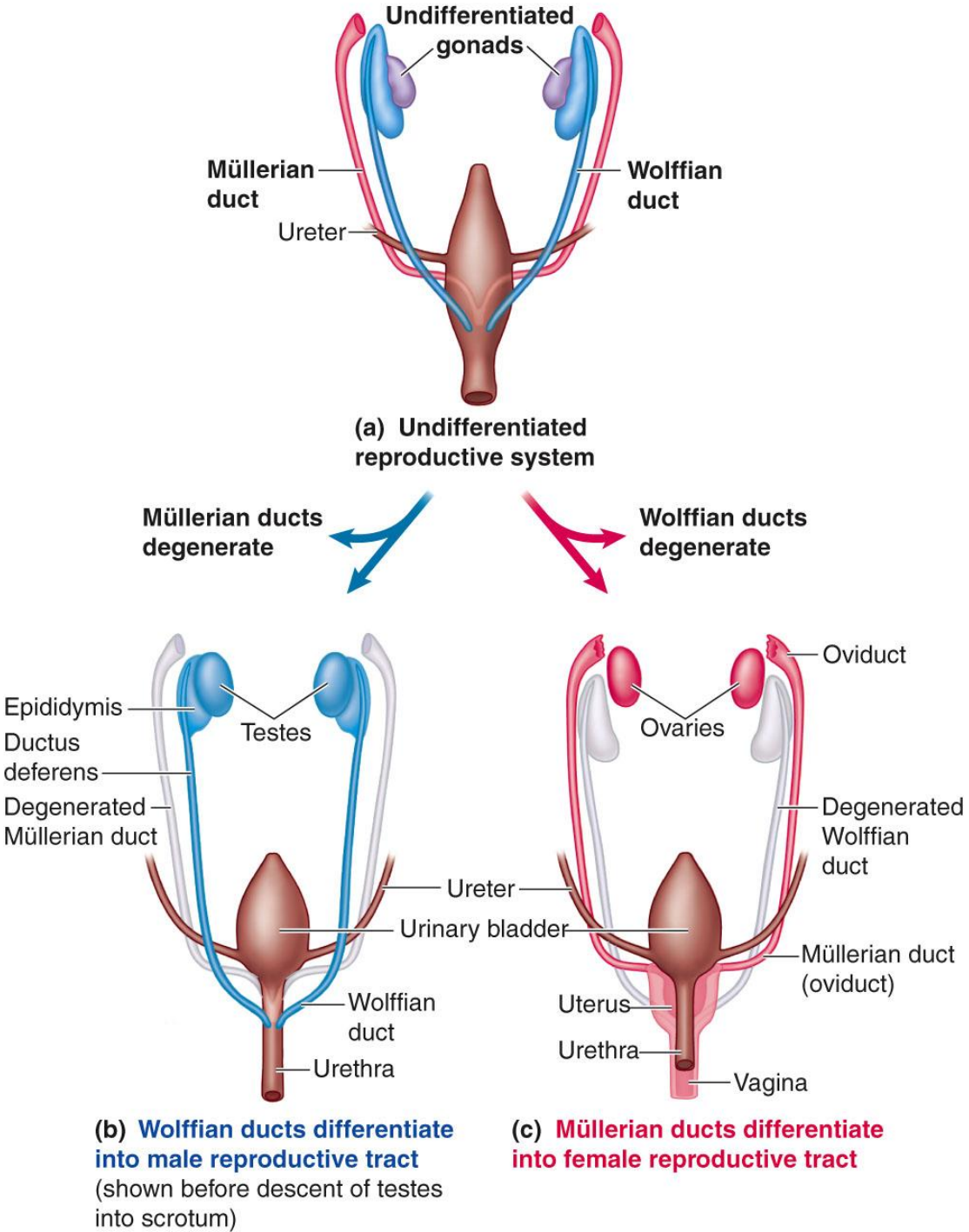
(a) Male sex determination and sexual differentiation

(b) Female sex determination and sexual differentiation

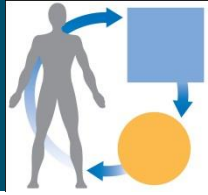
Sexual differentiation of the external genitalia.



Sexual differentiation of the reproductive tract

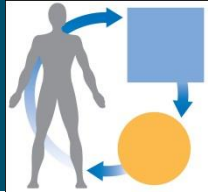


20.2. Male Reproductive Physiology: Testes



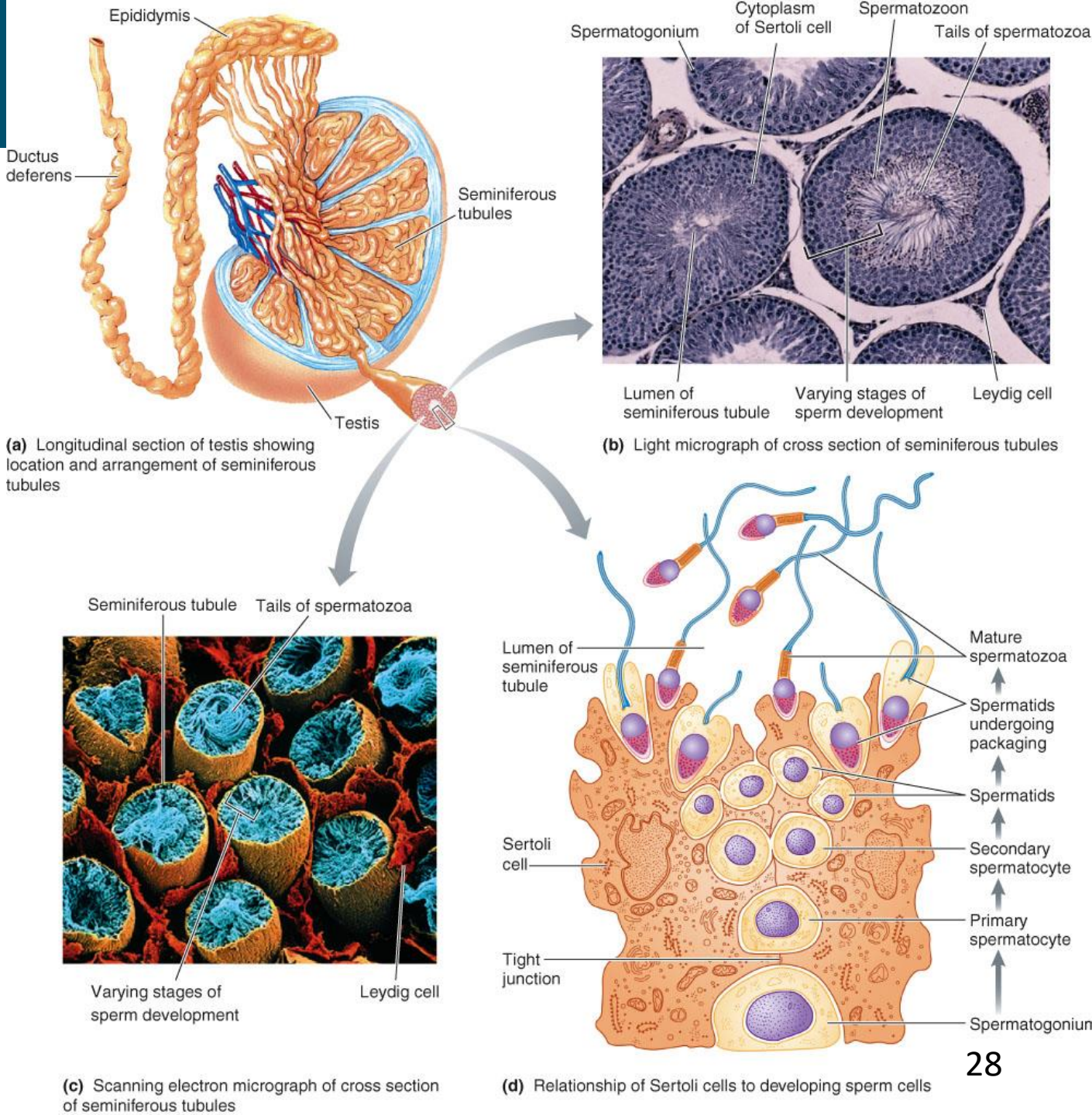
- Descend into scrotum during development.
- Scrotum provides cooler environment needed for **spermatogenesis.**
- Perform dual function:
  - produce sperm within **seminiferous tubules**
  - secrete testosterone produced by **Leydig (interstitial) cells** that lie between seminiferous tubules

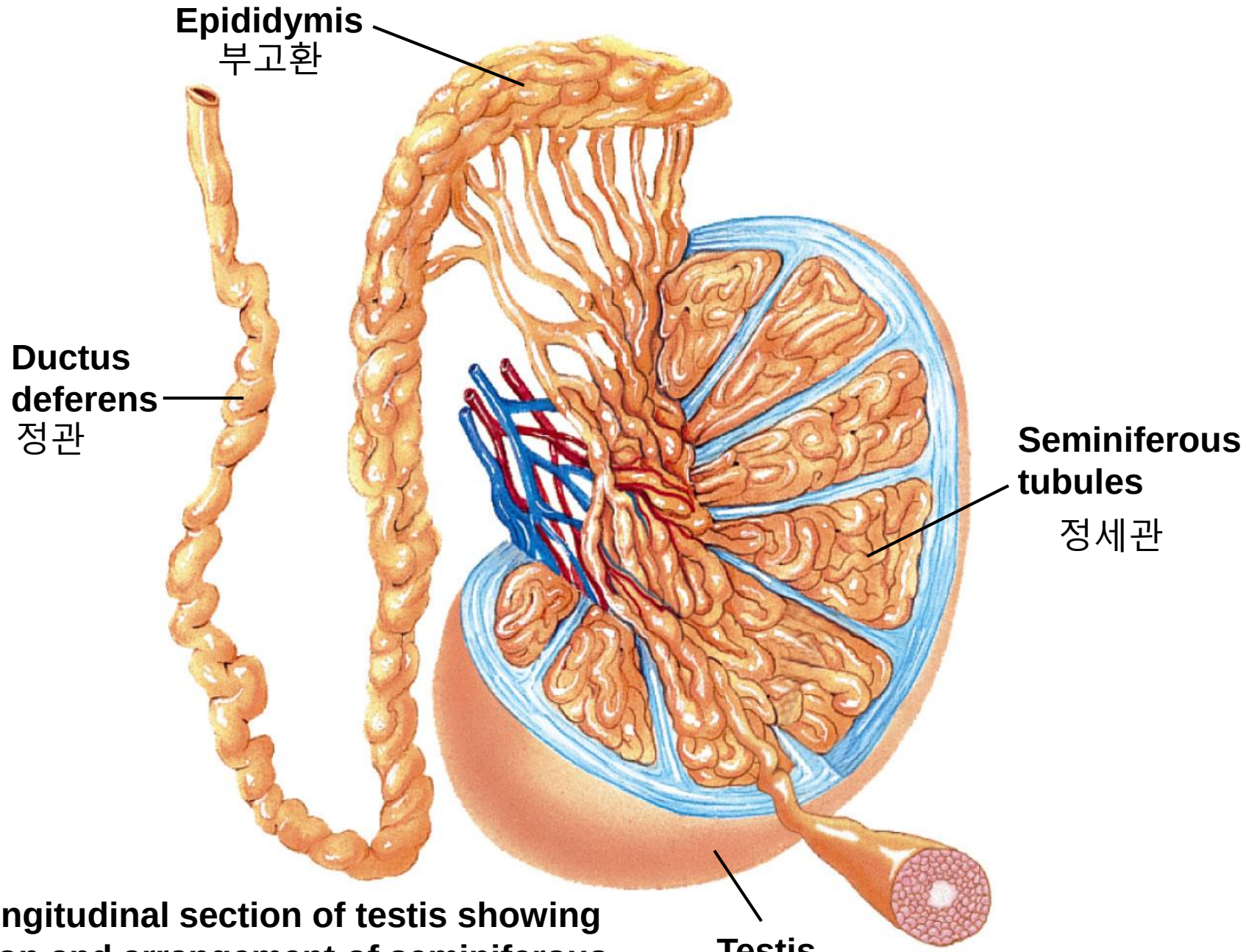
Male Reproductive Physiology



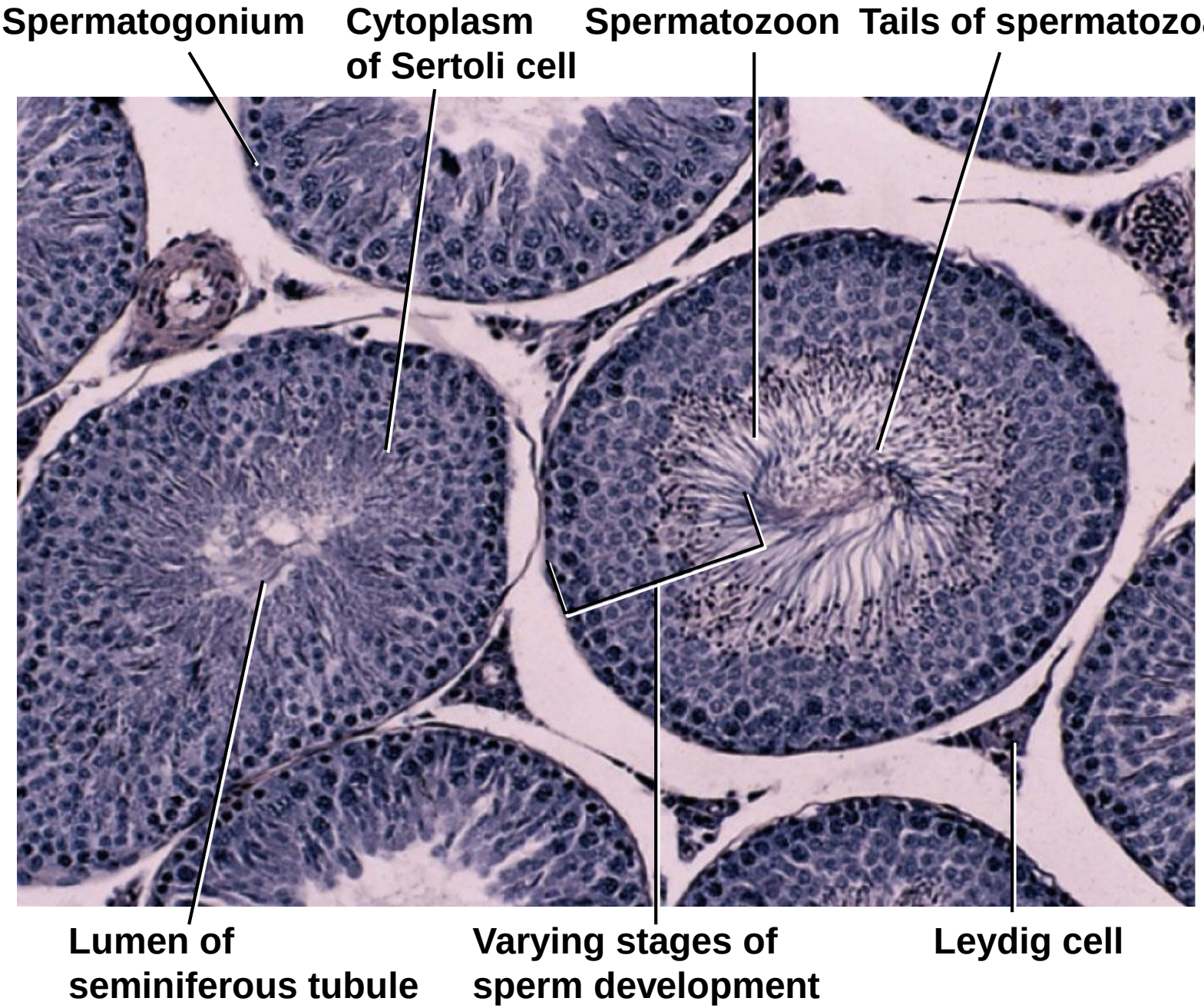
- Testosterone
  - Steroid hormone derived from cholesterol precursor molecule
  - Five categories of testosterone effects
    - Reproductive system before birth
    - Sex-specific tissues after birth
    - Other reproductive-related effects
    - Secondary sexual characteristics
    - Non-reproductive actions

Fig. 20-7. Anatomy of testis depicting the site of spermatogenesis

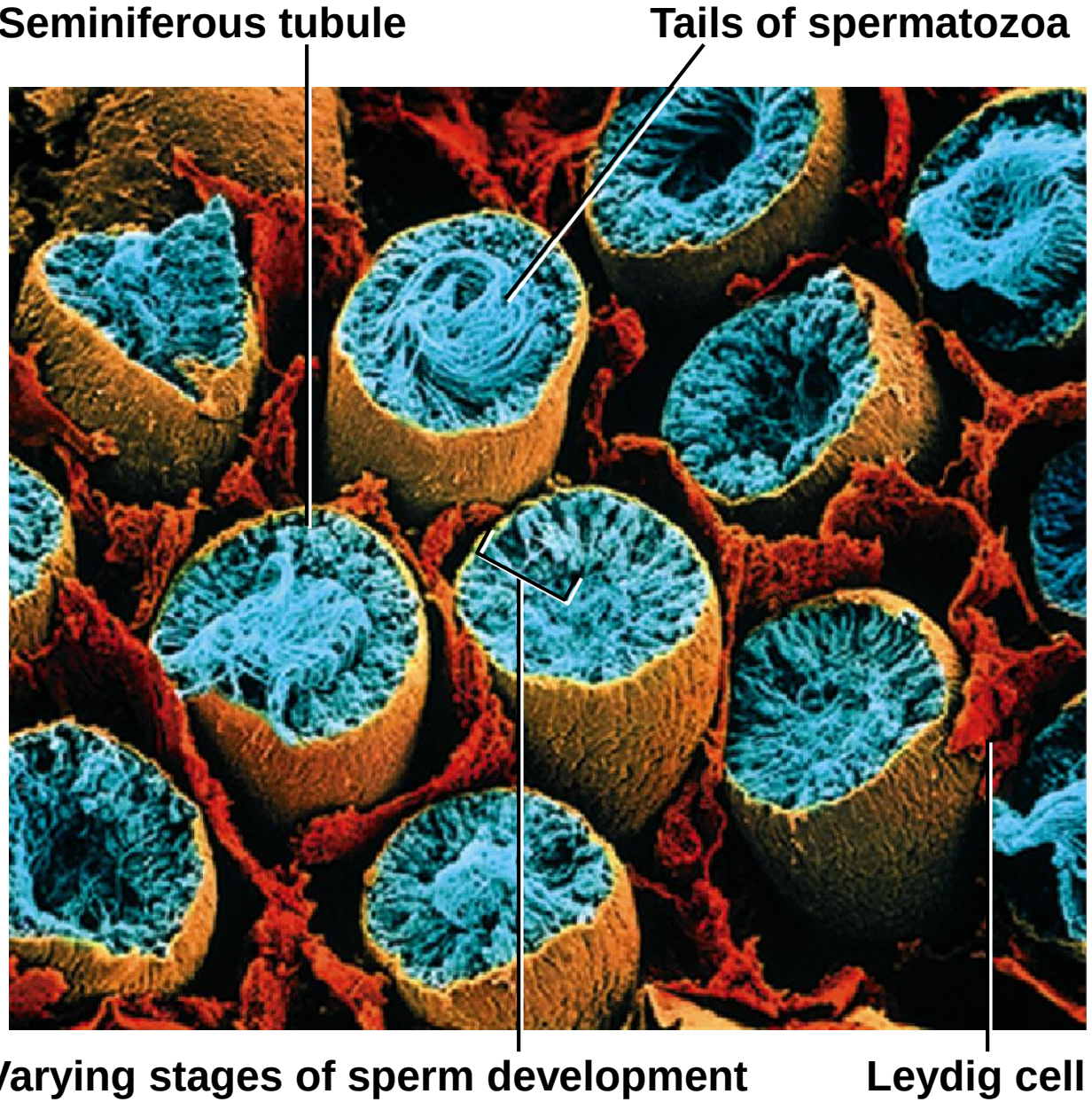




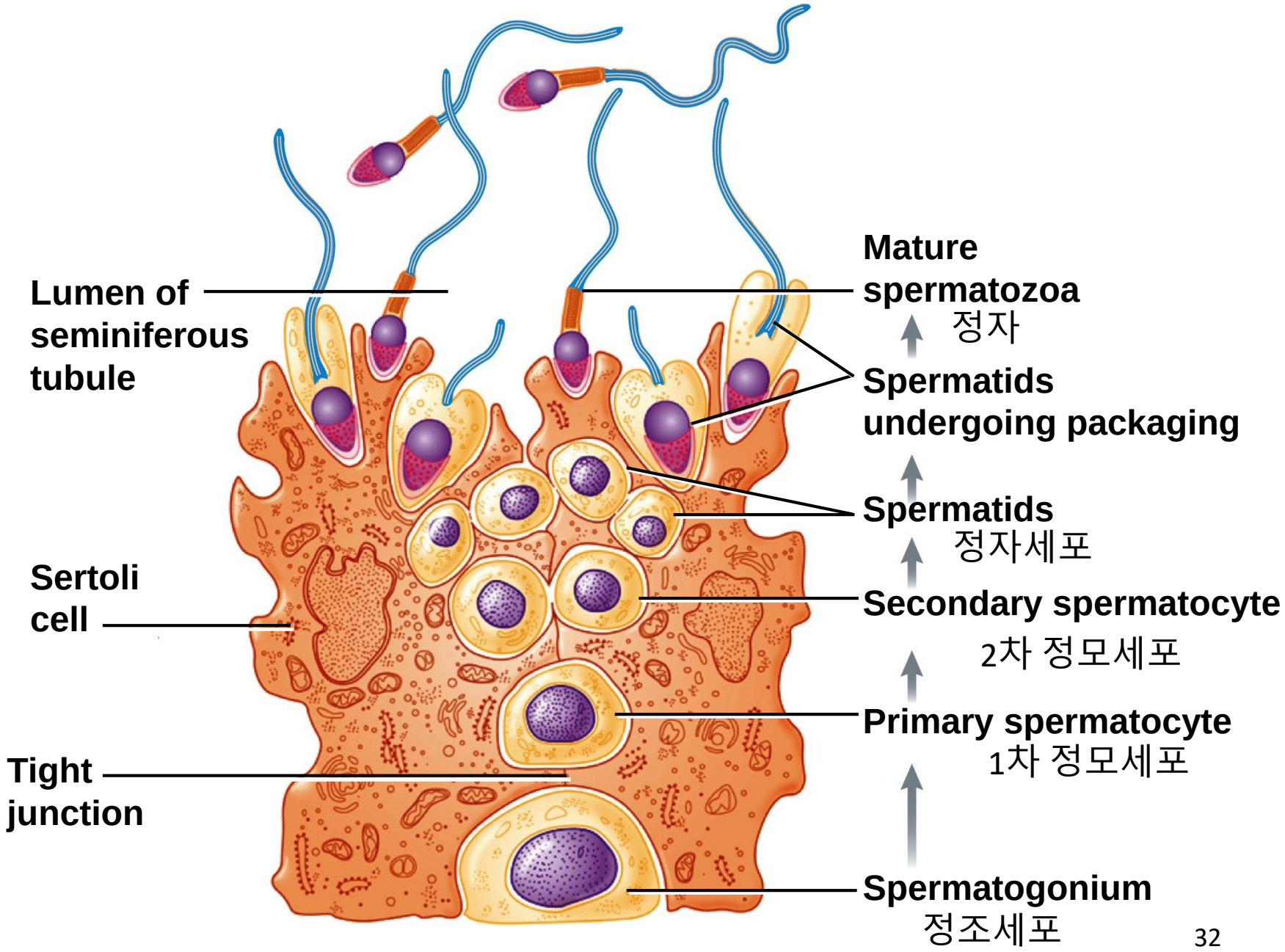
(a) Longitudinal section of testis showing location and arrangement of seminiferous tubules



(b) Light micrograph of cross section of seminiferous tubules

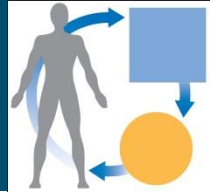


(c) Scanning electron micrograph of cross section of seminiferous tubules



(d) Relationship of Sertoli cells to developing sperm cells

Testosterone



- Secreted before birth to masculinize the developing reproductive system.
- Secretion stops until puberty.
- At puberty secretion begins again and continues throughout life.

