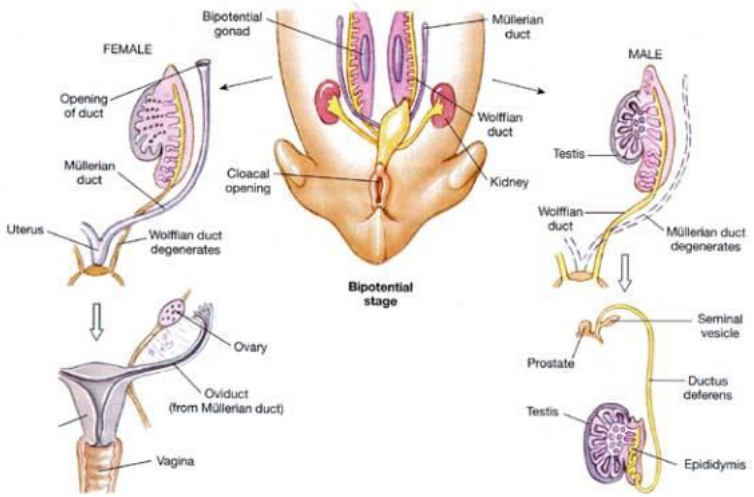
Mammalian Reproductive System

Lecture # 2

The Reproductive System

- Male and female reproductive systems develop from similar embryonic tissue.
- First few weeks of development, male and female embryos are indistinguishable.
- Adult reproductive systems share some functional similarities.



Basics of Reproduction in Mammals

- Male and Female (well developed Reproductive systems).
- Male and female reproductive systems develop from similar embryonic tissue.
- All reproductive activities start after (puberty): Age at which reproductive organs become functional
-

Age of Puberty	
Cattle:	6 to 12 Months
Sheep:	5 to 7 Months
Swine:	4 to 8 Months
Horses:	12 to 15 Months
Humans:	9 to 16 **YEARS**

Fertility: Male VS Female

- Male: all over his life span , Female: stop at menopause age!
- In Female: At birth, the normal female ovary contains about 1-2 million/oocytes (eggs). **Females are not capable of making new eggs**, and in fact, there is a continuous decline in the total number of eggs each month. By the time a girl enters puberty, only about 25% of her lifetime total egg pool remains, around 300,000. (No new oocyte cells are made during a woman's lifetime and sease the production of oocytes at the Menopause age!).
- In Male: The production of sperm is a continuous process once it has been initiated.

- Female- Reproduction process occurs within Cycles:
  - Menstrual or Estrous cycle- Repetitive cycle occurring when pregnancy does not occur.
- Gonads:
  - Within the abdominal cavity (in female)
  - Outside the abdominal cavity (in male)

- Gonads – primary sex organs
  - Testes in males
  - Ovaries in females
- Gonads produce gametes (sex cells) and secrete hormones
  - Sperm – male gametes
  - Ova (eggs) – female gametes

The Male Reproductive System

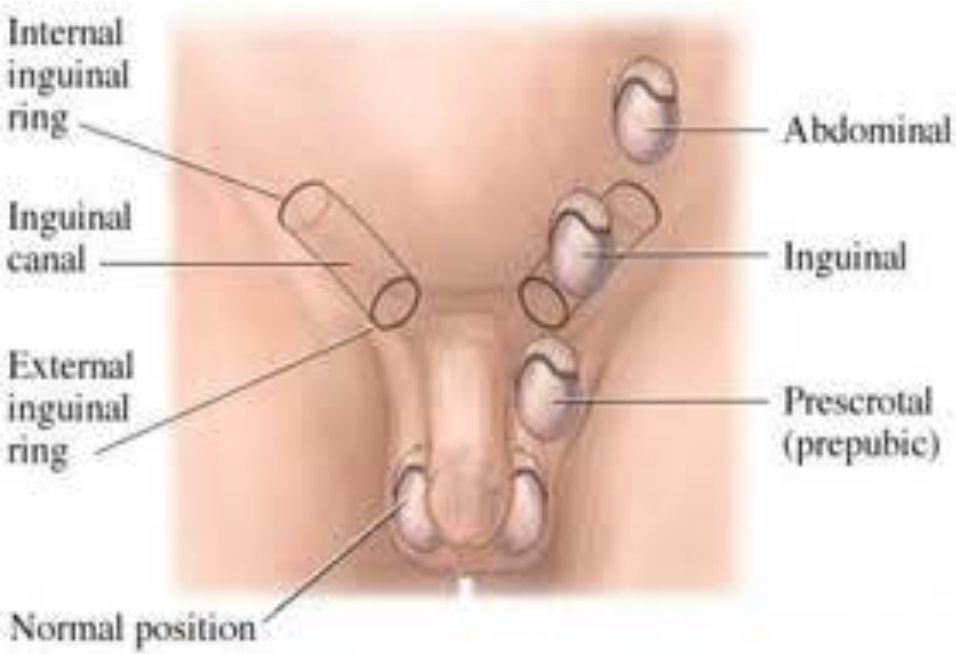
(Human)

Male reproductive system

- Gonads – testes
  - Produces sperm and secretes hormones
- System of ducts – transport and stores sperm, assists in their maturation, and conveys them to the exterior
  - Epididymis, ductus deferens, ejaculatory ducts, and urethra
- Accessory sex glands – adds secretions to semen
  - Seminal vesicles, prostate, and bulbourethral glands
- Supporting structures
  - Scrotum supports testes and penis delivers sperm into female reproductive tract

Descent of the Testes

- Ovoid structures about 5 cm long and 3 cm wide.
- Located within the scrotal sac (scrotum)
- During fetal development they are near the kidneys and slowly move inferiorly in the abdominal cavity.
- During the 7th month they descend through the inguinal canals

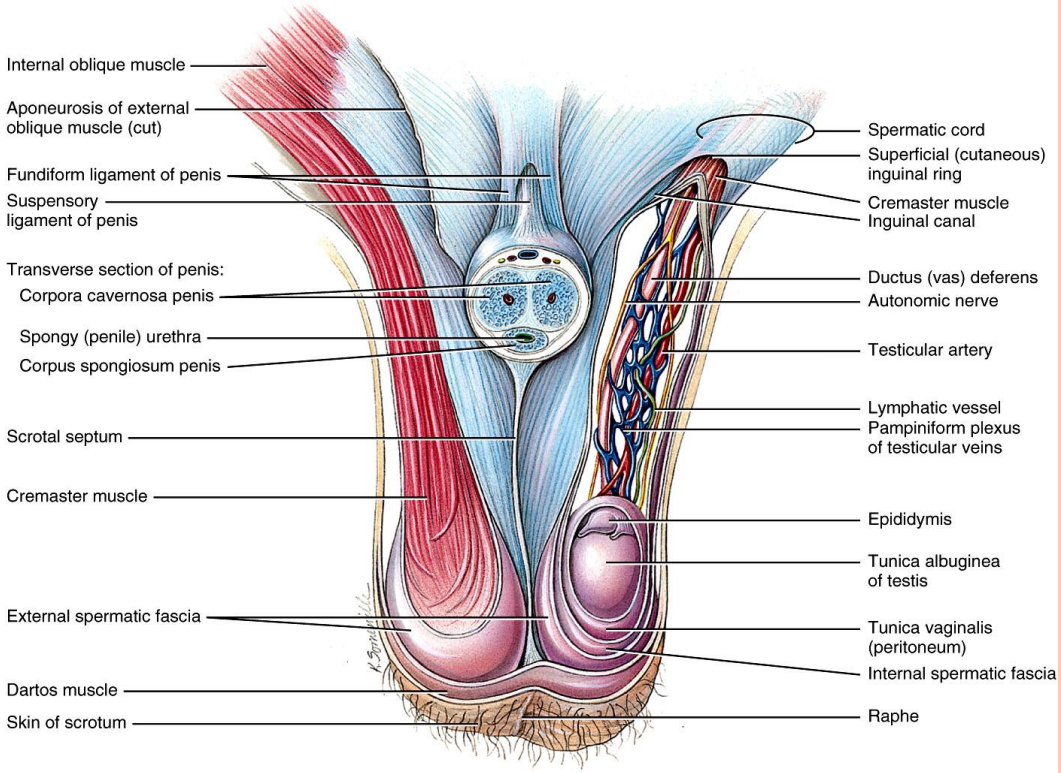


Cryptorchidism

- Failure of one or both testes to descend into the scrotum
  - Unilateral: one testis does not descend
    - testis that descends is fertile; reduced sperm concentrations
  - Bilateral- neither testes descend into scrotum
    - Results in sterility due to elevated temperature of both testes

Scrotum

- Sac of skin and superficial fascia that hangs outside the abdominopelvic cavity at the root of the penis
- Contains paired testicles separated by a midline septum
- Its external positioning keeps the testes 3°C lower than core body temperature

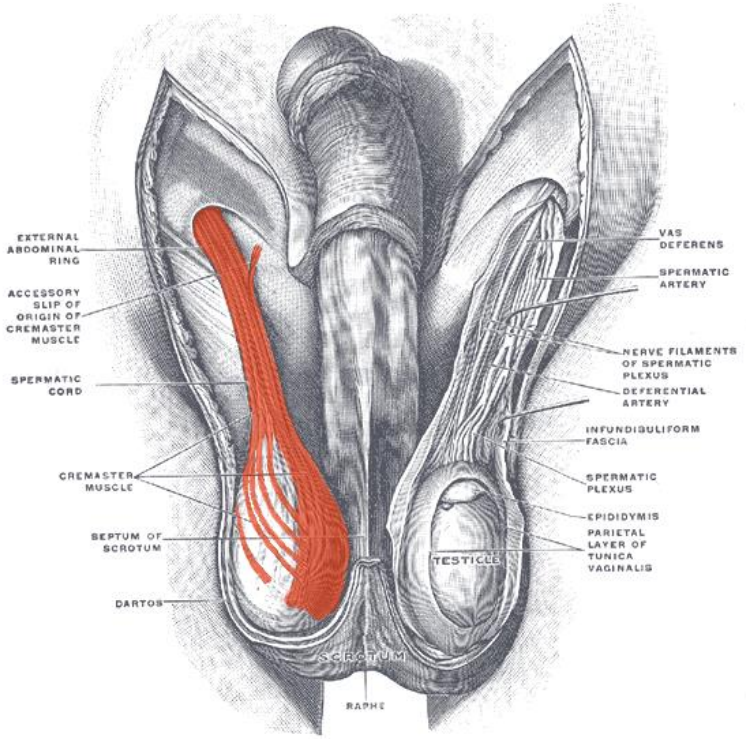


Anterior view of scrotum and testes and transverse section of penis

Figure 28.02 Tortora - PAP 12/e

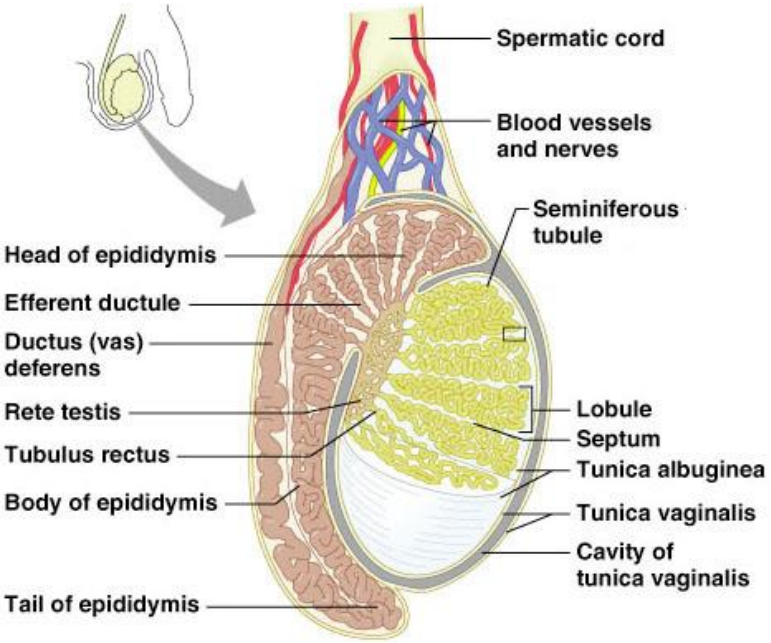
Wall of the Scrotum

- In the dermis, there is a thin layer of smooth muscle known as the **dartos muscle**. Contractions of this muscle causes wrinkling of the skin.
- The **cremaster muscle** is a thicker layer of skeletal muscle that lowers and raises the testes based on temperature.

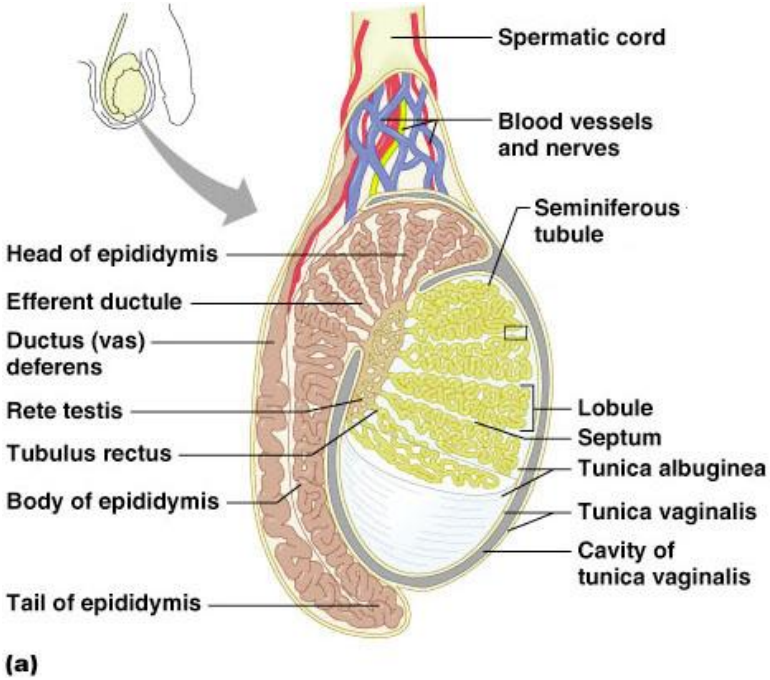


Inside the Scrotum

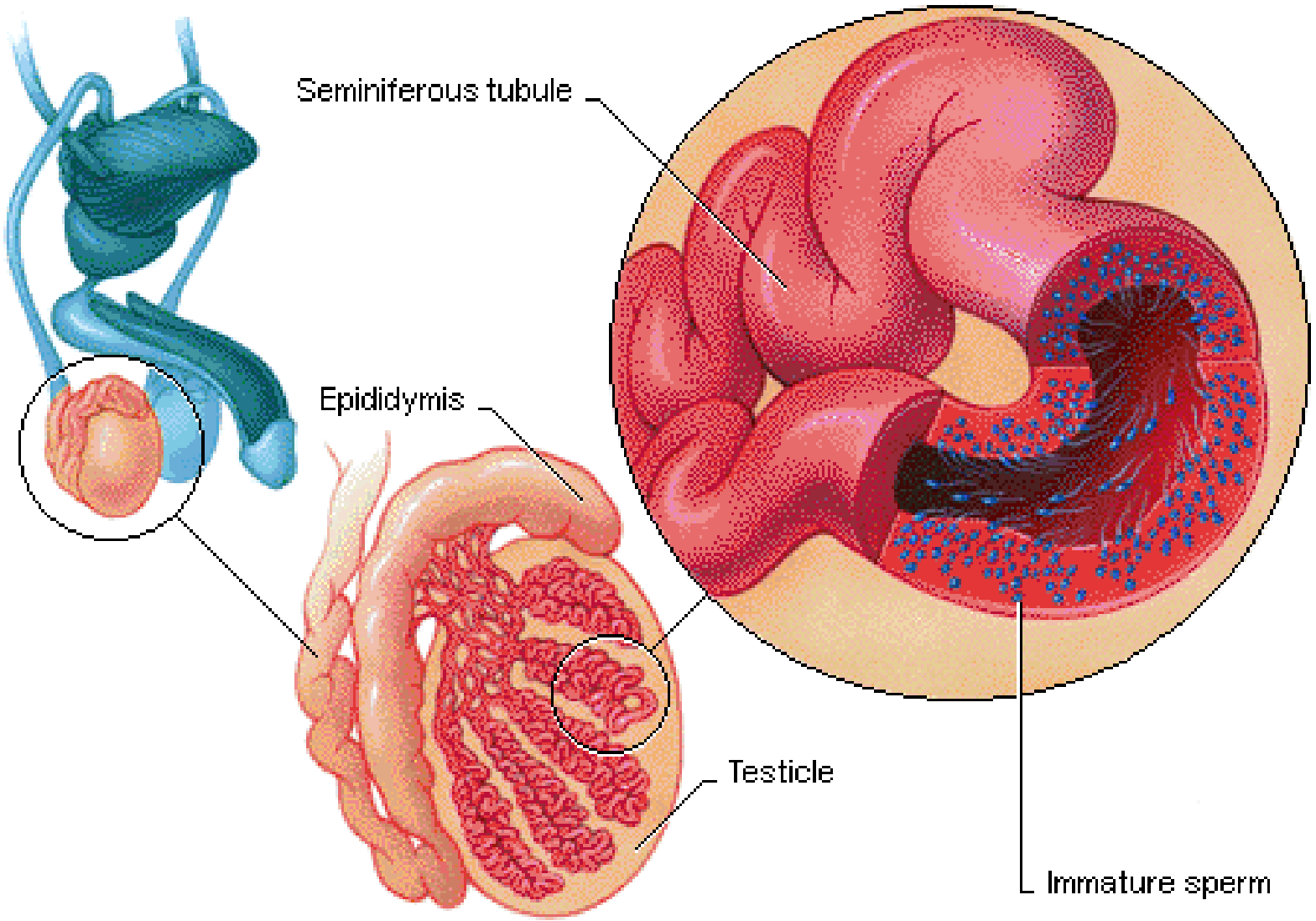
- Each testes is enclosed by the **tunica vaginalis**, a continuation of the peritoneum that lines the abdominopelvic cavity.
- A fibrous capsule covers each testis called the **tunica albuginea.**



Testicle



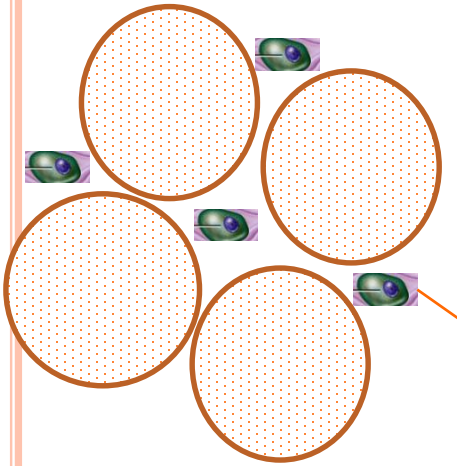
- The tunica albuginea gives rise to septa (partitions) that divide the testis into lobules (about 250)
- Each lobule contains 3 or 4 highly coiled **seminiferous tubules**
- These converge to become **rete testis** which transport sperm to the **epididymis**

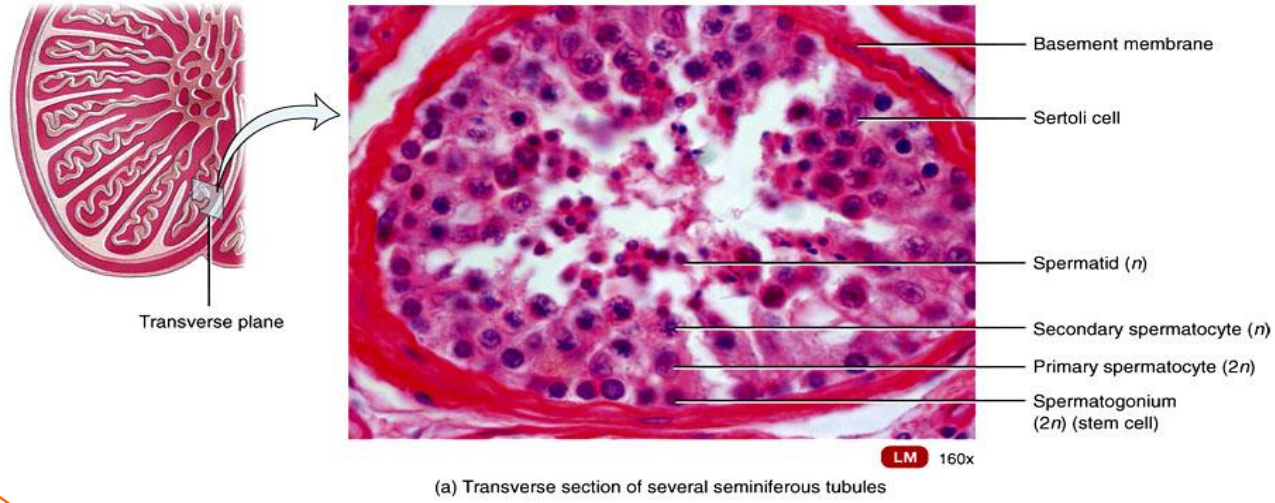

Seminiferous tubule
Epididymis
Testicle
Immature sperm

Seminferous tubule cells

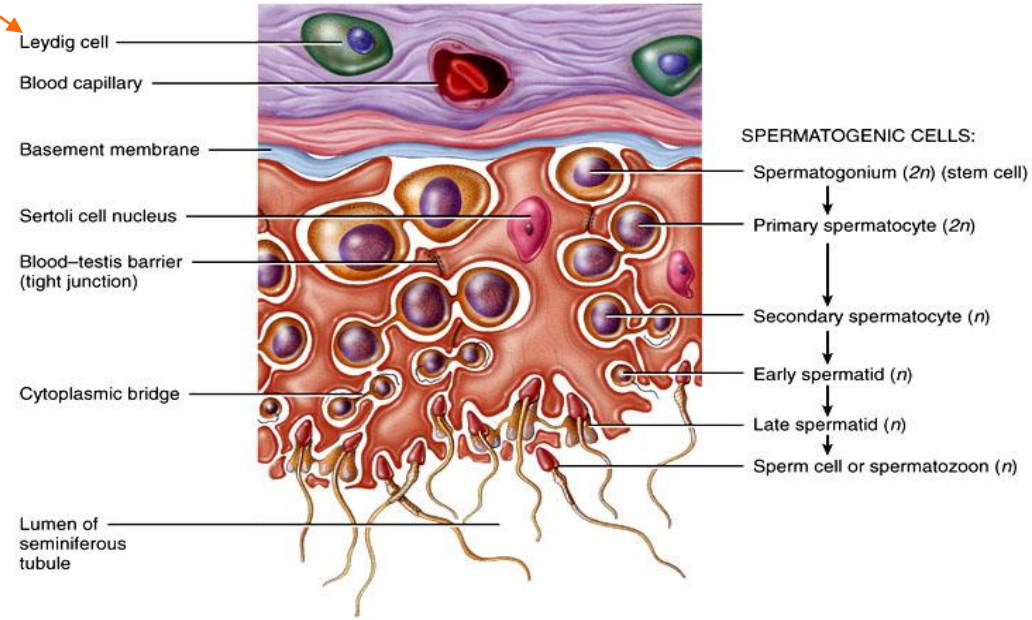
- Spermatogenic cells – sperm-forming cells
  - Spermatagonia (stem cell) develop from primordial germ cells that arise in yolk sac and enter testes in 5th week of development
  - Primary spermatocytes → secondary spermatocytes → spermatids → sperm cells → lumen
- Sertoli cells or sustenacular cells– support cells
  - Tight junction form blood-testis barrier – prevents immune response against sperm cell surface antigens
  - Nourish spermatocytes, spermatids and sperm, phagocytize excess spermatid cytoplasm, control movements of spermatogenic cells, release sperm into lumen, produce fluid for sperm transport, secrete inhibin, regulate effects of testosterone and follicle-stimulating hormone (FSH)
- Leydig (interstitial) cells found in spaces between seminiferous tubules
  - **Secrete testosterone**

