Physiology and Anatomy of Reproductive Systems

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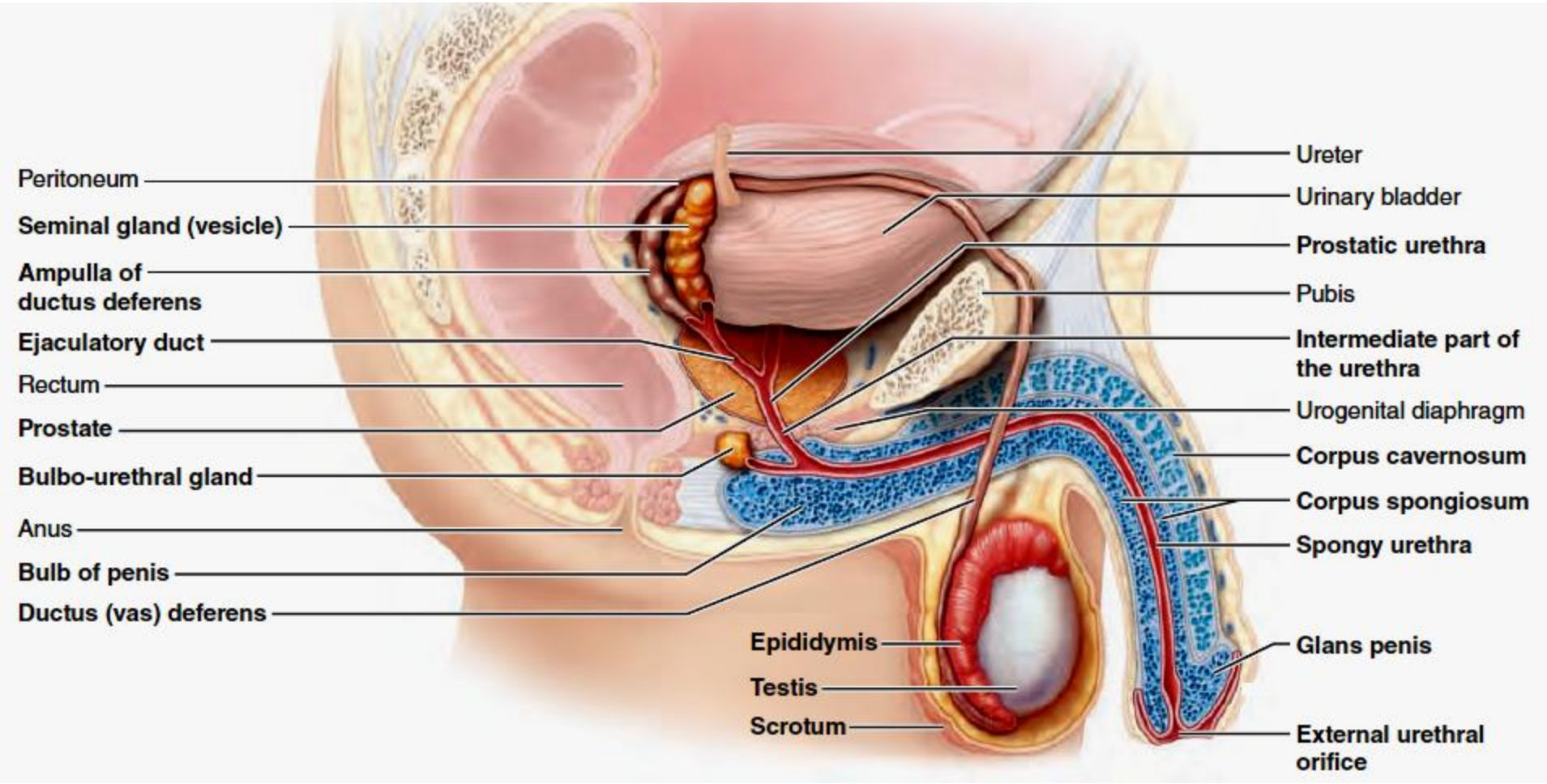
Disclosure

- The material and the illustrations are adopted from the textbook **“Human Anatomy and Physiology / Ninth edition/ Eliane N. Marieb 2013”**