TABLE 20-1 Effects of Testosterone

Effects before Birth

Masculinizes the reproductive tract and external genitalia

Promotes descent of the testes into the scrotum

Effects on Sex-Specific Tissues after Birth

Promotes growth and maturation of the reproductive system at puberty

Is essential for spermatogenesis

Maintains the reproductive tract throughout adulthood

Other Reproduction-Related Effects

Develops the sex drive at puberty

Controls gonadotropin hormone secretion

Effects on Secondary Sexual Characteristics

Induces the male pattern of hair growth (e.g., beard)

Causes the voice to deepen because vocal folds thicken

Promotes muscle growth responsible for the male body configuration

Nonreproductive Actions

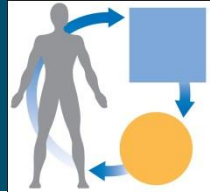
Exerts a protein anabolic effect

Promotes bone growth at puberty

Closes the epiphyseal plates after being converted to estrogen by aromatase

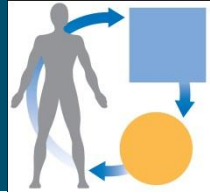
May induce aggressive behavior

Spermatogenesis

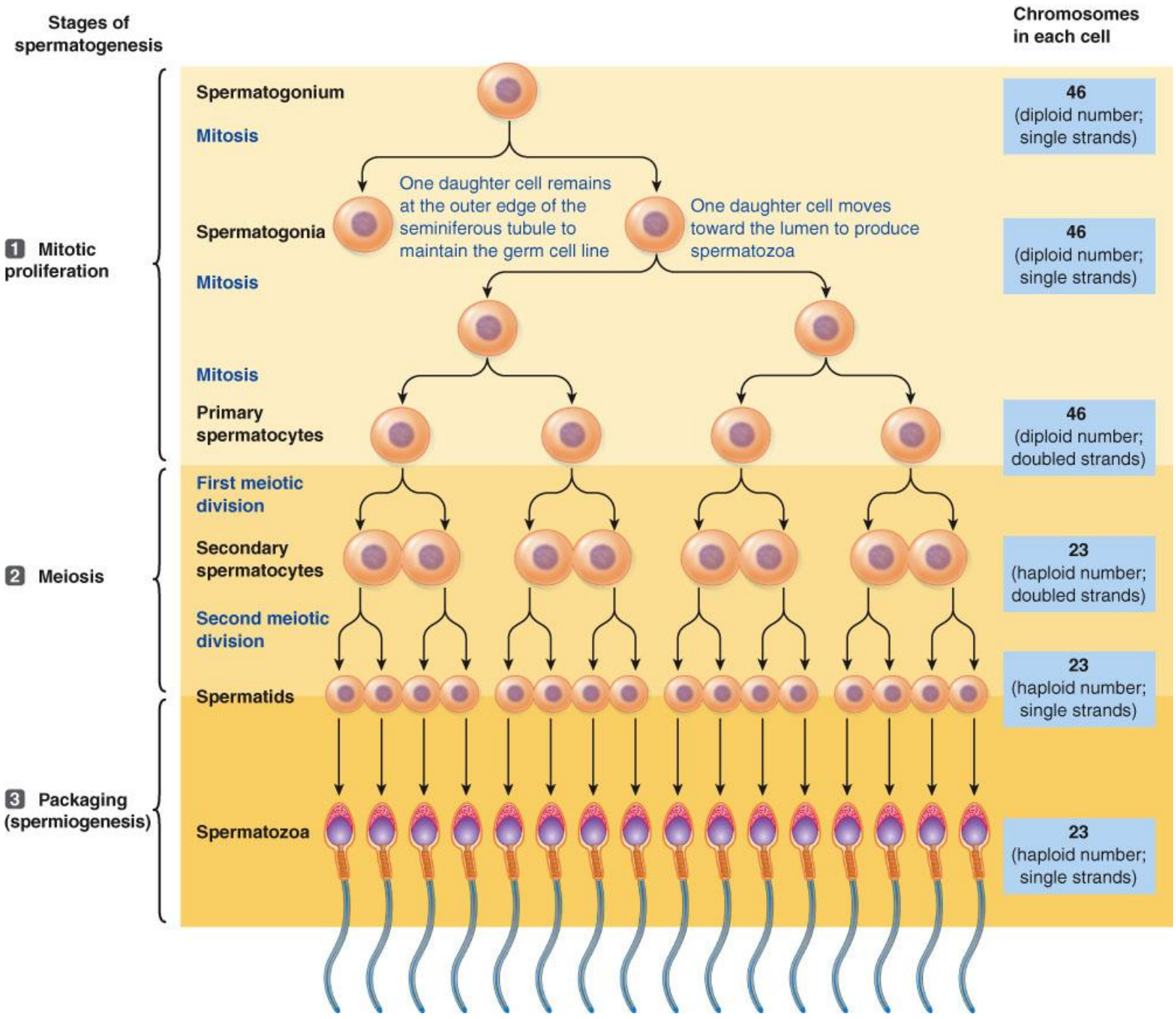


- About 250 m (800 ft) of sperm-producing seminiferous tubules are packed within the testes.
- Results in many highly specialized sperm.
- Requires both testosterone and FSH.
- Undifferentiated **diploid spermatogonia** are converted into **haploid spermatozoa (sperm).**

Spermatogenesis: three major stages



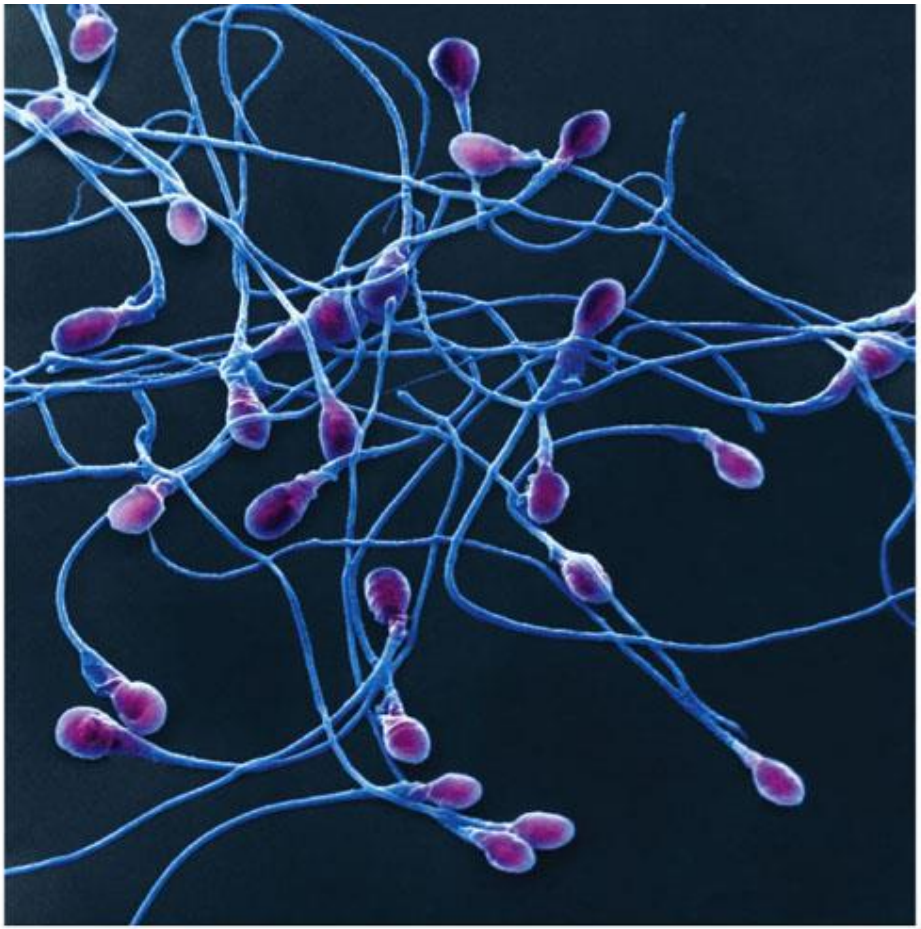
- Mitotic proliferation: spermatogonia divides mitotically twice to form four identical **primary spermatocytes.**
- Meiosis: each primary spermatocyte forms two **secondary spermatocytes** yielding four **spermatids.**
- Packaging or **spermiogenesis:** extensive remodeling of spermatids to form mobile **spermatozoa.**


Stages of spermatogenesis
Chromosomes in each cell
1 Mitotic proliferation
2 Meiosis
3 Packaging (spermiogenesis)
Spermatogonium
Mitosis
One daughter cell remains at the outer edge of the seminiferous tubule to maintain the germ cell line
One daughter cell moves toward the lumen to produce spermatozoa
Spermatogonia
Mitosis
Mitosis
Primary spermatocytes
First meiotic division
Secondary spermatocytes
Second meiotic division
Spermatids
Spermatozoa
46 (diploid number; single strands)
46 (diploid number; single strands)
46 (diploid number; doubled strands)
23 (haploid number; doubled strands)
23 (haploid number; single strands)
23 (haploid number; single strands)

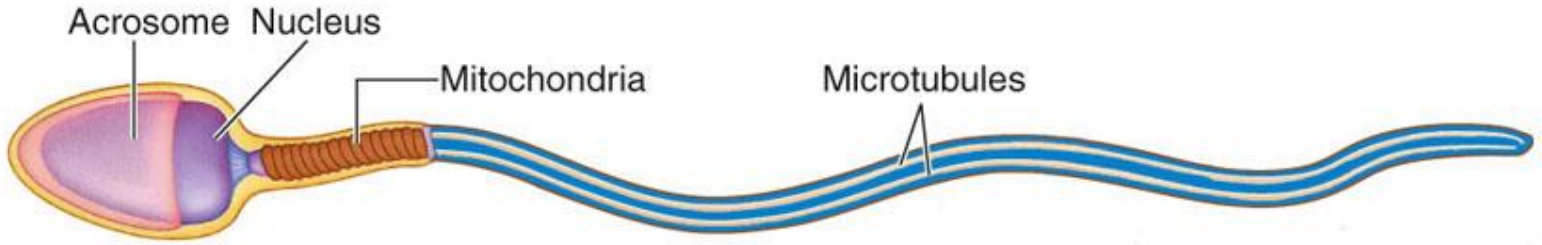
Spermatogenesis

- Spermatozoan
  - Remains closely associated with Sertoli cells throughout development
  - Consists of four parts
    - Head (머리)
      - Consists primarily of the nucleus (contains DNA)
    - Acrosome (선체)
      - Enzyme-filled vesicle that caps tip of the head
      - Used to penetrate ovum
      - Formed by endoplasmic reticulum and Golgi complex before these organelles are discarded
    - Midpiece (몸체)
      - Area where mitochondria are concentrated
    - Tail (꼬리)
      - Provides mobility for spermatozoan

Anatomy of a Spermatozoan



(a) Photomicrograph of human spermatozoa

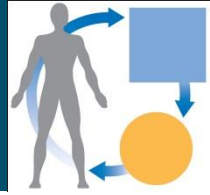


(b) Parts of spermatozoon

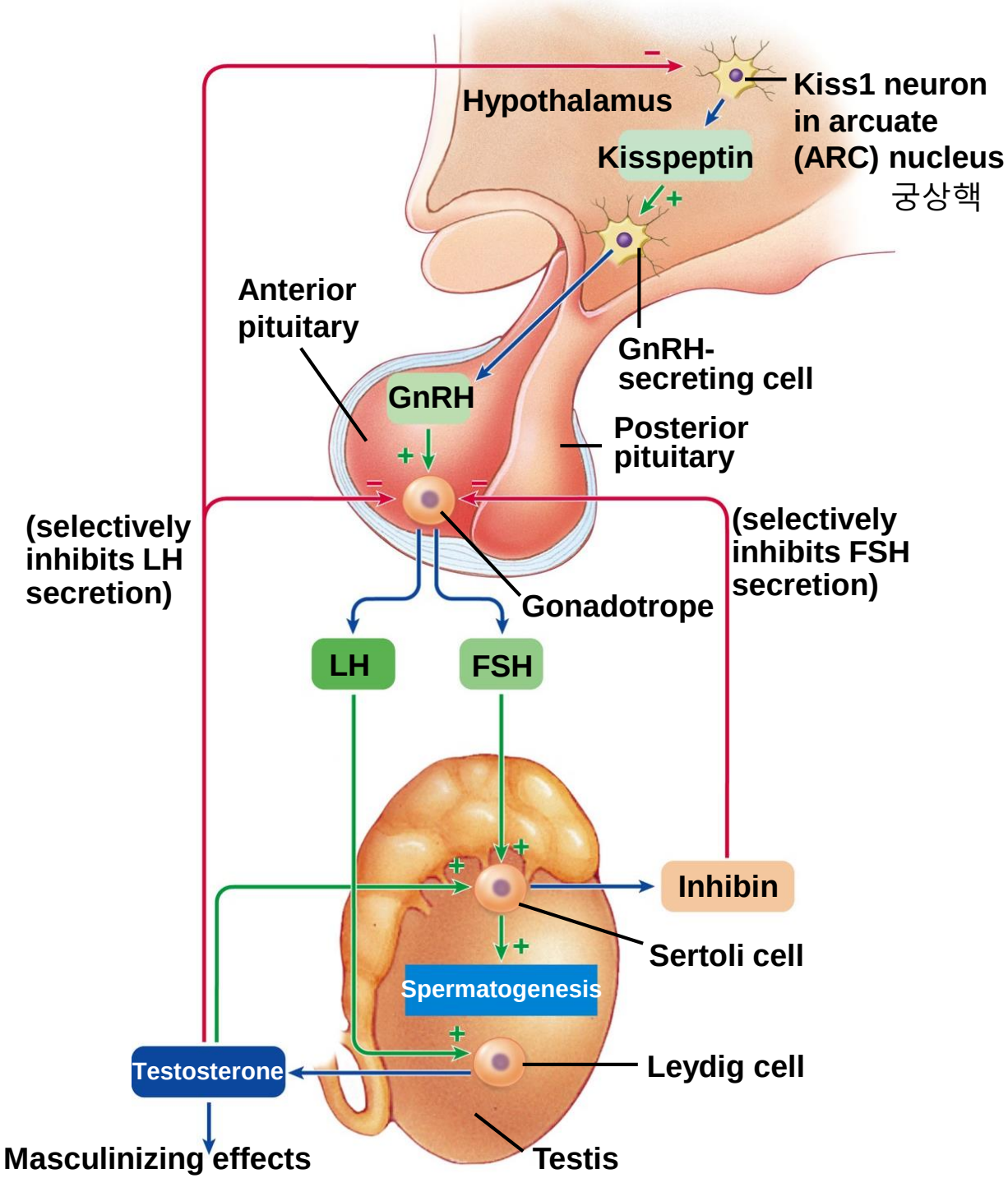
Spermatogenesis

- Functions of Sertoli cells located in seminiferous tubules
  - Form blood-testes barrier
  - Provide nourishment
  - Phagocytic function
  - Secrete seminiferous tubule fluid which flushes released sperm from tubule into epididymis for storage and additional processing
  - Secrete androgen-binding protein
  - Site of action to control spermatogenesis
    - Release **inhibin**
    - Acts in negative-feedback fashion to regulate FSH secretion

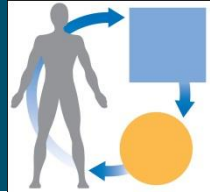
Regulation of Testes



- Testes are regulated by the anterior pituitary hormones, **luteinizing hormone (LH)** and **follicle-stimulating hormone (FSH).**
- LH and FSH are controlled by GnRH (생식샘자극호르몬-방출호르몬) from hypothalamus.
- Testosterone secretion is regulated by LH stimulation of the Leydig cells.
- Testosterone feedback inhibits LH secretion.

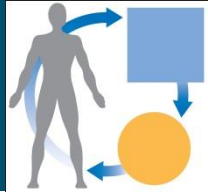

Hypothalamus
Kiss1 neuron in arcuate (ARC) nucleus
궁상핵
Kisspeptin
Anterior pituitary
GnRH-secreting cell
GnRH
Posterior pituitary
(selectively inhibits LH secretion)
(selectively inhibits FSH secretion)
Gonadotrope
LH
FSH
Inhibin
Sertoli cell
Spermatogenesis
Testosterone
Leydig cell
Masculinizing effects
Testis

Male Ducts and Glands



- **Epididymis** and **ductus deferens:**
  - store and concentrate the sperm
  - Increase sperm motility and fertility prior to ejaculation
- During ejaculation, sperm are mixed with secretions released by accessory glands:
  - **seminal vesicles**
  - **prostate gland**
  - **bulbourethral glands**

Male Ducts and Glands



- **Seminal vesicles**:
  - supply fructose for energy
  - supply prostaglandins
  - provide more than half the semen
  - secrete fibrinogen
- **Prostate gland**:
  - secretes alkaline fluid
  - provides clotting enzymes and fibrinolysin
- **Bulbourethral glands**:
  - release lubricating mucus

Location and Functions of the Components of the Male Reproductive System

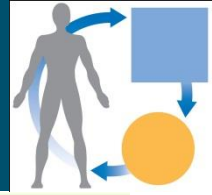
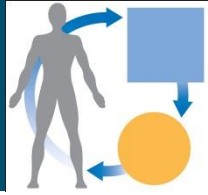


TABLE 20-2 Location and Functions of the Components of the Male Reproductive System

Component	Number and Location	Functions
Testis	Pair; located in the scrotum, a skin-covered sac suspended within the angle between the legs	Produce sperm Secrete testosterone
Epididymis and Ductus Deferens	Pair; one epididymis attached to the rear of each testis; one ductus deferens travels from each epididymis up out of the scrotal sac through the inguinal canal and empties into the urethra at the neck of the bladder	Serve as the sperm's exit route from the testis Serve as the site for maturation of the sperm for motility and fertility Concentrate and store the sperm
Seminal Vesicle	Pair; both empty into the last portion of the ductus deferens, one on each side	Supply fructose to nourish the ejaculated sperm Secrete prostaglandins that stimulate motility to help transport the sperm within the male and female Provide the bulk of the semen Provide precursors for the clotting of semen
Prostate Gland	Single; completely surrounds the urethra at the neck of the bladder	Secretes an alkaline fluid that neutralizes the acidic vaginal secretions Triggers clotting of the semen to keep the sperm in the vagina during penis withdrawal
Bulbourethral Gland	Pair; both empty into the urethra, one on each side, just before the urethra enters the penis	Secrete mucus for lubrication

20.3. Male Sex Cycle



- Male sex act involves erection (발기) and ejaculation (사정).
- Sexual response cycle:
- **Excitement phase (흥분기)**
  - erection and heightened sexual awareness
- **Plateau phase (평탄기)**
  - steadily increasing heart rate, blood pressure, respiratory rate, and muscle tension

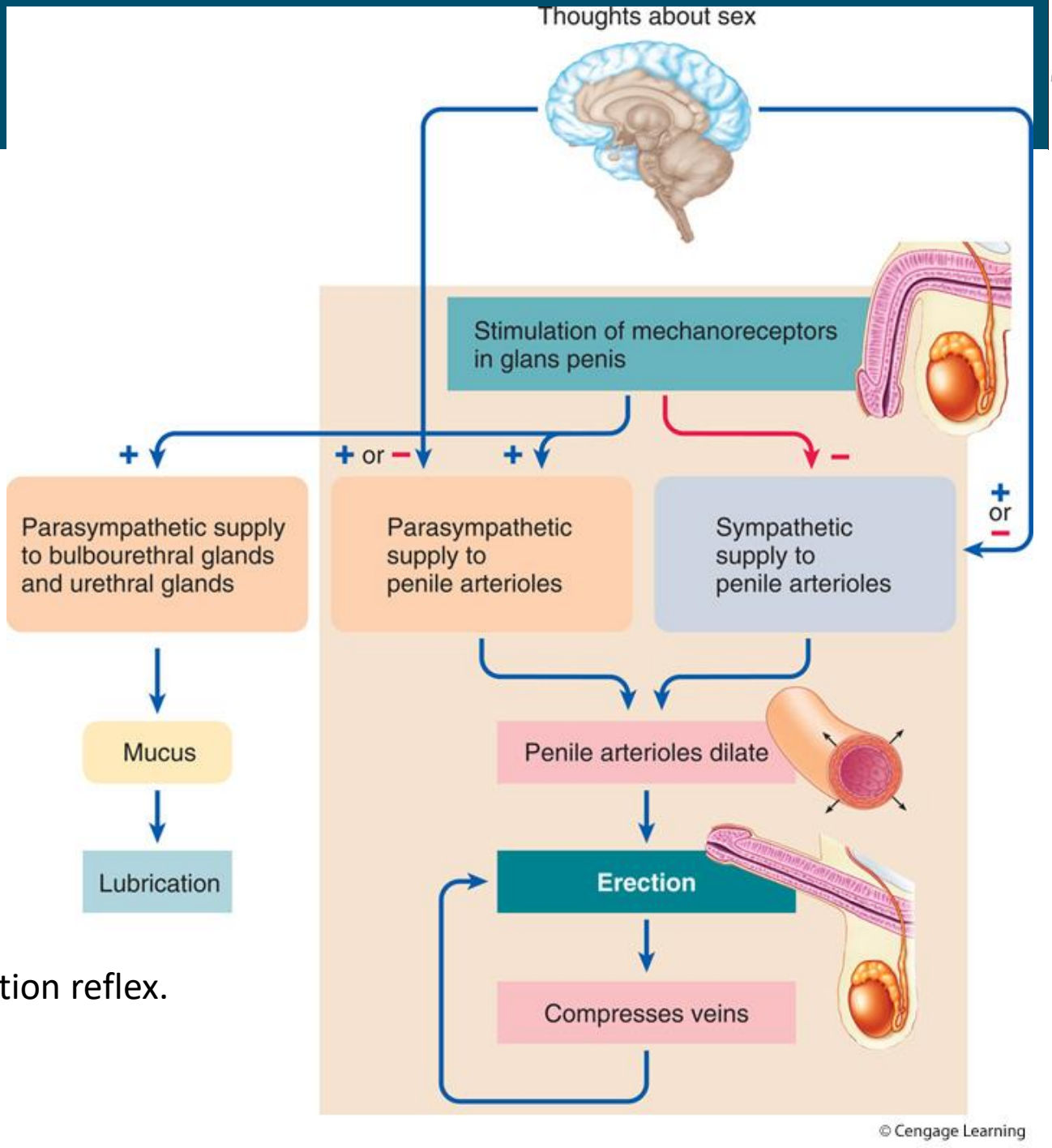
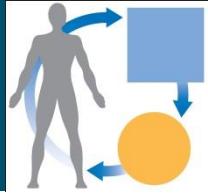


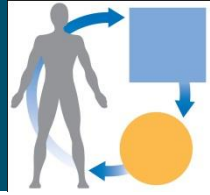
Figure 20-10 Erection reflex.

Males Sex Cycle



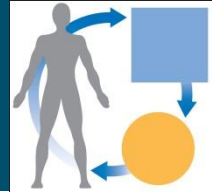
- **Orgasmic phase (오르가슴기)**
  - Ejaculation and other responses that are experienced as physical pleasure
- **Resolution phase (해빙기)**
  - return of genitalia and body systems to pre-arousal state

Ejaculate



- The volume and sperm content of the ejaculate depend on the length of time between ejaculations.
- The average volume of semen is 2.75 mL, ranging from 2 to 6 mL
- Average human ejaculate contains about 165 million sperm (1억6천5백만 마리) (60 million/mL) but some ejaculates contain as many as 400 million sperm (4억 마리).
- Infertile: < 20 million/mL

Ejaculation includes emission and expulsion



- Emission (사출): 전립샘액, 정자, 정낭액 등의 정액이 요도로 운반
- Expulsion (배출): 골격근의 율동적인 수축이 0.8초 간격 → 정액 배출
- Orgasm (오르가슴): heavy breathing, a heart rate of up to 180 beats per minute
- Resolution (해빙)

Figure 20-11 Scanning electron micrograph of sperm amassed at the surface of an ovum.