Seminiferous tubules and stages of sperm production





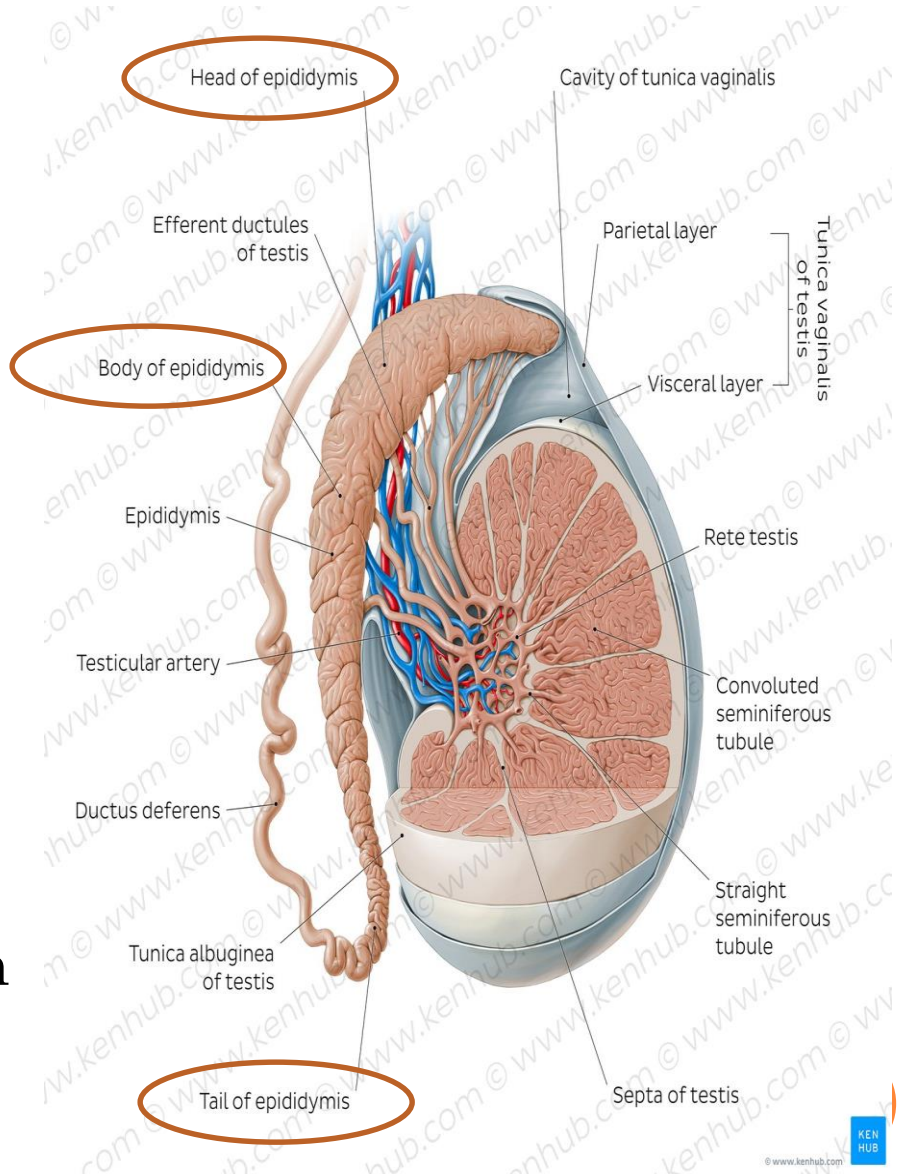
(a) Transverse section of several seminiferous tubules



Lecture 3

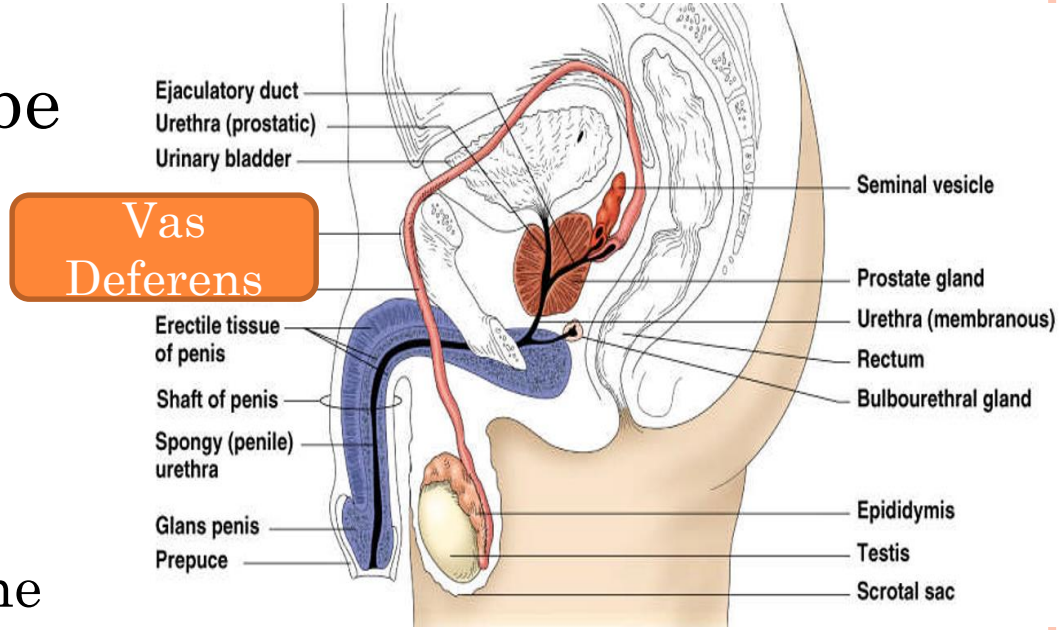
Epididymis

- Epididymis: long coiled tube (6-7 meters) that is a path for sperm
  - Sperm entering the caput epididymis are incomplete—they lack the ability to swim forward (motility) and to fertilize an egg.
  - Functions to mature and store sperm cells (at least 20 days)
    - Fluid secretion to nourish sperm
    - Becomes motile and fertile



Vas Deferens

- Vas Deferens – muscular slender tube from epididymis to urethra (45 cm)
  - Moves sperm to the urethra at ejaculation
  - **Vasectomy** – cutting of the ductus deferens at the level of the testes to prevent transportation of sperm. (for male sterilization or permanent contraception)

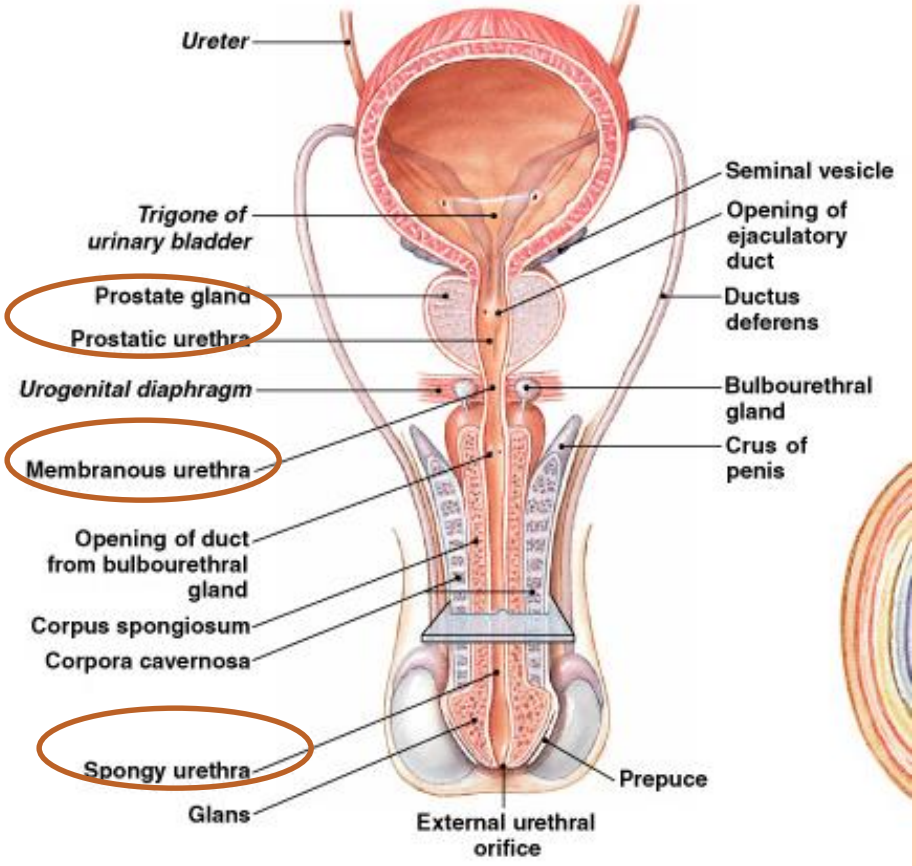


URETHRA

Urethra - long tube from bladder to penis

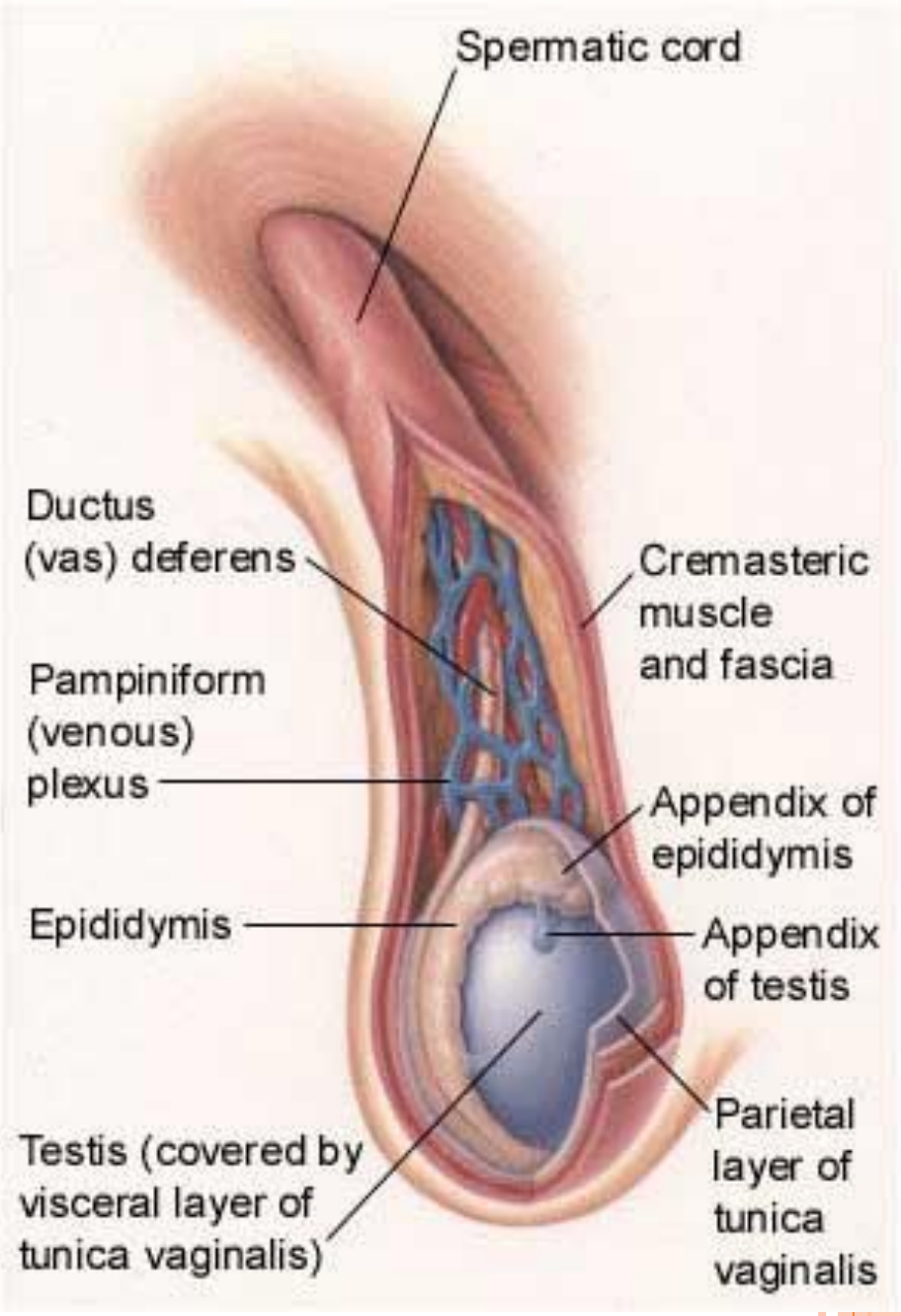
(Passageway for urine and sperm out of the body)

- Regions of the urethra
  - Prostatic urethra –surrounded by prostate
  - Membranous urethra – from prostatic urethra to penis
  - Spongy (penile) urethra – runs the length of the penis



Spermatic Cord

- Contains the structures running from the testicles to the pelvic cavity.
  - Passes through the inguinal canal
- Contents:
  - Vas Deferens
  - Nerves
  - Blood Vessels

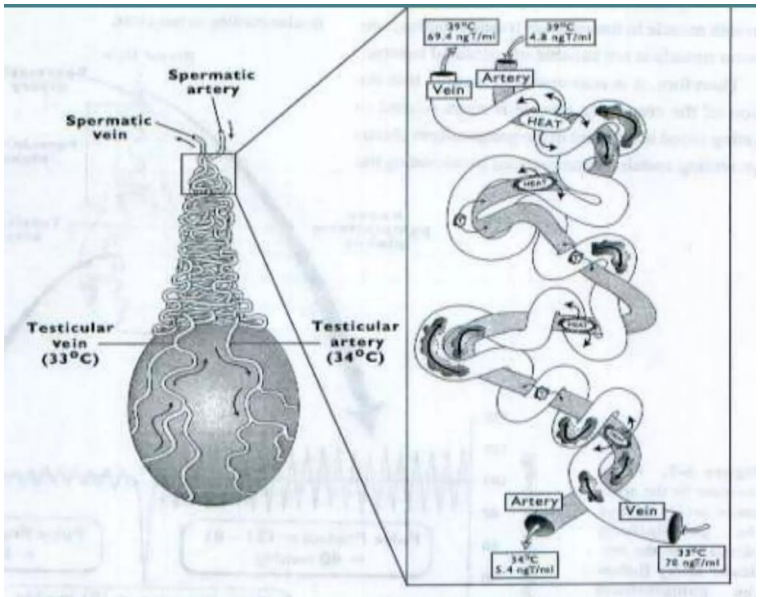


COUNTER-CURRENT HEAT-EXCHANGE SYSTEM

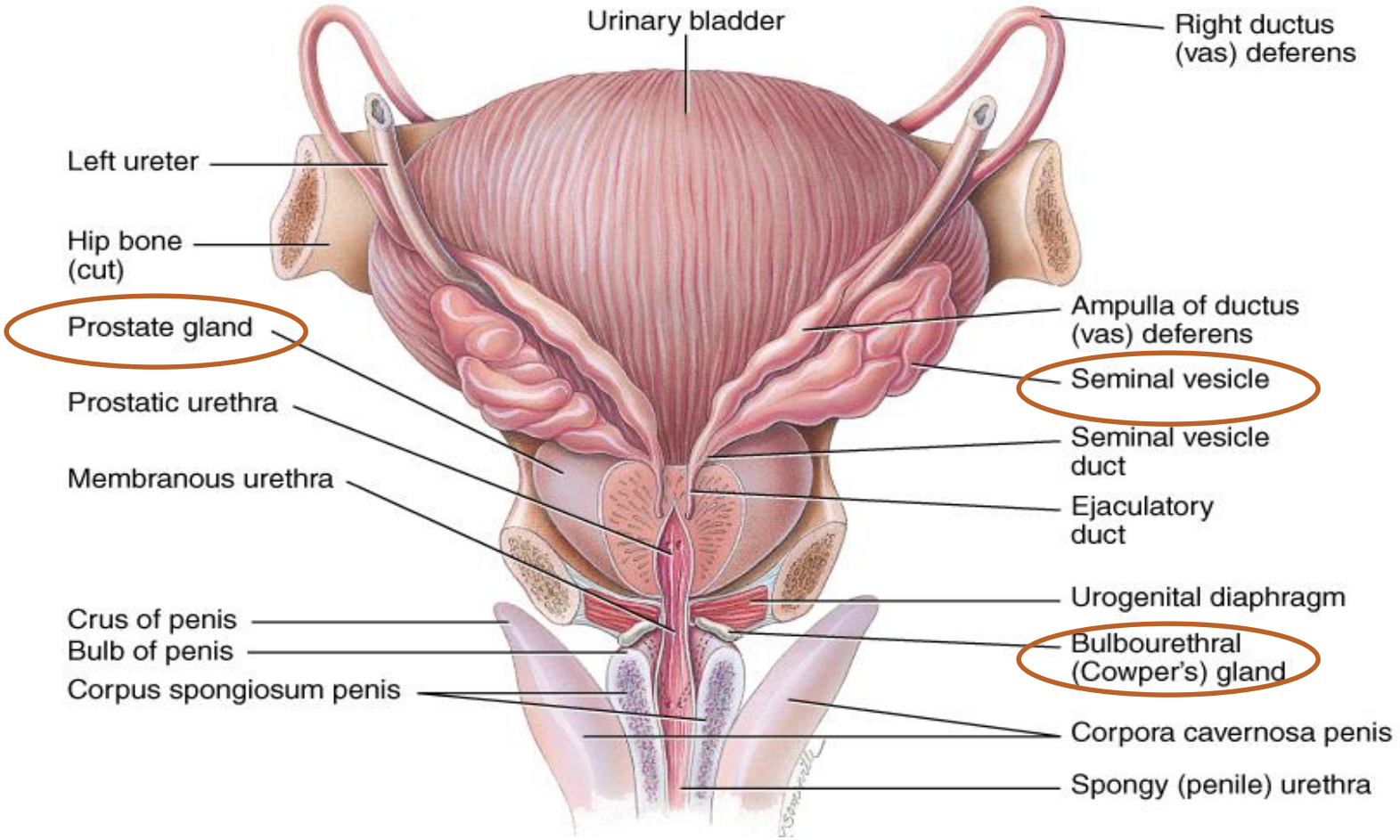
Counter - current system

- The pampiniform plexus is a vascular structure consisting of an intimately tangled artery and vein and this structure is important for proper temperature control of the testis and it is wrapped around the spermatic cord
- Testicular artery that takes blood to the testes from abdominal aorta descents from the pampiniform plexus of veins the return blood from testes.
- Heat exchange b/w the artery and the veins via this arrangement also help in scrotal temperature

- Because of the counter current the testes receives cooler blood compared to other part of the body
- Blood returning from the testis has lost heat to the environment and this it is cooler than artery blood.
- When the artery blood enters the pampiniform tissue it loses its heat to the cooler blood and cooled blood travel around the testis and veins
- This mechanism is effective only it loses its heat by the radiation, convection and evaporation to the environment



Accessory Glands:



Accessory Glands:

1- Seminal Vesicles

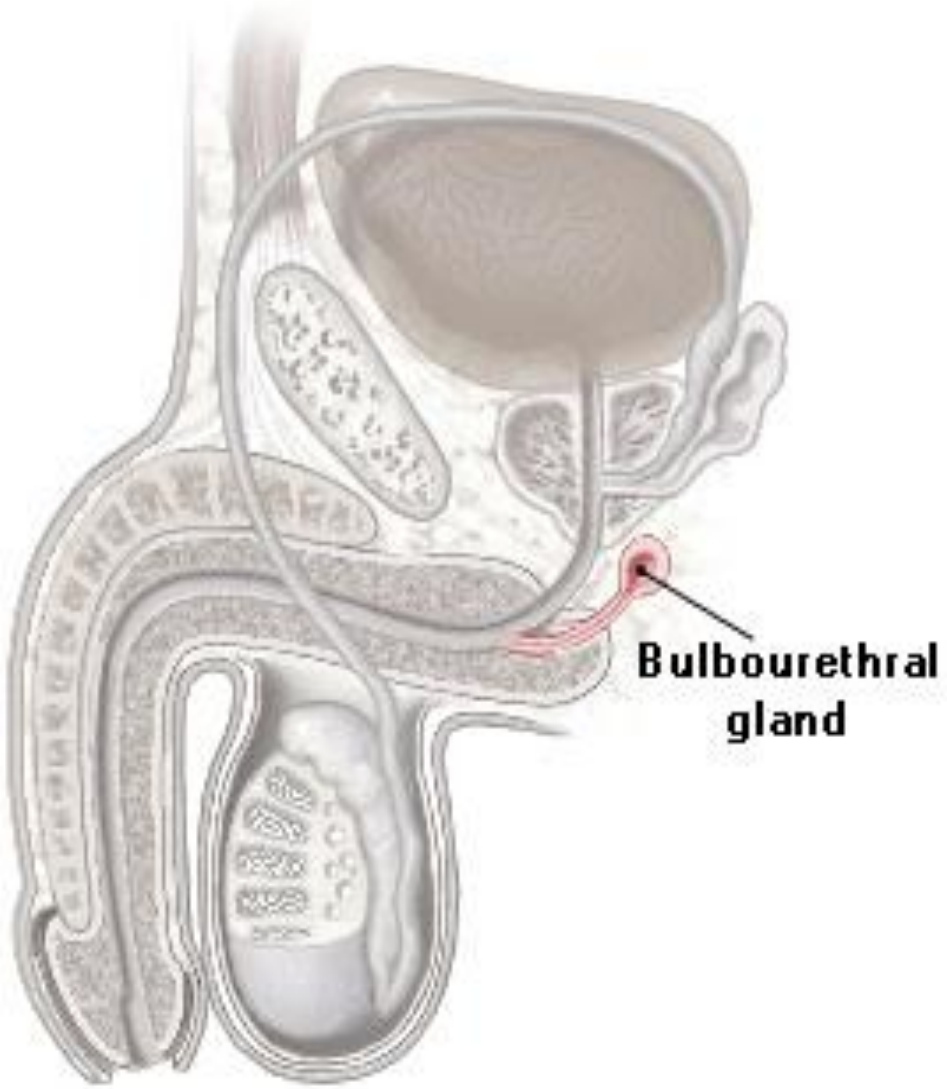
- Lie on the posterior wall of the bladder and **secrete 60% of the volume of semen**
  - Seminal fluid:
    - Fructose: provides energy for the sperm.
    - Fibrinogen: helps turn semen into a bolus that can be readily propelled into the vagina.
    - Prostaglandins: decrease cervical mucus viscosity and stimulate reverse peristalsis of the uterus.
- Join the ductus deferens to form the ejaculatory duct

2- Prostate Gland

- Gland that encircles part of the urethra inferior to the bladder
- About 25% of semen volume (Secretes a milky fluid)
- Plays a role in the activation of sperm
- Enters the prostatic urethra during ejaculation
- Prostatic secretions include:
  - Citrate: is a food source (TCA cycle)
  - Proteolytic enzymes: acts to "decoagulate" the semen that was coagulated by seminal vesicle secretions, which helps the sperm begin their journey once inside the vagina

3- Bulbourethral Glands (Cowper's Glands)

- Pea-sized glands inferior to the prostate
- Produce alkaline mucus prior to ejaculation that neutralizes traces of acidic urine in the urethra



Accessory Glands:

Seminal Fluid Components, Function and Location

Mucus	Lubricant	Bulbourethral glands
Water	Provides liquid medium	All accessory glands
Buffers	Neutralize acidic environment of the vagina	Prostate, bulbo-urethral glands
Nutrients	Nourish sperm	
Fructose		Seminal vesicles
Citric acid		Prostate
Vitamin C		Seminal vesicles
Carnitine		Epididymis
Enzymes	Clot semen in vagina, then liquefy the clot	Seminal vesicles and prostate
Zinc	Unknown; possible association with fertility	Unknown
Prostaglandins	Smooth muscle contraction; may aid sperm transport	Seminal vesicles

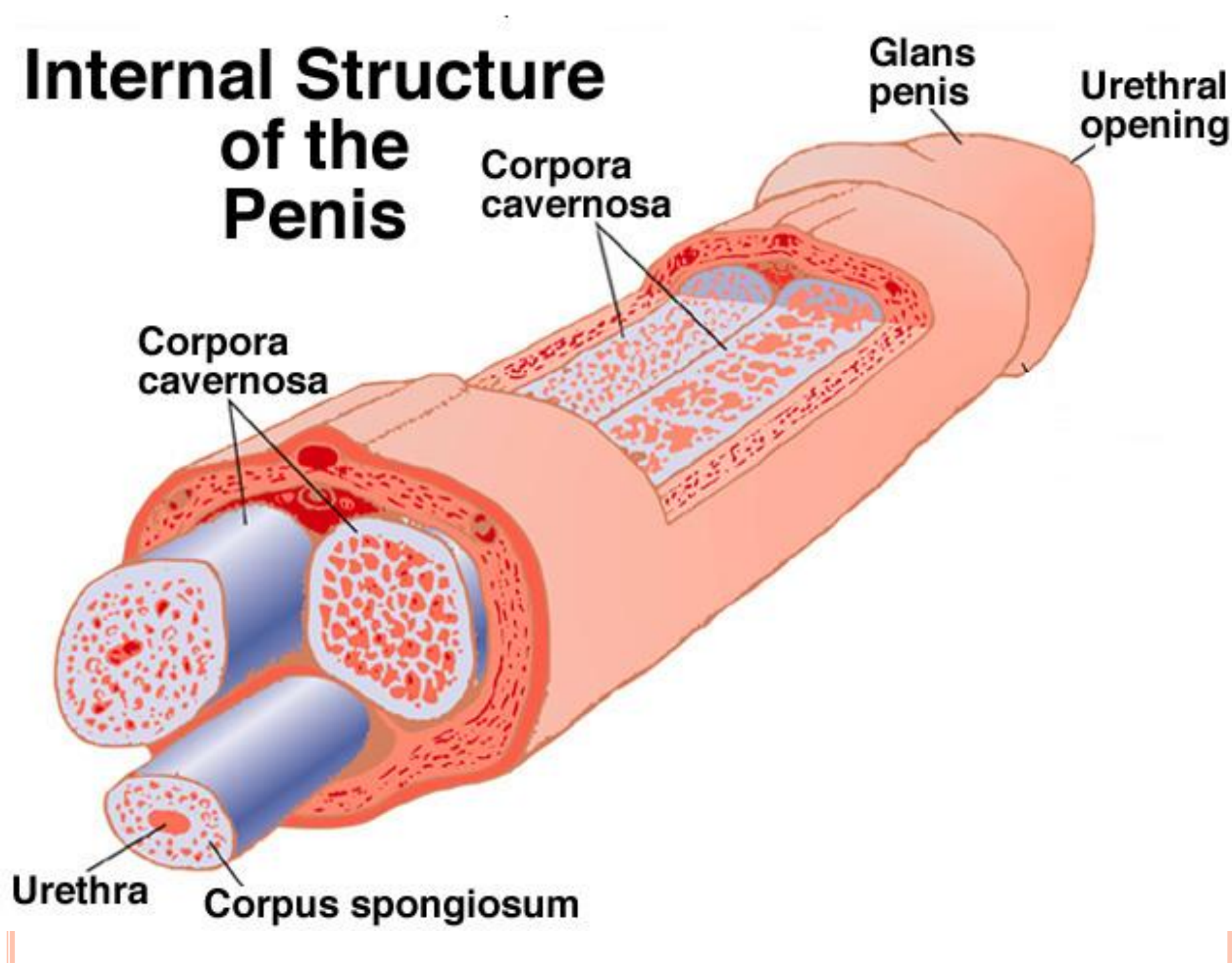
The Penis

- Nerves, blood vessels, fibrous tissue, and three parallel cylinders of spongy tissue.
- There is no bone and little muscular tissue (although there are muscles at the base of the penis)
- Terms:
  - Root, shaft, glans, cavernous bodies, spongy body, foreskin (defined on next slide)

The Penis

- **Penis**: consists of internal root, external shaft, & glans.
- **Root**: the portion of the penis that extends internally into the pelvic cavity.
- **Shaft**: the length of the penis between the glans and the body.
- **Glans**: the head of the penis; has many nerve endings.
- **Cavernous bodies**: the structures in the shaft of the penis that engorge with blood during sexual arousal.
- **Spongy body**: a cylinder that forms a bulb at the base of the penis, extends up into the penile shaft, and forms the penile glans. Also engorge with blood during arousal.
- **Foreskin**: a covering of skin over the penile glans (Circumcision).