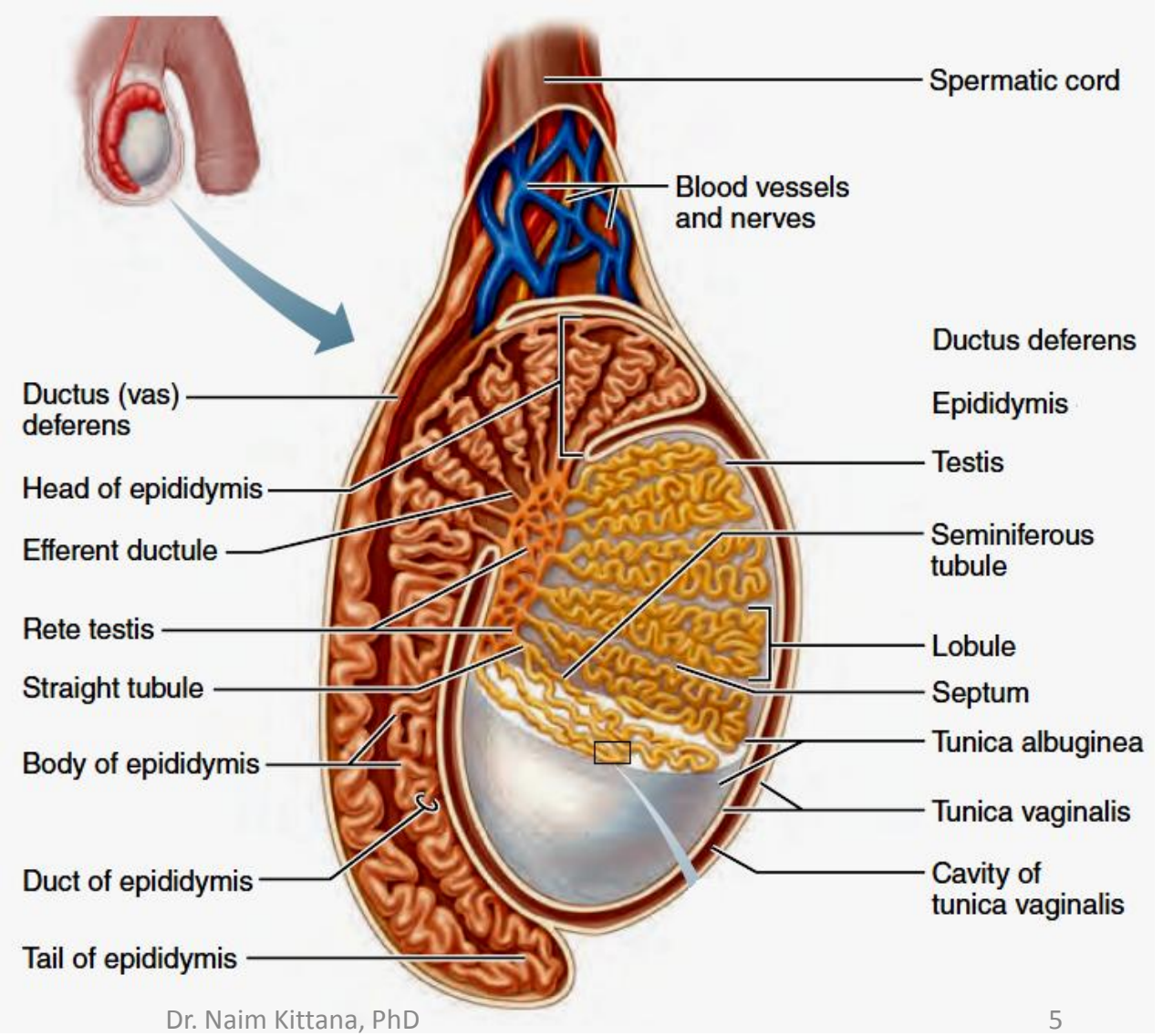
Male reproductive system

Male reproductive system



The Testes

- Each testis is covered externally by a tunica albuginea that extends internally to divide the testis into many lobules.
- Each lobule contains sperm-producing seminiferous tubules (the actual "sperm factories") and interstitial endocrine cells that produce androgens



The Male Duct System

- **The epididymis:**
  - hugs the external surface of the testis and serves as a site for sperm maturation and storage

- **The ductus (vas) deferens**
  - extending from the epididymis to the ejaculatory duct, propels sperm into the urethra by peristalsis during ejaculation
  - Its terminus fuses with the duct of the seminal gland, forming the ejaculatory duct, which empties into the urethra within the prostate

- **The urethra**
  - Extends from the urinary bladder to the tip of the penis. It conducts semen and urine to the body exterior

The Male Accessory Glands

- **Seminal glands:**
  - Secretes yellowish viscous alkaline fluid containing
    - fructose sugar
    - citric acid
    - Prostaglandins
    - other substances that enhance sperm motility or fertilizing ability.

  - Seminal gland secretion accounts for some 70% of the volume of semen

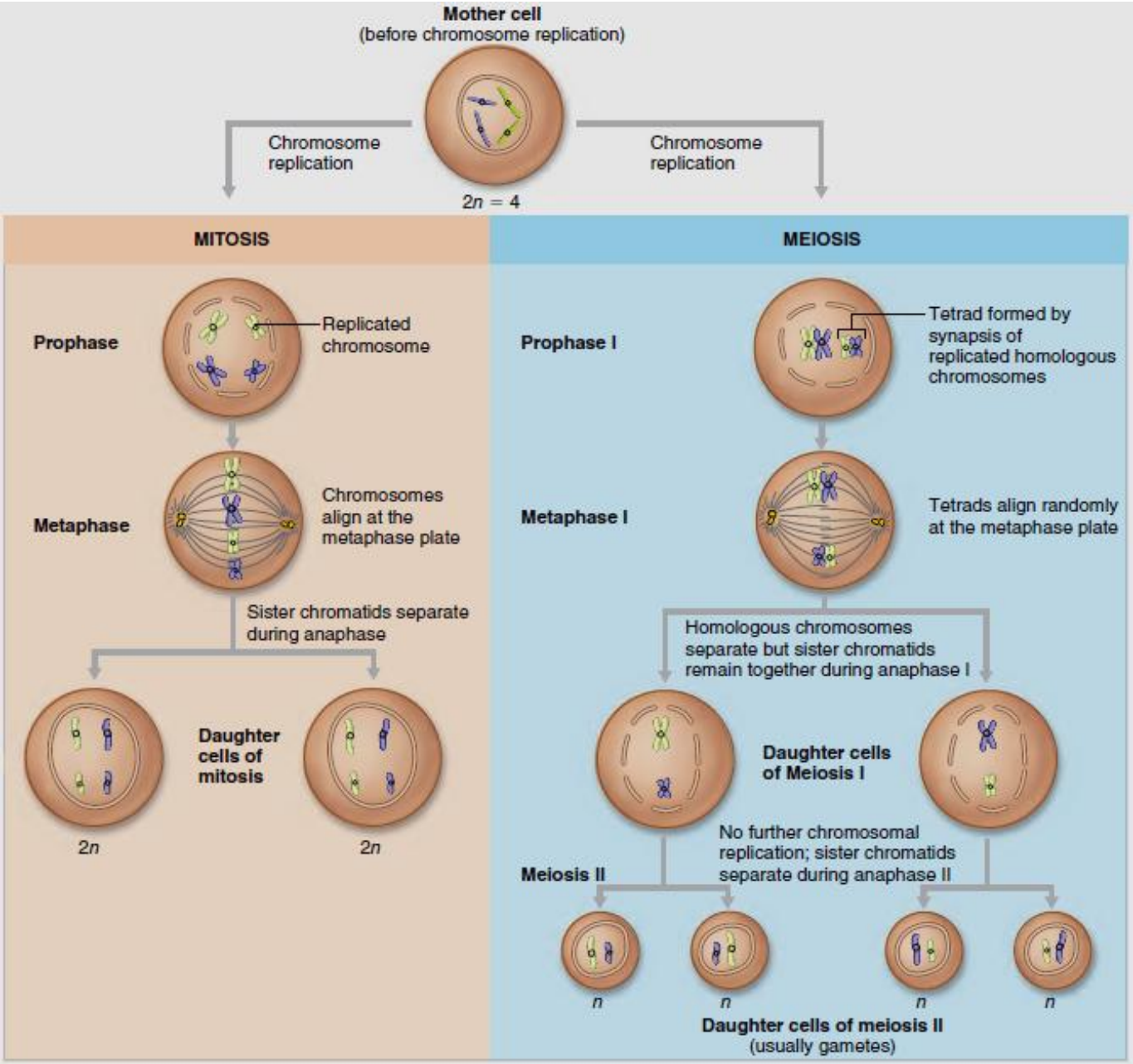
The Male Accessory Glands

- **The prostate gland**
  - Secretes a fluid that plays a role in activating sperm and accounts for up to one-third of the semen volume.

The Male Accessory Glands

- The accessory glands produce the bulk of the semen
- Semen is an alkaline fluid that dilutes and transports sperm
- **It contains:**
  - fructose from the seminal glands
  - an activating fluid from the prostate
  - mucus from the bulbo-urethral glands
  - nutrients
  - Prostaglandins
  - antibiotic chemicals
  - Clotting factors