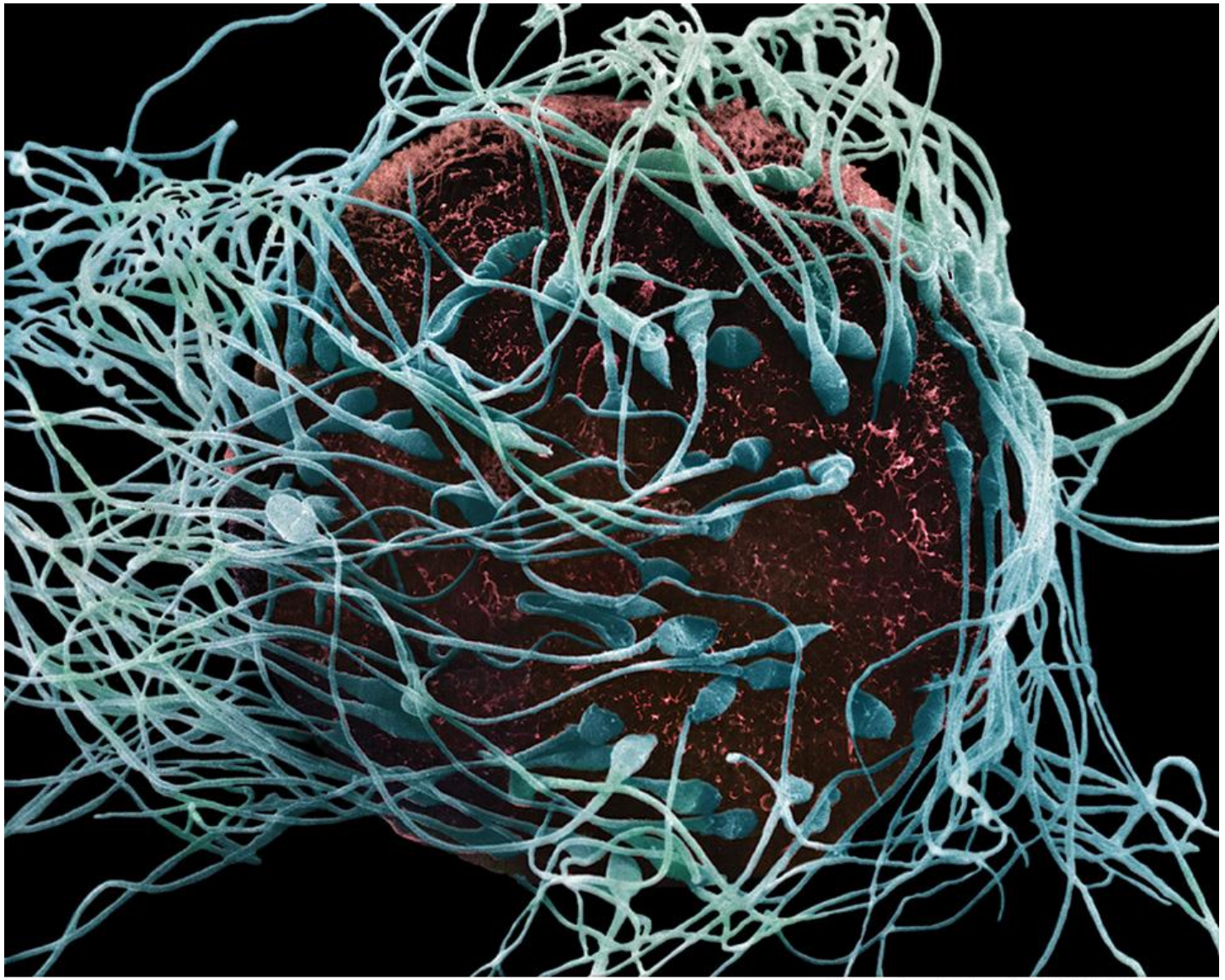
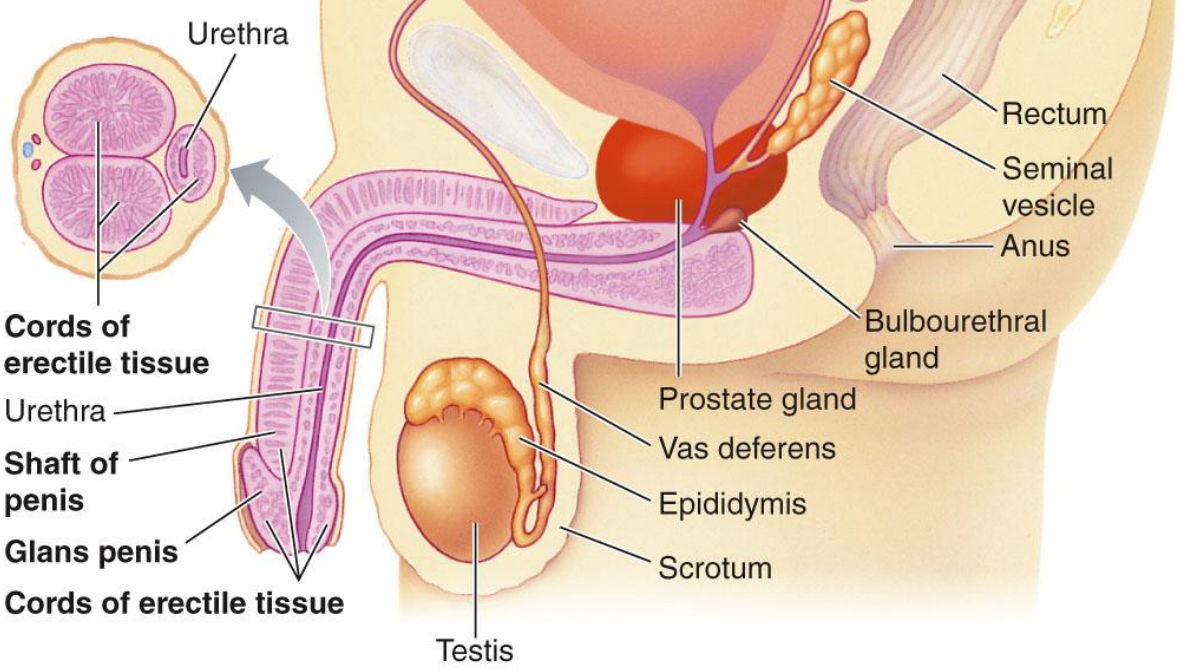


TABLE 20-3 Components of the Male Sex Act

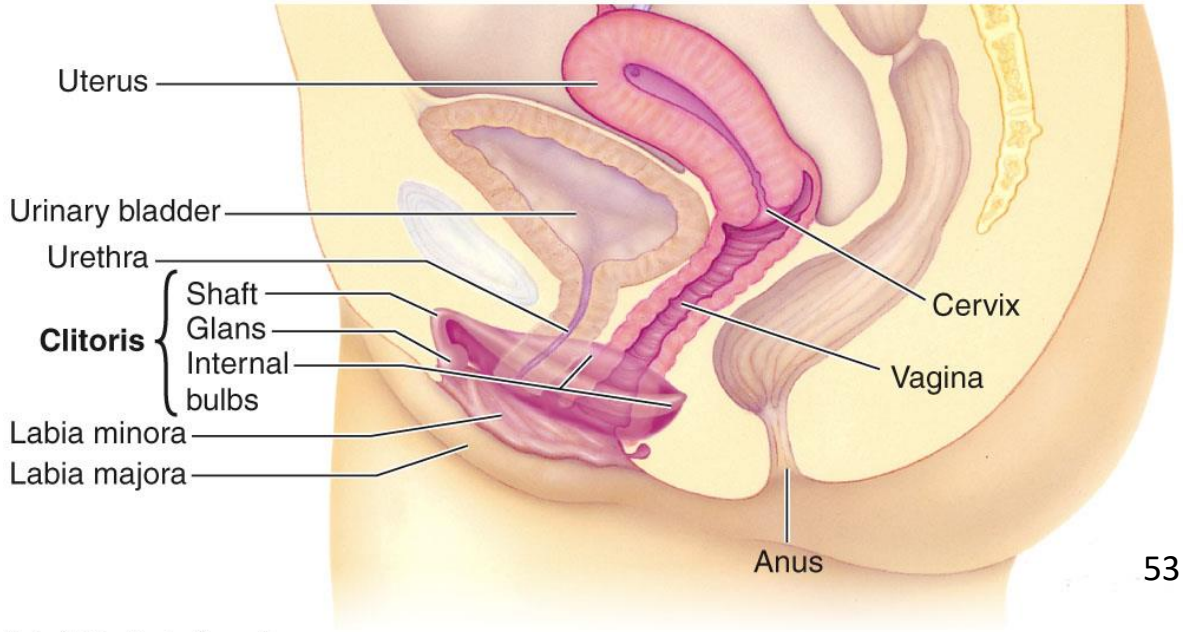
Components of the Male Sex Act	Definition	Accomplished by
Erection	Hardening of the normally flaccid penis to permit its entry into the vagina	Engorgement of the penis erectile tissue with blood as a result of marked parasympathetically induced vasodilation of the penile arterioles and mechanical compression of the veins
Ejaculation		
Emission phase	Emptying of sperm and accessory sex-gland secretions (semen) into the urethra	Sympathetically induced contraction of the smooth muscle in the walls of the reproductive ducts and accessory sex glands
Expulsion phase	Forceful expulsion of semen from the penis	Motor neuron–induced contraction of the skeletal muscles at the base of the penis

Erectile tissue in

Males and females

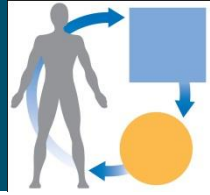


(a) Penis in males



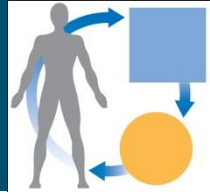
(b) Clitoris in females

Female Sex Cycle



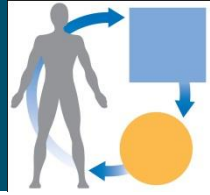
- Female sexual cycle is similar to male cycle.
- Same four phases of the sexual cycle:
- **Excitement**:
  - initiated by physical or psychological stimuli
- **Plateau**:
  - changes initiated during excitement phase intensify
  - systemic responses similar to those in male occur

Female Sex Cycle



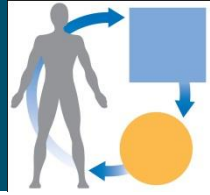
- **Orgasm experience** in females is similar to that in males except:
  - no female counterpart to ejaculation
  - no refractory period (불응기) following orgasm
- **Resolution**:
  - pelvic and systemic responses subside
  - time of great physical relaxation

20.4. Female Reproductive Physiology



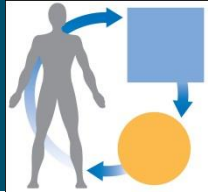
- More complex than male reproductive physiology
- Characterized by complex cycling
- Ovaries:
  - produce ova (oogenesis)
  - secrete female sex hormones:
    - **estrogen**
    - **progesterone**

Female Reproductive Physiology



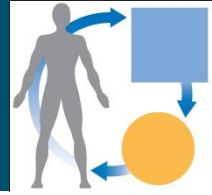
- **Estrogen**:
  - essential for ova maturation and release
  - establishes secondary sexual characteristics
  - essential for transport of sperm in oviducts
  - contributes to breast development
- **Progesterone**:
  - important in preparing environment for nourishing embryo/fetus
  - essential for milk production

Oogenesis



- Identical steps of chromosome replication and division during gamete production in both sexes.
- Timing and end result are different.
- During fetal life, oogonia begin steps of the first meiotic division but do not complete it.
- Just before ovulation, the primary oocyte completes its first meiotic division.

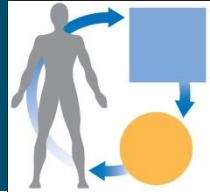
Oogenesis



- Identical steps of chromosome replication and division during gamete production in both sexes
  - Timing and end result are very different

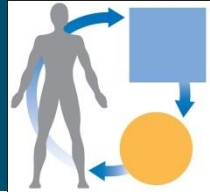
Spermatogenesis	Oogenesis
Accomplished within two months	Take anywhere from 12 to 50 years to complete on cyclic basis from onset of puberty until menopause
Postpubertal male can produce several hundred million sperm each day	Female born with limited, largely nonrenewable supply of germ cells
Each primary spermatocyte yields four equally viable spermatozoa	Each primary oocyte yields only one cytoplasm-rich ovum and three cytoplasm-poor polar bodies that disintegrate

Oogenesis



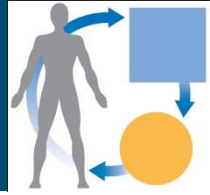
- Oogonia
  - Undifferentiated primordial germ cells in fetal ovaries
  - Divide mitotically to give 6 million to 7 million oogonia by fifth month of gestation rise to
  - During last part of fetal life begin early steps of first meiotic division but do not complete it
    - Now known as primary oocytes
      - Contain diploid number of 46 replicated chromosomes
      - Remain in meiotic arrest for years until they are prepared for ovulation
      - At birth only about 2 million primary follicles
      - About 300,000 primary follicles
      - About 400 will mature and release ova; 99.98% never ovulate but instead undergo **atresia (폐경)**

Oogenesis



- Primary oocyte
  - Surrounded by single layer of granulosa cells (과립세포)
  - Oocyte + granulosa cells → primary follicle
- Primary follicle
  - After development starts there are two possible fates
    - Reach maturity and ovulate
    - Degenerate to form scar tissue (atresia)
- Between puberty and menopause
  - Follicles develop into secondary (antral) follicles on cyclic basis

Oogenesis



- Almost all the cytoplasm remains with one daughter cell, the **secondary oocyte.**
- Other daughter cell forms the **first polar body.**
- Sperm entry into the secondary oocyte triggers the second meiotic division.
- During the second division the **second polar body** is produced.

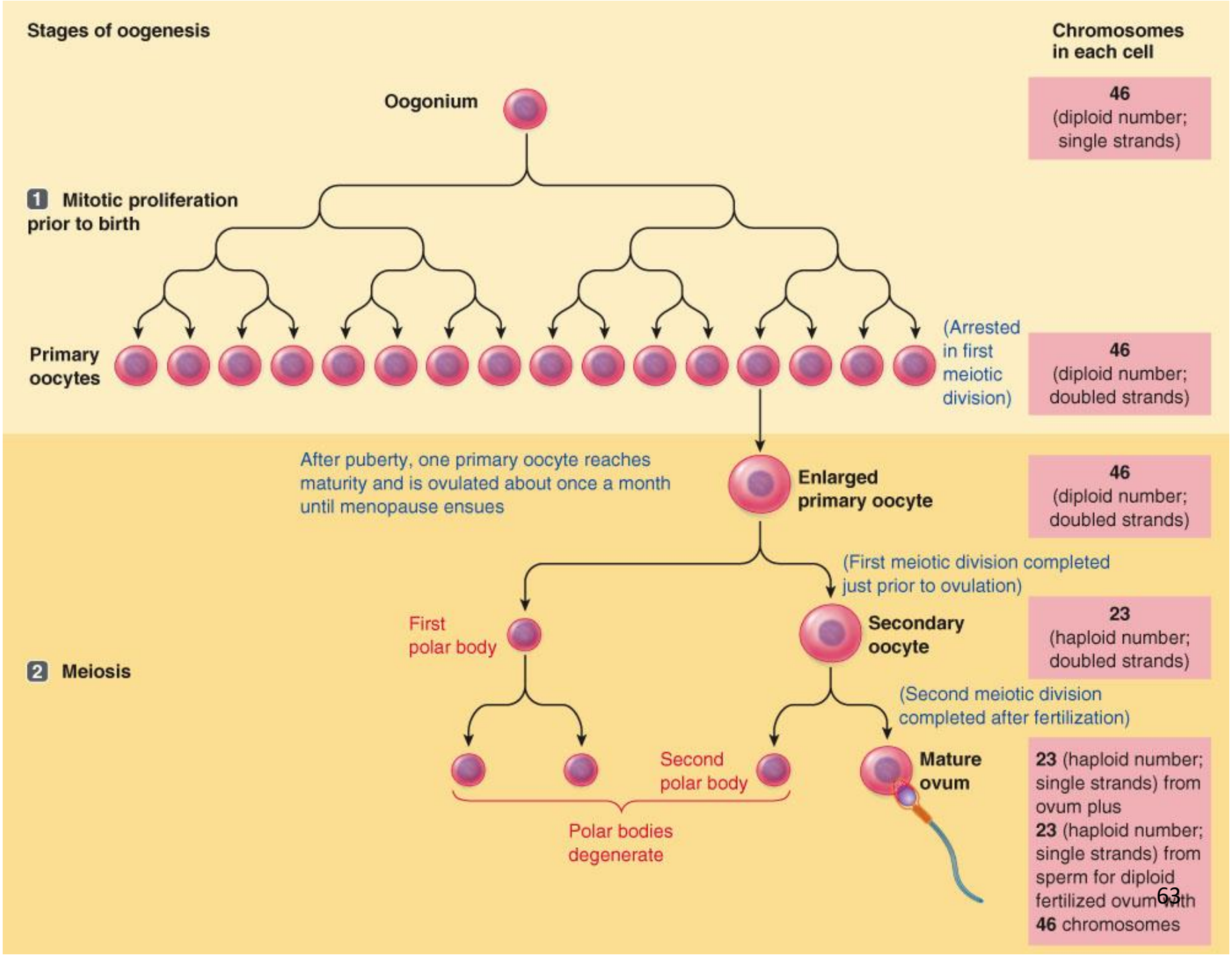
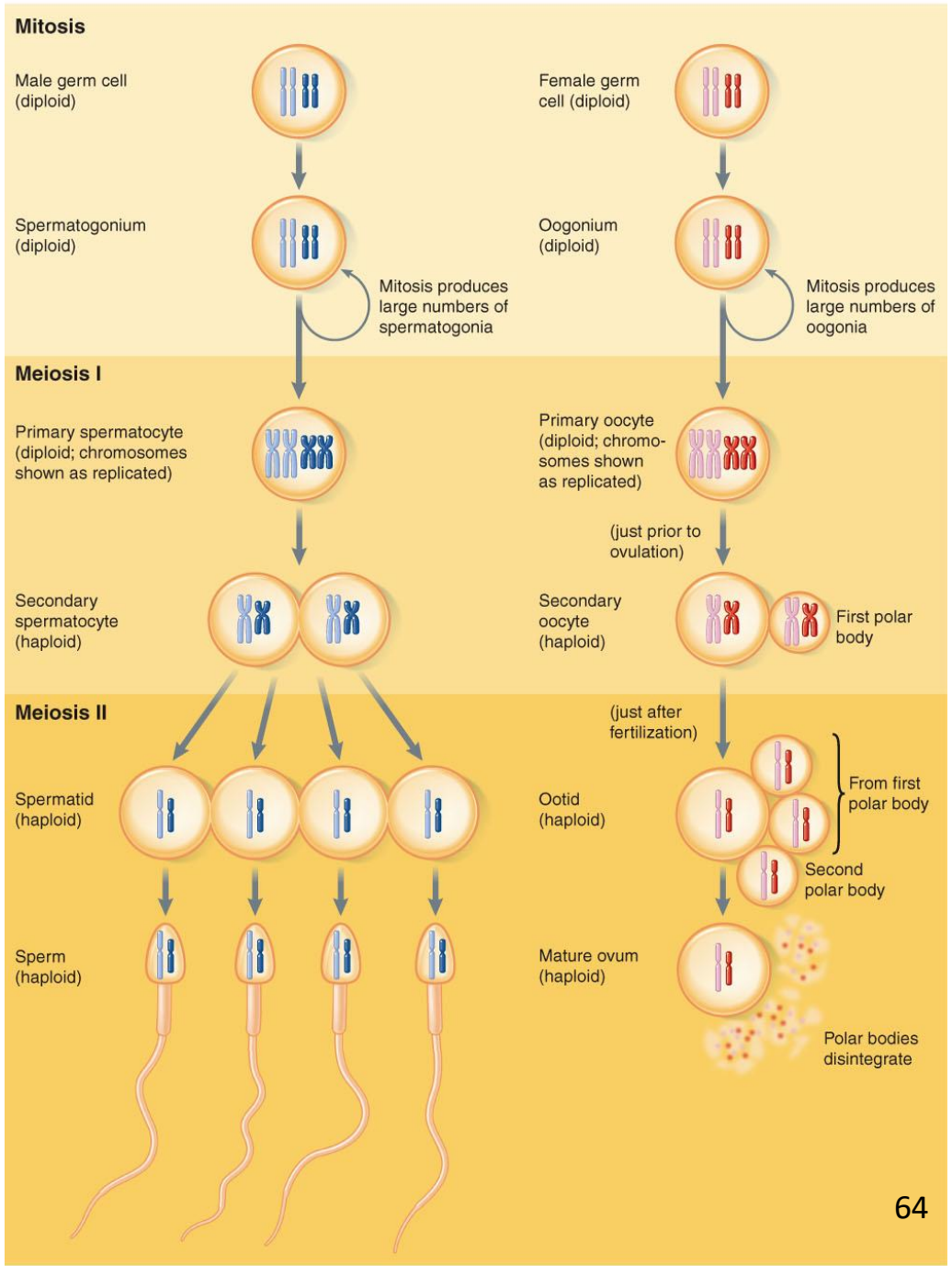
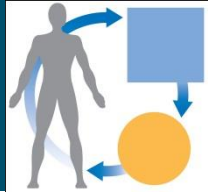

Stages of oogenesis
Chromosomes in each cell
Oogonium
46 (diploid number; single strands)
1 Mitotic proliferation prior to birth
Primary oocytes
(Arrested in first meiotic division)
46 (diploid number; doubled strands)
After puberty, one primary oocyte reaches maturity and is ovulated about once a month until menopause ensues
Enlarged primary oocyte
46 (diploid number; doubled strands)
(First meiotic division completed just prior to ovulation)
First polar body
Secondary oocyte
23 (haploid number; doubled strands)
2 Meiosis
(Second meiotic division completed after fertilization)
Second polar body
Mature ovum
Polar bodies degenerate
23 (haploid number; single strands) from ovum plus 23 (haploid number; single strands) from sperm for diploid fertilized ovum with 46 chromosomes

Fig. 20-13. Comparison of mitotic divisions producing spermatozoa and eggs from germ cells

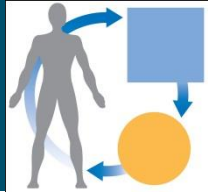


Ovarian Cycle



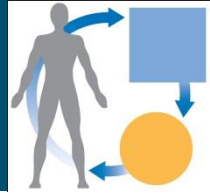
- Average cycle lasts 28 days.
- Normally interrupted only by pregnancy.
- Finally terminated by menopause.
- Consists of two alternating phases:
  - **follicular phase** (여포기) dominated by presence of maturing follicles
  - **luteal phase** (황체기) characterized by presence of **corpus luteum**

Follicular phase



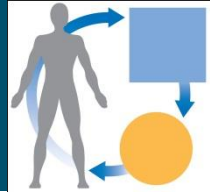
- First half of cycle.
- **Granulosa cells (과립세포)** of some primary follicles proliferate.
- Oocyte inside each follicle enlarges.
- **Theca cells (포막세포)** in follicle secrete increased amounts of estrogen.
- Rapid follicular growth continues during follicular phase.