Internal Structure of the Penis



Internal structure of the penis: top view

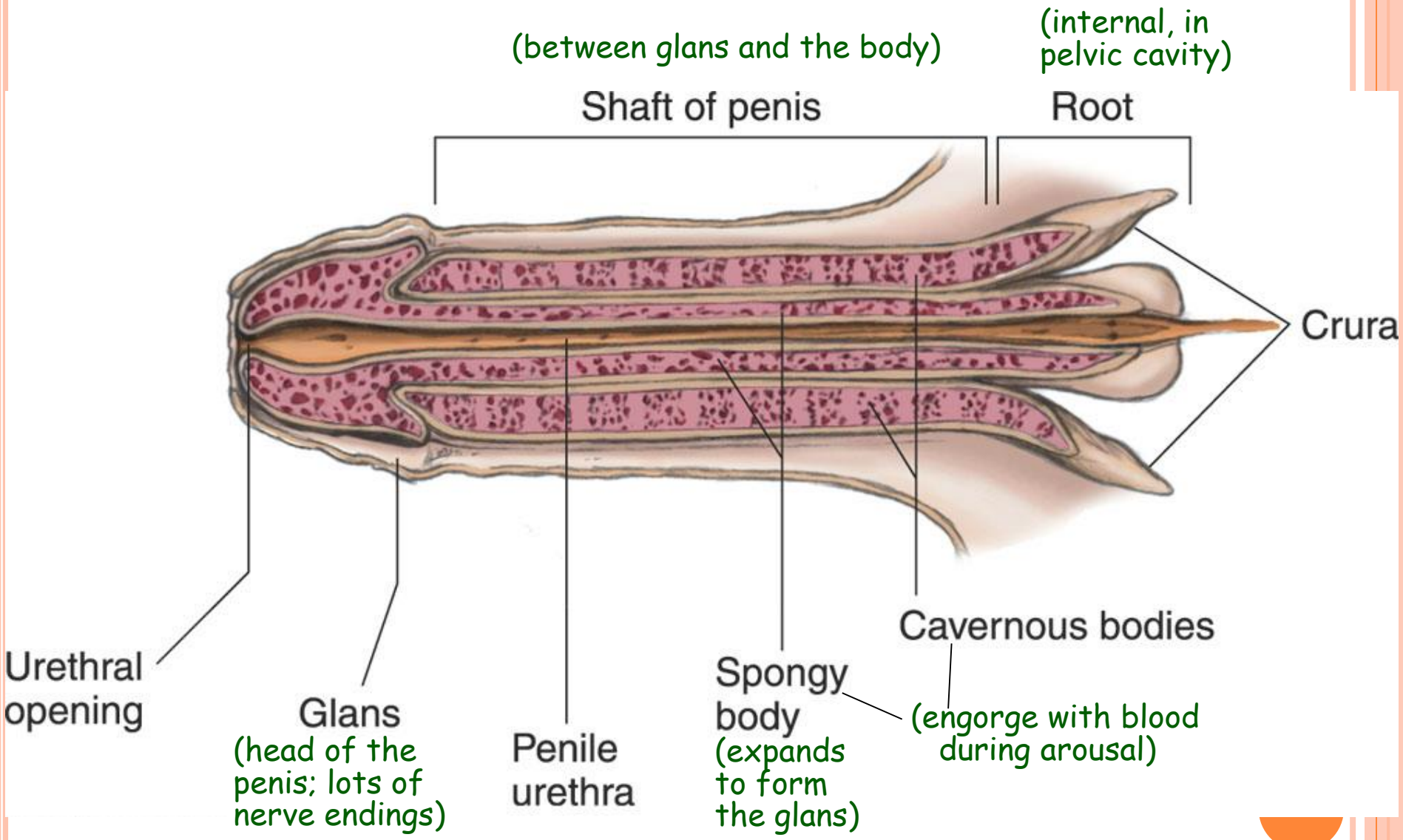


Fig 5.1a Interior structure of the penis: (a) view from above.

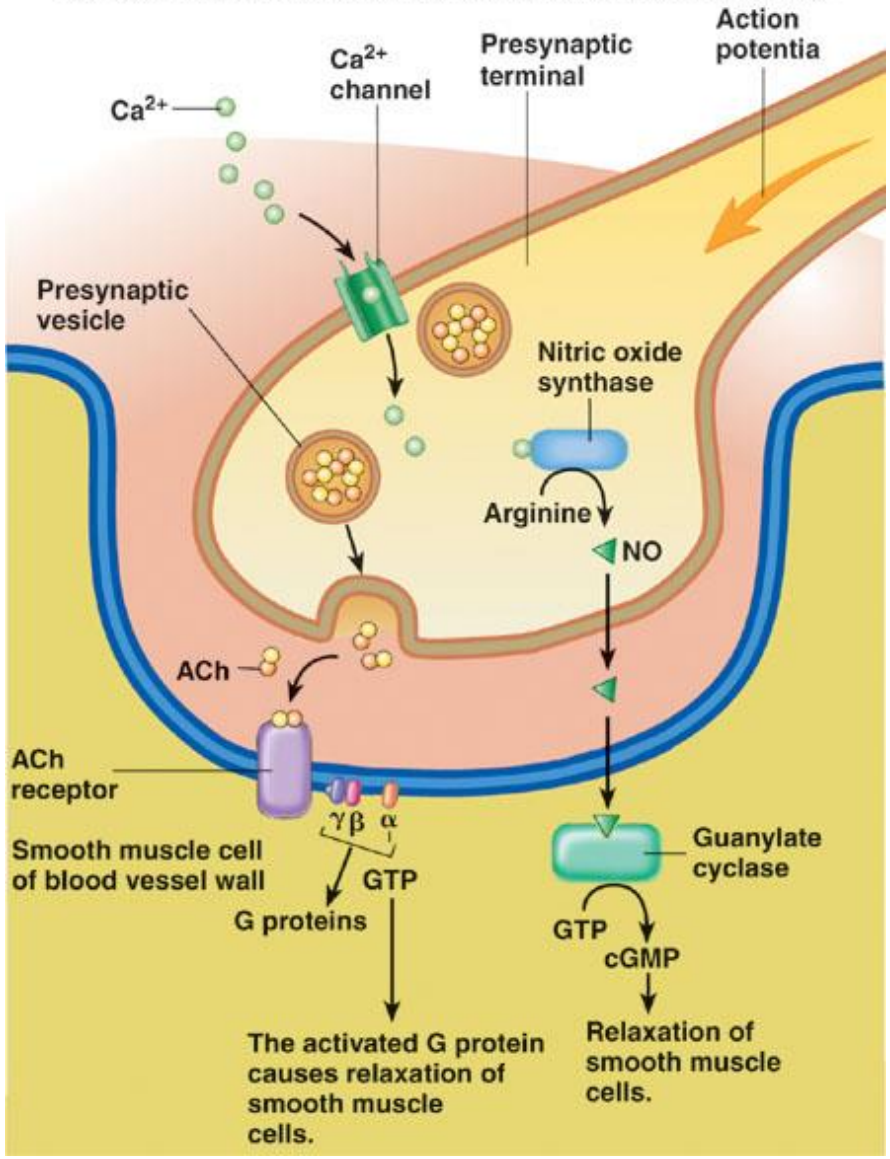
Male sexual function: Erection

- Brain sends message that causes relaxation of the arteries that supply blood to the cavernous and spongy bodies in the penis.
- Veins that drain blood away from cavernous and spongy bodies can't keep up with blood inflow, producing an erection.
- Erection is maintained by pressure of spongy and cavernous bodies against the skin, partially closing off the veins.
- Involves both psychological and physiological factors

Mechanism Of Erection:

- An **erection** is a physiological phenomenon in which the penis becomes firmer, engorged and enlarged.
- erection is triggered by
  - the parasympathetic division of the autonomic nervous system (ANS),
  - causing nitric oxide (a vasodilator) levels to rise in the trabecular arteries and smooth muscle of the penis.
  - The arteries dilate causing the penis to fill with blood; simultaneously the ischiocavernosus and bulbospongiosus muscles compress the veins of the corpora cavernosa
  - restricting the egress and circulation of this blood. Erection subsides when parasympathetic activity reduces to baseline.

Neural Control of Erection



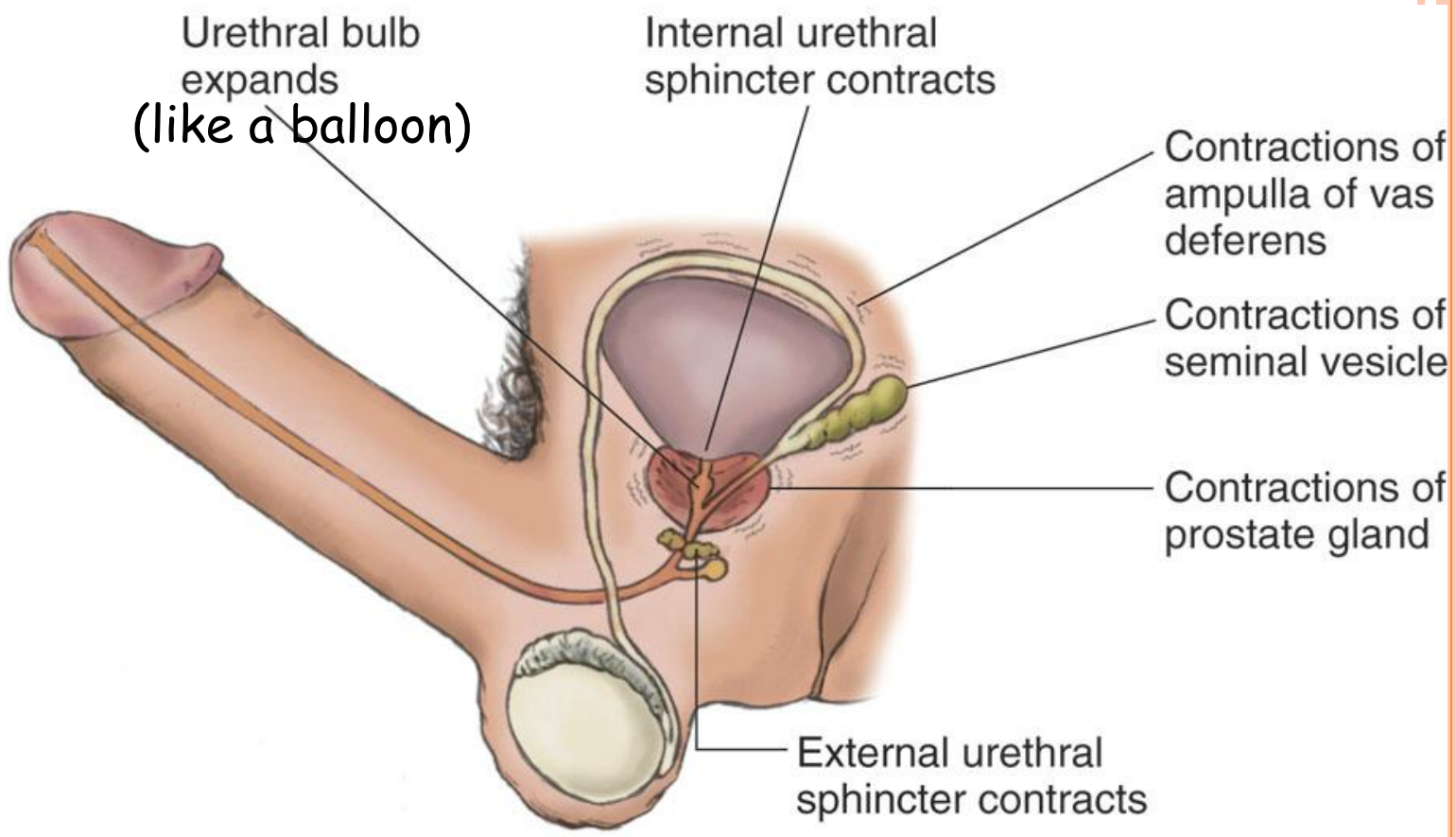
Ejaculation

- **Ejaculation**: the process by which semen is expelled through the penis outside the body.
- Ejaculation is a separate process from orgasm, and the two may not always occur simultaneously.
  - It is possible for men to experience multiple orgasms w/o ejaculation.
- 2 phases (see next slides for details):

1) Emission phase: semen collects in the urethral bulb
   - This stage is usually sensed by the man as the "point of no return"
2) Expulsion phase: semen is expelled

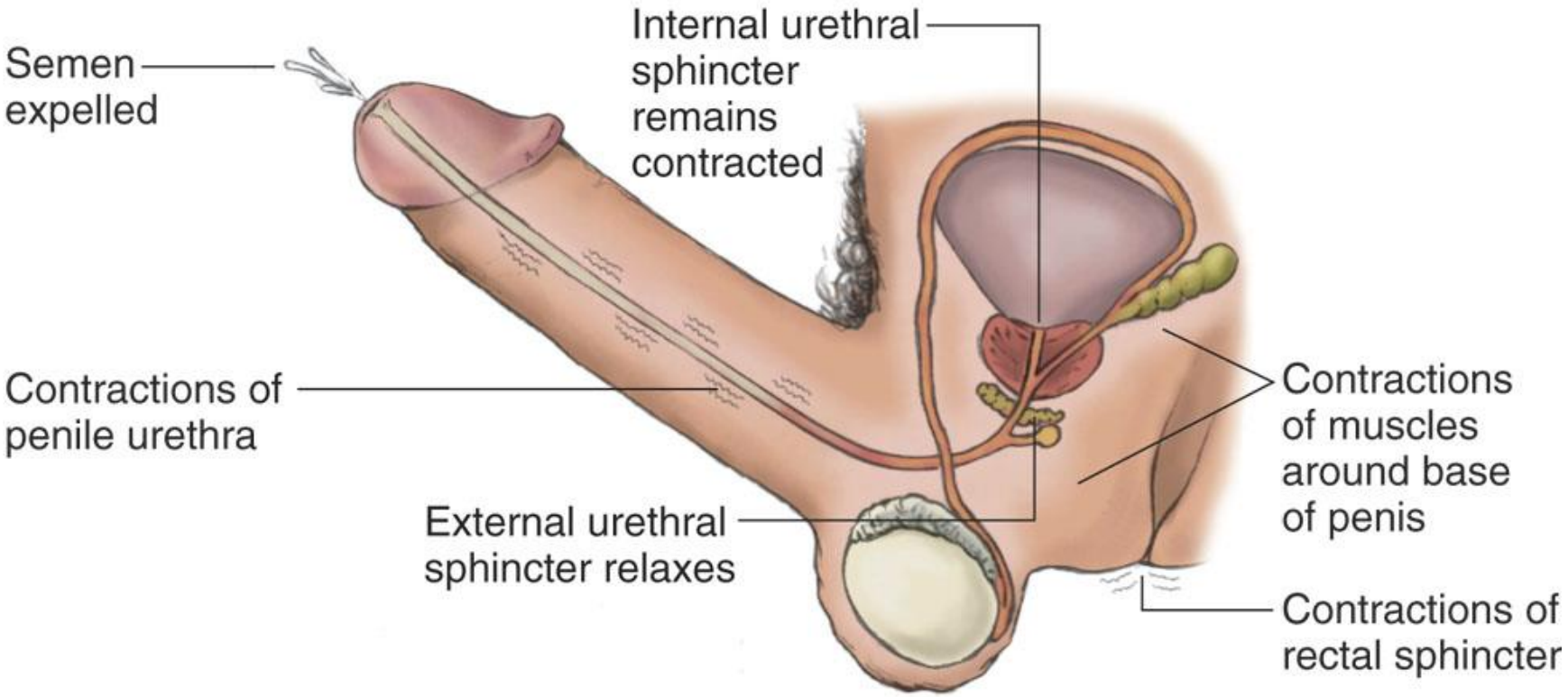
Emission phase of ejaculation (phase 1)

- Contractions in the prostate, seminal vesicles, and vas deferens force secretions into urethral bulb.
- Both the internal and external urethral sphincters close, trapping semen in the urethral bulb



Expulsion phase of ejaculation (phase 2)

- Collected semen is expelled out of the body by rhythmic contractions of muscles surrounding the urethral bulb and also on the urethra.
- External urethral sphincter relaxes to allow semen out; internal urethral sphincter stays contracted to prevent the escape of urine.



Lecture 4

Spermatogenesis

- Spermatogenic stem cells (spermatogonium) of the seminiferous tubules give rise to sperm in a series of events:
  - Mitosis of spermatogonia, forming spermatocytes
  - Meiosis forms spermatids from spermatocytes
  - Spermiogenesis: spermatids form sperm
- Spermatogenesis produces four haploid sperm cells.
- Spermatogenesis begins at puberty, when testosterone levels rise. Testosterone is critical to spermatogenesis.

Fate of the spermatogonial stem cells

Type A spermatogonia

Renewal

Differentiation

Apoptosis

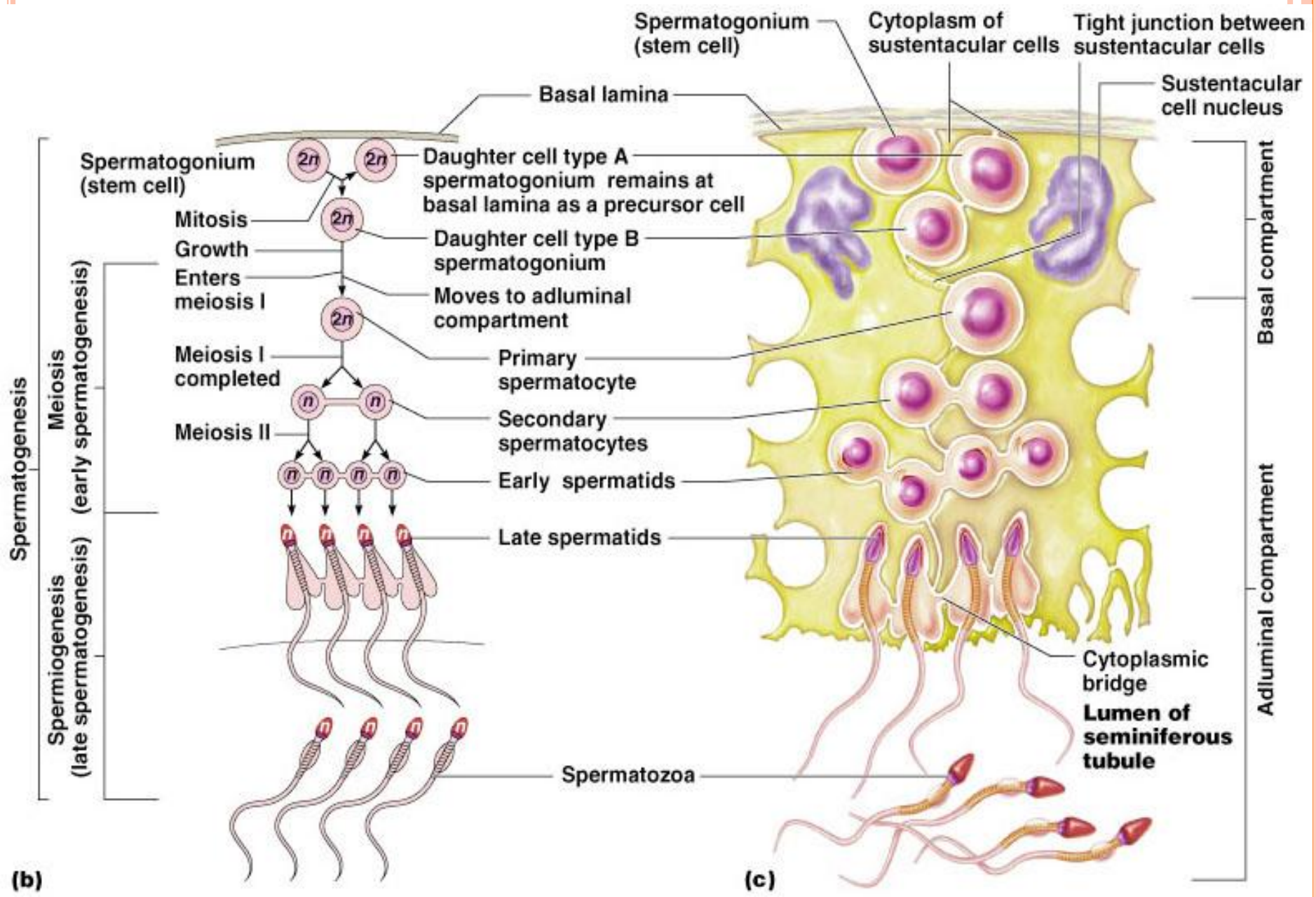
Type A spermatogonia

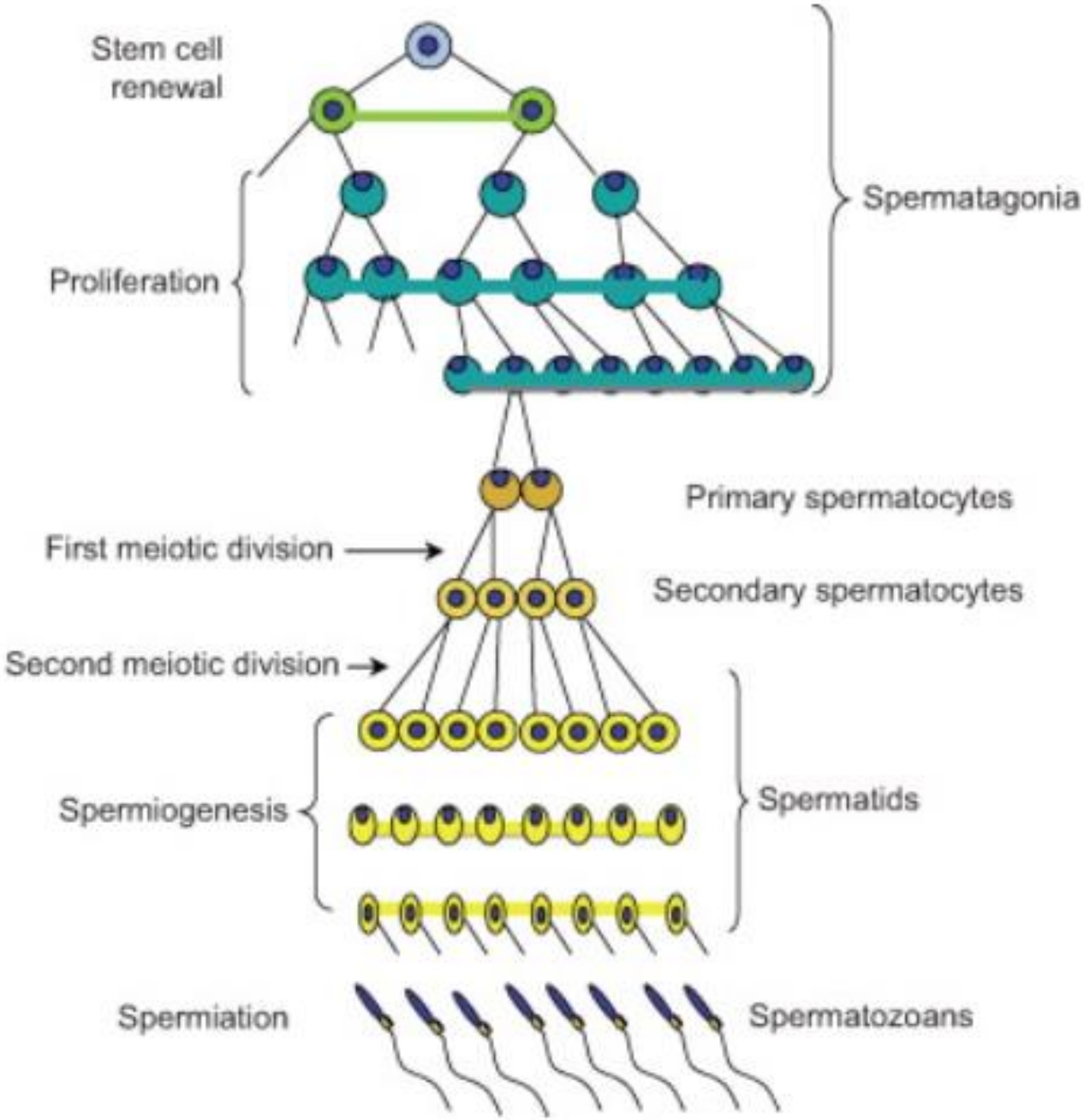
Type B spermatogonia

Cell death

SPERMATOGENESIS

- Spermatogonia (containing 46 chromosomes) undergo DNA replication and produce primary spermatocytes (with 46 pairs of chromosomes) .[some spermatozoid undergo mitosis to maintain a large population , so that spermatogenesis can be continuous for many decades].
- Primary spermatocytes undergo "crossing - over" to shuffle their genes ,and undergo meiosis I which results in secondary spermatocytes (each containing 46 unique chromosomes) .
- Secondary spermatocytes undergo meiosis II which produces spermatids (with 23 unique chromosomes) .
- Spermatids now transform themselves into spermatozoa (also containing 23 unique chromosomes) in a final event called spermatogenesis .


