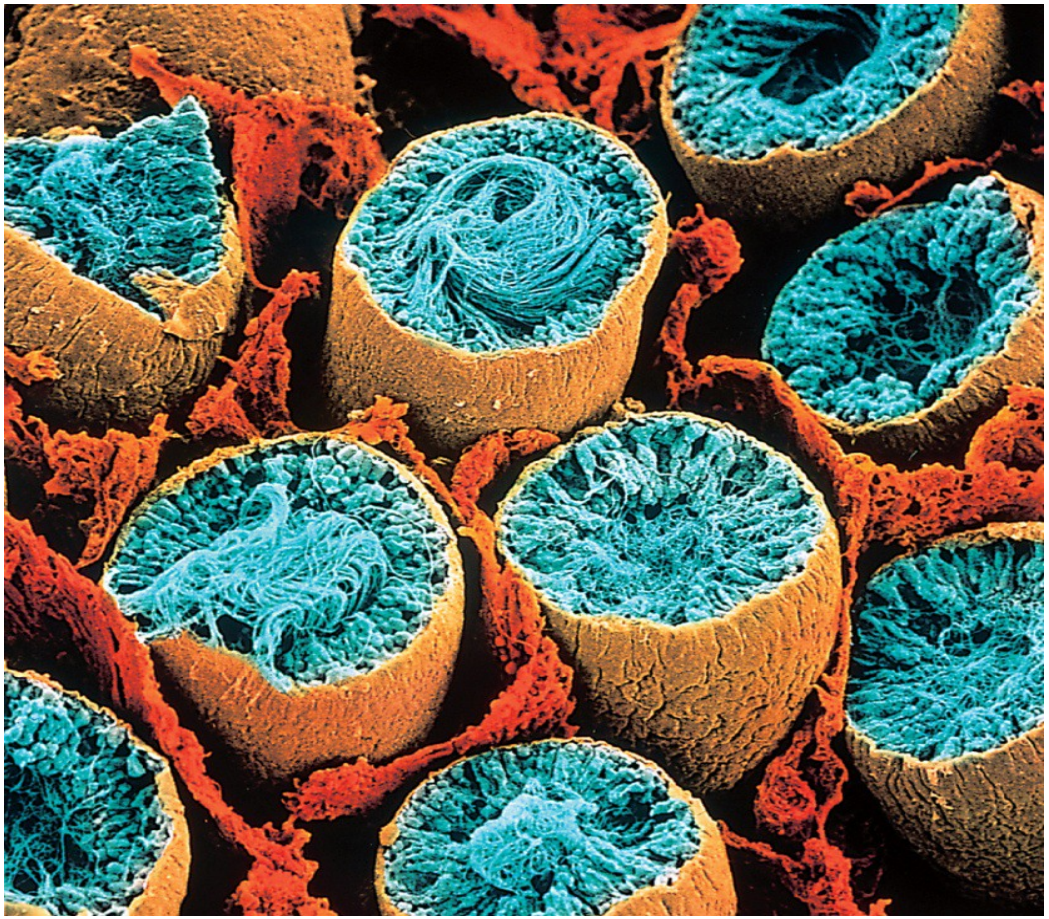
## Chapter 27 & Chapater 28

# Male and Female Reproductive Systems



# Sexual Reproduction

The essence of sexual reproduction is bi-parental

offspring receive “combination” of genes from two parents

offspring is therefore not genetically identical to either parent

parents gonads produce gametes (sperm and eggs) by meiosis

sperm and eggs formed by haploid cell division / union of gametes forms diploid cell

*“We will die, but our genes will live on in a different container, our offspring”.* *Unknown Author*

# Overview of Reproductive System

**Purpose of Sexual Reproduction**

Perpetuate the species

Exchange genetic information between female and male

Allow for the expression of dominate and recessive genes

**Male reproductive system**

produce sperm

sperm = male gamete

deliver sperm to female reproductive system

**Female reproductive system**

produce egg

egg = female gamete

more cyclical than male reproductive system

female reproductive system receives sperm

egg provides all the nutrients for the zygote

harbors the embryo / fetus (conceptus)

nourishes the offspring postpartum

female reproductive system more complicated!

# Gender Characteristics

Secondary sex characteristics = features that distinguish the sexes

- play a role in mate attraction
- both sexes activate apocrine glands to produce pheromones at puberty to attract a mate
- both sexes develop pubic and axillary hair
- female characteristics = redistribution of body fat  breast enlargement, and relatively hairless appearance of the skin
- male characteristics = facial hair, coarse and visible hair on the torso and limbs, relatively muscular physique, deeper voice

# Primary VS Secondary Sex Organs

Primary sex organs

- gonadal tissue produce gametes (ovum and sperm)
- ovaries produce ovums (eggs)
- testes produce sperm

Secondary sex organs

- organs other than the gonads
- necessary for reproduction
- females //  uterine tubes, uterus, and vagina
- males // penis, glands, and ducts

# Endocrine Control of Puberty

Puberty is initiated after nuclei in hypothalamus mature and start to secrete gonadotrophin releasing hormone (GnRH)

Female 10 to 14 years of age

Male 12 to 16 years of age

At time of puberty - GnRH stimulates anterior pituitary to release the “gonadotropes”

follicle stimulating hormone (FSH)

luteinizing hormone (LH)

# The Gametes

Sperm (spermatozoon immature sperm)

flagella provides motility

contributes only it's DNA to zygote / 23 chromosomes

Egg (also called the ovum)

provides all the first cell's cytoplasm, including all the organelles, plus 23 chromosomes to zygote

provides all nutrients for now developing blastocyte

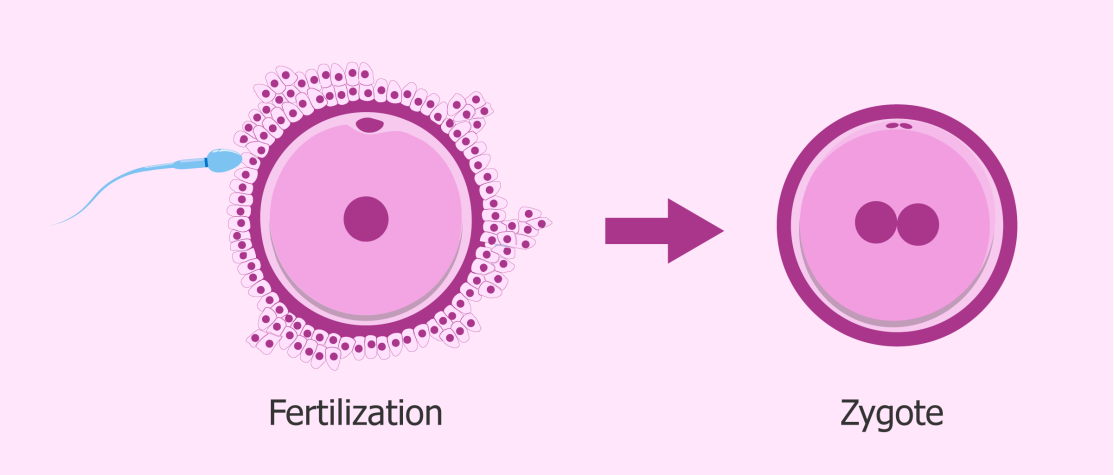
in mammals, female is the parent that provides a sheltered internal environment and prenatal nutrition of the embryo

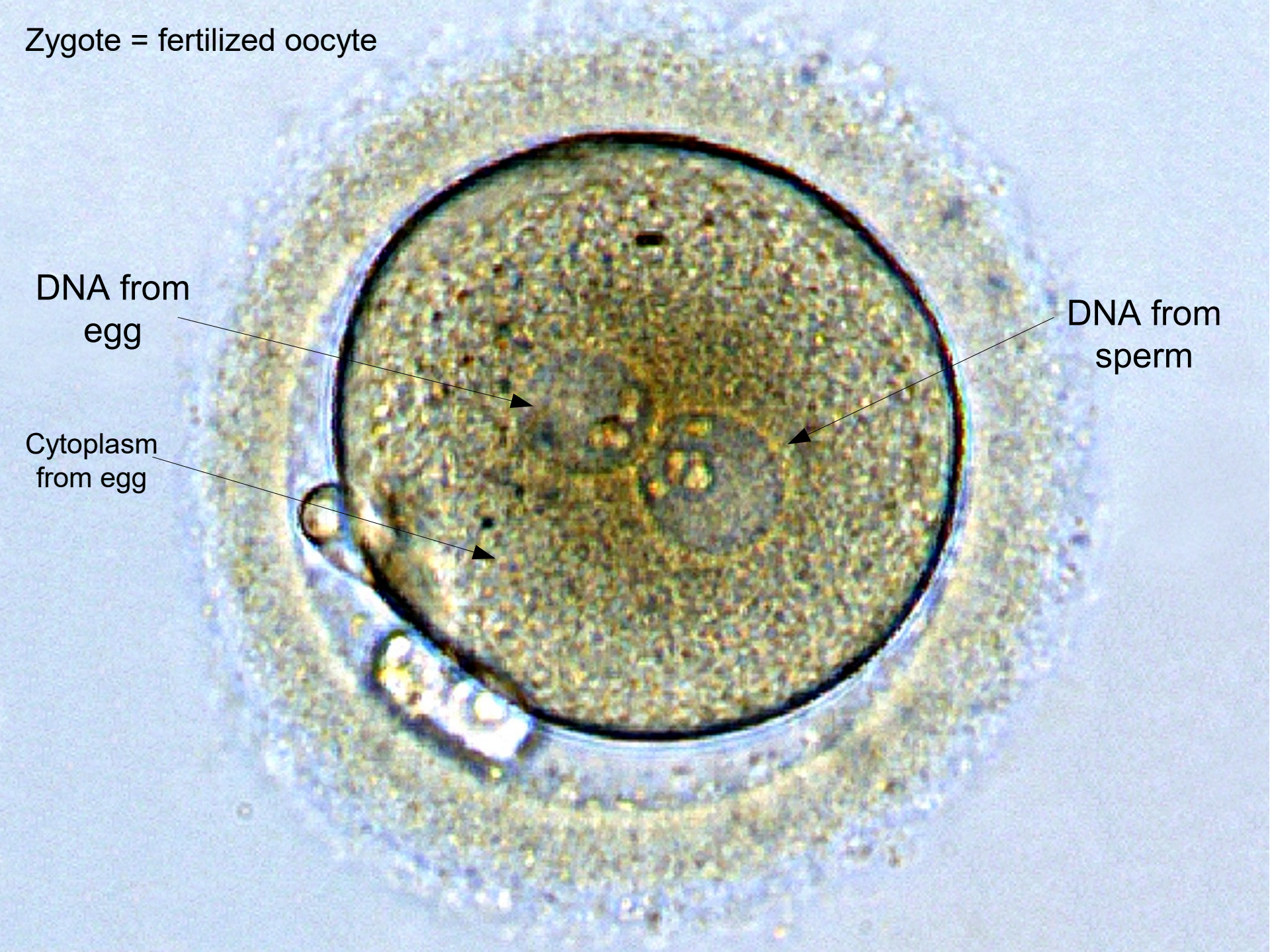
# What is the first human diploid cell?

The sperm is a haploid cell (23 chromosomes) /// Males have an organ (the penis) to deliver sperm into the female reproductive tract

The ovum (egg) is a haploid cell (23 chromosomes) /// Females have an organ (the vagina) to receive male gamete (sperm)

Zygote = union of male and female gametes (46 chromosomes) /// union occurs in the infundibulum of the female's Fallopian tube /// becomes the <u>first diploid cell!</u>

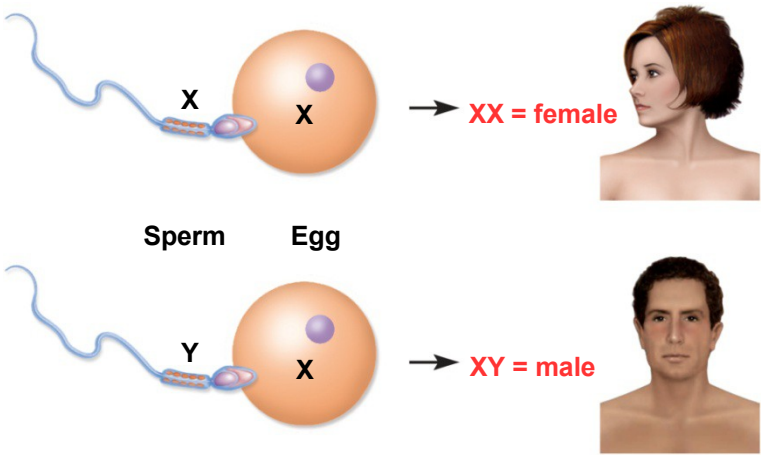



Zygote = fertilized oocyte
DNA from egg
DNA from sperm
Cytoplasm from egg

# Sex Determination

Human cells contain 23 pairs of chromosomes (46 chromosomes!)

- 22 pairs are called autosomes
- 1 pair called sex chromosomes




Sex chromosome either an X or a Y

If sex chromosome pair = XY = males

If sex chromosome pair = XX = females

Male gamete carry both a Y and a X chromosome

Female gamete carry only two X chromosomes

In gamete formation (haploid cell division = meosis) // the sex chromosomes are "split" /// each gamete will only have one of the two sex chromosomes /// when zygote forms – it will have one from each parent

# Chromosomal Sex Determination

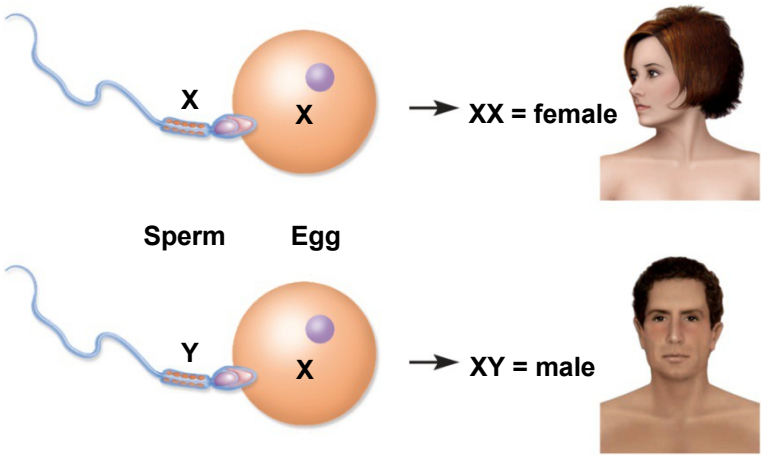
Sex of child determined by which chromosome is provided by the sperm (male)

Sperm may contribute either X or Y

Egg (female) may only provide “X” chromosome

If X carrying sperm fertilizes the egg then fetus = female

If Y carrying sperm fertilizes the egg then fetus = male

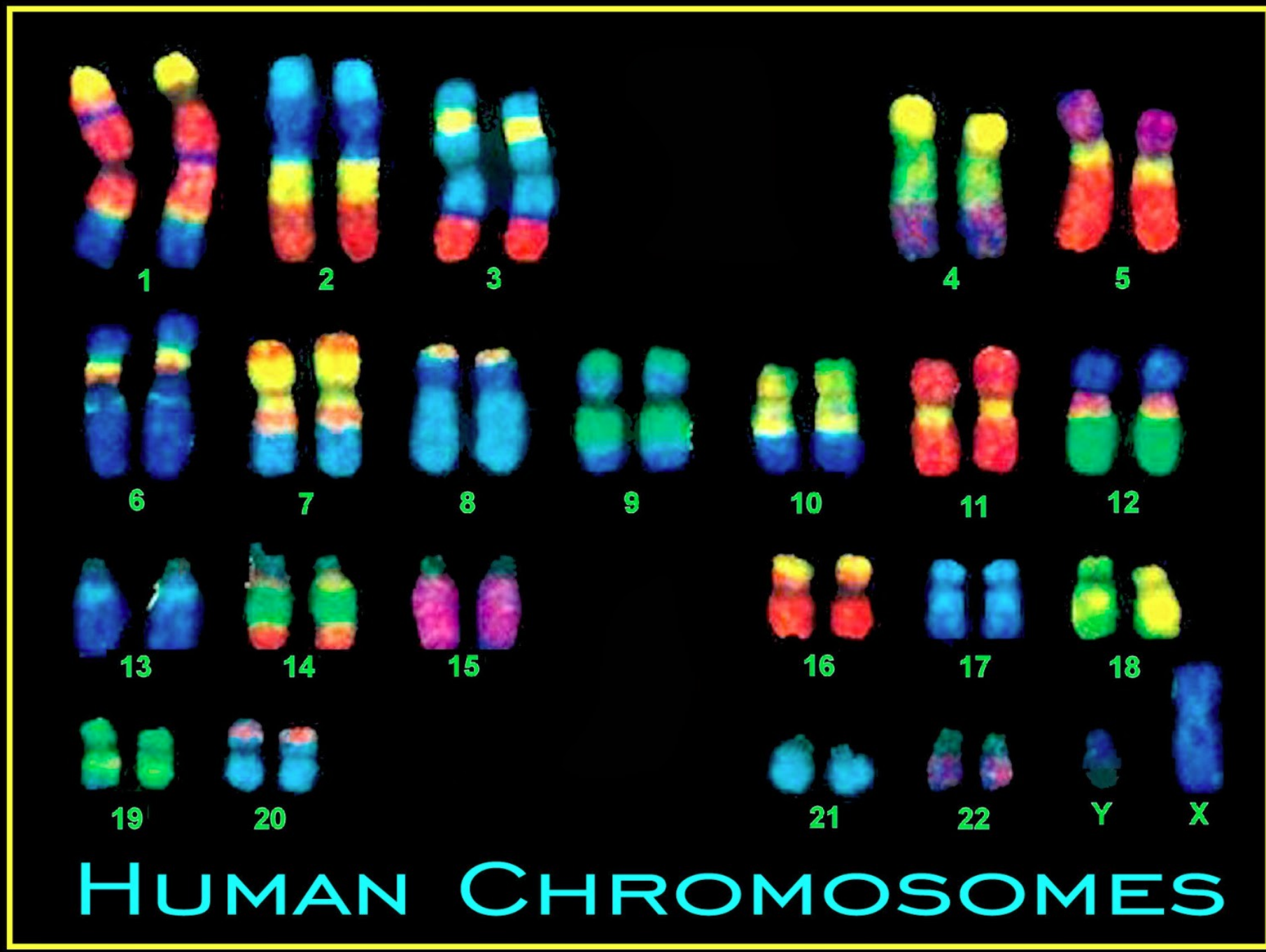



| | X | Y |
|---|---|---|
| X | X X | X Y |
| X | X X | X Y |

Punnet Square

# Chromosomes

- Humans have 46 chromosomes (**diploid** =2N)
- 2 of them are **sex chromosomes** (the last pair)
  - X and Y→ they determine what sex you are
    - XX = female
    - XY = male
- 44 of them are **autosomes**
  - they do **not** determine the sex of an individual.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HUMAN CHROMOSOMES

# Meiosis

Meiosis is haploid cell division /// reduce chromosome number by half

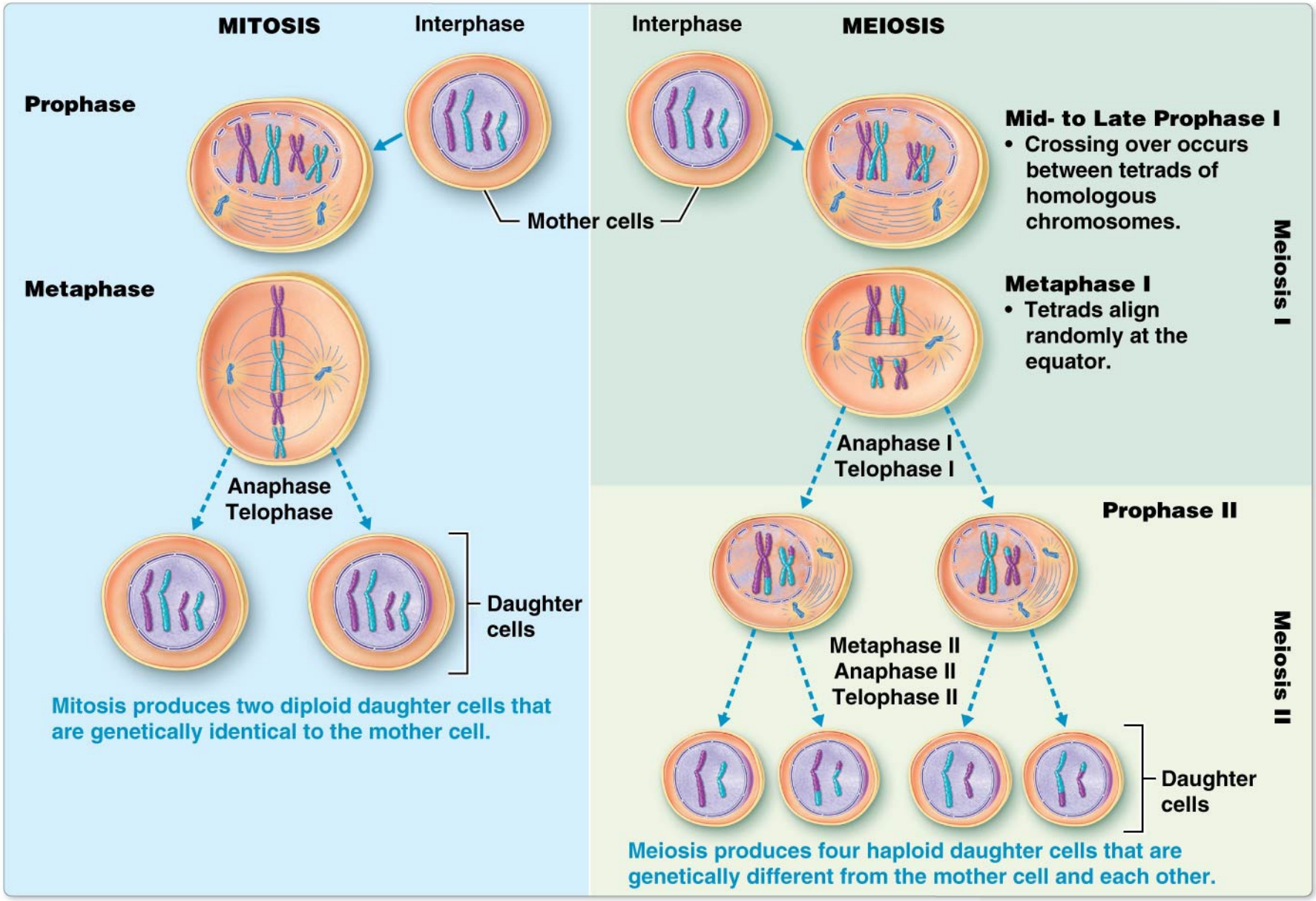
Type of cell division seen only in the formation of gametes // in gonads // females = ovaries produce eggs // males = testes produce sperm

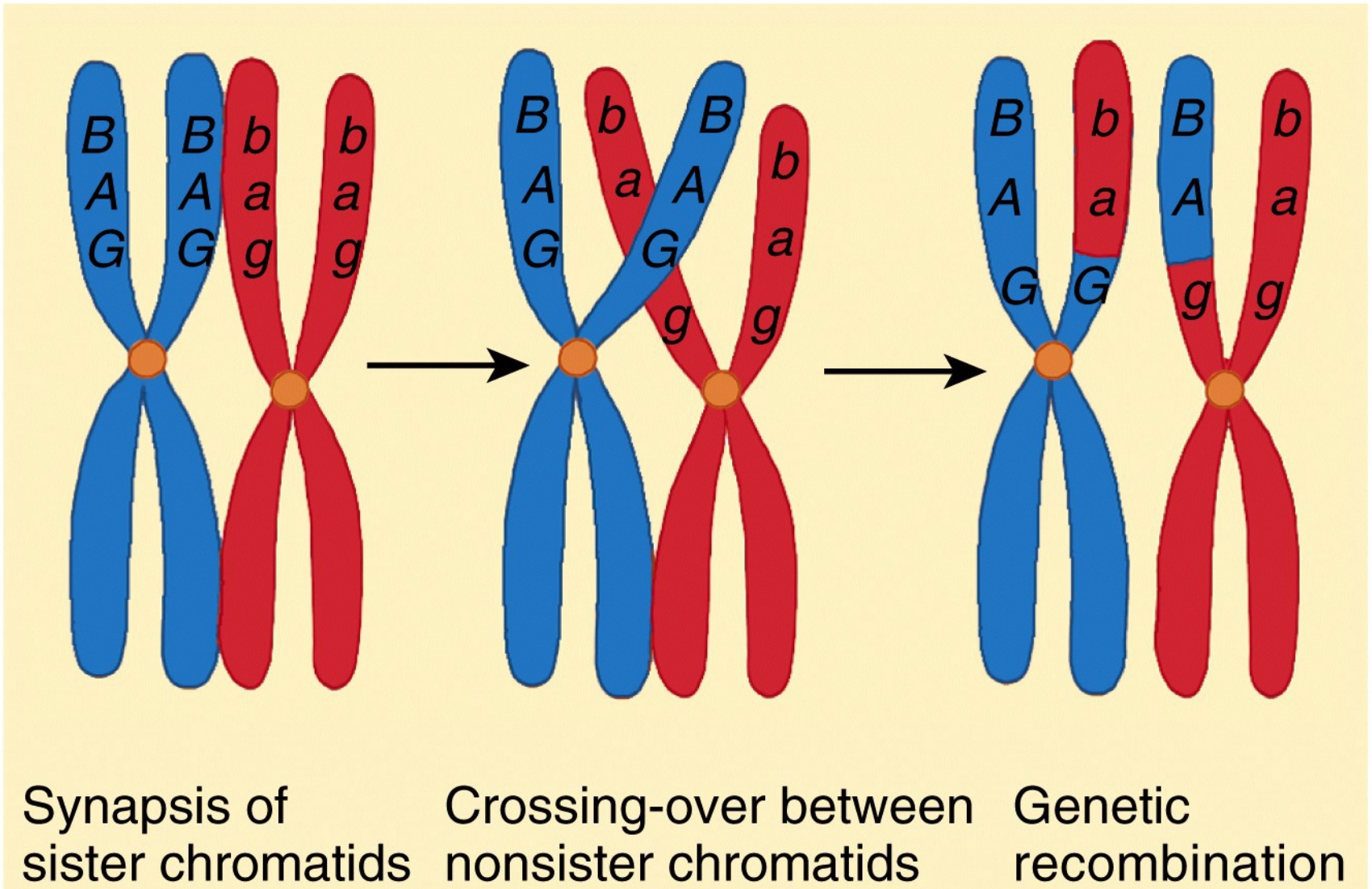
Humans reduce chromosome number from 46 to 23 chromosomes

Sperm and egg haploid cells unite to form a zygote with 46 chromosomes

Note: mitosis conserves the chromosomal number /// epithelial cells use mitosis to make copy of itself. /// somatic cells

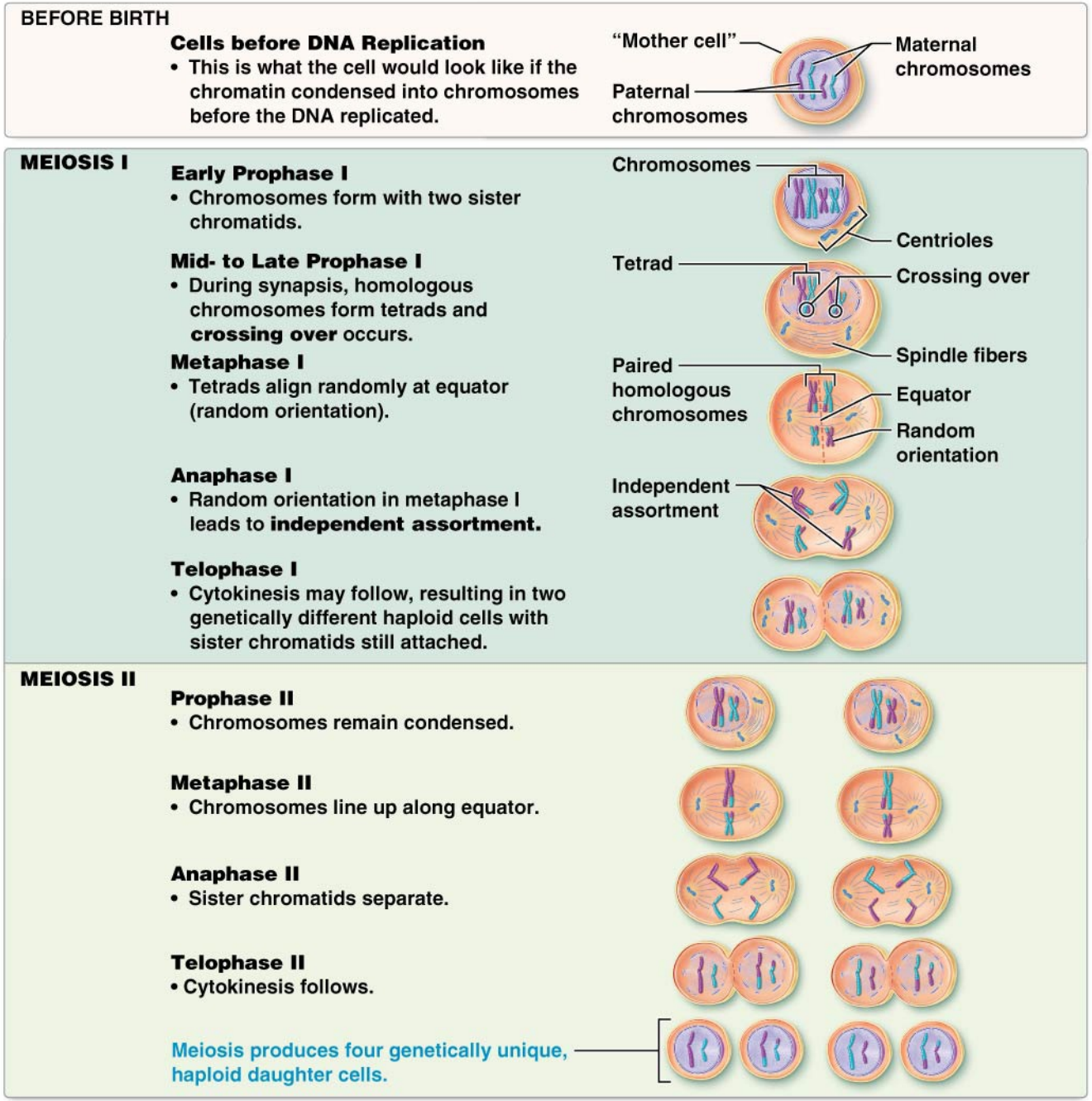
# Comparing Mitosis and Meiosis






(b) Details of crossing-over during prophase I

**Stages of meiosis. For simplicity, the cell is shown with only two pairs of homologous chromosomes.**

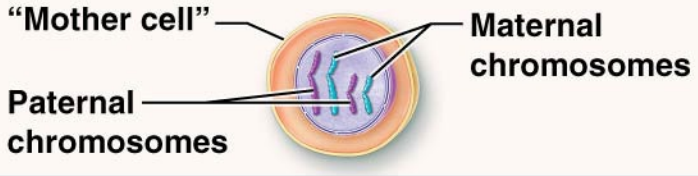


**Stages of meiosis. For simplicity, the cell is shown with only two pairs of homologous chromosomes.**

BEFORE BIRTH

**Cells before DNA Replication**

- This is what the cell would look like if the chromatin condensed into chromosomes before the DNA replicated.




MEIOSIS I

**Early Prophase I**

- Chromosomes form with two sister chromatids.

**Mid- to Late Prophase I**

- During synapsis, homologous chromosomes form tetrads and **crossing over** occurs.

**Metaphase I**

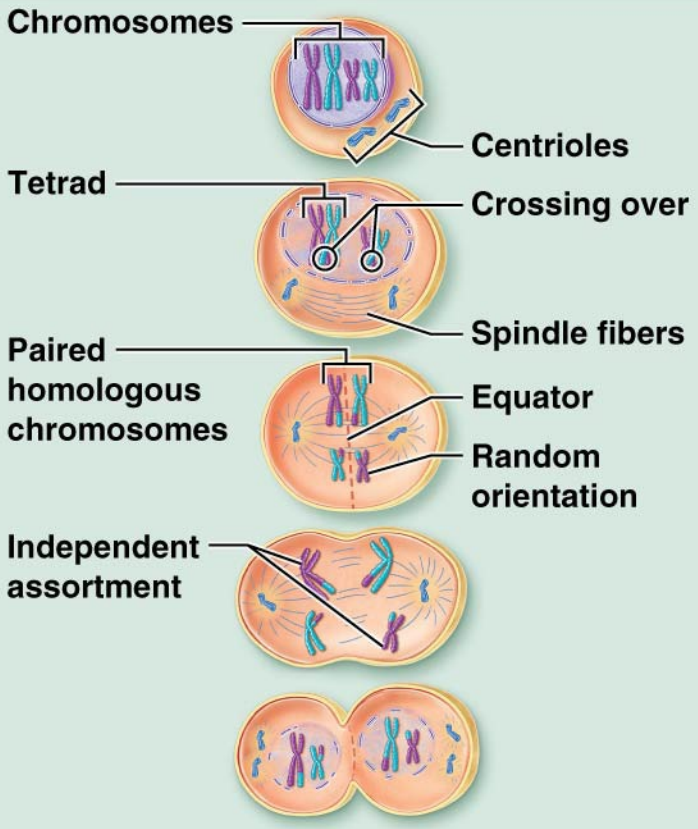
- Tetrads align randomly at equator (random orientation).

**Anaphase I**

- Random orientation in metaphase I leads to **independent assortment.**

**Telophase I**

- Cytokinesis may follow, resulting in two genetically different haploid cells with sister chromatids still attached.



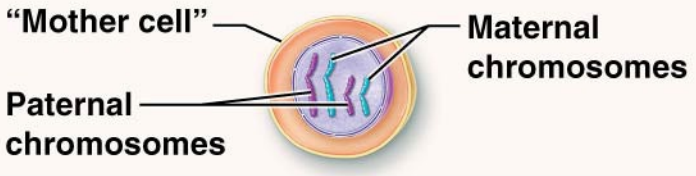
# Stages of meiosis.

**For simplicity, the cell is shown with only two pairs of homologous chromosomes.**

BEFORE BIRTH

**Cells before DNA Replication**

- This is what the cell would look like if the chromatin condensed into chromosomes before the DNA replicated.




MEIOSIS II

**Prophase II**

- Chromosomes remain condensed.

**Metaphase II**

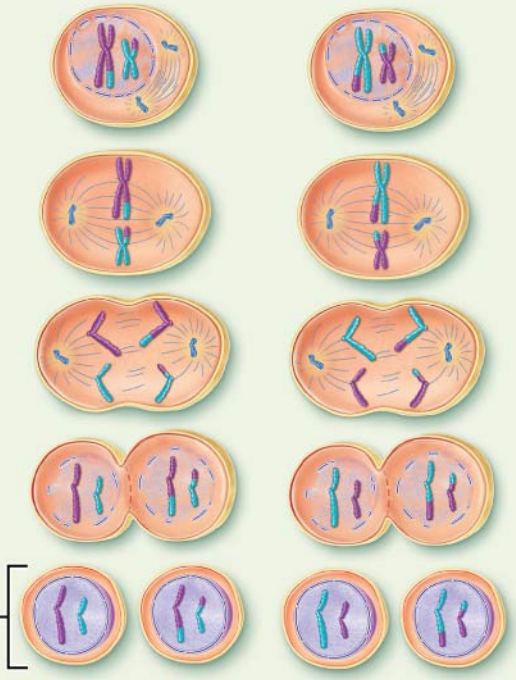
- Chromosomes line up along equator.

**Anaphase II**

- Sister chromatids separate.

**Telophase II**

- Cytokinesis follows.