Follicular phase

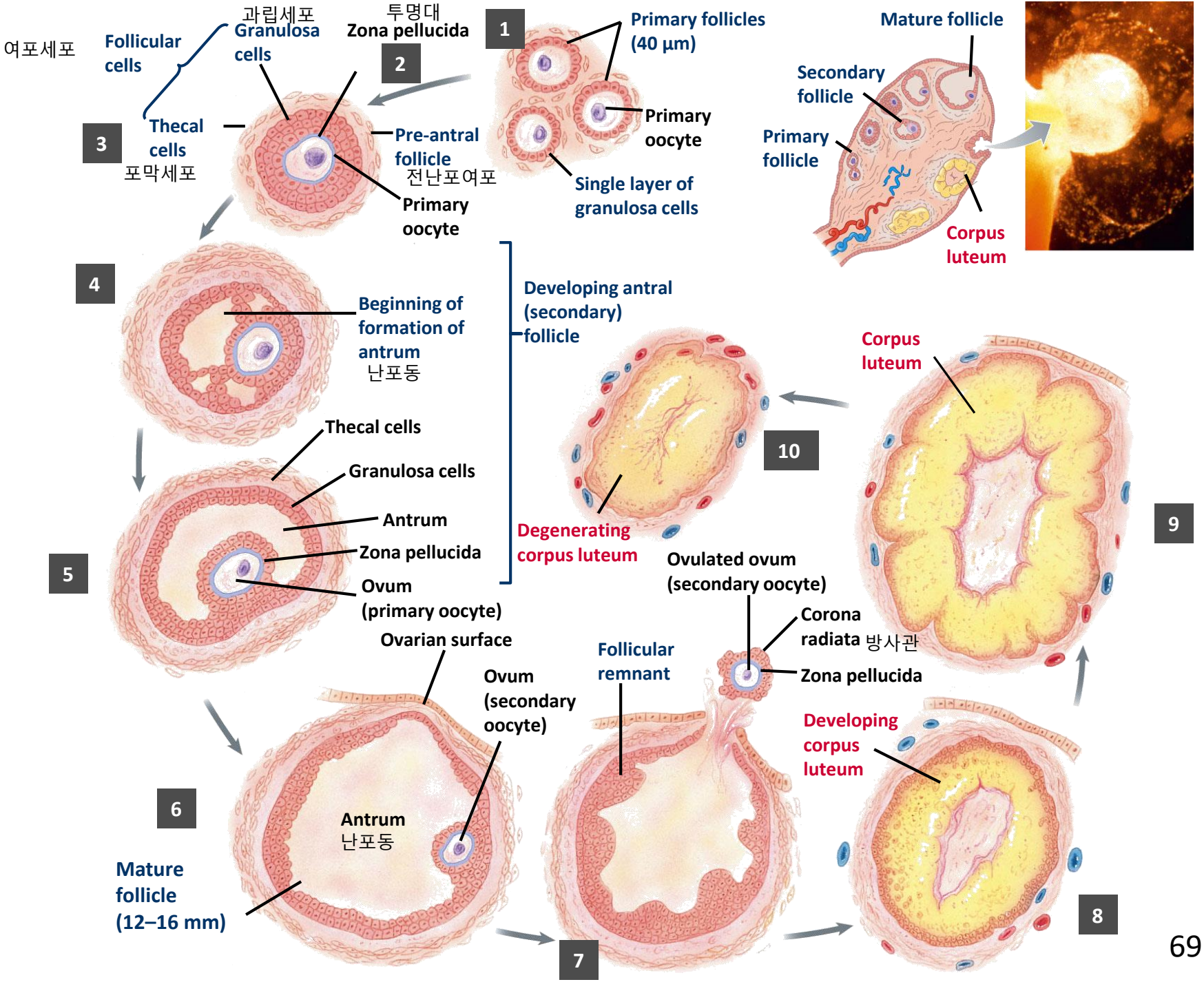


- One follicle usually grows more rapidly.
- Matures in about 14 days after beginning of follicular development.
- Follicle ruptures to release oocyte from ovary (**ovulation**)
- Released oocyte enters oviduct.

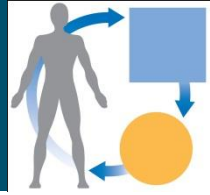
Luteal Phase



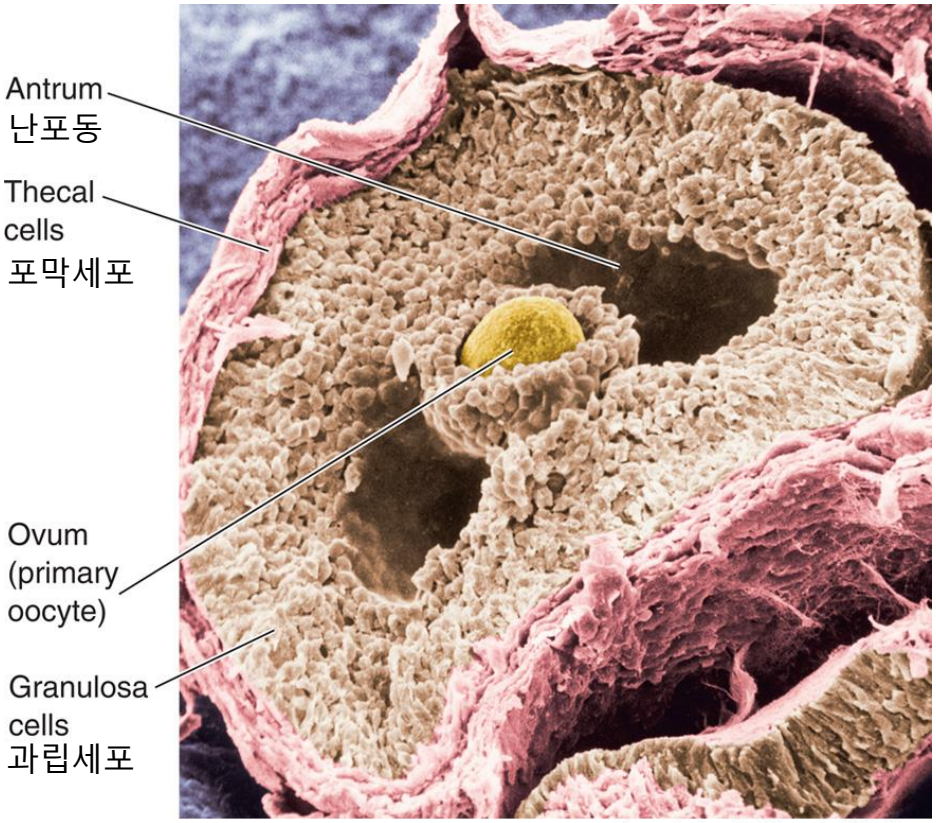
- Final 14 days of ovarian cycle.
- Follicular cells converted into **corpus luteum.**
- Corpus luteum produces progesterone and estrogen.
- Hormones prepare uterus for implantation if fertilized egg is present.
- If fertilization or implantation does not occur corpus luteum degenerates.


여포세포
과립세포
Follicular cells
Granulosa cells
투명대
Zona pellucida
1
2
3
Thecal cells
포막세포
Pre-antral follicle
전난포여포
Primary oocyte
Primary follicles (40 µm)
Primary oocyte
Single layer of granulosa cells
Mature follicle
Secondary follicle
Primary follicle
Corpus luteum
4
Beginning of formation of antrum
난포동
Developing antral (secondary) follicle
5
Thecal cells
Granulosa cells
Antrum
Zona pellucida
Ovum (primary oocyte)
Degenerating corpus luteum
10
Corpus luteum
9
Ovulated ovum (secondary oocyte)
Corona radiata 방사관
Zona pellucida
Ovarian surface
Ovum (secondary oocyte)
Follicular remnant
Developing corpus luteum
6
Antrum
난포동
Mature follicle (12–16 mm)
7
8

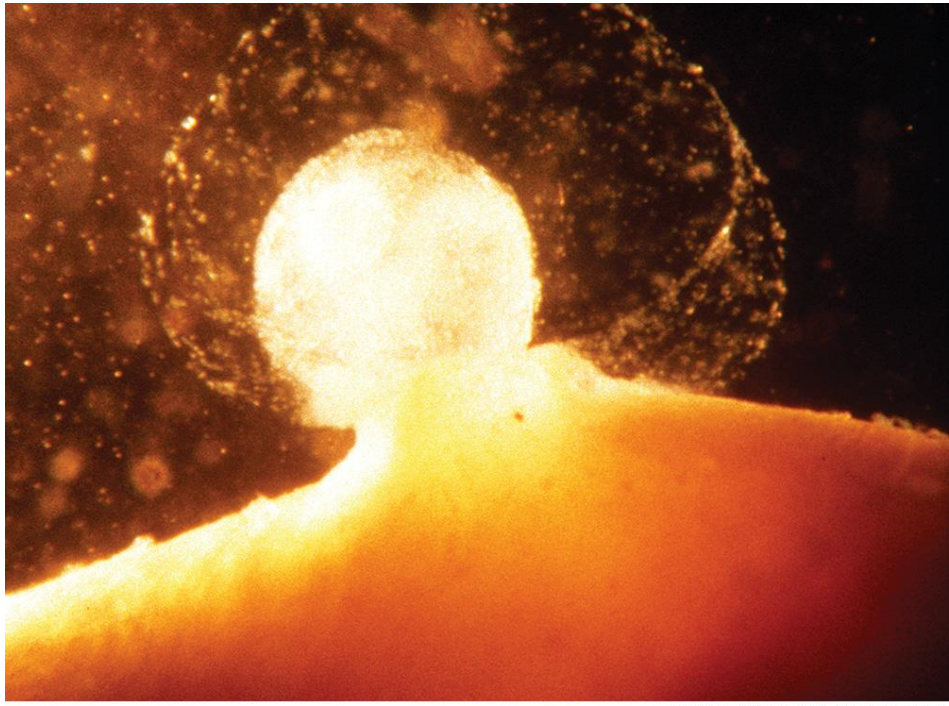
Ovarian Cycle



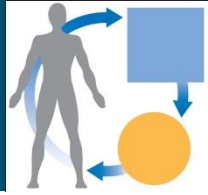
1. In a primary follicle, a primary oocyte is surrounded by a single layer of granulosa cells.
2. Under the influence of local paracrines, granulosa cells proliferate and form the zona pellucida around the oocyte.
3. Surrounding ovarian connective tissue differentiates into thecal cells, converting a primary follicle into a preantral follicle.
4. Follicles reaching the preantral stage are recruited for further development under the influence of FSH at the beginning of the follicular phase of the ovarian cycle. A recruited follicle develops into an antral, or secondary, follicle as an estrogen-rich antrum starts to form.
5. The antrum continues to expand as the secondary follicle rapidly grows.
6. After about 2 weeks of rapid growth under the influence of FSH, the follicle has developed into a mature follicle, which has a greatly expanded antrum; the oocyte, which by now has developed into a secondary oocyte, is displaced to one side.
7. At midcycle, in response to a burst in LH secretion, the mature follicle, bulging on the ovarian surface, ruptures and releases the oocyte, resulting in ovulation and ending the follicular phase.
8. Ushering in the luteal phase, the ruptured follicle develops into a corpus luteum under the influence of LH.
9. The corpus luteum continues to grow and secrete progesterone and estrogen that prepare the uterus for implantation of a fertilized ovum.
10. After 14 days, if a fertilized ovum does not implant in the uterus, the corpus luteum degenerates, the luteal phase ends, and a new follicular phase begins under the influence of a changing hormonal milieu.



© Cengage Learning; photo: P. Bagavandoss/Science Source


© Cengage Learning; photo: C. Edelmann/Science Source

Ovarian Cycle Hormones

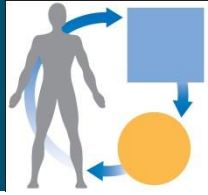


- During follicular phase, rise in FSH signals ovarian follicle to secrete more estrogen.
- Rise in estrogen feeds back to inhibit FSH secretion.
- LH rises and peaks in mid-cycle.
- LH rise triggers ovulation.
- Estrogen output decreases as mature follicle is converted to a corpus luteum.

TABLE 20-4 Stages of Follicular Development

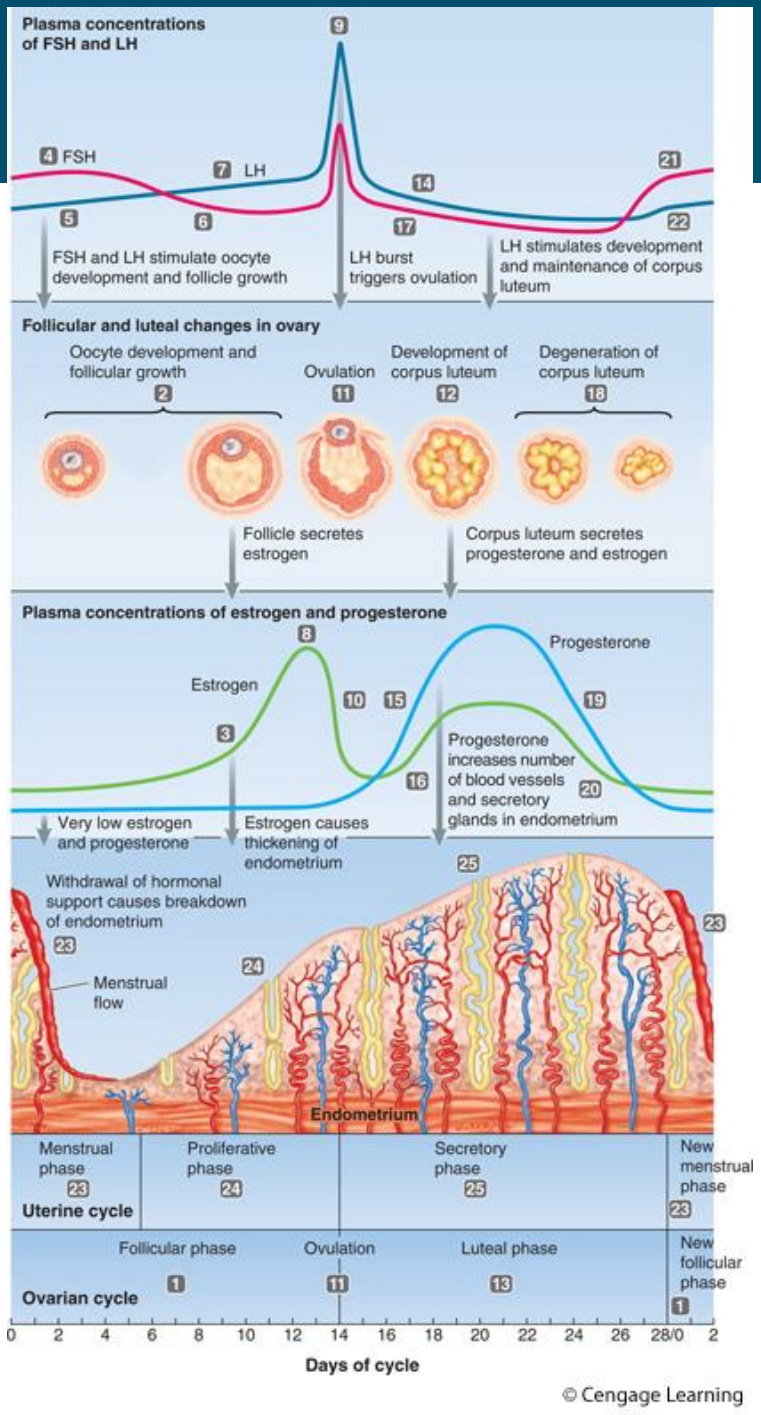
Phase	Size of Follicle (in mm)	Status of Follicle	Influence of Gonadotropins on Follicle	Hormone Production by	Status of Gamete
Resting primordial follicle	0.04	Gamete is surrounded by single layer of granulosa cells.	None	None	The primary oocyte has entered the first meiotic division and is in meiotic arrest.
Preantral follicle	0.04–1	Granulosa cells thicken and proliferate; zona pellucida forms; thecal cells develop.	None (Early growth of selected follicles occurs under paracrine influence.)	None (Follicular cells [granulosa cells and thecal cells collectively] develop capacity to secrete estrogen but do not do so.)	The primary oocyte begins to grow and stockpile nutrients.
Early developing antral follicle	1–2	The antrum starts to form, contributing to follicular growth.	The follicle is dependent on both FSH and LH for estrogen secretion but is not influenced by cyclical fluctuations in these hormones.	Estrogen production begins; part is secreted into the blood; part remains in the follicle, expanding the antrum.	The primary oocyte grows rapidly and reaches near full size.
Recruitable antral follicle	2–5	After a follicle is recruited, the antrum continues to expand and the follicle grows rapidly.	The follicle is extremely sensitive to FSH and is recruited by the increase in FSH at the onset of the follicular phase of the ovarian cycle for further rapid growth and development.	The follicle continues to produce increasing amounts of estrogen.	The primary oocyte grows slowly and remains in meiotic arrest.
Dominant, mature follicle	15–20	The antrum occupies most of the greatly expanded follicle, which bulges on the ovarian surface. The oocyte and its surrounding layers are displaced to one side.	Rapid growth of the dominant follicle is stimulated by FSH during the follicular phase of the ovarian cycle.	A marked increase in estrogen secretion takes place, which triggers the LH surge responsible for ovulation.	The oocyte completes its first meiotic division and becomes a secondary oocyte just before ovulation.

Ovarian Cycle Hormones

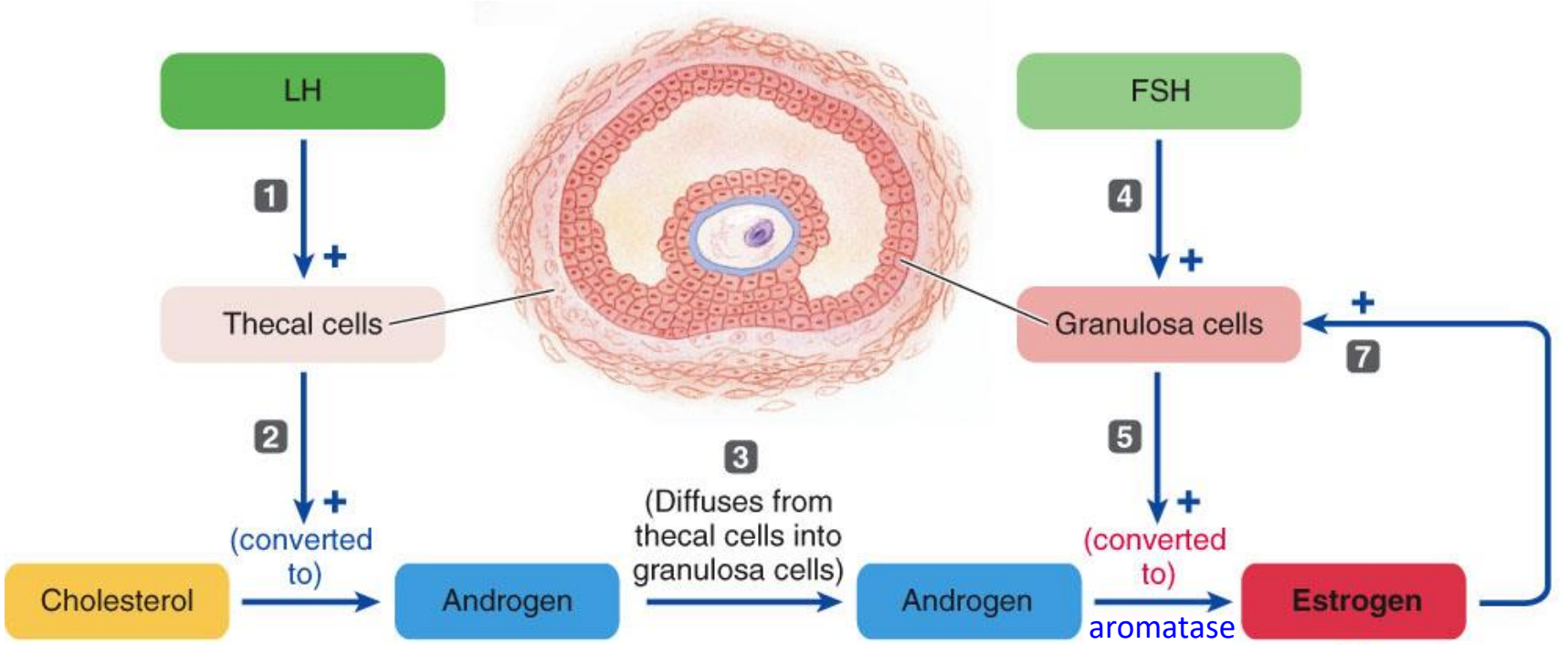


- Corpus luteum secretes progesterone and estrogen during luteal phase.
- Progesterone output inhibits release of FSH and LH.
- Low LH results in corpus luteum degeneration.
- Progesterone levels decline.
- FSH inhibition removed.
- FSH rises initiating new cycle.

Fig. 20-17.
Correlation Between Hormonal Levels and Cyclic Ovarian and Uterine Changes



Production of estrogen by an ovarian follicle



1. LH stimulates the thecal cells in the ovarian follicle.
2. On stimulation, the thecal cells convert cholesterol into androgen.
3. Androgen diffuses from the thecal cells into the adjacent granulosa cells.
4. FSH stimulates the granulosa cells in the ovarian follicle.
5. On stimulation, the granulosa cells convert androgen into estrogen.

6a Part of the estrogen is secreted into the blood, where it exerts systemic effects.

6b Part of the estrogen remains within the follicle and contributes to antral formation.

7. Local estrogen, along with FSH, stimulates proliferation of the granulosa cells.

Fig. 20-19.
Feedback control of FSH and tonic LH secretion during the follicular phase