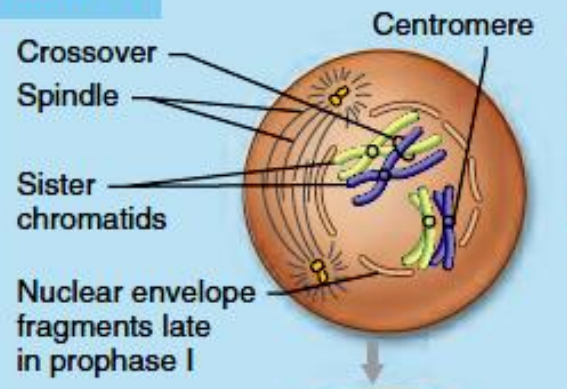
Mitosis vs. Meiosis



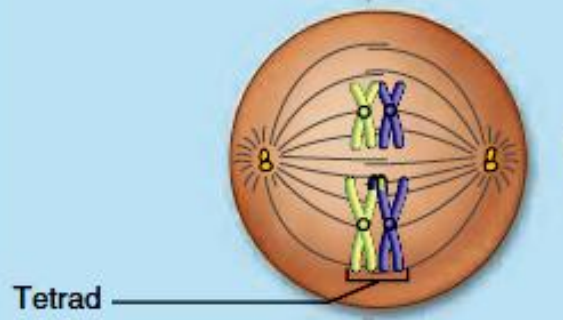
Mitosis vs. Meiosis

	MITOSIS	MEIOSIS
Number of divisions	One, consisting of prophase, metaphase, anaphase, and telophase.	Two, each consisting of prophase, metaphase, anaphase, and telophase. DNA replication does not occur between the two nuclear divisions.
Synapsis of homologous chromosomes	Does not occur.	Occurs during prophase I; tetrads form, allowing crossovers.
Daughter cell number and genetic composition	Two. Each diploid ($2n$) cell is identical to the mother cell.	Four. Each haploid (n) cell contains half as many chromosomes as the mother cell and is genetically different from the mother cell.
Roles in the body	For development of multicellular adult from zygote. Produces cells for growth and tissue repair as multicellular adult develops. Ensures genetic makeup of all body cells is constant.	Produces cells for reproduction (gametes). Introduces genetic variability in the gametes and reduces chromosomal number by half so that when fertilization occurs, the normal diploid chromosomal number is restored (in humans, $2n = 46$).

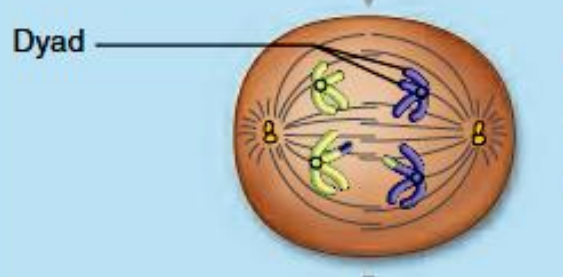
MEIOSIS I



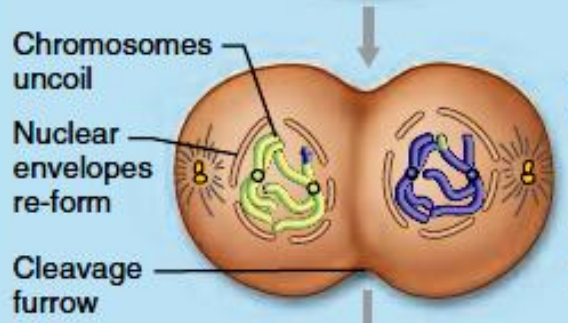
Prophase I
Prophase events occur, as in mitosis. Additionally, synapsis occurs: Homologous chromosomes come together along their length to form tetrads. During synapsis, the "arms" of homologous chromatids wrap around each other, forming several crossovers. The nonsister chromatids trade segments at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



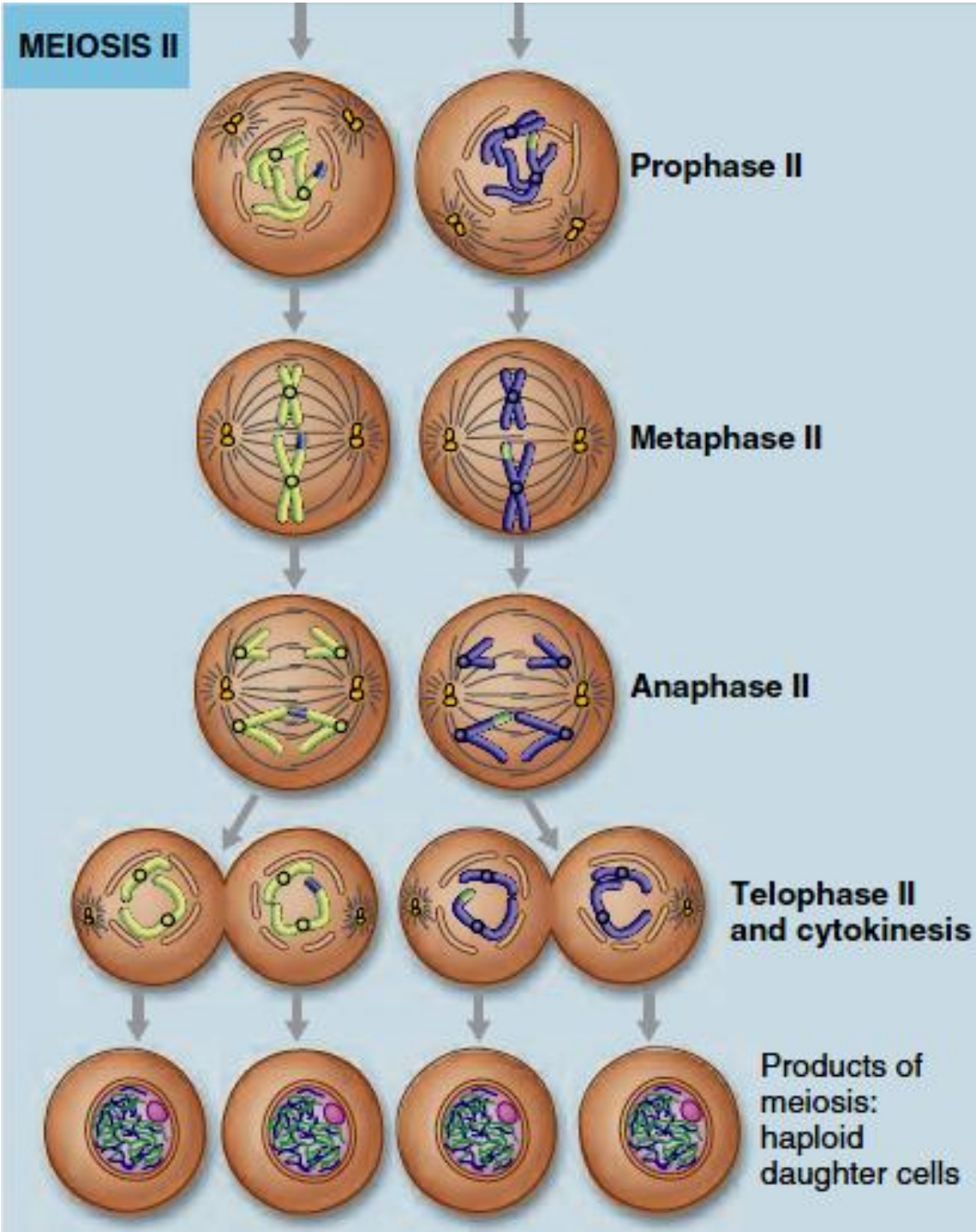
Metaphase I
The tetrads align randomly on the spindle equator in preparation for anaphase.



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 end. 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 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.)

