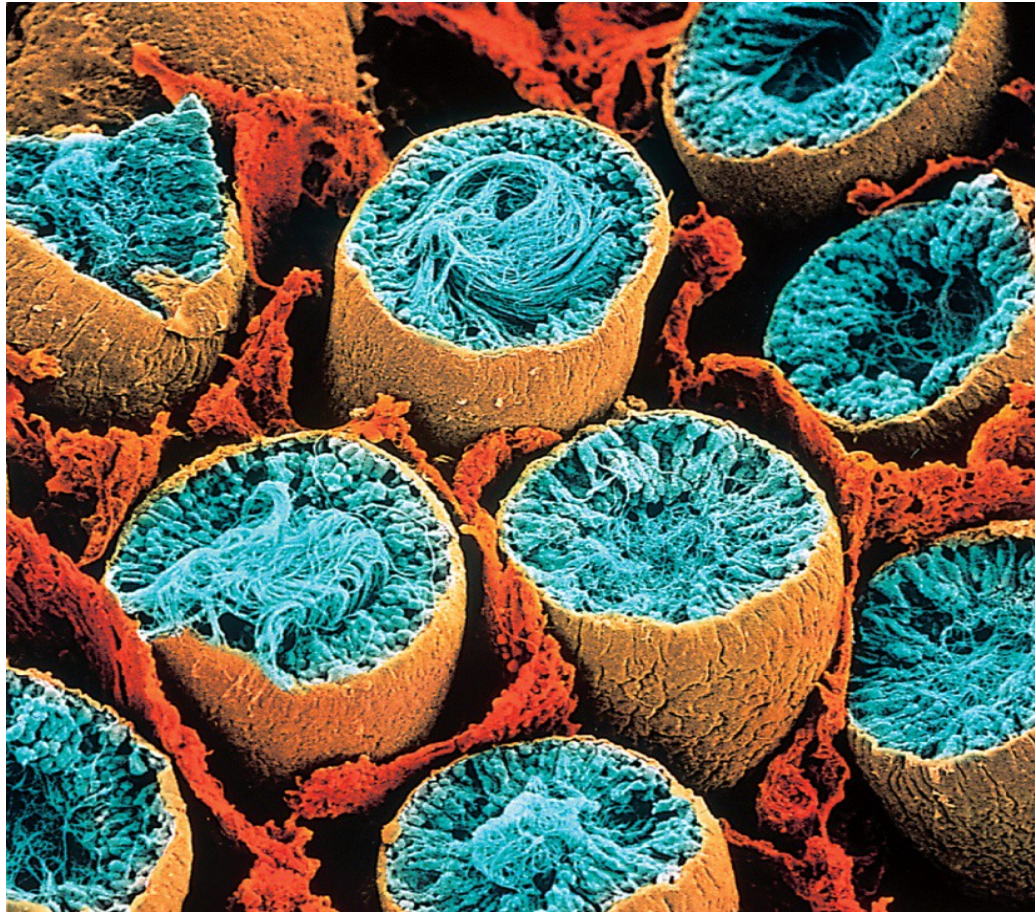


## Chapter 27 & Chapter 28

# Male and Female Reproductive Systems



# Sexual Reproduction

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The essence of sexual reproduction is bi-parental

offspring receive “combination” of genes from two parents

offspring is not genetically identical to either parent

parent's gonadal tissue produce gametes (sperm and eggs)  
by meiosis

sperm and eggs are haploid cells (23 chromosomes) / the  
union of gametes forms diploid cell (46 chromosomes)

the first diploid cell is called the zygote

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



# Overview of Reproductive System

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## **Purpose of Sexual Reproduction**

Perpetuate the species

Exchange genetic information between female and male

Allow for the expression of dominant and recessive genes

## **Male reproductive system**

produce sperm

sperm = male gamete

deliver sperm to female's 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

female nurtures the embryo / fetus (conceptus)

nourishes the offspring with mammary gland after postpartum

**therefore, the female reproductive system is more complicated!**



# Gender Characteristics

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Secondary sex characteristics = features that distinguish male and female form

- play a role in mate attraction
- male and female have apocrine glands that produce pheromones at puberty to attract a mate
- both sexes develop pubic and axillary hair
- **female puberty characteristics** = redistribution of body fat with breast enlargement, and relatively hairless appearance of the skin
- **male puberty 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)
- > female / ovaries produce ovums (eggs)
- > male / 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

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

Female occurs at 10 to 14 years of age

Male occurs at 12 to 16 years of age

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

- > follicle stimulating hormone (FSH)
- > luteinizing hormone (LH)

FSH & LH target tissue

- females = ovaries
- males = testes

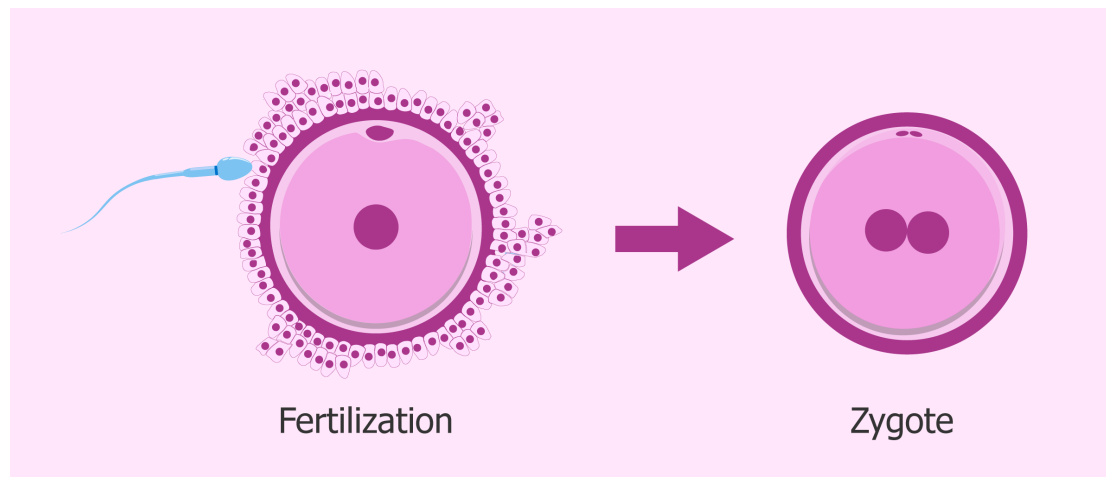


# What is the first human diploid cell?

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 vagina receives male gametes (sperm)

**Zygote** = union of male and female gametes (46 chromosomes) /// union occurs in the infundibulum of the female's fallopian tube /// it is the first diploid cell!



# 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 cytoplasm for the first diploid cell (the zygote), including all the organelles plus 23 chromosomes from

provides all the nutrients for developing blastocyte

in mammals, female is the parent providing a sheltered internal environment and prenatal nutrition for the embryo

# Zygote = fertilized oocyte



# Sex Determination



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

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

Sex gene is either an X or a Y

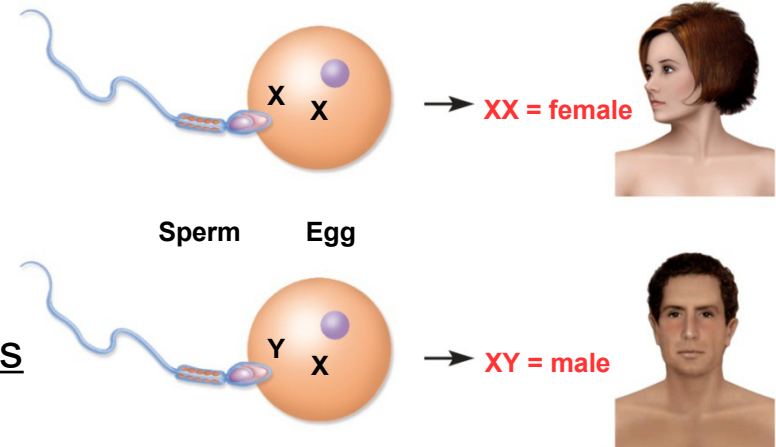
If sex gene pair in chromosome = XY = males

If sex gene pair in chromosome = XX = females

The male's chromosome have an allele pair (genes) coded as Y and X // only one gene will be selected to be carried by the sperm // X or Y

The female chromosome have an allele pair (genes) with only the X gene // females may only transmit the X gene in the ovum

In gamete formation (**haploid cell division = meiosis**) // the sex chromosomes are “split” /// each gamete will only have one gene of the allele pair sex chromosome /// when the zygote forms – it will have one sex gene from each parent



# Chromosomal Sex Determination

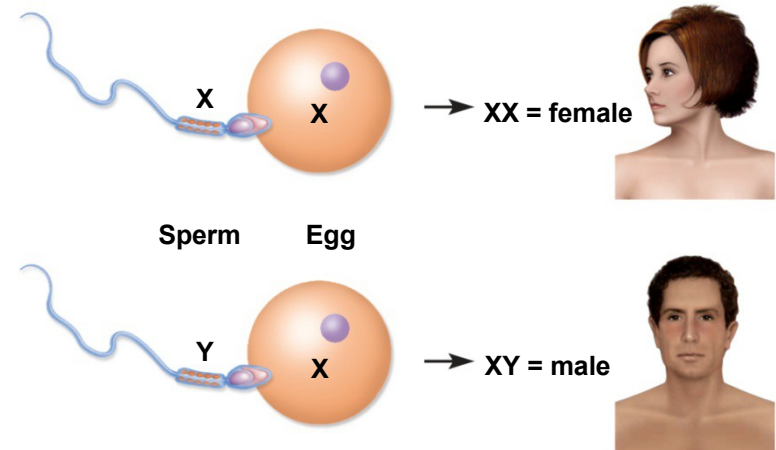
The punnet square illustrates the four possible outcomes