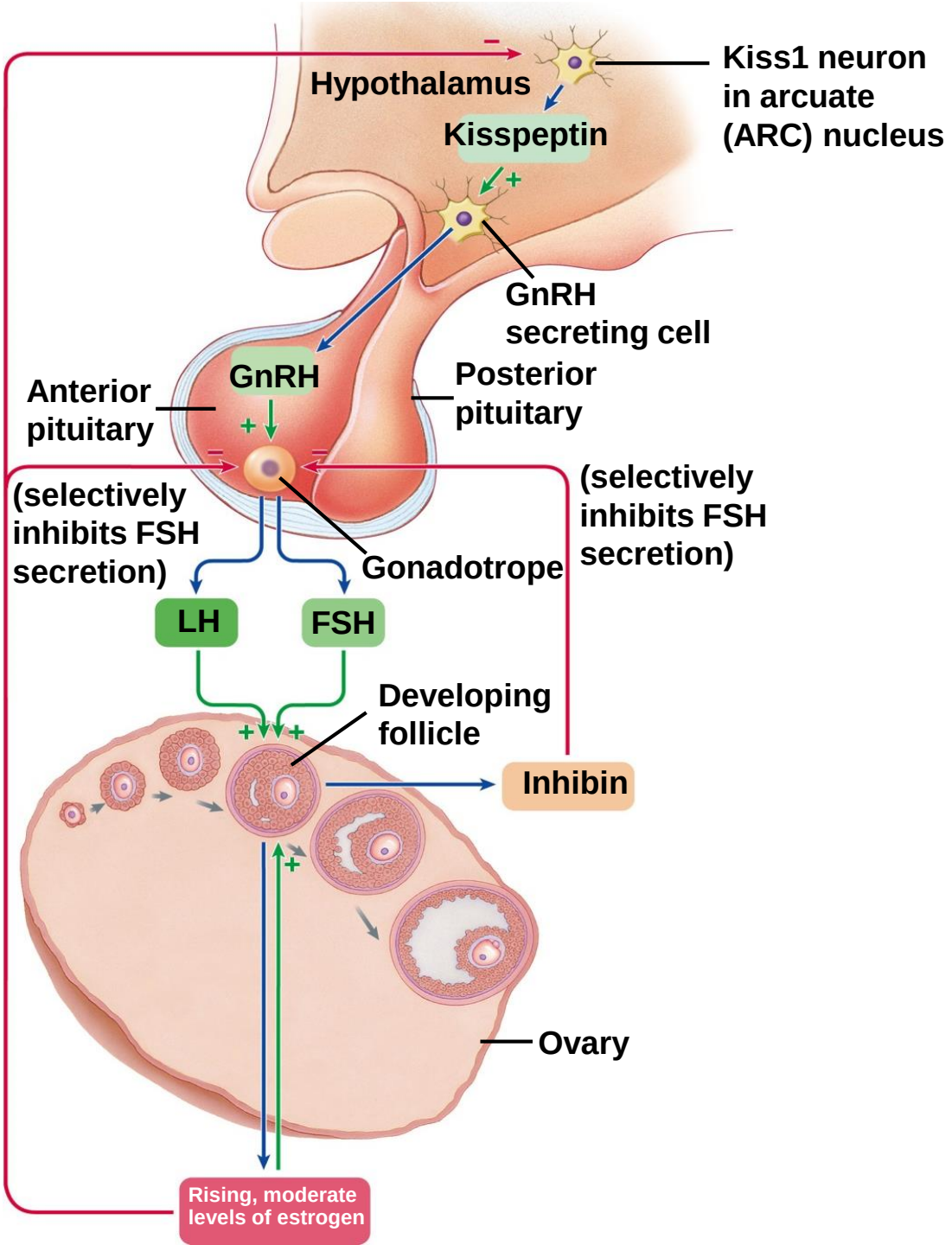


Fig.20-20. Control of the LH surge at ovulation

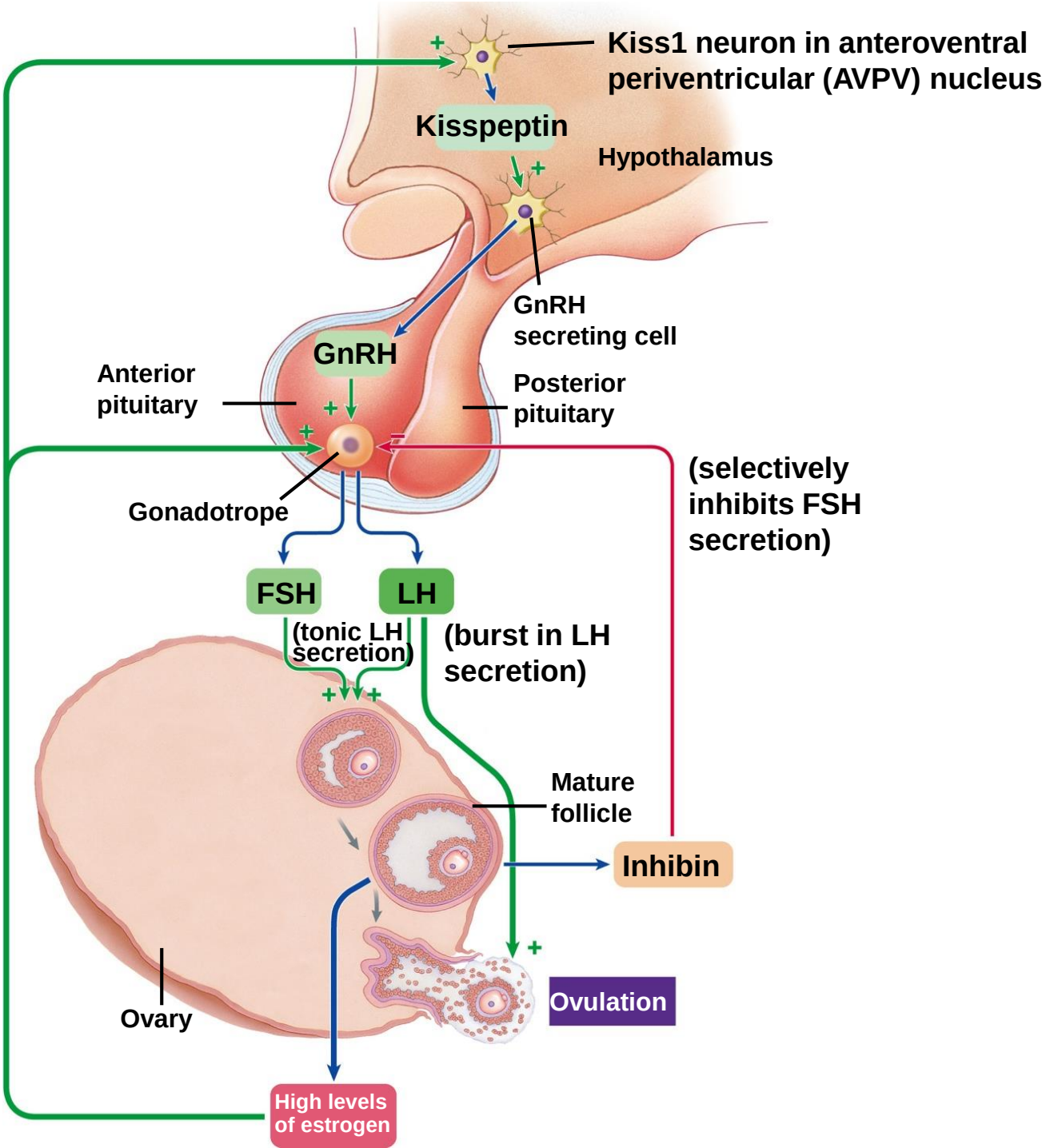
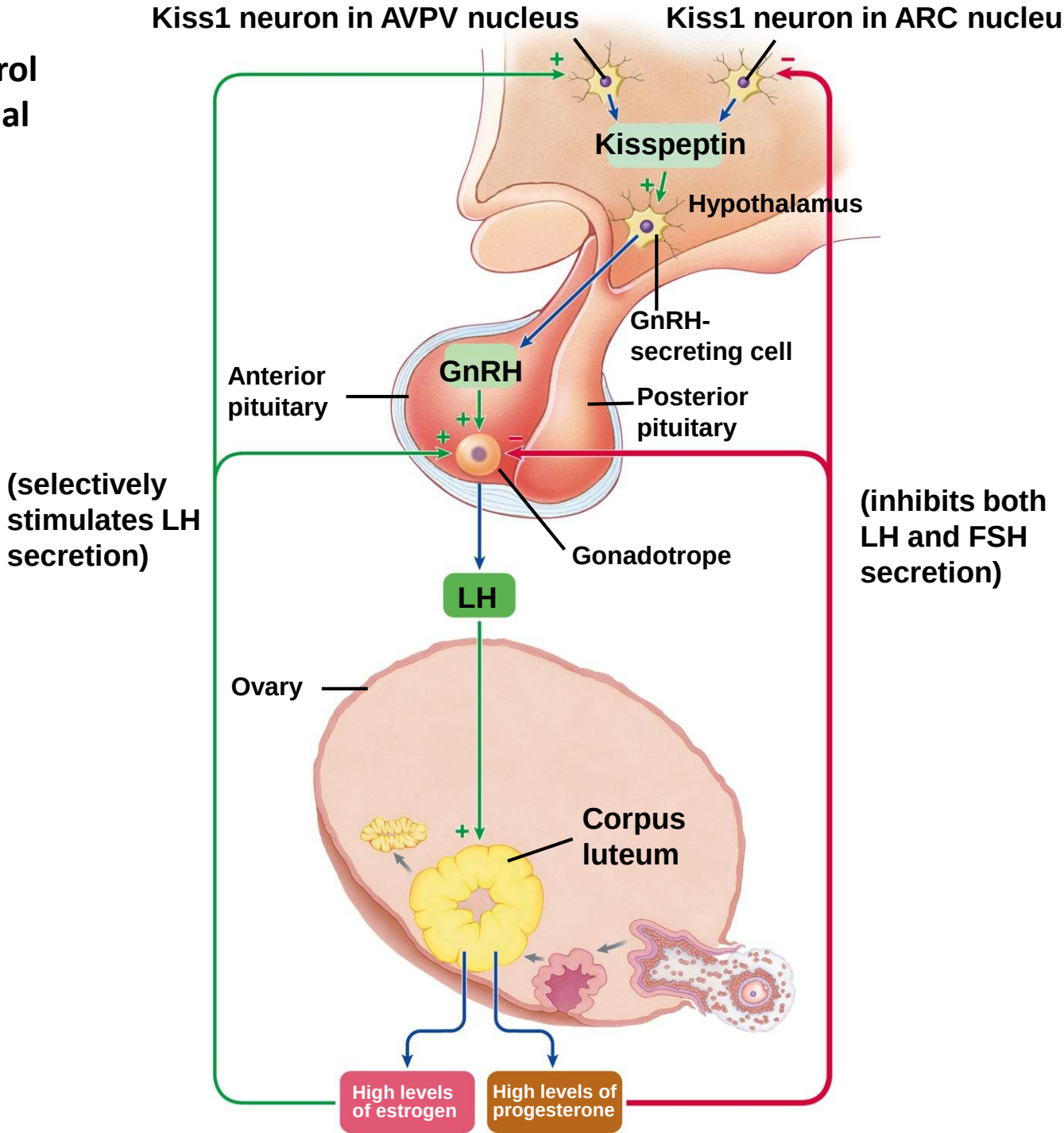
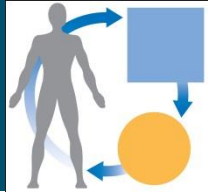


Fig. 20-21. Feedback control during the luteal phase

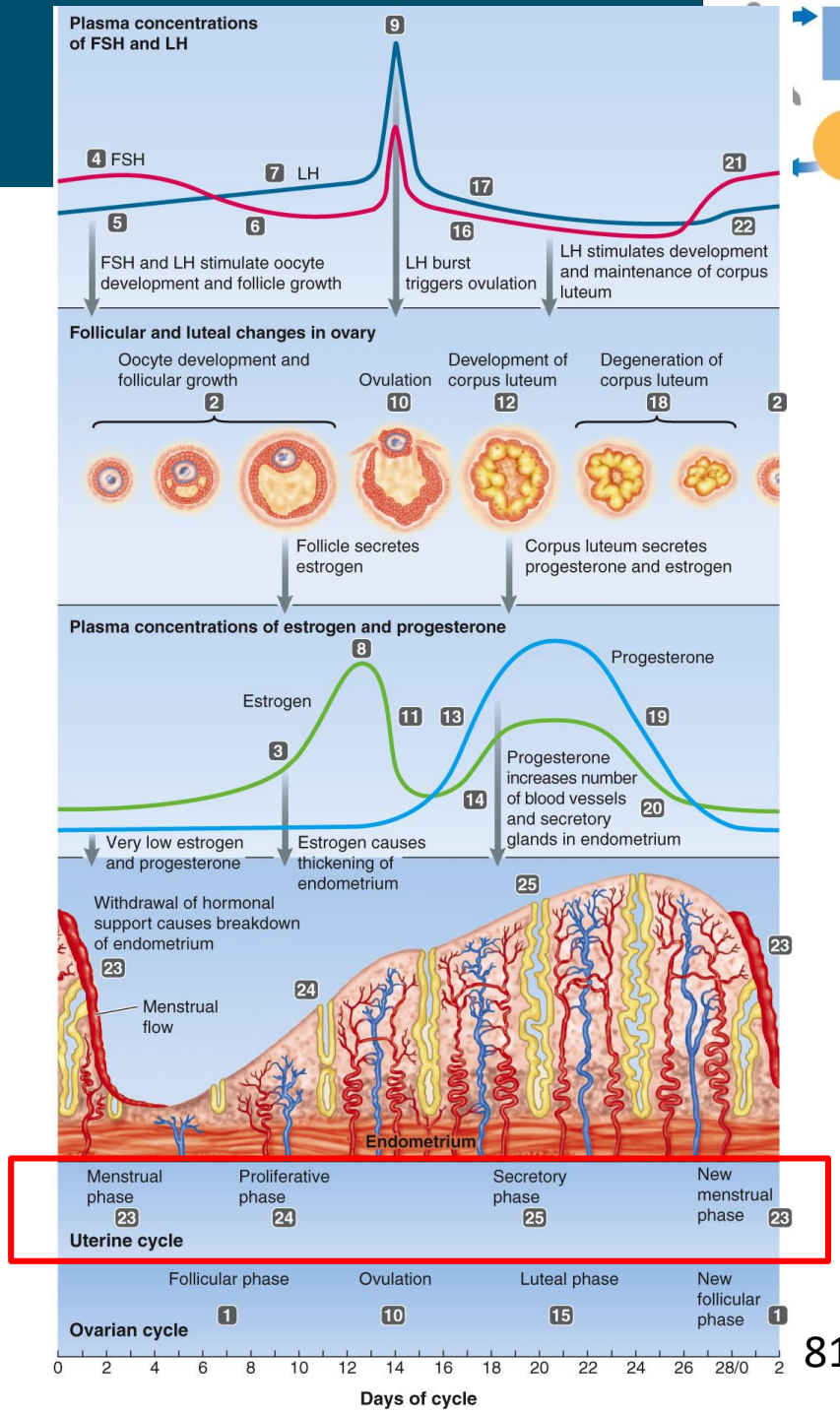


Uterine Cycle (자궁주기)

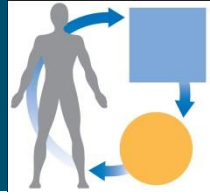


- Reflects hormonal changes during ovarian cycle.
- Menstrual cycle (월경주기)
- Averages 28 days.
- Consists of three phases:
  - **menstrual phase** (월경기)
  - **proliferative phase** (증식기)
  - **secretory or progestational phase** (분비기)

Correlation between hormonal levels and cyclic ovarian and uterine changes

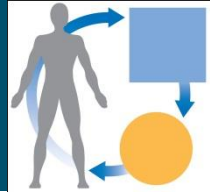


Menstrual Phase



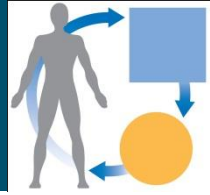
- Characterized by discharge of blood and endometrial debris from vagina.
- First day of menstruation starts new cycle.
- Corpus luteum degenerates.
- Progesterone and estrogen levels fall.
- Triggers release of uterine **prostaglandin.**

Menstrual Phase (월경기)



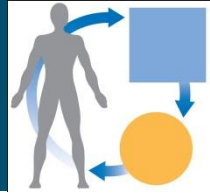
- Uterine prostaglandins causes vasoconstriction of endometrial vessels.
- Blood supply disrupted and endometrium degenerates.
- Prostaglandins stimulates rhythmic contractions of uterus.
- Contractions expel blood and endometrial debris from uterine cavity **(menstrual flow).**

Proliferative Phase (증식기)

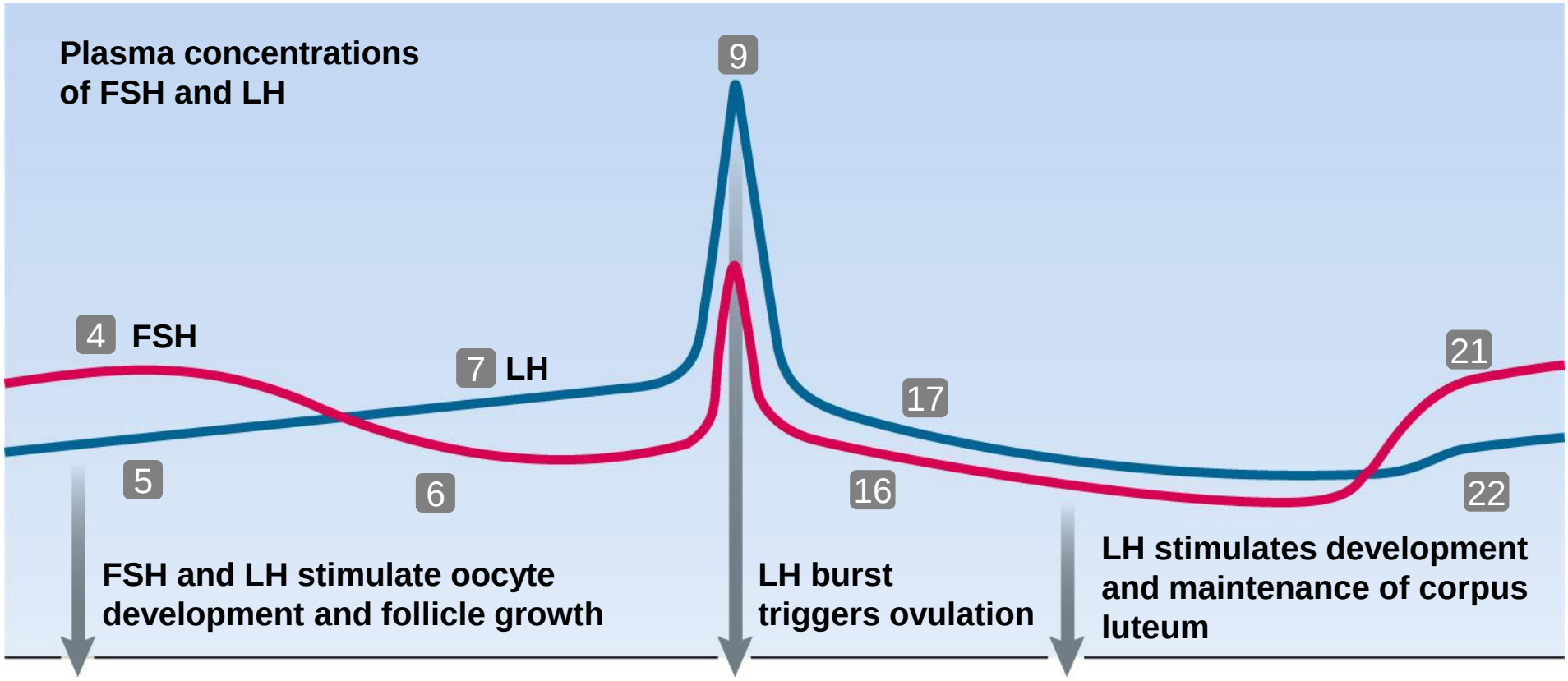


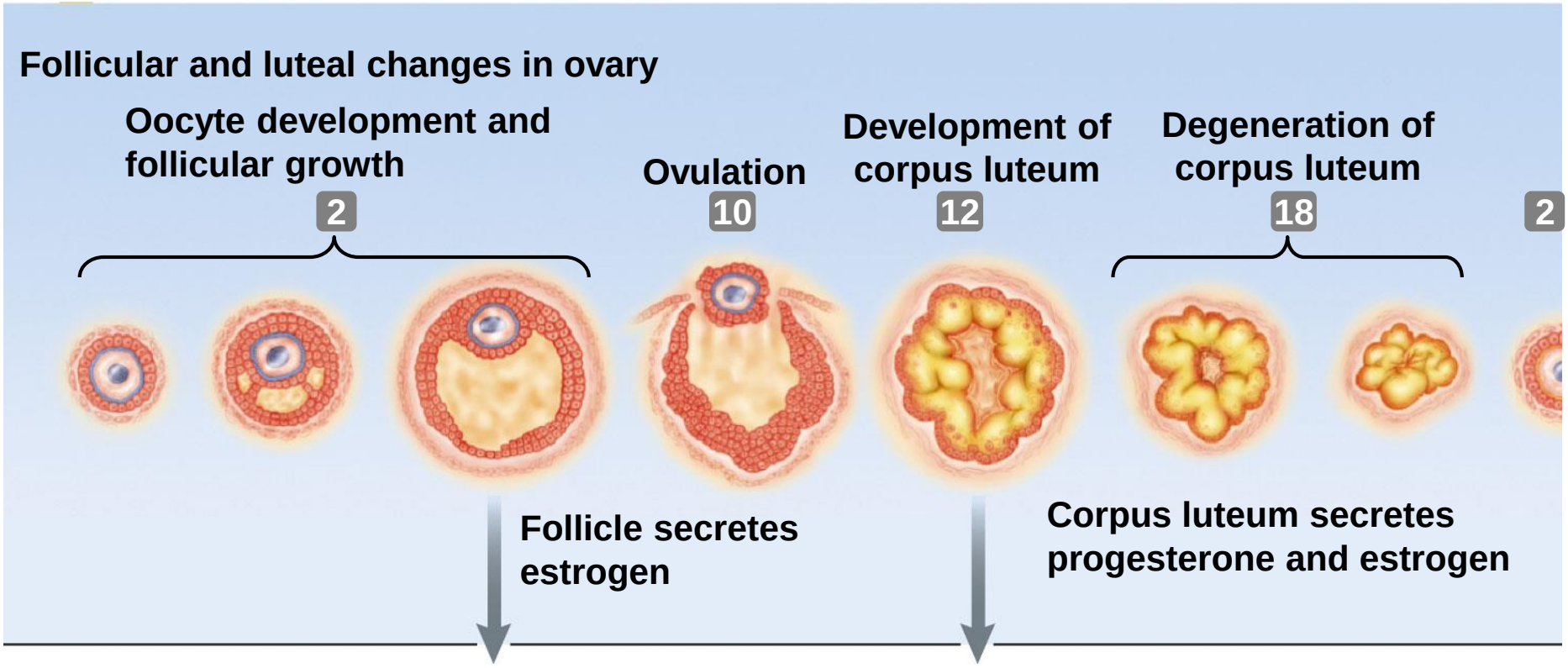
- Begins with last portion of ovarian follicular phase.
- Estrogen from growing follicles promotes endometrial repair and proliferation.
- Phase lasts from end of menstruation to ovulation.
- Peak estrogen levels at mid-phase trigger LH surge responsible for ovulation.

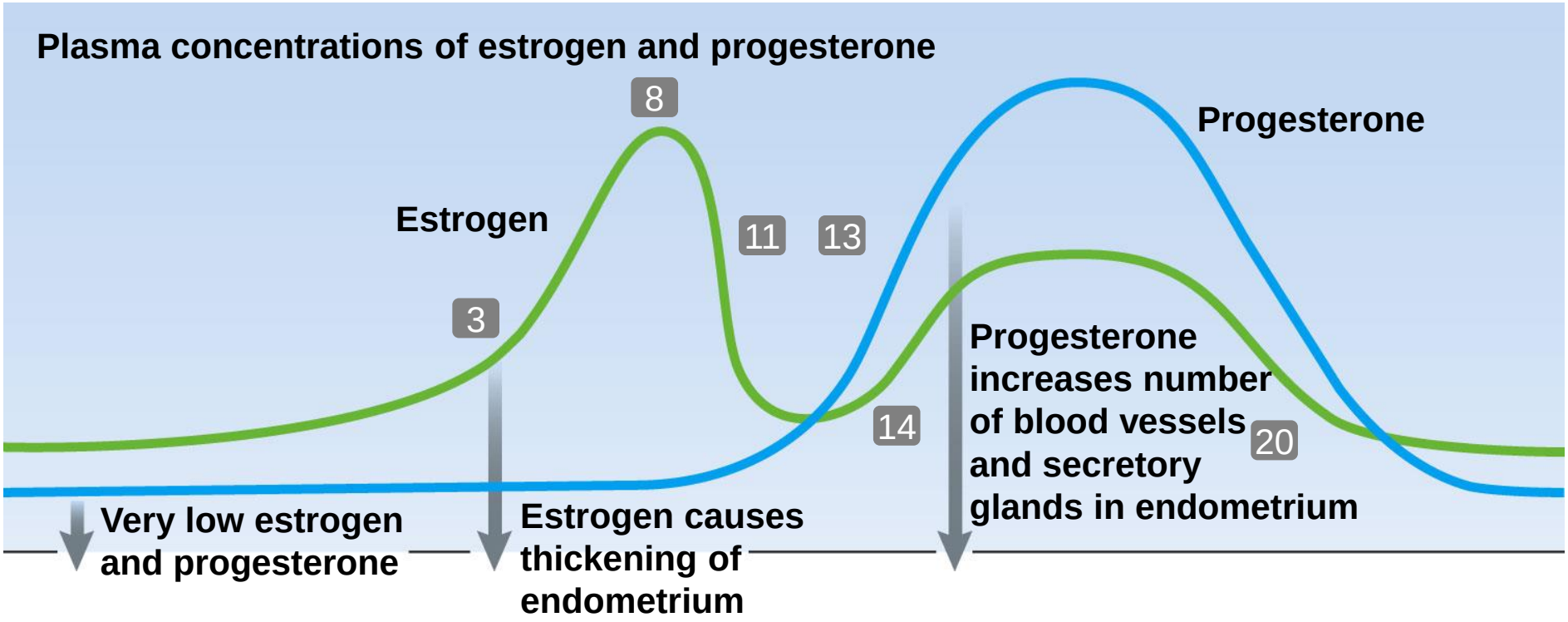
Secretory Phase (분비기)

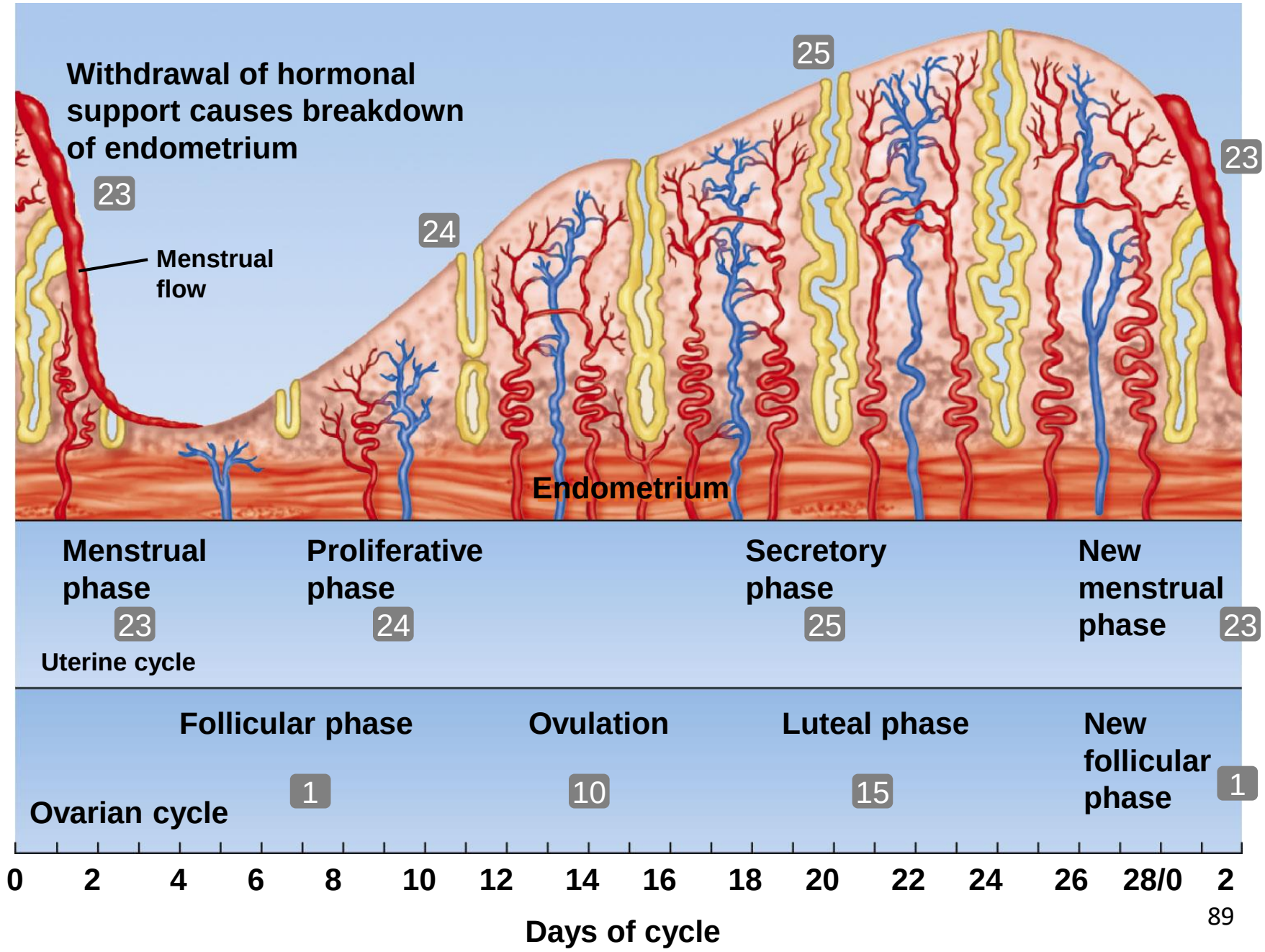


- Phase begins after ovulation when new corpus luteum is formed.
- Corpus luteum secretes large amounts of progesterone and estrogen.
- Progesterone converts endometrium to vascularized, glycogen-filled tissue.
- If fertilization and implantation do not occur corpus luteum degenerates and cycle repeats.