Spermatogenesis

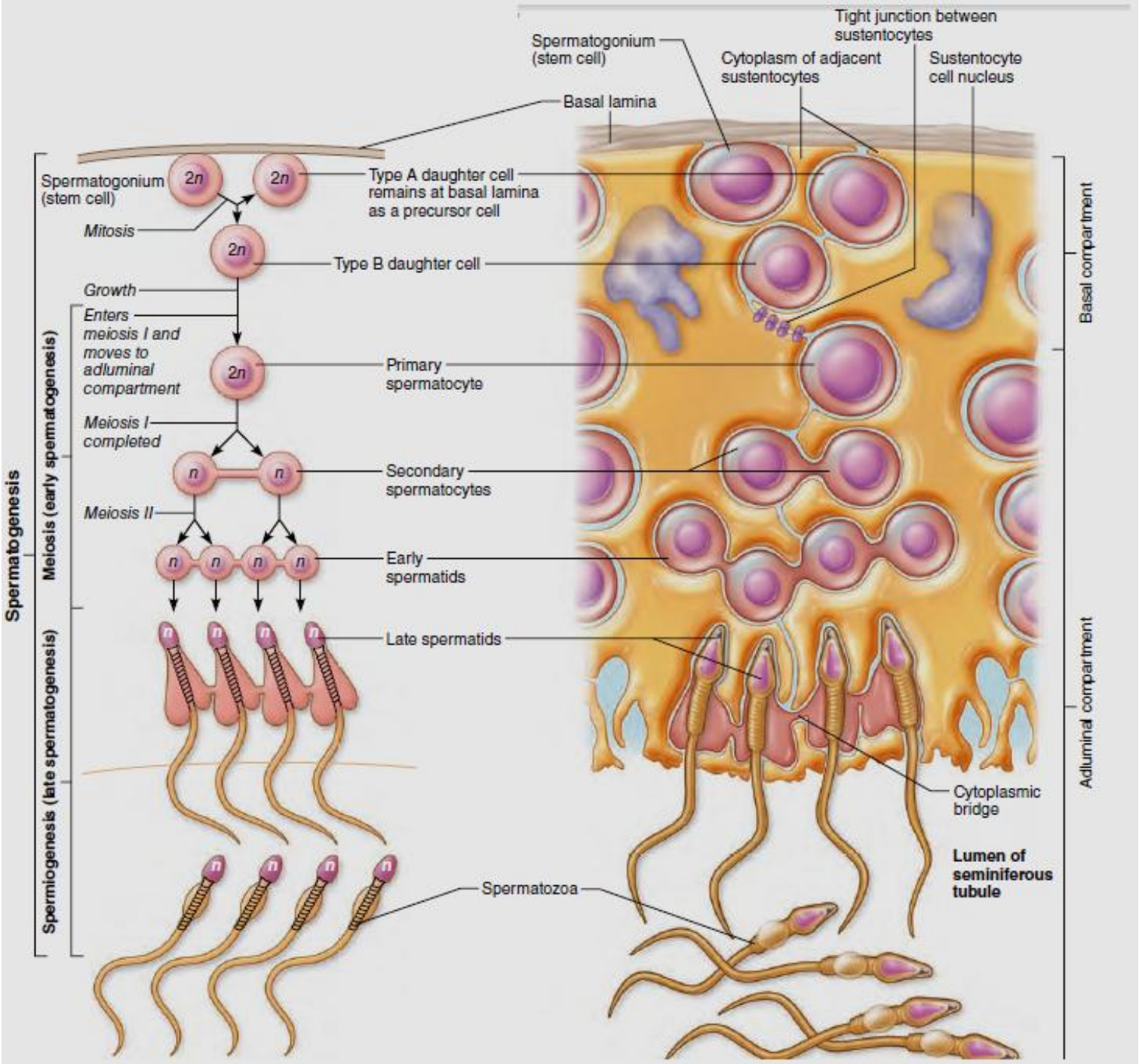
- The production of male gametes in the seminiferous tubules, begins at puberty
- Meiosis, the basis of gamete production, consists of two consecutive nuclear divisions without DNA replication in between.
- Meiosis reduces the chromosomal number by half and introduces genetic variability

Spermatogenesis

- Spermatogonia divide by mitosis to maintain the germ cell line.
- Some of their progeny become primary spermatocytes
- Spermatocytes undergo meiosis I to produce secondary spermatocytes
- Secondary spermatocytes undergo meiosis II, each producing two haploid (*n)* spermatids.
- **Spermiogenesis converts spermatids to functional sperm,**

Spermatogenesis

- Sustentocytes form the blood testis barrier, nourish spermatogenic cells, move them toward the lumen of the tubules, and secrete fluid for sperm transport


Tight junction between sustentocytes
Spermatogonium (stem cell)
Cytoplasm of adjacent sustentocytes
Sustentocyte cell nucleus
Basal lamina
Spermatogonium (stem cell)
2n
2n
Type A daughter cell remains at basal lamina as a precursor cell
Mitosis
2n
Type B daughter cell
Growth
Enters meiosis I and moves to adluminal compartment
2n
Primary spermatocyte
Meiosis I completed
n
n
Secondary spermatocytes
Meiosis II
n
n
n
n
Early spermatids
Late spermatids
Spermatogenesis
Meiosis (early spermatogenesis)
Spermiogenesis (late spermatogenesis)
Basal compartment
Adluminal compartment
Cytoplasmic bridge
Lumen of seminiferous tubule
Spermatozoa

Hormonal Regulation of Male Reproductive Function

- GnRH, produced by the hypothalamus, stimulates the anterior pituitary gland to release FSH and LH
- FSH causes sustentocytes to produce androgen-binding protein (ABP).
- LH stimulates interstitial endocrine cells to release testosterone, which binds to ABP, stimulating spermatogenesis.
- Testosterone and inhibin (produced by sustentocytes) feed back to inhibit the hypothalamus and anterior pituitary.
- **Maturation of hormonal controls occurs during puberty and** takes about three years