Spermatogonium (stem cell)
Basal lamina
Spermatogonium (stem cell)
Daughter cell type A spermatogonium remains at basal lamina as a precursor cell
Mitosis
Daughter cell type B spermatogonium
Growth
Enters meiosis I
Moves to adluminal compartment
Meiosis I completed
Primary spermatocyte
Secondary spermatocytes
Meiosis II
Early spermatids
Late spermatids
Spermatozoa
Spermatogenesis
Meiosis (early spermatogenesis)
Spermiogenesis (late spermatogenesis)
(b)
Cytoplasm of sustentacular cells
Tight junction between sustentacular cells
Sustentacular cell nucleus
Basal compartment
Adluminal compartment
Cytoplasmic bridge
Lumen of seminiferous tubule
(c)


Stem cell renewal
Proliferation
Spermatagonia
Primary spermatocytes
First meiotic division
Secondary spermatocytes
Second meiotic division
Spermiogenesis
Spermatids
Spermiation
Spermatozoans

Spermatogenesis:

- Golgi phase: Development of the acrosome vesicle

- Capphase (acrosomal phase): Formation of the acrosomal cap together with the start of nuclear condensation and development of the flagellum

- Acrosome phase: Differentiation of the acrosome, and elongation of the nucleus and cell body

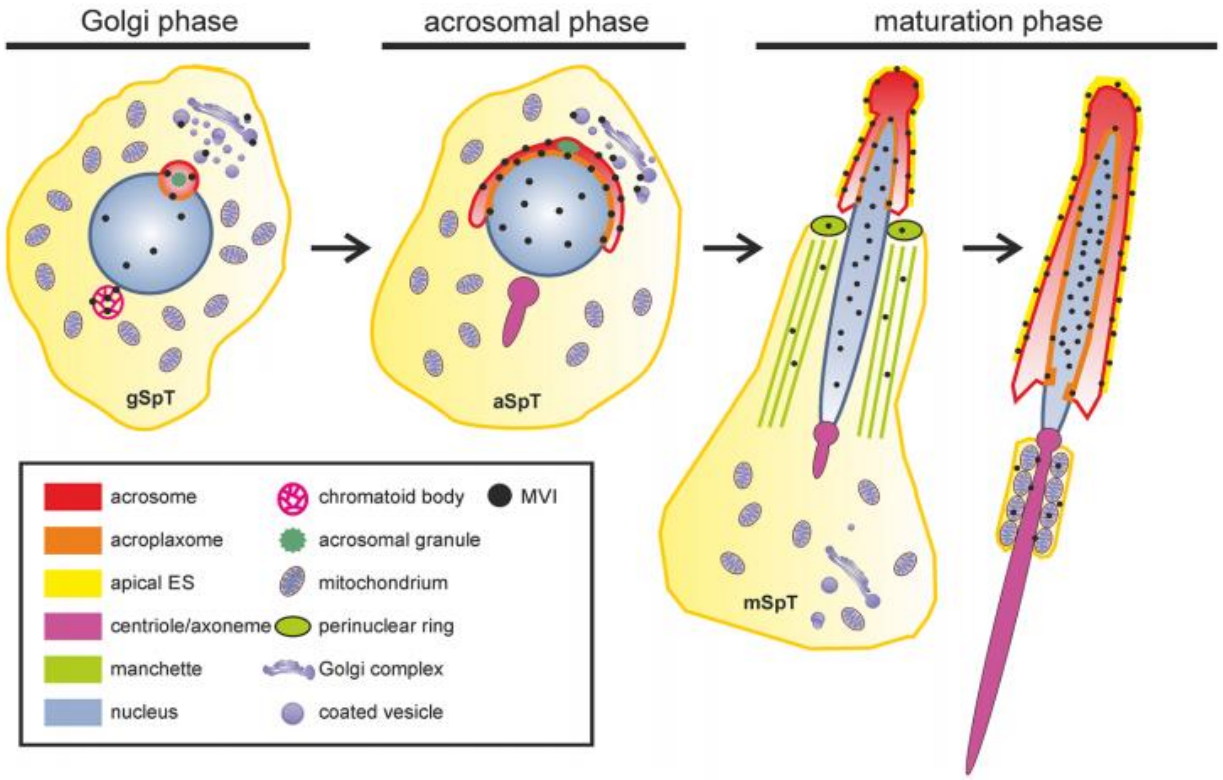
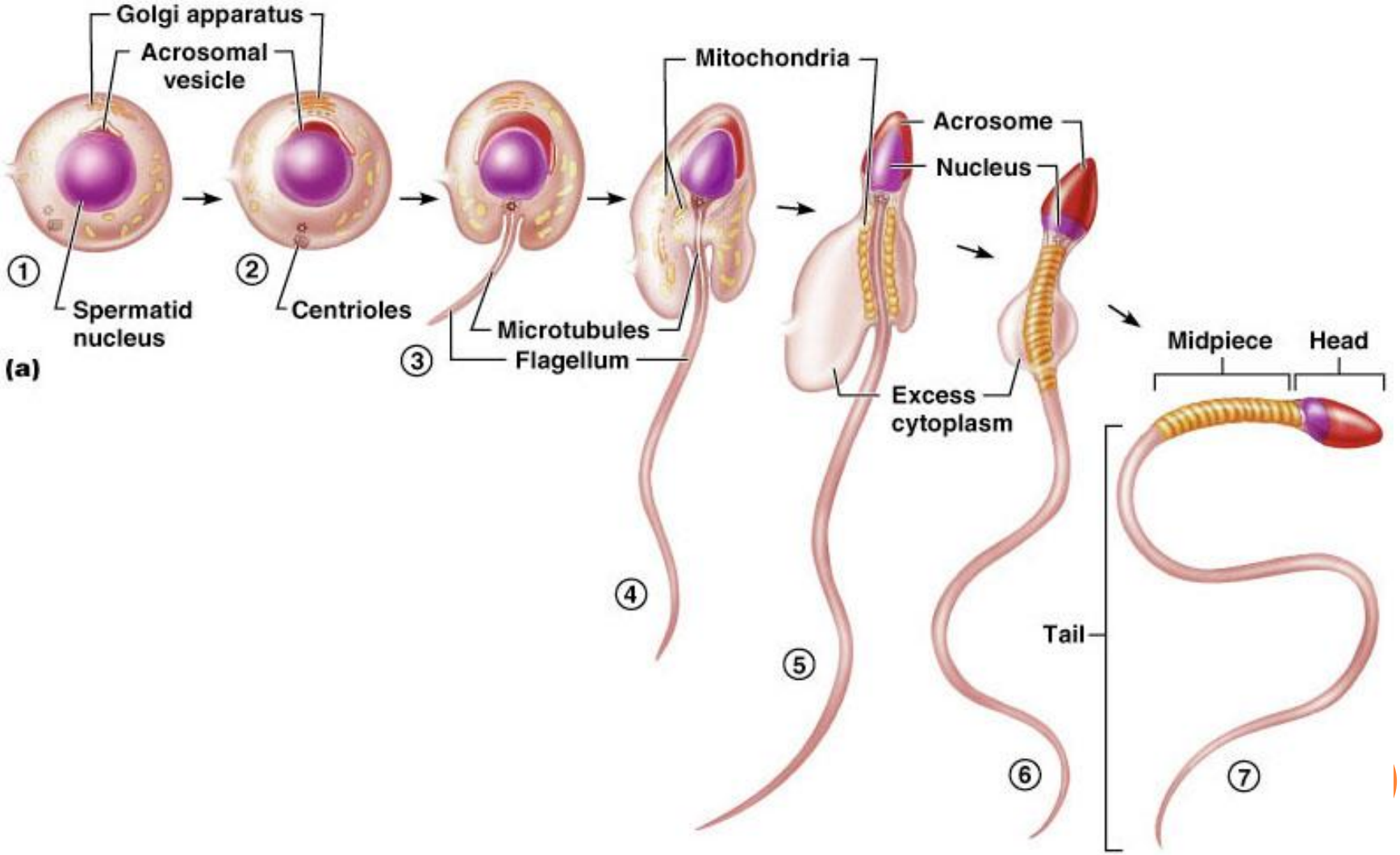


Fig. 9 Schematic representation of MVI distribution (*black dots*) during mouse spermiogenesis. *aSpT* round spermatid at the acrosome phase, *gSpT* round spermatid at the Golgi phase, *mSpT* elongated spermatid at the maturation phase

Spermiogenesis: Spermatids to Sperm



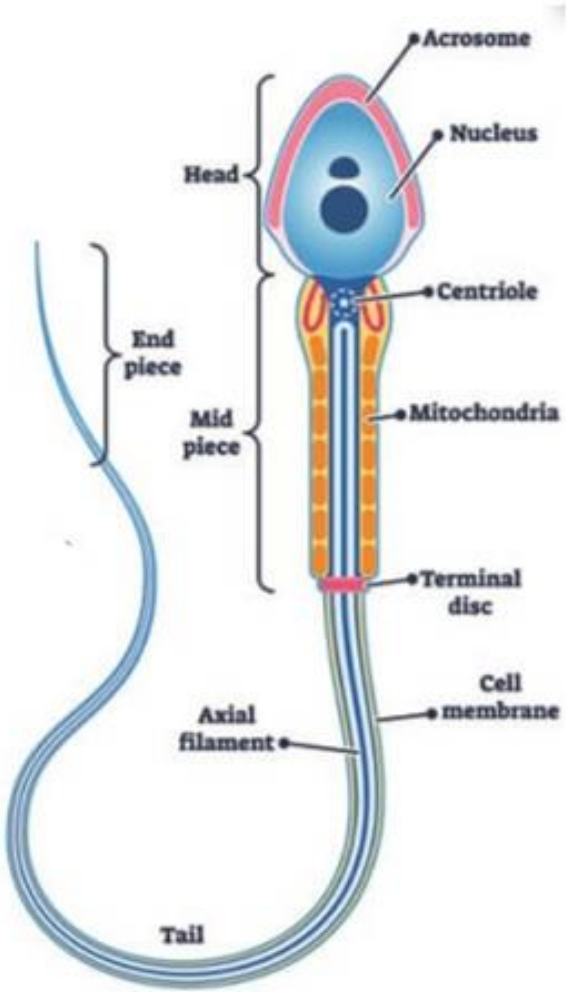
Sperm

- Sperm have three major regions

1. Head :contains DNA and has a helmet-like acrosome containing hydrolytic enzymes that allow the sperm to penetrate and enter the egg

2. Midpiece: contains mitochondria spiraled around the tail filaments

3. Tail :a typical flagellum produced by a centriole



Comparison of Sperm Morphology

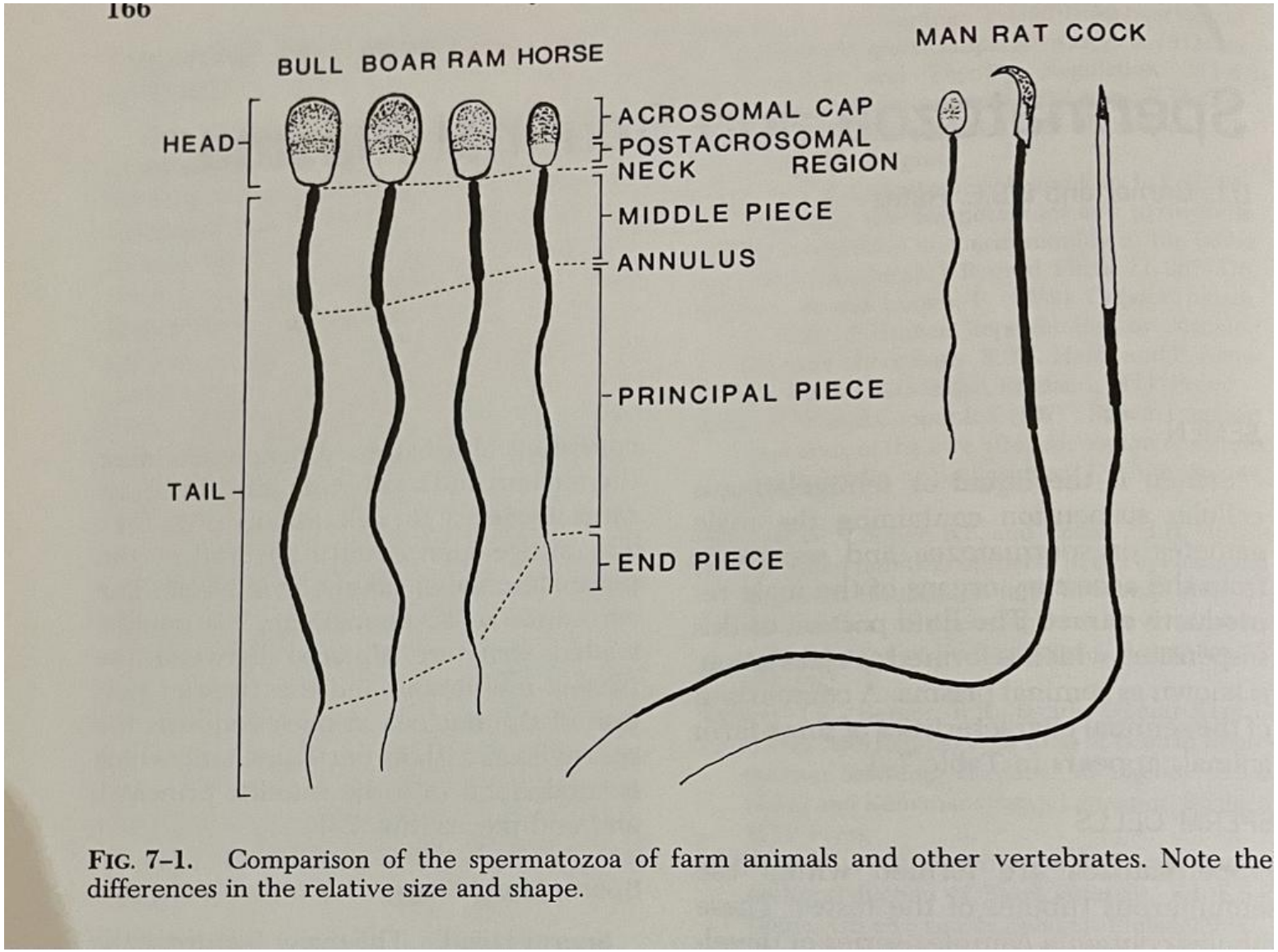


FIG. 7–1. Comparison of the spermatozoa of farm animals and other vertebrates. Note the differences in the relative size and shape.

Semen in Farm Animals

Table 7–1. Characteristics and Chemical Components of Semen from Farm Animals*

Characteristic on component	Bull	Ram	Boar	Stallion	Cock
Ejaculate volume (ml)	5–8	0.8–1.2	150–200	60–100	0.2–0.5
Sperm concentration (million/ml)	800–2000	2000–3000	200–300	150–300	3000–7000
Sperm/ejaculate (billion)	5–15	1.6–3.6	30–60	5–15	0.6–3.5
Motile sperm (%)	40–75	60–80	50–80	40–75	60–80
Morphologically normal sperm (%)	65–95	80–95	70–90	60–90	85–90
Protein (g/100 ml)	6.8	5.0	3.7	1.0	1.8–2.8
pH	6.4–7.8	5.9–7.3	7.3–7.8	7.2–7.8	7.2–7.6
Fructose	460–600	250	9	2	4
Sorbitol	10–140	26–170	6–18	20–60	0–10
Citric acid	620–806	110–260	173	8–53	Nil
Inositol	25–46	7–14	380–630	20–47	16–20
Glyceryl phosphoryl choline (GPC)	100–500	1100–2100	110–240	40–100	0–40
Ergothioneine	0	0	17	40–110	0–2
Sodium	225 ± 13	178 ± 11	587	257	352
Potassium	155 ± 6	89 ± 4	197	103	61
Calcium	40 ± 2	6 ± 2	6	26	10
Magnesium	8 ± .3	6 ± .8	5–14	9	14
Chloride	174–320	86	260–430	448	147

*Adapted from Foote, 1980; Gilbert, 1980; Lake, 1971; White, 1980. Mean values of chemical components (mg/100 ml ± S.E.) unless otherwise indicated. Hyphenated values indicate ranges.

Journey of a Sperm

- At the end of spermatogenesis , spermatozoa are propelled by cilia in the inner walls of rete testis toward the epididymes (the tails of these sperm are not movable at this point) .
- Inside the epididymis, certain enzymatic reactions occur that allow spermatozoa to be fully matured and functional , but not yet have the ability to fertilize the egg .
- If no ejaculation occurs during the 3- day storage time in the epididymis , phagocytes will destroy millions of older sperm in storage.
- During ejaculation , rapid peristalsis in the epididymis and vas deferens propel the millions of sperm , passing the accessory sex glands ,and be expelled through the urethra into the vagina of the female .

Journey of a Sperm….

- After several minutes in the vagina (about 25% of sperm is destroyed by the acidic secretion of vagina), the tail becomes functional , propelling the sperm through the cervix and into the uterus.
- Half of the sperm will swim into the left uterine tube , while the other half swim towards the right uterine tube . only one of the uterine tubes carries the egg cell.
- Sperm continue swimming toward the deeper end of uterine tube , against the expulsion force of the cilia lining the inner wall of uterine tube
- During this movement in the uterine tube, the acrosome is slowly activated to prepare for the release of acrostin enzyme.

Journey of a Sperm….

- By the time sperm has arrived at the ampoule region of uterine tube , only about 50 sperm are viable enough to try to fertilize the egg. And usually only 1 sperm will penetrate through the coatings surrounding the egg.
- Each ejaculation emits about 2-6 ml of semen which contains about 300-400 million sperm . it takes the sperm about 2-12 hours to reach the fertilization site in the uterine tube , but many sperm can survive some where in the female reproductive tract for up to 2-3 days .
- One of the sperm will eventually penetrate through zone pellucida ,and allow its cell membrane to fuse with the cell membrane of ovum . This causes a rapid electrical depolarization at the cell membrane of ovum, preventing other sperm entering the ovum (a phenomenon called poly sperm) .

Capacitation of the sperm

- Sperms **cannot** fertilize oocytes when they are newly ejaculated.
- The process of capacitation takes 5-7 hours.
- Capacitated sperms are more active.
- Location: capacitation occurs in the uterus and oviducts and is facilitated by substances of the female genital tract.
- The acrosomal reaction cannot occur until capacitation has occurred.

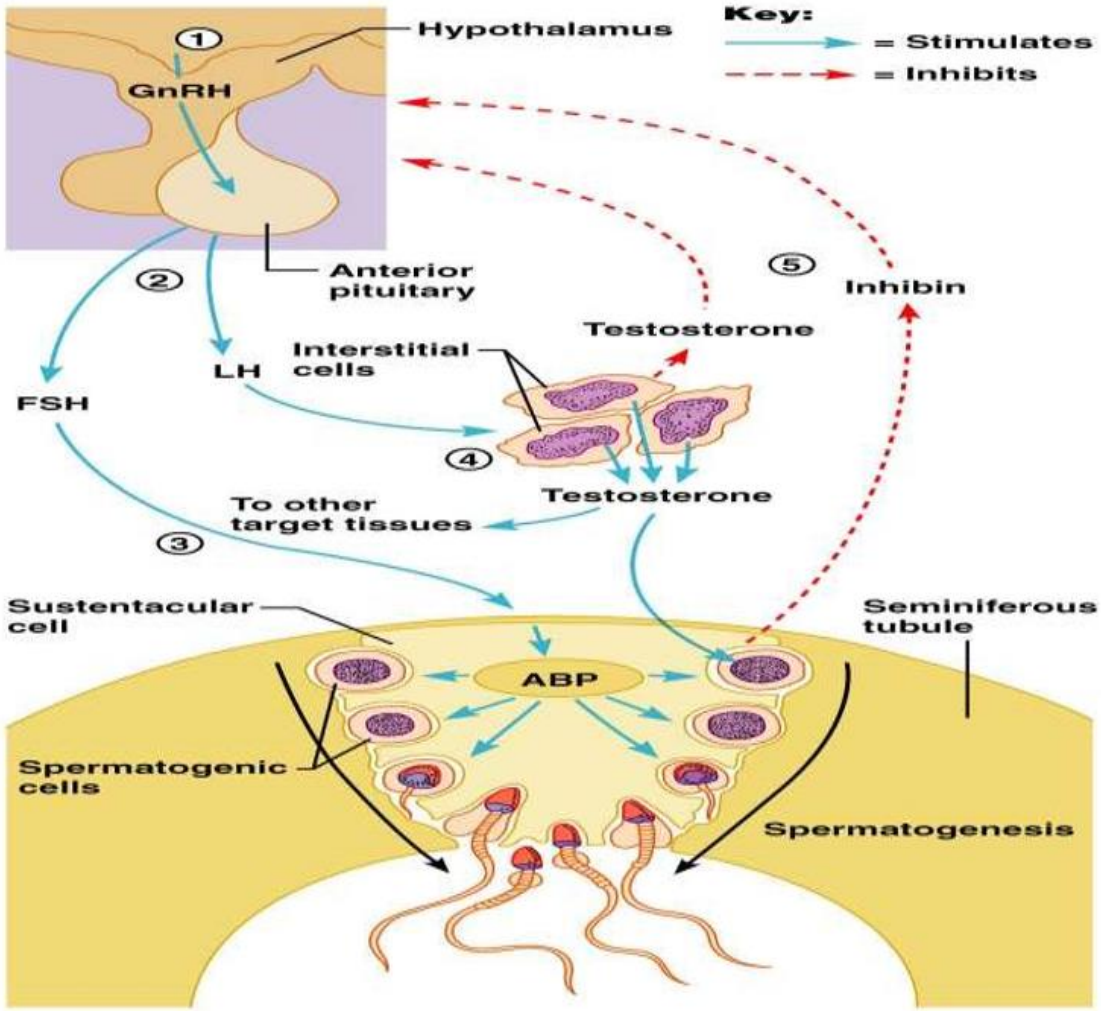
Duration of Spermatogenesis

	Bull	Ram	Boar	Stallion	Man
cycle (days)	13.5	10.4	8.3	12.2	16
Spermatogenesis	61	47	39	57	75

Hormonal control of ♂ reproductive function

- 1. Hypothalamic and pituitary hormones:
  - The male body remains reproductively immature until the hypothalamus releases GnRH (Ganadotropin – releasing hormone), which stimulates the anterior pituitary gland to release gonadotropins (FSH, LH) .
  - FSH- stimulates spermatogenesis .
  - LH (ICSH) – stimulates the interstitial cells to produce male sex hormone (testosteronne) .
  - Inhibin prevents over secretion of FSH . (Inhibin – from substentacular cells of seminiferous tubules).

The brain – testicular axis



Testosterone is important in every phase of male life

- Testosterone is the most important endogenous sex hormone and androgen in the male
- It is vital for the proper development and functioning of the male phenotype
- Testosterone and its main metabolites, DHT (Dihydrotestosterone) and estradiol, exert a number of anabolic and metabolic effects that can influence many physical and mental functions in men

Stage of male life	Effect of testosterone
In utero (embryo)	• Sex differentiation
Puberty	• Virilization
Adulthood	• Maintenance of the male phenotype • Sexual function • Anabolic effects

DHT, dihydrotestosterone

Nieschlag E et al. Andrology: Male reproductive health and dysfunction, 3rd edition, Springer, 2010.