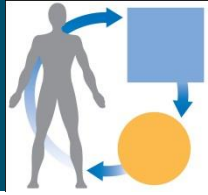

Plasma concentrations of FSH and LH
9
4 FSH
7 LH
21
17
5
6
16
22
FSH and LH stimulate oocyte development and follicle growth
LH burst triggers ovulation
LH stimulates development and maintenance of corpus luteum


Follicular and luteal changes in ovary
Oocyte development and follicular growth
2
Ovulation
10
Development of corpus luteum
12
Degeneration of corpus luteum
18
2
Follicle secretes estrogen
Corpus luteum secretes progesterone and estrogen


Plasma concentrations of estrogen and progesterone
8
Progesterone
Estrogen
11
13
3
Progesterone increases number of blood vessels and secretory glands in endometrium
14
20
Very low estrogen and progesterone
Estrogen causes thickening of endometrium

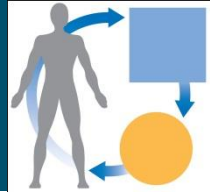

Withdrawal of hormonal support causes breakdown of endometrium
23
Menstrual flow
24
25
23
Endometrium
Menstrual phase
23
Proliferative phase
24
Secretory phase
25
New menstrual phase
23
Uterine cycle
Follicular phase
Ovulation
Luteal phase
New follicular phase
1
Ovarian cycle
1
10
15
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28/0 2
Days of cycle

Menopause (폐경)



- Cessation of woman's menstrual cycle
- Usually occurs between ages of **45** and **55**
- **Midlife hypothalamic change** may trigger onset of menopause
- Preceded by period of progressive ovarian failure
  - Increasingly irregular cycles
  - Dwindling estrogen levels
    - Loss of estrogen primarily affects skeleton and cardiovascular system
- Period of transition called the climacteric (갱년기, 월경폐지기)

Fertilization (수정)



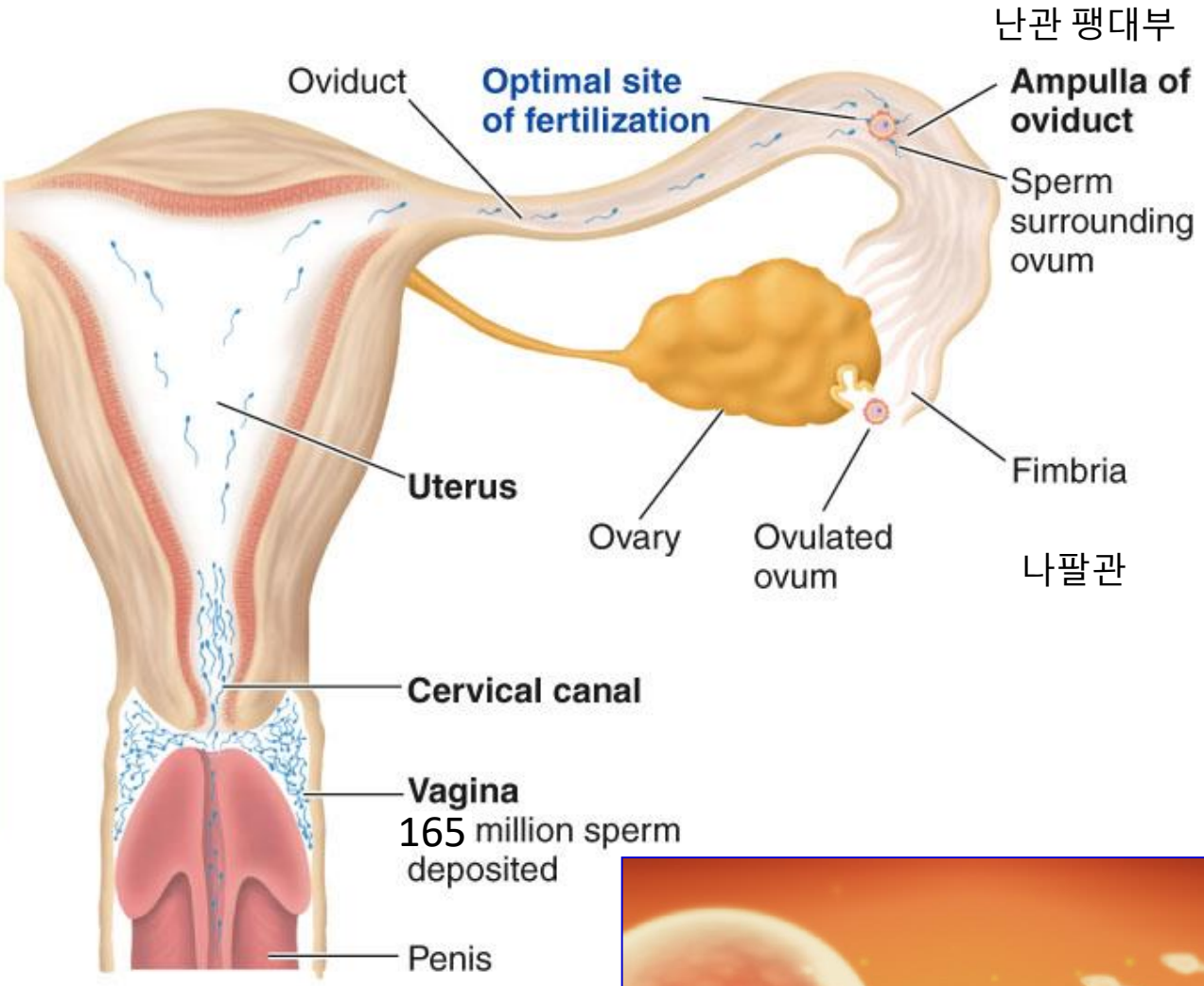
- Oviduct (난관) is the site of fertilization.
- Must occur within 24 hours after ovulation.
- Sperm usually survive 48 hours but can survive up to 5 days in female reproductive tract.
- Sperm deposited in vagina travel through cervical canal, uterus to upper third of oviduct.

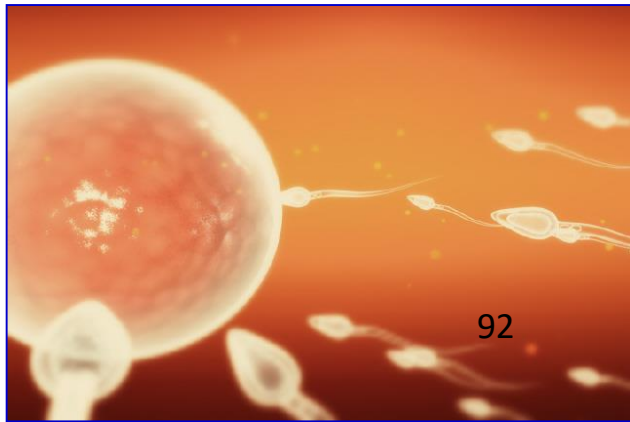
  - Female reproductive tract aids in sperm migration
    - Contractions of myometrium
    - Upward contractions of oviduct smooth muscle
    - Allurin released by mature eggs

Ovum and sperm transport to the site of fertilization

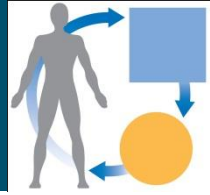
Location	Time of appearance (min after ejaculation)	Percent of ejaculated sperm*
Fertilization site (upper third of oviduct)	30–60	0.001
Uterus	10–20	0.1
Cervical canal	1–3	3
Vagina	0	100

*Based on data from animals.
Sperm and ovum enlarged.





Fertilization (수정)



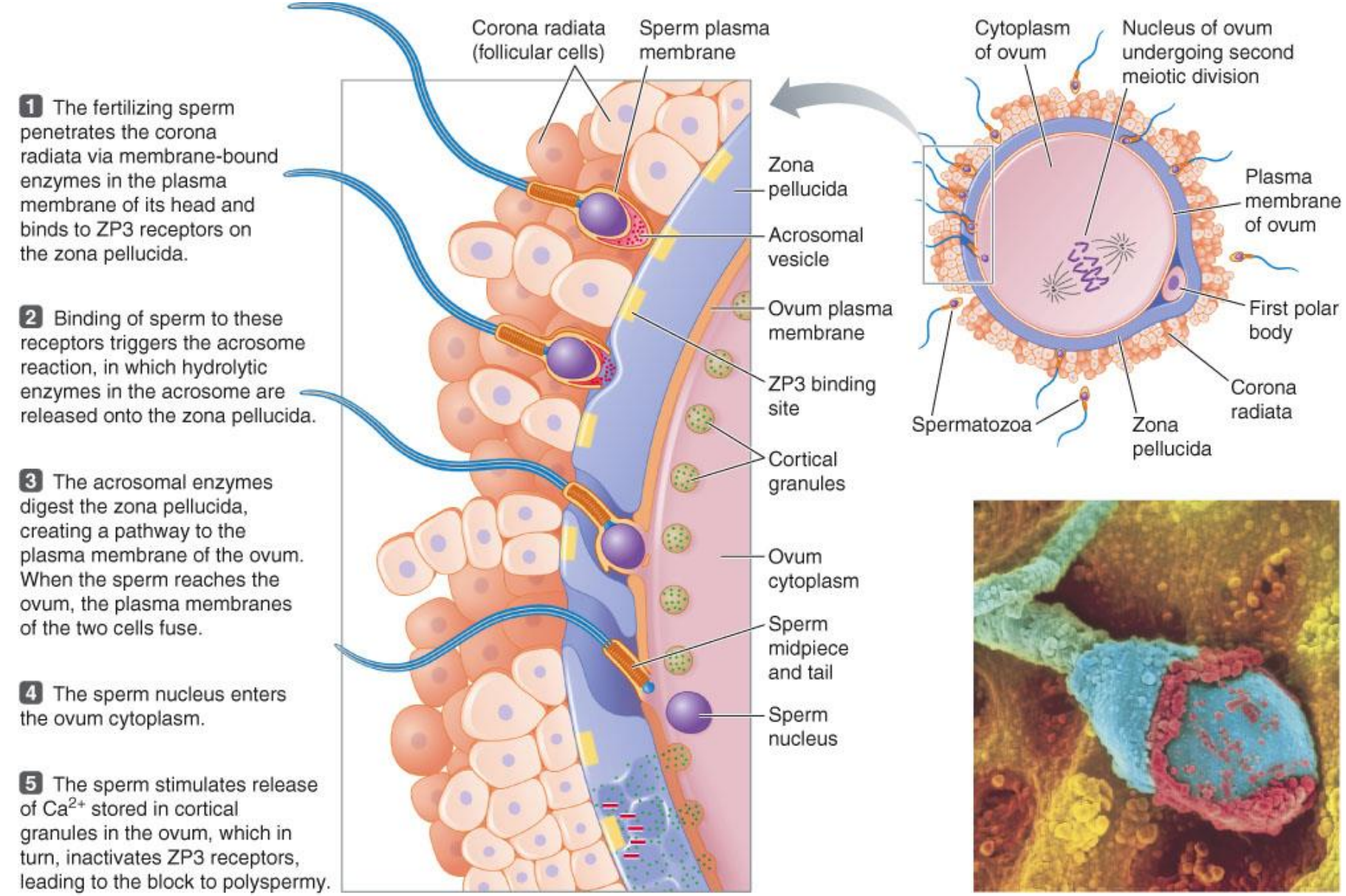
- First sperm to reach ovum fuses with plasma membrane of ovum.
- Triggers chemical change in ovum membrane that makes outer layer impermeable to entry of any more sperm.
- Head of sperm pulled into ovum.
- Within hour, sperm and egg nuclei fuse.
- Fertilized ovum now called a **zygote (접합자).**

Fertilization

- First sperm to reach ovum
  - Fuses with plasma membrane of ovum
  - Triggers chemical change in ovum's surrounding membrane that makes outer layer impermeable to entry of any more sperm
  - Head of fused sperm gradually pulled into ovum's cytoplasm
  - Within hour, sperm and egg nuclei fuse

    - Fertilized ovum now called a **zygote (접합자)**

Process of fertilization



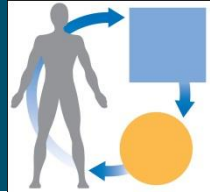
(a) Sperm tunneling through the barriers surrounding an ovum

(b) Scanning electron micrograph of spermatozoon with acrosomal enzymes (in red) exposed after acrosomal reaction

여러 가지 피임법의 실패할 확률

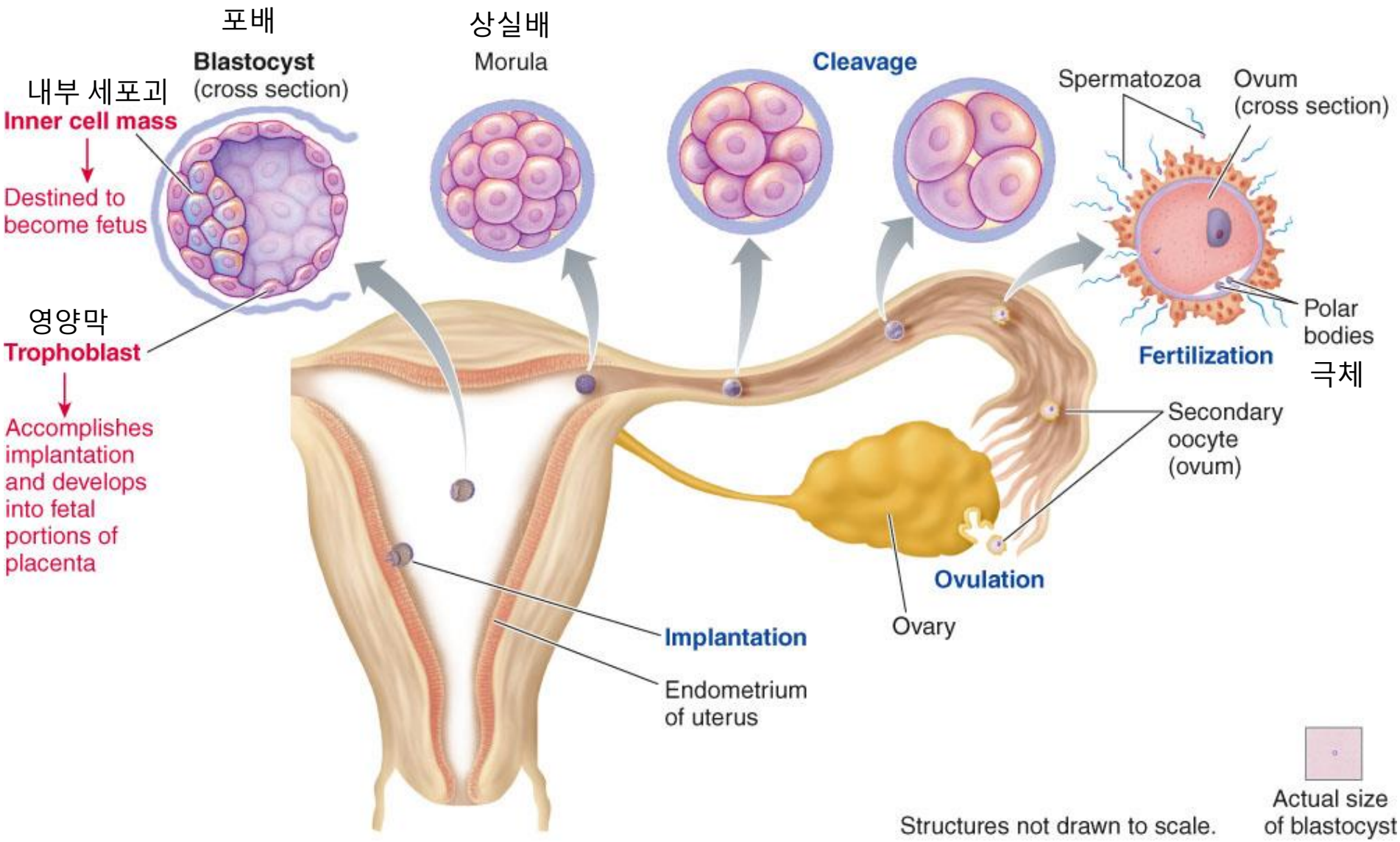
피임법	실패율
일반 성교	90
자연피임	20~30
성교 중단(질외사정)	23
화학 피임제	20
콘돔	10~15
경구피임약	2~2.5
피임제 이식	1
자궁 내 기구	4

Implantation (착상)

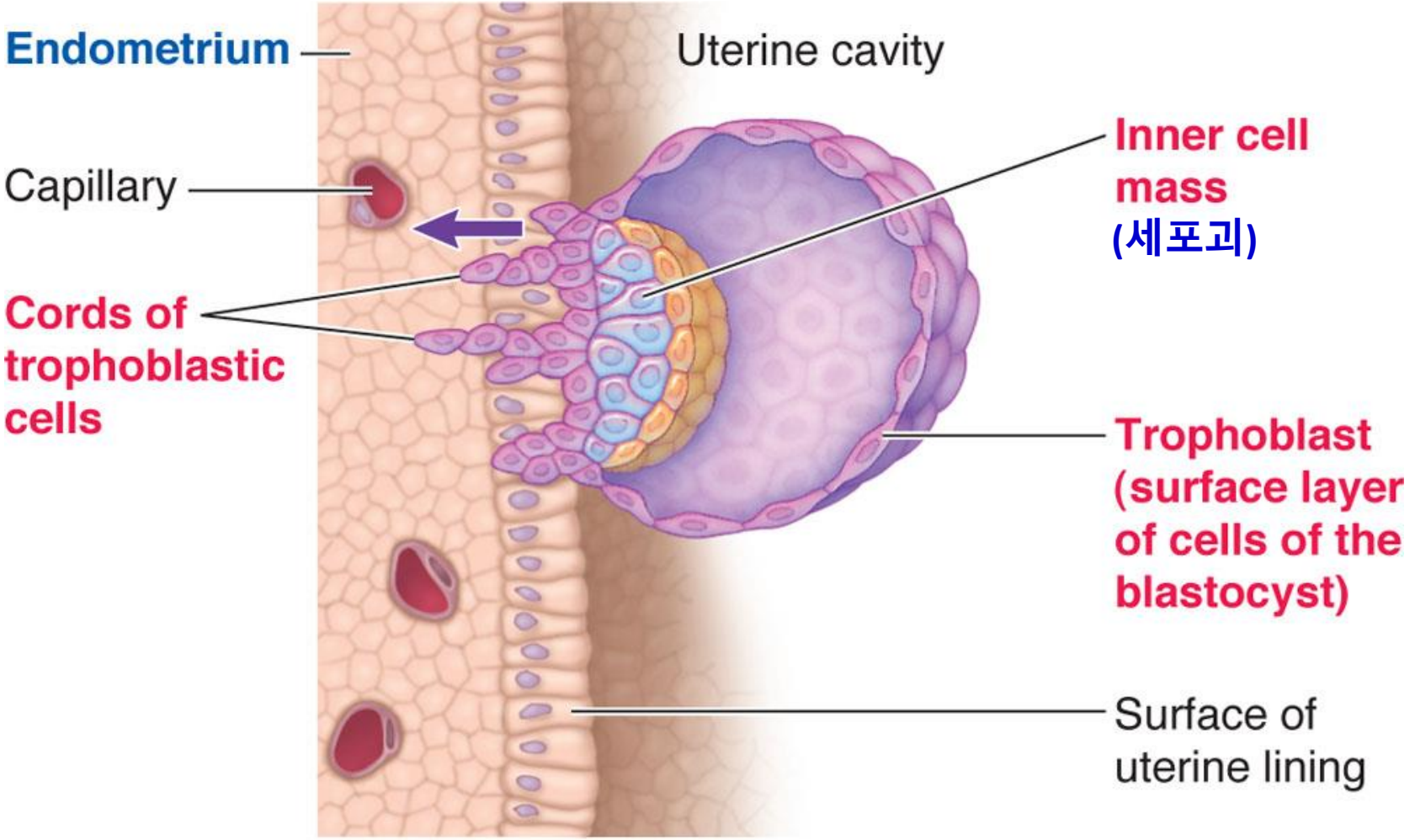


- Fertilized ovum divides mitotically.
- Within a week, grows and differentiates into **blastocyst** capable of implantation.
- Blastocyst has **inner cell mass** that becomes the embryo and then fetus.
- **Trophoblast cells (영양막 세포)** of blastocyst support fetus during intrauterine life.