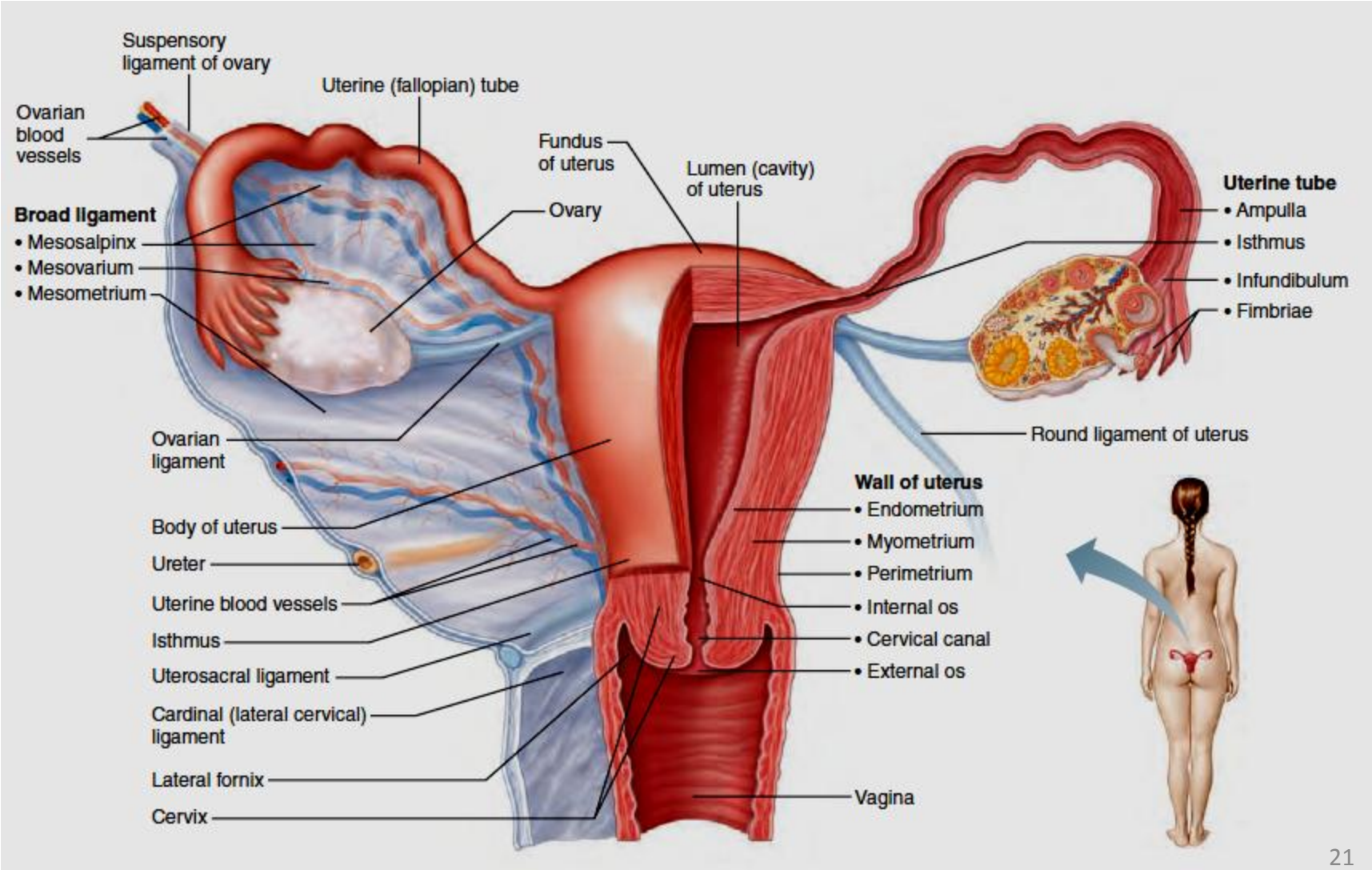
Hormonal Regulation of Male Reproductive Function

- **Testosterone stimulates maturation of the male reproductive** organs and triggers the development of the secondary sex characteristics of the male

- It exerts anabolic effects on the skeleton and skeletal muscles, stimulates spermatogenesis, and is responsible for male sex drive

Anatomy of the Female Reproductive System

Internal reproductive organs of a female, posterior view



The Ovaries

- The ovaries flank the uterus laterally and are held in position by the ovarian and suspensory ligaments and mesovaria.

- Within each ovary are oocyte-containing follicles at different stages of development and possibly a corpus luteum.

The Female Duct System

- The uterine tube extends from near the ovary to the uterus.
- Its fimbriae and ciliated distal end along with peristalsis create currents that help move an ovulated oocyte into the uterine tube
- The uterus has fundus, body, and cervical regions. It is supported by some ligaments.

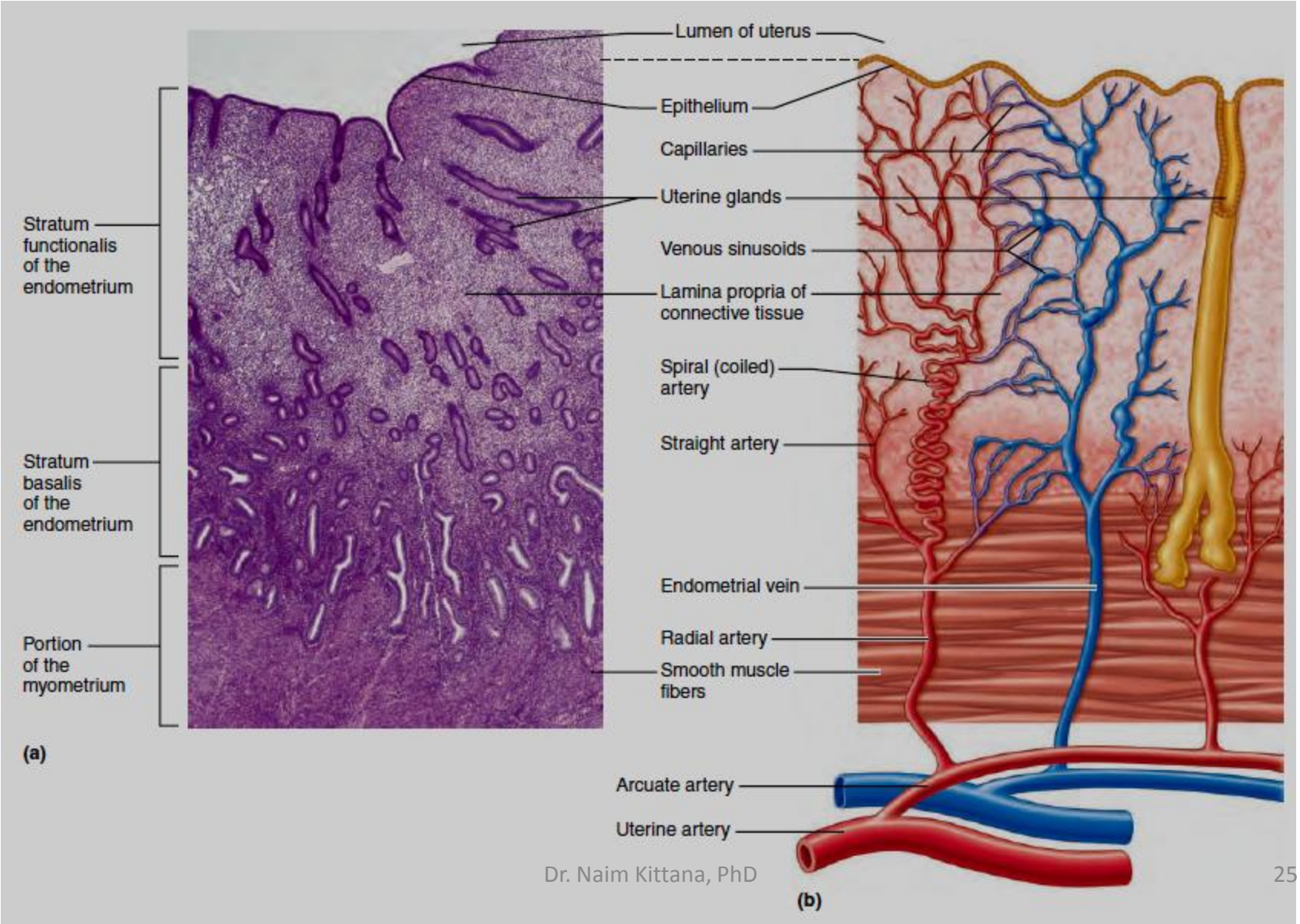
The Female Duct System

- The uterine wall is composed of the outer perimetrium, the myometrium, and the inner endometrium

- The endometrium consists of
  A. a functional layer (stratum functionalis), which sloughs off periodically unless an embryo has implanted
  B. an underlying basal layer (stratum basalis), which rebuilds the functional layer.