Testosterone acts on diverse target tissues to cause a variety of biological effects

Target	Biological effect of testosterone and its metabolites
Reproductive organs[1,2]	Prenatal sex differentiation; pubertal virilization and development of testes, penis, epididymis, seminal vesicles and prostate; in adults, maintenance of reproductive organs, potency and sexual function, and initiation/maintenance of spermatogenesis
Muscle[1]	Increased volume, strength and lean body mass
Skin and hair[1]	Increased sebum production, hair growth and male hair pattern
Liver[1,3]	Increased synthesis of clotting factors, hepatic triglyceride lipase, sialic acid, α1-antitrypsin, haptoglobin; decreased production of SHBG and other hormone-binding proteins, transferrin, fibrinogen
Lipids[1,2]	Improvements in dyslipidemia; decreased plasma total cholesterol, LDL-C and triglycerides, and increased plasma HDL-C concentrations
Blood glucose[2]	Improvements in hyperglycemia; decreased fasting blood glucose and HbA_{1c}
Bone[1]	Accelerated linear growth; closure of epiphyses; increased bone mass
Brain[1]	Improvements in cognitive function, socialization, concentration, self-confidence, mood, libido; in adults, possible neuroprotective effect
Hematopoietic system[1,2]	Stimulation of erythropoietin biosynthesis in the kidney; direct effects on hematopoietic stem cells, leading to increased hemoglobin production
Immune cells[4]	Suppression of humoral and cellular immune responses; anti-inflammatory effect

HbA_{1c}, glycated hemoglobin; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SHBG, sex hormone-binding globulin

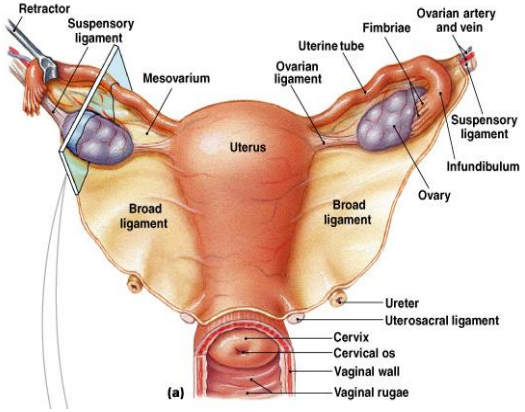
1. Nieschlag E et al. Andrology: Male reproductive health and dysfunction, 3rd edition, Springer, 2010.
2. Traish AM. Sex Med Rev. 2018;6(1):86–105. **3.** Nebido® Product Monograph, Bayer AG, 2017.
4. Cutolo M et al. Ann N Y Acad Sci. 2002;966:131–42.

Regulation of male sex hormone

- □ a. Negative feedback mechanism regulates testosterone conc. As the conc. of testosterone rises , the hypothalamus is inhibited , and the Ant. pituitary secretion of gonadotropins is reduced . □ As the conc. of testosterone falls , the hypothalamus signals the ant. Pituitary to secrete gonadotropins . □ b. The conc. of testosterone remains relatively stable from day to day.

Female Reproductive System

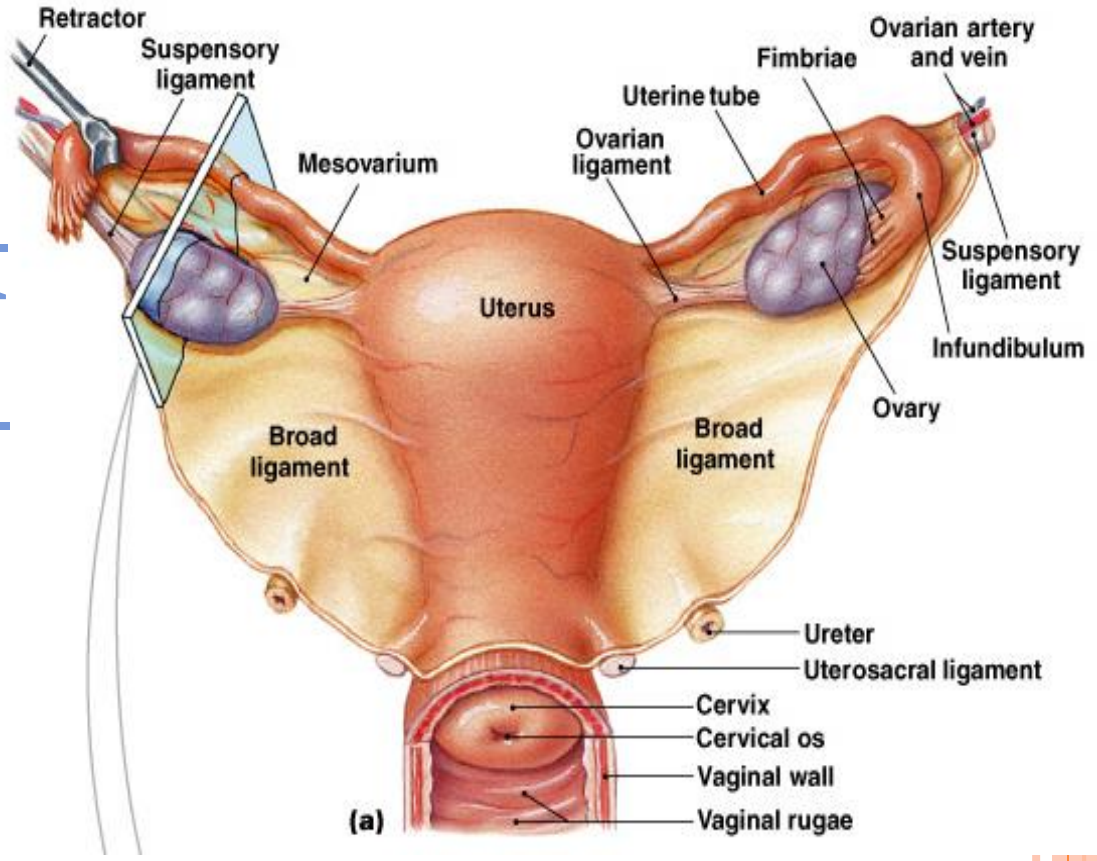
Lecture # 5



Female Reproductive System

- Ovaries
- Duct System
  - Uterine tubes (fallopian tubes)
  - Uterus
  - Vagina
- External genitalia (Vulva)

Internal genitalia



Female Reproductive System

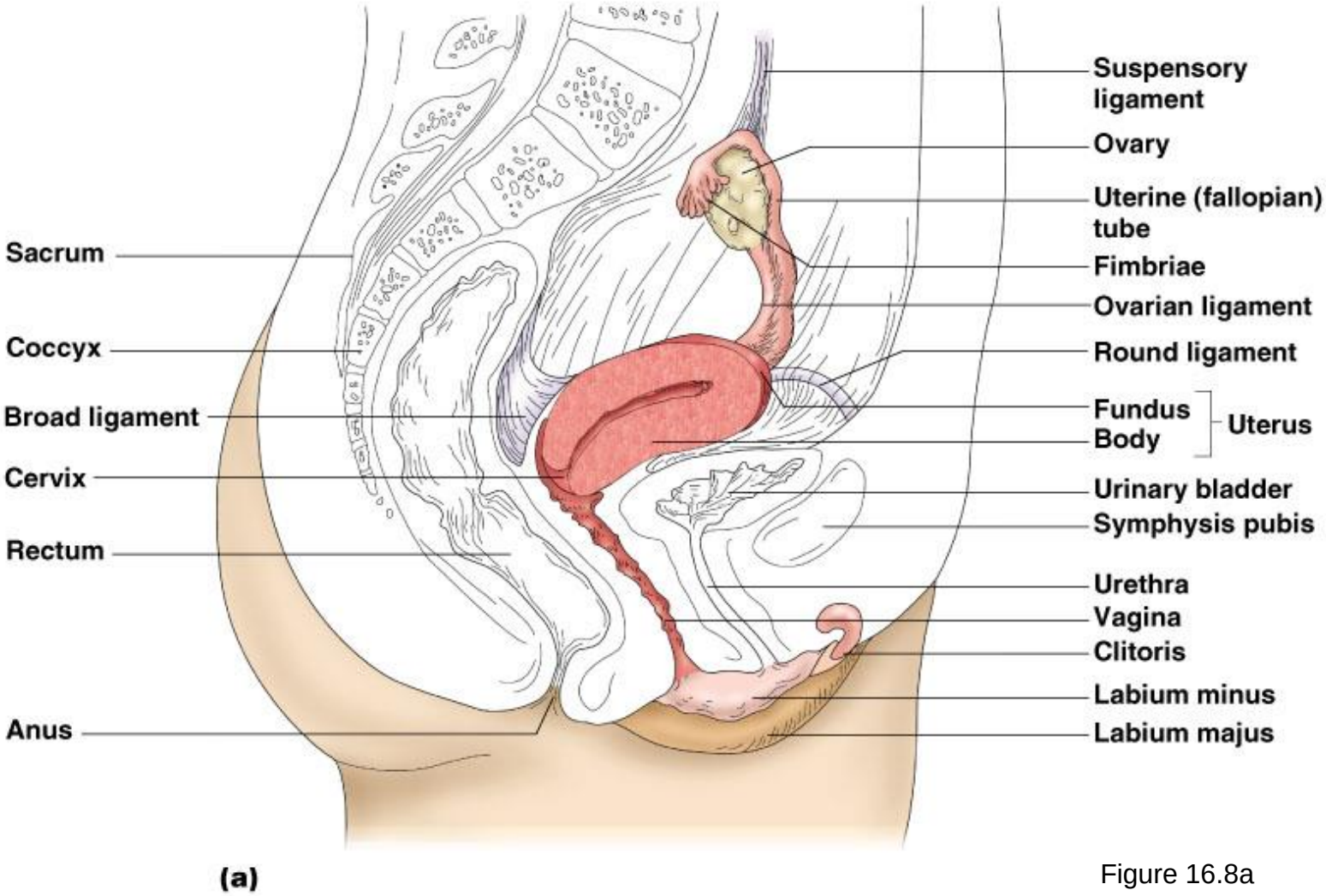


Figure 16.8a

ovary

- Primary sex organ that produces egg cells in a process called oogenesis , and also produces female sex hormones such as estrogens and progesterone.
- Developed near the kidneys during fetal development ,and toward the end of pregnancy descend into the pelvic cavity .
- Consists of ovarian cortex where the ovarian cycle occurs , and ovarian medulla where scar tissues and connective tissue are located .
- Enclosed by a layer of cubical cells called germinal epithelium.
- Bound to the uterine tubes and uterus by ovarian ligaments .
- At birth most female ovaries contain between 200,000 to 400,000 immature ova (oocytes) in each ovary

Ovaries

- Composed of ovarian follicles (sac-like structures)
- Structure of an ovarian follicle
  - Oocyte
  - Follicular cells

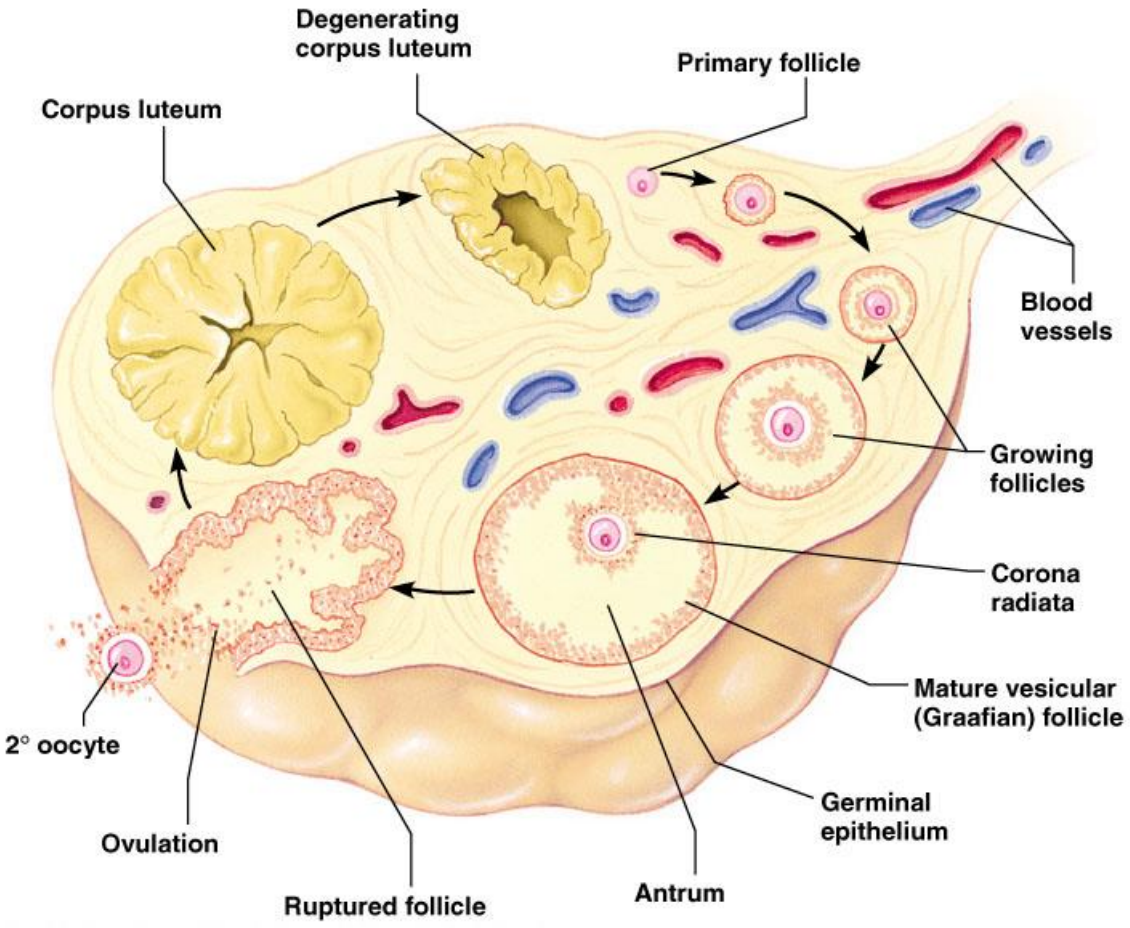


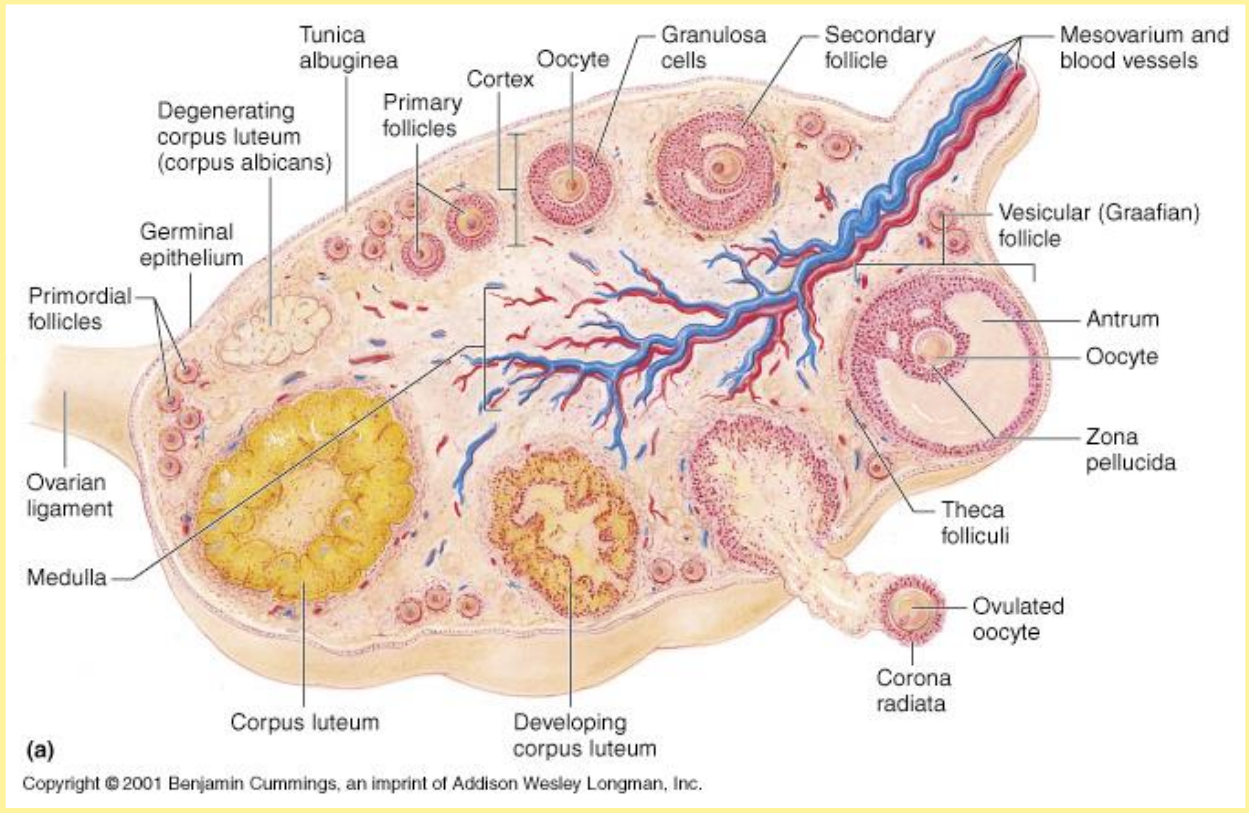
Figure 16.7

Ovarian Follicle Stages

- Primary follicle – contains an immature oocyte
- Graafian (vesicular) follicle – growing follicle with a maturing oocyte
- Ovulation – when the egg is mature the follicle ruptures
  - Occurs about every 28 days
- The ruptured follicle is transformed into a **corpus luteum**

Folliculogenesis

Folliculogenesis is the process of ovarian follicle development. In order to reach the ovulatory stage, an ovarian follicle will pass through the following stages: primordial (resting), primary, secondary (pre-antral), tertiary (antral), and, finally, the pre-ovulatory (Graafian) follicle stage. According to dogma in the field, in females, the peak number of ovarian follicles occurs in the fetus at mid-gestation and is approximately seven million. This number then declines to two million at birth, half a million at puberty, 25 thousand at the age of 37 years, and less than one thousand at menopause. This progressive decline in follicle count with age is due to a natural breakdown process called follicular atresia that affects 99.9% of all follicles.

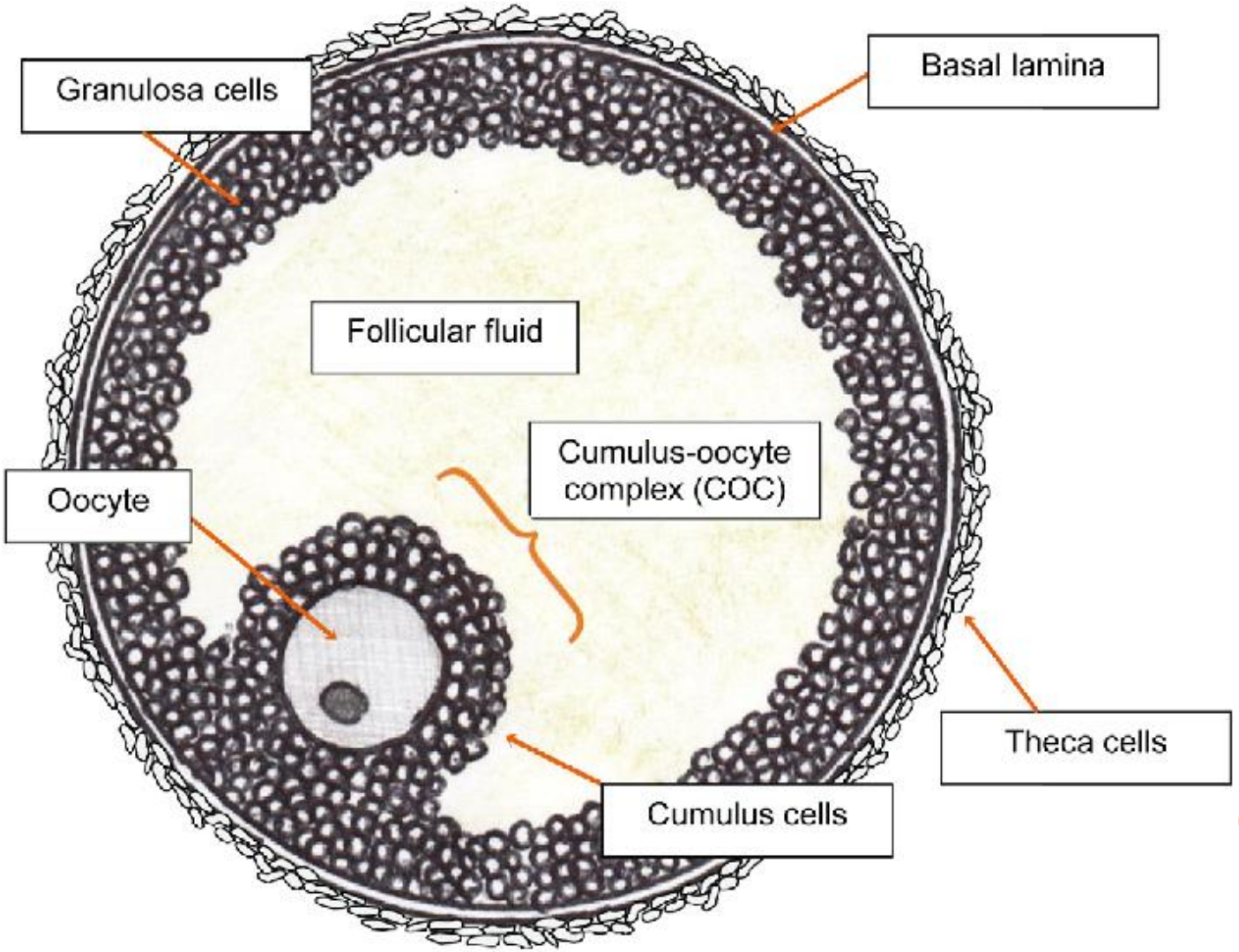


Stages of Folliculogenesis

Stage	Description	Size
Primordial	Dormant, small, only one layer of flat granulosa cells	Primordial follicles are about 0.03-0.05 mm in diameter.
Primary	Mitotic cells, cuboidal granulosa cells	Almost 0.1 mm in diameter
Secondary	Presence of theca cells, multiple layers of granulosa cells	The follicle is now 0.2 mm in diameter
***Early tertiary* (or *antral* or *Graafian*)**	Formation of an antrum	The early tertiary follicle is arbitrarily divided into five classes. Class 1 follicles are 0.2 mm in diameter, class 2 about 0.4 mm, class 3 about 0.9 mm, class 4 about 2 mm, and class 5 about 5 mm.
Late tertiary	Fully formed antrum, no further cytodifferentiation, no novel progress	Class 6 follicles are about 10 mm in diameter, class 7 about 16 mm, and class 8 about 20 mm. It is common for non-dominant follicles to grow beyond class 5, but rarely is there more than one class 8 follicle.
Preovulatory	Building growth in estrogen concentration, all other follicles atretic or dead	

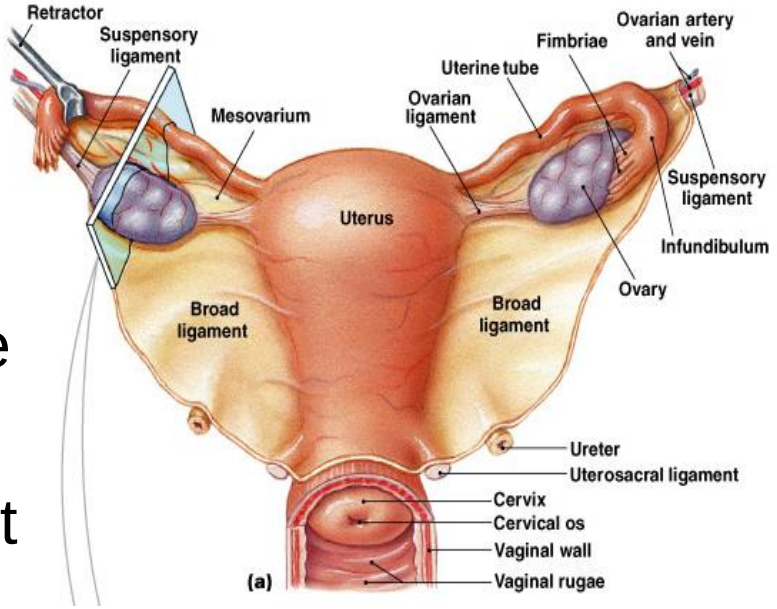
تفاصيل كل مرحلة: الرجوع إلى الرابط التالي:https://www.bionity.com/en/encyclopedia/Folliculogenesis.html

The antral follicle



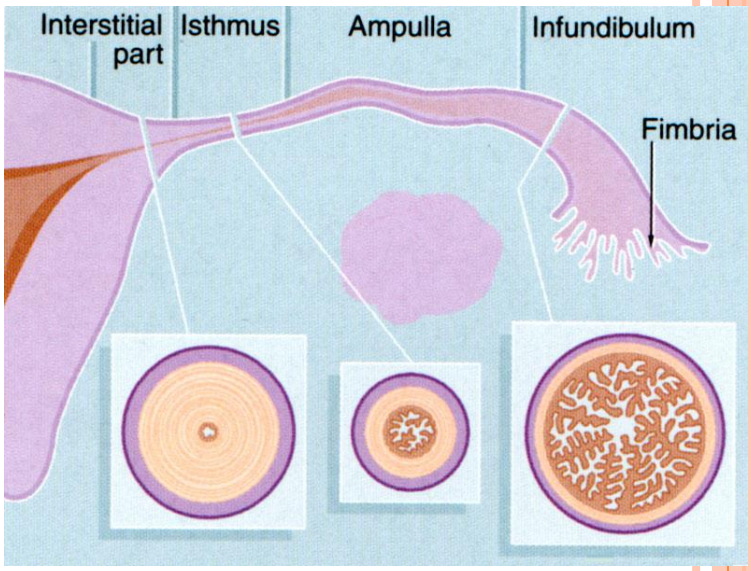
Uterine (Fallopian) Tubes (Oviduct)

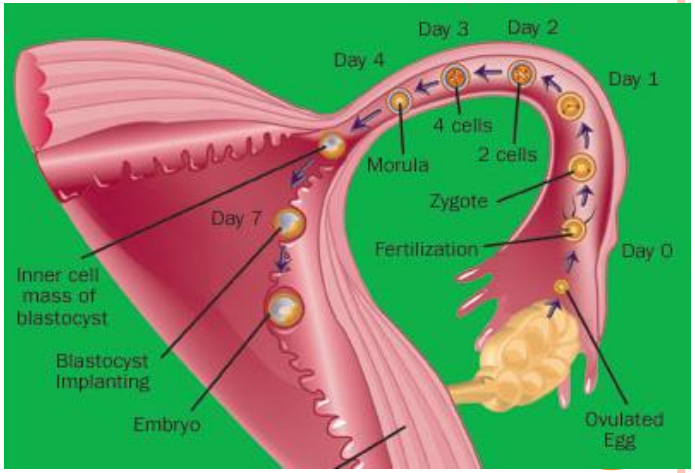
- Receive the ovulated oocyte
- Provide a site for fertilization
- Attaches to the uterus
- Does not physically attach to the ovary
- Supported by the broad ligament
- The fallopian tube is 4-6 inches long
- An egg takes about 3-4 days to travel the length of the tube.