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

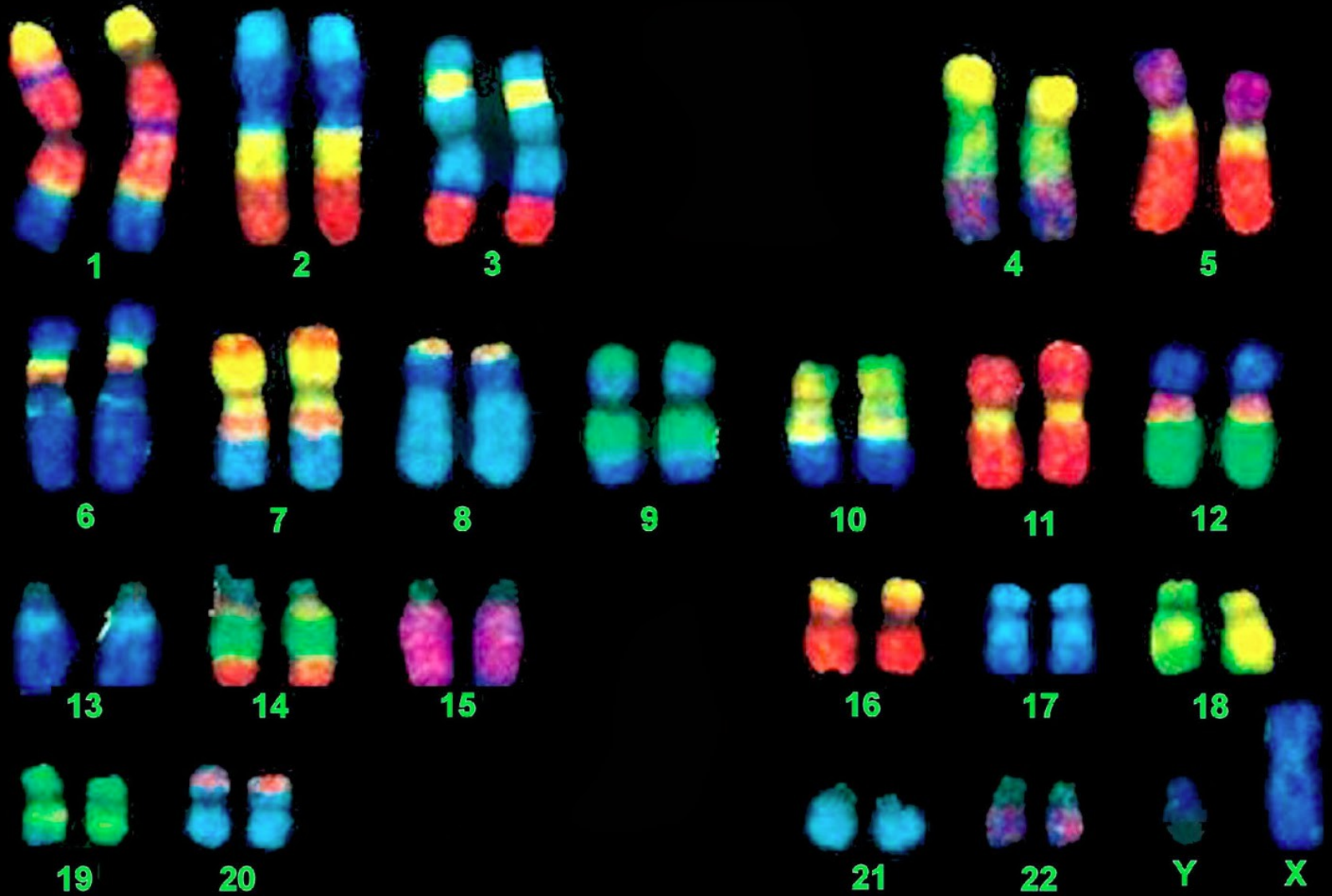


	X	Y
X	X X	X Y
X	X X	X Y

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.



# HUMAN CHROMOSOMES



# Meiosis

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Meiosis is haploid cell division /// meiosis reduces the chromosome number by half

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

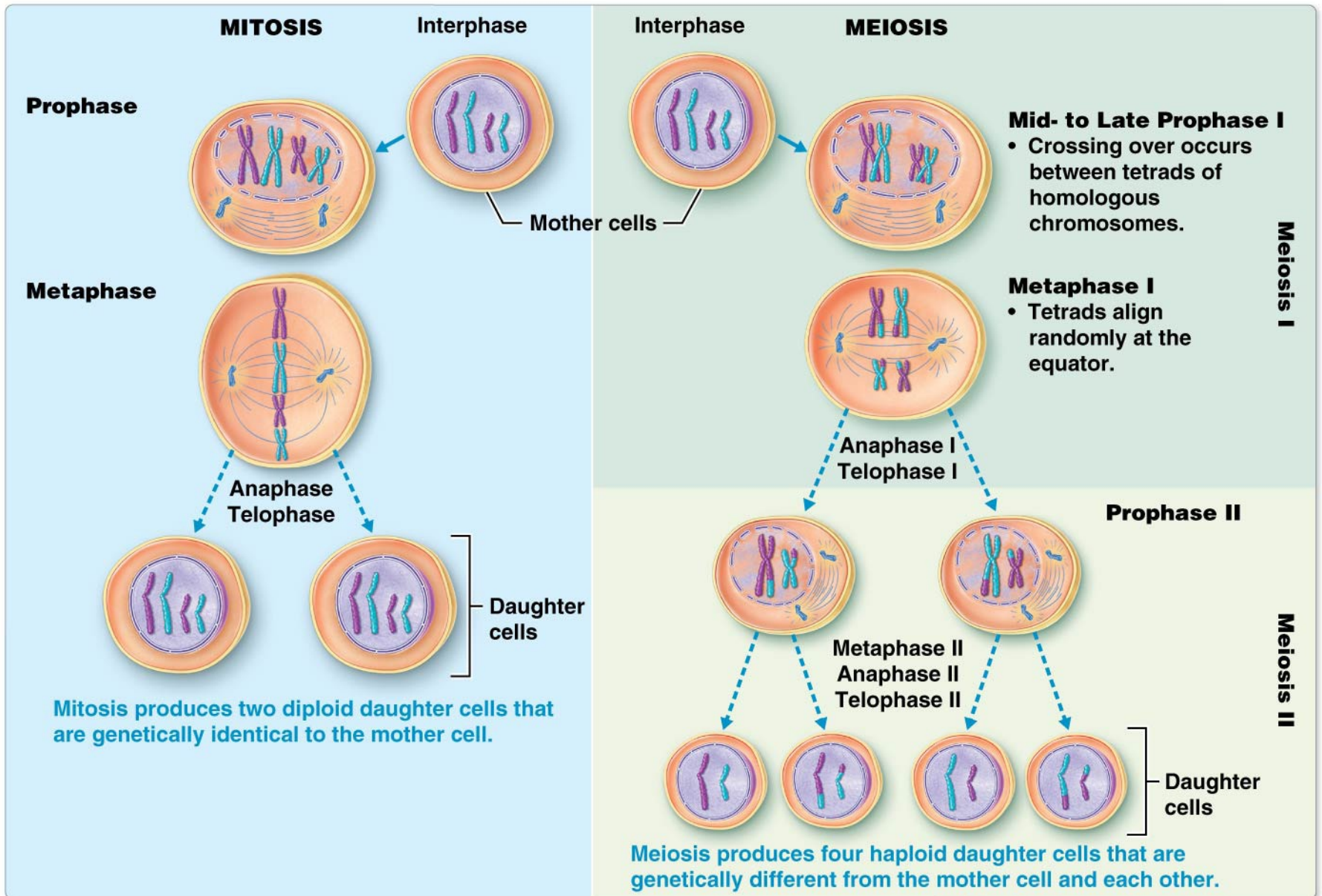
Humans reduce chromosome number from 46 to 23 chromosomes (diploid to haploid)

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

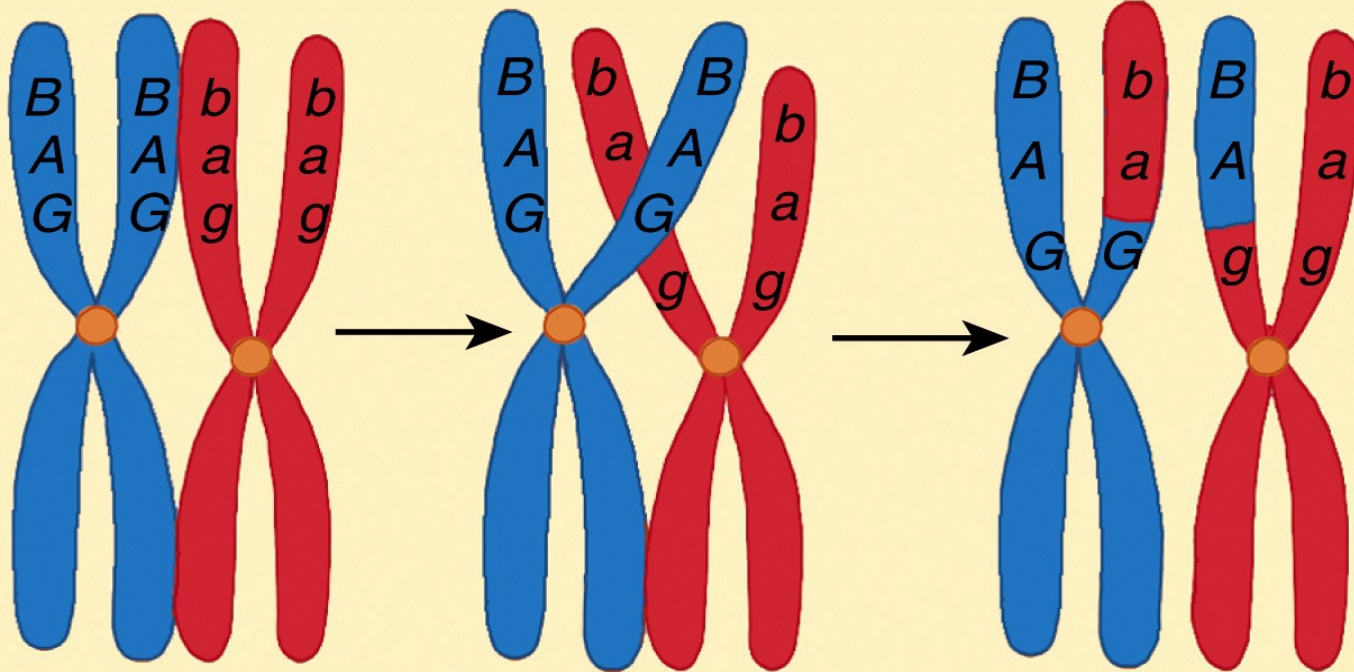
Note: **mitosis conserves the chromosomal number** /// epithelial cells use mitosis to make copy of itself. /// the **somatic cells**

*Think of meiosis as following the phases of mitosis twice but only duplicating the chromosomes in the “S phase” once. This then reduces the chromosome number by half.*

# Comparing Mitosis and Meiosis



Crossing-Over is an important event because it increases the possibility for maximizing the mixing of the genes between the male and female chromosomes.