- The vagina extends from the uterus to the exterior.
- It is the copulatory organ and allows passage of the menstrual flow or a baby

The endometrium and its blood supply



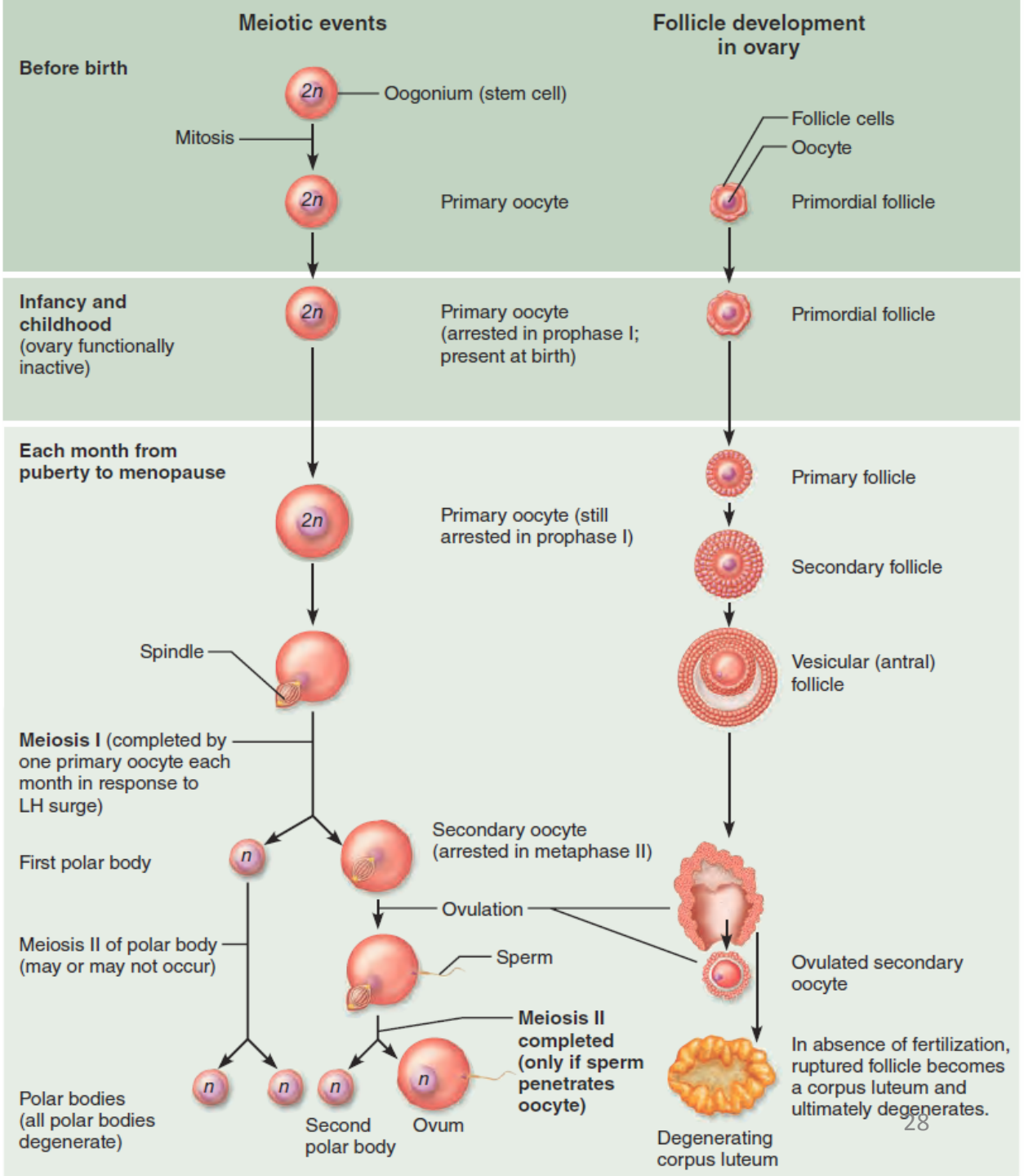
Physiology of the Female Reproductive System

- Oogenesis, the production of eggs, begins in the fetus.
- Oogonia, the diploid stem cells of female gametes, are converted to primary oocytes before birth.
- The infant female's ovaries contain about 1 million primary oocytes arrested in prophase of meiosis I. At puberty, meiosis resumes.

Physiology of the Female Reproductive System

- Each month, one primary oocyte completes meiosis I, producing a large secondary oocyte and a tiny first polar body.
- Meiosis II of the secondary oocyte produces a functional ovum and a second polar body, but does not occur in humans unless a sperm penetrates the secondary oocyte.
- The ovum contains most of the primary oocyte's cytoplasm.
- The polar bodies are nonfunctional and degenerate.

Events of oogenesis



The Ovarian Cycle

- During the follicular phase (days 1–14), several primary follicles begin to mature.
- Generally, only one follicle per month completes the maturation process, becoming the dominant follicle.
- Late in this phase, the oocyte in the dominant follicle completes meiosis I.

The Ovarian Cycle

- Ovulation occurs about day 14 in response to LH surge, releasing the secondary oocyte into the peritoneal cavity, and the other developing follicles deteriorate.

- In the luteal phase (days 15–28), the ruptured follicle is converted to a corpus luteum, which produces progesterone and estrogen for the remainder of the cycle.

- If fertilization does not occur, the corpus luteum degenerates after about 10 days.

Hormonal Regulation of the Ovarian Cycle

- Beginning at puberty, the hormones of the hypothalamus, anterior pituitary, and ovaries interact to establish and regulate the ovarian cycle.
- Establishment of the mature cyclic pattern, indicated by menarche, takes about four years.
- Leptin serves a permissive role in puberty's onset, stimulating the hypothalamus when adipose tissue is sufficient for the energy requirements of reproduction.