Uterine Tube (Oviduct)

- Uterine tube (or fallopian tube): consists of firmbriae , finger – like appendages that collect the ovum from the ovary during ovulation.
- Infundibulum channels the ovum from the firmbriae into the uterine tube .
- Ampulla is the curvature of the uterine tube where most fertilization occurs .
- Inner wall of uterine tube is made of ciliated mucosa , where the cilia propel the ovum toward the uterus .



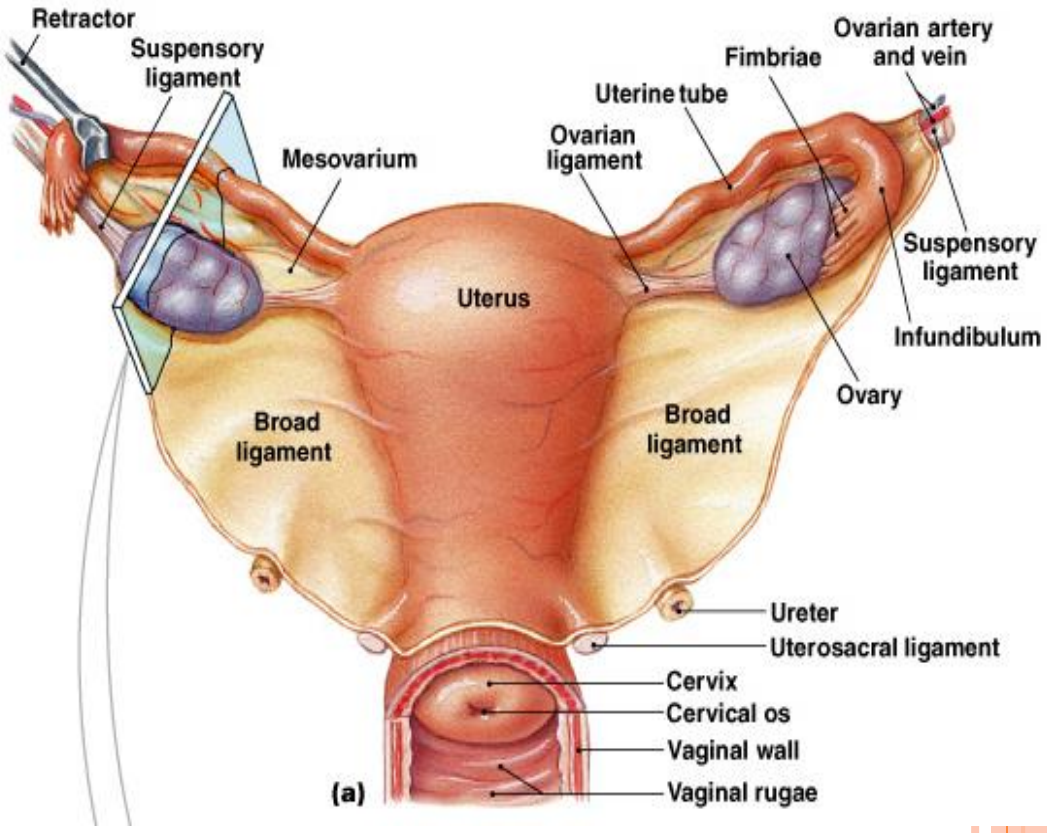


Functions of the Oviduct

- **Gamete transport (ovum pickup, ovum transport, sperm transport).**
- **Final maturation of gamete post ovulate oocyte maturation, sperm capicitation.**
- **Fluid environment for early embryonic development.**
- **Transport of fertilized and unfertilized ovum to the uterus.**

Uterus

- **Located between the urinary bladder and rectum (is about 3 Inches long)**
- **The uterus is a hollow, muscular, pear-shaped organ**



Regions of the Uterus

- Body – main portion
- Fundus – area where uterine tube enters
- Cervix – narrow outlet that protrudes into the vagina

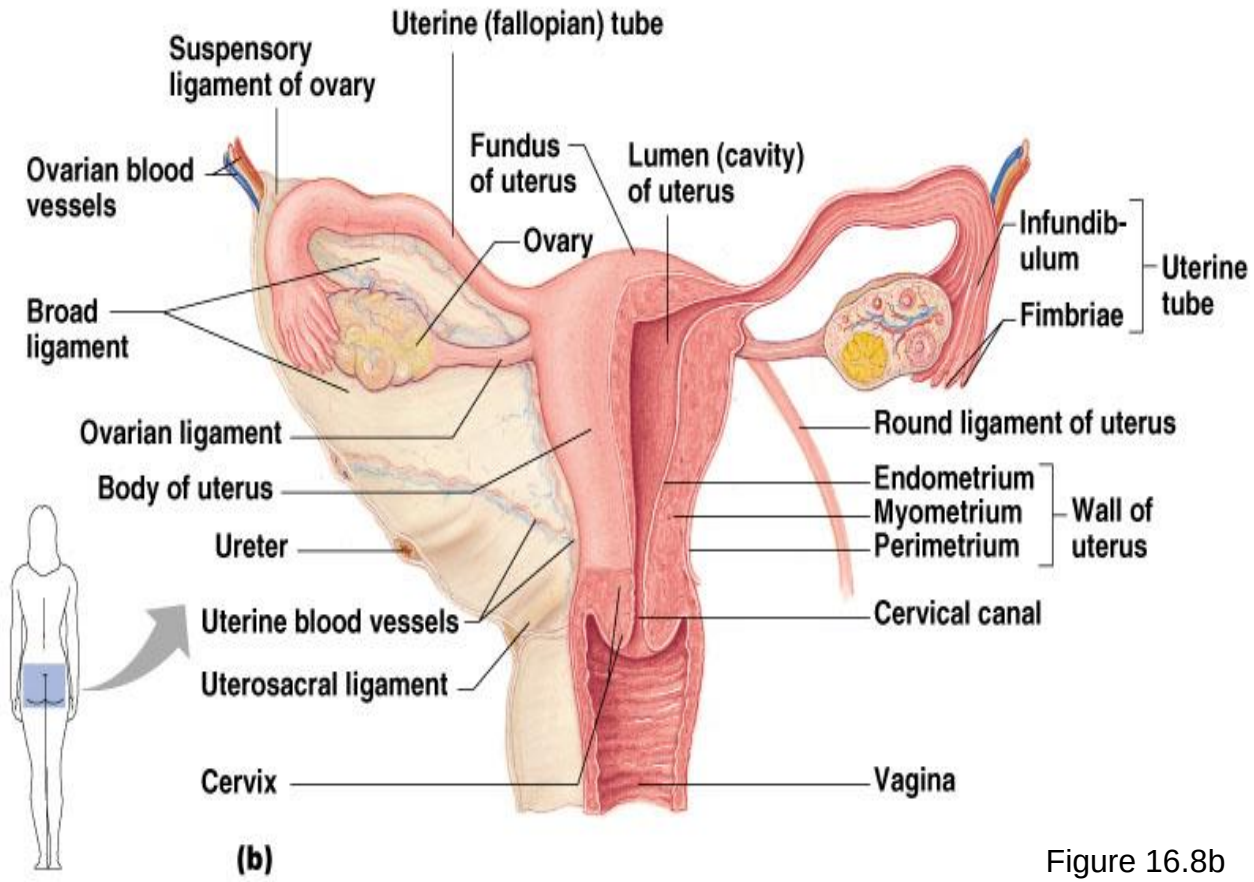


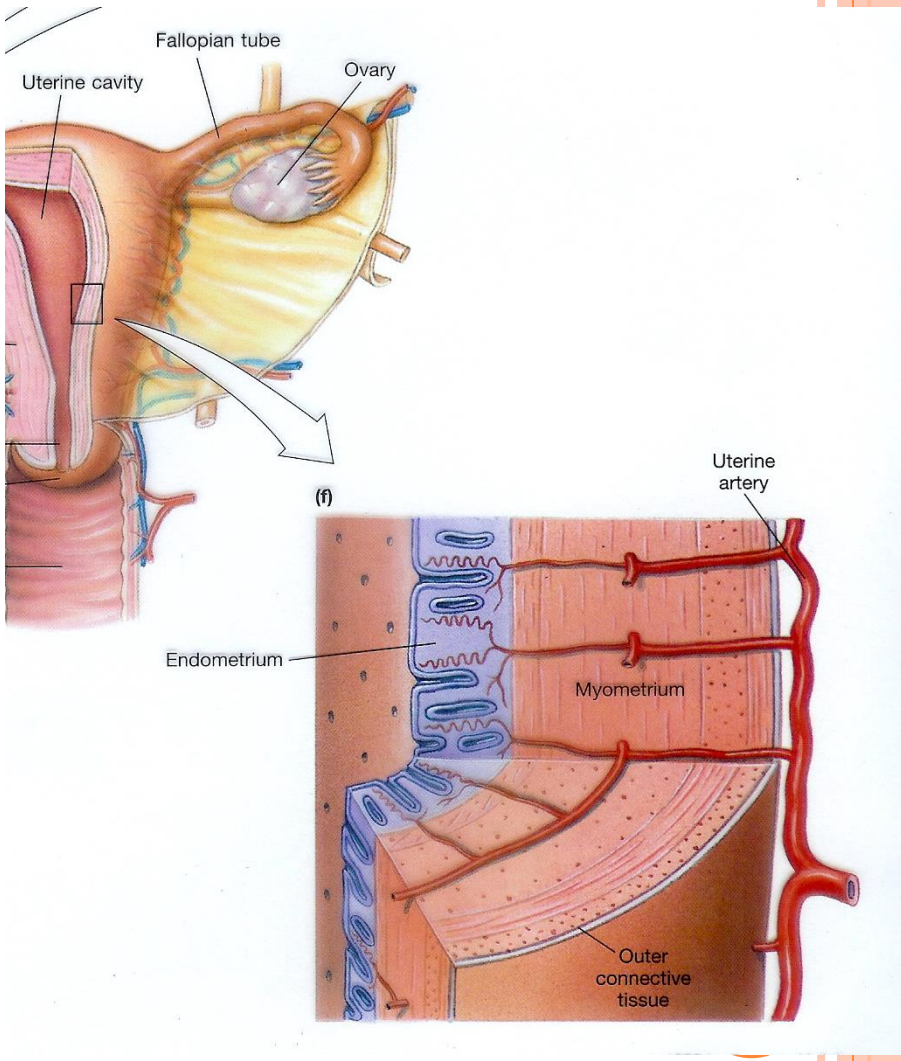
Figure 16.8b

- **Layers of uterine wall:**

- endometrium (mucosa) – single layer of simple columnar epithelium on connective tissue with some ciliated cells

- myometrium (muscular layer) – major portion; bundles of smooth muscle cells in layers (longitudinal, circular, longitudinal)- elastic fibers abundant

- perimetrium (serosa) – outermost layer of fibroelastic tissue



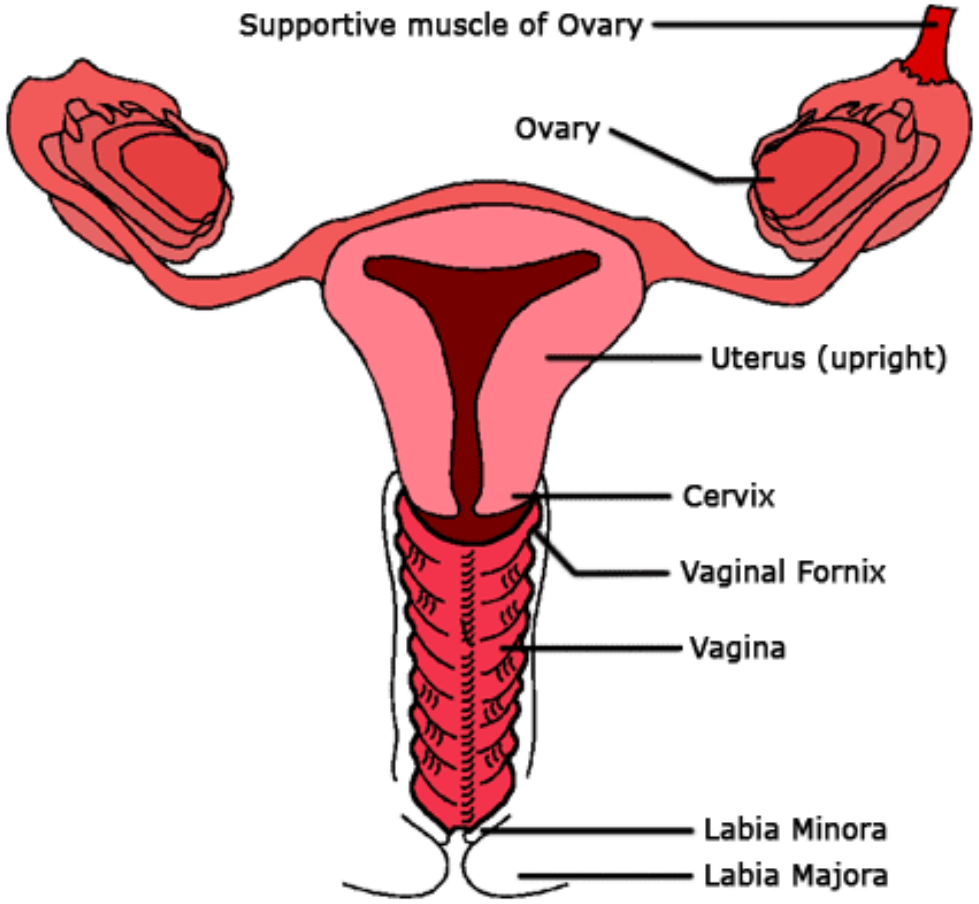
The Function of the uterus

- Menstruation ----the uterus sloughs off the endometrium.
- Pregnancy ---the uterus support fetus and allows the fetus to grow.
- Labor and birth---the uterine muscles contract and the cervix dilates during labor to expel the fetus

The vagina…

The vagina extends from the cervix to the outside of the body. It is a 3 ½ inch long muscular tube that expands in length and width during sexual arousal.

The vagina is the female organ copulation (sexual intercours receiving the seminal fluid from male penis. It is also a passage for menstruation or the birth of a fetus.

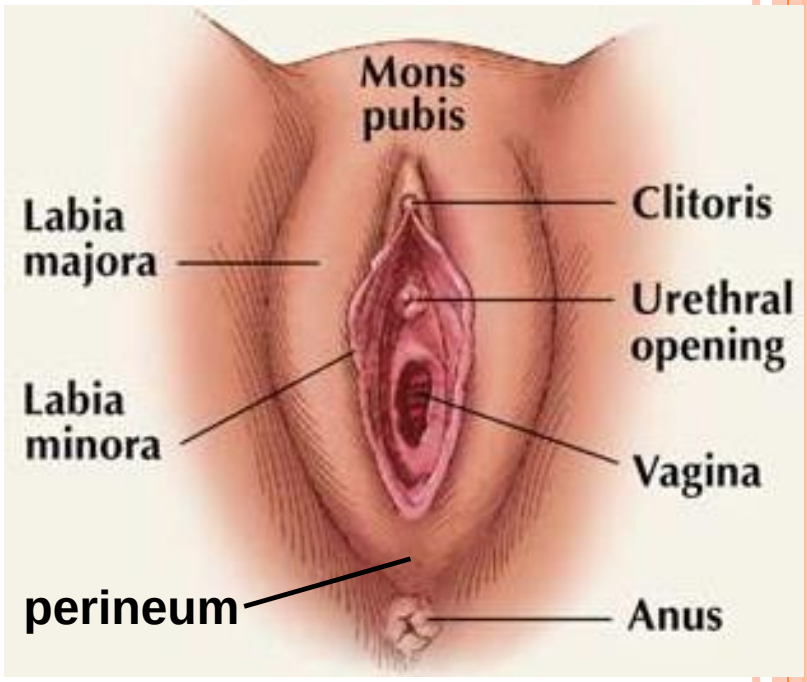


- **Hymen** – partially closes the vagina until it is ruptured (usually about 1-2 cm inside the vaginal opening).

Female External Genitalia: the vulva…

The vulva is 4 organs making up the external genitalia of the female:

1. Mons pubis: triangular-shaped pad of fatty tissue over the pubis bone, covered with pubic hair



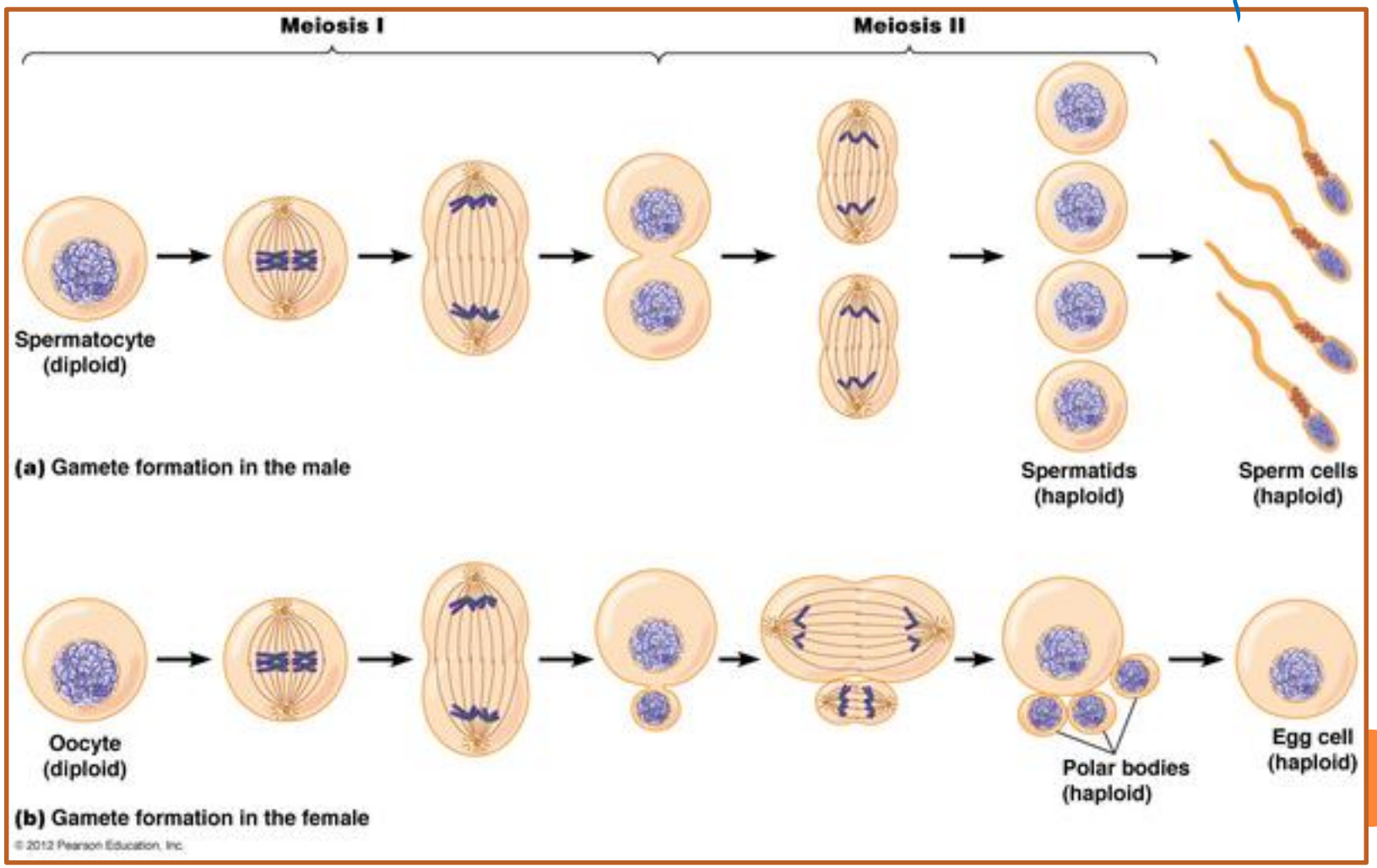
2. Labia majora: 2 large folds of adipose tissue on the sides of the vaginal opening
3. Labia minora: 2 smaller folds of adipose tissue on the inside of the labia majora

4. **Clitoris:** Contains erectile tissue, Corresponds to the male penis.

Oogenesis

- The total supply of eggs are present at birth
- Ability to release eggs begins at puberty
- Reproductive ability ends at menopause
- Oocytes are matured in developing ovarian follicles

Gamete formation in males and females



Oogenesis

- Oogonia – female stem cells found in a developing fetus
- Oogonia undergo mitosis to produce primary oocytes
- Primary oocytes are surrounded by cells that form primary follicles in the ovary
- Oogonia no longer exist by the time of birth

Oogenesis

- Primary oocytes are inactive until puberty
- Follicle stimulating hormone (FSH) causes some primary follicles to mature
  - Meiosis starts inside maturing follicle
    - Produces a secondary oocyte and the first polar body
  - Meiosis is completed after ovulation only if sperm penetrates
    - Two additional polar bodies are produced