Synapsis of  
sister chromatids

Crossing-over between  
nonsister chromatids

Genetic  
recombination

(b) Details of crossing-over during prophase I

# First Stage of Meiosis

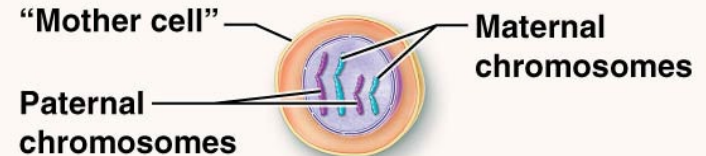
For simplicity, the cell is shown with only two pairs of homologous chromosomes.

*Male gonadal tissue produce four viable haploid cells (sperm) but female gonadal tissue produce only one viable haploid cell (the ovum) and three polar bodies that die by apoptosis.*

## 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

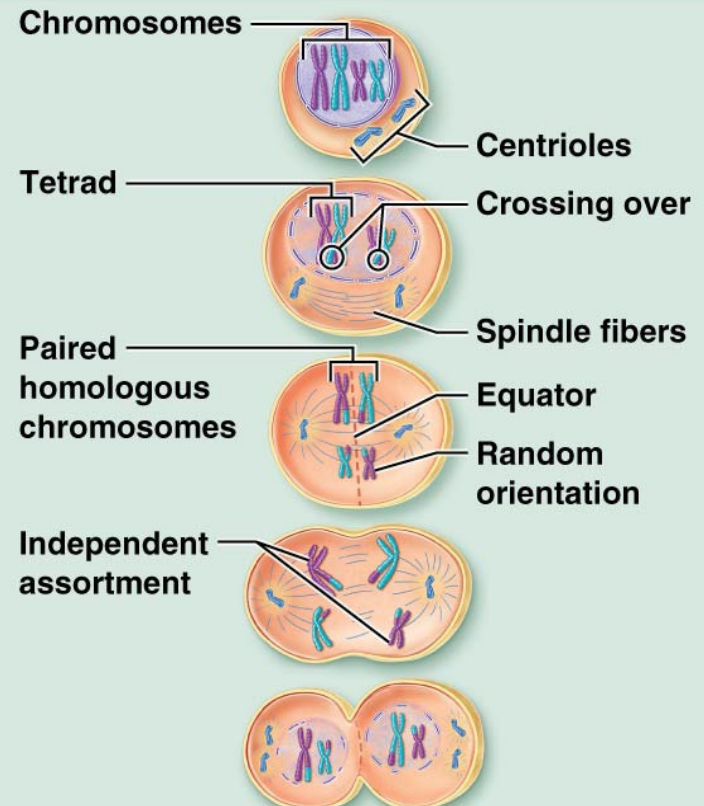
- Tetrads align randomly at equator (random orientation).

### 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.



# Second Stage of Meiosis

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

## MEIOSIS II

### Prophase II

- Chromosomes remain condensed.

### Metaphase II

- Chromosomes line up along equator.

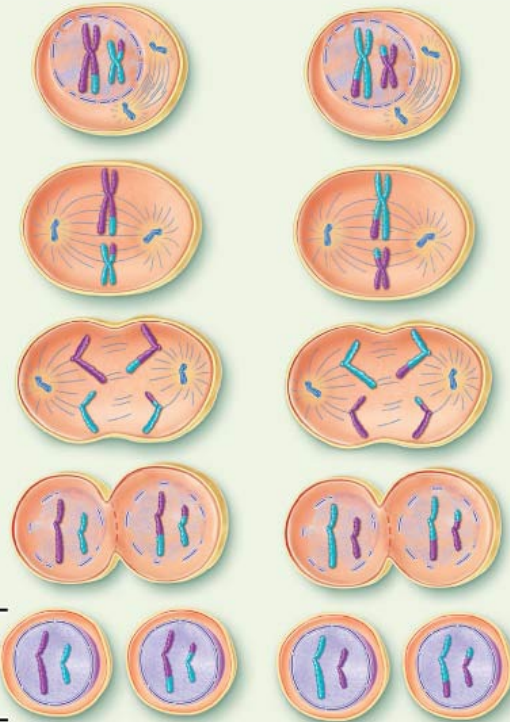
### Anaphase II

- Sister chromatids separate.

### Telophase II

- Cytokinesis follows.

Meiosis produces four genetically unique, haploid daughter cells.

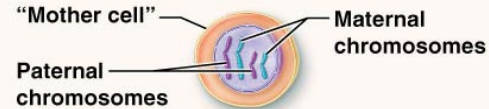


# Stages of Meiosis

## 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

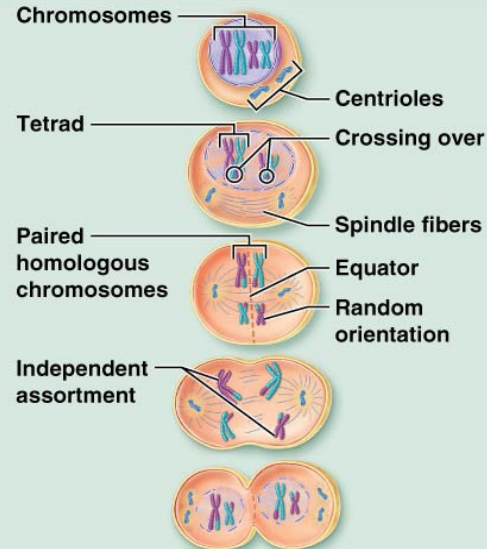
- Tetrads align randomly at equator (random orientation).

### 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.



## MEIOSIS II

### Prophase II

- Chromosomes remain condensed.

### Metaphase II

- Chromosomes line up along equator.

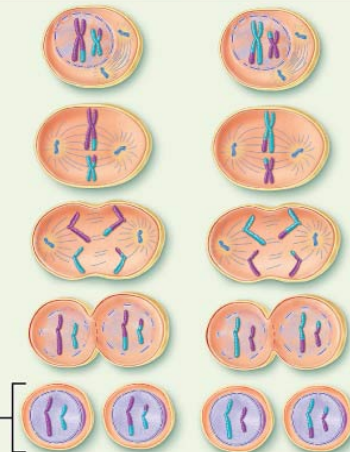
### Anaphase II

- Sister chromatids separate.

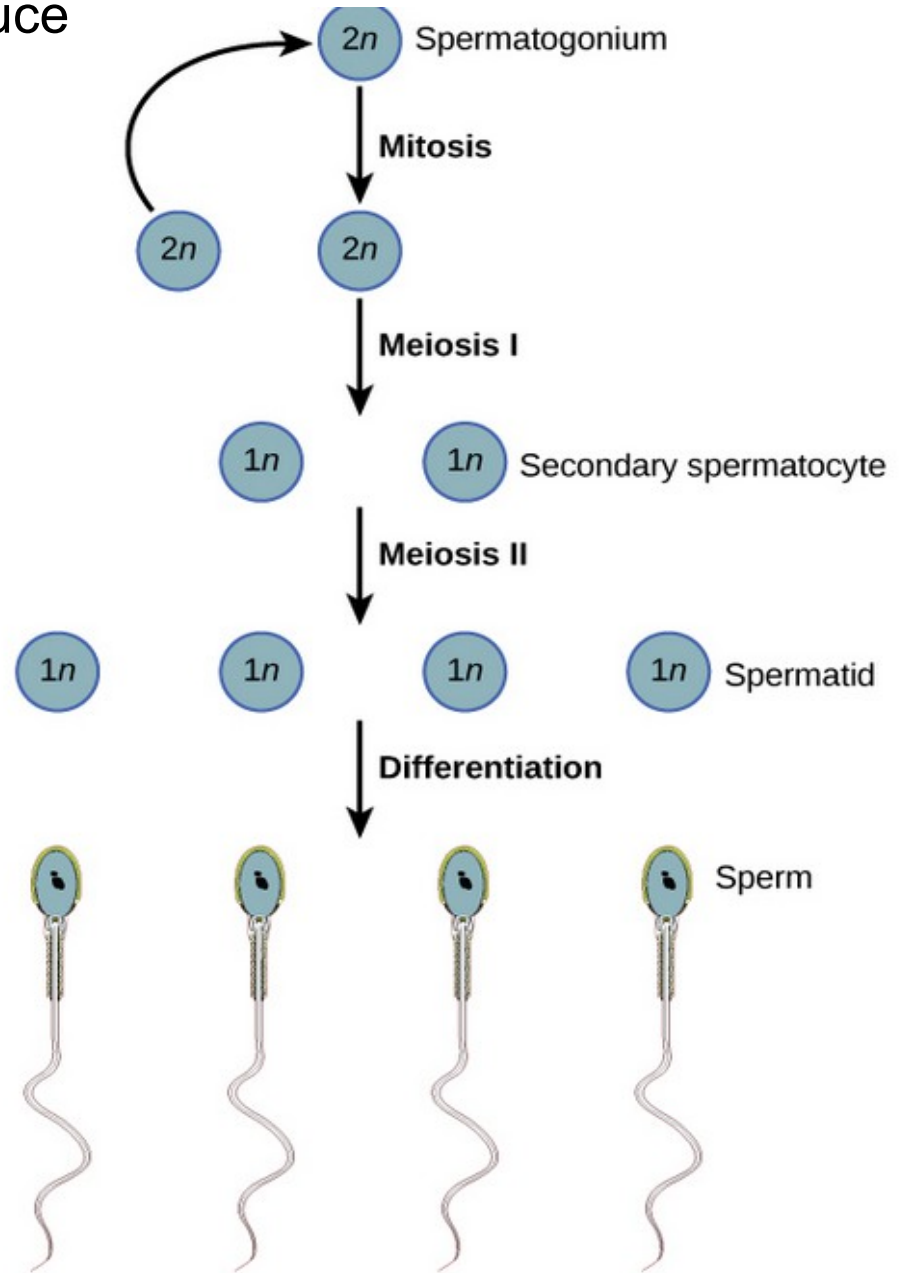
### Telophase II

- Cytokinesis follows.