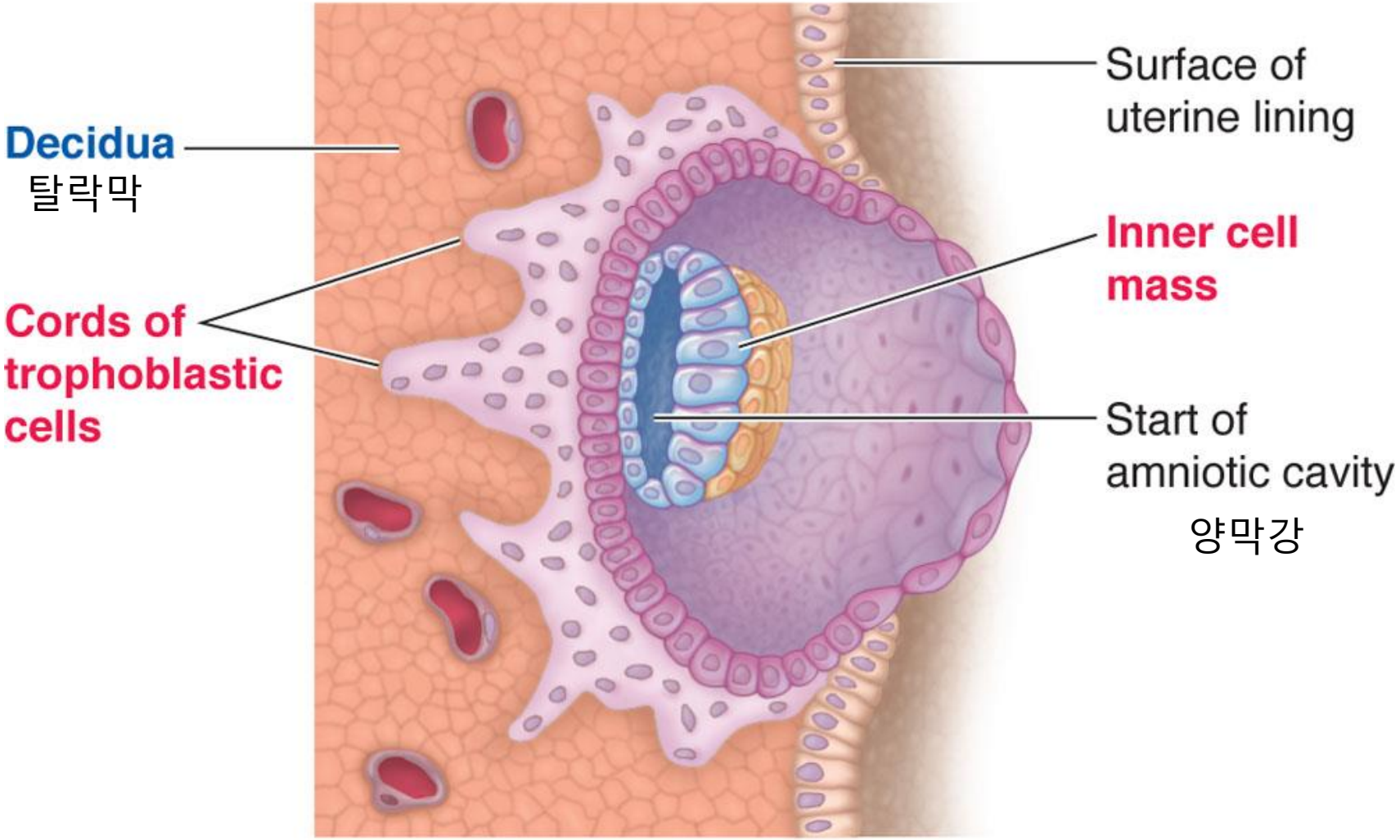
Early stages of development from fertilization to implantation



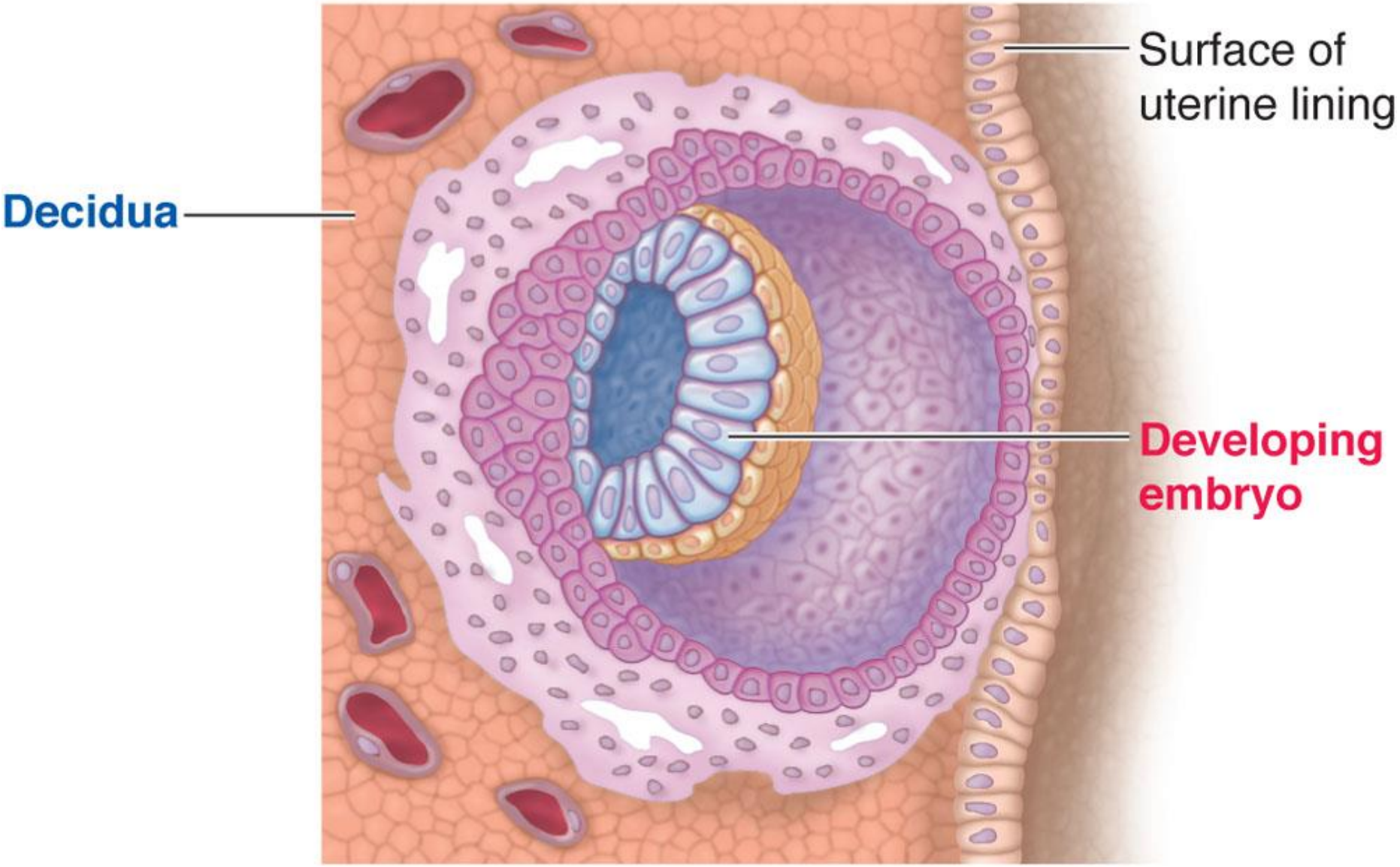
Implantation of the blastocyst



1 When the free-floating blastocyst adheres to the endometrial lining, cords of trophoblastic cells begin to penetrate the endometrium.

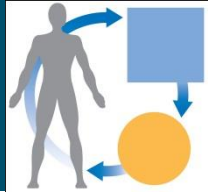


2 Advancing cords of trophoblastic cells tunnel deeper into the endometrium, carving out a hole for the blastocyst. The boundaries between the cells in the advancing trophoblastic tissue disintegrate.

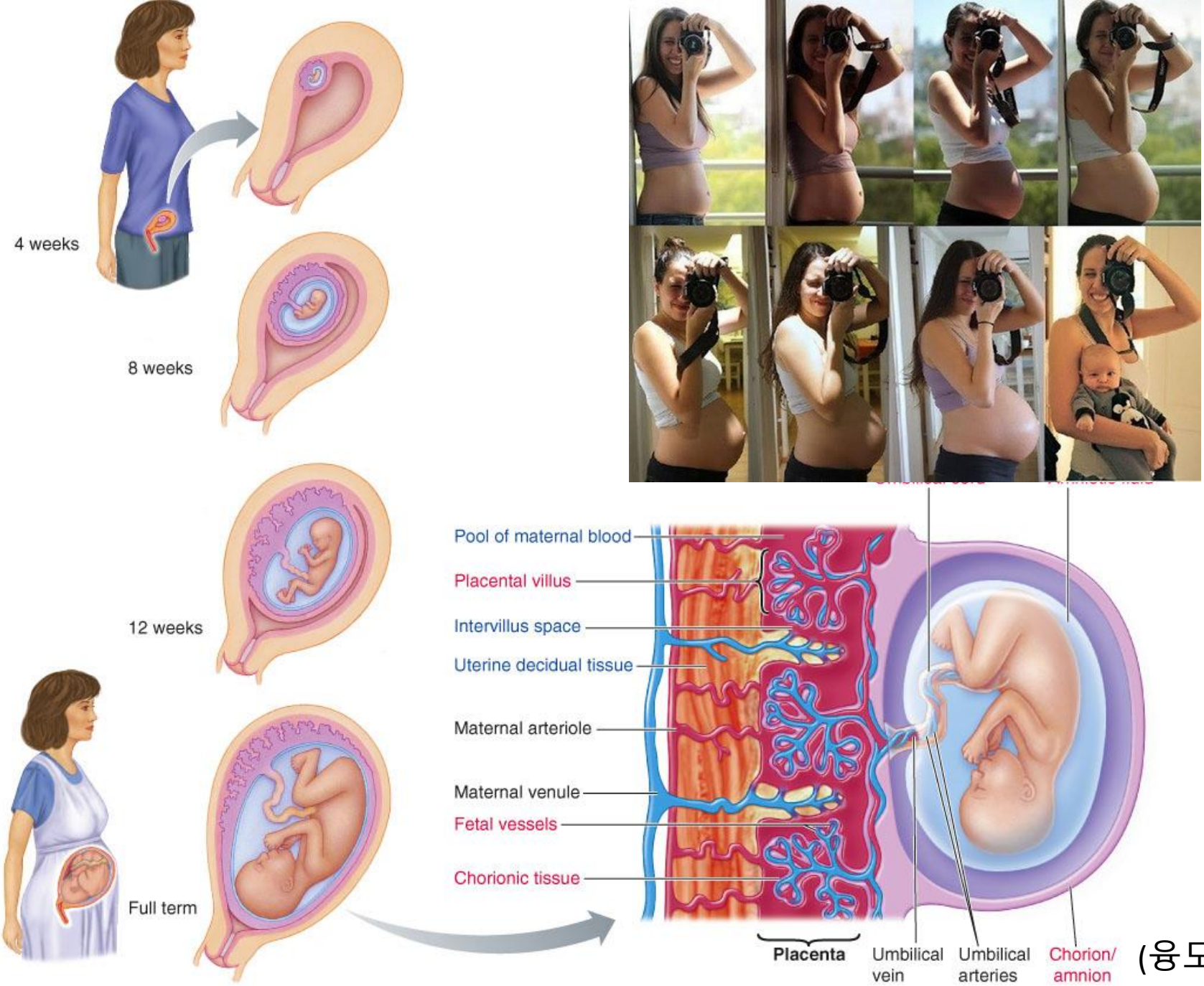


3 When implantation is finished, the blastocyst is completely buried in the endometrium.

Placenta (태반)

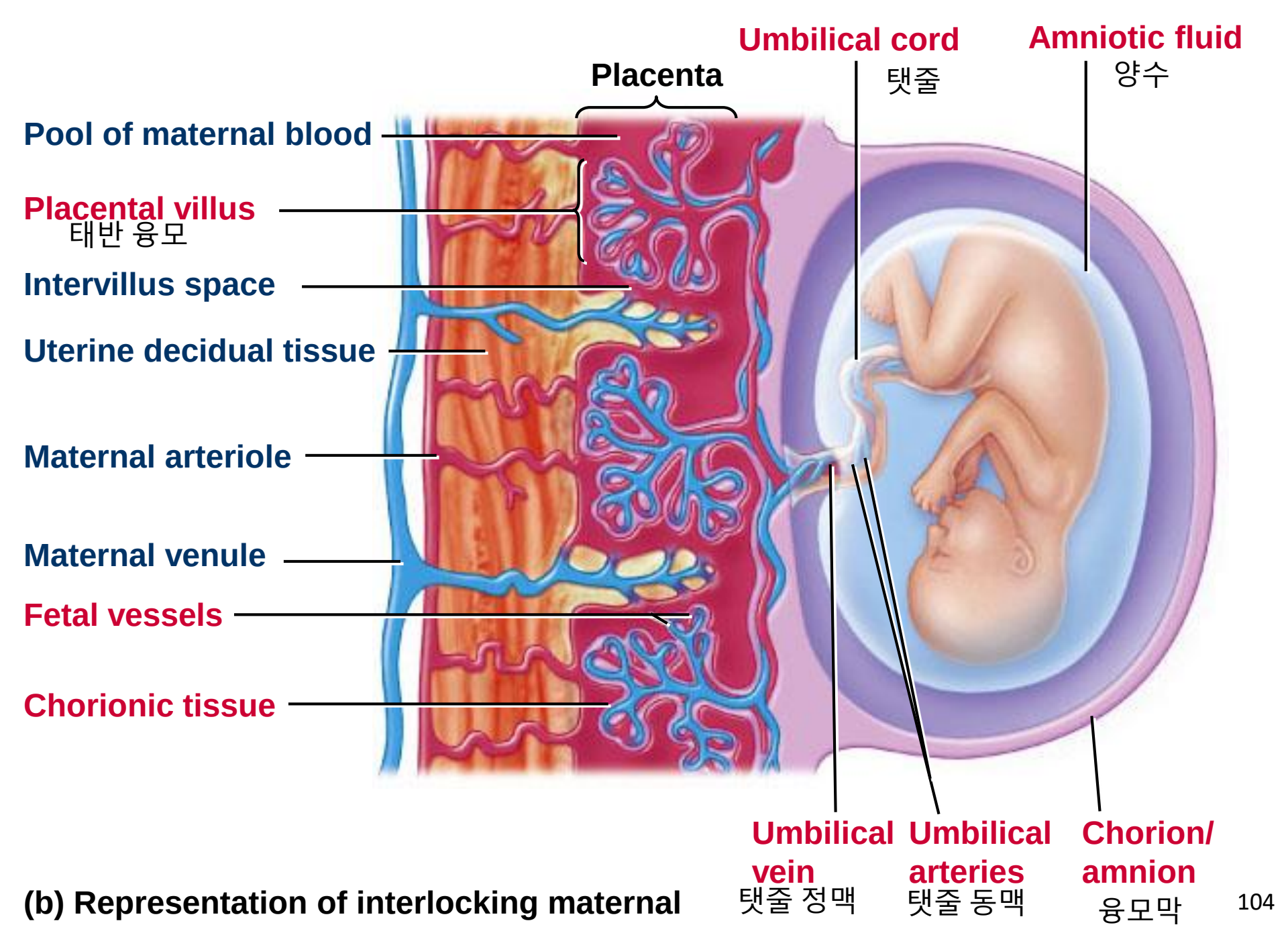


- Organ of exchange between maternal and fetal blood.
- Secretes hCG, estrogen, and progesterone.
- hCG maintains the corpus luteum during the first trimester of gestation until the placenta takes over.
- Estrogen and progesterone are essential for maintaining a normal pregnancy.



(a) Relationship between developing fetus and uterus as pregnancy progresses

(b) Representation of interlocking maternal and fetal structures that form the placenta



(b) Representation of interlocking maternal and fetal structures that form the placenta

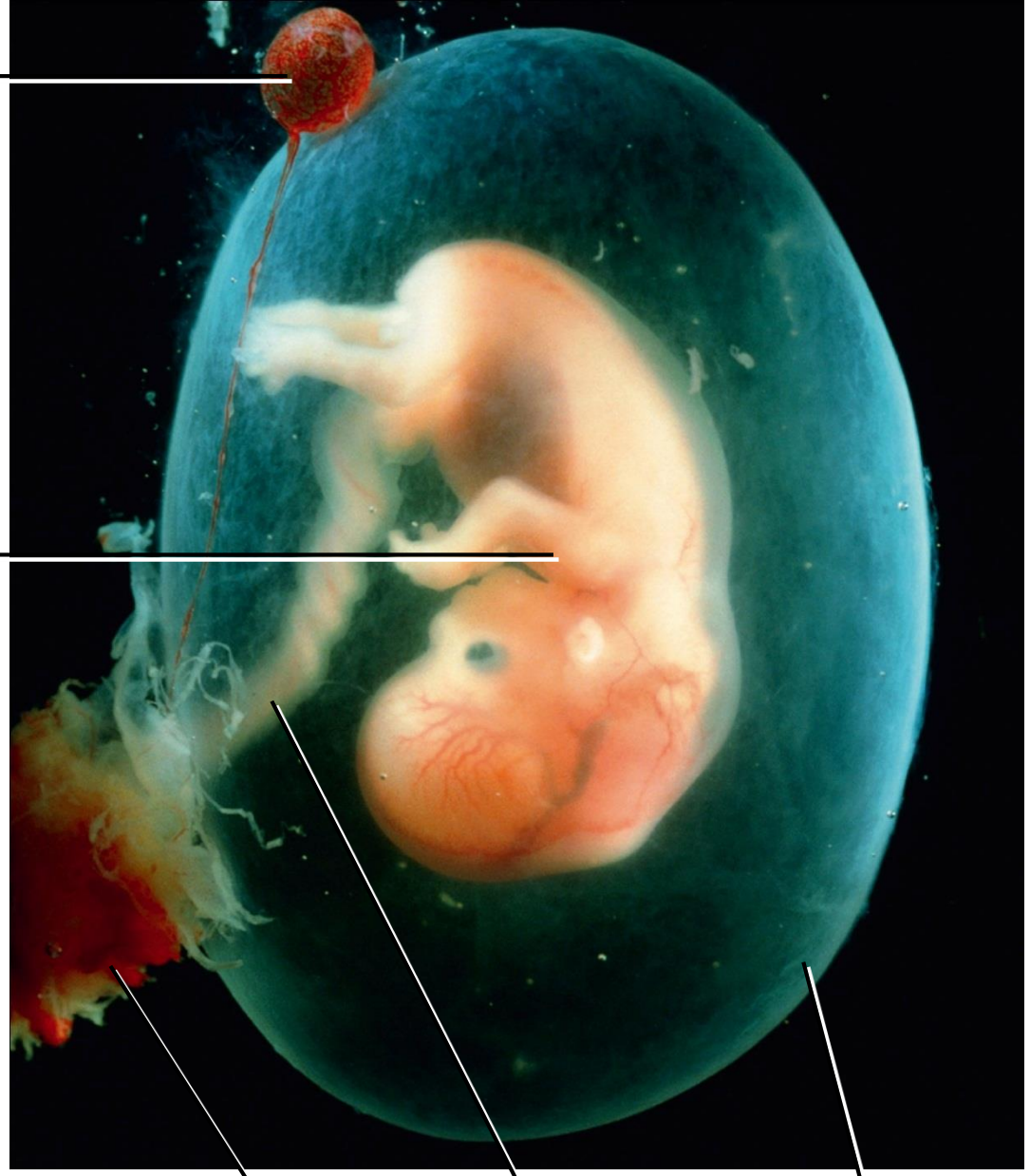
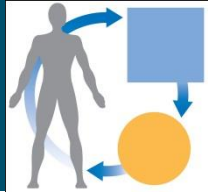

Remnant of yolk sac
Human embryo at 7 to 8 weeks of development
(c)
Placenta
Umbilical cord
Amniotic fluid

TABLE 20-5 Placental Hormones

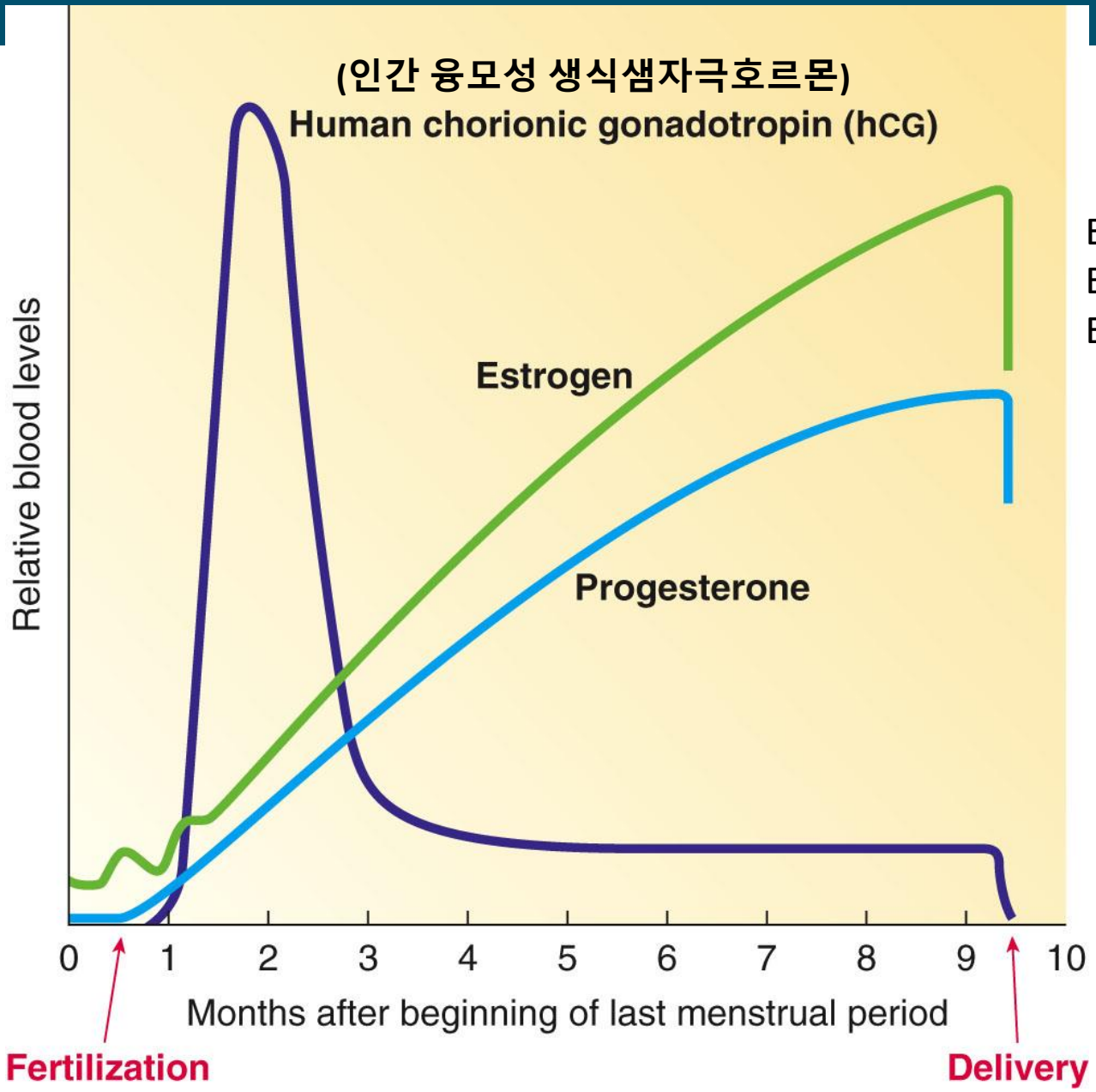
Hormone	Function
Human chorionic gonadotropin (hCG)	Maintains the corpus luteum of pregnancy
	Stimulates secretion of testosterone by the developing testes in XY embryos
Estrogen (also secreted by the corpus luteum of pregnancy)	Stimulates growth of the myometrium, increasing uterine strength for parturition
	Helps prepare the mammary glands for lactation
Progesterone (also secreted by the corpus luteum of pregnancy)	Suppresses uterine contractions to provide a quiet environment for the fetus
	Promotes formation of a cervical mucus plug to prevent uterine contamination
	Helps prepare the mammary glands for lactation
Human chorionic somatomammotropin (has a structure similar to that of both growth hormone and prolactin)	Reduces maternal use of glucose and promotes the breakdown of stored fat (similar to growth hormone) so that greater quantities of glucose and free fatty acids may be shunted to the fetus
	Helps prepare the mammary glands for lactation (similar to prolactin)
Relaxin (also secreted by the corpus luteum of pregnancy)	Softens the cervix in preparation for cervical dilation at parturition
	Loosens the connective tissue between the pelvic bones in preparation for parturition
Placental PTHrp (parathyroid hormone–related peptide)	Increases maternal plasma Ca^{2+} level for use in calcifying fetal bones; if necessary, promotes localized dissolution of maternal bones, mobilizing their Ca^{2+} stores for use by the developing fetus

Human Chorionic Gonadotropin (hCG)
인간 융모막 생식샘자극호르몬



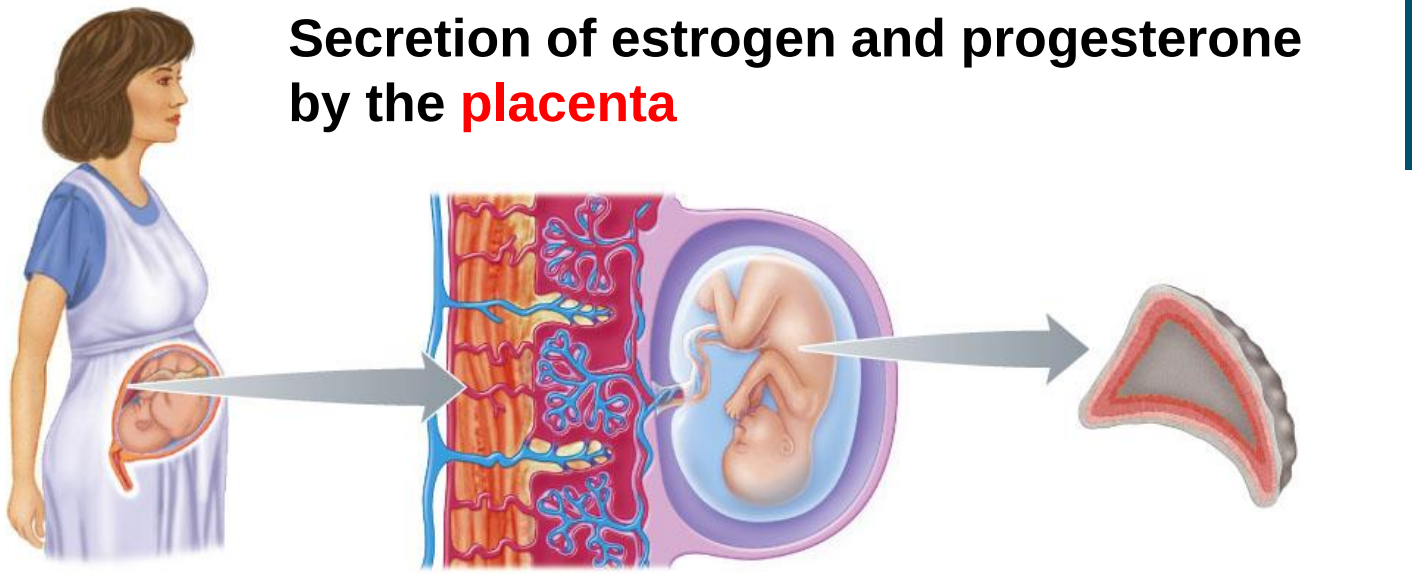
- Implanted blastocyst produces **hCG.**
- hCG stimulates and maintains the corpus luteum so that it does not degenerate.
- **Corpus luteum of pregnancy** produces greater amounts of estrogen and progesterone for an additional 10 weeks.
- At this time, the placenta takes over secretion of these hormones.