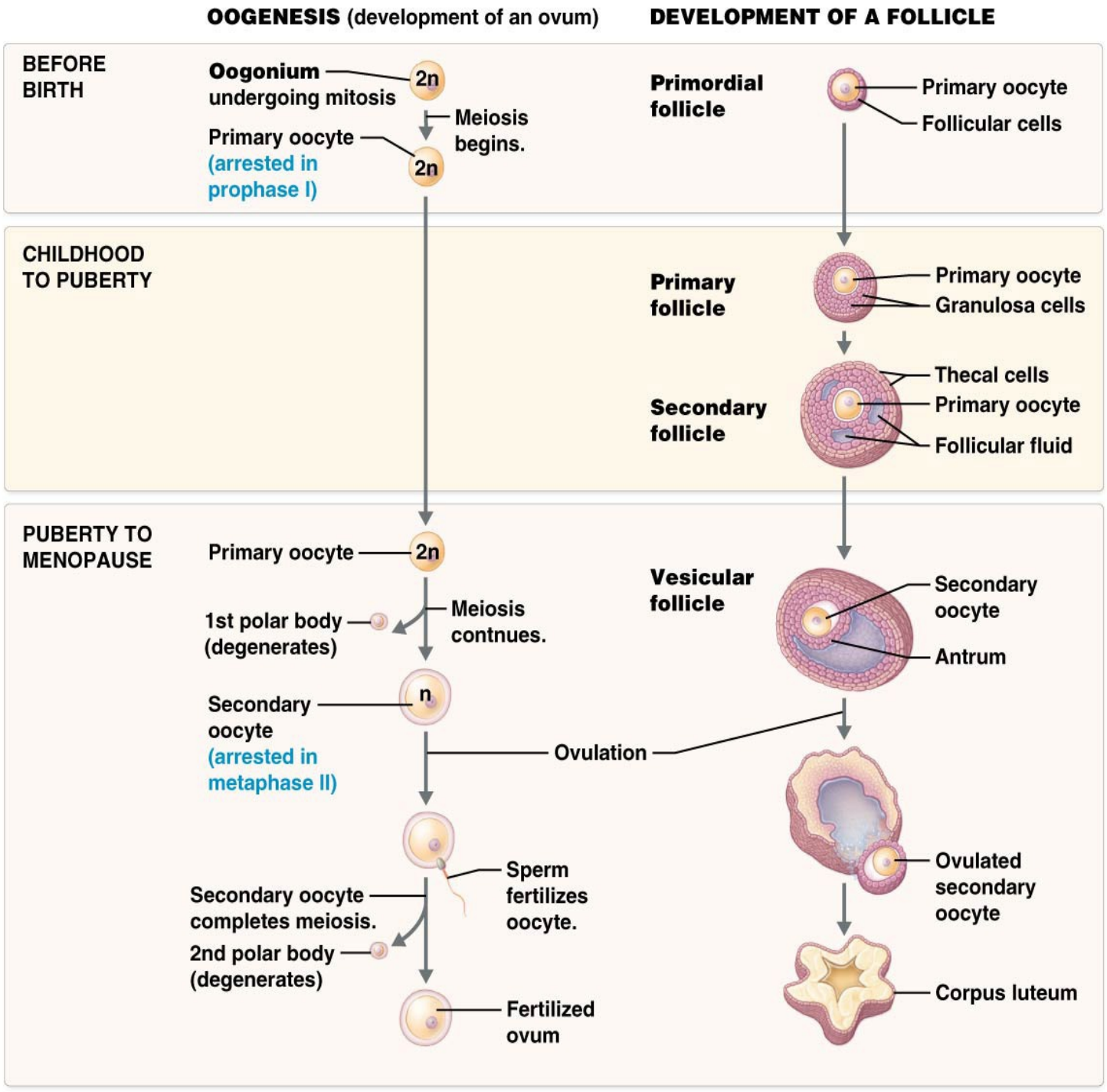


Meiosis produces four genetically unique, haploid daughter cells.

At birth female have approximately 4 million primary oocytes per ovary.

At pubery the number of primary oocytes have dropped to 400,000 per ovary.

Only about 400 primary oocytes will reach maturity and ovulate during a woman's reproductive lifetime.



- Many of these hormones function in male and females physiology but have different target tissues that trigger different types of functions in female and male reproductive physiology.

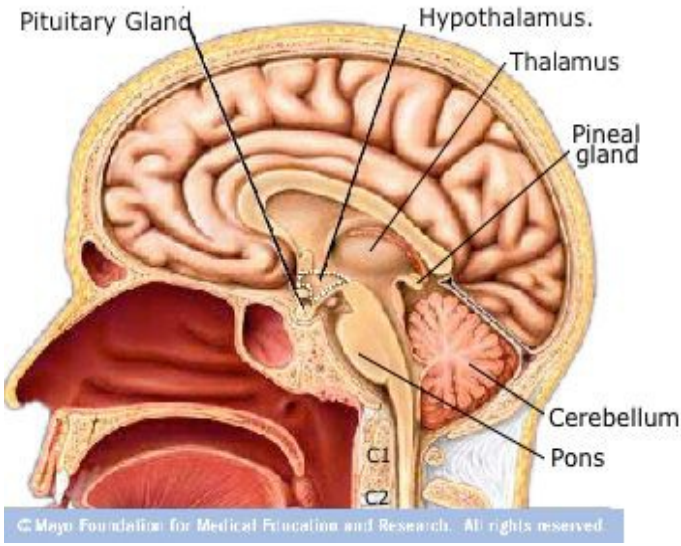
- Describe the following hormones as to their site of production, function, and target tissues:

  - Gonadotropin Releasing Hormone
  - Follicle stimulating hormone (FSH)
  - Luteininzing hormone (LH) or interstitial cell stimulating hormone (ICSH)
  - Human chorionic gonadotropin (hCG)
  - Prolactin
  - Oxytocin
  - Estrogen
  - Progesterone
  - Inhibin
  - Testosterone
  - Relaxin

-

# Gonadotropin Releasing Hormone

- Starts the sexual cycle in males and females
- GRH produced by nuclei in hypothalamus
- Delayed nuclei maturation /// secretion begins when nuclei completes development – this initiates puberty
- GRH target tissue anterior pituitary (via portal system)
- Stimulates release of follicle stimulating hormone and luteinizing hormone from anterior pituitary
- GRH similar function in male and female physiology....however
- LH and FSH different target tissue in genders // timing of maturation also gender different

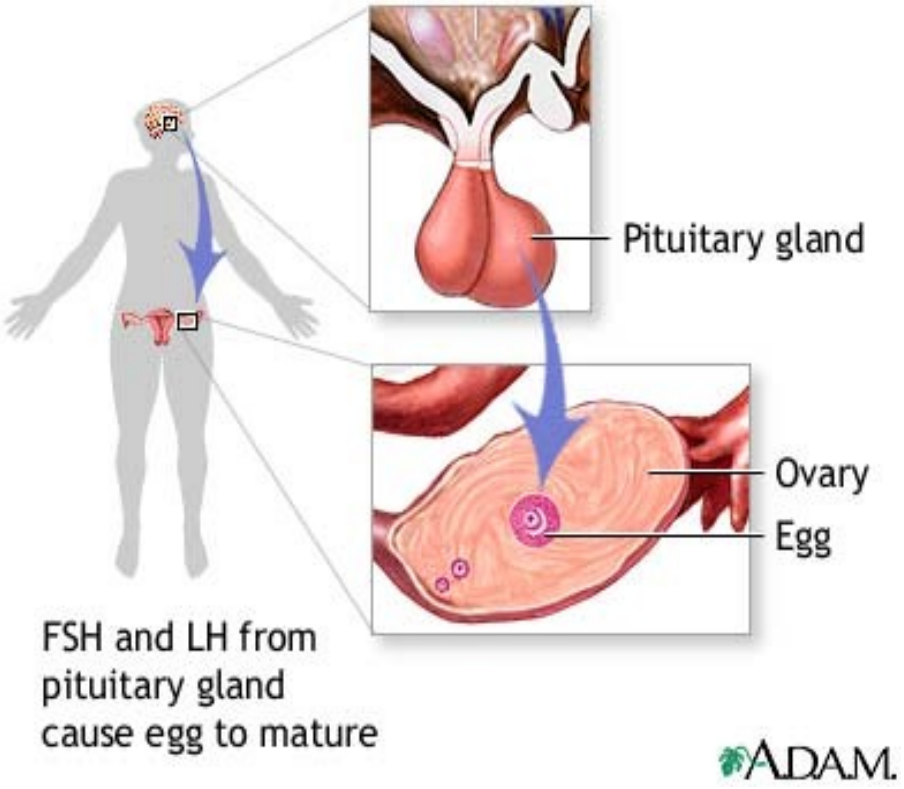



Note

GRH is released later in males and earlier in females

# Follicle Stimulating Hormone (FSH) - Females

- FSH produced by anterior pituitary
  - Target tissue = primoidal eggs in ovaries
  - Stimulates growth of follicles (early stage of ovum / egg)
  - Stimlate follicles to secrete estrogen
  - One follicle upregulated with FSH receptors as FSH secretion decreases
  - Only follicle with most receptors continues to grow! /// this will become a graafian follicle

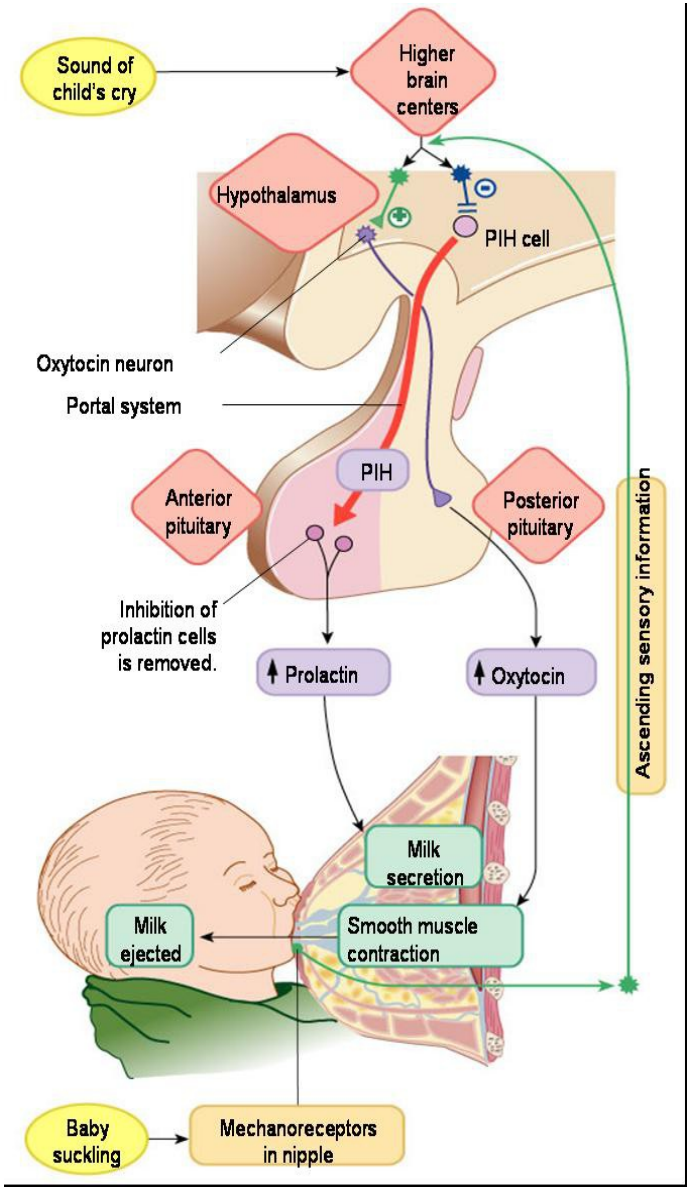


# Luteininzing hormone (LH) - Females

- LH produced by anterior pituitary
  - target tissue = mature eggs in ovaries
  - Spike in LH production near day 14 initiates ovulation
  - binds to follicular cells remaining on surface of ovary // converts follicular cells into corpus luteum
  - Corpus luteum secretes inhibin, relaxin, progesterone (small amount of estrogen)
  - Starts luteal phase of the ovarian cycle / second 14 days of ovary cycle

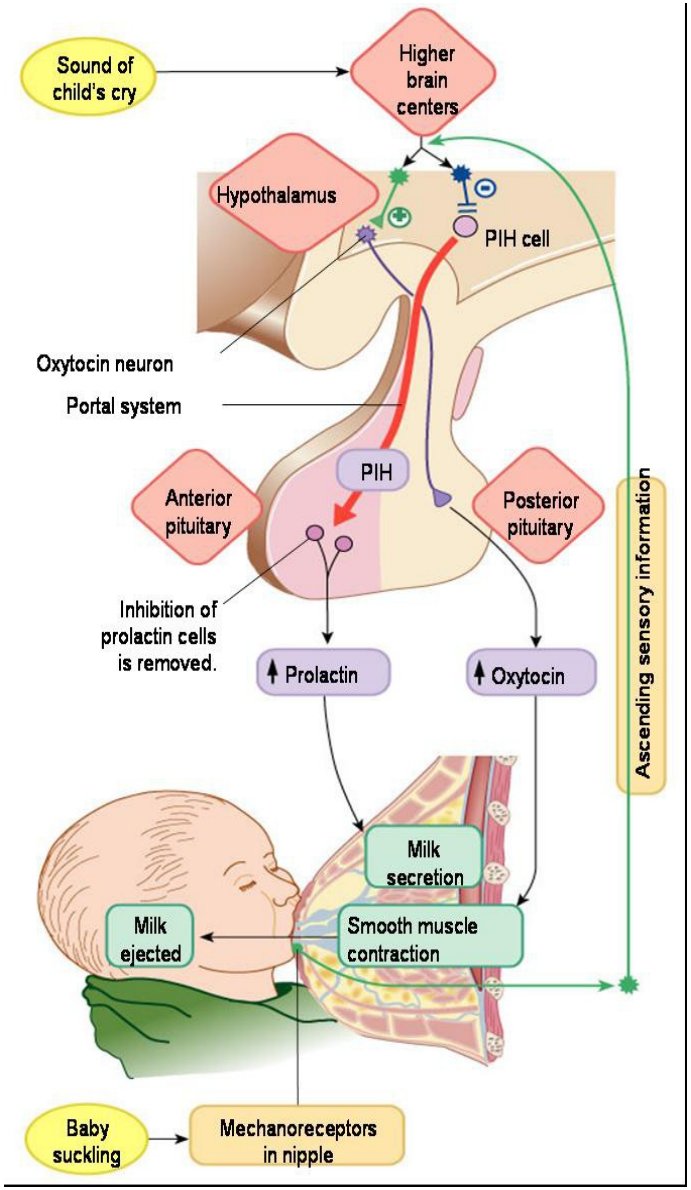
# Prolactin

- Females physiology
  - Released from anterior pituitary // normally inhibited until after birth
  - Target tissue = epithelial glandular cells of the mammary gland
  - Mammary gland needs to be “primed” by estrogen and progesterone which occurs during pregnancy
  - Prolactin stimulates milk production



# Oxytocin

- Females // Released from posterior pituitary // involved in two different "neuroendocrine reflexes"
  - Receptors located on myometrium of uterus // parturition
  - Receptors located on smooth muscle associated with mammary gland // milk let down reflex
  - Receptors in brain // emotional bonding - psychological bonding between mother and baby



# Estrogen

- Females //  Released from different tissues at different times during the sexual cycle and throughout pregnancy
  - FSH stimulate primordial follicles in ovary to produce estrogen
  - After ovulation, corpus luteum produces estrogen as well as progesterone, relaxin, and inhibin
  - After CL stops producing hormones then placenta produces estrogen, relaxin, and progesterone
  - Estrogen has multiple functions:
    - development of secondary sexual characteristics
    - tissue growth in mammary glands
    - responsible for proliferation phase of the menstrual (uterine)  cycle
    - makes cervical canal less viscous
    - mimics the effects of aldosterone (water retention)

# Progesterone

- Females // Released from different tissues at different times during the sexual cycle and pregnancy
  - Produced first by corpus luteum and later by placenta
  - Maintains endometrium /// need to determine if egg will be fertilized and if a placenta can be established
  - Responsible for secretory phase of the menstrual cycle
  - If placenta formed then placenta will produce progesterone and corpus luteum no longer needed – becomes corpus albicans
  - Multiple functions: development of secondary sexual characteristics / tissue growth in mammary glands (ducts) / secretory phase of the menstrual cycle
  - Diuretic effect // opposite effect of estrogen
  - Makes cervical canal more viscous

# Inhibin

Female physiology

- Secreted by corpus luteum
- Target tissue - anterior pituitary
- Inhibits the release of FSH // this delays the start of a new cycle (note – estrogen also inhibits FSH)
- The delay is needed to see if zygote implants in endometrium and if the pregnancy is still viable

# Relaxin

- Female physiology
  - produced first by corpus luteum and then later by placenta
  - “quiets” uterine contraction //  therefore aids in the implantation of blastocyte
  - later in pregnancy the hormone “softens” the connective tissue in the pelvic girdle
  - prepares the pelvic girdle for parturition

# Human chorionic gonadotropin (hCG)

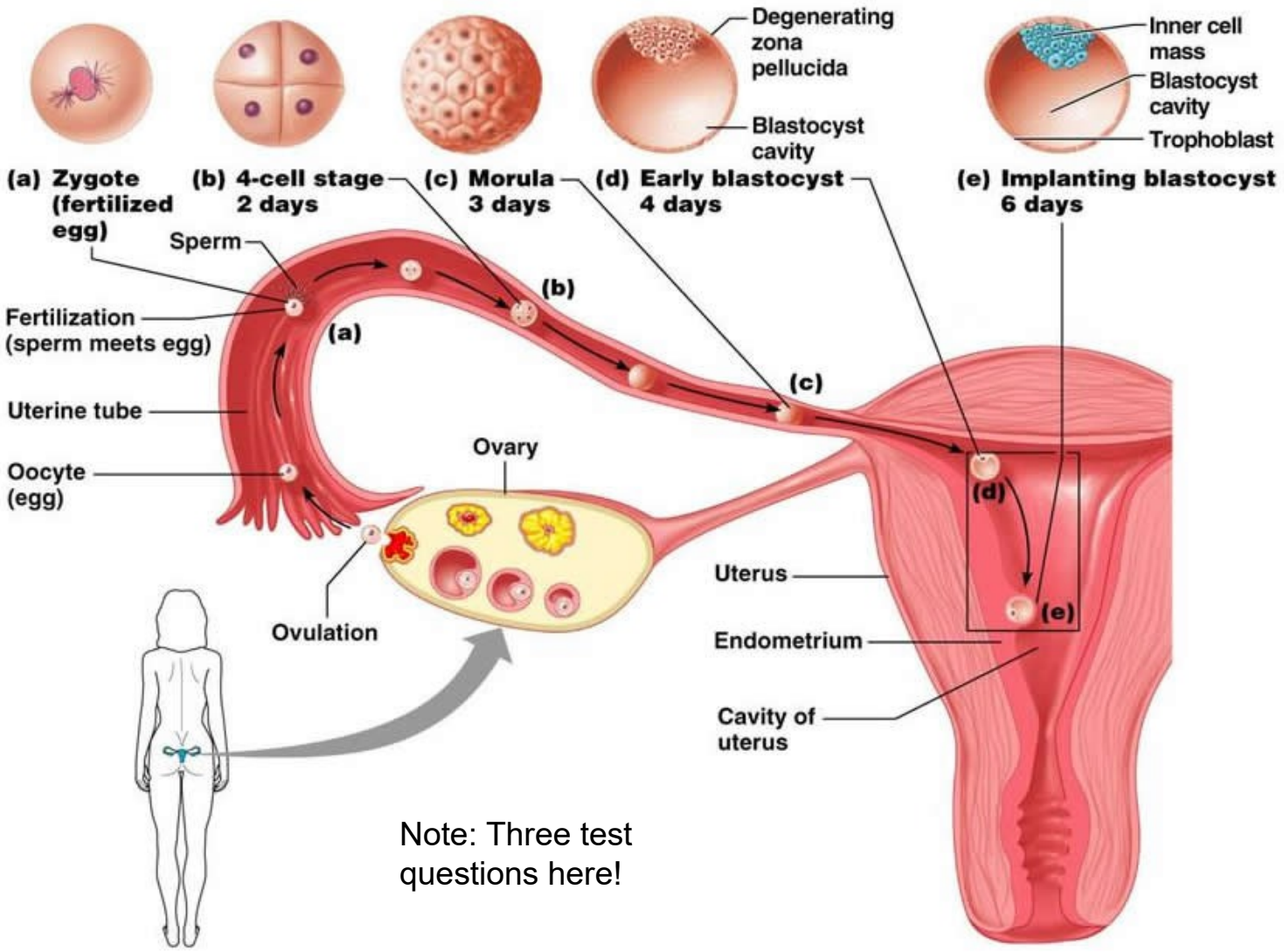
- Produced by blastocyte (fertilized egg first becomes a zygote then undergoes mitosis to become a blastocyte)

- HCG in blood and urine four days after fertilization of ovum // home pregnancy test

- Target tissue is corpus luteum // Stimulates CL to continue to production of progesterone

- Progesterone required to maintains endometrium (maintains pregnancy)

- After placenta developed, placenta now secretes progesterone and corpus luteum is no longer required // corpus luteum turns into corpus albicans (scar tissue)

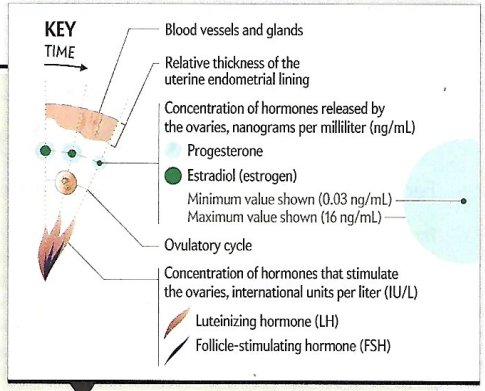



- Blastocyste secretes human chorionic gonadotropin by fourth day after fertilization // this stimulates corpus luteum to continue progesterone secretion to maintain stratum faciculus // hCG secreted in urine and used in home pregnancy test

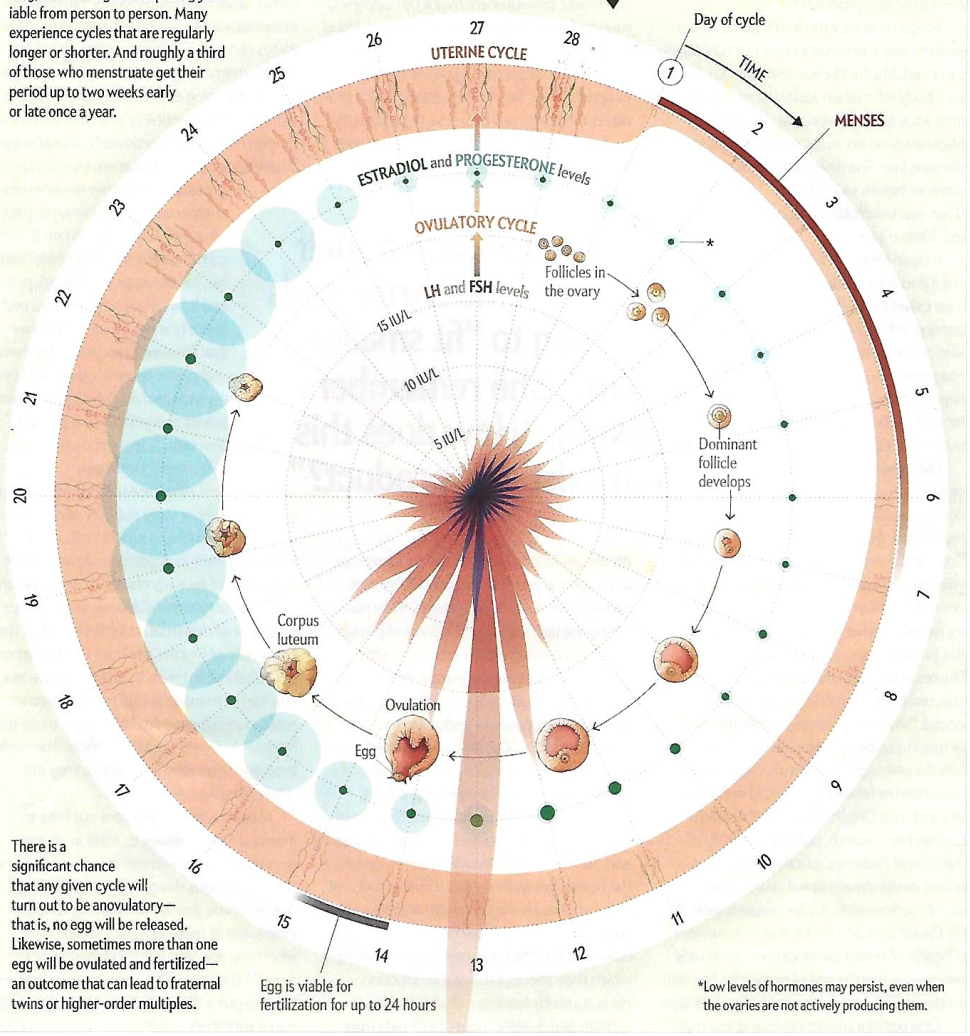
- Placenta is not functional until after the eighth week.

# The Menstrual Cycle

Humans are among the very few species to experience a period. The menstrual cycle starts in the brain, which sends signals to the pituitary gland (*not shown*) to produce hormones that stimulate the ovaries. The ovaries house egg-containing follicles that release an egg during ovulation. The ovaries also secrete hormones to help prepare the uterus to host an embryo, which results if the egg is fertilized by a sperm. If no embryo implants, the uterus disposes of its lining, and the cycle begins again.




The average menstrual cycle is 28 days long, but the length is surprisingly variable from person to person. Many experience cycles that are regularly longer or shorter. And roughly a third of those who menstruate get their period up to two weeks early or late once a year.




There is a significant chance that any given cycle will turn out to be anovulatory—that is, no egg will be released. Likewise, sometimes more than one egg will be ovulated and fertilized—an outcome that can lead to fraternal twins or higher-order multiples.

See review article posted on Web site Unit 4 – C27-28 under Articles of Interest:

A Review of Female Reproductive Health published in Scientific American

The science of women's reproductive health has been a history of misinformation and huge gaps of knowledge. These are the articles included in the SA review.

The point of the period

Set it and forget it.

Maternal Mortality

Eggs on Ice

Menstral Cycle Composit Graphic

# What is the fertility window?

The fertile window is the period of time during which it is possible to become pregnant after sex.

This is the day of ovulation plus the time sperm can live inside the cervix before it fertilizes the egg. The ovum is only viable for 24 hours. Sperm are viable in female reproductive tract for up to seven days.

According to the American College of Obstetricians and Gynecologists (ACOG), a person can become pregnant if they have sex **anywhere from 5 days before until 1 day after ovulation.**

**(Test Answer: 5 days before ovulation and until 1 day after ovulation)**

Depending on the menstrual cycle, the fertile window may vary from one person to another.

# Overview of Female Reproductive Structure

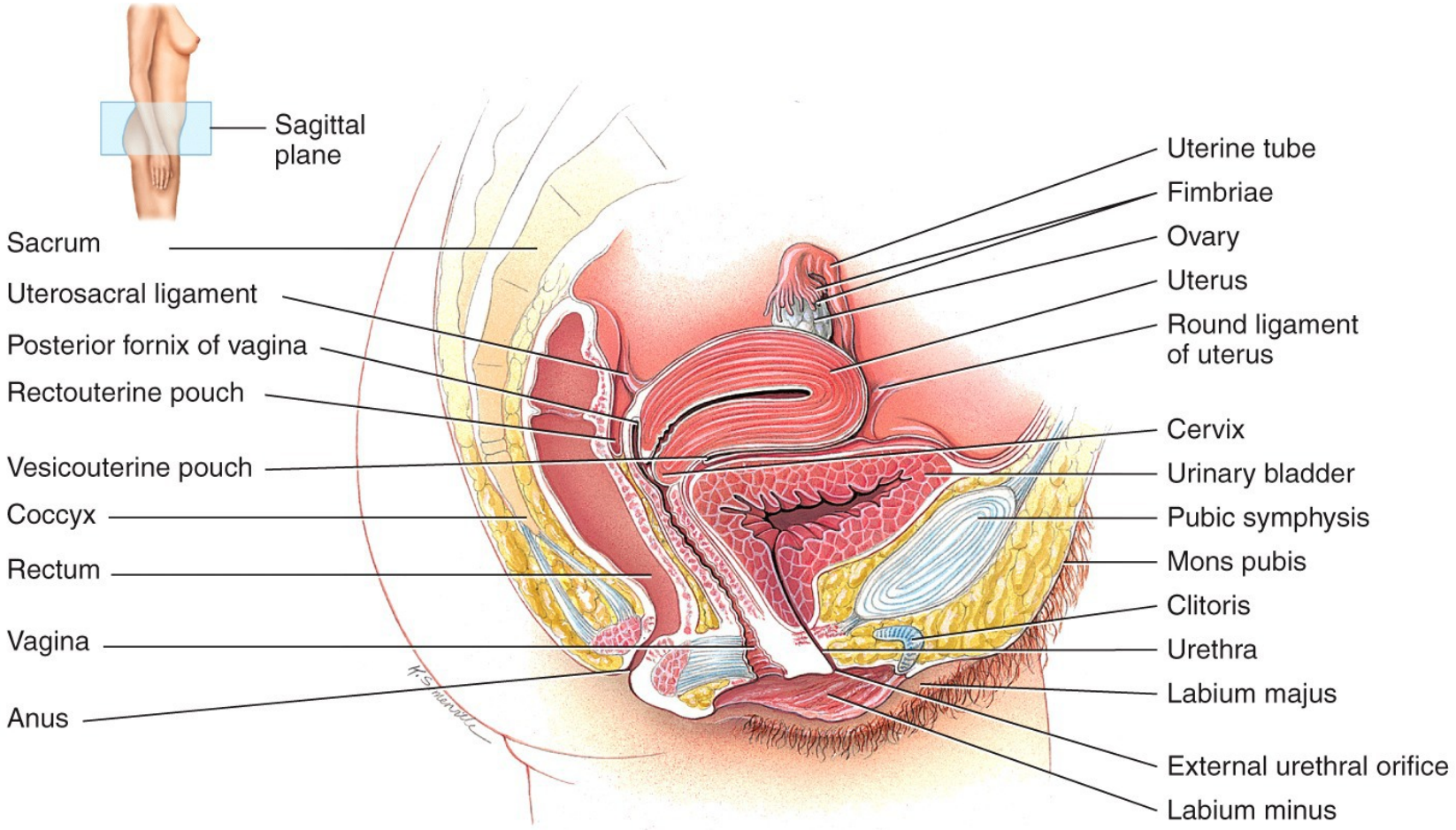
Female reproductive structure consists of primary and secondary sex organs

primary sex organs (the gonads) // produce gametes – ovaries

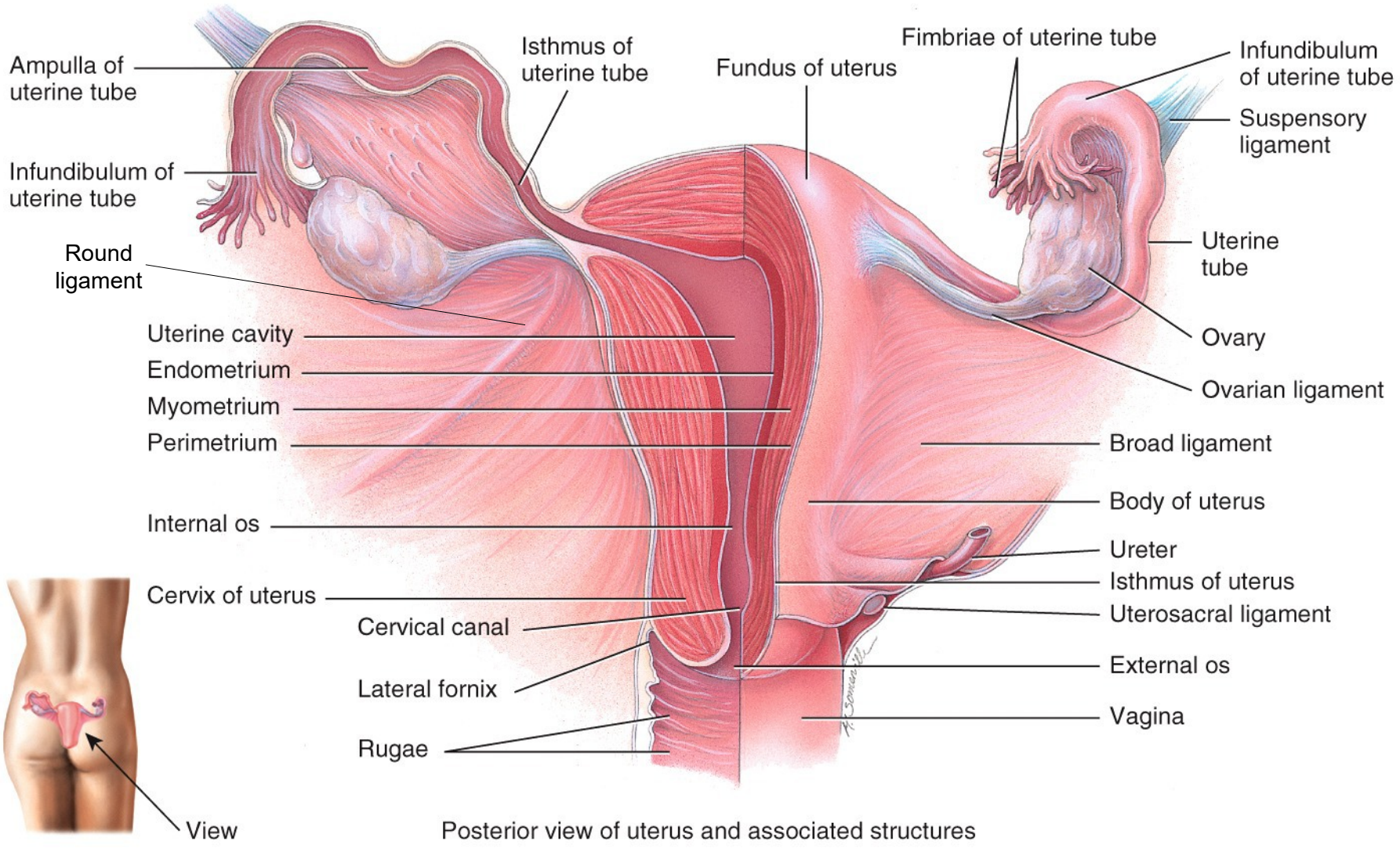
secondary sex organs // organs other than the gonads that are necessary for reproduction /// uterine tubes, uterus, and vagina

- Primary sex organ = ovaries //  produce female gamete (egg)

- Secondary sex organs = fallopian tubes, uterus, vagina

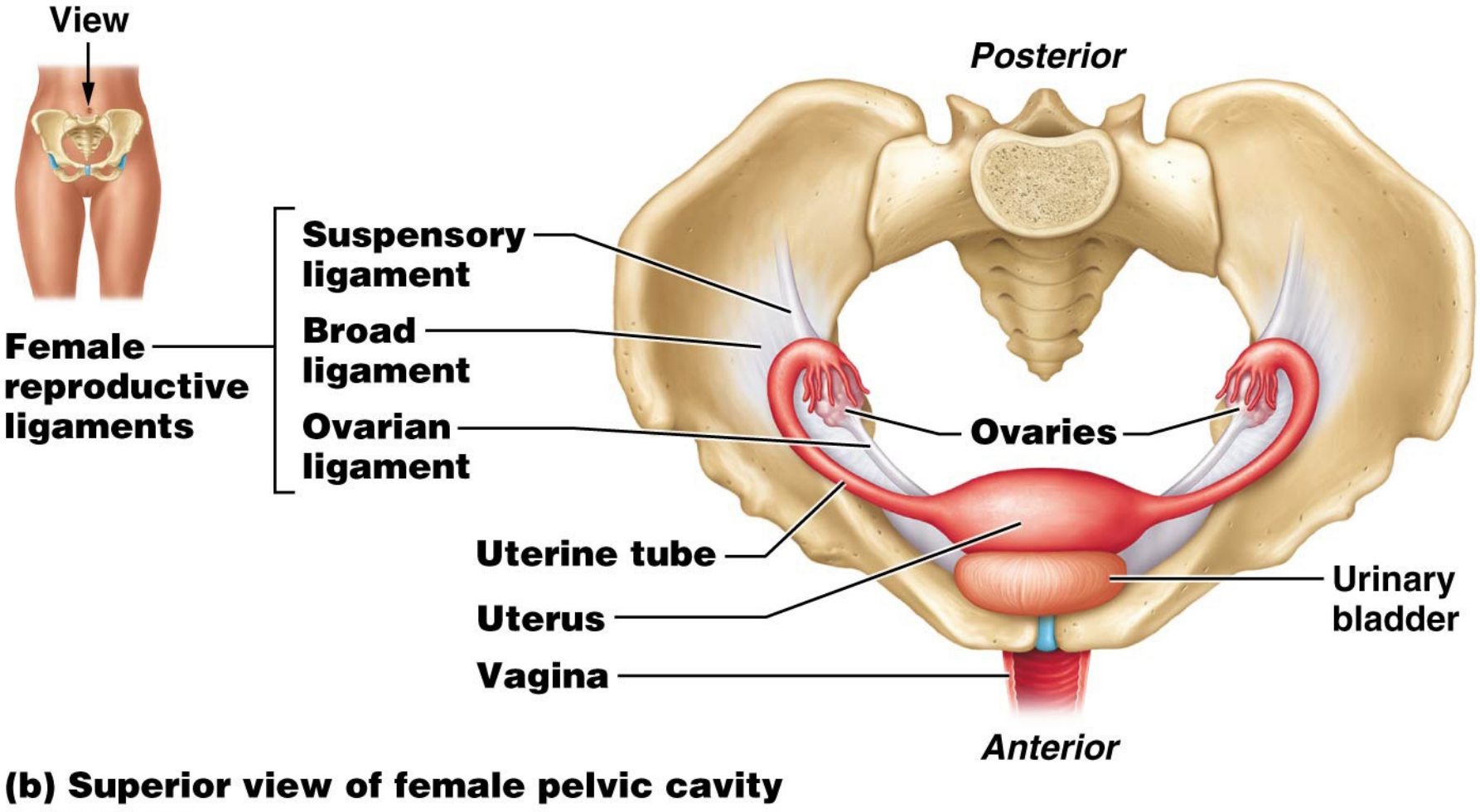



(a) Sagittal section




Posterior view of uterus and associated structures

Internal organs of the female reproductive system.