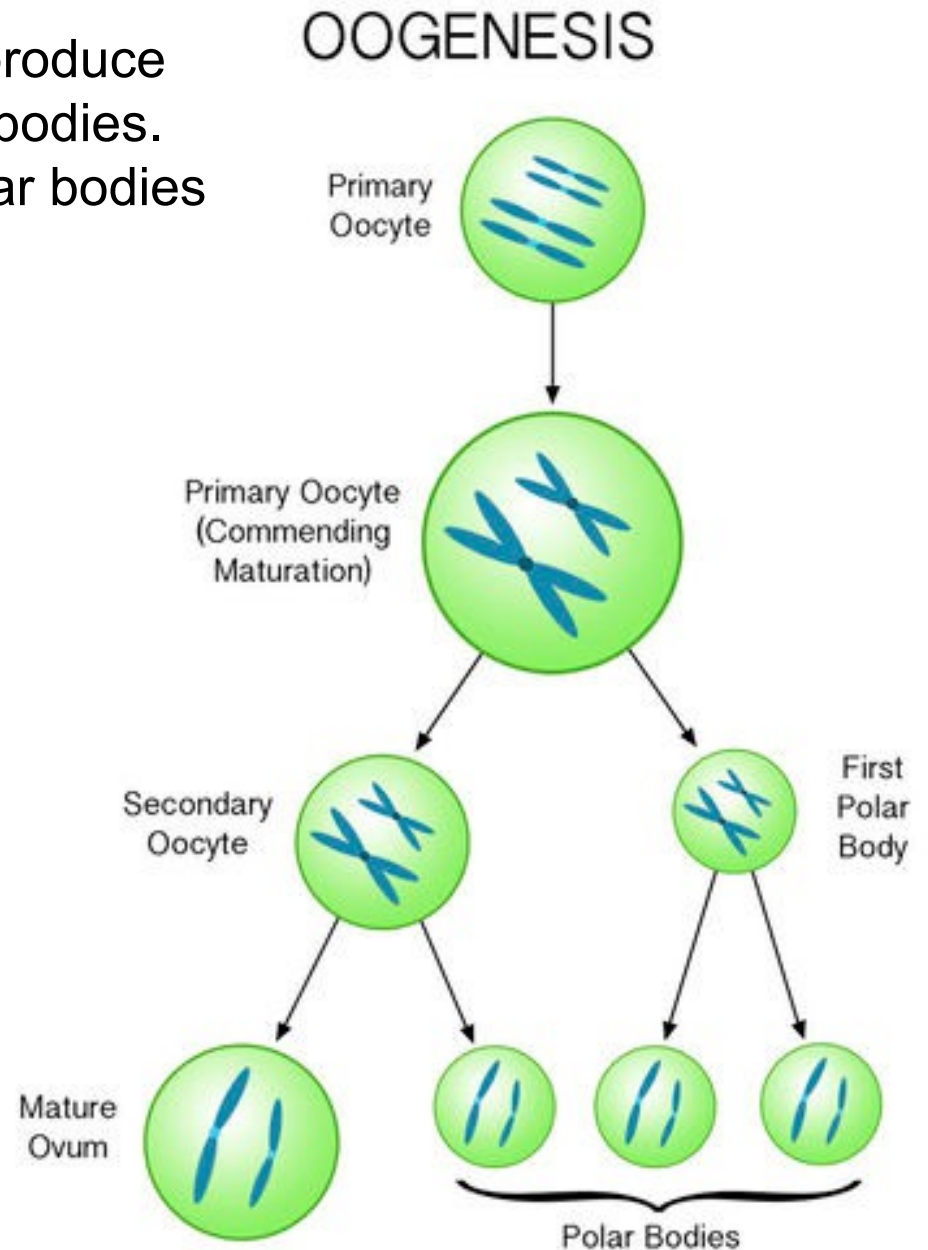
Meiosis produces four genetically unique, haploid daughter cells.



Meiosis in male gonadal tissue produce four viable sperm.



Meiosis in female gonadal tissue produce one mature ovum and three polar bodies. It is not possible to fertilize the polar bodies and they die by apoptosis.

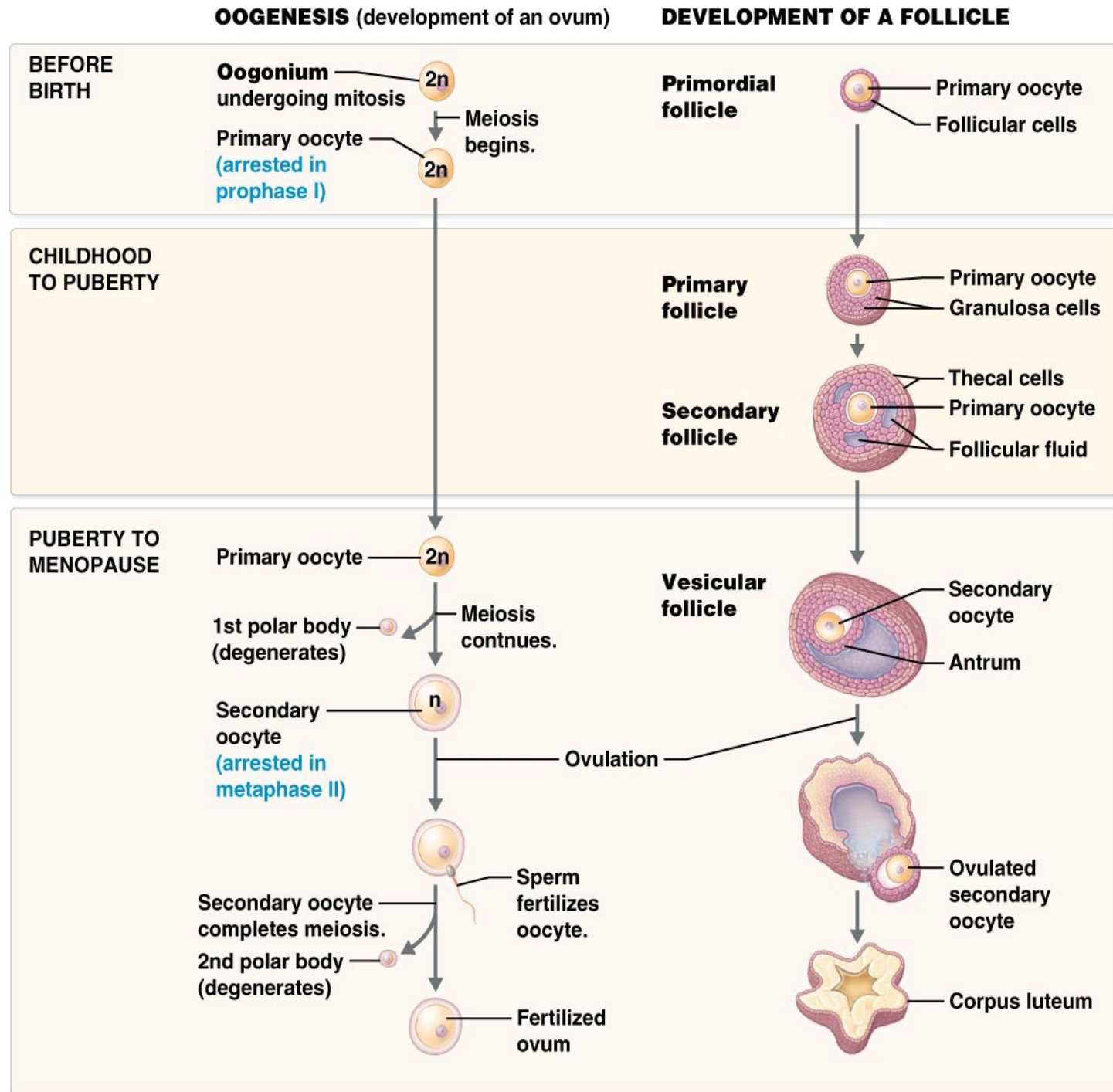


There are 8 million oogoniums before birth.

At birth females have 4 million primary oocytes per ovary.

By puberty the number of primary oocytes will reduce to 400,000 per ovary.