Oogenesis

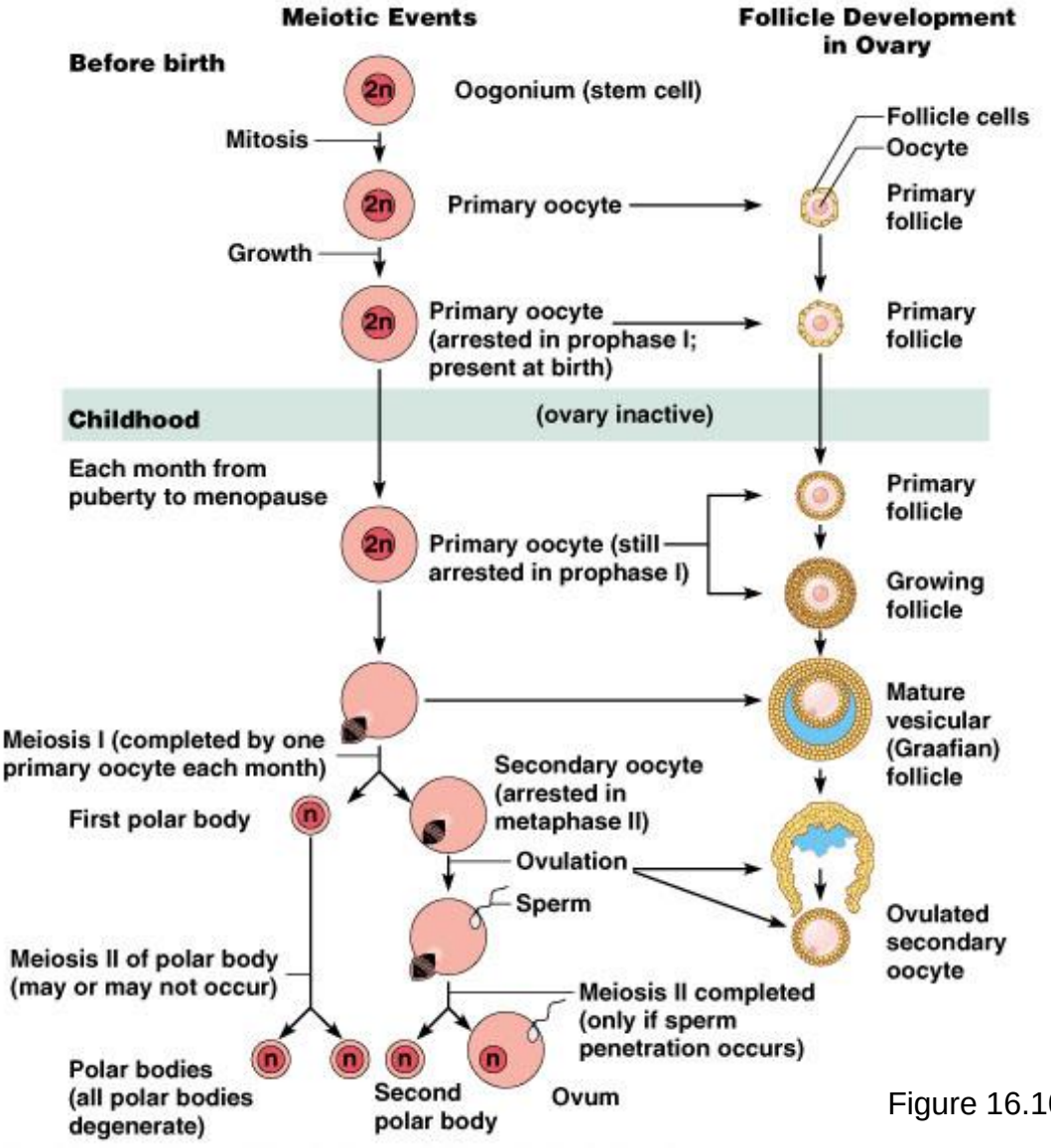
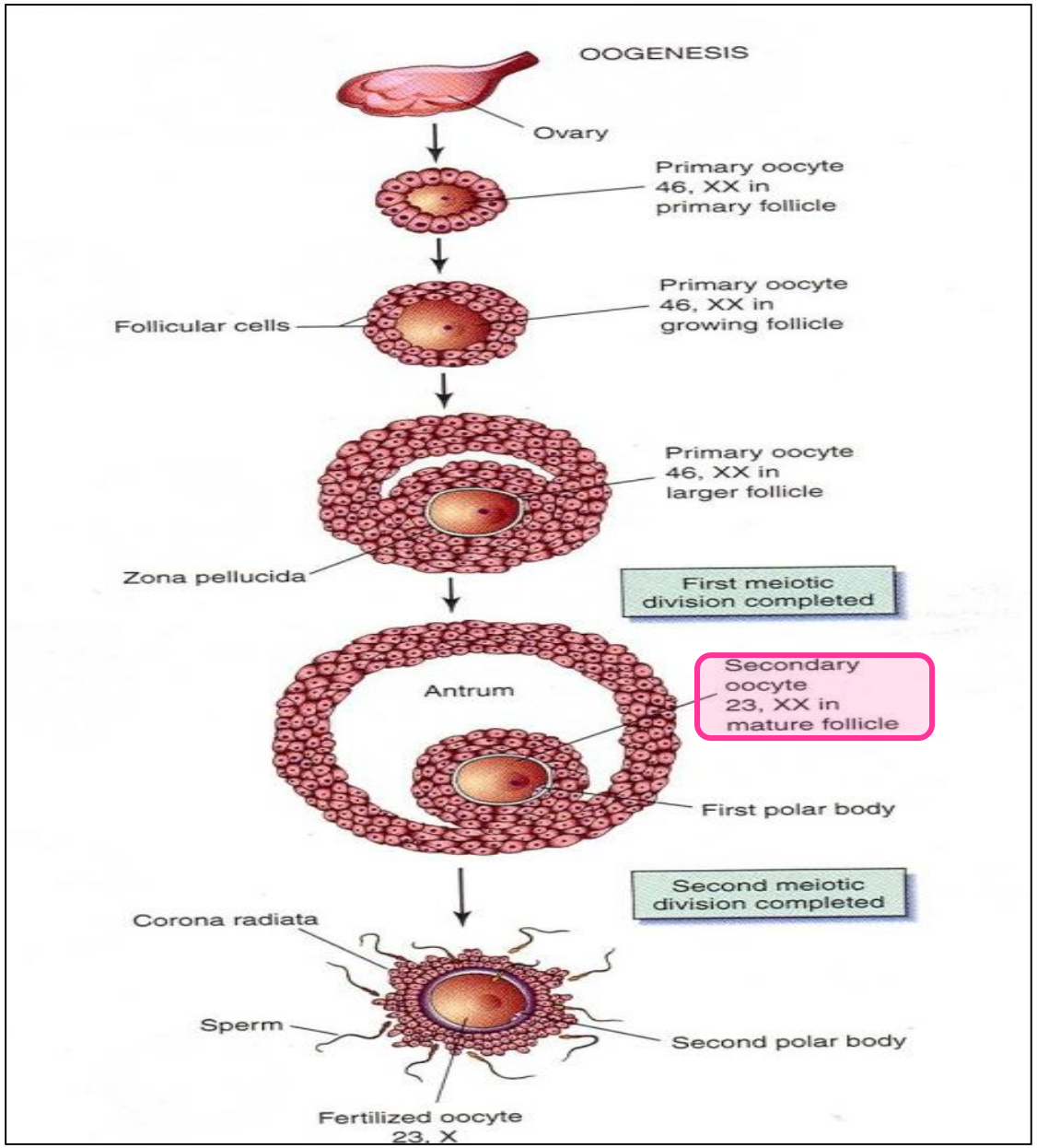


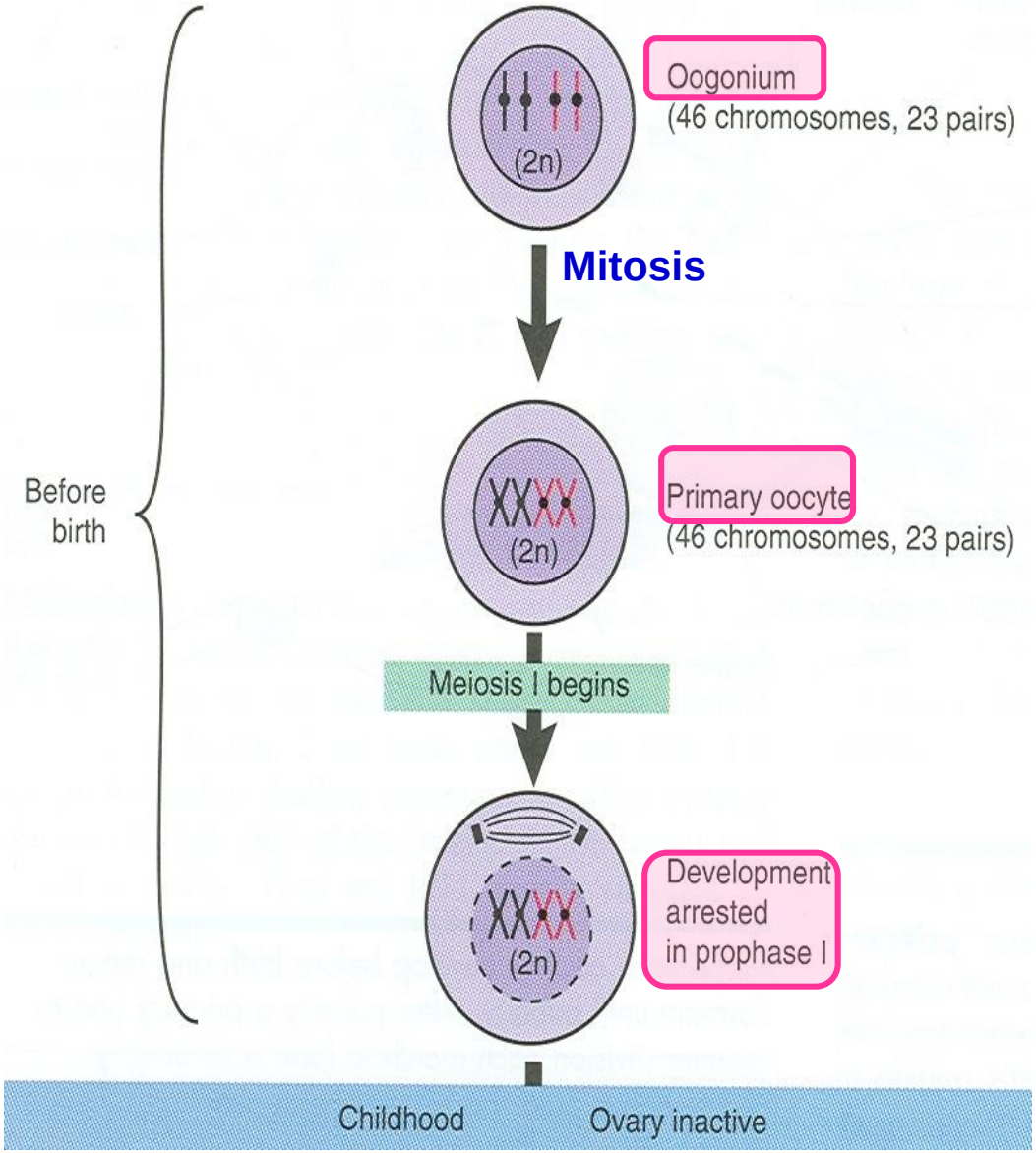
Figure 16.10

OOGENESIS



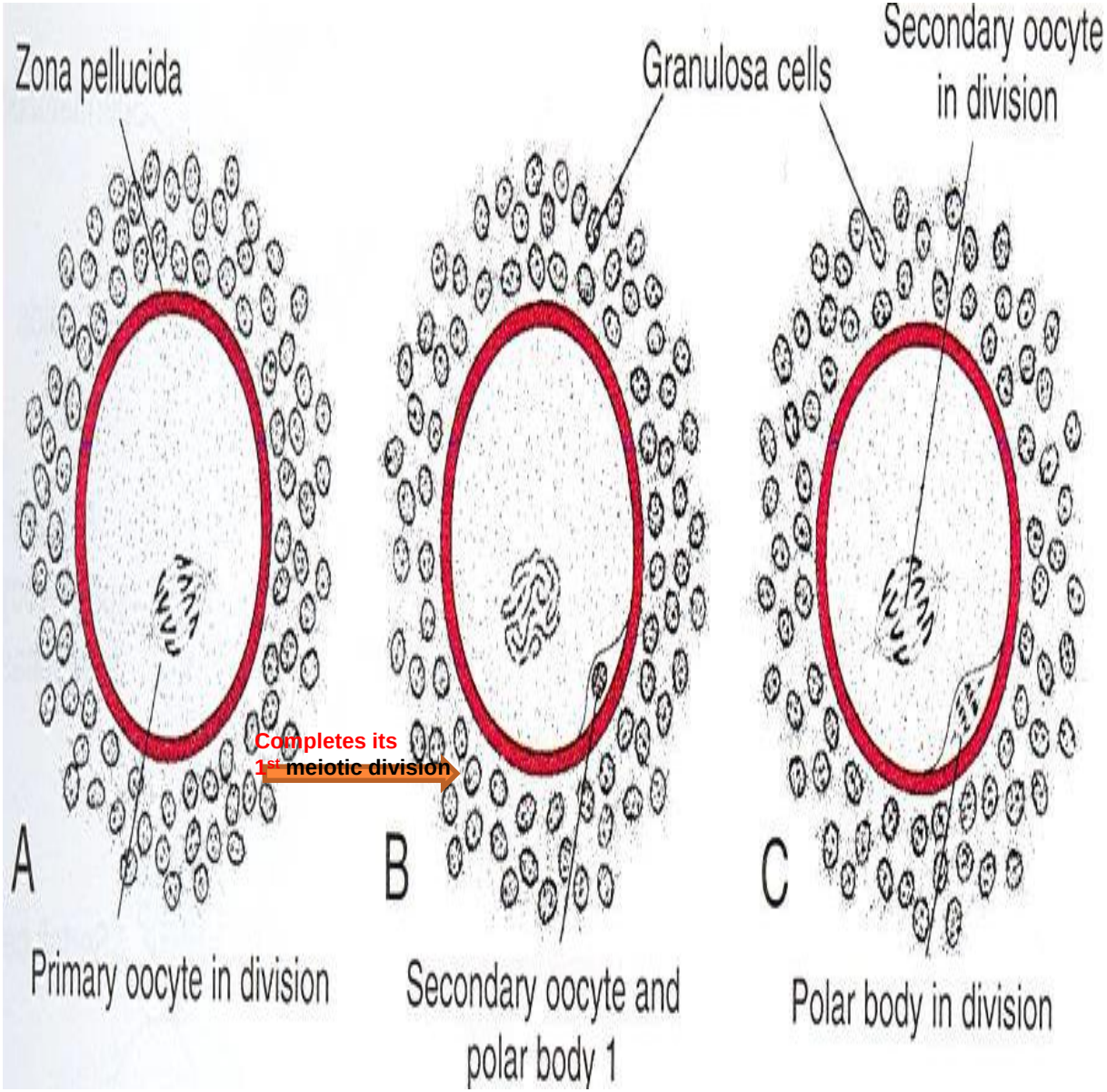
- **AIM:**
- **Formation of secondary oocytes with haploid number of chromosomes.**
- **SITE:**
- **Cortex of the ovary**
- **TIME:**
- **Starts during fetal life becomes completed after puberty & continues until menopause.**
- ***It occurs monthly Except during pregnancy.***

OOGENESIS



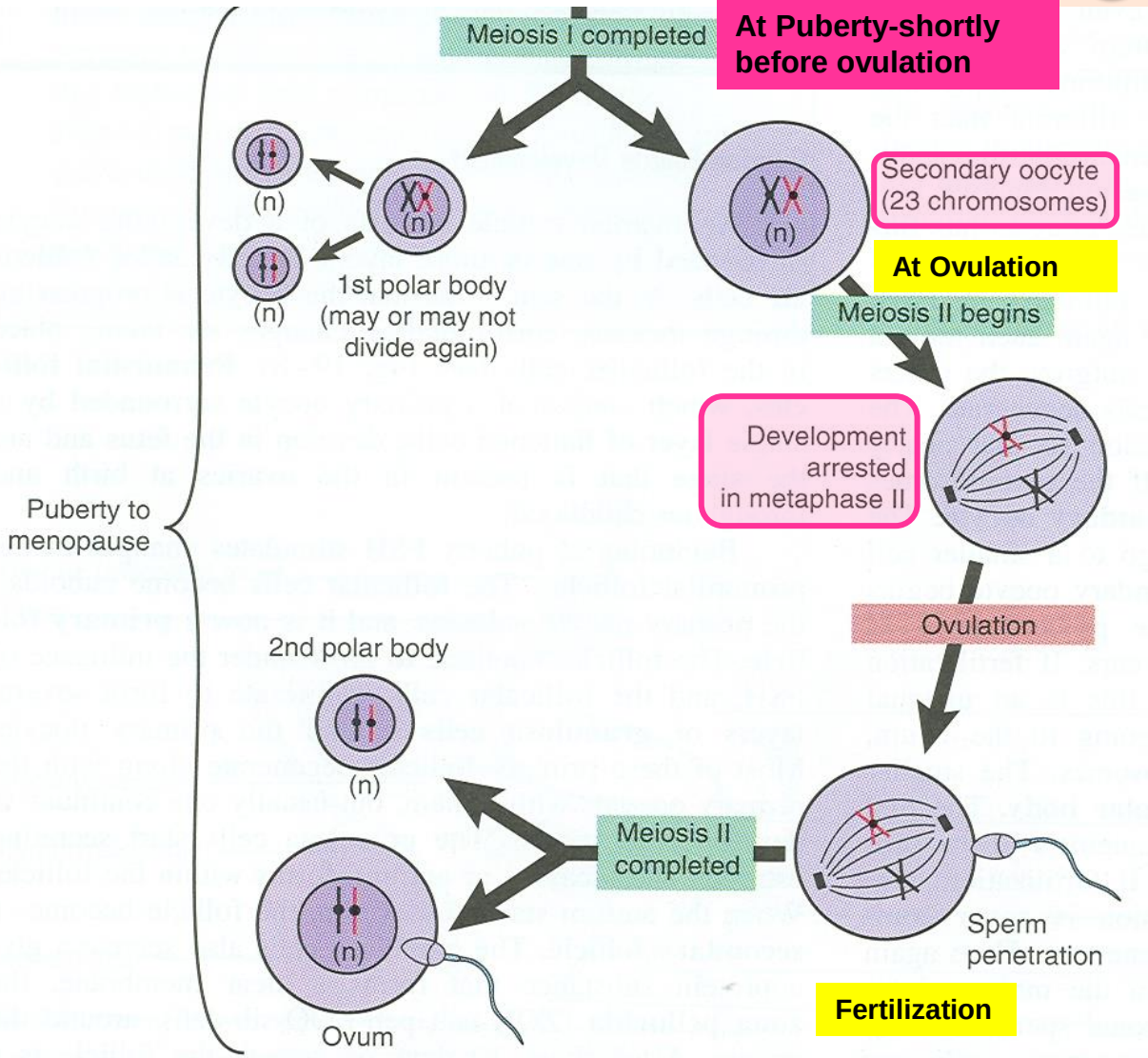
- ***Before Birth*: *(During early fetal life)*, primitive ova (*Oogonia*). proliferate by mitotic division and enlarge to form *Primary Oocytes (46)***
- ***Before and At Birth : all primary oocytes completed the prophase of the 1st meiotic division and***
- ***remain arrested and do not finish their first meiotic division until puberty.***

OOGENESIS



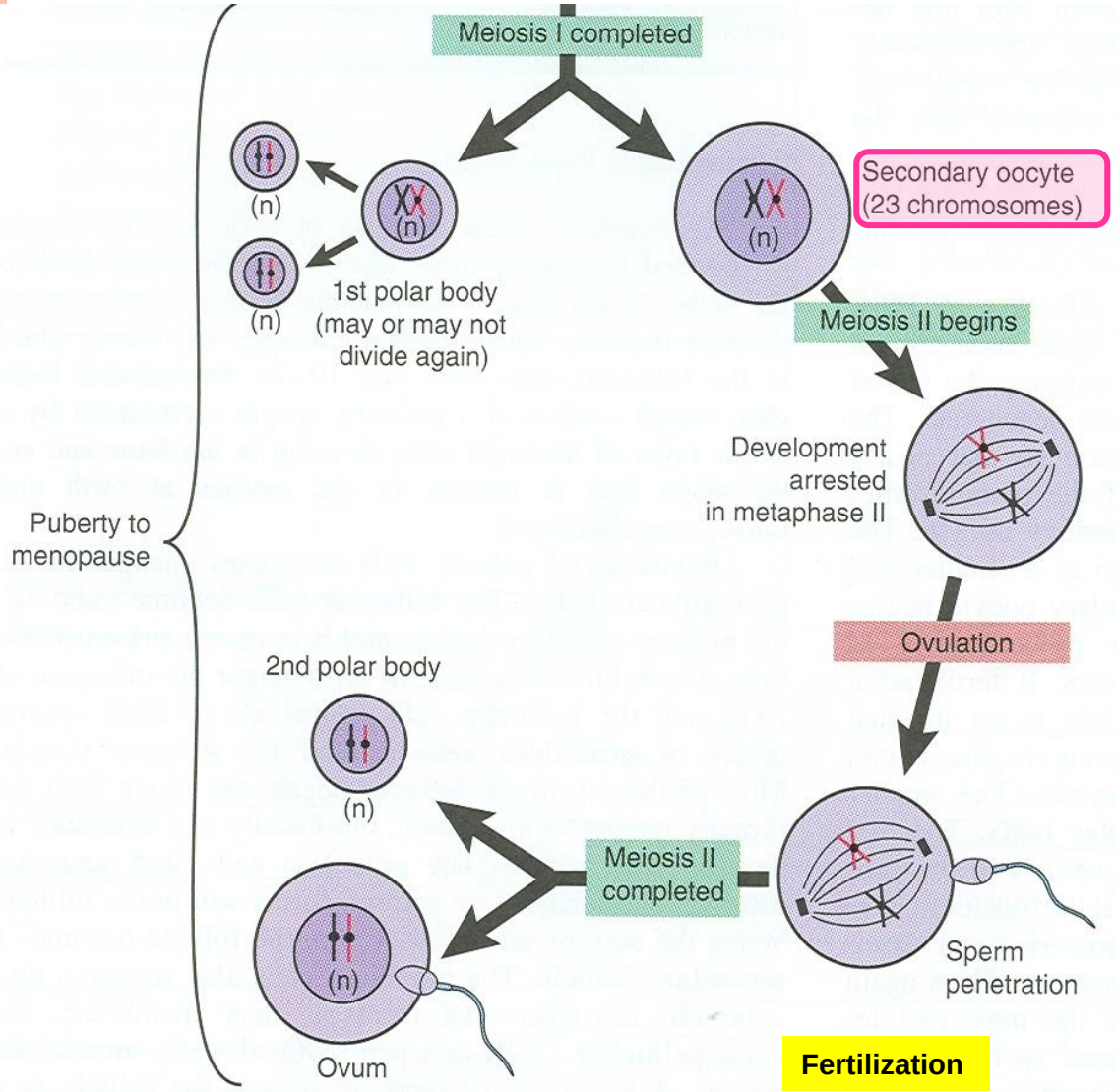
- ***At Puberty***
- ***Shortly before ovulation, the Primary Oocyte completes its first meiotic division to give Secondary oocyte (23) & First Polar Body.***
- ***The Secondary Oocyte receives almost all the cytoplasm.***
- ***The First Polar Body receives very little.***
- ***It is small nonfunctional cell that soon degenerates.***

OOGENESIS



- ***At ovulation, the <u>secondary oocyte begins</u> the <u>second meiotic division</u> but progresses only to <u>metaphase</u> where division is arrested.***

OOGENESIS



- ***If the secondary oocyte is fertilized, the second meiotic division is completed otherwise it degenerates 24 hours after ovulation.***
- ***Most of the cytoplasm is retained by the Mature Oocyte (Fertilized Oocyte).***
- ***The rest is in the 2nd Polar Body which soon degenerates.***

DURING FETAL LIFE	AFTER PUBERTY DURING EACH OVARIAN CYCLE	AFTER FERTILIZATION
Proliferation: each oogonium divides by mitosis into 2 daughter oogonia (with diploid number of chromosomes: (44 + XX) **Growth:** oogonium enlarges to form primary oocyte (with diploid number). Primary oocytes begin 1st meiotic division which stops at **prophase**	1st meiotic division is completed: (shortly before ovulation): a reduction division by which a primary oocyte divides into one secondary oocyte (haploid number of chromosomes: (22 + X) & 1st polar body (degenerates) 2nd meiotic division begins: begins at ovulation, progresses only to **metaphase** and becomes arrested.	2nd meiotic division is completed: 2ry oocyte divides into a mature ovum (haploid number) & 2nd polar body (degenerates).

N.B.: NO PRIMARY OOCYTES FORM AFTER BIRTH

The Reproductive Cycles of Females

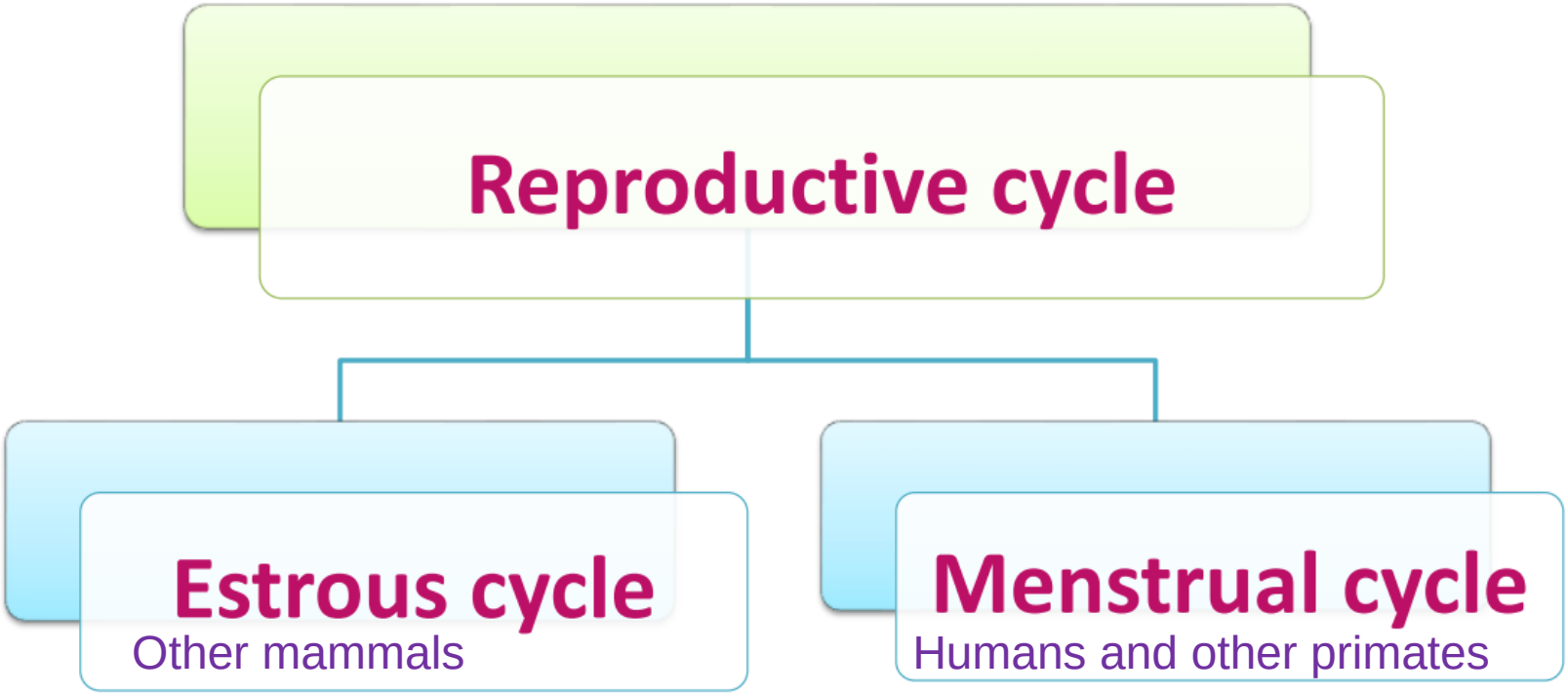
The Reproductive Cycles of Females

Reproductive Cycle :

- Periodic changes in **ovary** and **uterine endometrium** of reproductively matured females in most mammals to become capable of breeding and to give birth of young is called reproductive cycle.
- This is finely regulated by a set of hormones from pituitary and ovary.