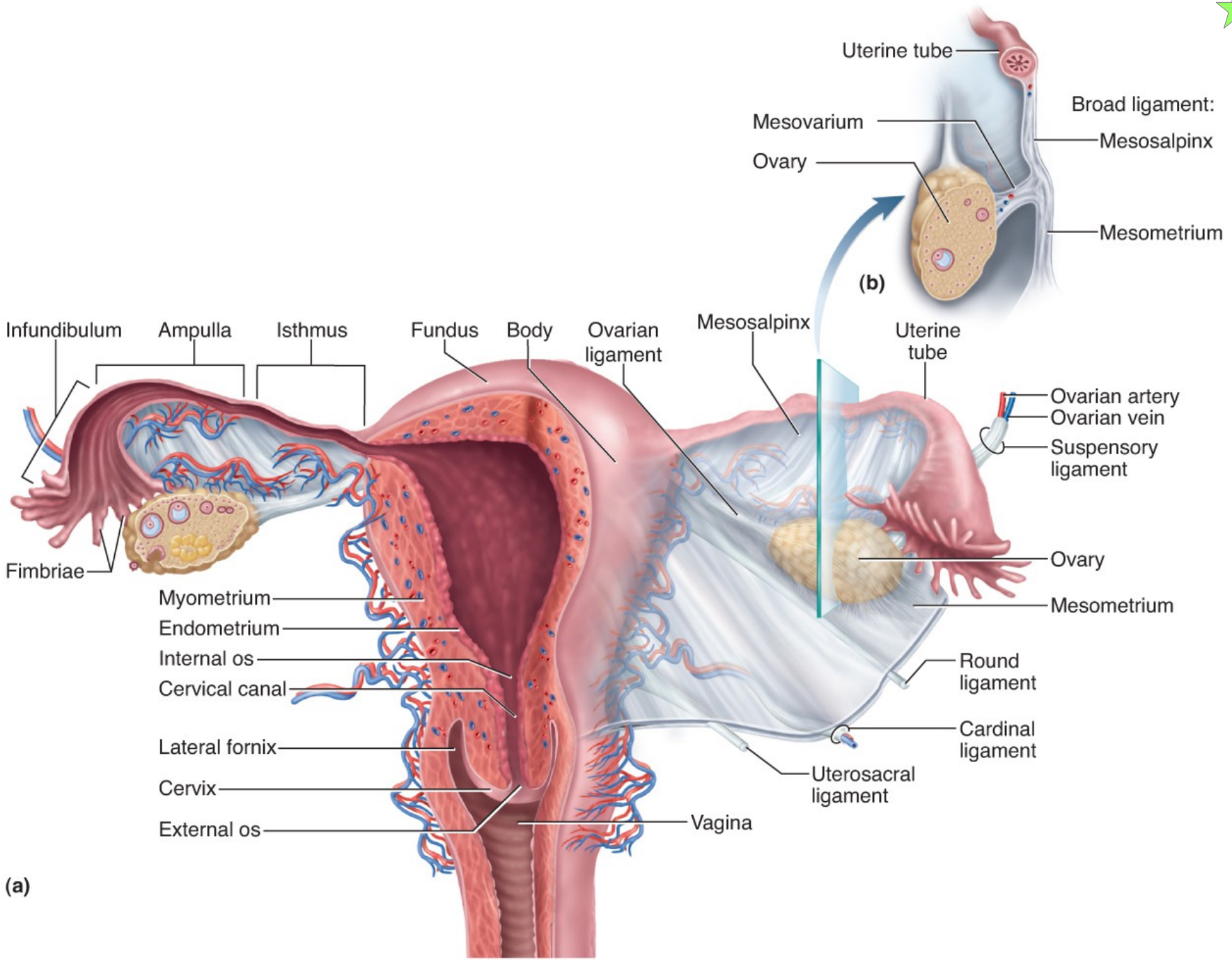


# The Uterus

- Uterus – thick muscular (smooth muscle) chamber that opens into the roof of the vagina
  - usually tilts forward over the urinary bladder
  - Location where conceptus develops ///  provides a source of nutrition and expels the fetus at the end of its development
  - pear-shaped organ
    - fundus – broad superior curvature
    - body (corpus) – middle portion
    - cervix – cylindrical inferior end

# The Uterus

- Lumen is roughly triangular
  - upper two corners are the openings to the uterine tube
  - lower apex is internal os
  - uterus is not a hollow cavity /// a potential space in the non-pregnant uterus
- Cervical canal connects the lumen to vagina
  - internal os – superior opening of the canal into the body of the uterus
  - external os – inferior opening of the canal into the vagina
- Cervical glands – secretes mucus that prevents the spread of microorganisms from the vagina to the uterus /// cervical plug = estrogen reduces viscosity and progesterone increases the viscosity



# Uterine Wall Layers
## (serosa / myometrium / endometrium)

- External layer covered by serosa (visceral serous membrane) = outer layer
- Myometrium = middle muscular layer //  constitutes most of the uterine wall
  - composed mainly of smooth muscle
    - sweep downward from fundus and spiral around the body
    - less muscular and more fibrous near cervix
    - produces labor contractions, expels fetus

# Uterine Wall

endometrium = the mucosa of the uterus

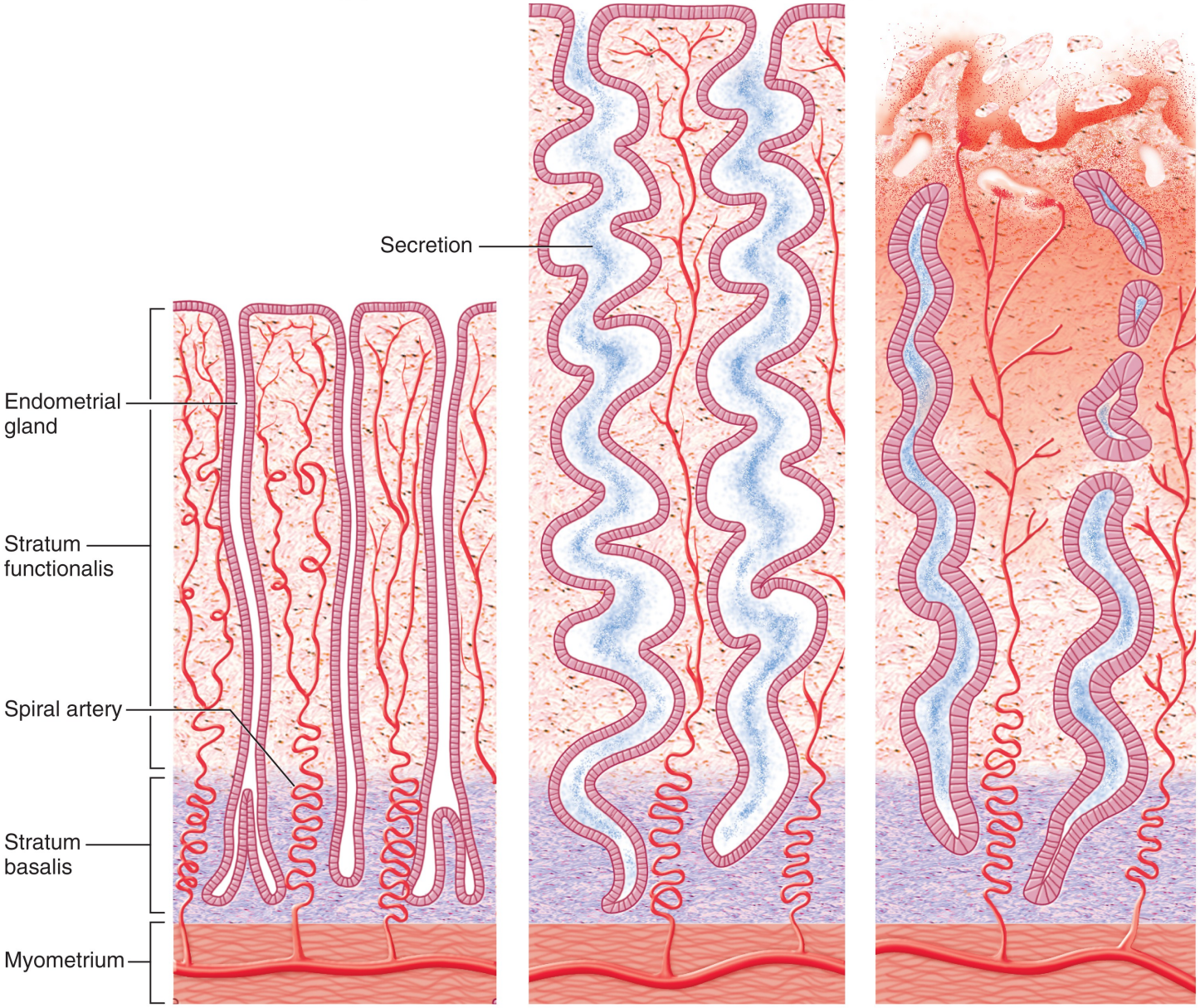
endometrium = simple columnar epithelium, compound tubular glands, and a stroma populated with leukocytes, macrophages, and other cells.

stratum functionalis – superficial half, shed each menstrual period

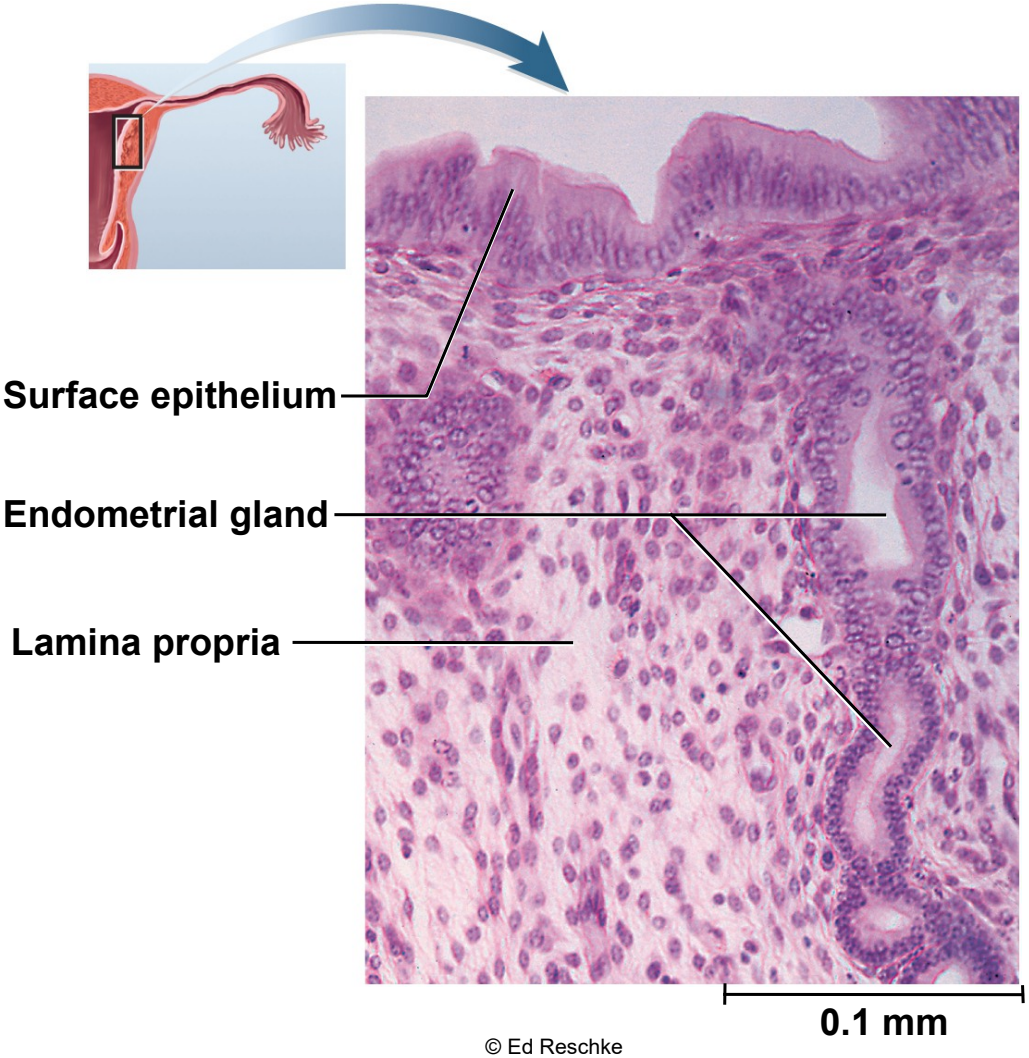
stratum basalis - deep layer, stays behind and regenerates a new stratum functionalis with each menstrual cycle

during pregnancy, the endometrium is the site of attachment of the conceptus /// the placenta grows “out of the conceptus” /// forms interphase between maternal tissue and conceptus // the placenta is the organ that exchanges nutrients and waste products between conceptus and mother

# Endometrium

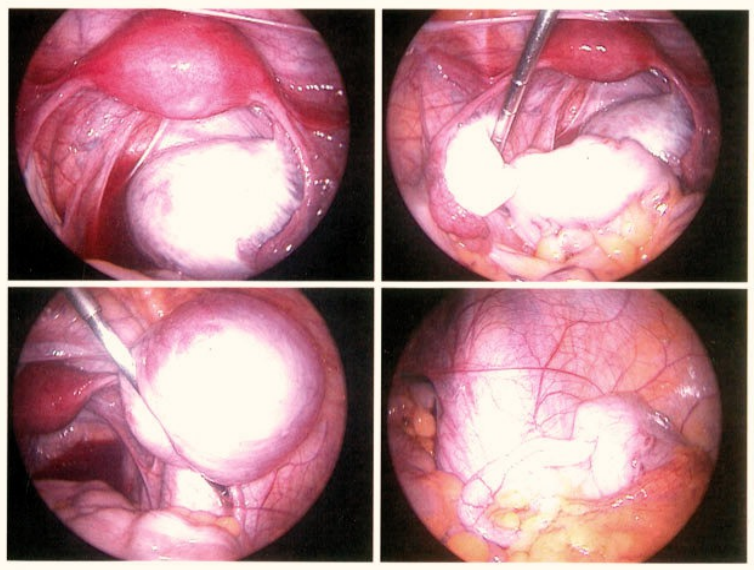


# Histology of Endometrium

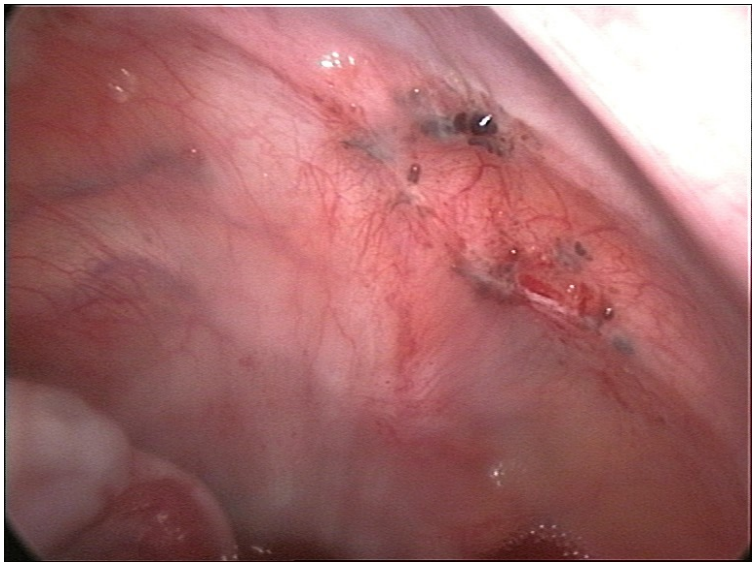


# Endometriosis

Endometriosis (en-doe-me-tree-O-sis) is an often painful disorder in which tissue that normally lines the inside of your uterus — the endometrium — grows outside your uterus. Endometriosis most commonly involves your ovaries, fallopian tubes and the tissue lining your pelvis.



Endometriotic cyst on ovary



Endometriotic lesions at the peritoneum of the pelvic wall

- Blastocyte attaches to endometrium to initiate the formation of the placenta /// occurs at about day 6-7

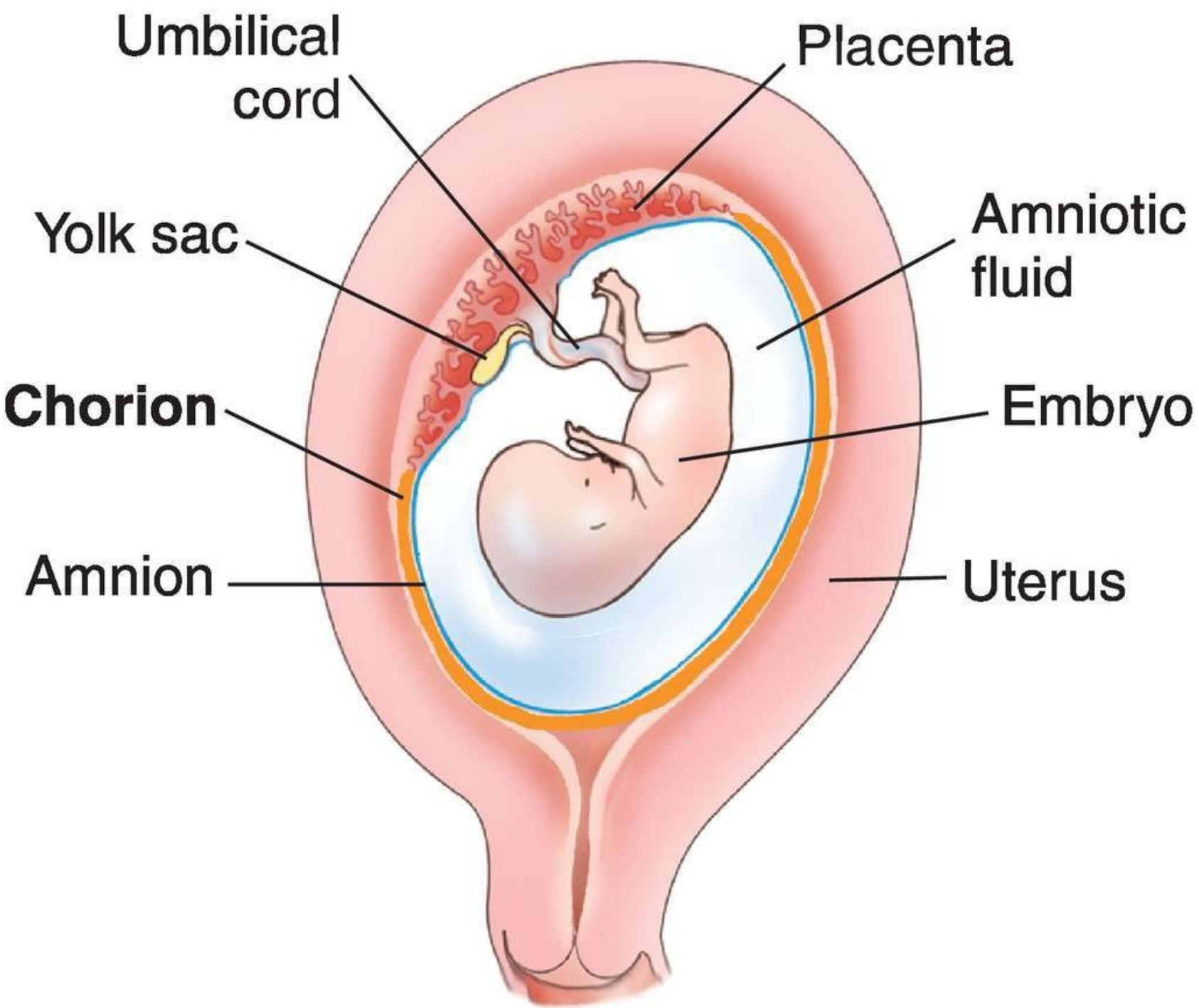
- Placenta is the organ used to exchange nutrients and metabolic waste between mother and conceptus // nicknamed the fetus first organ

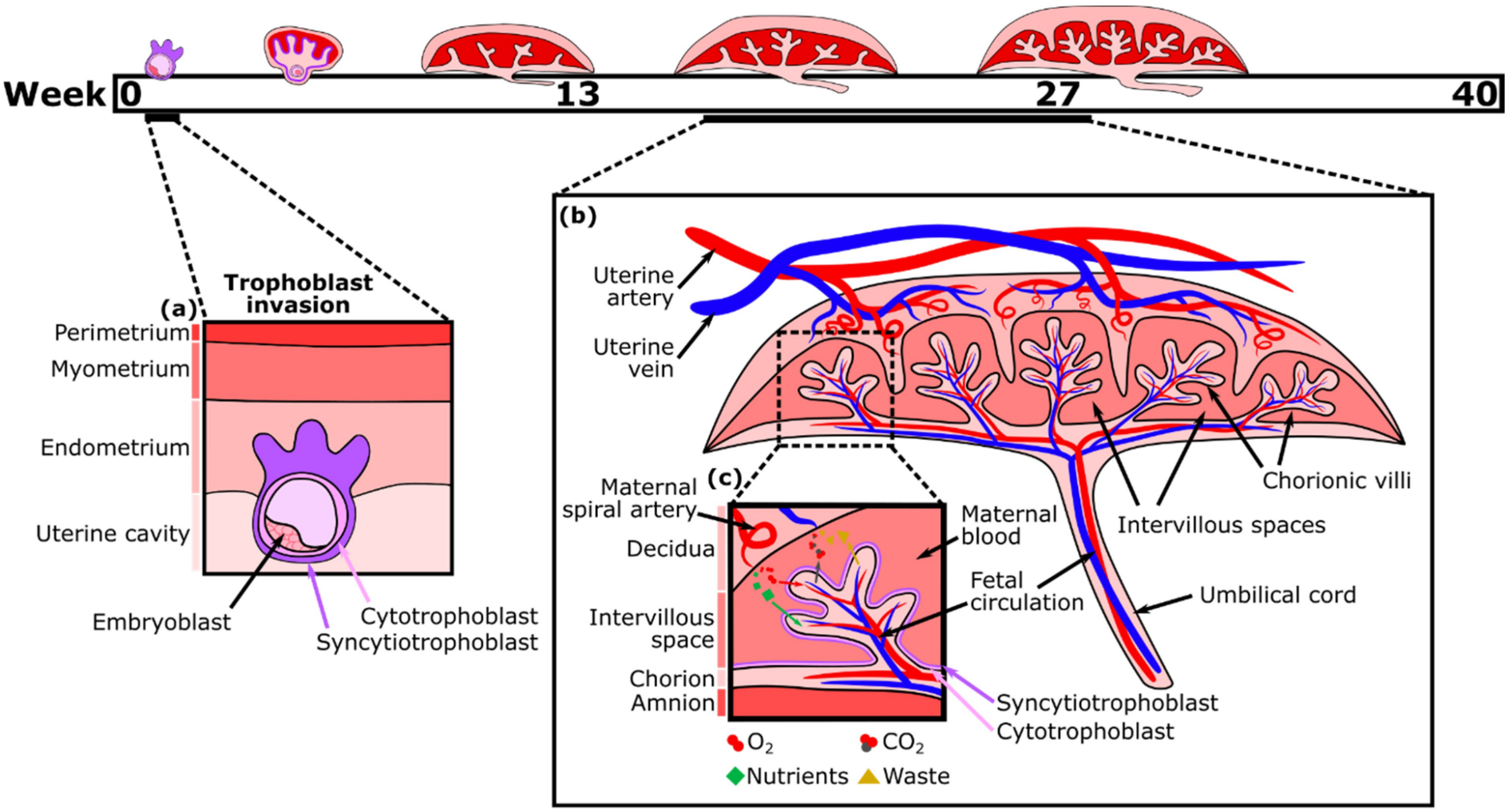
- Placenta fully developed at week 8 – before this time the conceptus gets nutrients from digested endometrial cells and "uterine milk" /// secretions from endometrial glands

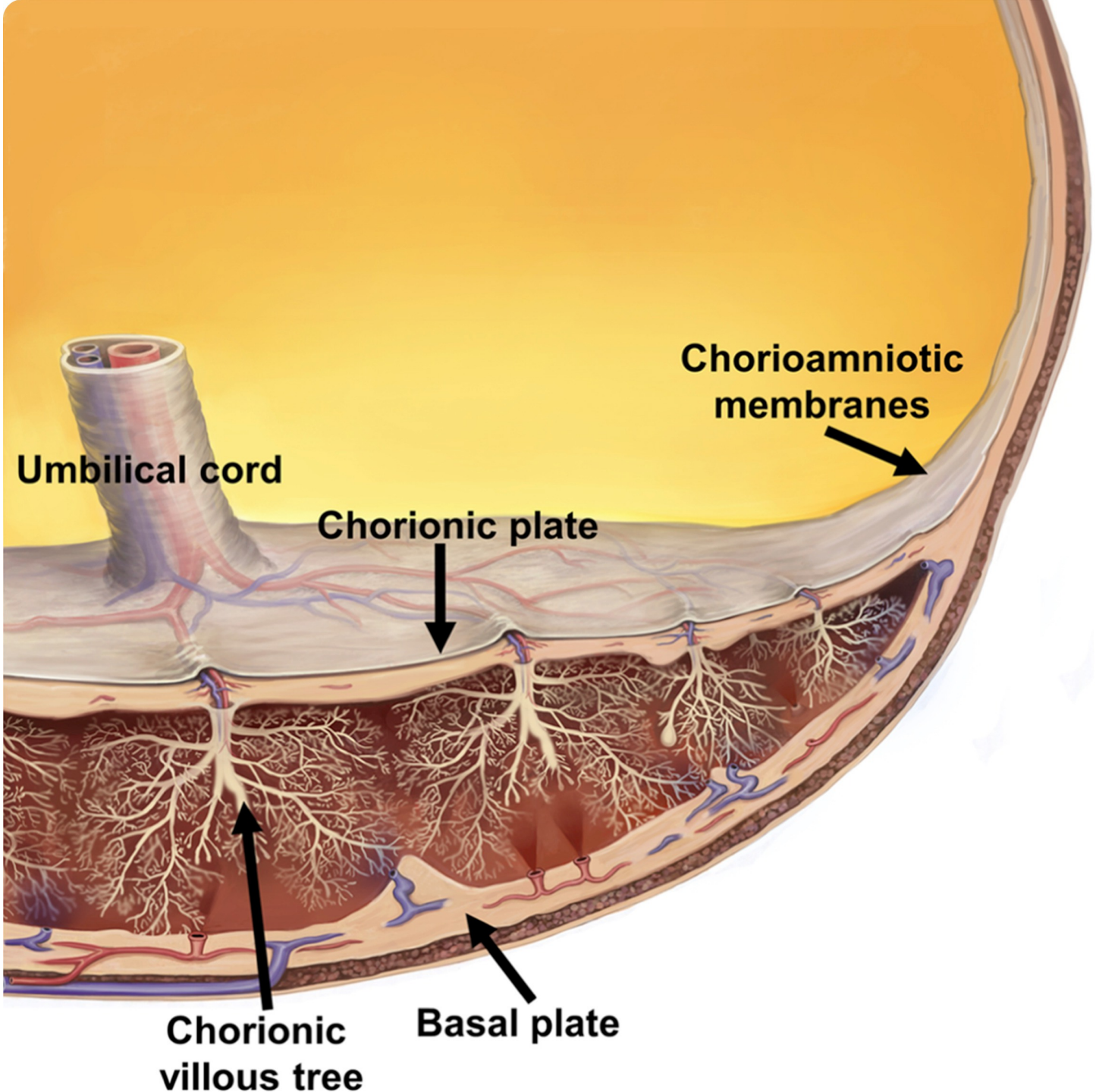
- As the placenta develops, it secretes several hormones that maintain pregnancy and alter female physiology
  - Estrogen
  - Progesterone
  - Human chorionic gonadotropin (hCG) – stops secretion after wk 12
  - Relaxin
  - Placental prolactin
  - Placental lactogen
  - Other recently discovered hormones not included

# The placenta is the “baby's first organ”

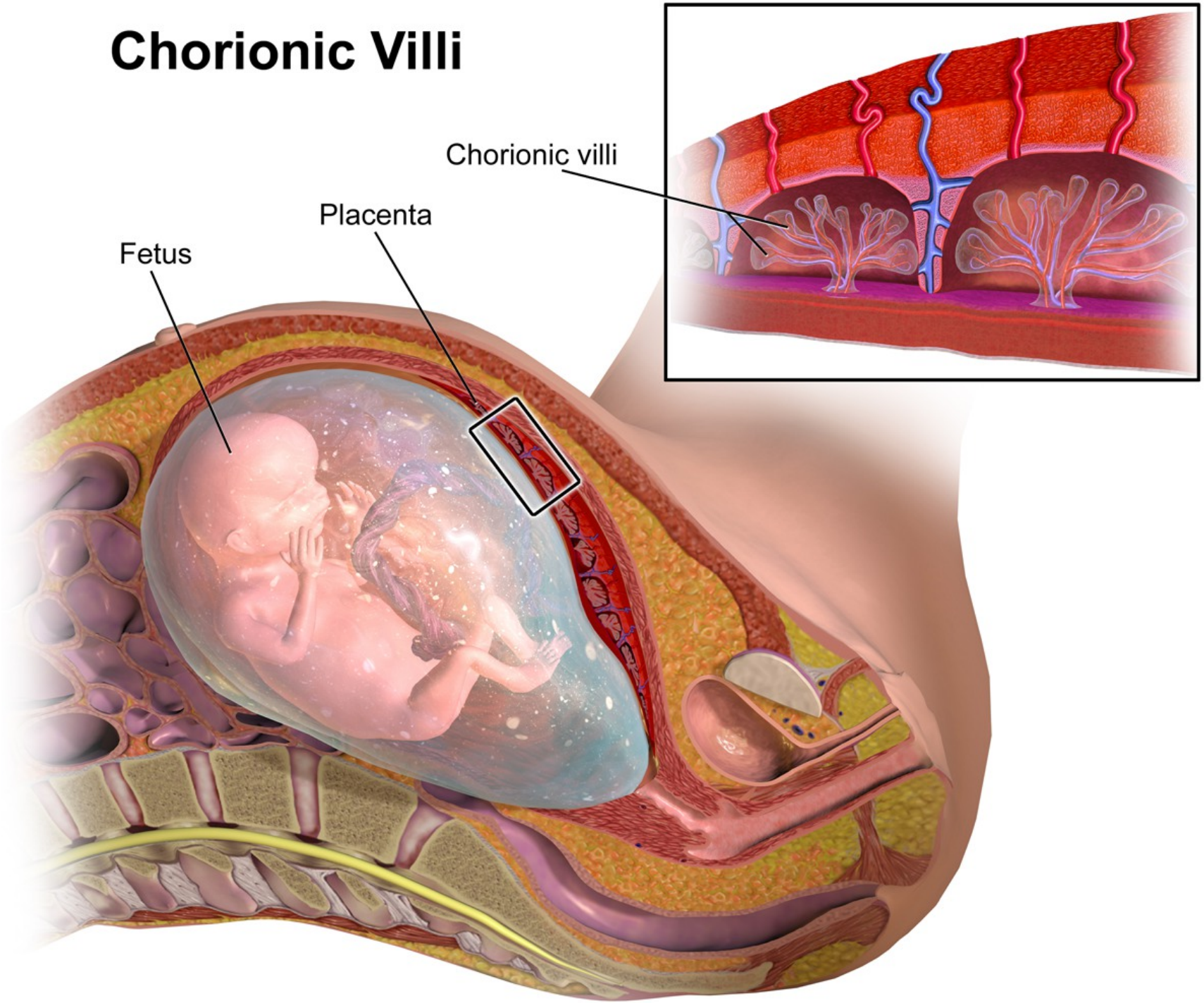
It is the embryonic tissues from the embryo that grows into the maternal endometrium to form union with maternal blood vessels.


Umbilical cord
Placenta
Yolk sac
Amniotic fluid
Chorion
Embryo
Amnion
Uterus


Week
0
13
27
40
(a)
Trophoblast invasion
Perimetrium
Myometrium
Endometrium
Uterine cavity
Embryoblast
Cytotrophoblast
Syncytiotrophoblast
(b)
Uterine artery
Uterine vein
Chorionic villi
Intervillous spaces
Umbilical cord
(c)
Maternal spiral artery
Decidua
Intervillous space
Chorion
Amnion
Maternal blood
Fetal circulation
Syncytiotrophoblast
Cytotrophoblast
$O_2$
$CO_2$
Nutrients
Waste


Chorioamniotic membranes
Umbilical cord
Chorionic plate
Chorionic villous tree
Basal plate

# Chorionic Villi



# What hormones are produced by the placenta?

The placenta produces estrogen and progesterone. Progesterone acts to maintain pregnancy by supporting the lining of the uterus (womb), which provides the environment for the fetus and the placenta to grow.

Progesterone prevents the shedding of this lining (similar to that which occurs at the end of a menstrual cycle), since this would result in pregnancy loss.

Progesterone also suppresses the ability of the muscular layer of the uterine wall to contract, which is important in preventing labor from occurring before the end of pregnancy.

Estrogen levels rise towards the end of pregnancy. Estrogen acts to stimulate the growth of the uterus to accommodate the growing fetus and allows the uterus to contract by countering the effect of progesterone. In this way, it prepares the uterus for labor

Estrogen also stimulates the growth and development of the mammary glands during pregnancy, in preparation for breastfeeding.

The placenta also releases other protein hormones. (see next slide).

# What hormones are produced by the placenta?

The placenta also releases human chorionic gonadotrophin, human placental lactogen, placental growth hormone, relaxin and kisspeptin.

Human chorionic gonadotrophin is the first hormone to be released from the developing placenta. HCG was first secreted by the blastocyte at 72 hours and is measured in a pregnancy test.

HCG acts as a signal to the mother’s body that pregnancy has occurred by maintaining progesterone production from the corpus luteum, a temporary endocrine gland found in the ovary.

The function of human placental lactogen is not completely understood, although, it is thought to promote the growth of the mammary glands in preparation for lactation. It is also believed to help regulate the mother's metabolism by increasing maternal blood levels of nutrients for use by the fetus.