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

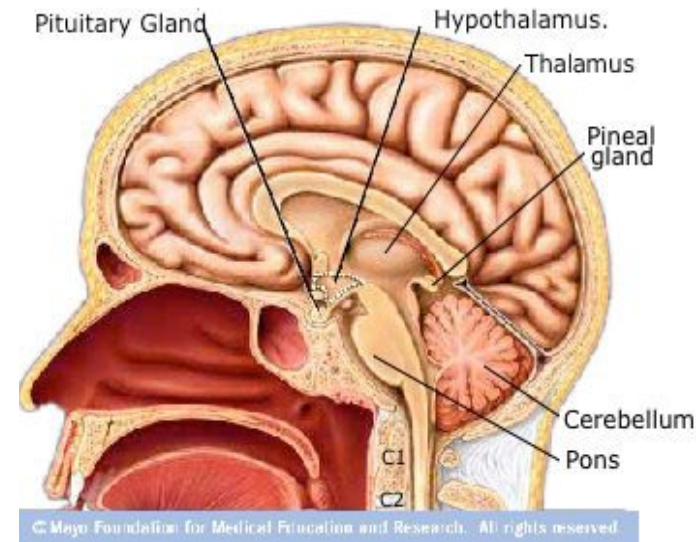


- You will need to describe the following hormone's site of production, target tissues, and outcomes
  - Gonadotropin Releasing Hormone
  - Follicle stimulating hormone (FSH)
  - Luteinizing hormone (LH) or interstitial cell stimulating hormone (ICSH)
  - Human chorionic gonadotropin (hCG)
  - Prolactin
  - Oxytocin
  - Estrogen
  - Progesterone
  - Inhibin
  - Testosterone
  - Relaxin
- Many of these hormones have functions in both male and females reproductive physiology, however. These hormones may have different target tissues resulting in different types of outcomes in female and male reproductive physiology.

# Gonadotropin Releasing Hormone



- Starts the sexual cycle in males and females
- GRH produced by nuclei in the hypothalamus // these nuclei mature more slowly
- Hormone secretions begins after nuclei completes development – this initiates puberty
- GRH target tissue is anterior pituitary (via portal system)
- Stimulates release of follicle stimulating hormone and luteinizing hormone from anterior pituitary
- GRH has similar function in male and female physiology....however
- LH and FSH different target tissue in genders // females ovaries // males testes

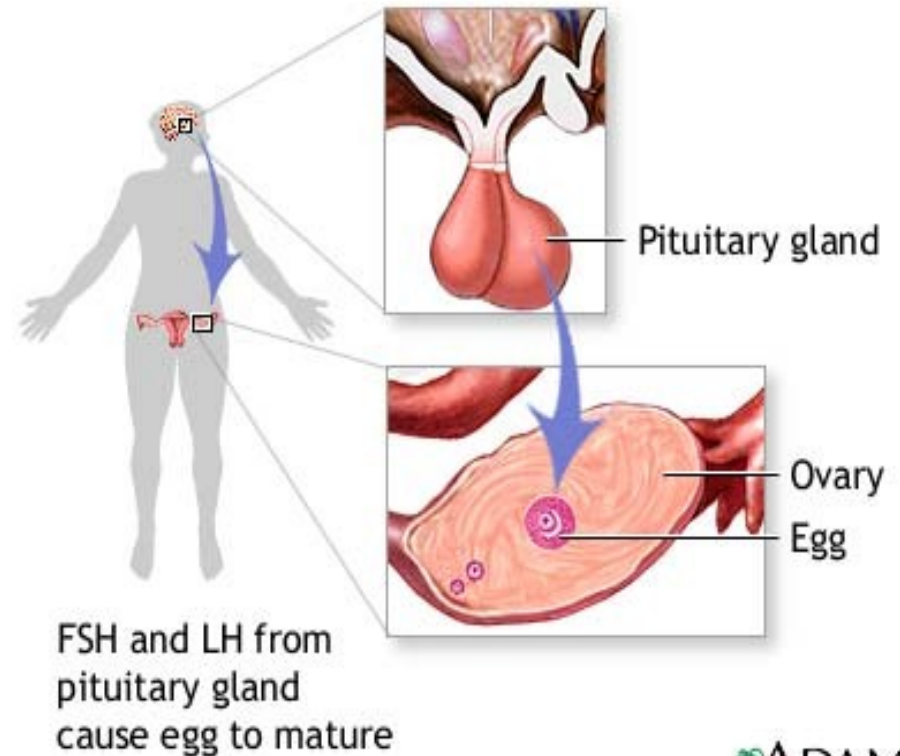


GRH is released later in males and earlier in females

# Follicle Stimulating Hormone (FSH) - Females



- FSH produced by anterior pituitary
  - Target tissue = primordial eggs in ovaries
  - Stimulates growth of follicles (early stages of ovum = egg)
  - Stimulate follicles to secrete **estrogen**
  - Only one follicle will be up-regulated with FSH receptors // **follicular phase**
  - The follicle with the most receptors continues to grow and will become a Graafian follicle // this follicle to be fertilized!



# Luteinizing hormone (LH) - Females

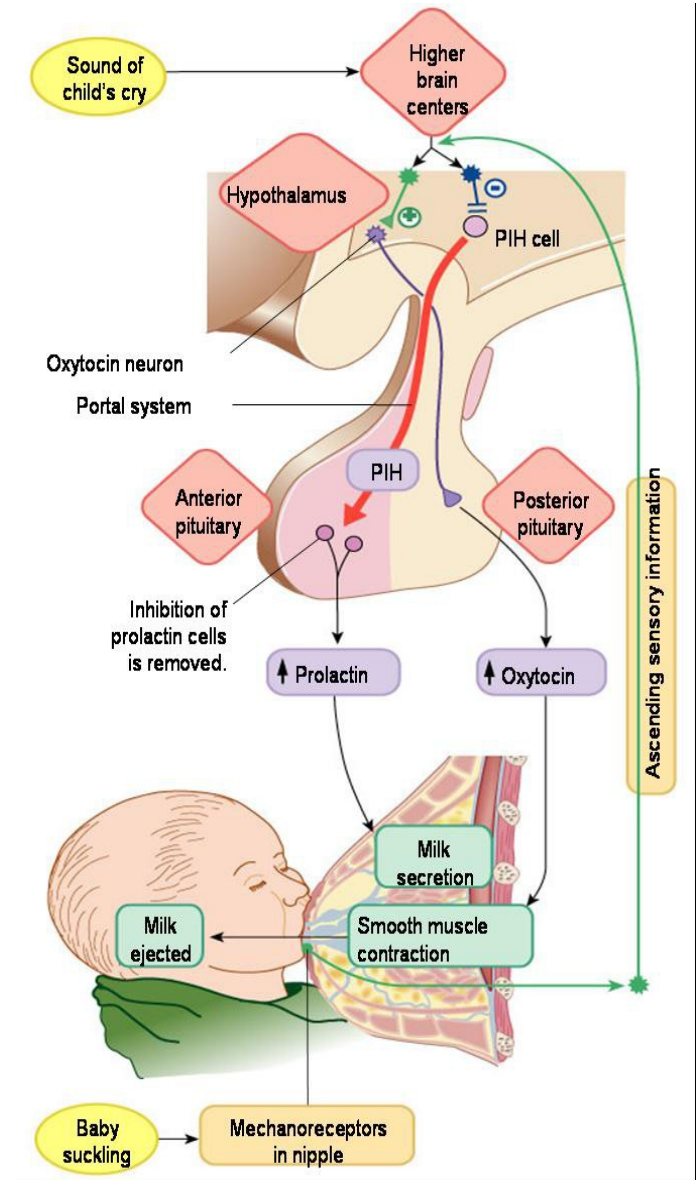
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- LH produced by anterior pituitary
  - target tissue = mature egg in ovary
  - Spike in LH production near day 14 initiates ovulation
  - binds to follicular cells remaining on surface of ovary // converts follicular cells into corpus luteum
  - Corpus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

# Prolactin

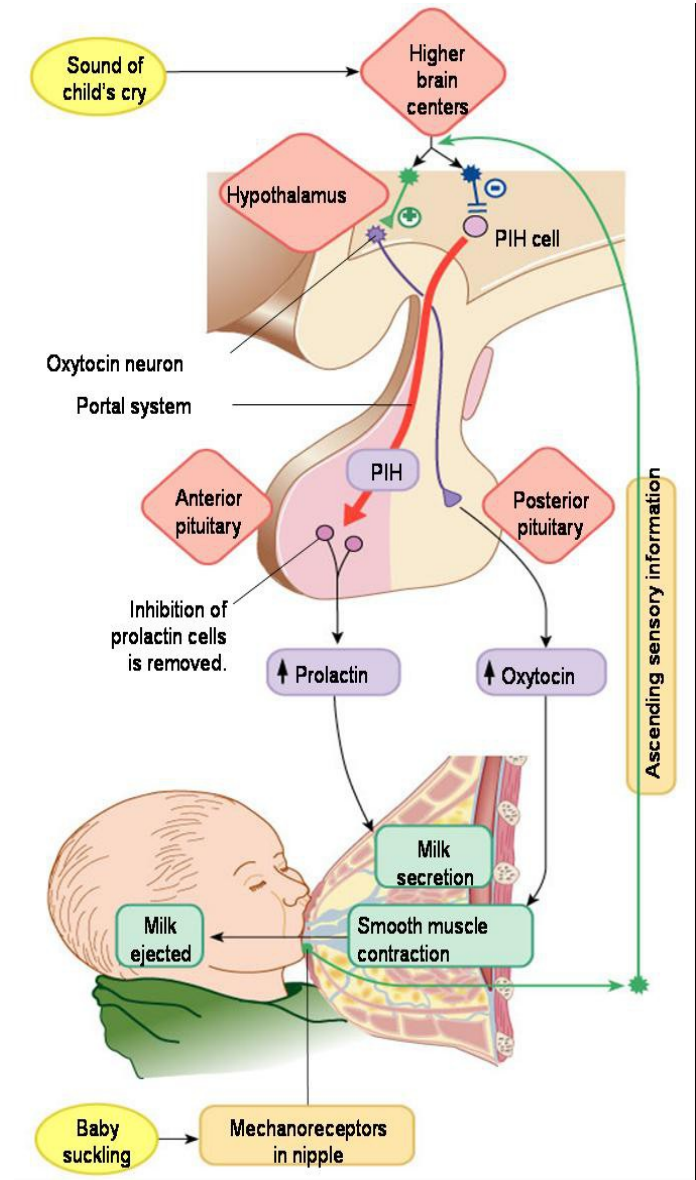
- Females physiology
  - Released from anterior pituitary // normally inhibited until after birth
  - Target tissue = epithelial glandular cells of the mammary gland
  - Mammary gland needs to be “primed” by estrogen and progesterone which occurs during pregnancy
  - Prolactin stimulates milk production