Hormonal Regulation of the Ovarian Cycle

- The hormonal events of each ovarian cycle are as follows:

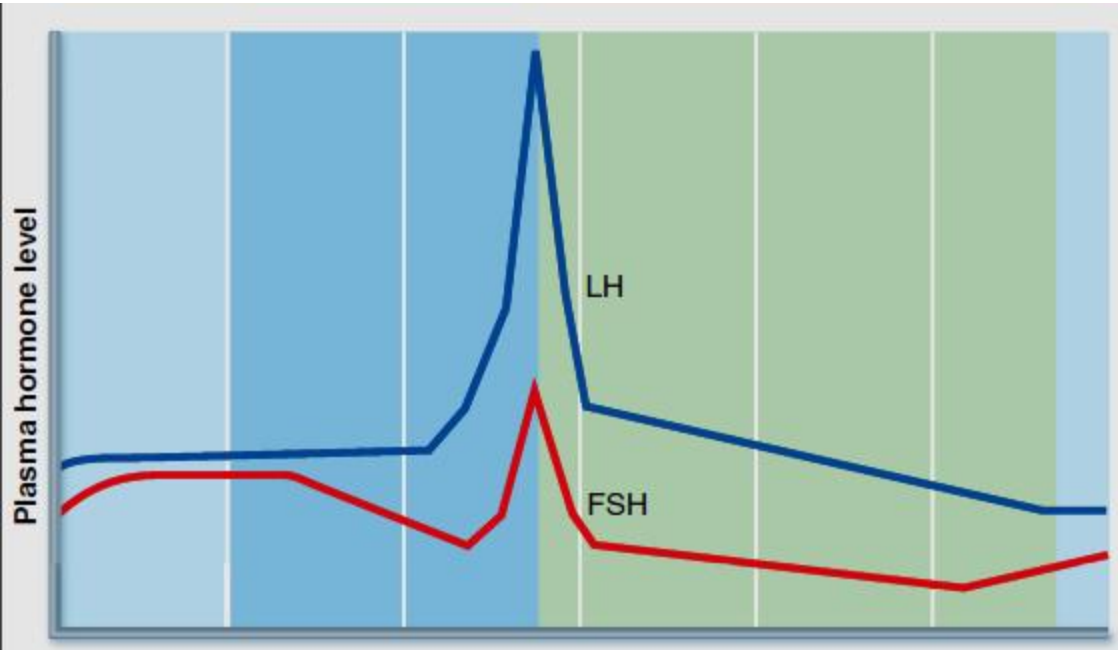
  (1) GnRH stimulates the anterior pituitary to release FSH and LH, which stimulate follicle maturation and estrogen production.

  (2) When blood estrogen reaches a certain level, positive feedback exerted on the hypothalamic-pituitary-gonadal axis causes a sudden release of LH that stimulates the primary oocyte to continue meiosis and triggers ovulation.

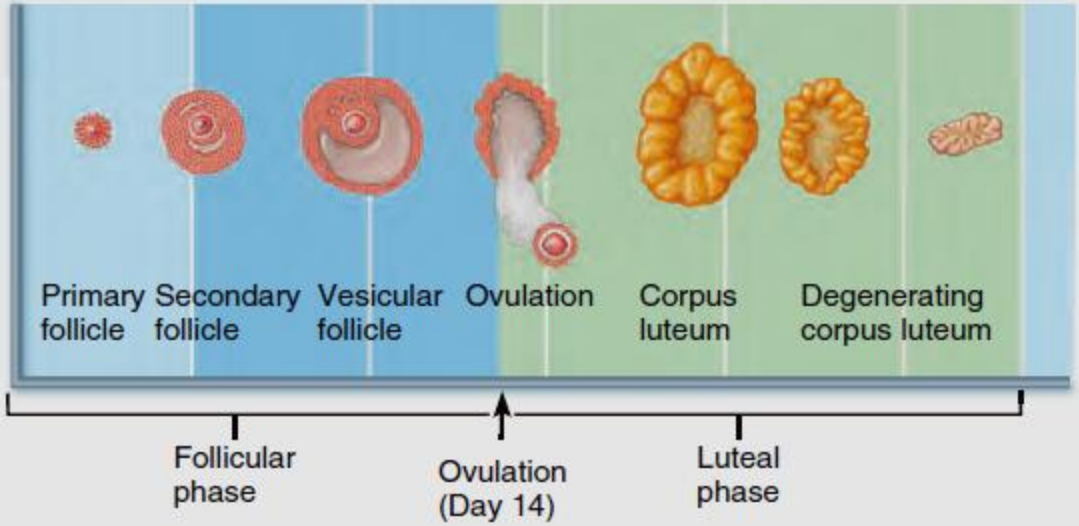
  (3) LH then causes conversion of the ruptured follicle to a corpus luteum and stimulates its secretory activity.

  (4) Rising levels of progesterone and estrogen inhibit the hypothalamic-pituitary-gonadal (HPG) axis, the corpus luteum deteriorates, ovarian hormones drop to their lowest levels, and the cycle begins anew.

Regulation of the Ovarian Cycle

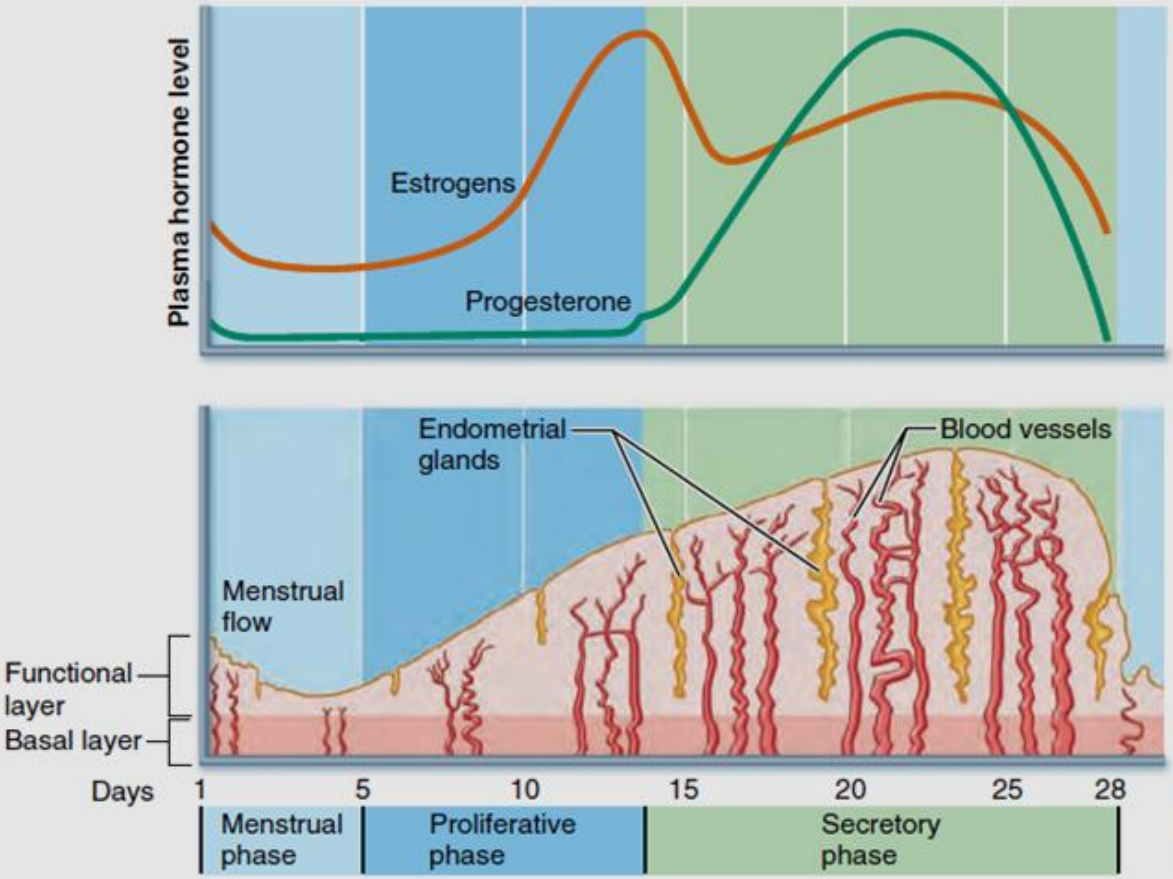


(a) Fluctuation of gonadotropin levels: Fluctuating levels of pituitary gonadotropins (follicle-stimulating hormone and luteinizing hormone) in the blood regulate the events of the ovarian cycle.