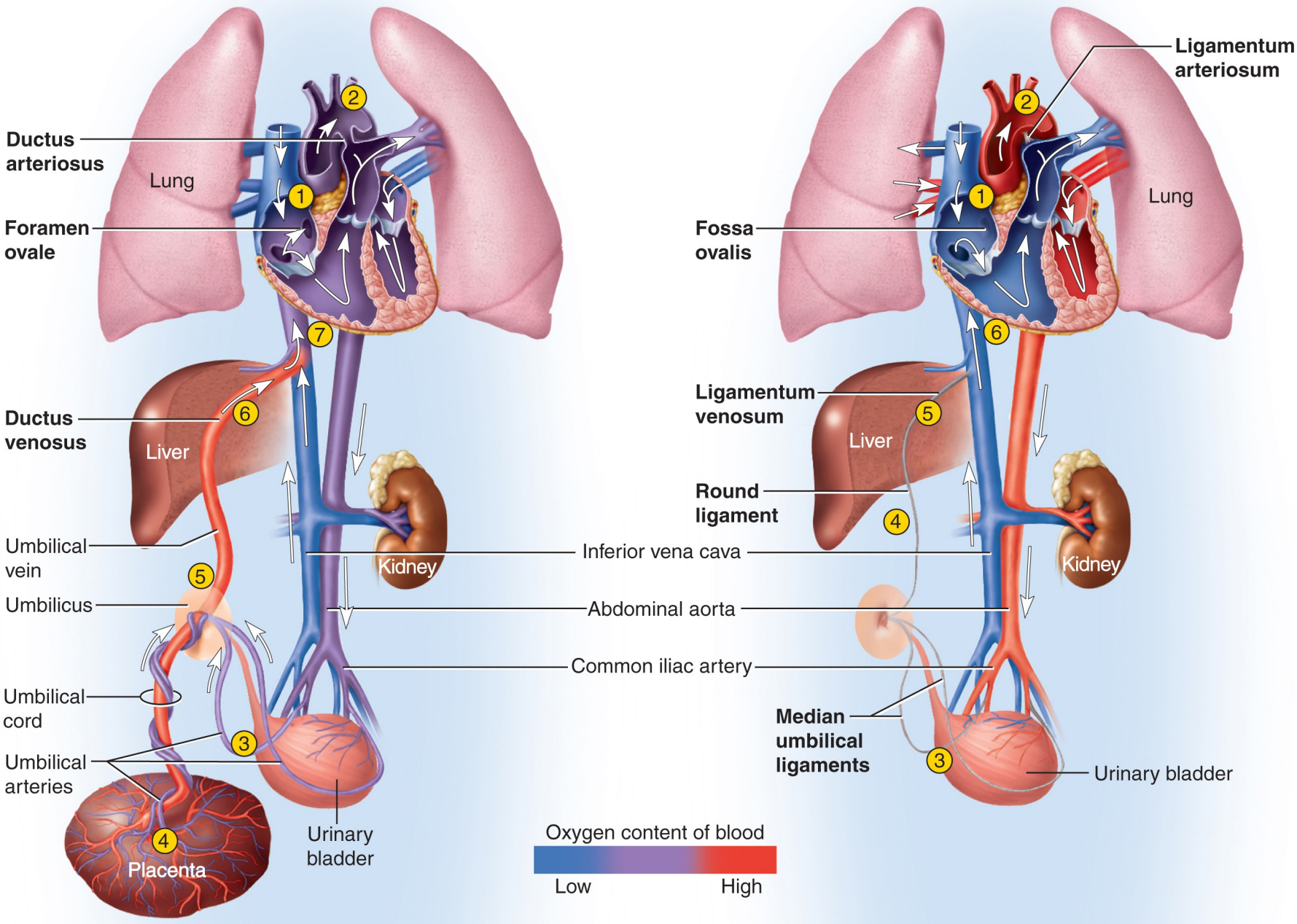
A similar role is played by placental growth hormone, which predominates during pregnancy due to suppression of growth hormone produced by the maternal pituitary gland.

# What hormones are produced by the placenta?

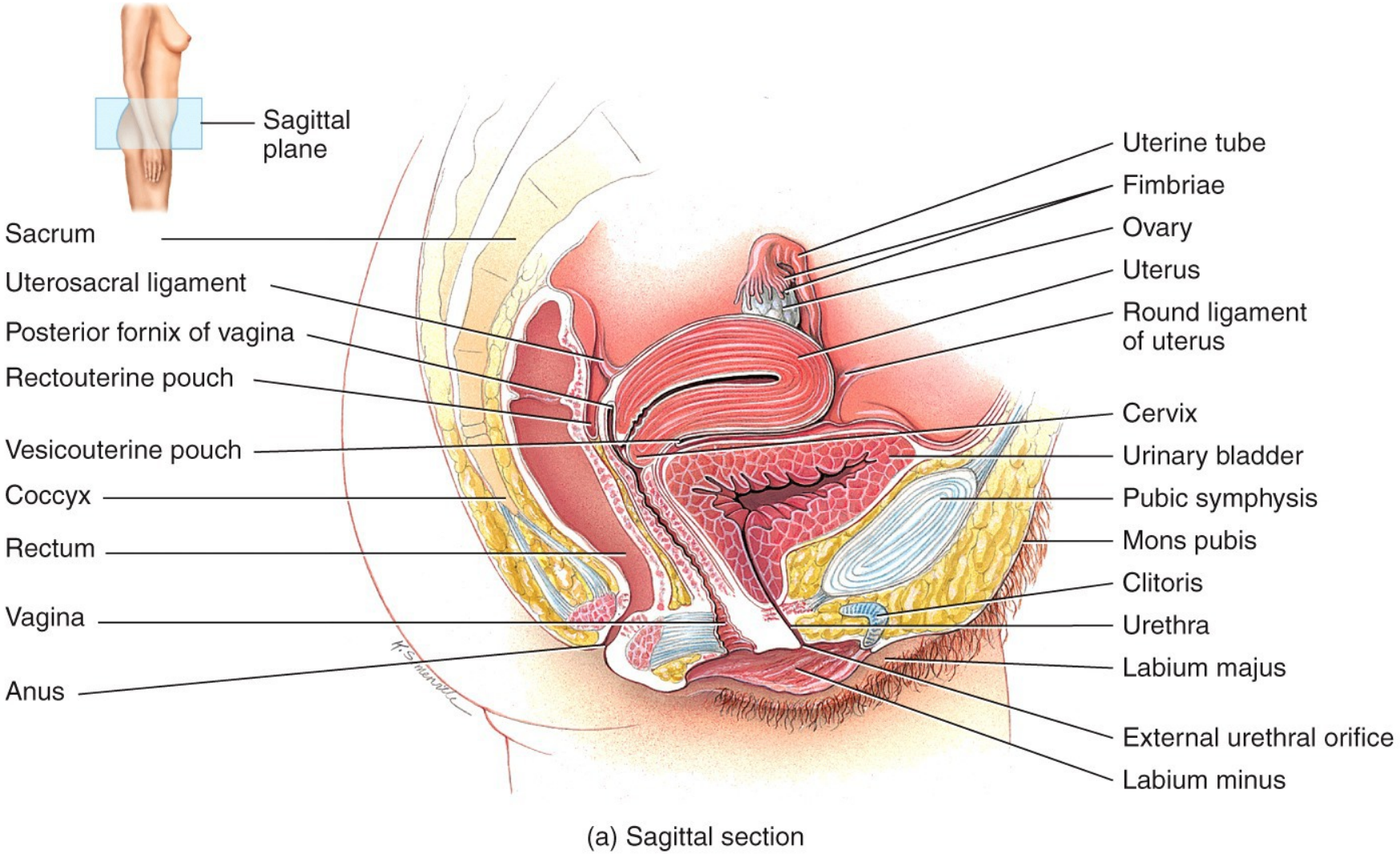
Relaxin causes the relaxation of pelvic ligaments and softening of the cervix at the end of pregnancy, which aids the process of labor

Kisspeptin is a recently identified hormone, which is important for many aspects of human fertility. In the placenta, kisspeptin appears to regulate placental growth into the lining of mother's womb (endometrium).

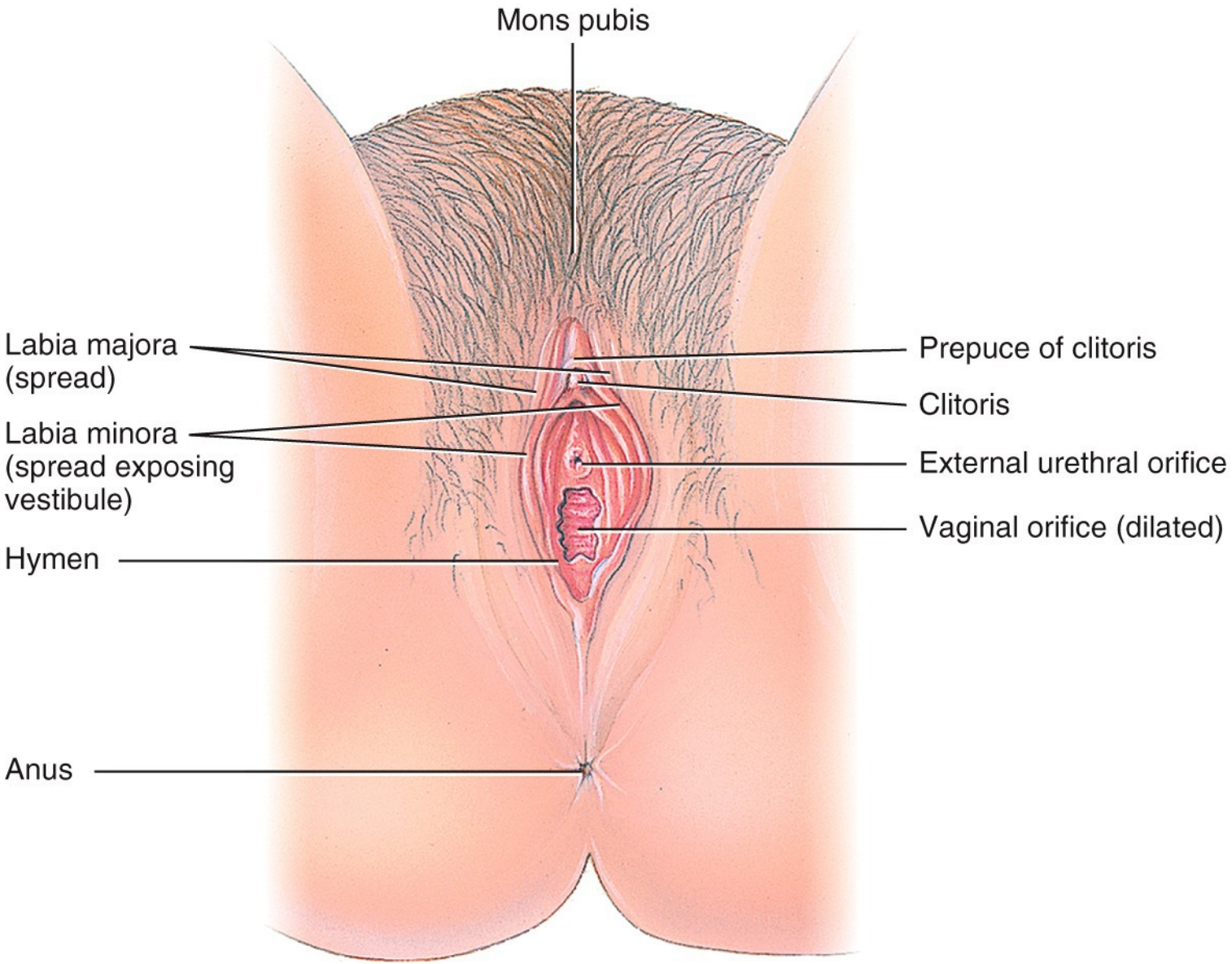
A number of other peptide hormones have been recently identified to regulate blood vessel formation within the placenta, which is crucial in allowing the placenta to exchange nutrients from the mother to baby; these peptide hormones include soluble endoglin (sEng), soluble fms-like tyrosine kinase 1 (sFlt-1) and placental growth factor (PlGF).



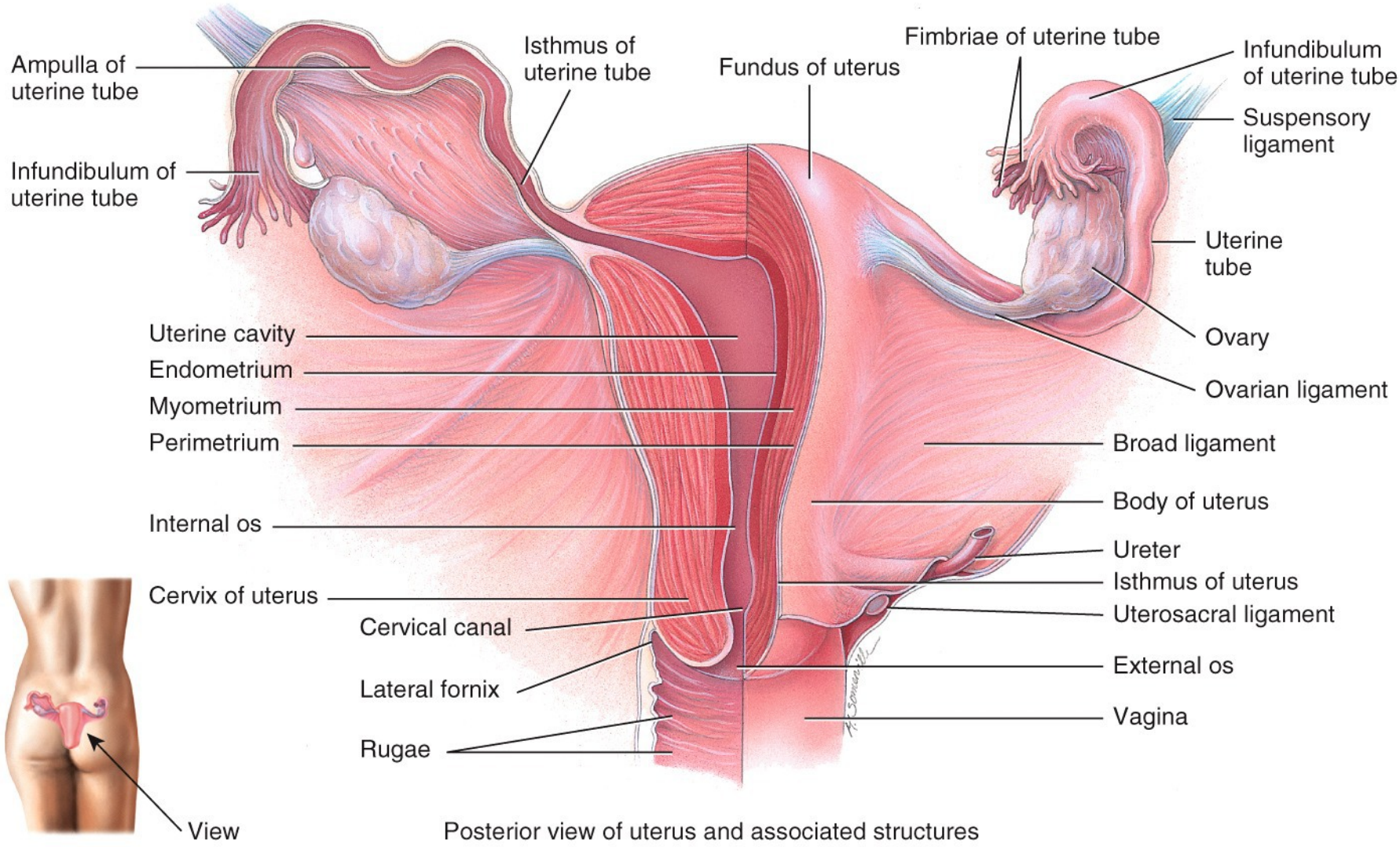
# Female Reproductive Organs



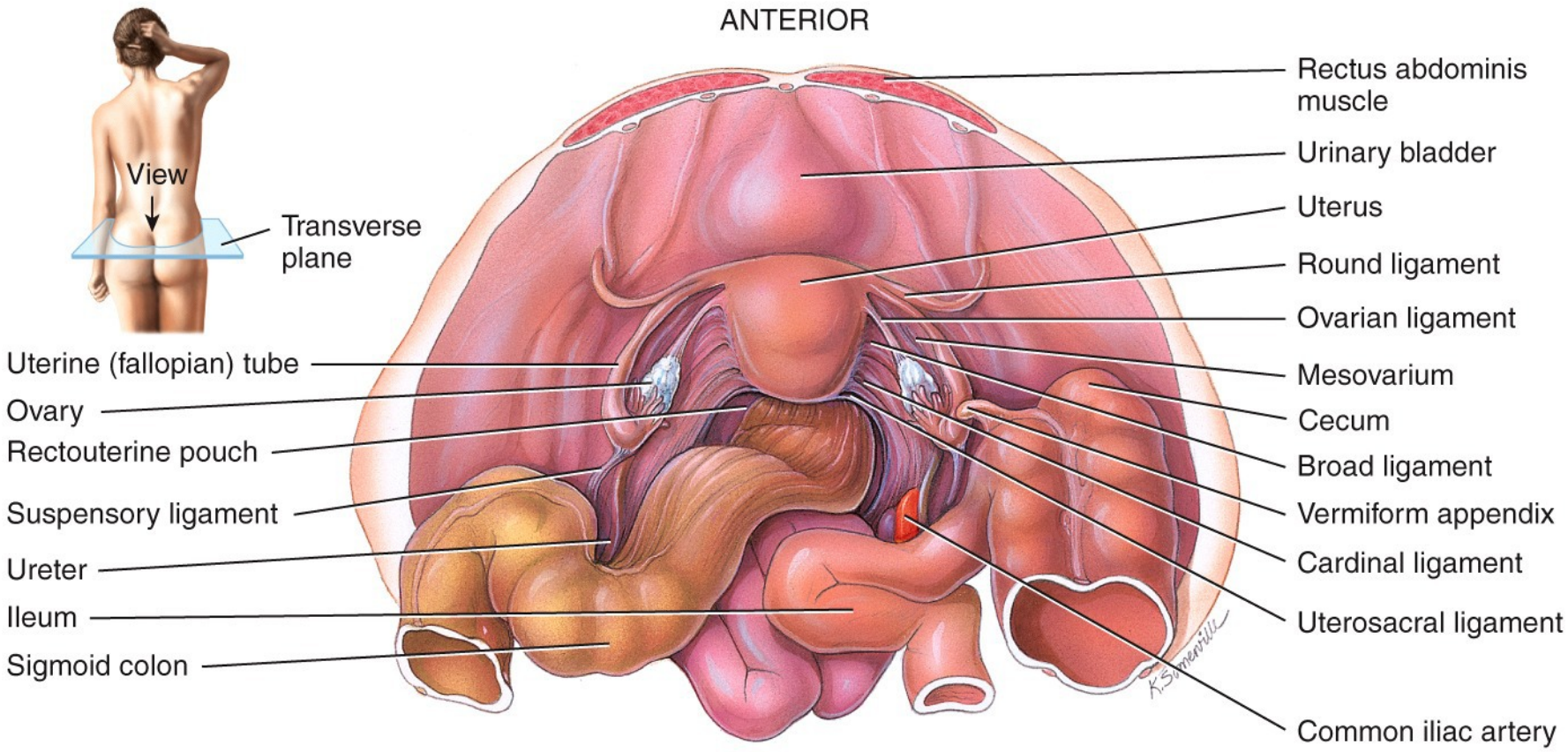

(a) Sagittal section




(c) Inferior view



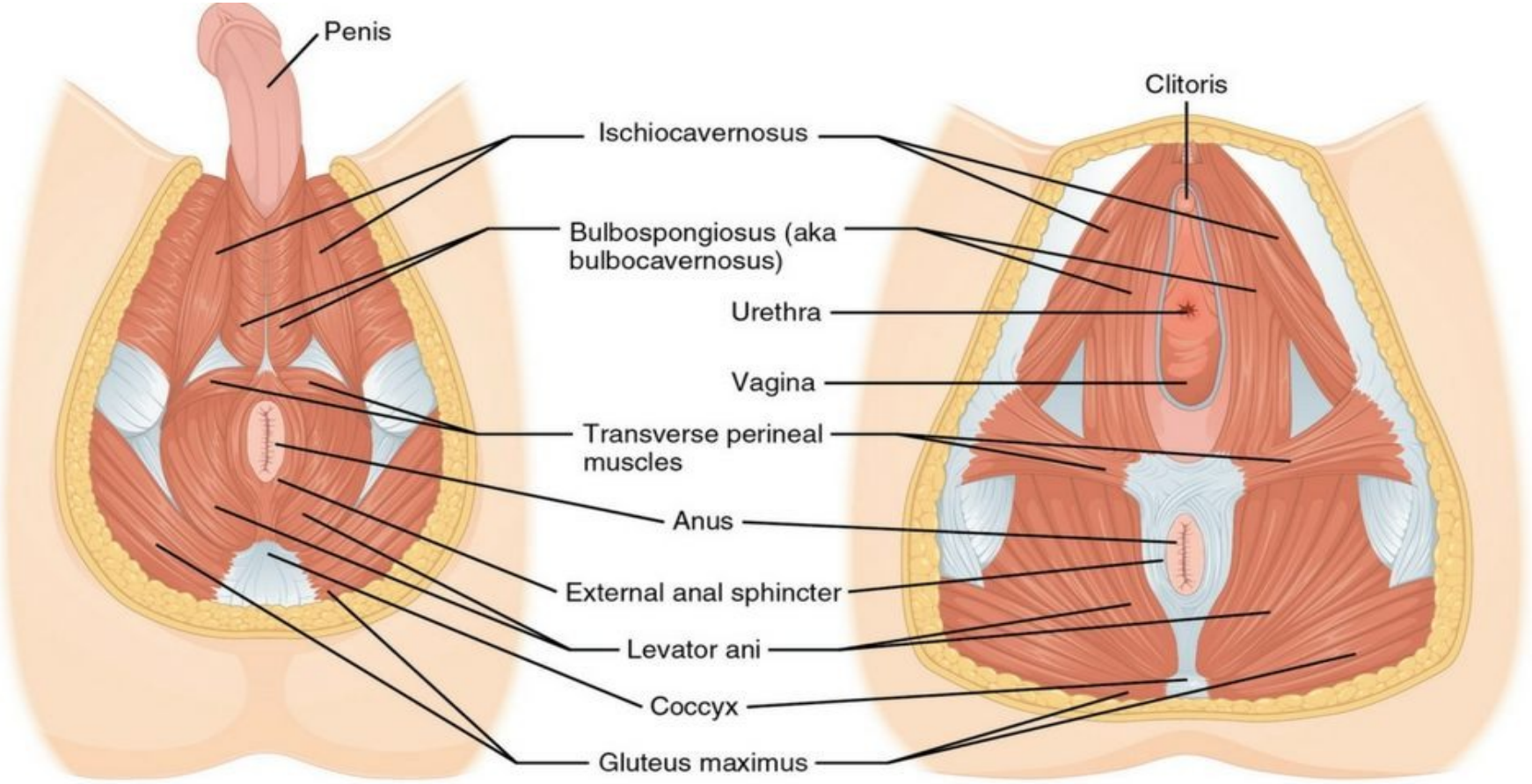

Posterior view of uterus and associated structures




Superior view of transverse section

# Perineum Location & Perineal Muscles

The perineum is the space between the anus and scrotum in the male and between the anus and the vulva in the female.[2] The perineum is the region of the body between the pubic symphysis (pubic arch) and the coccyx (tail bone), including the perineal body and surrounding structures. There is some variability in how the boundaries are defined.[3] The perianal area (peri- and anal) is a subset of the perineum.

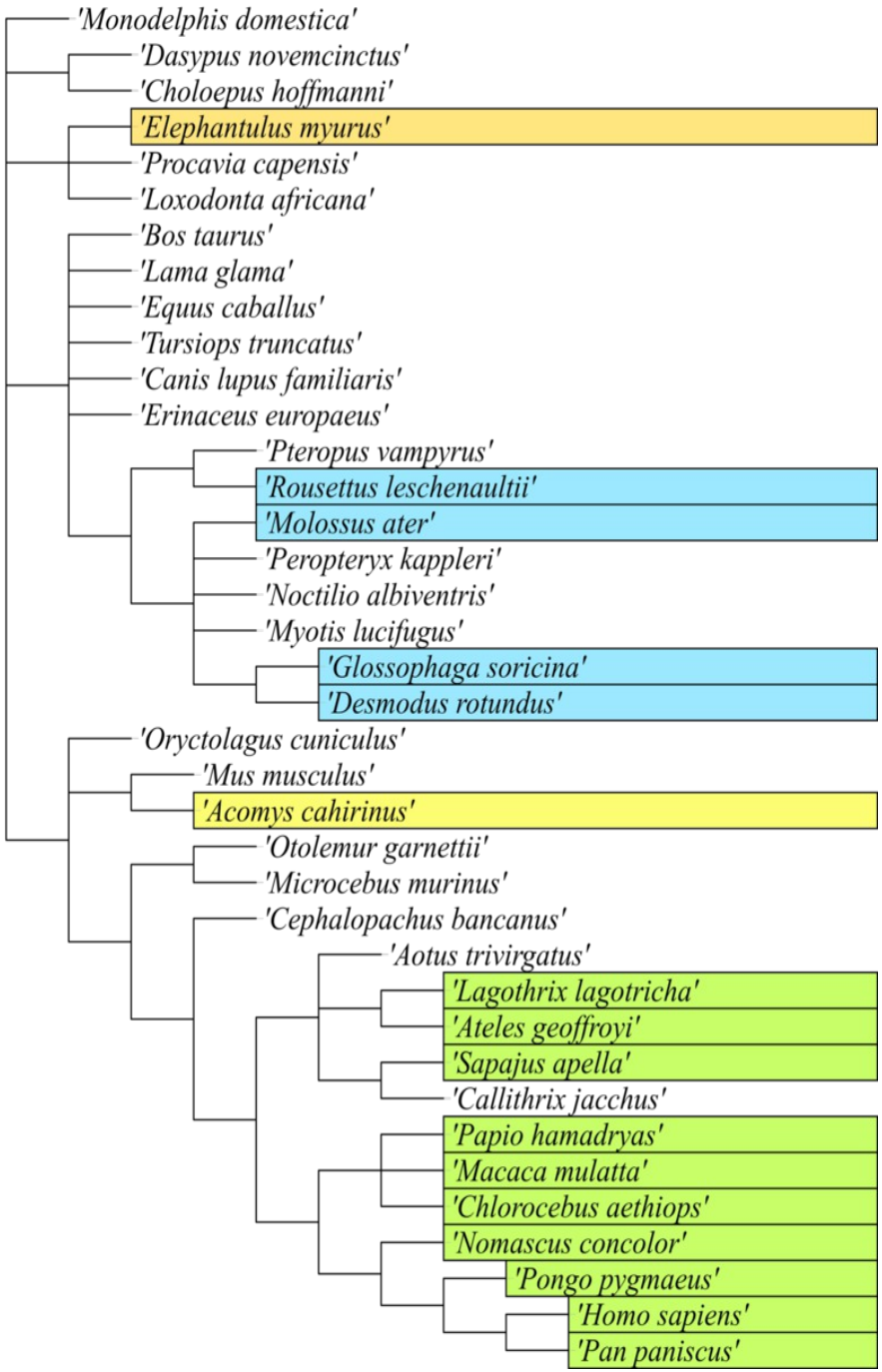



Male perineal muscles: inferior view

Female perineal muscles: inferior view

# The Menstrual Cycle

- The menstrual cycle is also referred to as the sexual cycle. It is approximately 28 days long and occurs when there is no pregnancy.
- It is associated with changes in the tissues of the uterus
- There are four phases: menstrual, proliferative, secretory, premenstrual.
- The first phase starts on day one of the cycle with the discharge of blood
- *The menstrual cycle coincides with ovarian events associated with the development of the female gamete (ovum / egg)*
- *Humans, chimpanzees, six species of bats, and elephant shrews are among the only animals on earth that have periods (i.e. mensis) !*
- *All other mammals reabsorb their endometrium. Evolutionary physiologist study mensis to understand what might be the adaptive advantage of the period. (see The Point of a Period – Scientific American)*




Phylogeny tree of menstruating and select non-menstruating mammals. Each color indicates a convergent evolutionary event: green, Primates; blue, Chiroptera; orange, Afrotheria; yellow, Rodentia.

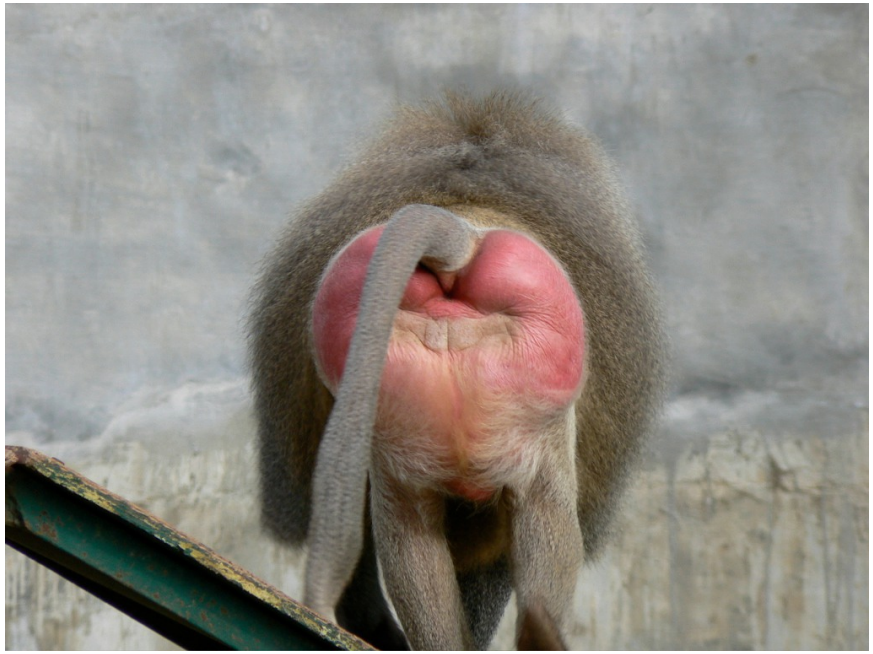
Orange - Afrotheria – elephant shrews
Blue - Chiroptera – bats
Yellow - Rodentia – rodents
Green - primates

Many have questioned the evolution of overt menstruation in humans and related species, speculating on what advantage there could be to losing blood associated with dismantling the endometrium rather than absorbing it, as most mammals do.

Leading hypothesis is energy conservation. Takes less energy to discard and reform endometrium than to maintain endometrium through receptive state.

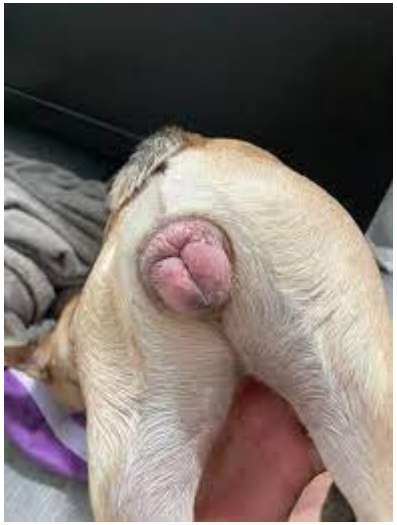
These animals are the only animals to have periods and shed their endometrium.

They do not “exhibit” but hide when they are most fertile.  Other mammals visually display estrus when they are in “heat” and a time when they are most likely to produce a fertilized egg.



What is estrus in monkeys?

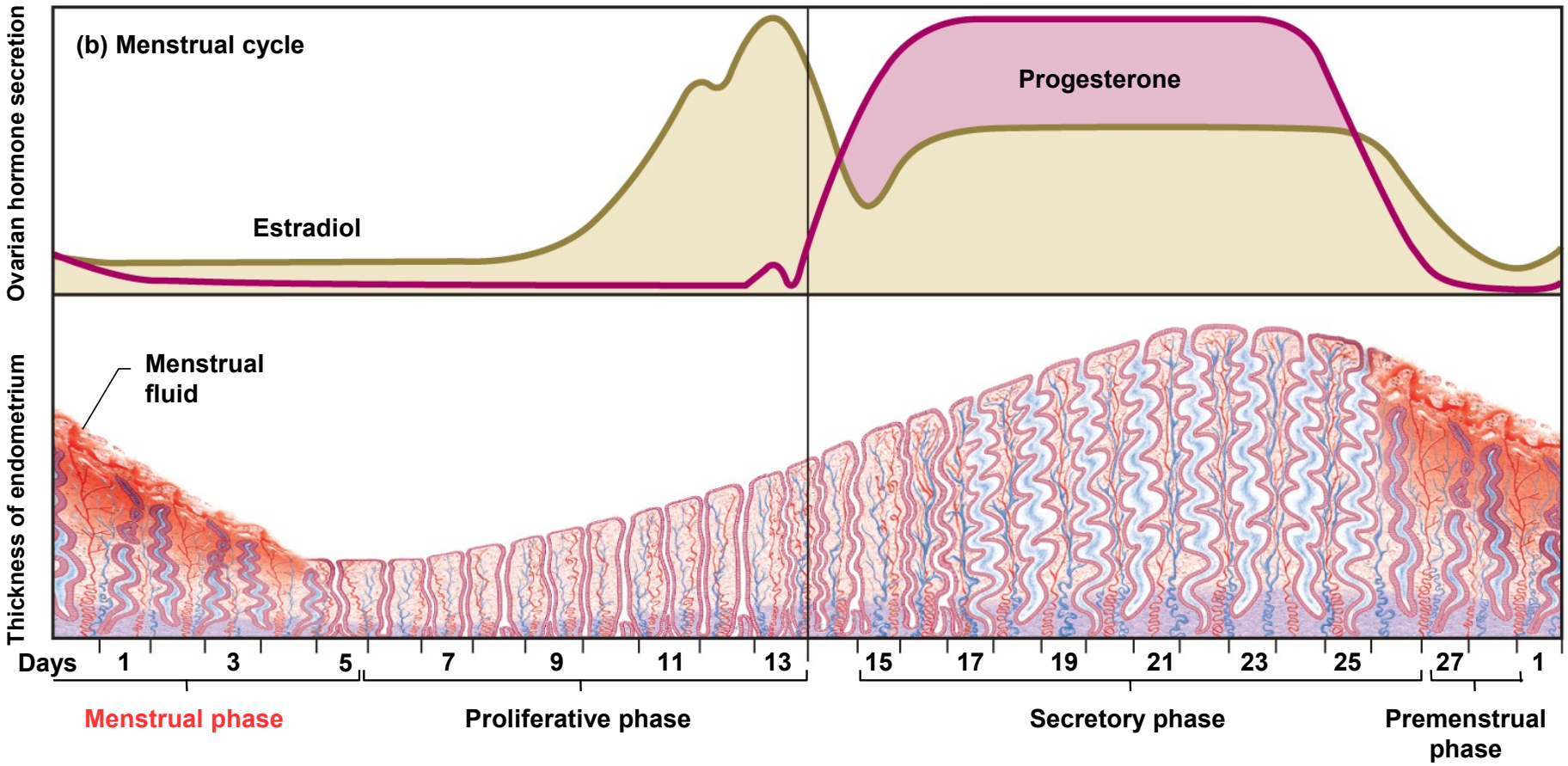
Estrus is the period in the sexual cycle of female mammals, except the higher primates, during which they are in heat—i.e., ready to accept a male and to mate.