Menstrual Versus Estrous Cycles

- Two different types of cycles occur in females



- In both cases ovulation occurs at a time in the cycle
  - After the endometrium has started to thicken in preparation for implantation

Menstrual Versus Estrous Cycles

- **In menstrual cycles**
  - The endometrium is shed from the uterus in a bleeding called menstruation
  - Sexual receptivity is not limited to a specific timeframe

- **In estrous cycles**
  - The endometrium is reabsorbed by the uterus
  - Sexual receptivity is limited to a “heat” period

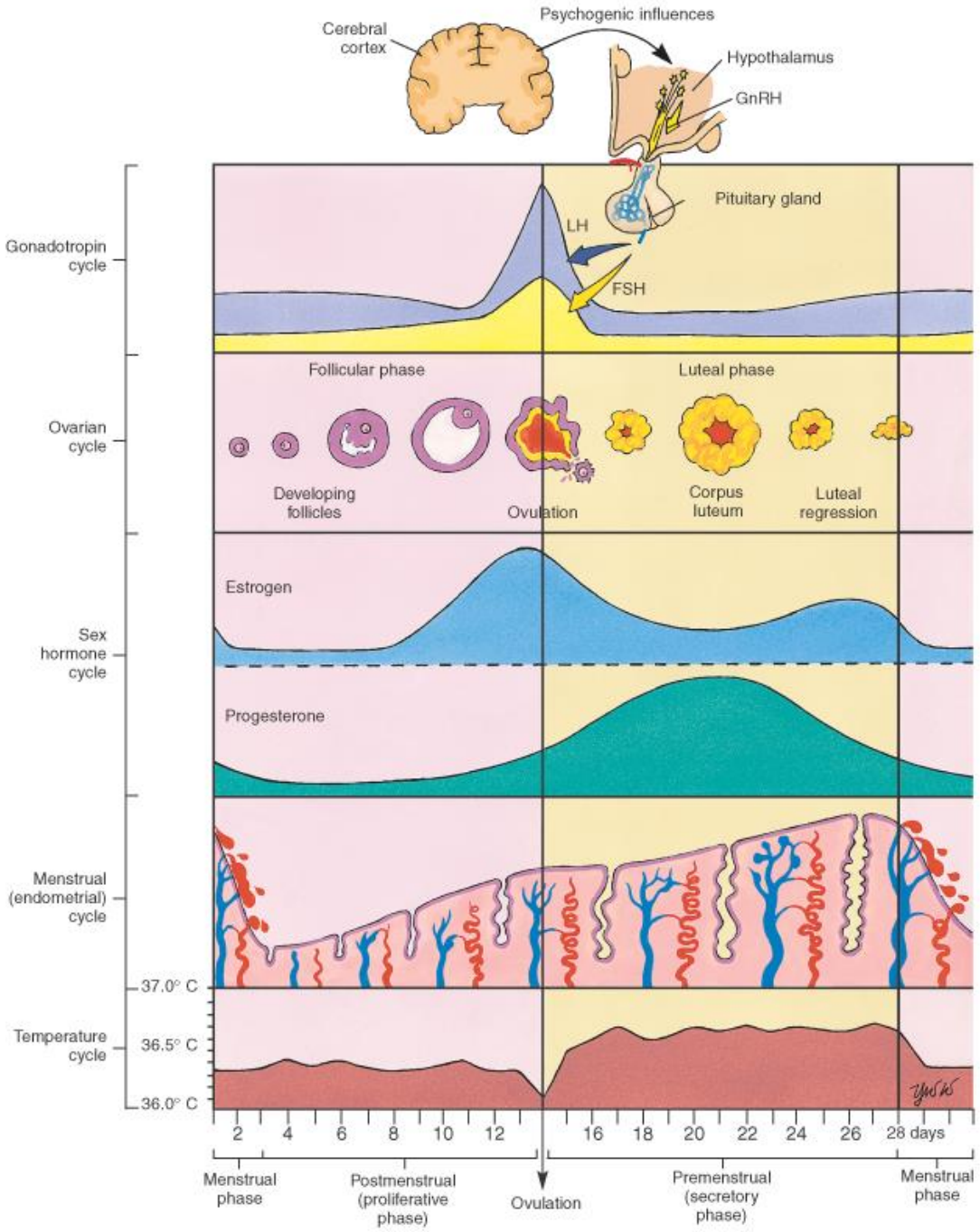
The Human Female Reproductive Cycle: A Closer Look

Menstrual Cycle = Uterine & Ovarian Cycles

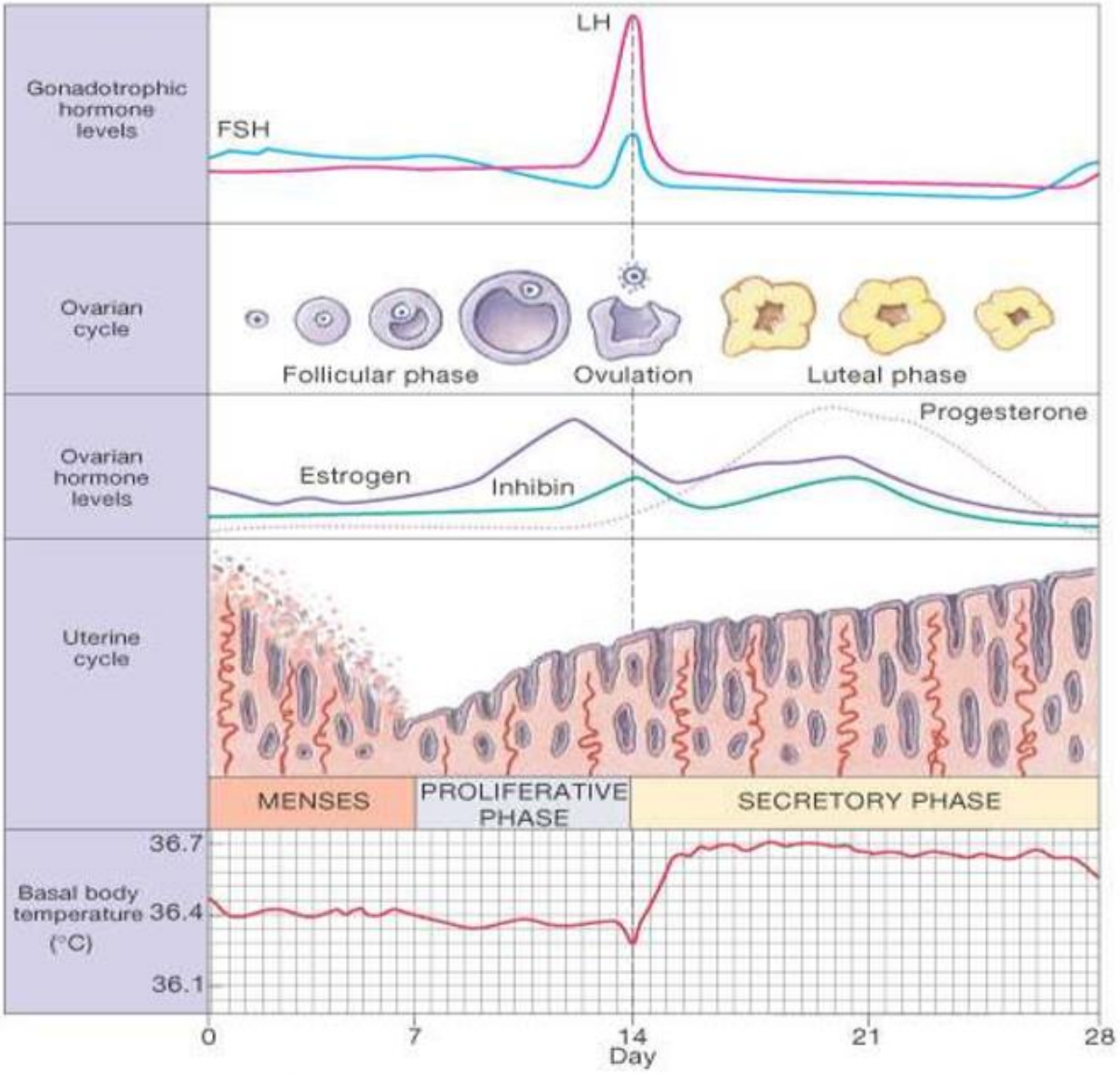
- occurs in non-pregnant women from puberty (12-14 yrs) until menopause (45-55 yrs)
- cyclic changes that occur on the average every 28 days (range 21 to 35 days) to the endometrium correlating with cyclic changes in the ovaries as regulated by female hormones

Stages:

1. Menstruation
   - discharge of blood and endometrial tissue from the vagina
   - lasts approximately 3 days
   - ends as a new follicle develops in the ovaries



The Menstrual Cycle



2. Proliferative stage – Follicular

- follicle matures in the ovary and secretes estrogen

- estrogen stimulates the restoration and thickening of the endometrium in preparation for receiving a fertilized egg

- days 4 – 14

3. Ovulation

- release of a mature egg from the ovary

- normally on day 14

- caused by the surge of LH

4. Secretory Stage (premenstrual or luteal phase):

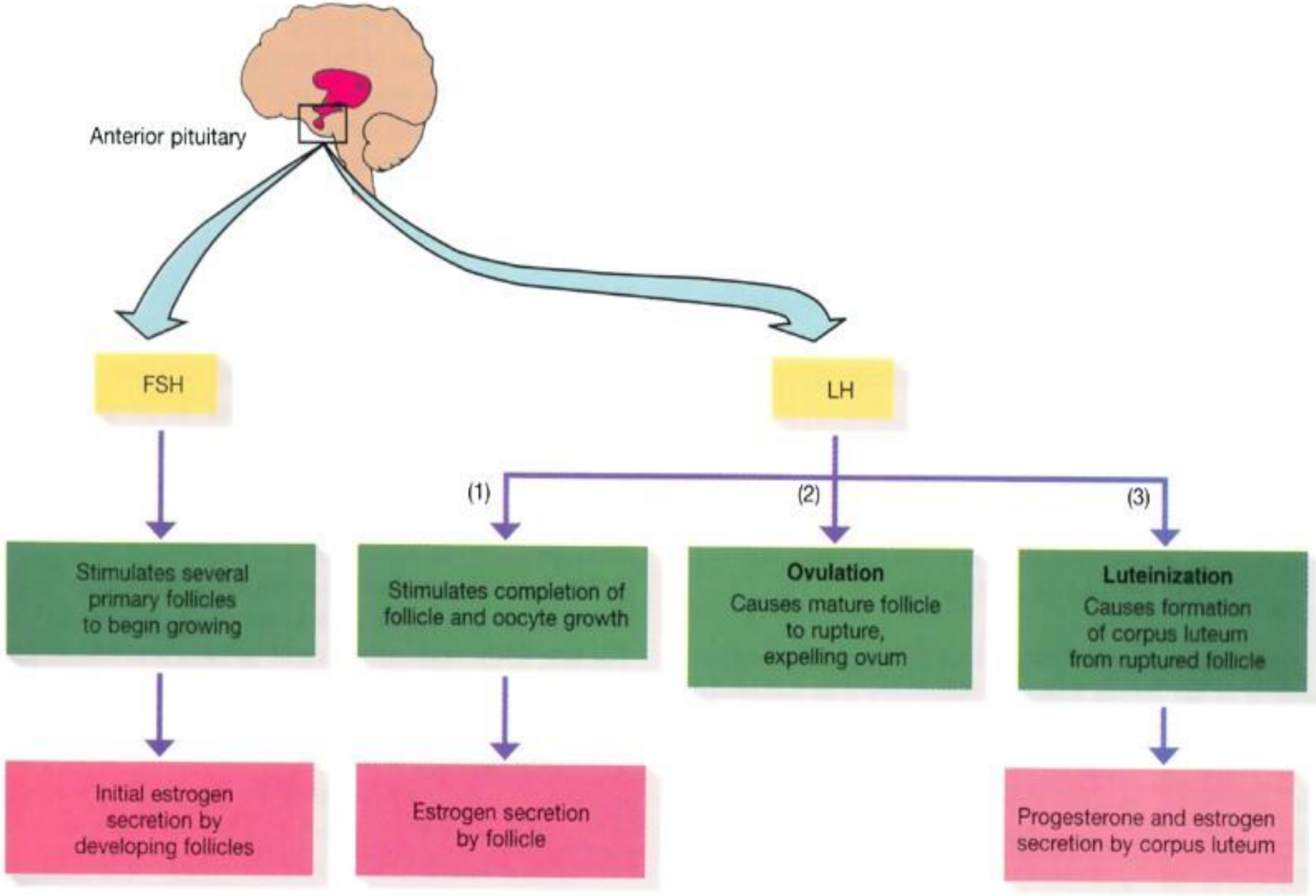
- ruptured follicle develops into the corpus luteum which releases progesterone

- progesterone causes the endometrium to thicken further

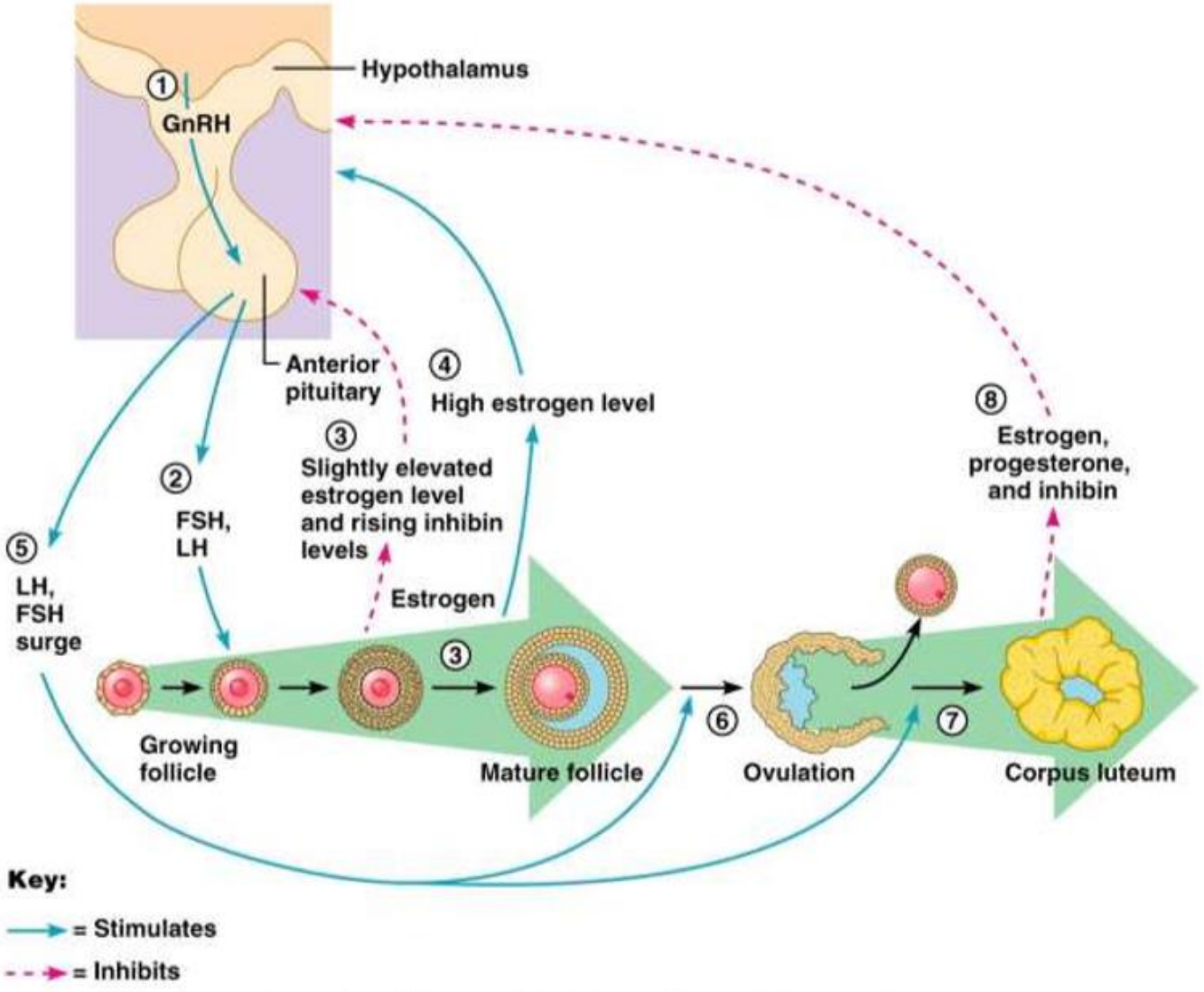
-days 15 – 28

- if fertilization is not achieved, corpus luteum regresses, progesterone level decreases and endometrium sloughs off along with unfertilized egg (menses)

Pituitary Gland produces luteinizing hormone (LH) and follicle stimulating hormone (FSH) which maintain the follicle and corpus luteum



Regulation of ovarian function



Estrous Cycle

In Animals

Estrous Cycle

- • Found in most mammals except primates
- • Derived from Latin oestrus meaning "frenzy".
- • There is a brief period of reproduction called heat period or estrus

Estrus (heat, estrous period)

- Period of time when a female will accept a male in copulation
- The female must stand **(standing heat)** to be mounted before the reproductive process can begin
- Estrus detection methods: visual inspection, teaser animals, marker aids

- • 4 phases- proestrus, estrus, metestrus or diestrus and anestrus

DEFINITIONS:

- ESTROUS CYCLE: Reproductive cycle of female, generally defined as period from one estrus to the next.

- Two phases:
  - Follicular Phase
  - Luteal phase

TYPES OF ESTROUS CYCLE

Cycle is categorized by frequency occurrence throughout the year:

1- Polyestrus: Uniform distribution of estrous

- cycles which occur regularly throughout the year
- • Example: Cattle, Swine, Rodents

2- Seasonally polyestrus:

Cycles occur only during certain times of the year

• Long-day breeders:

– Cycle when day length increases

Example: Mare

• Short-day breeders:

– Begin to cycle as day length decreases

Example: "Sheep and Goats"

3- Monoestrus:

One cycle per year

- Periods of estrus last for several days
- Example: Dogs, Wolves, Foxes, Bears

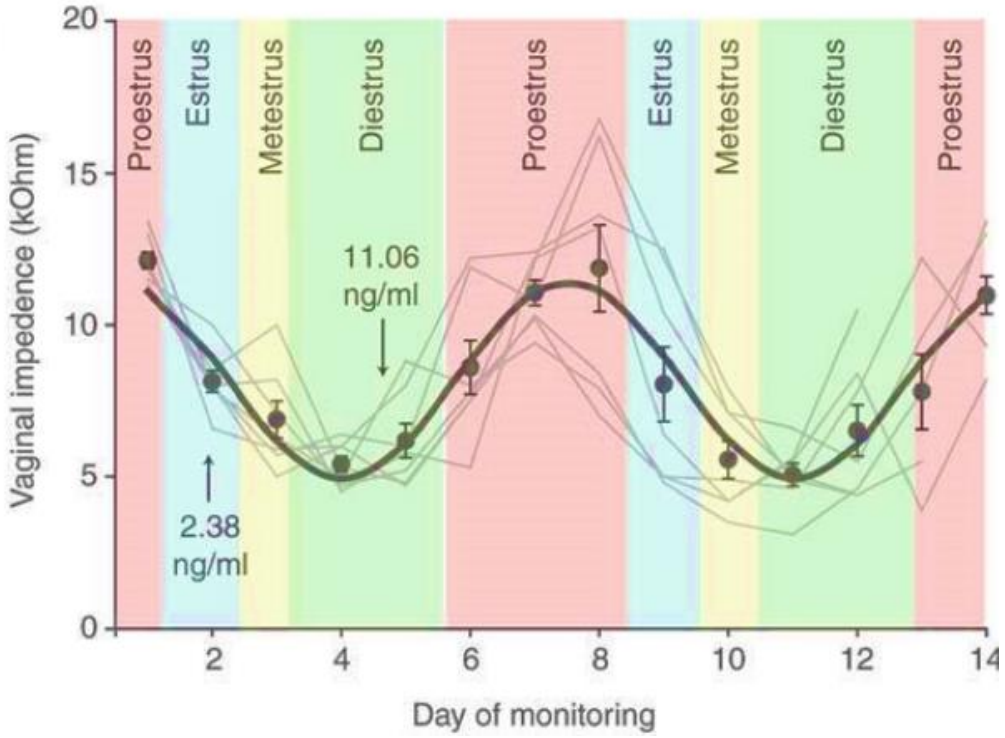
PHASES OF ESTROUS CYCLE

- FOLLICULAR PHASE:
  - – Short phase - only 20% of cycle
  - – Period from regression of corpus luteum to ovulation
  - – Preovulatory follicle
  - – Dominant hormone is estradiol

- LUTEAL PHASE:
  - – Long phase - 80% of cycle
  - – Period from ovulation to corpus luteum regression
  - – Corpora lutea
  - – Dominant hormone is progesterone
  - – Follicle continue to grow and regress during this
  - phase

STAGES OF ESTROUS CYCLE

- Four stages:
  - – Proestrus
  - – Estrus
  - – Metestrus
  - – Diestrus



- • Follicular phase = Proestrus + Estrus
- • Luteal phase = Metestrus + Diestrus

STAGES OF ESTROUS CYCLE

- **PROESTRUS**
  - • Begins when progesterone declines(luteolysis) and ends at onset of estrus
  - • Lasts 2 to 5 days
  - • Period of major endocrine transition
  - Progesterone dominance to estrogen dominance
  - FSH and LH responsible

- **“Building Up”**
  - – Ovarian follicle, with enclosed ovum, increase in size
  - – Estrogens absorbed from the follicles into
  - blood stream stimulate increased vascularity
  - and cell growth of tubular genitalia, in
  - preparation for estrus and pregnancy

STAGES OF ESTROUS CYCLE

- **Estrus**
  - • Period of sexual receptivity
  - • Large increase in estrogen
    – stimulates release of GnRH
  - • FSH decreases due to estrogen and inhibin
    – During or shortly after estrus, ovulation occurs due to major surge in LH
  - – LH levels increase due to GnRH
  - – Estrus stops once ovulation occurs.

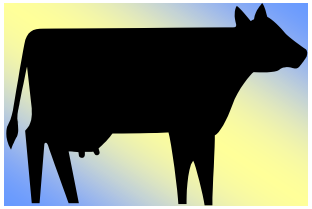
STAGES OF ESTROUS CYCLE

- **Metestrus**
  - • Corpus Luteum predominant
  - • ↑Increase in progesterone, ↓ decrease in estrogen
  - • Endometrial lining thickens and uterine
  - muscles show increased development.

- **Diestrus**
  - Relatively short period of time between estrous cycles during the breeding season of polyestrous animals
  - No reproductive activity

Summary of Stages

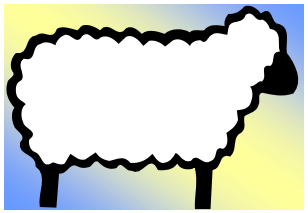
- • **Proestrus** = Formation of ovulatory follicle + E2 secretion
- • **Estrus** = Sexual recepitivity + peak E2 secretion
- • **Metestrus** = CL formation + beginning of P4 secretion
- • **Diestrus** = Sustained luteal secretion of P4



Reproductive Cycles

COW

Estrus	10 – 26 hrs. (18 hr avg.)
Estrous Cycle	18 – 24 days (21 day avg.)
Ovulation	4 – 16 hrs. post estrus
Gestation	283 days

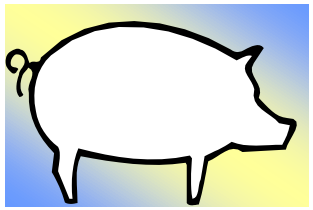


EWE

Estrus	20 – 42 hrs. (30 hr avg.)
Estrous Cycle	15 – 18 days (17 day avg.)
Ovulation	12– 18 hrs. estrus onset
Gestation	150 days

SOW

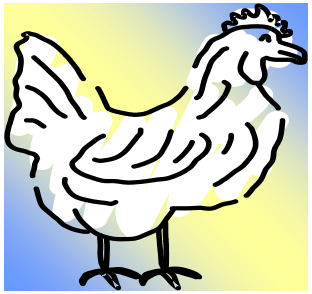
Estrus	1 – 4 days (2 day avg.)
Estrous Cycle	16 – 25 days (21 day avg.)
Ovulation	16 – 48 hrs. estrus onset
Gestation	114 days (3 months, 3 weeks, 3 days)



Reproductive Cycles

GOAT

Estrus	2 – 3 days (2.5 day avg.)
Estrous Cycle	15 – 24 days (21 day avg.)
Ovulation	Near end of estrus
Gestation	151 days



POULTRY

Estrus	20 – 42 hrs. (30 hr avg.)
Estrous Cycle	15 – 18 days (17 day avg.)
Ovulation	12– 18 hrs. estrus onset
Gestation	150 days

MARE

Estrus	4 – 9 days (5 day avg.)
Estrous Cycle	15 – 24 days (21 day avg.)
Ovulation	1 – 2 days before end of estrus
Gestation	336 days