(b) Ovarian cycle: Structural changes in the ovarian follicles during the ovarian cycle are correlated with (d) changes in the endometrium of the uterus during the uterine cycle.

Regulation of the Ovarian Cycle



(c) Fluctuation of ovarian hormone levels: Fluctuating levels of ovarian hormones (estrogens and progesterone) cause the endometrial changes of the uterine cycle. The high estrogen levels are also responsible for the LH/FSH surge in (a).

(d) The three phases of the uterine cycle:

- Menstrual: The functional layer of the endometrium is shed.
- Proliferative: The functional layer of the endometrium is rebuilt.
- Secretory: Begins immediately after ovulation. Enrichment of the blood supply and glandular secretion of nutrients prepare the endometrium to receive an embryo.

Both the menstrual and proliferative phases occur before ovulation, and together they correspond to the follicular phase of the ovarian cycle. The secretory phase corresponds in time to the luteal phase of the ovarian cycle.

The Uterine (Menstrual) Cycle

- Varying levels of ovarian hormones in the blood trigger events of the uterine cycle.

- During the menstrual phase of the uterine cycle (days 1–5), the functional layer sloughs off in menses.

- During the proliferative phase (days 6–14), rising estrogen levels stimulate its regeneration, making the uterus receptive to implantation about one week after ovulation.

The Uterine (Menstrual) Cycle

- During the secretory phase (days 15–28), the uterine glands secrete nutrients, and endometrial vascularity increases further.

- Falling levels of ovarian hormones during the last few days of the ovarian cycle cause the spiral arteries to become spastic and cut off the blood supply of the functional layer, and the uterine cycle begins again with menstruation

Effects of Estrogens and Progesterone

- Estrogen promotes oogenesis.
- At puberty, it stimulates the growth of the reproductive organs and the and promotes the appearance of the secondary sex characteristics.
- Progesterone cooperates with estrogen in breast maturation and regulation of the uterine cycle.

Menopause

- During menopause, ovulation and menstruation cease.
- Hot flashes and mood changes may occur.
- Postmenopausal events include atrophy of the reproductive organs, bone mass loss and increasing risk for cardiovascular disease

Related Clinical Terms

- **Dysmenorrhea**: Painful menstruation; may reflect abnormally high prostaglandin activity during menses.

- **Endometrial cancer**: Cancer that arises from the uterine endometrium (usually from uterine glands). Most important sign is vaginal bleeding, which allows early detection. Risk factors include obesity and HRT.

- **Endometriosis**: An inflammatory condition in which endometrial tissue occurs and grows atypically in the pelvic cavity. Characterized by abnormal uterine or rectal bleeding, dysmenorrhea, and pelvic pain. May cause sterility.

- **Salpingitis**: Inflammation of the uterine tubes.

Related Clinical Terms

- **Hysterectomy**: Surgical removal of the uterus.
- **Laparoscopy**: Examination of the abdominopelvic cavity with a laparoscope, a viewing device at the end of a thin tube inserted through the anterior abdominal wall. Laparoscopy is often used to assess the condition of a woman's pelvic reproductive organs.
- **Oophorectomy**: Surgical removal of the ovary.

Related Clinical Terms
Ovarian cancer

- Malignancy that typically arises from the cells in the germinal epithelial covering of the ovary.
- The fifth most common reproductive system cancer.
- Its incidence increases with age.
- Early symptoms are nondescript and easily mistaken for other disorders (back pain, abdominal discomfort, nausea, bloating, and flatulence).

Related Clinical Terms
Ovarian cancer

- Diagnosis may involve palpating a mass during a physical exam, visualizing it with an ultrasound probe, or conducting blood tests for a protein marker for ovarian cancer.

- Medical assessment is often delayed until after metastasis has occurred

- Five-year survival rate is 90% if the condition is diagnosed before metastasis.

Related Clinical Terms
Ovarian cysts

- The most common disorders of the ovary; some are tumors.
- Types include
  1) Simple follicle retention cysts in which single or clustered follicles become enlarged with a clear fluid

  2) Dermoid cysts, which are filled with a thick yellow fluid and contain partially developed hair, teeth, bone, etc.

  3) Chocolate cysts filled with dark gelatinous material, which are the result of endometriosis of the ovary.

- None of these is malignant, but the latter two may become so.

Related Clinical Terms
Polycystic ovary syndrome (PCOS)

- The most common endocrinopathy in women and the most common cause of anovulatory infertility.

- Affects 5–10% of women

- Characterized by:
  - Signs of androgen excess
  - Increased cardiovascular risk (evidenced by high blood pressure, decreased HDL cholesterol levels, and high triglycerides)
  - linked to extreme obesity and some degree of insulin resistance.
  - Treated with insulin-sensitizing drugs (Metfomin).

Accomplishing Fertilization

1. An oocyte is fertilizable for up to 24 hours; most sperm are viable within the female reproductive tract for one to two days.
2. Sperm must survive the hostile environment of the vagina and become capacitated (capable of reaching and fertilizing the oocyte).
3. Hundreds of sperm must release their acrosomal enzymes to break down the egg's corona radiata and zona pellucida.
4. When one sperm binds to receptors on the egg, it triggers the slow block to polyspermy (release of cortical granules).
5. Following sperm penetration, the secondary oocyte completes meiosis II. Then the ovum and sperm pronuclei fuse (fertilization), forming a zygote.

Cleavage and Blastocyst Formation

- Early development consists of cleavage, a rapid series of mitotic divisions without intervening growth, that begins with the zygote and ends with a blastocyst.

- The blastocyst consists of the trophoblast and an inner cell mass. Cleavage produces a large number of cells with a favorable surface-to-volume ratio

Implantation

- The trophoblast adheres to, digests, and implants in the endometrium.
- Implantation is completed when the blastocyst is entirely surrounded by endometrial tissue, about 12 days after ovulation.
- hCG released by the blastocyst maintains hormone production by the corpus luteum, preventing menses.
- hCG levels decline after four months.

Placentation

- The placenta acts as the respiratory, nutritive, and excretory organ of the fetus and produces the hormones of pregnancy.
- It is formed from embryonic and maternal tissues.
- Typically, the placenta is functional as an endocrine organ by the third month.