Dog

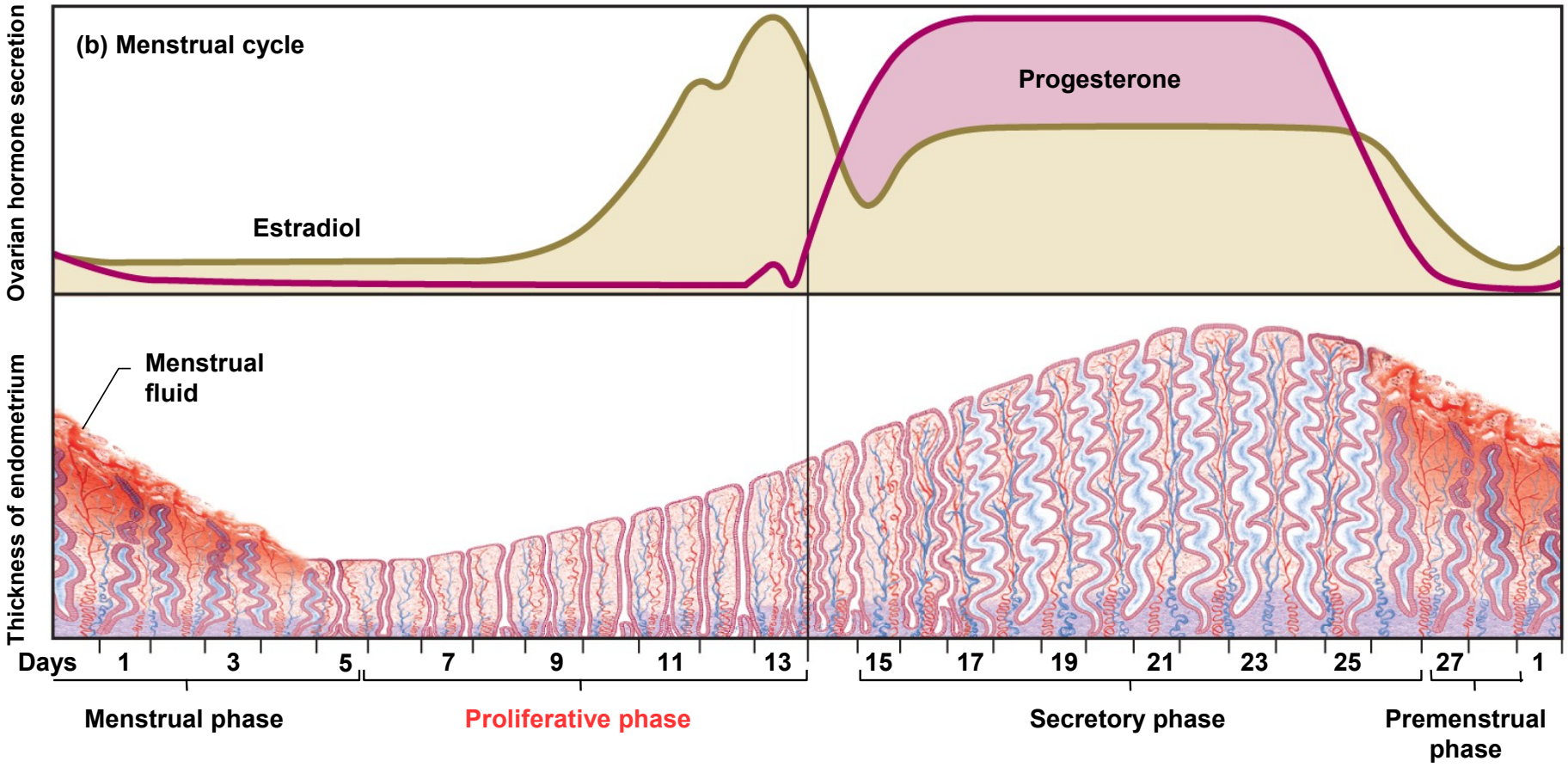
Horse

# First Phase = Menstrual Phase



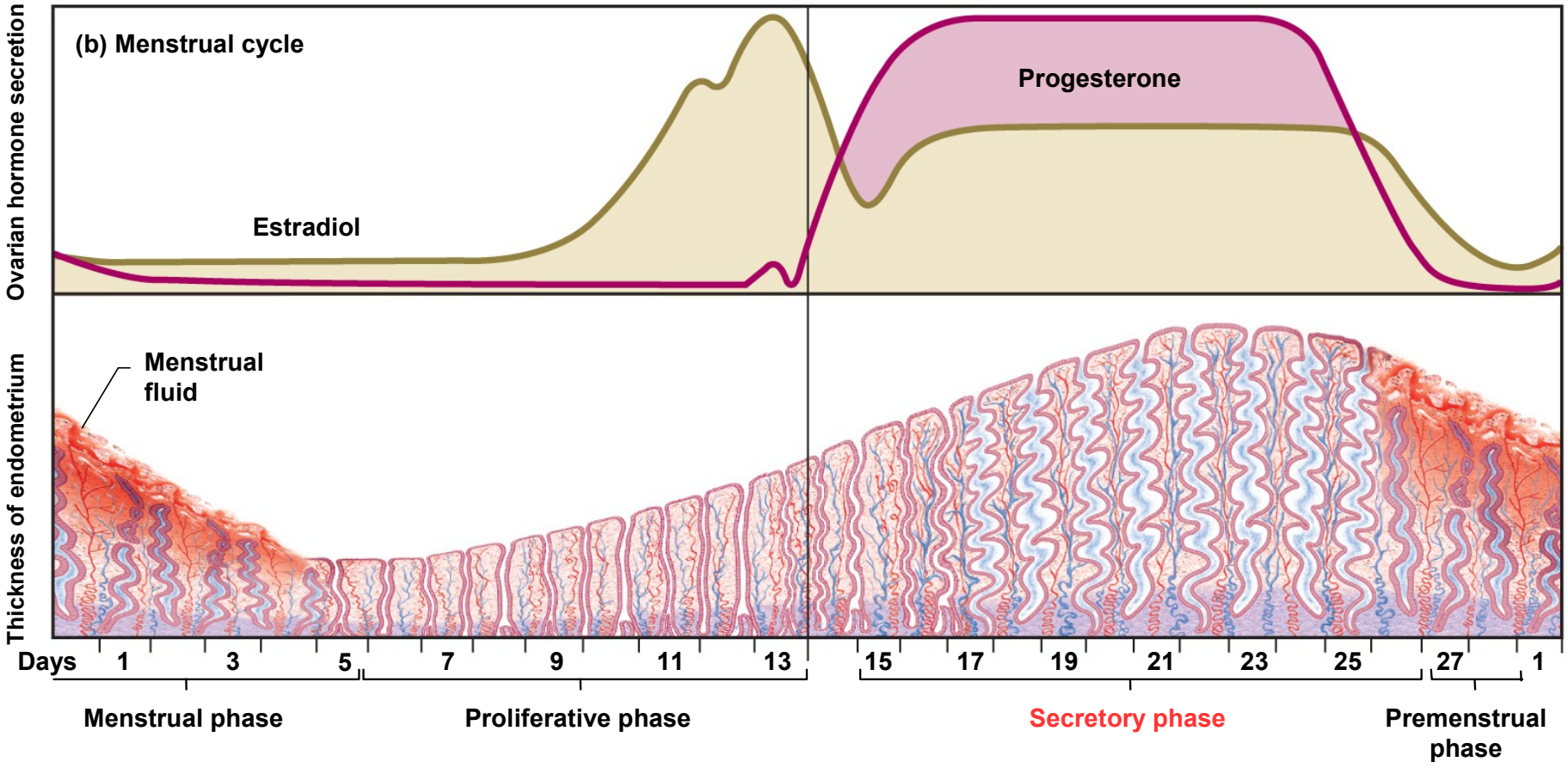

- Beginning of new cycle /// first discharge of endometrium from previous cycle

# Second Phase = Proliferative Phase



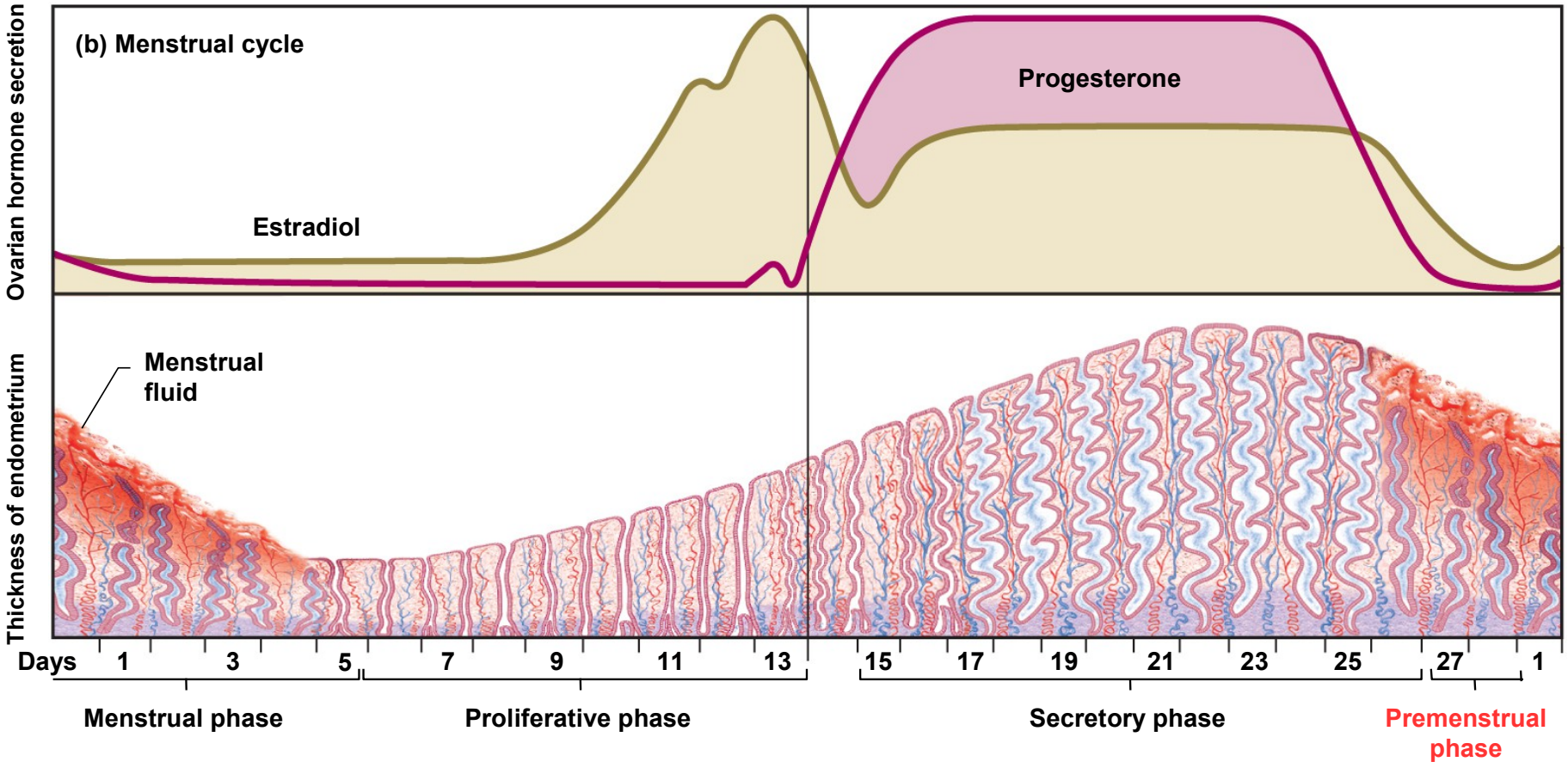

- Hyperplasia of endometrium //  under control of estrogen
- Estrogen now also up-regulates endometrium with progesterone receptors

# Third Phase = Secretory Phase



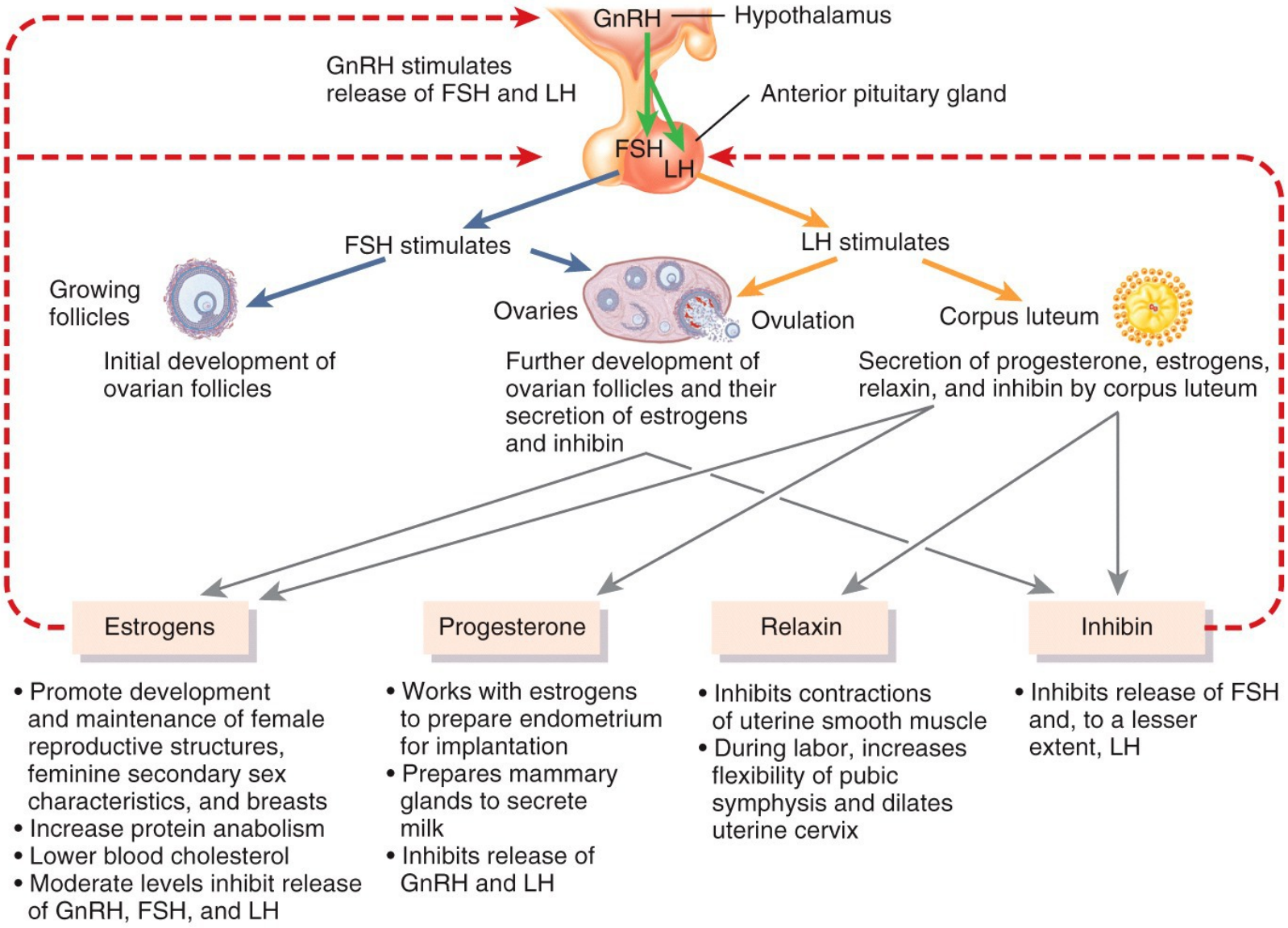

- Follows release of ovum from ovary
- Corpus luteum secretes progesterone
- Progesterone stimulates endometrium secretions (uterine milk)
- Endometrium maintained as long as progesterone present

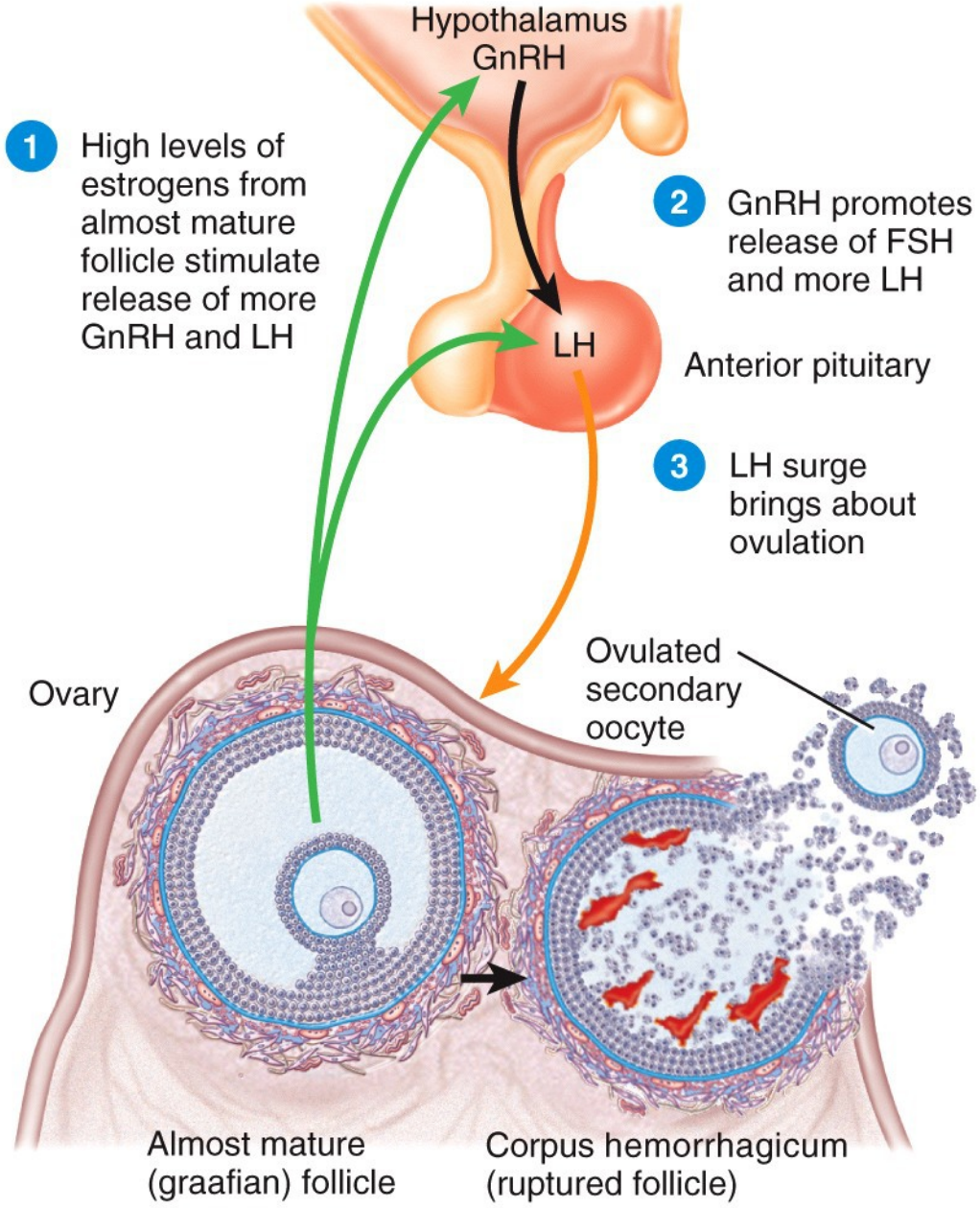
# Fourth Phase = Premenstrual Phase




- Corpus luteum stops producing progesterone, conceptus not viable
- Spiral arteries constrict // infarction with loss of endometrium

# Ovarian Cycle

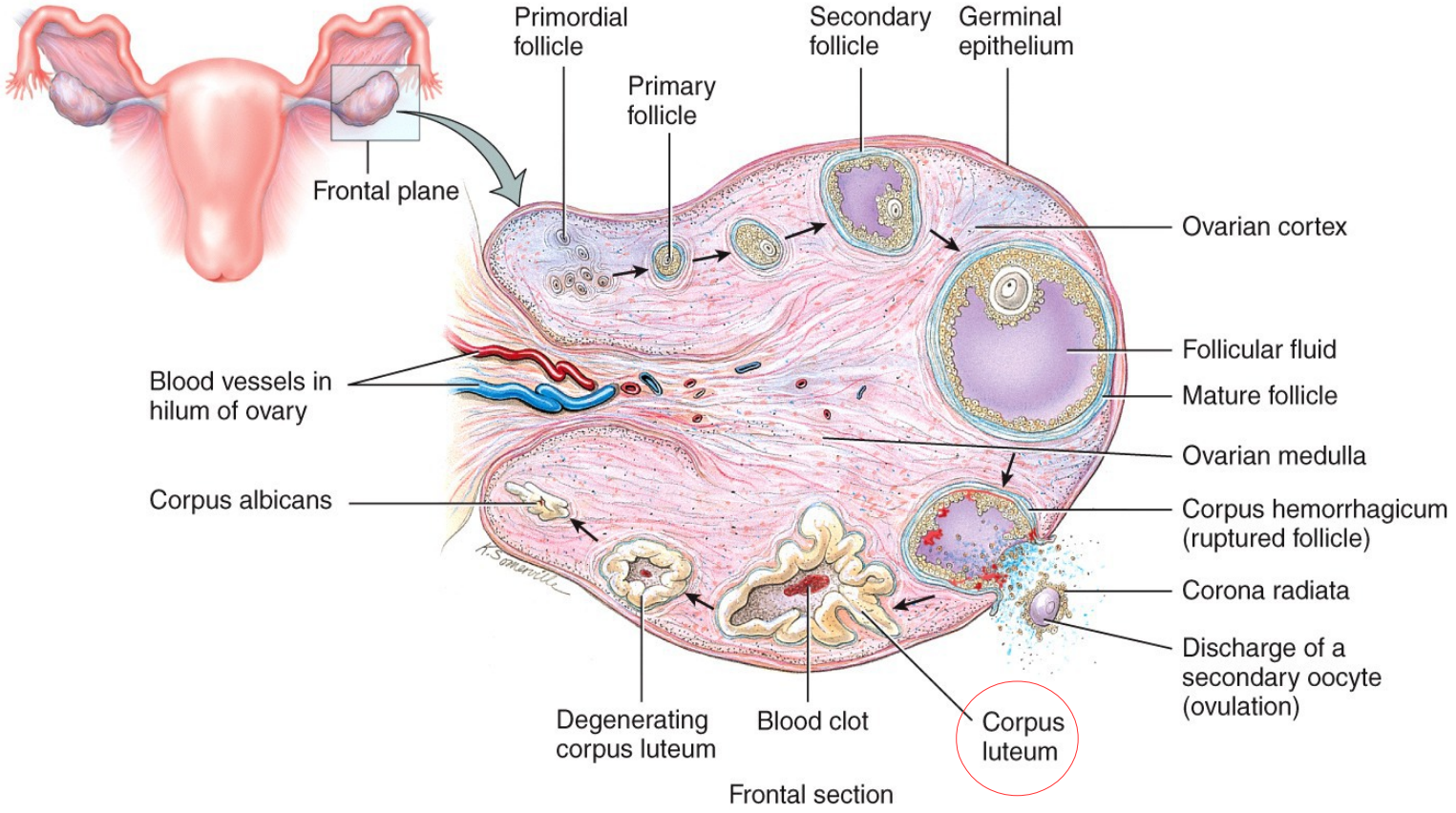





This slide explains how high levels of estrogen secreted by the almost mature follicle has positive feedback on anterior pituitary which causes the LH surge. The LH surge stimulates ovulation!

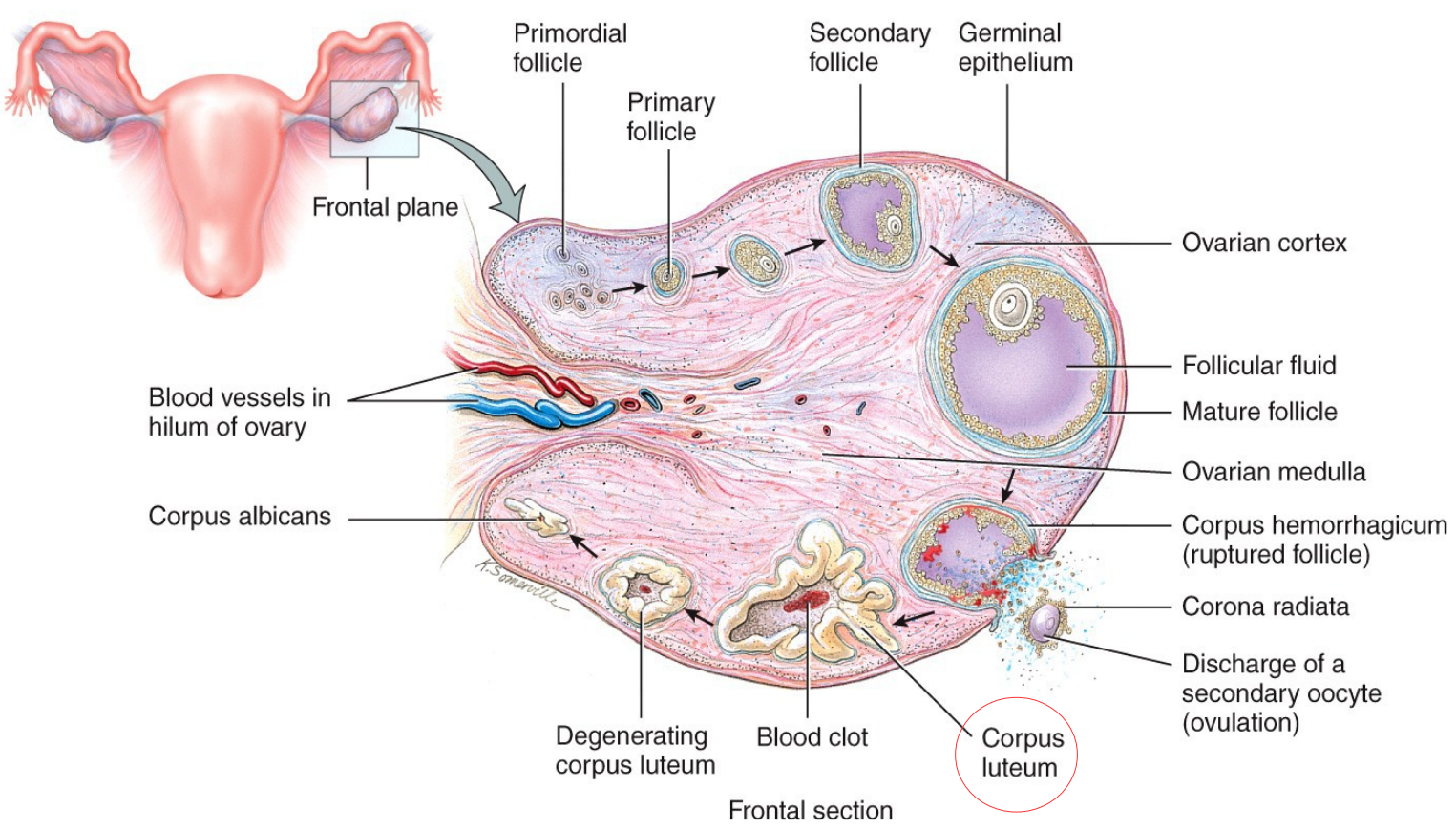
After ovulation, epithelial cells that surrounded follicle stay on surface of ovary and become the corpus luteum

CL now produces estrogen, progesterone, relaxin, and inhibin




At birth, there are approximately 1 million eggs in each ovary; and by the time of puberty, only about 400,000 remain.

Of these, only 300 to 400 will be ovulated during a woman's reproductive lifetime. Fertility can drop as a woman ages due to decreasing number and quality of the remaining eggs.



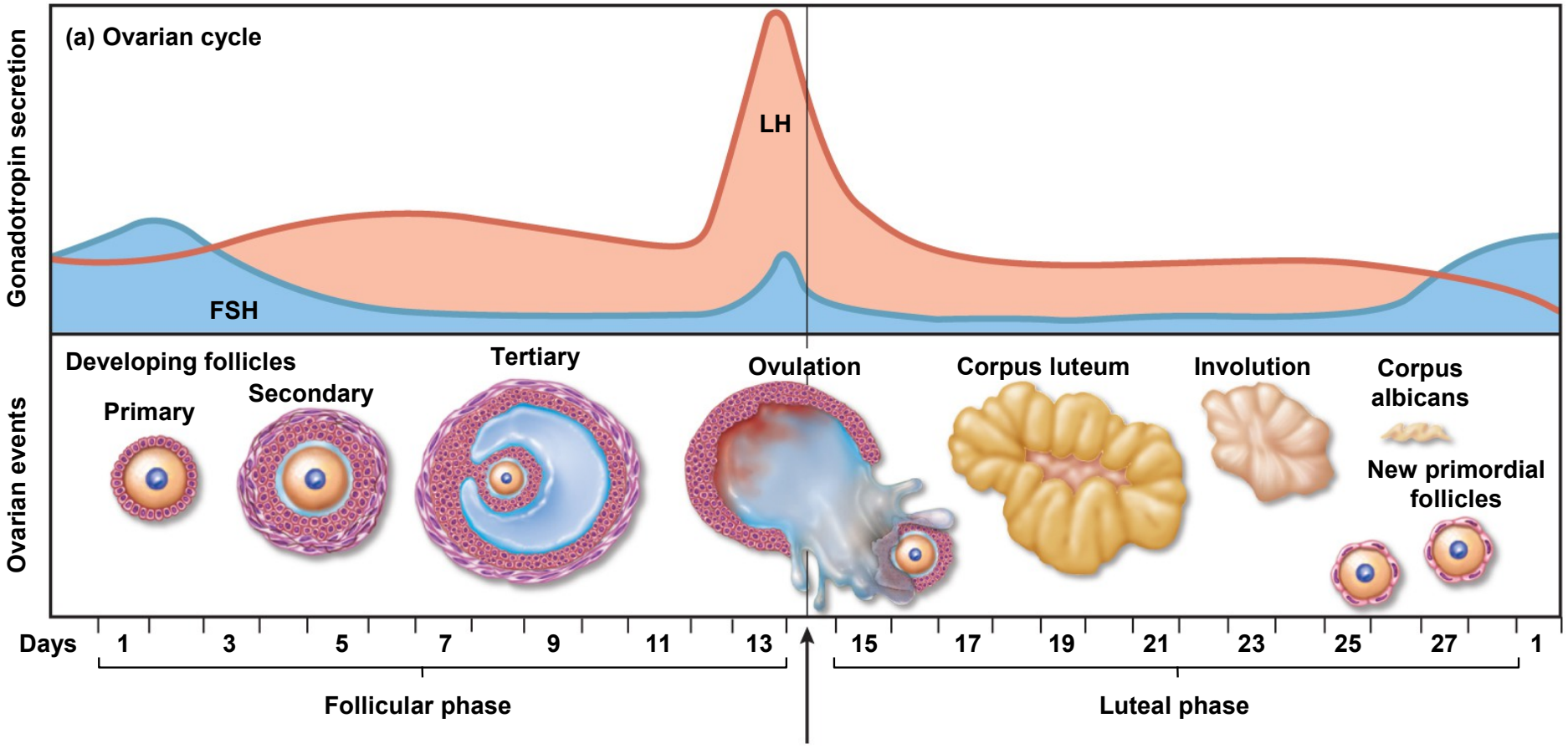

Starting at adolescence, each month about 24 primary follicles start to develop (called a cohort of follicles).

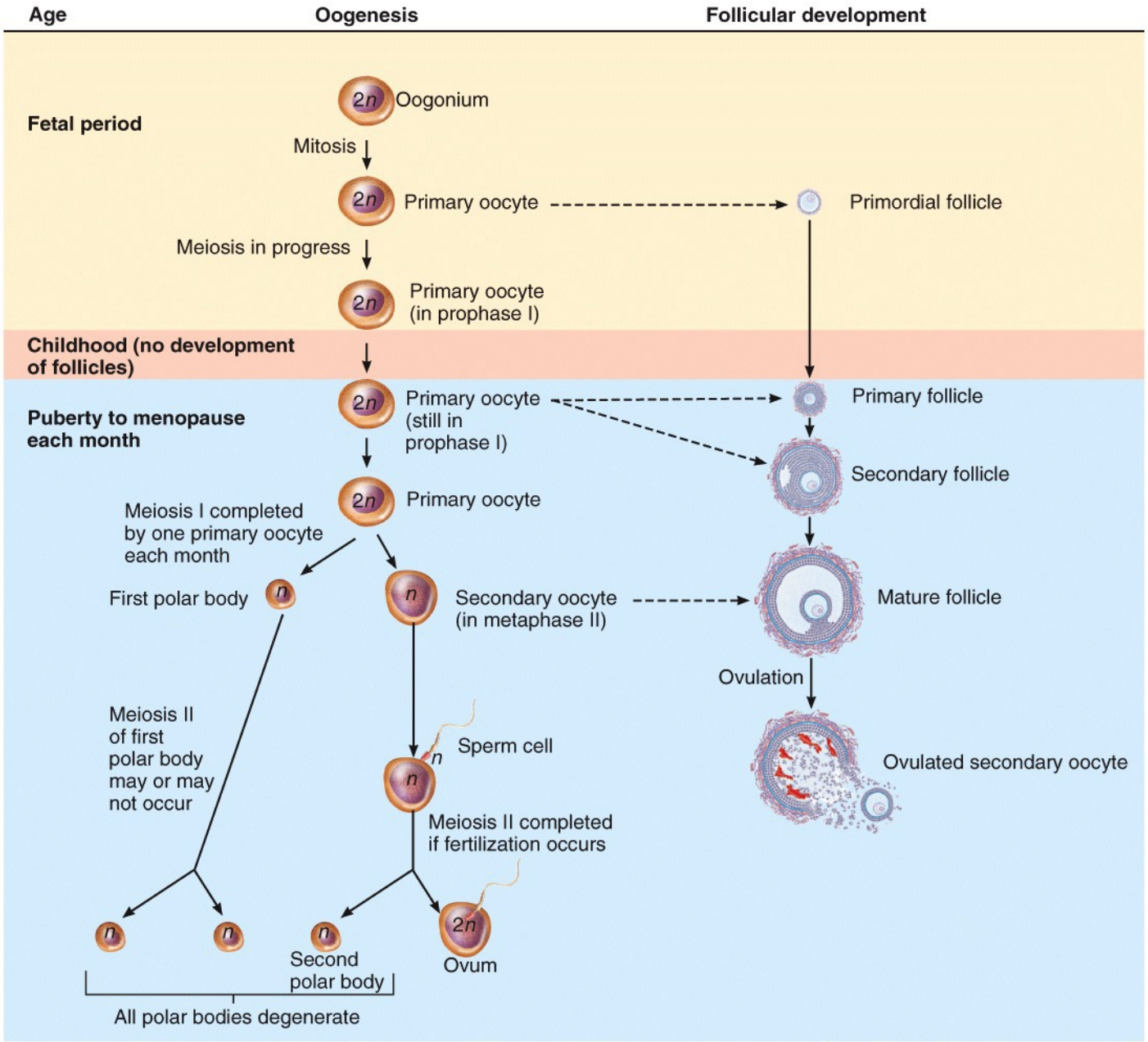
It actually takes 290 days for one of these follicles to develop into a mature oocyte.

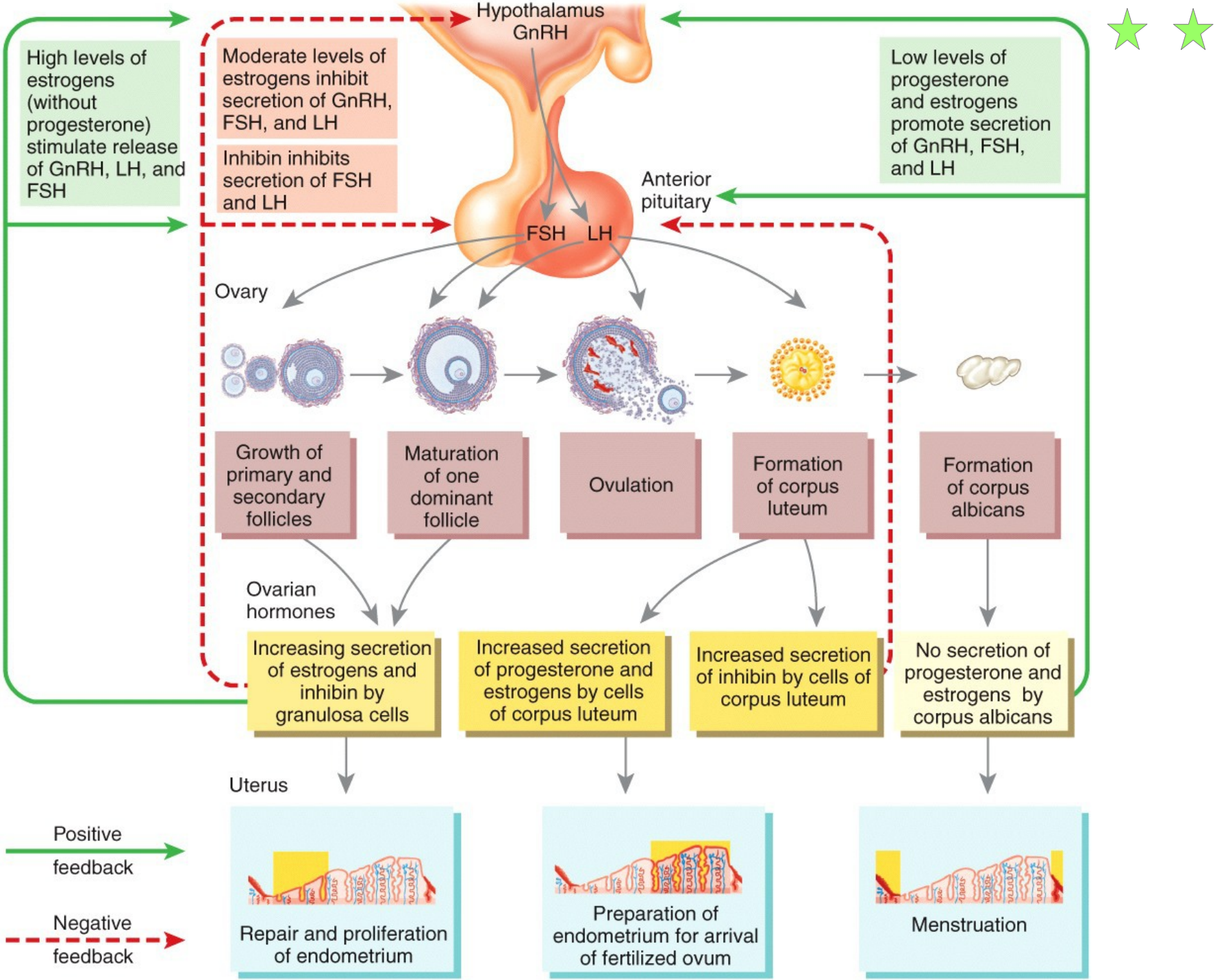
But there are always “waves” of follicles, separated by 28 days in their development /// developing at different stages within the ovary

Each month, only one follicle from each cohort reach maturity and ovulates with the LH surge.