# 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 begins to produces estrogen, relaxin, and progesterone (as well as other hormones)
  - 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 (allow sperm to enter uterus)
    - 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 is established then placenta will produce progesterone and corpus luteum is 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** – water loss // opposite effect of estrogen
  - Makes cervical canal more viscous // **“the cervical plug”**



# Inhibin

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## 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)
- This delay is needed to see if zygote implants in endometrium and to see if the pregnancy is still viable

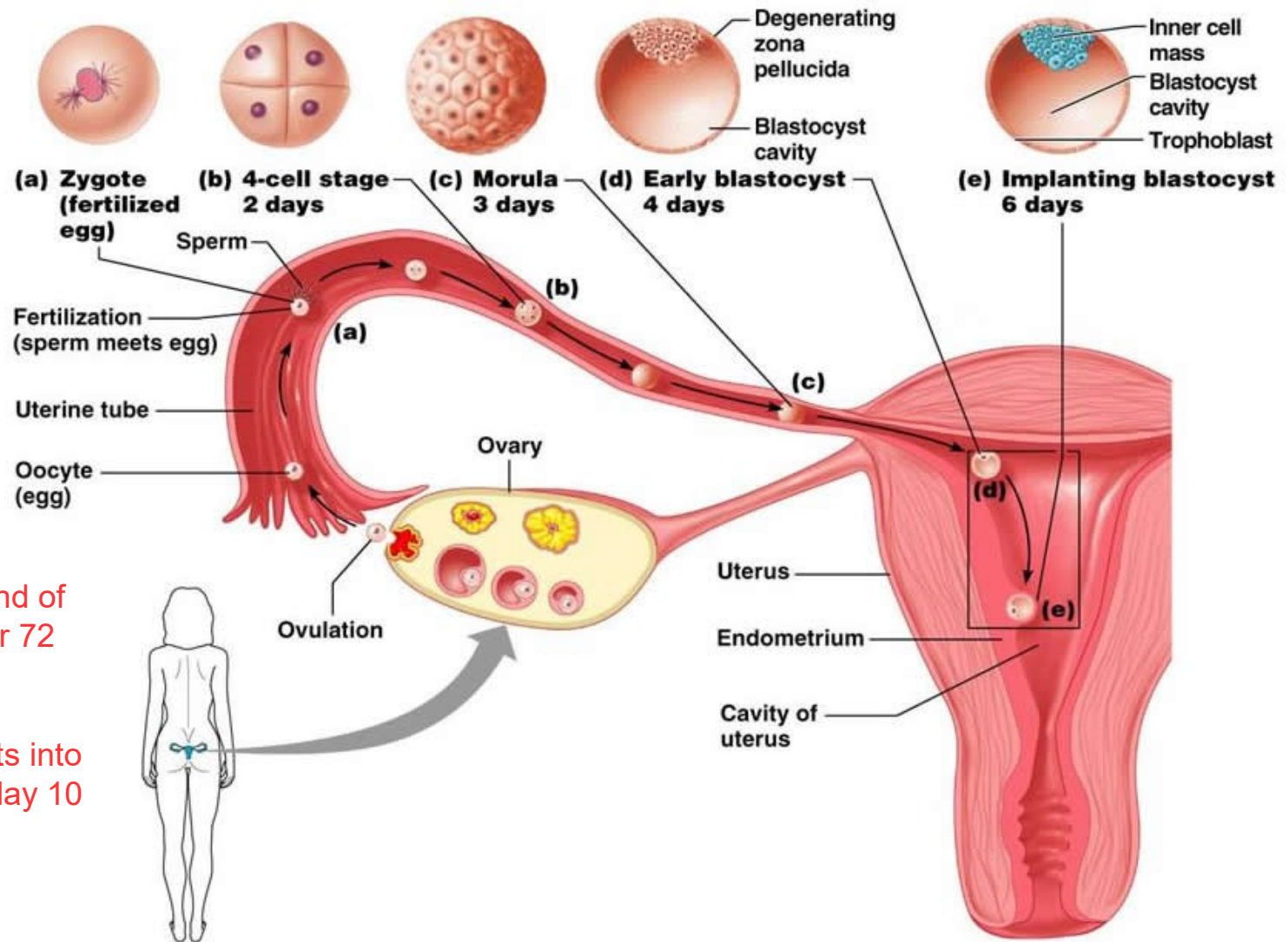
# Relaxin

- 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, just before parturition, the hormone “softens” the connective tissue in the pelvic girdle // this 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)
- Able to measure HCG in blood and urine four days after fertilization of ovum // this is the 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 will continue to secrete progesterone
- Corpus luteum is no longer required to secrete progesterone // corpus luteum turns into corpus albicans (scar tissue)



Morula reaches end of fallopian tube after 72 hours (3<sup>rd</sup> day).

Blastocyst implants into endometrium on day 10 after fertilization

- Blastocyst 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

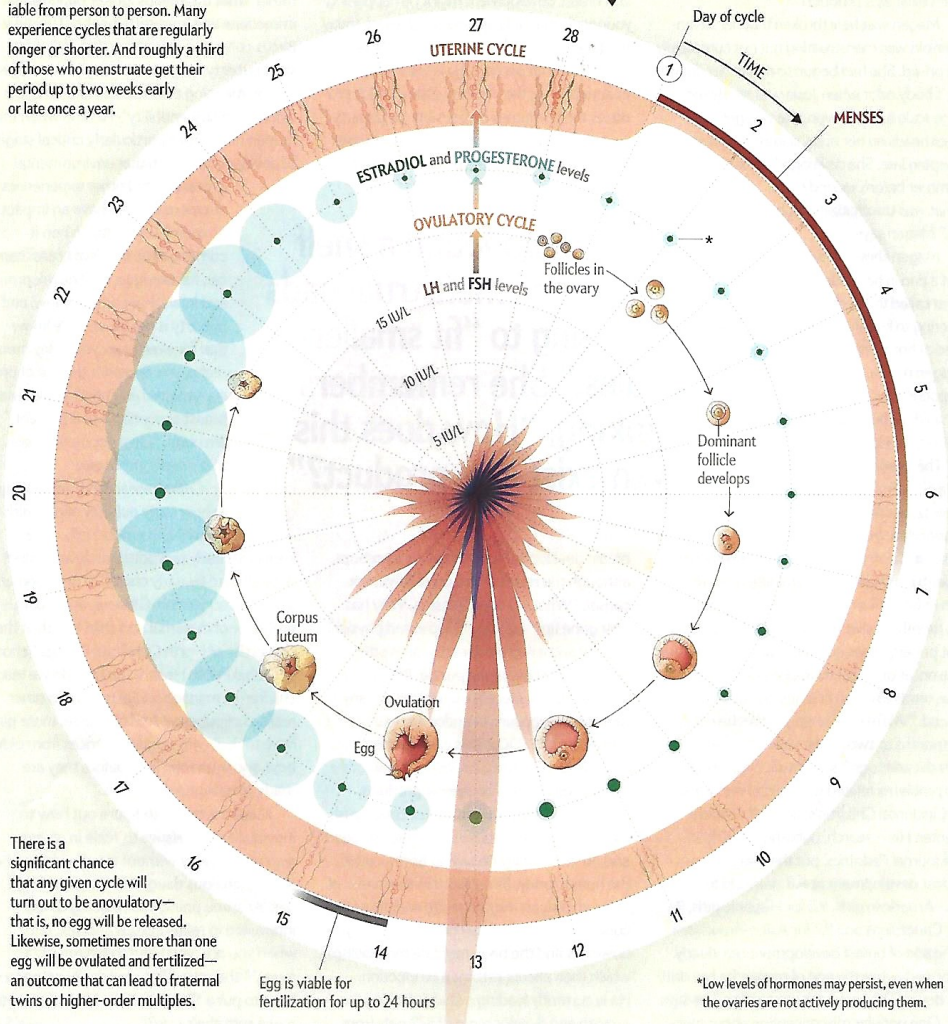
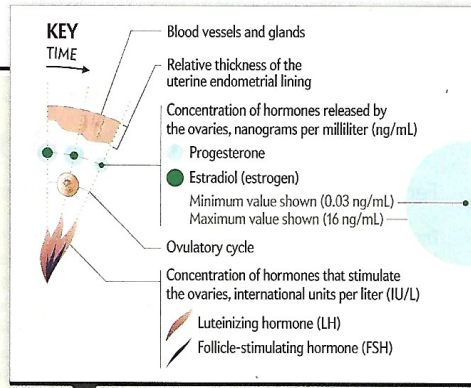
Humans are among the very few species to experience a period. The menstrual cycle starts in the brain, which sends signals to the pituitary gland (*not shown*) to produce hormones that stimulate the ovaries. The ovaries house egg-containing follicles that release an egg during ovulation. The ovaries 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.

Egg is viable for fertilization for up to 24 hours

\*Low levels of hormones may persist, even when the ovaries are not actively producing them.