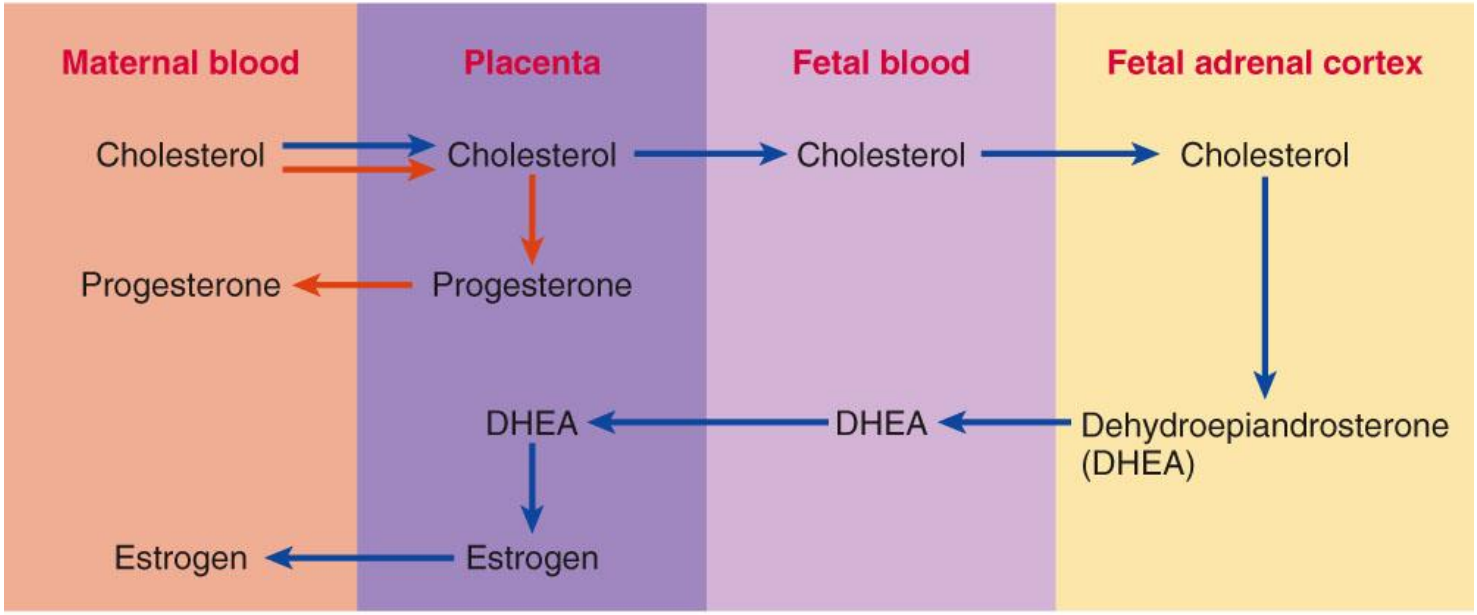
Secretion Rates of Placental Hormones



E1 (estrone)
E2 (estradiol)
E3 (estriol)

Secretion of estrogen and progesterone by the placenta

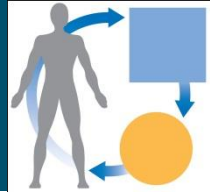




KEY

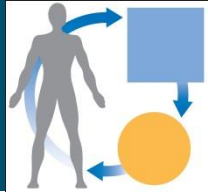
- Pathway for placental synthesis of progesterone
- Pathway for placental synthesis of estrogen

Pregnancy (임신)



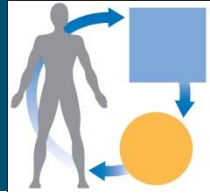
- About 38 weeks from conception (40 weeks from the first day of the last menstrual period)
- Physical changes within mother occur to meet demands of pregnancy:
  - uterine enlargement (more than 20 times)
  - breasts enlarge and develop ability to produce milk
  - volume of blood increases 30%

Pregnancy



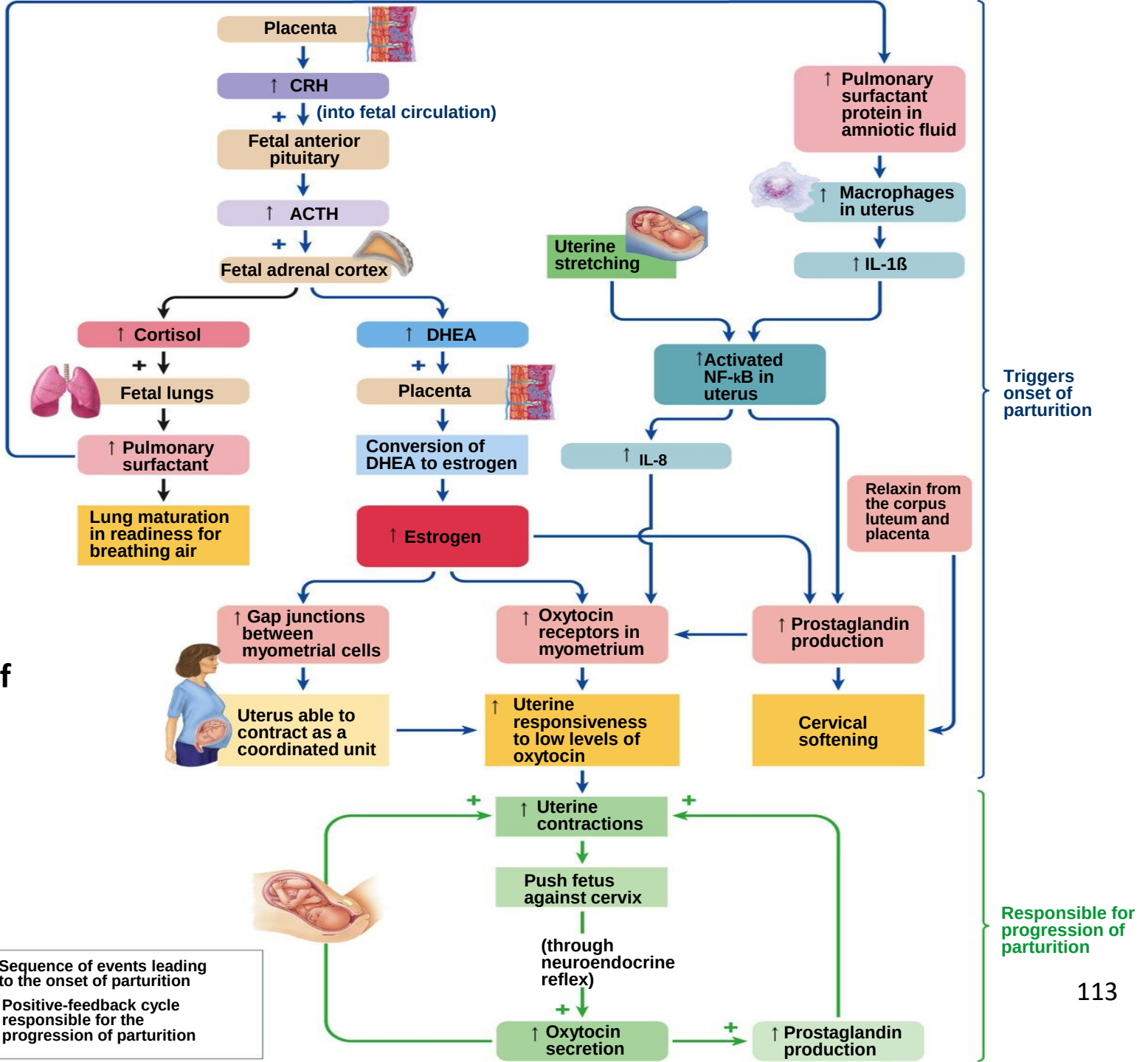
- Physical changes within mother to meet demands of pregnancy_cont'd:
  - weight gain
  - respiratory activity increases by about 20%
  - urinary output increases
  - kidneys excrete additional wastes from fetus
  - nutritional requirements increase

Parturition (출산)



- Labor (진통) and delivery (분만) requires:
  - dilation of cervical canal
  - contractions of uterine myometrium
- Pressure of fetus against cervix promotes oxytocin secretion.
- Oxytocin causes stronger contractions.
- **Positive-feedback** cycle progressively increases until cervical dilation and delivery are complete.

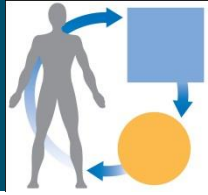
Initiation and progression of parturition



Parturition (출산)

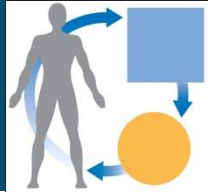
- Once contractions begin at labor onset, positive-feedback cycle progressively increases force
- Pressure of fetus against cervix reflexly increases oxytocin secretion **[줄탁동시, 啐啄同時,** 병아리가 알에서 나오기 위해서는 새끼와 어미 닭이 안팎에서 서로 쪼아야 한다는 뜻으로, 선종(禪宗)의 공안 가운데 하나임]
- Role of oxytocin
  - Causes stronger contractions
  - **Positive-feedback cycle** progressively increases until cervical dilation and delivery are complete

Stages of Labor

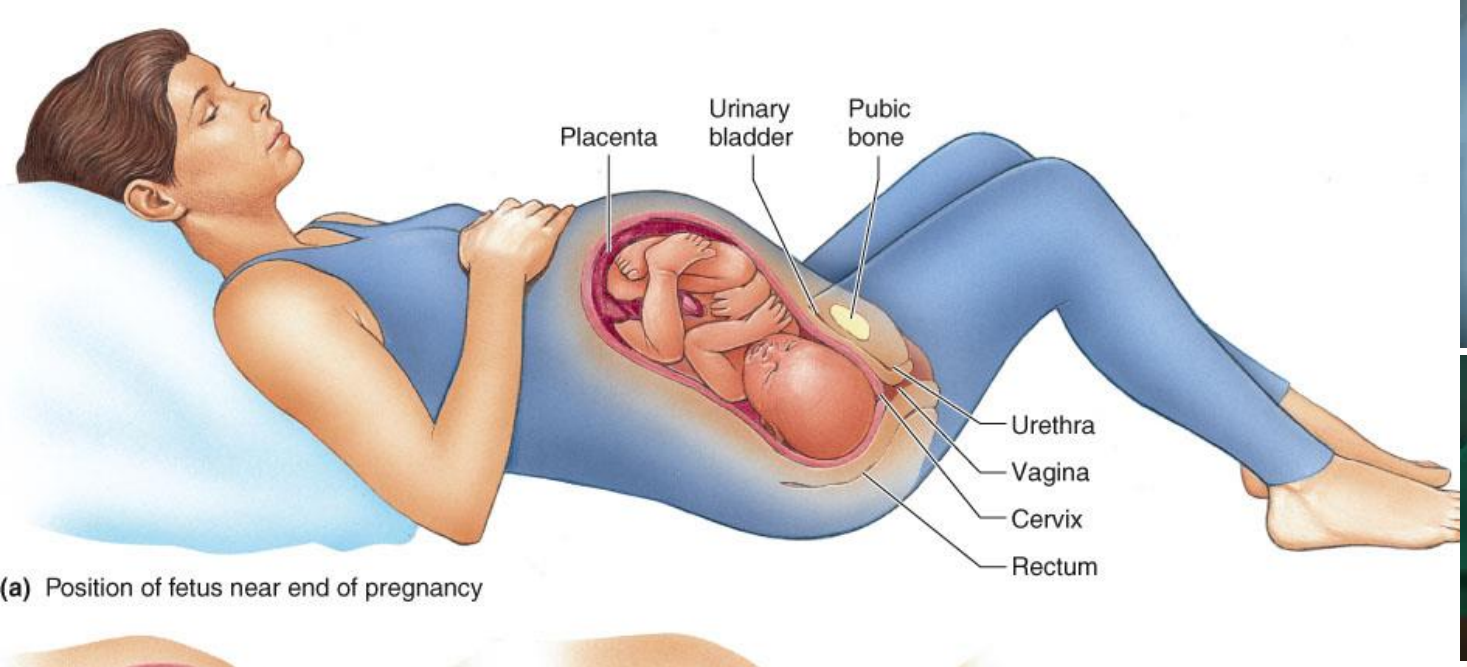


- **Cervical dilation:**
  - longest stage
  - lasts from several hours to as long as 24 hours
- **Delivery of baby:**
  - begins when cervical dilation is complete
  - usually lasts 30 to 90 minutes
  - stretch receptors in the vagina activate a neural reflex that triggers contractions of the abdominal wall to assist in delivery

Stages of Labor



- **Delivery of placenta:**
  - second series of uterine contractions separates placenta from uterus
  - shortest stage – usually completed within 15 to 30 minutes after baby is born
  - after delivery, uterus shrinks to pregestational size **(involution,** 퇴축**)**



(a) Position of fetus near end of pregnancy

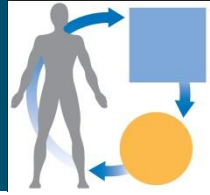
1 First stage of labor: Cervical dilation

2 Second stage of labor: Delivery of baby

3 Third stage of labor: Delivery of placenta

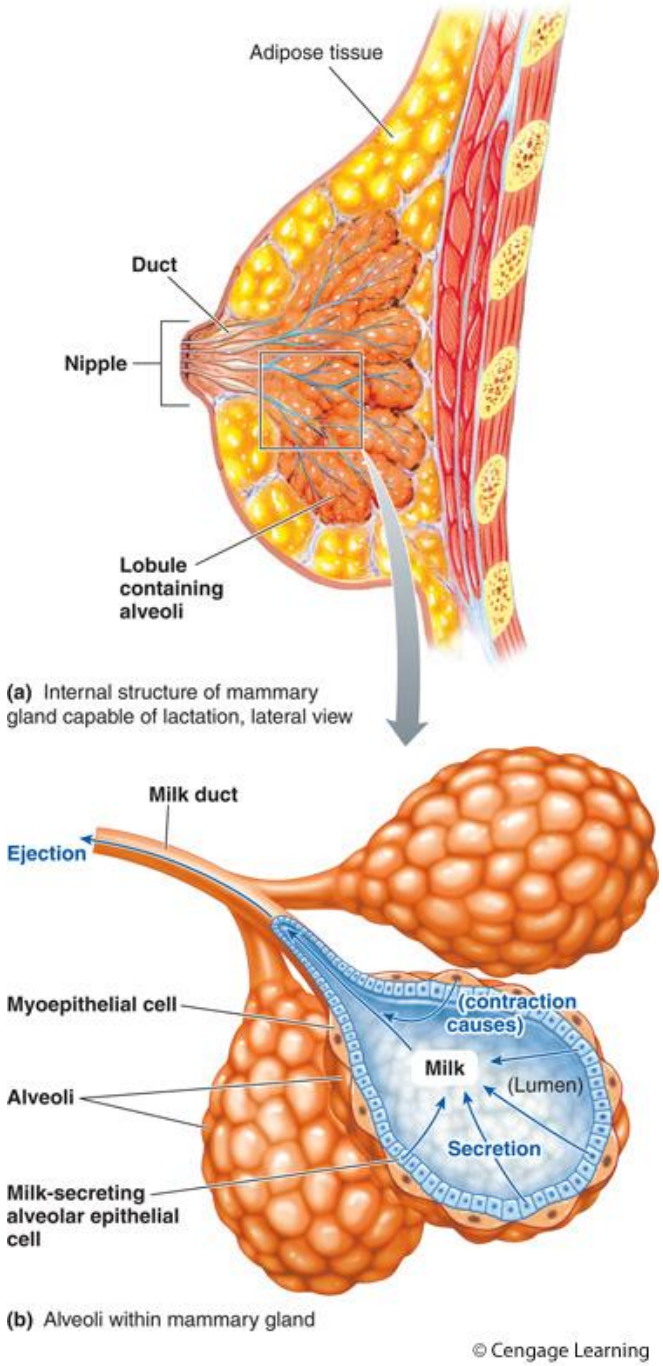
(b) Stages of labor

Lactation (수유)

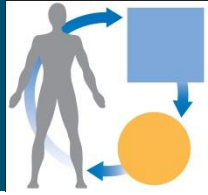


- During gestation, elevated placental estrogen and progesterone promote development of mammary glands.
- Prolactin stimulates synthesis of enzymes essential for milk production.
- Withdrawal of placental steroids at parturition initiates lactation.

Mammary gland anatomy



Lactation



- Suckling triggers release of hormones:
  - Oxytocin causes milk ejection by stimulating cells surrounding alveoli to contract
  - Prolactin stimulates secretion of more milk to replace milk ejected as baby nurses

TABLE 20-6 Actions of Estrogen and Progesterone

Estrogen

Effects on Sex-Specific Tissues

Is essential for egg maturation and release

Stimulates growth and maintenance of entire female reproductive tract

Stimulates granulosa cell proliferation, which leads to follicle maturation

Thins the cervical mucus to permit sperm penetration

Enhances transport of sperm to the oviduct by stimulating upward contractions of the uterus and oviduct

Stimulates growth of the endometrium and myometrium

Induces synthesis of endometrial progesterone receptors

Triggers onset of parturition by increasing uterine responsiveness to oxytocin during late gestation through a twofold effect: by inducing synthesis of myometrial oxytocin receptors and by increasing myometrial gap junctions so that the uterus can contract as a coordinated unit in response to oxytocin

Other Reproductive Effects

Promotes development of secondary sexual characteristics

Controls GnRH and gonadotropin secretion
- Low levels inhibit secretion
- High levels responsible for triggering LH surge

Stimulates duct development in the breasts during gestation

Inhibits milk-secreting actions of prolactin during gestation

Nonreproductive Effects

Promotes fat deposition

Increases bone density

Closes the epiphyseal plates

Improves blood cholesterol profile by increasing HDL and decreasing LDL

Promotes vasodilation by increasing nitric oxide production in arterioles (cardioprotective)

Progesterone

Prepares a suitable environment for nourishment of a developing embryo/fetus

Promotes formation of a thick mucus plug in cervical canal

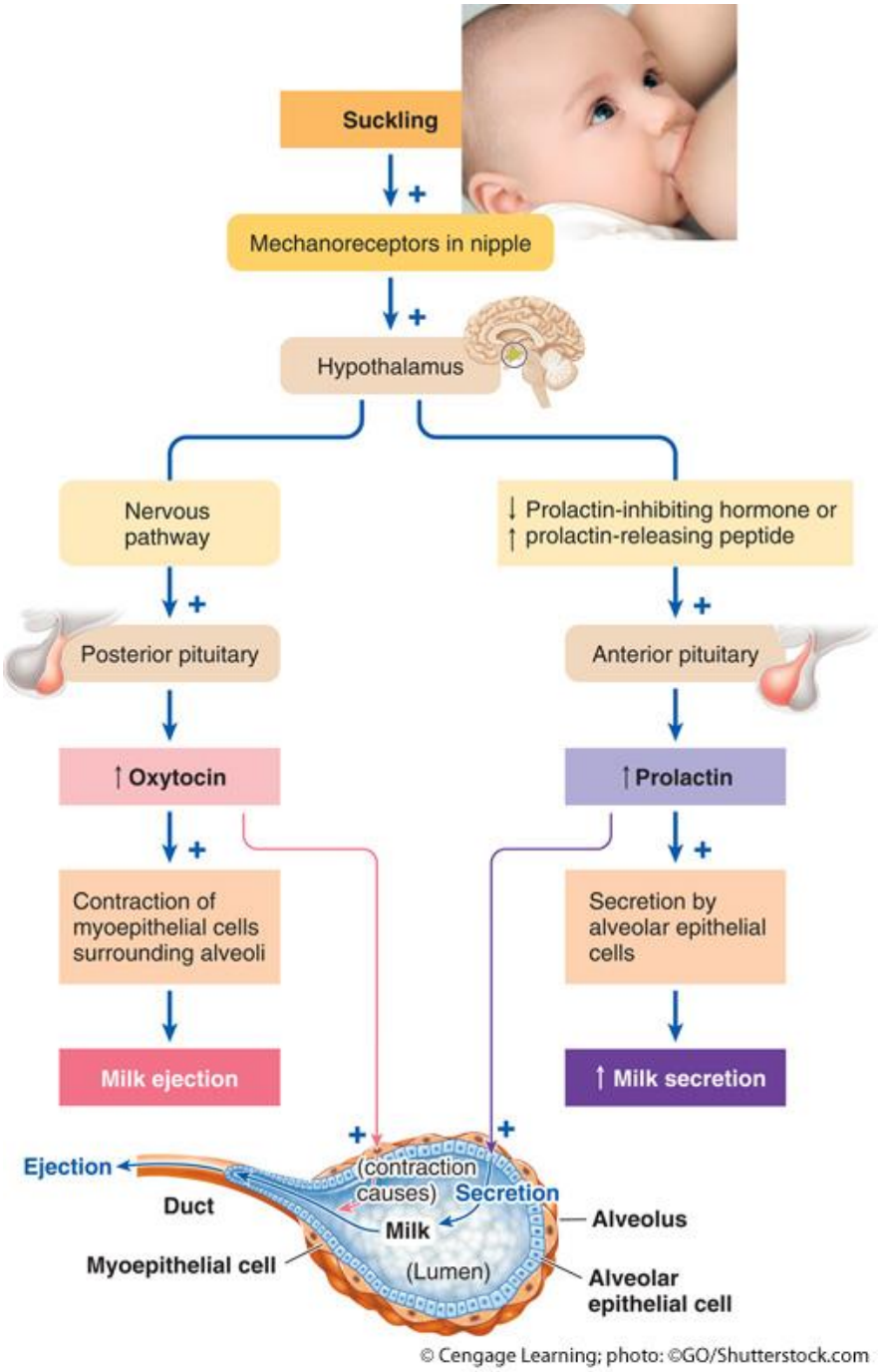
Inhibits hypothalamic GnRH and gonadotropin secretion

Stimulates alveolar development in the breasts during gestation

Inhibits milk-secreting actions of prolactin during gestation

Inhibits uterine contractions during gestation

Fig. 20-32
Suckling reflexes



Breast-feeding is advantageous to the infant

- Abundance of immune cells – B and T cells, macrophages, and neutrophils
- Secretory IgA
- Mucus: adhere to potentially harmful microorganisms, preventing them from attaching to and crossing the intestinal mucosa
- Lactoferrin: inhibit growth of harmful bacteria
- **Bifidus factor** in breast milk: promotes multiplication of the nonpathogenic microorganism *Lactobacillus bifidus* in the infant's digestive tract.
- Promote maturation of the baby's digestive system so that it is less vulnerable to diarrhea-causing bacteria and viruses
- Still other factors in breast milk hasten the development of the infant's own immune capabilities.

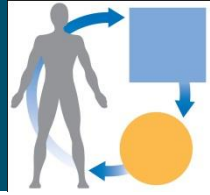
Advantageous Breast-Feeding for the Mother

- Oxytocin release triggered by nursing hastens uterine involution.
- Suckling suppresses the menstrual cycle by inhibiting LH and FHS secretion, probably by inhibiting GnRH.
- Lactation, therefore, tends to prevent ovulation, decreasing the likelihood of another pregnancy.
- Decrease the development of breast cancer.

Cessation of milk production at weaning

- There is no sucking and thus no oxytocin release.
- Cessation of lactation at weaning therefore results from a lack of suckling-induced stimulation of both prolactin and oxytocin secretion.

Summary by keywords



- Male reproductive system
- Spermatogenesis
- Female reproductive system
- Oogenesis
- Ovarian cycle
- Uterine cycle
- Pregnancy