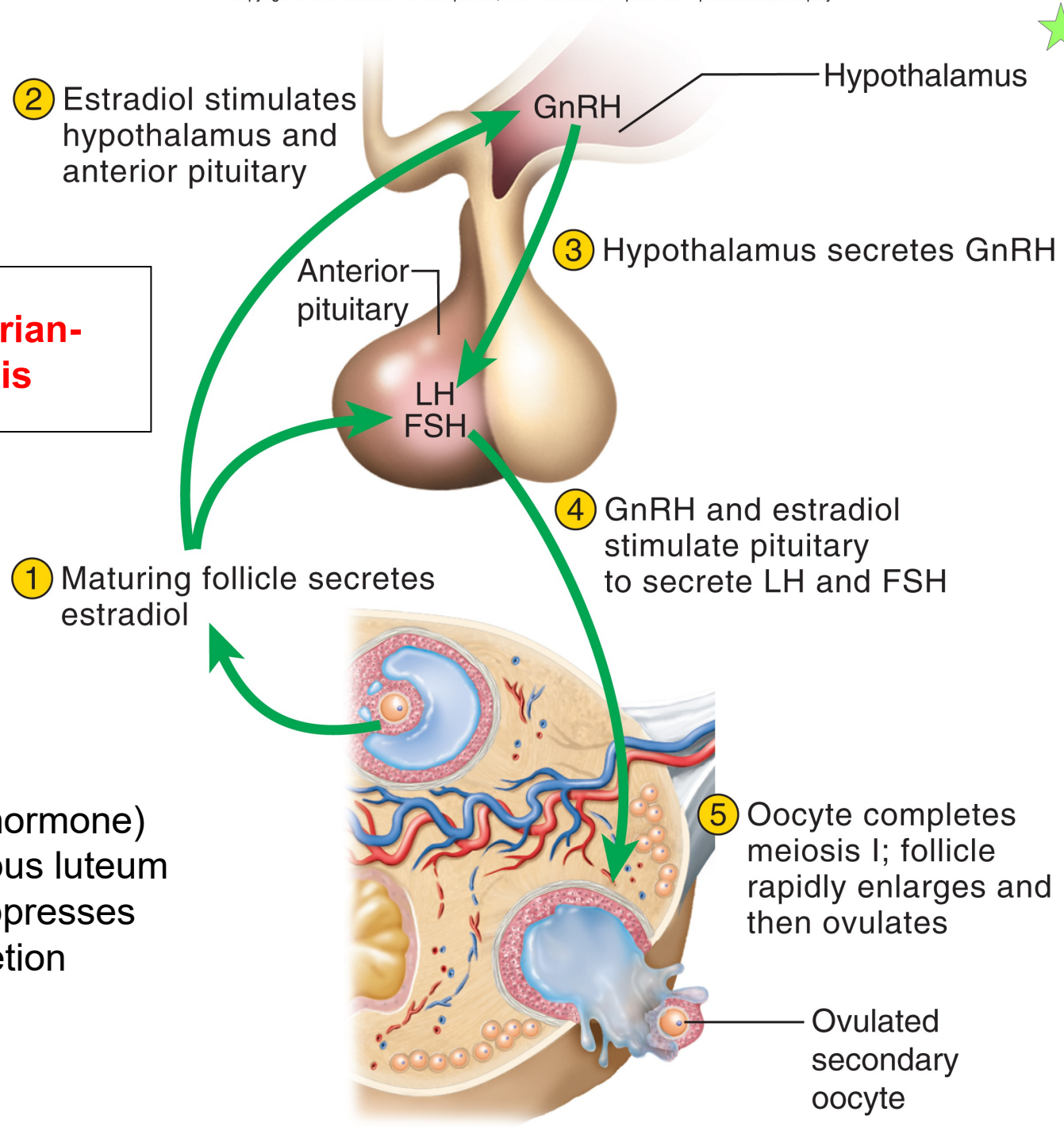
# Ovarian Cycle
# Follicular & Luteal Phases



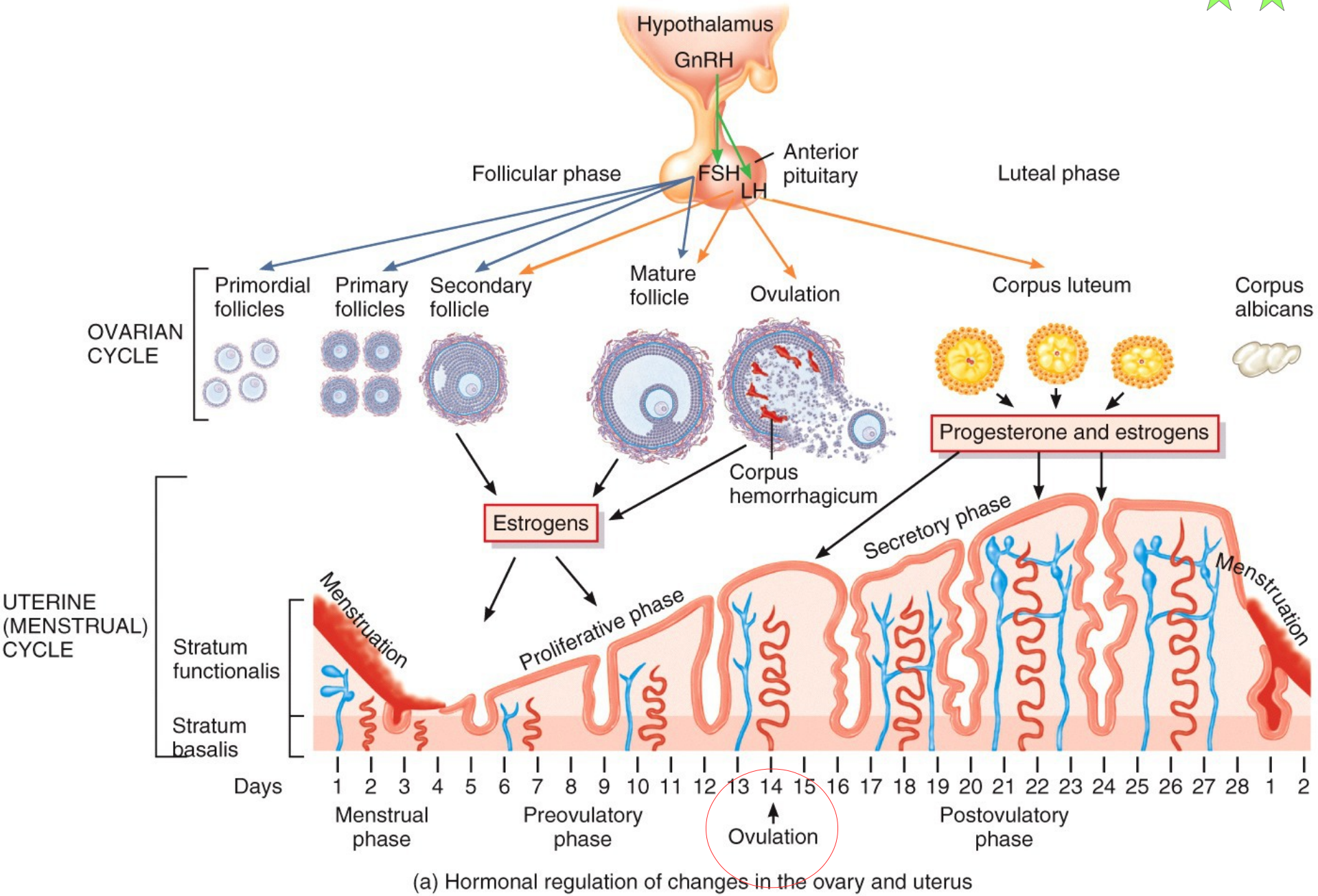

Age
Oogenesis
Follicular development
Fetal period
2n
Oogonium
Mitosis
2n
Primary oocyte
Primordial follicle
Meiosis in progress
2n
Primary oocyte
(in prophase I)
Childhood (no development of follicles)
Puberty to menopause each month
2n
Primary oocyte
(still in prophase I)
Primary follicle
Secondary follicle
2n
Primary oocyte
Meiosis I completed by one primary oocyte each month
First polar body
n
n
Secondary oocyte
(in metaphase II)
Mature follicle
Ovulation
Meiosis II of first polar body may or may not occur
n
Sperm cell
n
Ovulated secondary oocyte
Meiosis II completed if fertilization occurs
n
n
n
2n
Second polar body
Ovum
All polar bodies degenerate


Hypothalamus
GnRH
High levels of estrogens (without progesterone) stimulate release of GnRH, LH, and FSH
Moderate levels of estrogens inhibit secretion of GnRH, FSH, and LH
Inhibin inhibits secretion of FSH and LH
Low levels of progesterone and estrogens promote secretion of GnRH, FSH, and LH
Anterior pituitary
FSH
LH
Ovary
Growth of primary and secondary follicles
Maturation of one dominant follicle
Ovulation
Formation of corpus luteum
Formation of corpus albicans
Ovarian hormones
Increasing secretion of estrogens and inhibin by granulosa cells
Increased secretion of progesterone and estrogens by cells of corpus luteum
Increased secretion of inhibin by cells of corpus luteum
No secretion of progesterone and estrogens by corpus albicans
Uterus
Positive feedback
Negative feedback
Repair and proliferation of endometrium
Preparation of endometrium for arrival of fertilized ovum
Menstruation

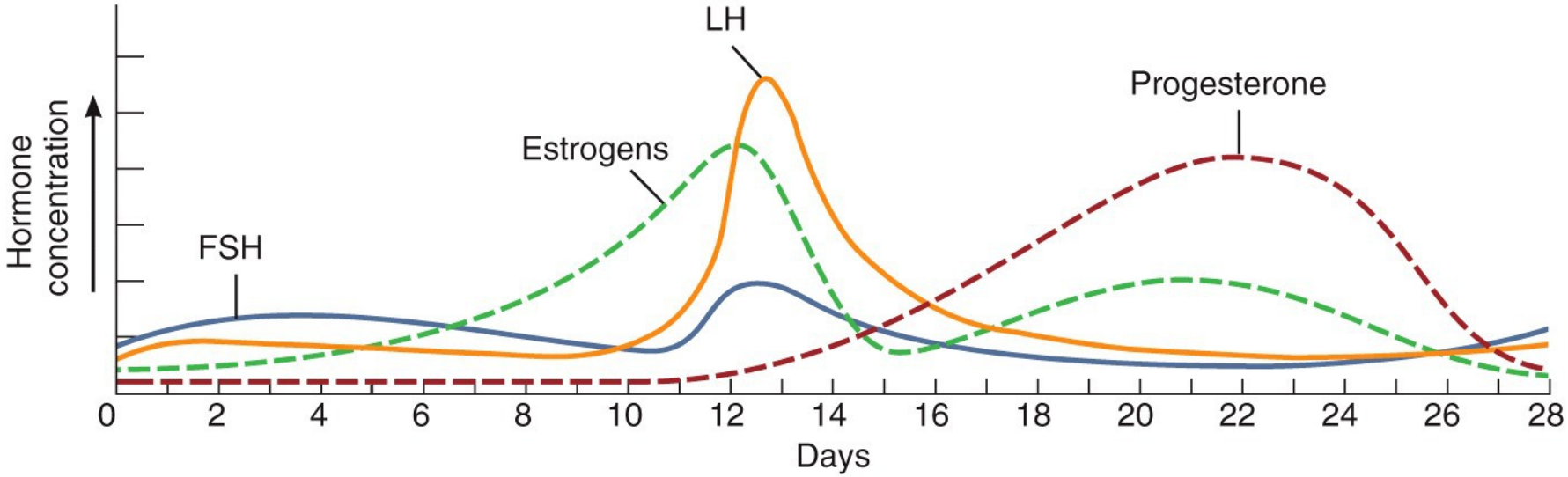
# Pituitary-Ovarian-Uterine Axis




Note: Inhibin (hormone) secreted by corpus luteum selectively suppresses FSH secretion




(a) Hormonal regulation of changes in the ovary and uterus




(b) Changes in concentration of anterior pituitary and ovarian hormones

These secretions regulate both the ovarian cycle and the menstrual cycles

The reproductive cycle describes what happens if a pregnancy occurs

The sexual cycle describes the events that occur if a pregnancy does not occur.

# When Is Pregnancy Most Likely to Occur?

200 million sperm enter the vagina

Fewer than two million enter cervix

Only about 200 reach the secondary oocyte

Fertilization most likely to occur 12 to 24 hours after ovulation

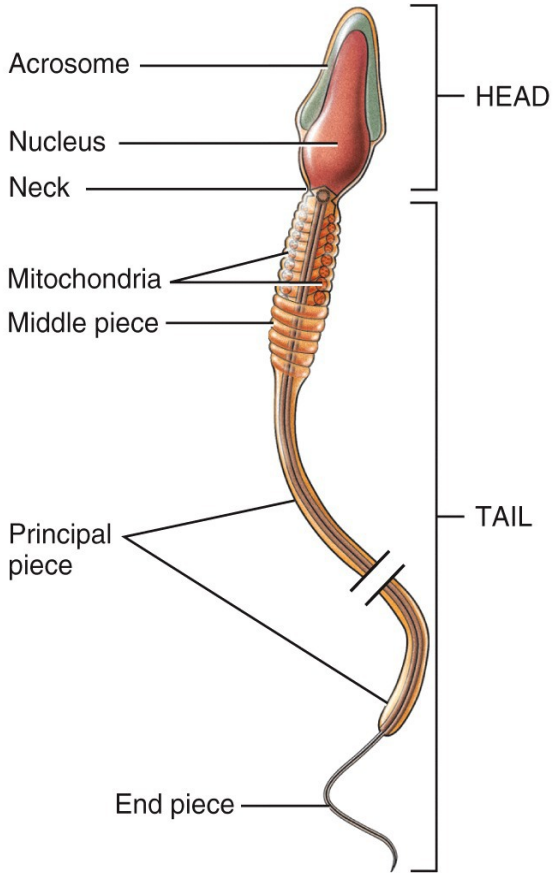
Egg is only viable for 24 hours

Sperm can not fertilize egg for first 10 hours after deposit in female (i.e. period of capacitation)

Sperm most viable 48 hours after they enter vagina /// may last for up to five days

According to the American College of Obstetricians and Gynecologists (ACOG), a woman can become pregnant if they have sex anywhere from 5 days before until 1 day after ovulation.

**(Test Answer: 5 days before ovulation and 1 day after)**



# Combined Oral Contraceptive Pill (COCP)
## Mechanism of action (Wiki)

**Another primary mechanism** of action of all progestogen-containing contraceptives is **inhibition of sperm penetration through the cervix** into the upper genital tract (uterus and fallopian tubes) by decreasing the water content and increasing the viscosity of the cervical mucus.

The estrogen and progestogen in COCPs have other effects on the reproductive system, but these have not been shown to contribute to their contraceptive efficacy:

Slowing tubal motility and ova transport, which may interfere with fertilization.

Endometrial atrophy and alteration of metalloproteinase content, which may impede sperm motility and viability, or theoretically inhibit implantation.

Endometrial edema, which may affect implantation.

Insufficient evidence exists on whether changes in the endometrium could actually prevent implantation. The primary mechanisms of action are so effective that the possibility of fertilization during COCP use is very small. Since pregnancy occurs despite endometrial changes when the primary mechanisms of action fail, endometrial changes are unlikely to play a significant role, if any, in the observed effectiveness of COCPs.

# Combined Oral Contraceptive Pill (COCP)
## Mechanism of action (Wiki)

Combined oral contraceptive pills were developed to prevent ovulation by suppressing the release of gonadotropins. Combined hormonal contraceptives, including COCPs, inhibit follicular development and prevent ovulation as a primary mechanism of action.

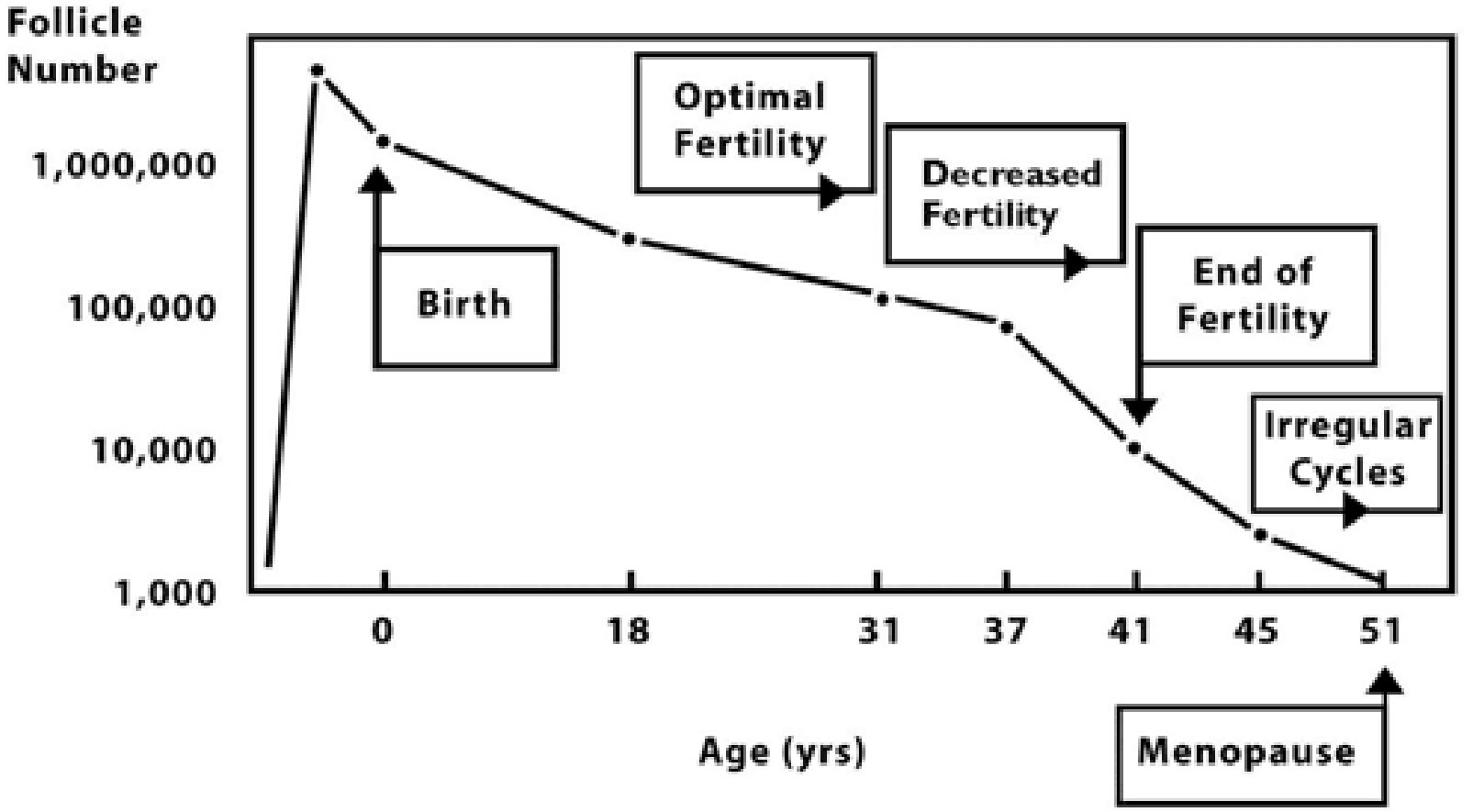
Progesterone negative feedback decreases the pulse frequency of gonadotropin-releasing hormone (GnRH) release by the hypothalamus, which decreases the secretion of follicle-stimulating hormone (FSH) and greatly decreases the secretion of luteinizing hormone (LH) by the anterior pituitary.

Decreased levels of FSH inhibit follicular development, preventing an increase in estradiol levels.

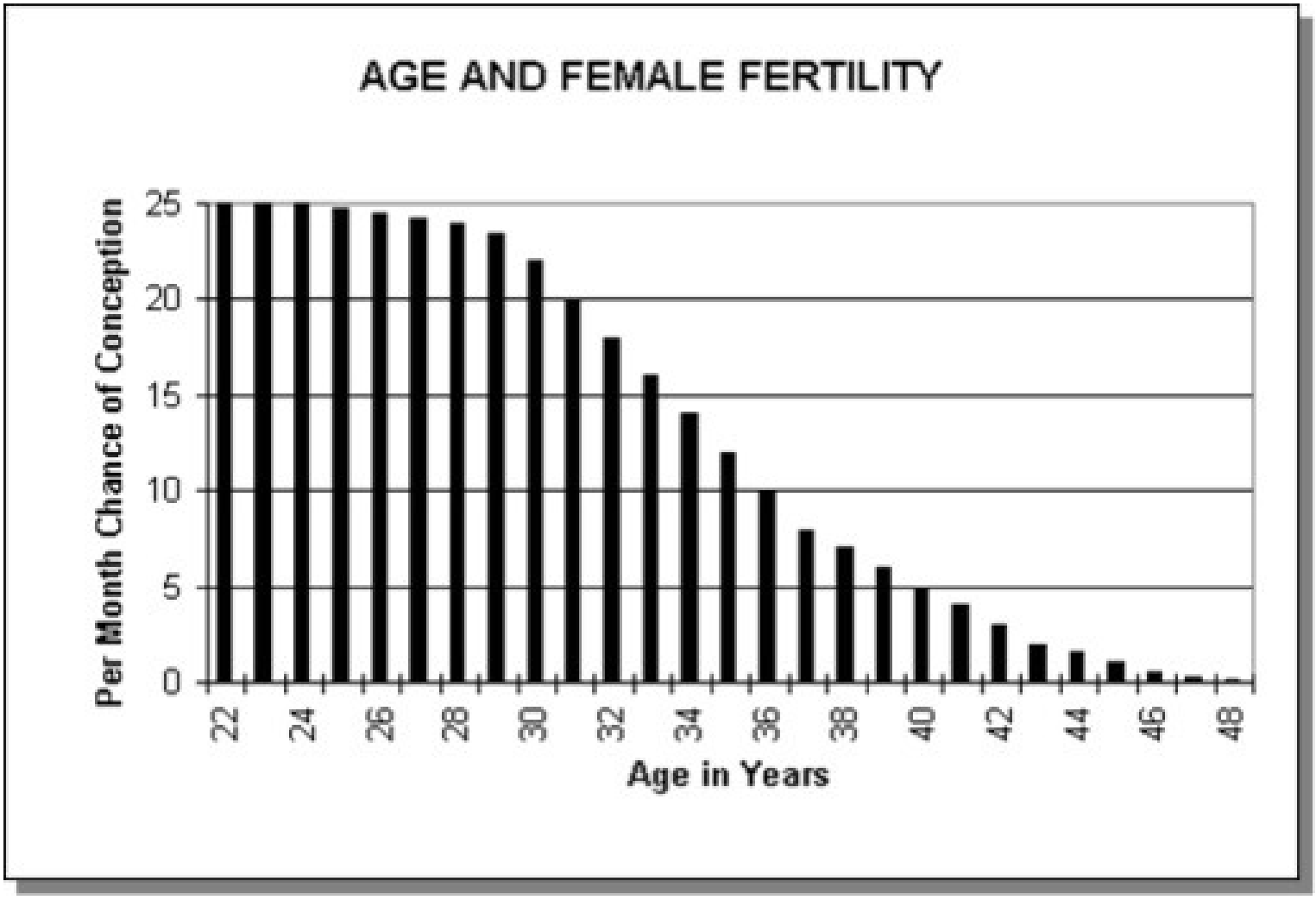
Progesterone negative feedback and the lack of estrogen positive feedback on LH secretion prevent a mid-cycle LH surge. Inhibition of follicular development and the absence of an LH surge prevent ovulation.

Estrogen was originally included in oral contraceptives for better cycle control (to stabilize the endometrium and thereby reduce the incidence of breakthrough bleeding), but was **also found to inhibit follicular development and help prevent ovulation.** Estrogen negative feedback on the anterior pituitary greatly decreases the secretion of FSH, which inhibits follicular development and helps prevent ovulation.

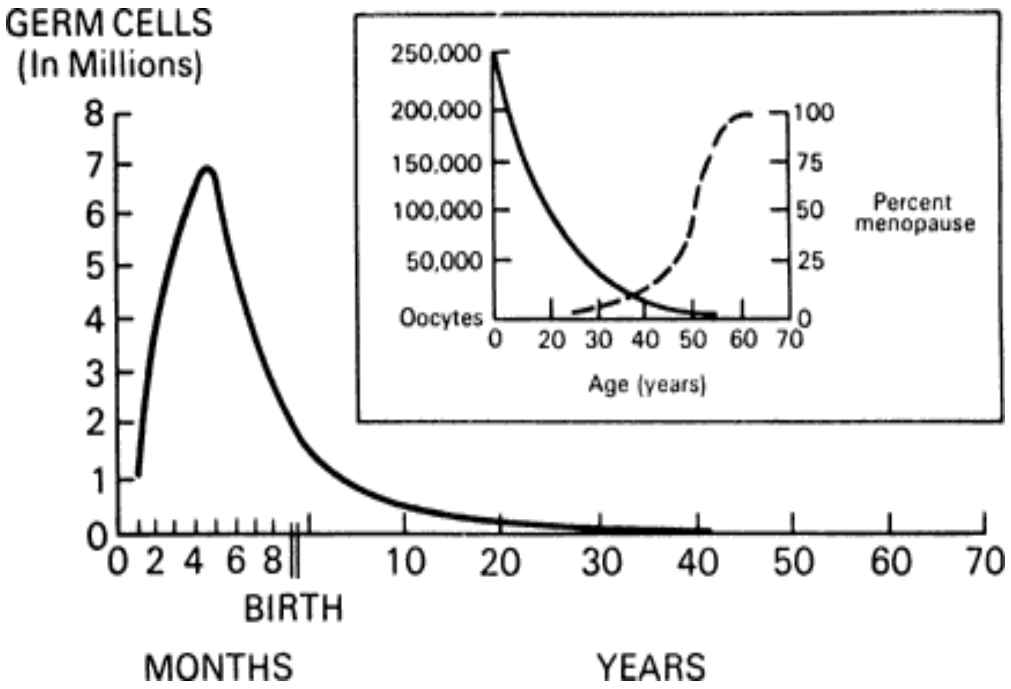
# Female Fertility




E.R. TE VELDE ET AL., 1998


AGE AND FEMALE FERTILITY
Per Month Chance of Conception
25
20
15
10
5
0
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Age in Years

# Female Oogenesis




First sign of gamete development seen during first five weeks of embyonic development.

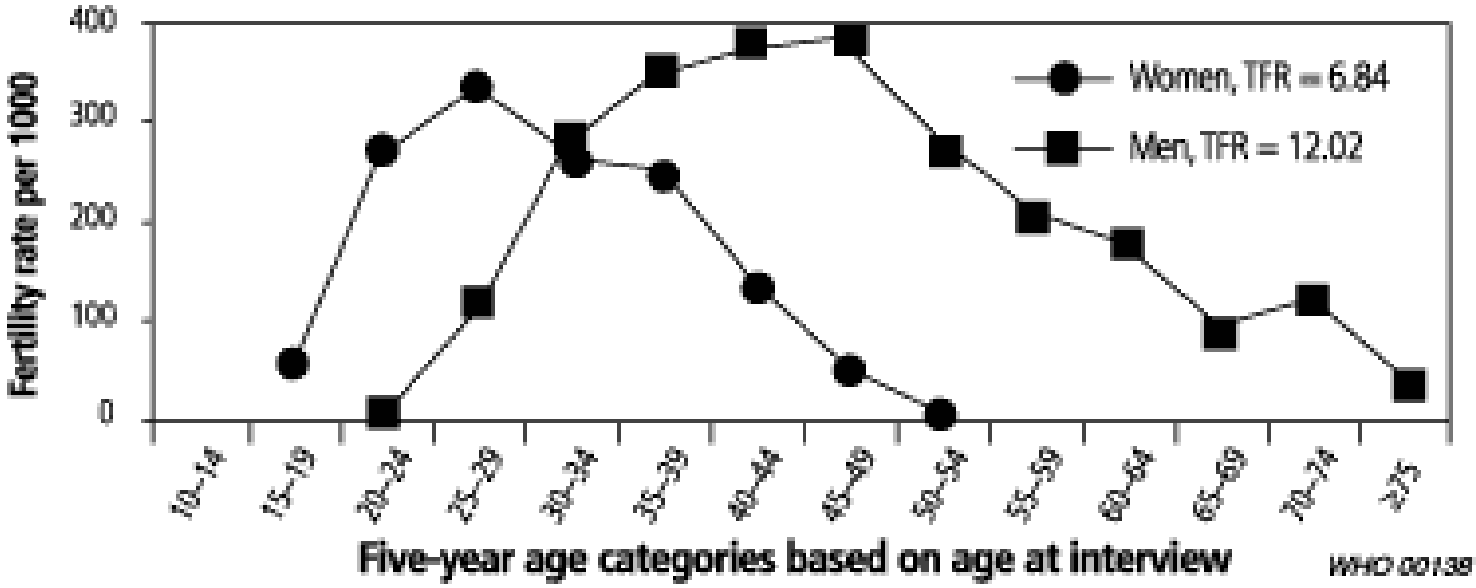
Called oogonia and continue to develop until fifth month.

By fifth month, female fetus has developed 6 to 7 million oogonia. They now enter state of arrested development until shortly before birth. Oogonia now referred to as primary oocytes.

Primary oocytes undergo atresia before birth and only about 2 million eggs remain at time of birth.

During childhood, most eggs undergo atresia and by puberty only 200,000 eggs remain. If woman ovulates between 14 and 50 on a 28 day cycle then she would only need 480 eggs!

Fig. 2. **Men's and women's age-specific fertility rates, 1993–97**
(TFR = total fertility rate)



# Male Reproductive Physiology

# Overview of Male Reproductive System

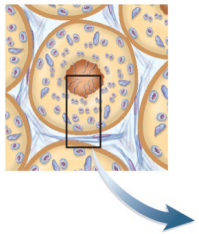
Reproductive system consists of primary and secondary sex organs

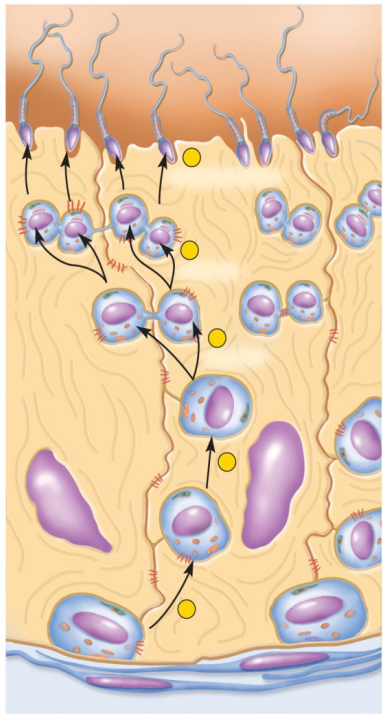
primary sex organs (the gonads) // produce gametes (testes)

secondary sex organs // organs other than the gonads that are necessary for reproduction – system of ducts, glands, and penis

# Follicle Stimulating Hormone (FSH) - Male

- FSH produced by anterior pituitary
  - Target tissue = sustentacular cells (SC) in the seminiferous tubules (located in testis)
  - SC secrete androgen binding protein
  - ABP required to concentrate testosterone inside seminiferous tubules
  - Note: LH stimulates interstitial cells to produce testosterone outside of the tubules





- Sustentacular cells may secrete inhibin if sperm are not ejaculated
- Inhibin stops production of FSH and no ABP is produced
- Testosterone is not concentrated in testes and spermatogenesis stops // note: testosterone is still produced under influence of LH

# Luteininzing hormone (LH)
# (also called interstitial cell stimulating hormone (ICSH)

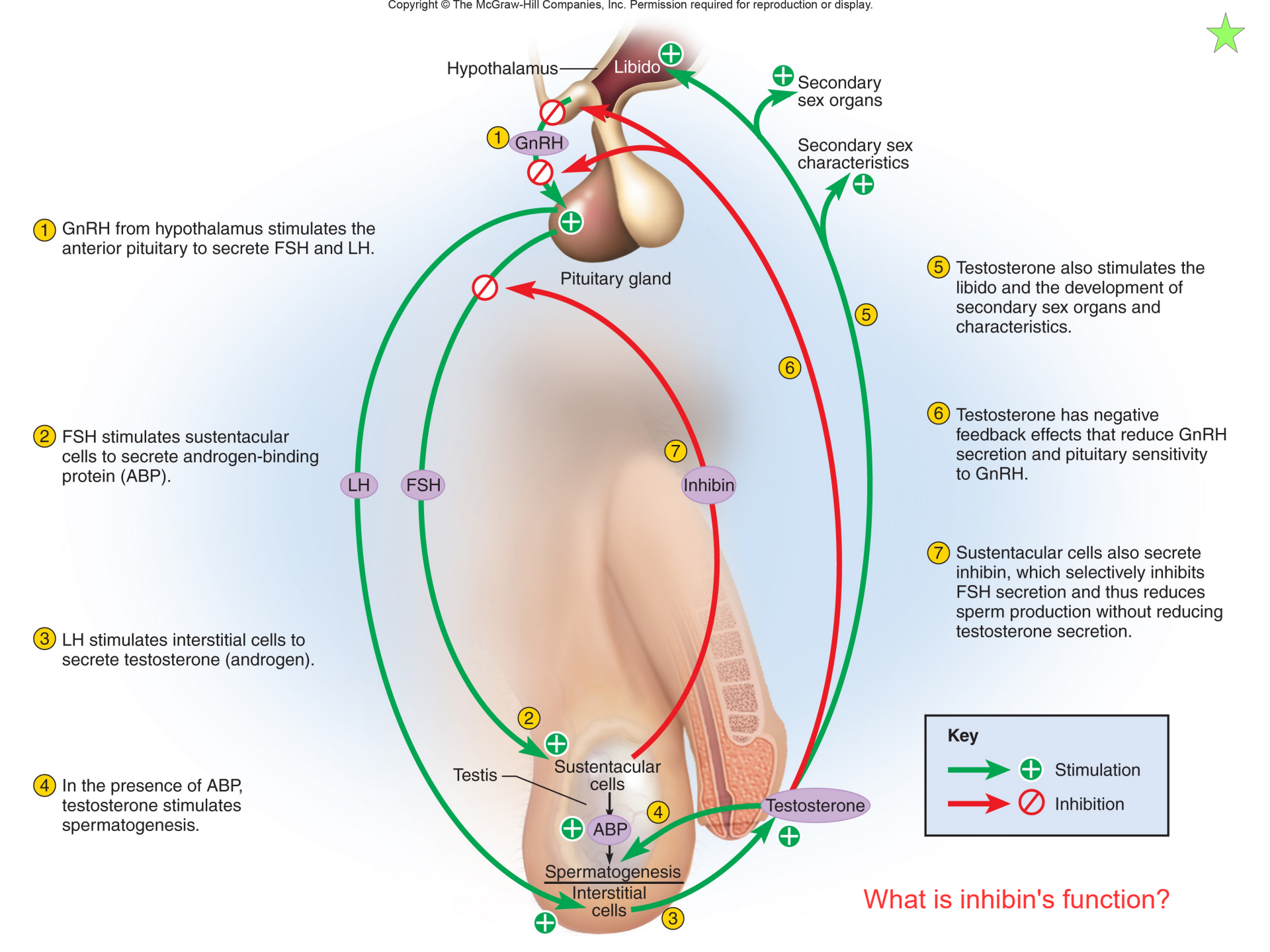
- LH produced by anterior pituitary
  - target tissue = interstitial cells in testes between seminiferous tubules
  - Testosterone must be concentrated inside seminiferous tubules for sperm production
  - ABP produced by Sertoli cells within semininferous tubules cause testosterone to migrate into seminiferous tubules
  - high concentration of testosterone inside semininerous tubules stimulates spermatogonium cells /// stimulates spermatogenesis

# Testosterone

- Produced by interstitial cells of the testes
  - LH receptors on interstitial cells
  - Interstitial cells produce testosterone
  - Testosterone responsible for secondary sexual characteristics
  - Testosterone also required for spermatogenesis
  - Testosterone must be concentrated by ABP within seminiferous tubules for spermatogenisis