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

Menstrual 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 to 1 day after ovulation)**

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

# Overview of Female Reproductive Structure

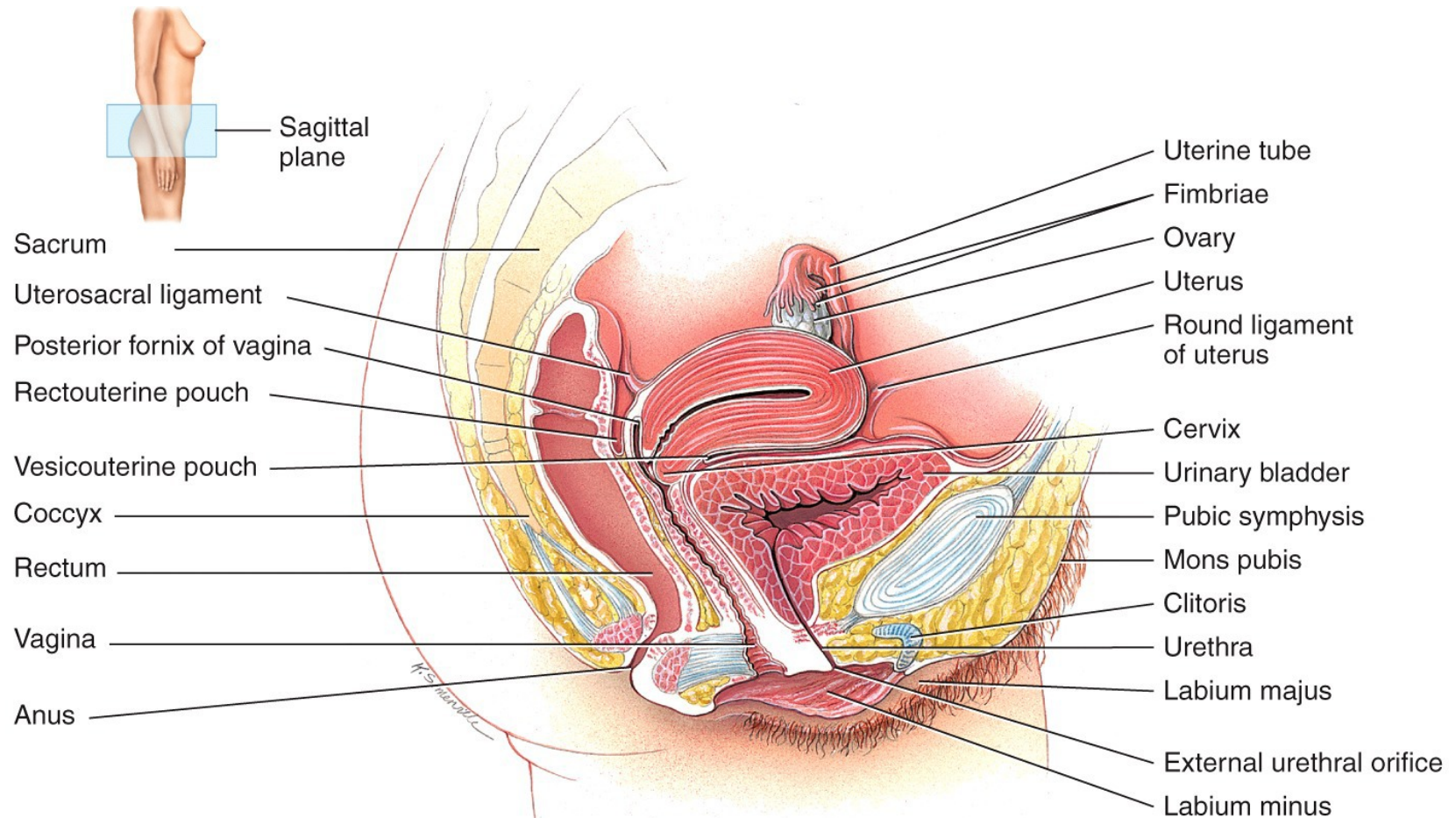
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Female reproductive structure consists of primary and secondary sex organs

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

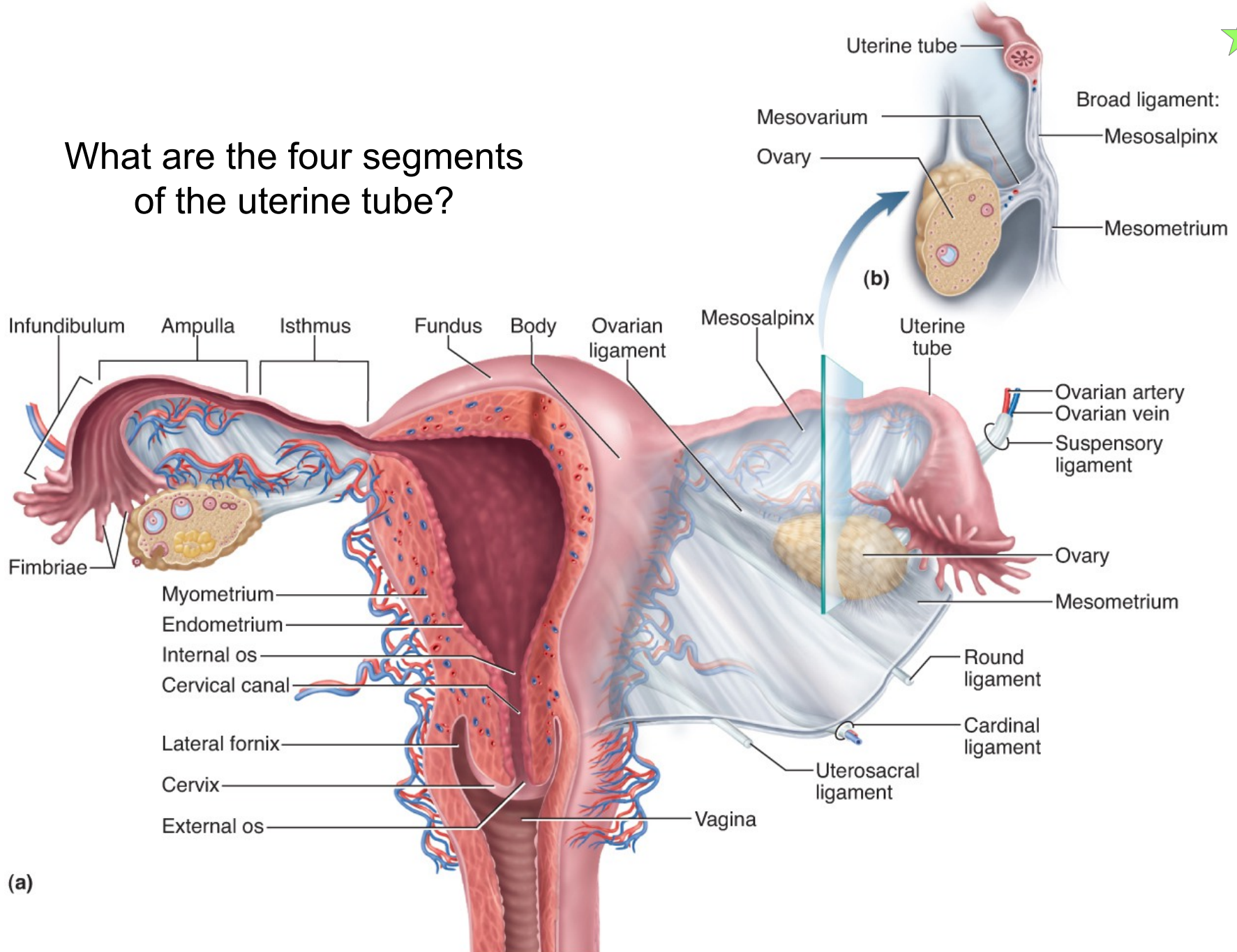
Secondary sex organs // organs other than the gonads that are necessary for reproduction /// uterine tubes, uterus, and vagina

- Primary sex organ = ovaries // produce female gamete (egg)
- Secondary sex organs = fallopian tubes, uterus, vagina