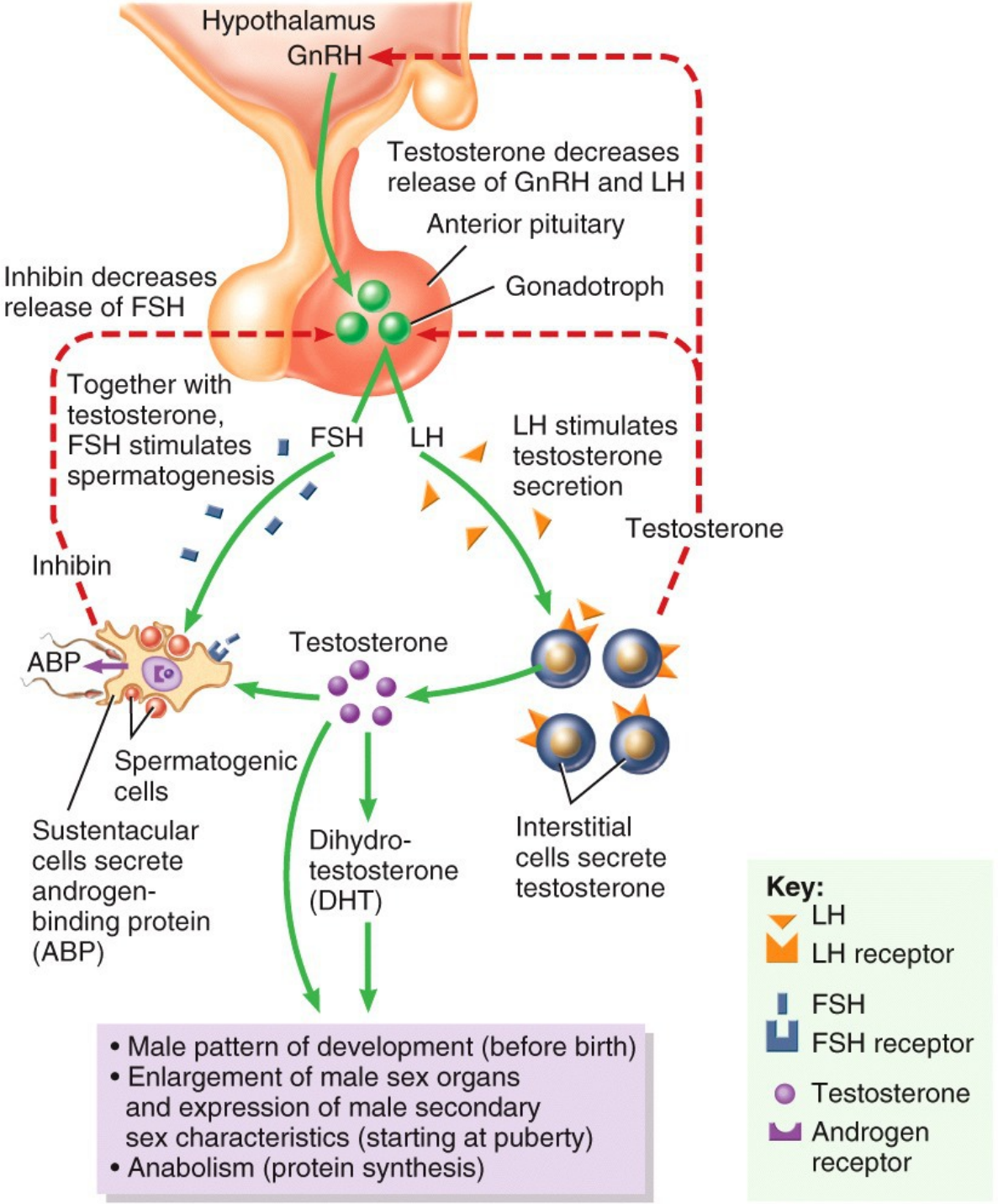
# Inhibin

- Released by sustentacular cells of testes
  - Inhibits FSH release
  - By stopping FSH - prevents SC from producing ABP //  this results in testosterone not being concentrated in testes which stops spermatogenesis
  - LH secretions continues to stimulate interstitial cells /// production of testosterone continues so other functions like muscle growth, hair growth, behavior, and other secondary sexual characteristics occurs

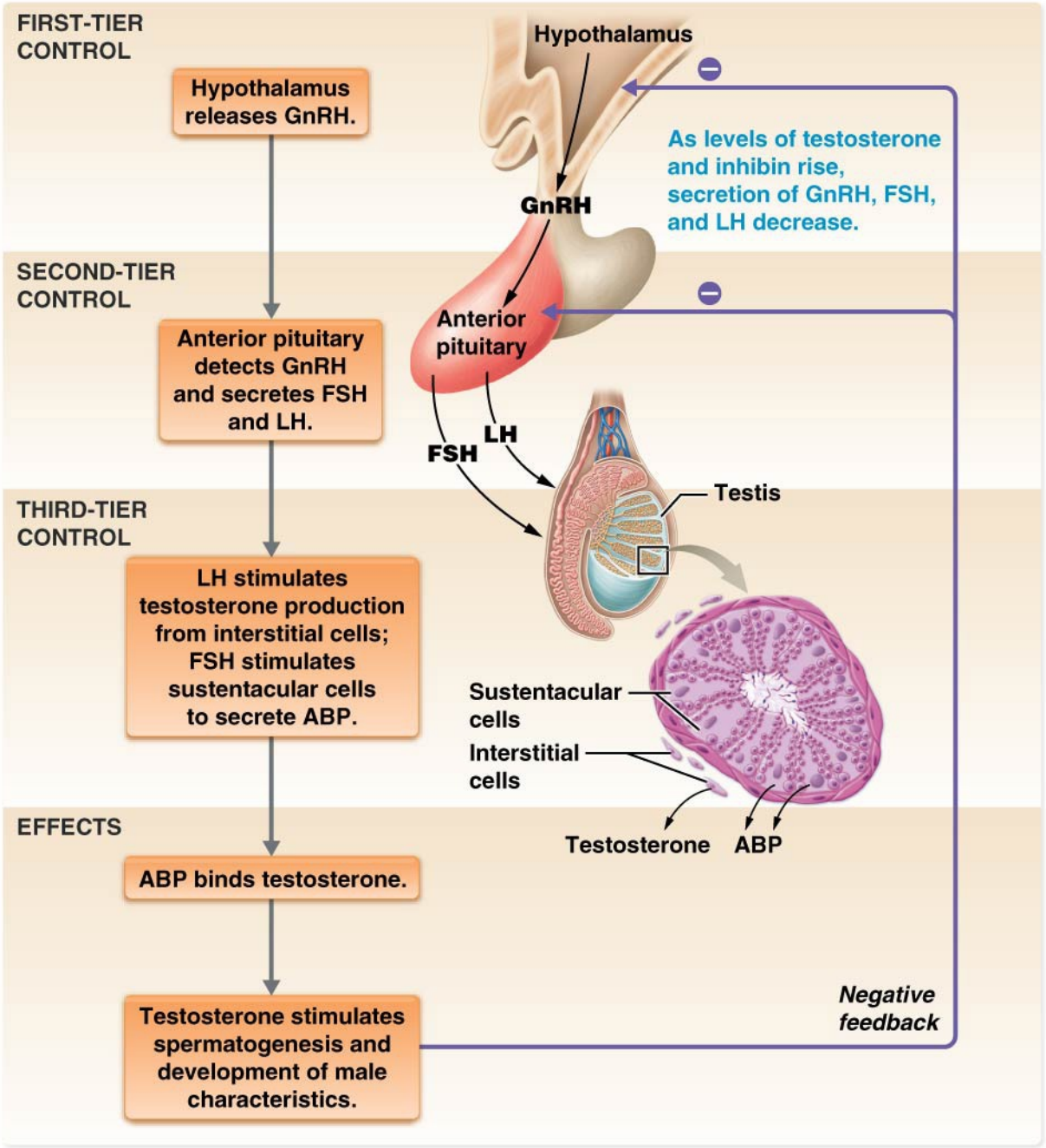



1. GnRH from hypothalamus stimulates the anterior pituitary to secrete FSH and LH.
2. FSH stimulates sustentacular cells to secrete androgen-binding protein (ABP).
3. LH stimulates interstitial cells to secrete testosterone (androgen).
4. In the presence of ABP, testosterone stimulates spermatogenesis.
5. Testosterone also stimulates the libido and the development of secondary sex organs and characteristics.
6. Testosterone has negative feedback effects that reduce GnRH secretion and pituitary sensitivity to GnRH.
7. Sustentacular cells also secrete inhibin, which selectively inhibits FSH secretion and thus reduces sperm production without reducing testosterone secretion.

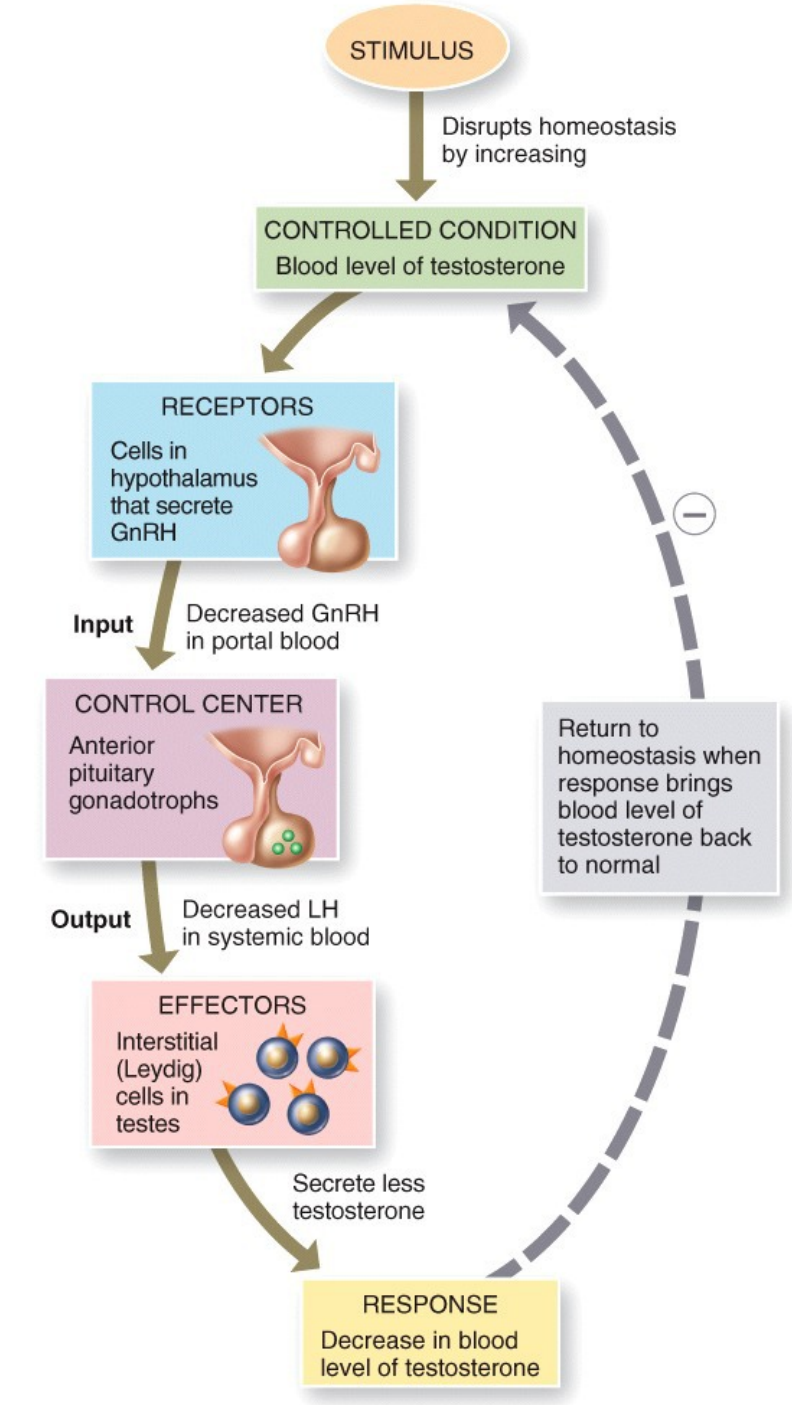
What is inhibin's function?

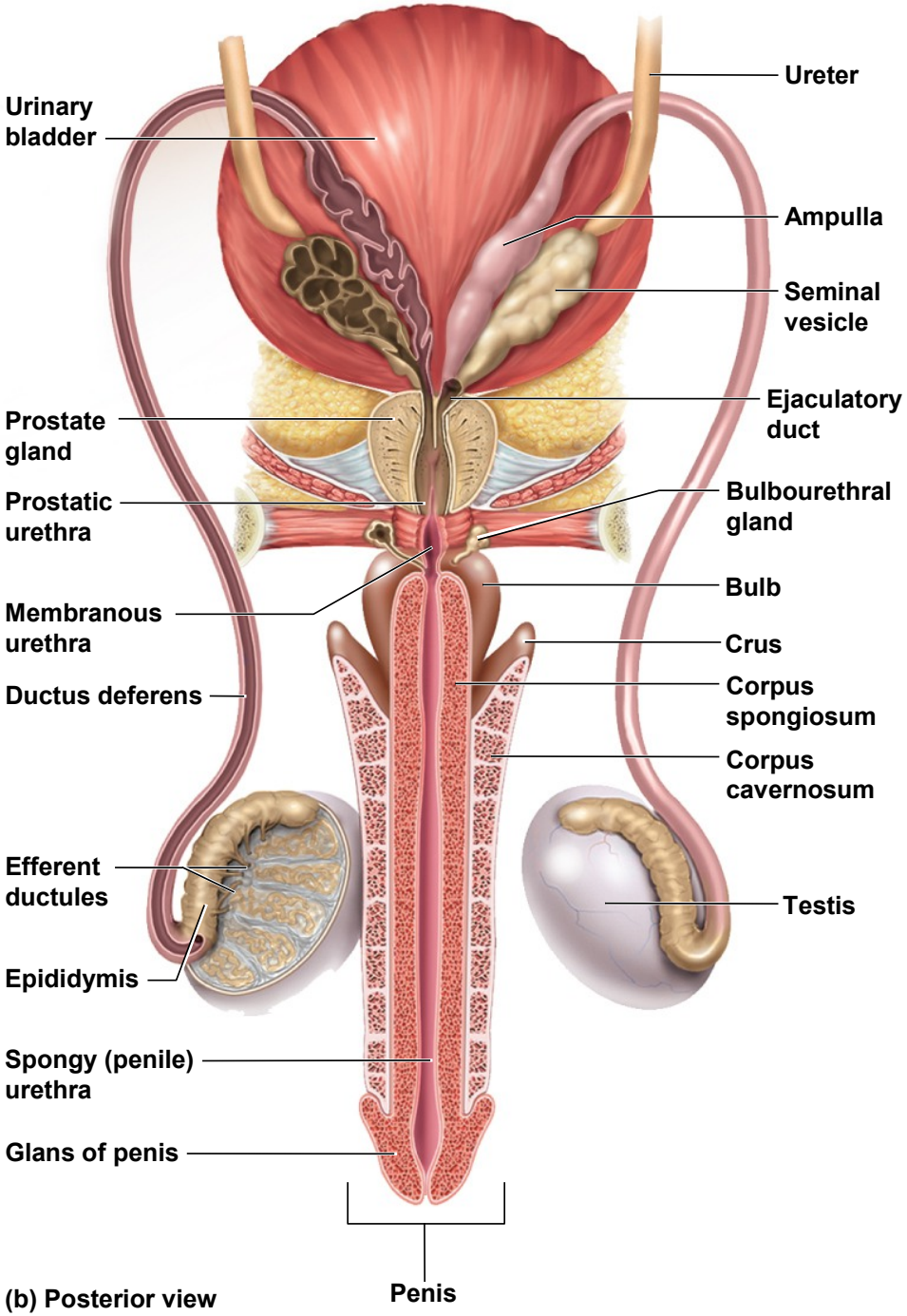

Hypothalamus
GnRH
Testosterone decreases release of GnRH and LH
Anterior pituitary
Gonadotroph
Inhibin decreases release of FSH
Together with testosterone, FSH stimulates spermatogenesis
FSH
LH
LH stimulates testosterone secretion
Testosterone
Inhibin
ABP
Testosterone
Spermatogenic cells
Sustentacular cells secrete androgen-binding protein (ABP)
Dihydro-testosterone (DHT)
Interstitial cells secrete testosterone
• Male pattern of development (before birth)
• Enlargement of male sex organs and expression of male secondary sex characteristics (starting at puberty)
• Anabolism (protein synthesis)
Key:
LH
LH receptor
FSH
FSH receptor
Testosterone
Androgen receptor

**Hormonal regulation of testicular function via the hypothalamic-pituitary-gonadal (HPG) axis.**



# Response to Excess Testosterone





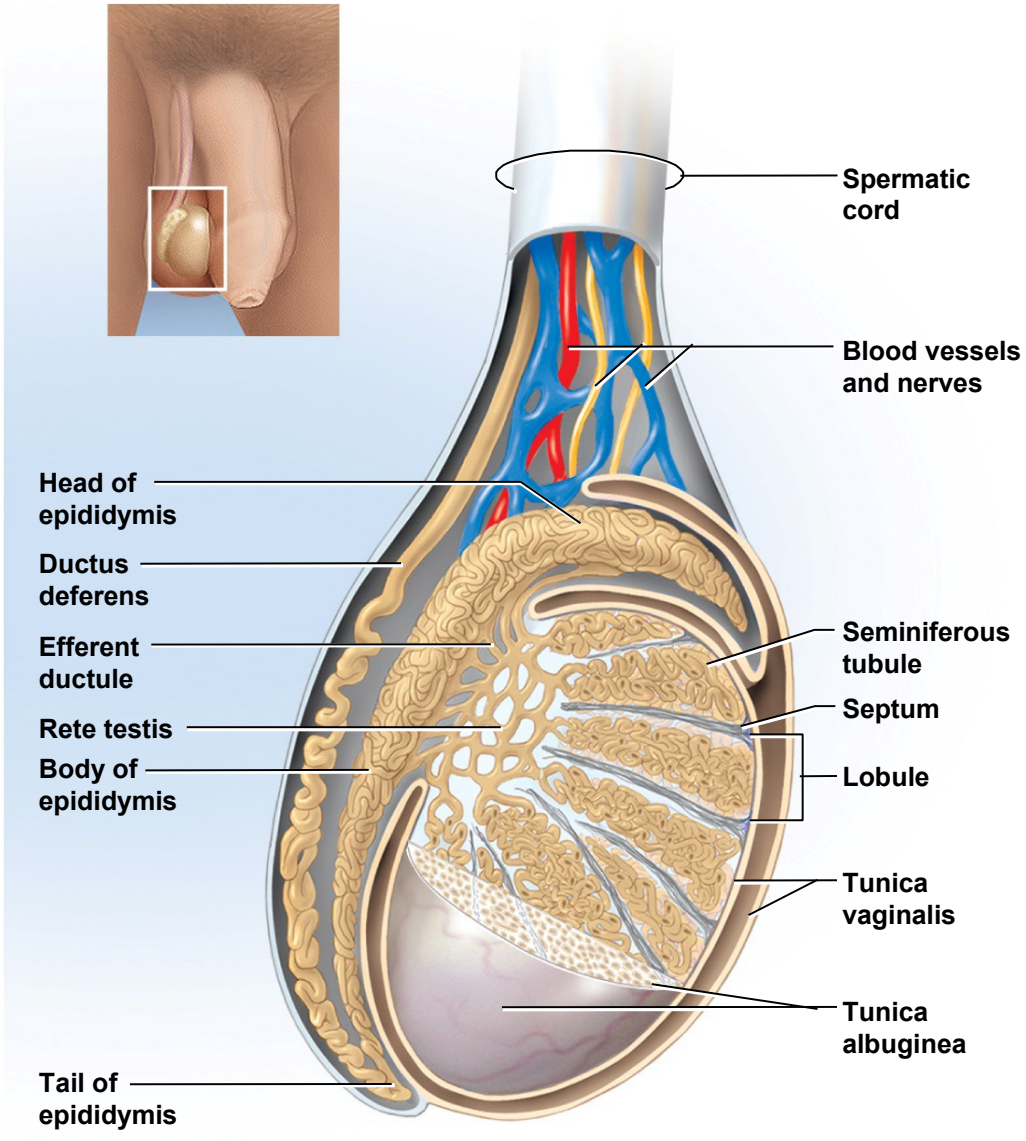

**Why is male testes outside the abdominal cavity?**

Testis must be outside abdominal cavity for spermatogenisis

Elevated temperature within the abdominal cavity will inhibit spermatogenisis.

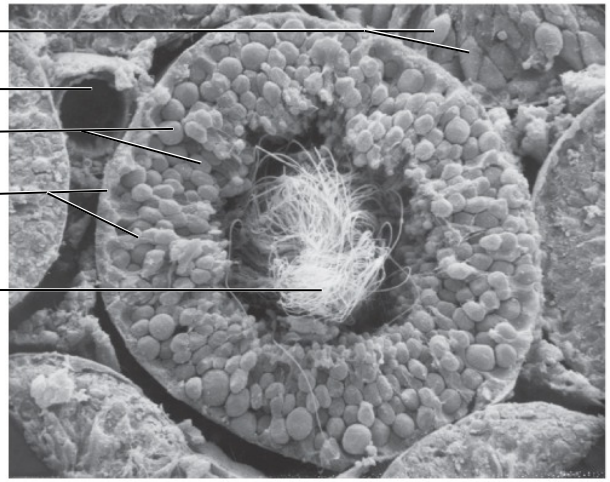
Testes must migrate from the abdominal cavity, through the spermatic cord, and into the scrotum.

# Testis and Associated Structures

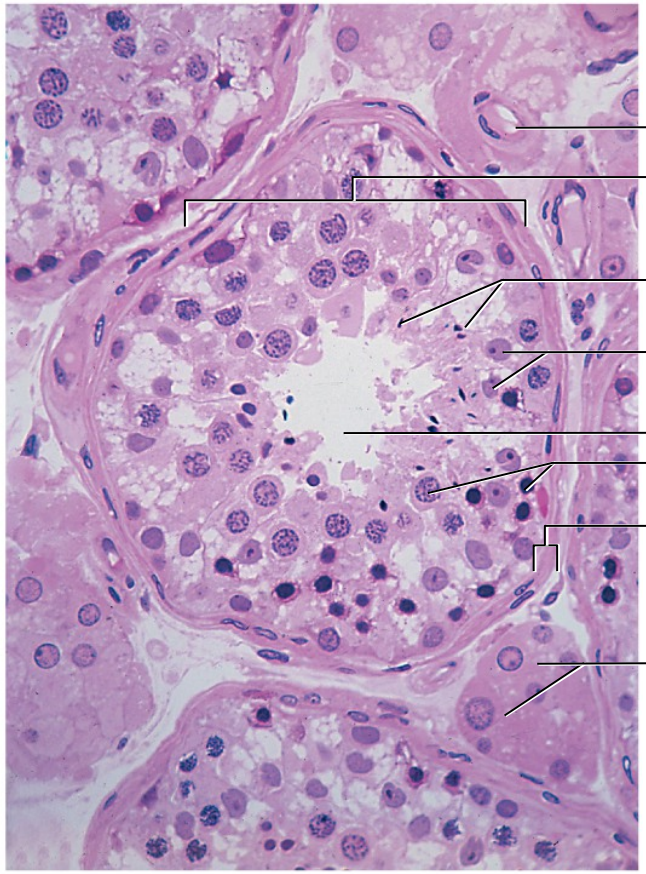



(b)

# Spermatogenesis and Histology of Testis




(a)




(b)

# Spermatogenesis and Meiosis

- Spermatogenesis - process of sperm production in seminiferous tubules
- Involves three principal events:
  - remodeling of large germ cells (stem cells) into small, mobile sperm cells with flagella
  - reduction of chromosome number by one-half in sperm cells (unites with egg to return to 46)
  - shuffling of genes so new combinations exist in the sperm that is different from the male
    - ensures genetic variation in the offspring
    - four sperm cells produced from one germ cell by meiosis (haploid cells)

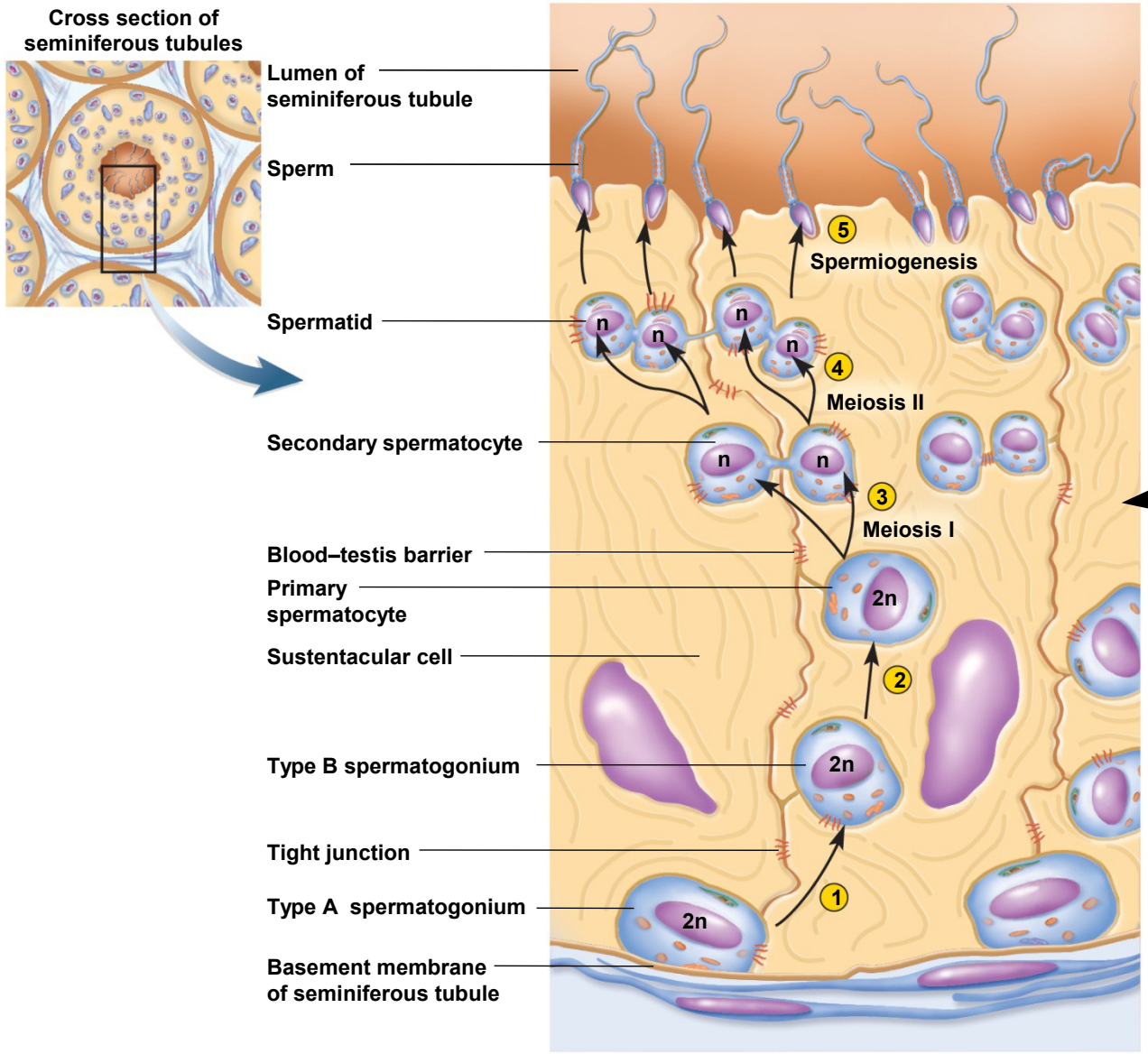
# Spermatogenesis and the Testes

- **Seminiferous Tubules**
  - one to three in each lobule
  - each tubule lined with a thick germinal epithelium for sperm generation /// these are the sustentaclar cells
- **Interstitial (Leydig) Cells**
  - between tubules // these cells produce testosterone
- **Sustentacular Cells (also called Sertoli Cells or Nurse Cells)**
  - SC located between germinal epithelium cells
  - protect the germ cells
  - promote their development
  - germ cells depend on “nurse cells” for their nutrients, waste removal, growth factors, and other needs
  - developing sperm connected to nurse cells by gap junctions

# Spermatogenesis

- Puberty brings on spermatogenesis
  - **spermatogonia** lie along the periphery of the seminiferous tubules and divide by mitosis
  - one daughter cell of each division remains in the tubule wall as a stem cell - **type A spermatogonium**
  - the other daughter cell migrates slightly away from the wall to become a future sperm – the **type B spermatogonium**
  - produce 400 million sperm per day

# Spermatogenesis




Sustentacular cells form the wall of the seminifierous tubule

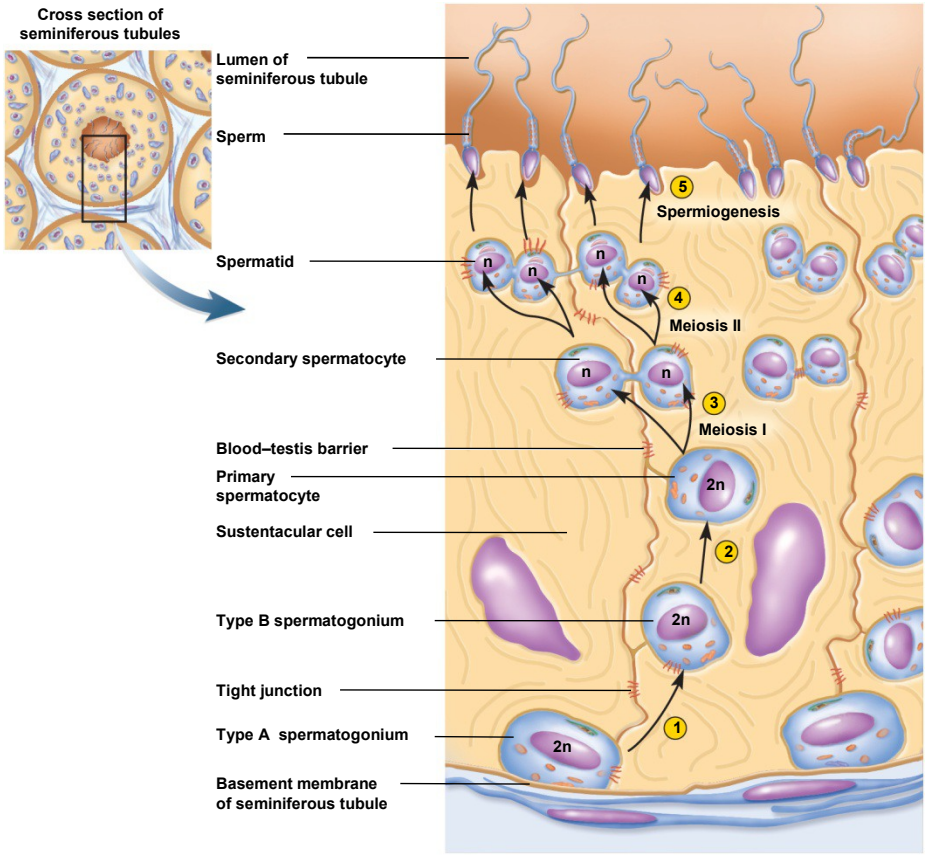
# Spermatogenesis and the Blood-Testis Barrier (BTB)

- BTB formed by tight junctions between **sustentacular cells**
  - separating developing sperm from immune system // sperm are “haploid”
  - prevents antibodies and other large molecules in the blood from getting to germ cells
  - germ cells are immunologically different from body cells and would be attacked by immune system

# Spermatogenesis and the Blood-Testis Barrier (BTB)

- once the primary spermatocyte undergoes meiosis, it becomes genetically different and needs to be protected from the host immune system
- the primary spermatocyte moves towards the lumen of the seminiferous tubule and a tight junction forms between sustentacular cells // blocking antibodies from reaching newly formed primary spermatocytes
- tight junctions create the blood-testis barrier



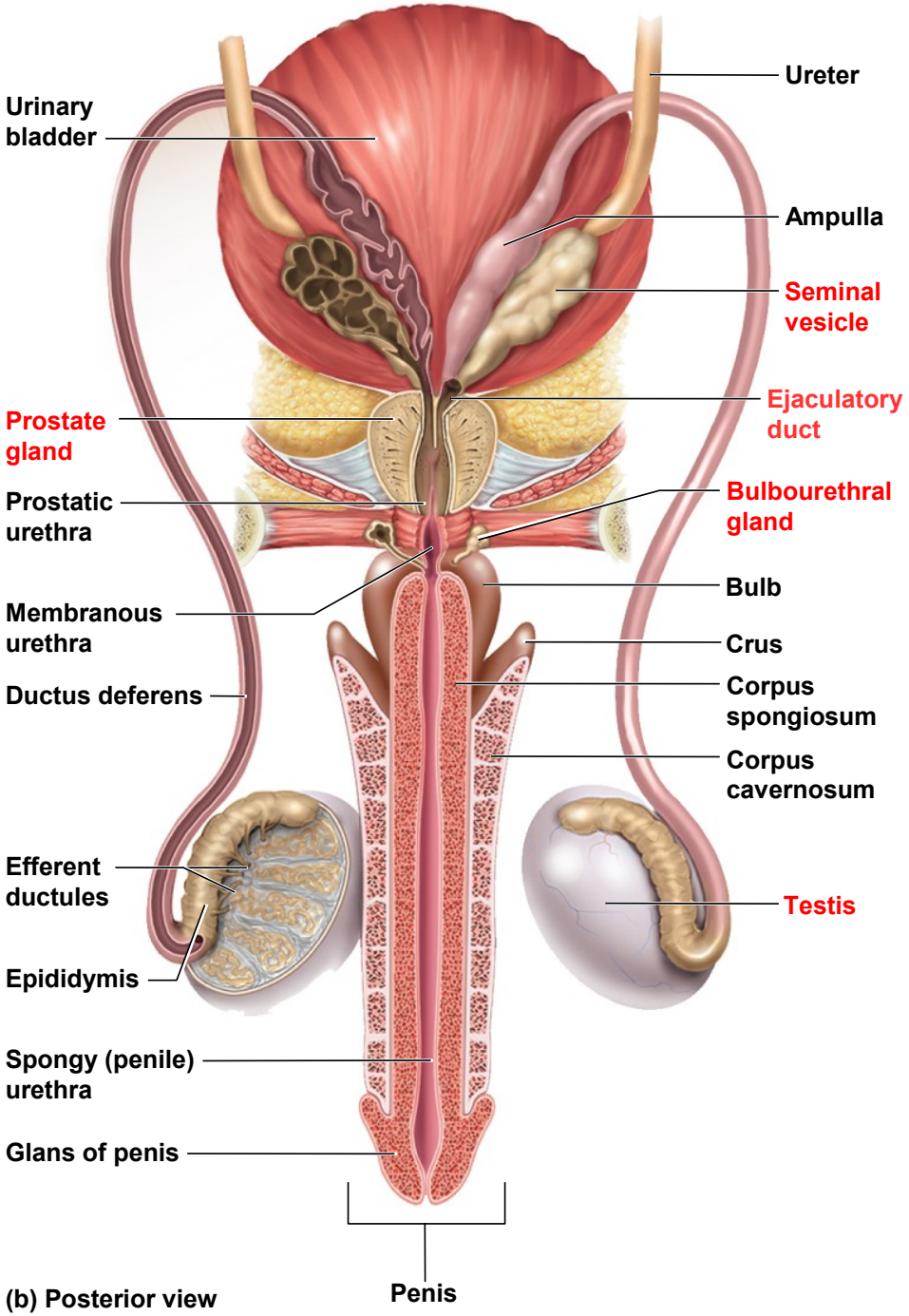


# Contributors to Semen's Volume

Three sets of glands in the male reproductive system add to the volume to semen // normal volume 2.5 ml (range 2.5 – 5 ml)

- seminal vesicles // 60%
- prostate gland // 30%
- secretions from seminiferous tubules and sperm volume // 10%
- bulbourethal gland (also called Cowper's gland) // < 0.1

# Male Duct System & Accessory Glands



# Seminal Vesicles

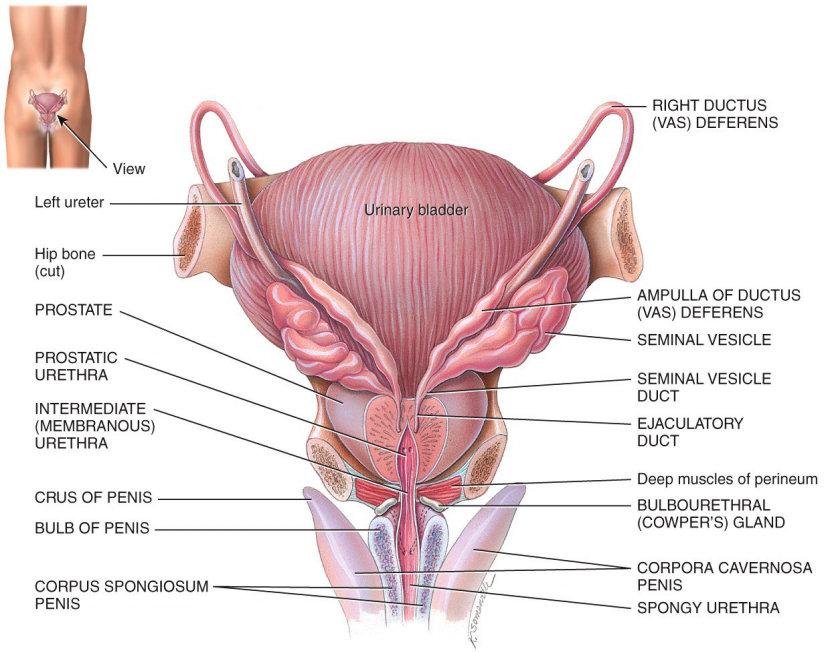
Pair of glands posterior to bladder

Seminal vesicle's secretions moves into ejaculatory duct during orgasm

Accounts for 60% of semen volume

Normal sperm count 30-400 million/mL

If lower than 20 to 25 million/mL = infertility



(a) Posterior view of male accessory organs of reproduction

# Seminal Vesicles

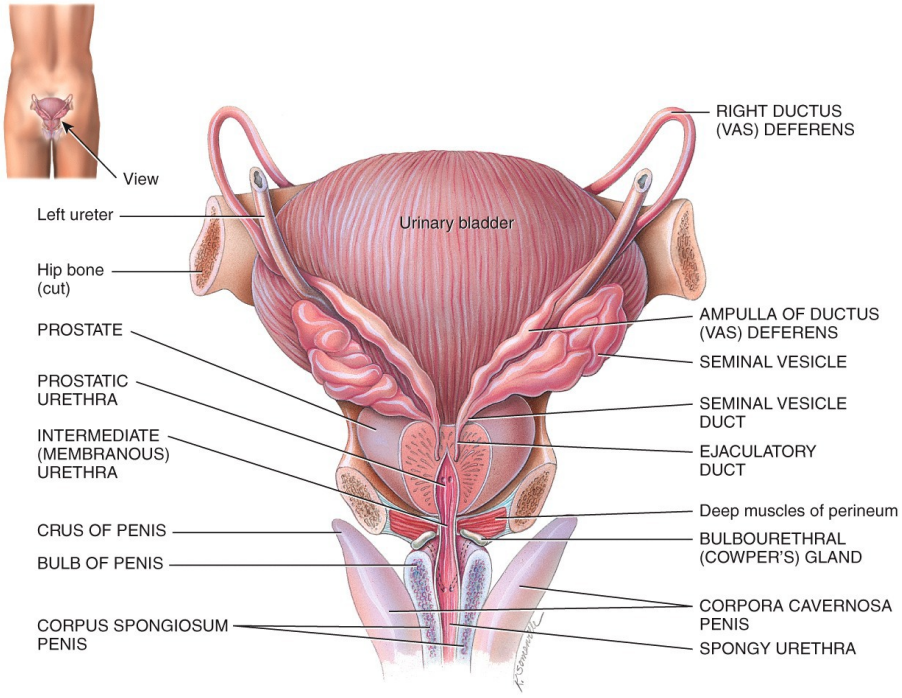
Seminal vesicles contribute viscous yellowish fluid

Contains fructose, other carbohydrates, citrate, prostaglandins, and pro-seminogelin.

Pro-seminogelin is a protein

Pro-seminogelin converted to seminogelin by clotting enzyme secreted by prostate gland

Seminogelin is a viscous, sticky molecule // function is to "stick" sperm near entrance of cervix



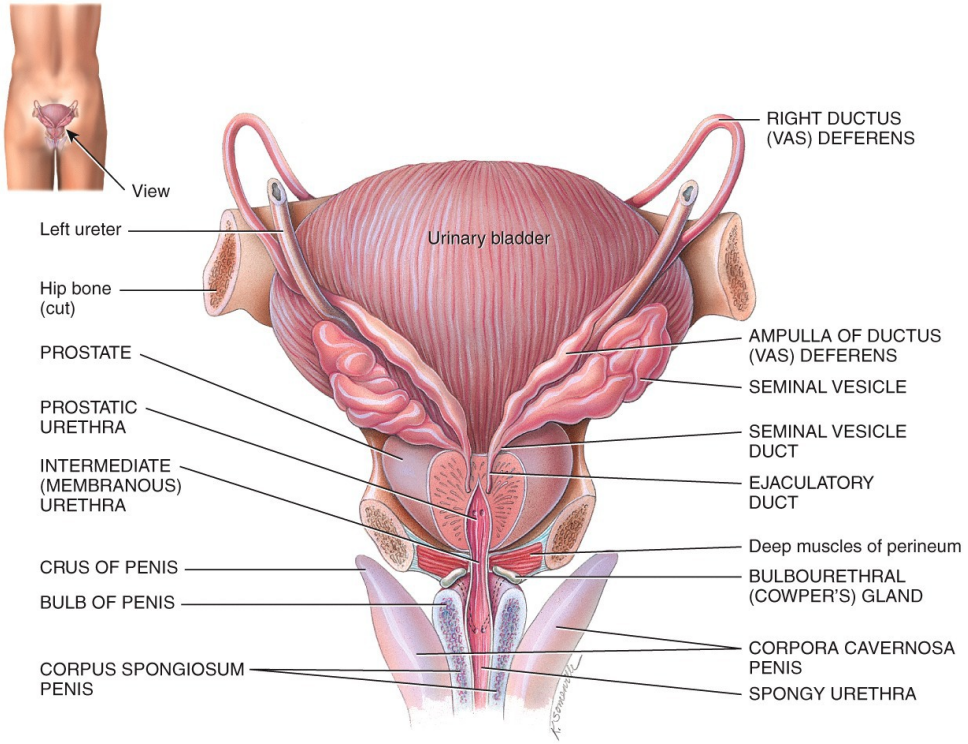
(a) Posterior view of male accessory organs of reproduction

# Prostate Gland

Surrounds urethra and ejaculatory ducts /// located inferior to the urinary bladder

30 to 50 compound tubuloacinar glands

Empty through about 20 pores into the prostatic urethra




(a) Posterior view of male accessory organs of reproduction

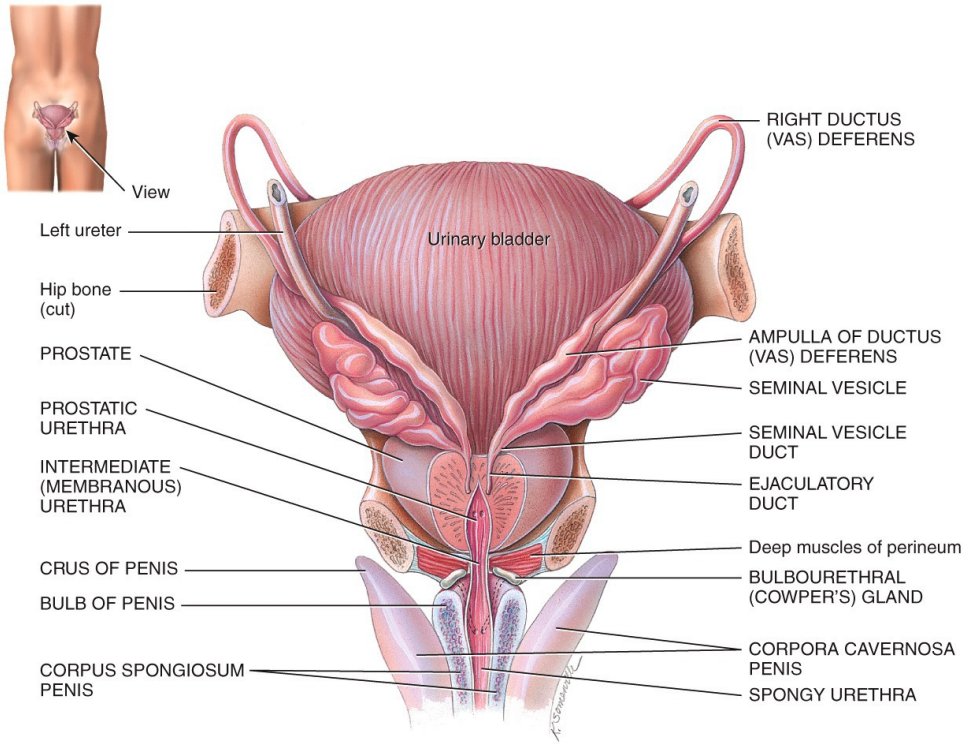
# Prostate Gland

Secretes thin, milky white fluid (30% seminal fluid volume)

Contains calcium, citrate, phosphate ions, and two enzymes /// target is pro-seminogelin

First protein is the "clotting enzyme" – converts proseminogelin into seminogelin

Second protein is the hydrolyzing enzyme – serine protease /// breaks down the clot (this is the prostate-specific antigen)



(a) Posterior view of male accessory organs of reproduction

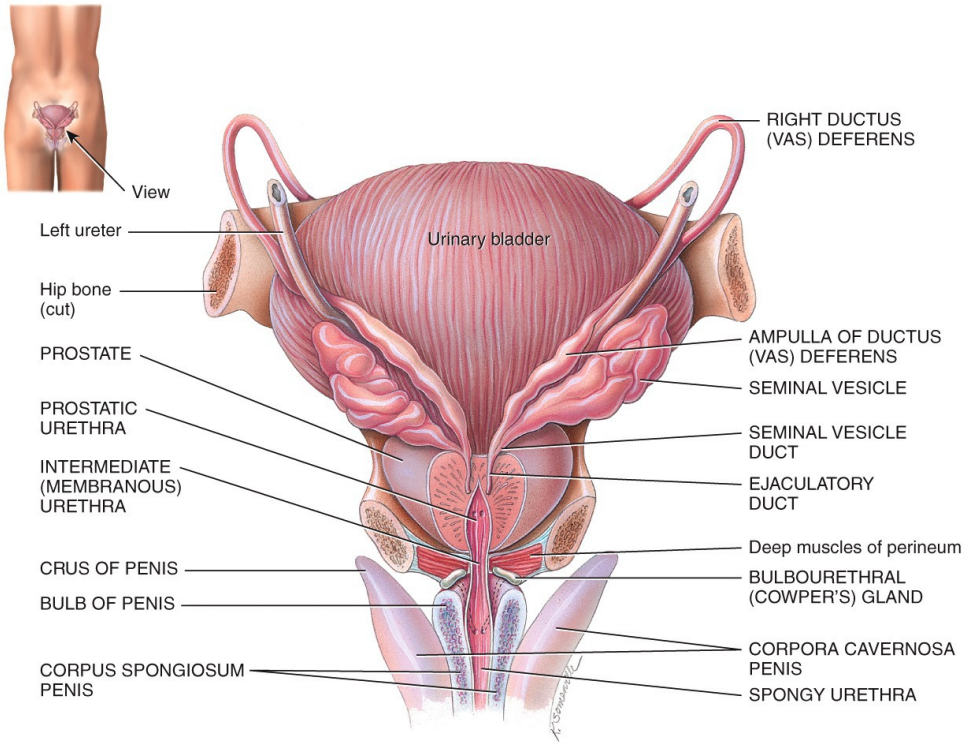
# Role of Pro-seminogelin in Fertilization

– **"Stickiness"** of semen promotes fertilization

- proseminogelin secreted from seminal vesicles
- clotting enzyme from prostate activates **proseminogelin**
- Clotting enzyme converts proseminogelin to a sticky fibrin-like protein – **seminogelin**
- seminogelin entangles the sperm // sticks semen to the inner wall of the vagina and cervix
- this ensures that the semen does not drain out of the vagina
- promotes uptake of sperm-laden "clott" near cervix into the uterus
- 20 to 30 minutes after ejaculation, serine protease from prostatic fluid breaks down seminogelin, and liquifies the semen
- now sperm become motile
- at same time, prostaglandins now thins the mucus of the cervix and initiates peristaltic waves in uterus and uterine tubes to promote movement of sperm towards ovum in fallopian tube

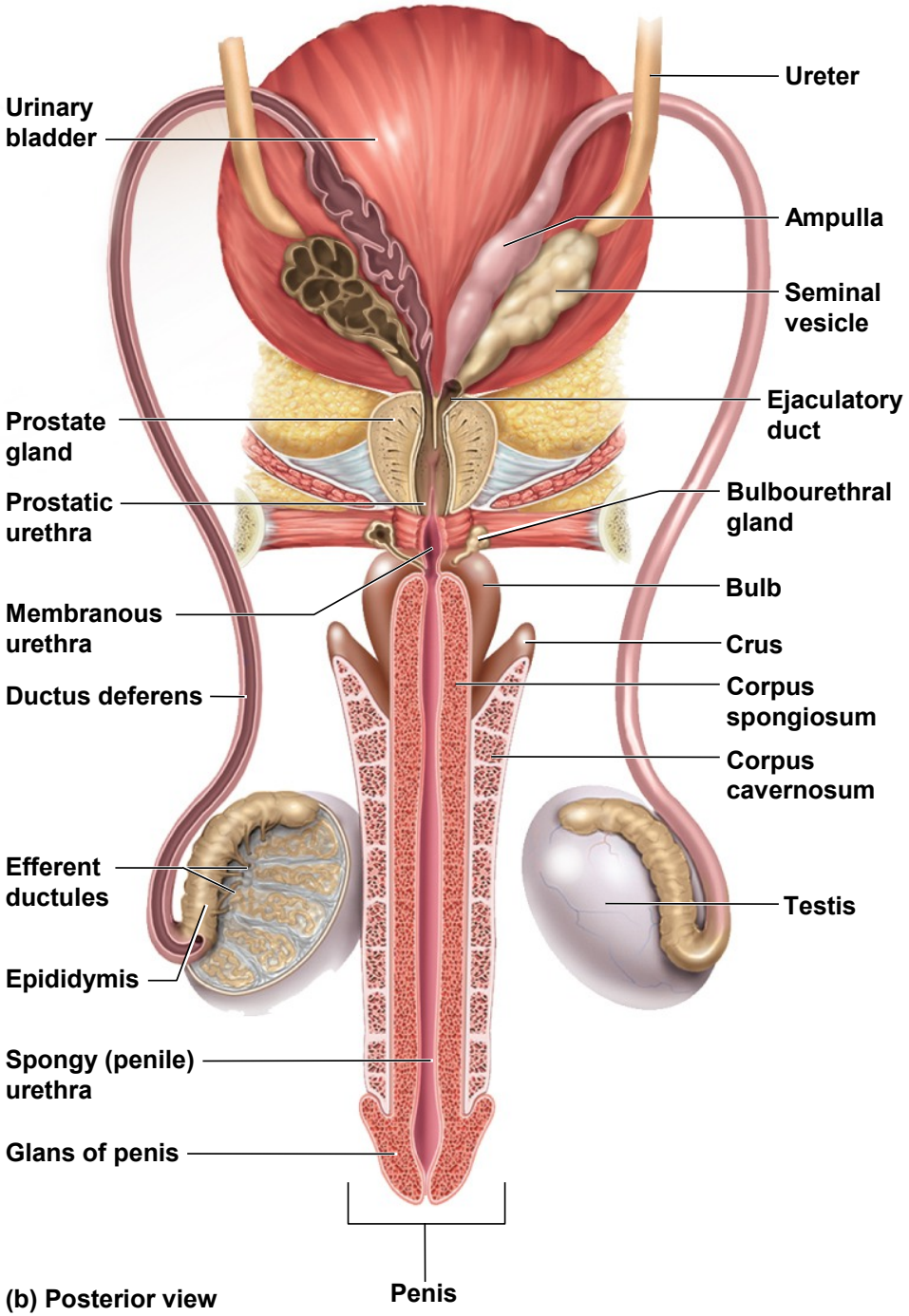
# Bulbourethral Glands (Cowper's Gland)

- located near bulb of penis
- during sexual arousal, they produce a clear viscous lubricating fluid
- lubricates the head of the penis in preparation for intercourse
- secretion also protects the sperm by neutralizing the acidity of residual urine in the urethra
- less than 0.1%



(a) Posterior view of male accessory organs of reproduction

# Male Duct System & Accessory Glands



# Sperm's Pathway in Male Duct System

Seminiferous tubules

Rete testes

Efferent ductules

Epididymis

Ductus deferens

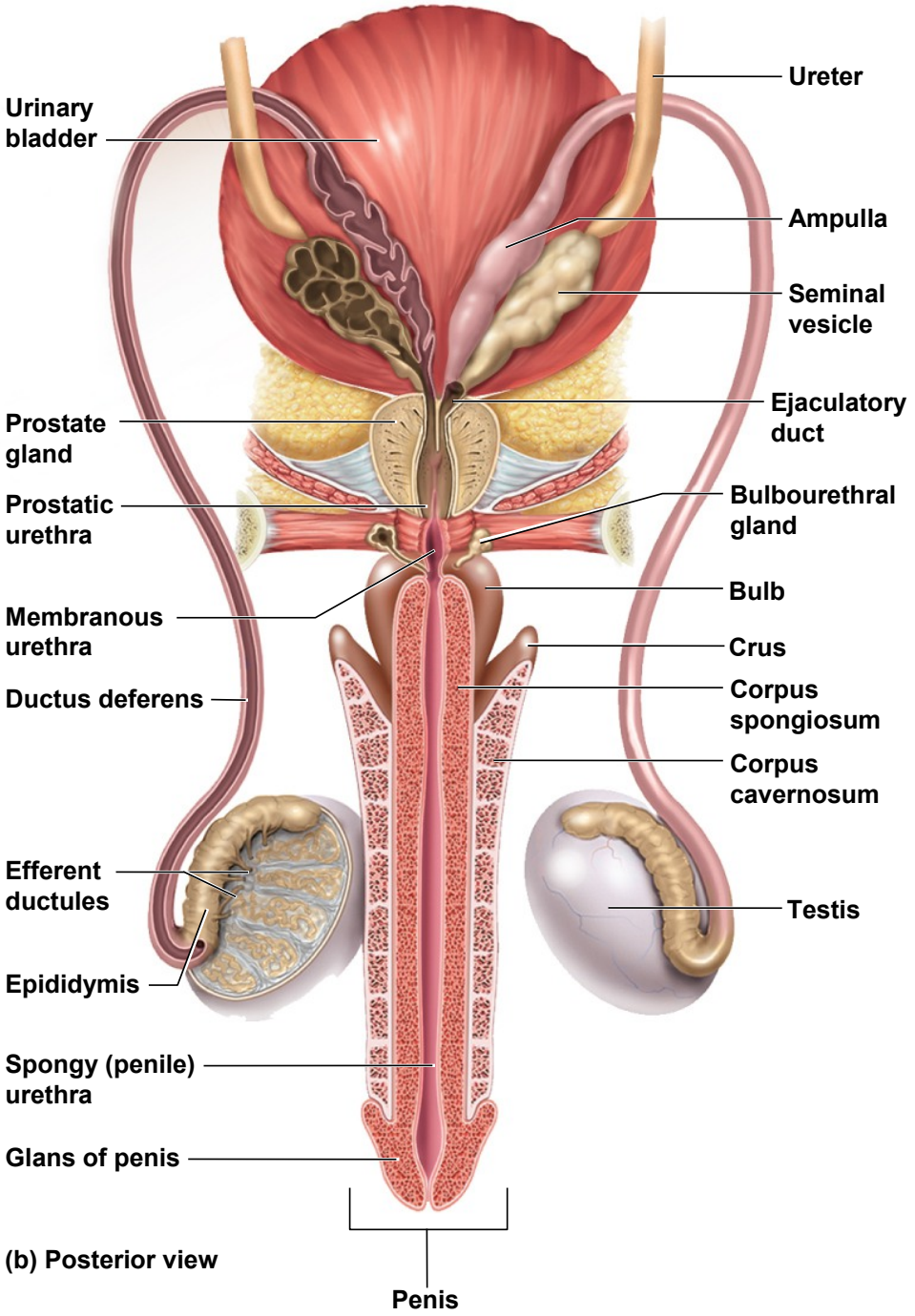
Ampulla of ductus deferens

Ejaculatory duct

Prostatic urethra

Membranous urethra

Penile urethra



# Two Requirements for Sperm Motility

Elevated pH /// prostate's fluid buffers vaginal acidity from 3.5 to 7.5

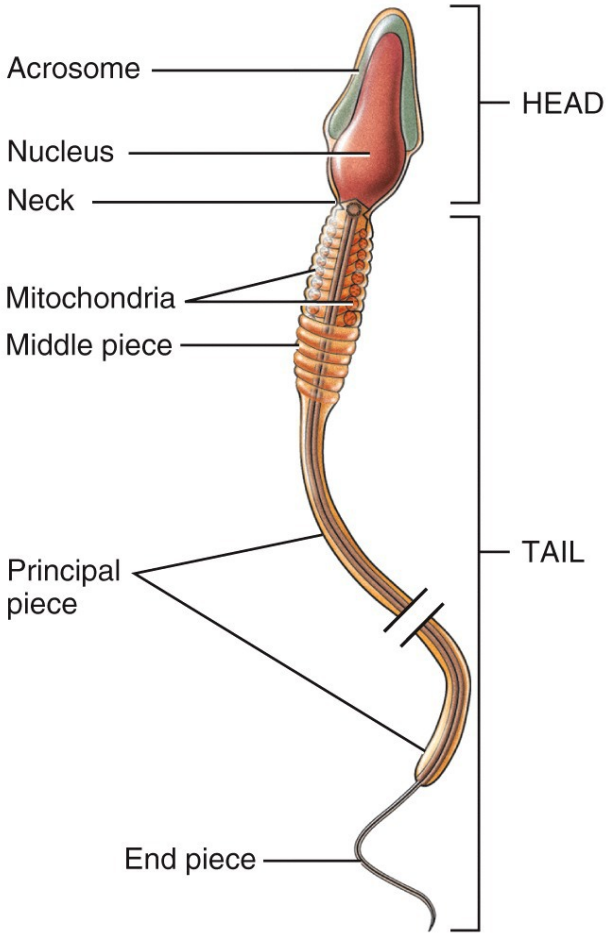
Energy source /// seminal vesicles provides fructose and other sugars
Sperm are not motile when in male ducts

Sperm may remain viable within epididymis for 60 days

Sperm's mitochondria use sugars as source of energy to propel flagella

40 million to 300 million / ml

Less than 20 million/ml = infertility



# Male Sexual Response

- Brought to general public by ground breaking publication of research papers by William Masters and Virginia Johnson (1966)

- Sexual Response divided into four recognizable phases (see next slide)

    - Excitement
    - Orgasm (event 1) – emission stage (sperm moved into urethra)
    - Orgasm (event 2) – ejaculation of sperm or expulsion stage
    - Resolution

  – similar phases occur in male and female sexual response

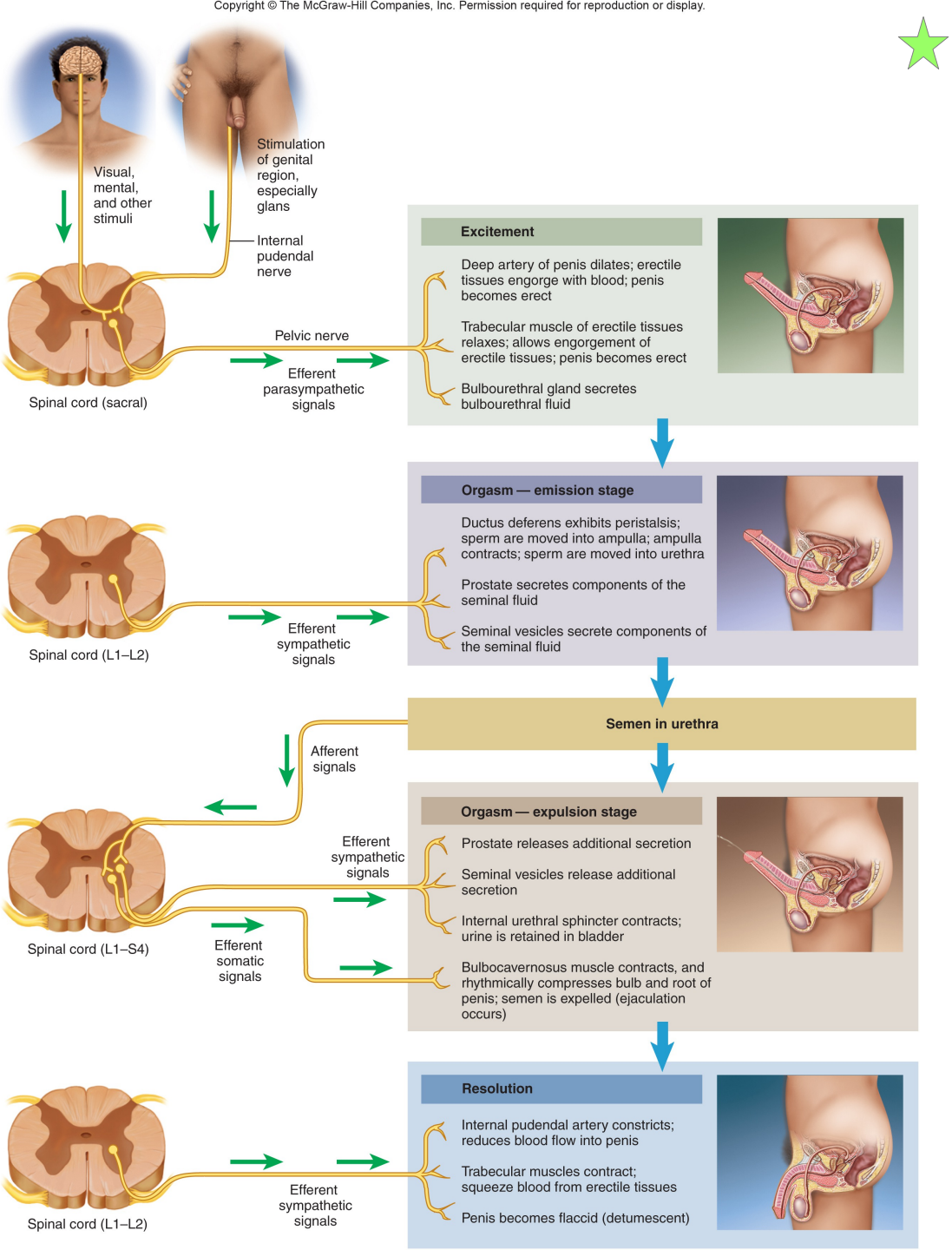
  – Masters & Johnson's work led to therapy for sexual dysfunction

  – sexual intercourse is also known as coitus, coition, or copulation

# Male Sexual Response

Occurs in Four Stages

- Excitment (engorgement of penile erectile tissue)
- Emission Stage of orgasm (<u>peristalsis moves sperm from epididymis into penile urethra</u>
- Secretions enter urethra from prostate and seminal vesicles)
- Explusion stage of orgasm (rhythmic contraction of bulbocavernosus muscle causes ejaculation // semen is expelled)
- Resolution (penis becomes flaccid)



# Male Sexual Response and Innervation of the Penis

The glans penis has abundance of tactile, pressure, and temperature receptors.

Dorsal nerve and internal pudendal nerve of penis lead to integrating centers in sacral spinal cord.

Autonomic nerves and somatic motor fibers carry impluses from integrating center to penis.

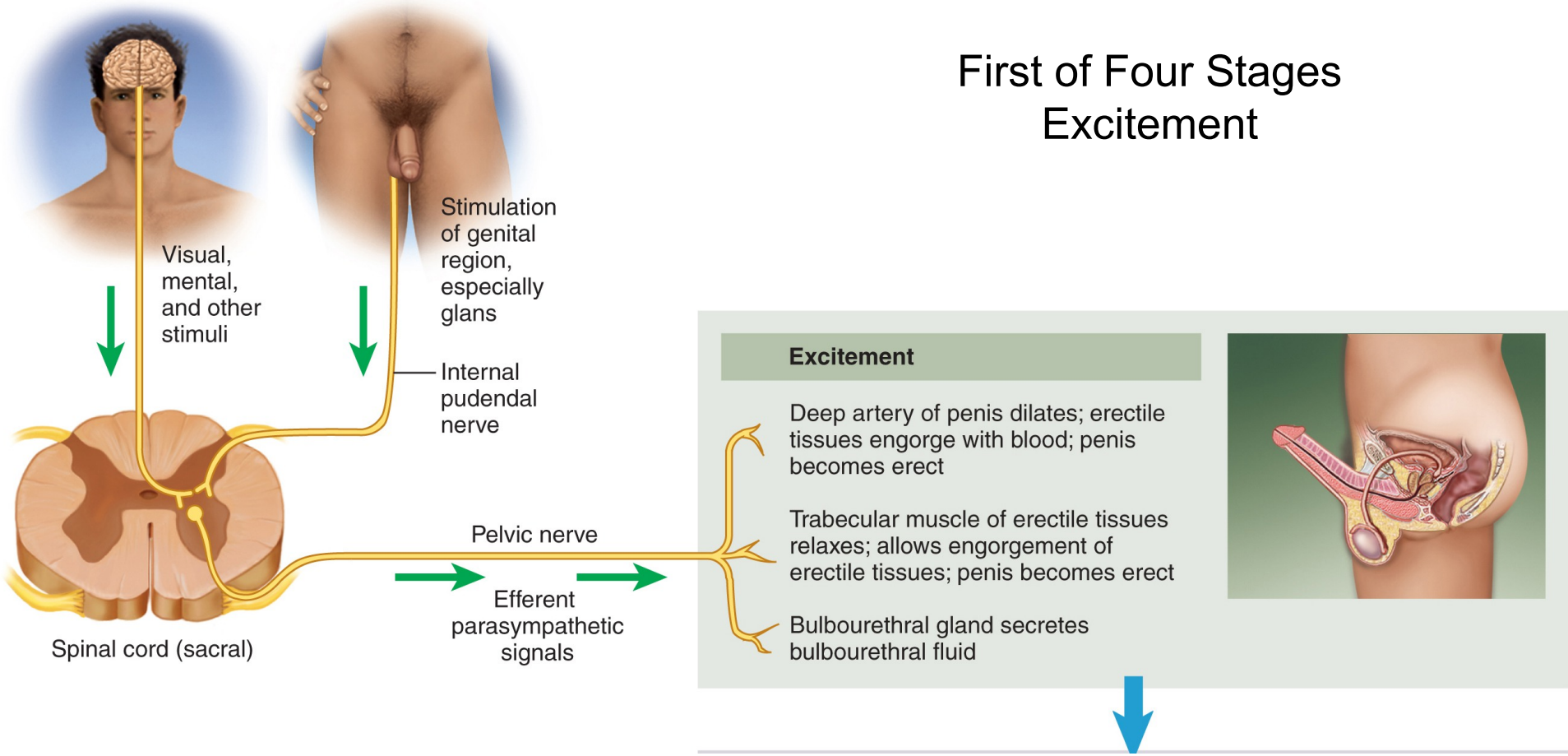
Sympathetic NS induce an erection in resonse to input from special senses and to sexual thoughts

Parasympathetic NS induce an erection in response to direct stimulation to the penis.

# Orgasm and Ejaculation

- **orgasm** or **climax** – a short but intense reaction that is associated *usually with the discharge of semen*
  - lasts 3 to 15 seconds
  - heart rate, blood pressure, and breathing greatly elevate with orgasm
- **male sperm ejaculation occurs in two stages:**
  - **Emission**
    - sympathetic nervous system stimulates peristalsis which propels sperm through ducts as glandular secretions are added // fluids enter spongy urethra
  - **Expulsion**
    - semen fills and expand urethra to activate somatic and sympathetic reflexes /// this stimulates muscular contractions that lead to expulsion
    - sympathetic reflex also constricts internal urethral sphincter so urine cannot enter the urethra and semen can not enter the bladder
- ejaculation and orgasm are not the same // orgasm can occur without ejaculation

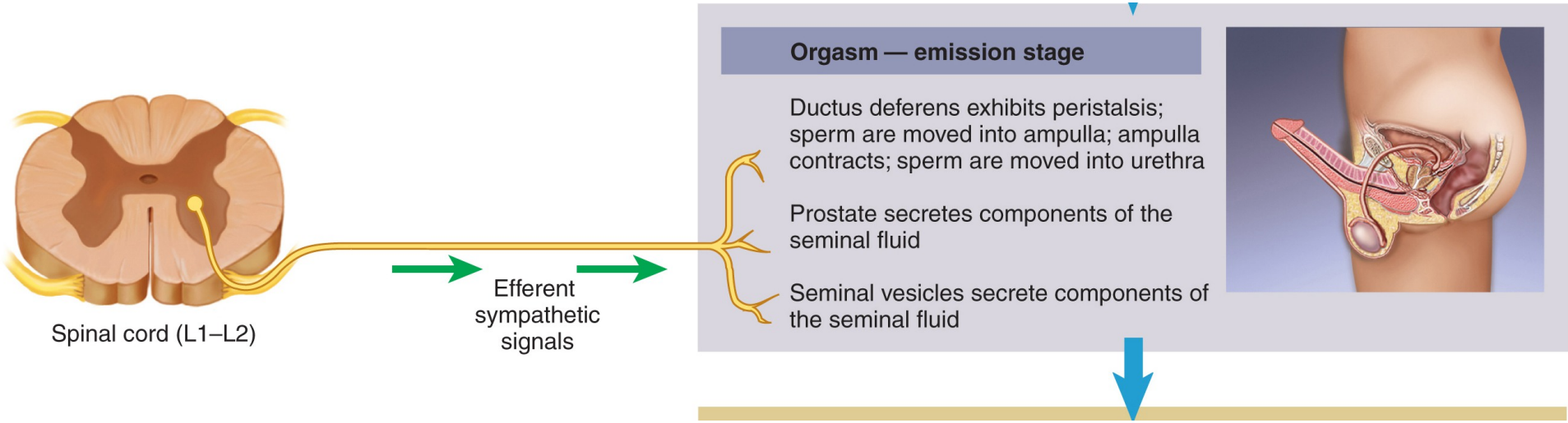
# First of Four Stages
# Excitement




Sympathetic NS induce an erection in resonse to input from special senses and to sexual thoughts

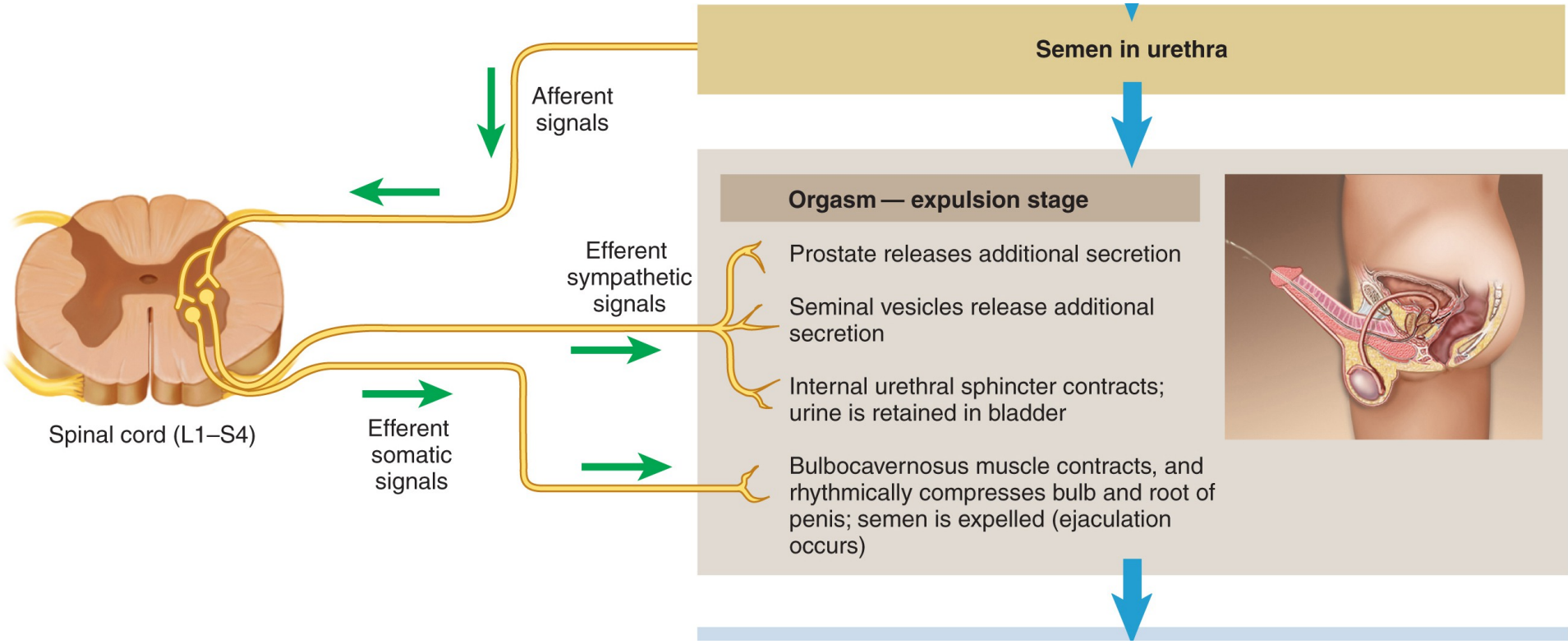
Parasympathetic NS induce an erection in response to direct stimulation to the penis.

# Second of Four Stages
# Emmission




Note: semen moves into urethra / this initiates an afferent nerve signal / see next slide

# Third of Four Stages
# Expulsion



# Third of Four Stages
# Resolution