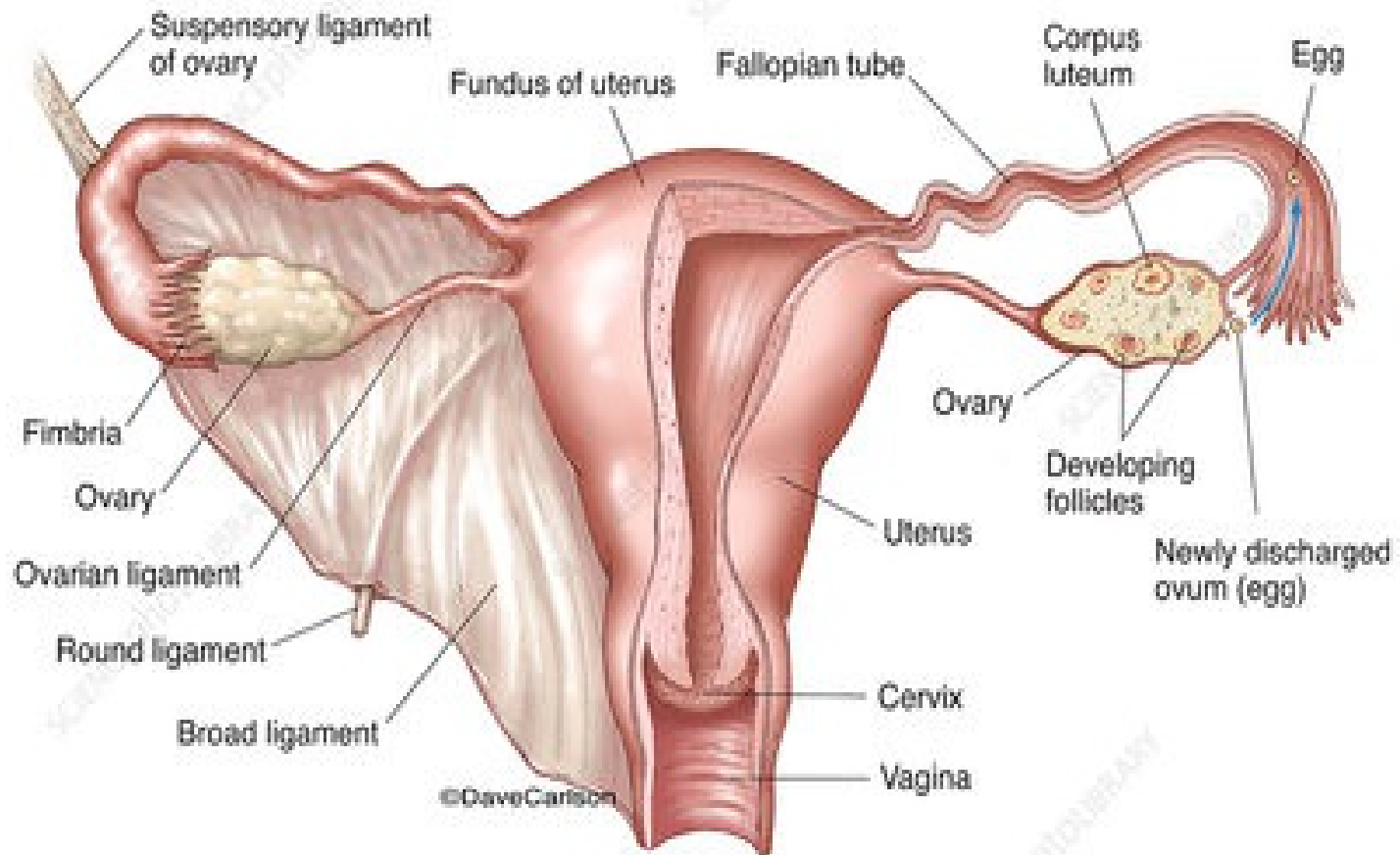


(a) Sagittal section

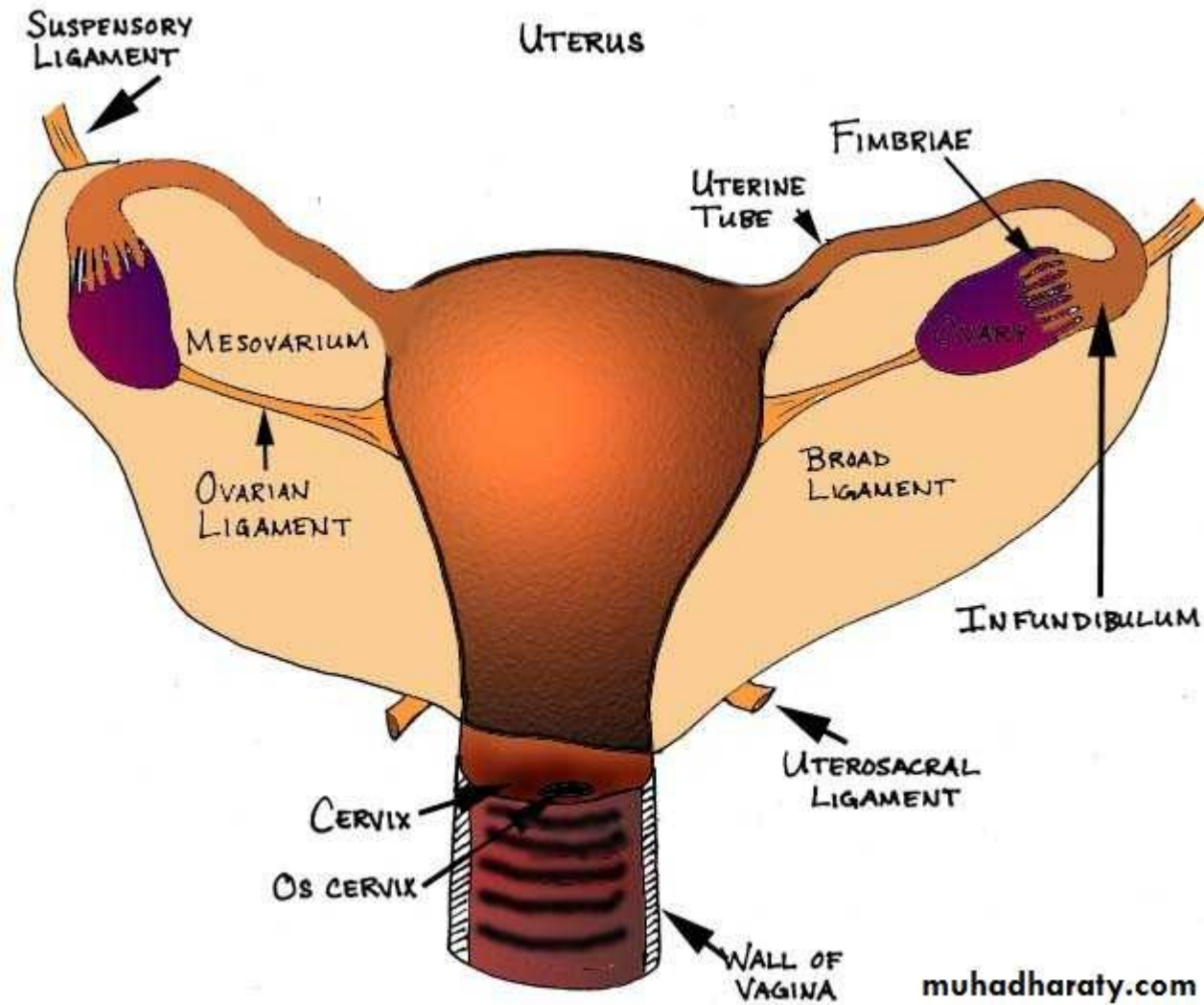
What are the four segments of the uterine tube?



## Internal organs of the female reproductive system.



## Internal organs of the female reproductive system.



# The Uterus

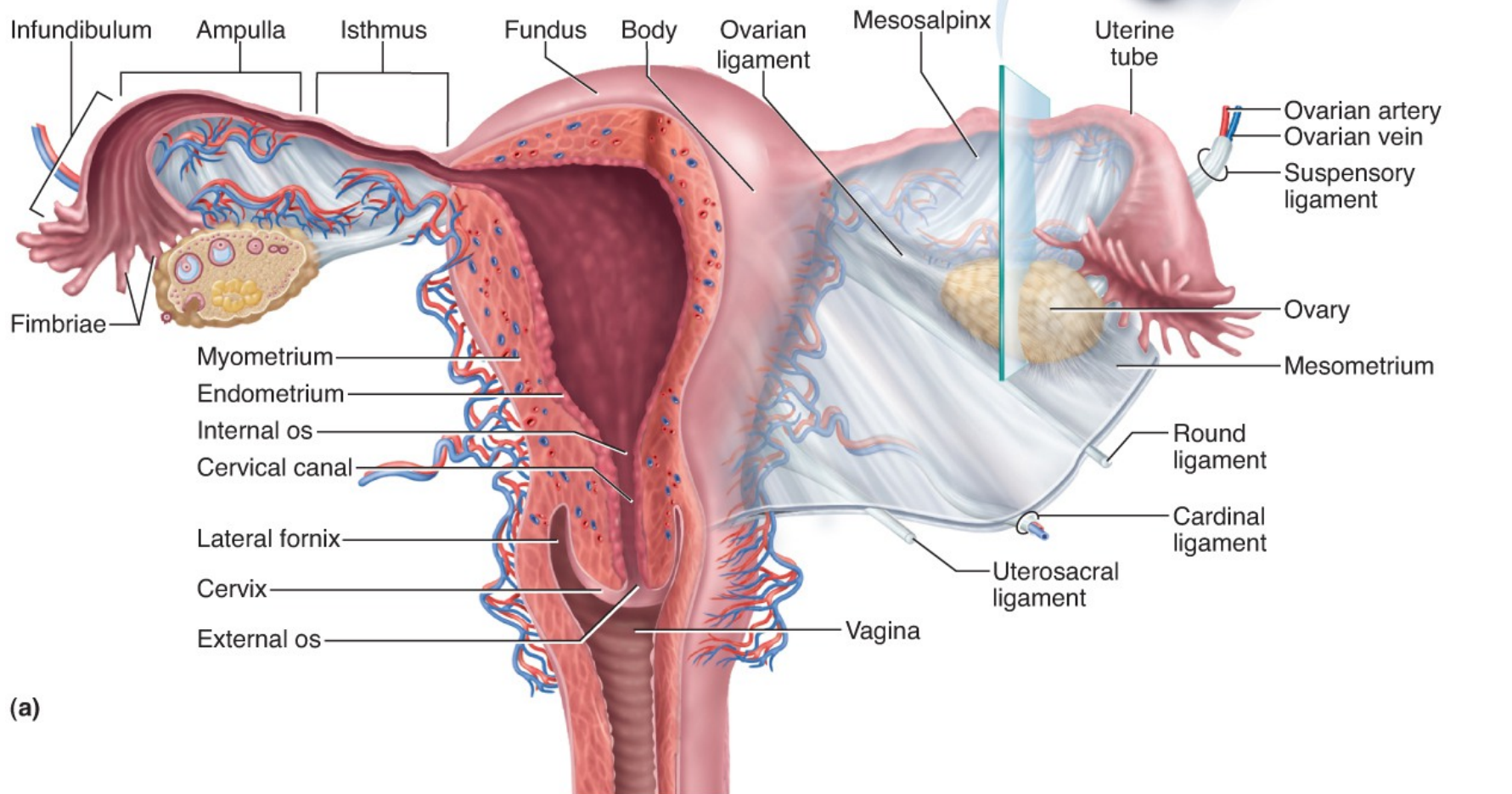
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- Uterus – thick muscular (smooth muscle) chamber that opens into the roof of the vagina
  - usually tilts forward over the urinary bladder
  - Location where conceptus develops /// provides a source of nutrition and expels the fetus at the end of 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 – secrete 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



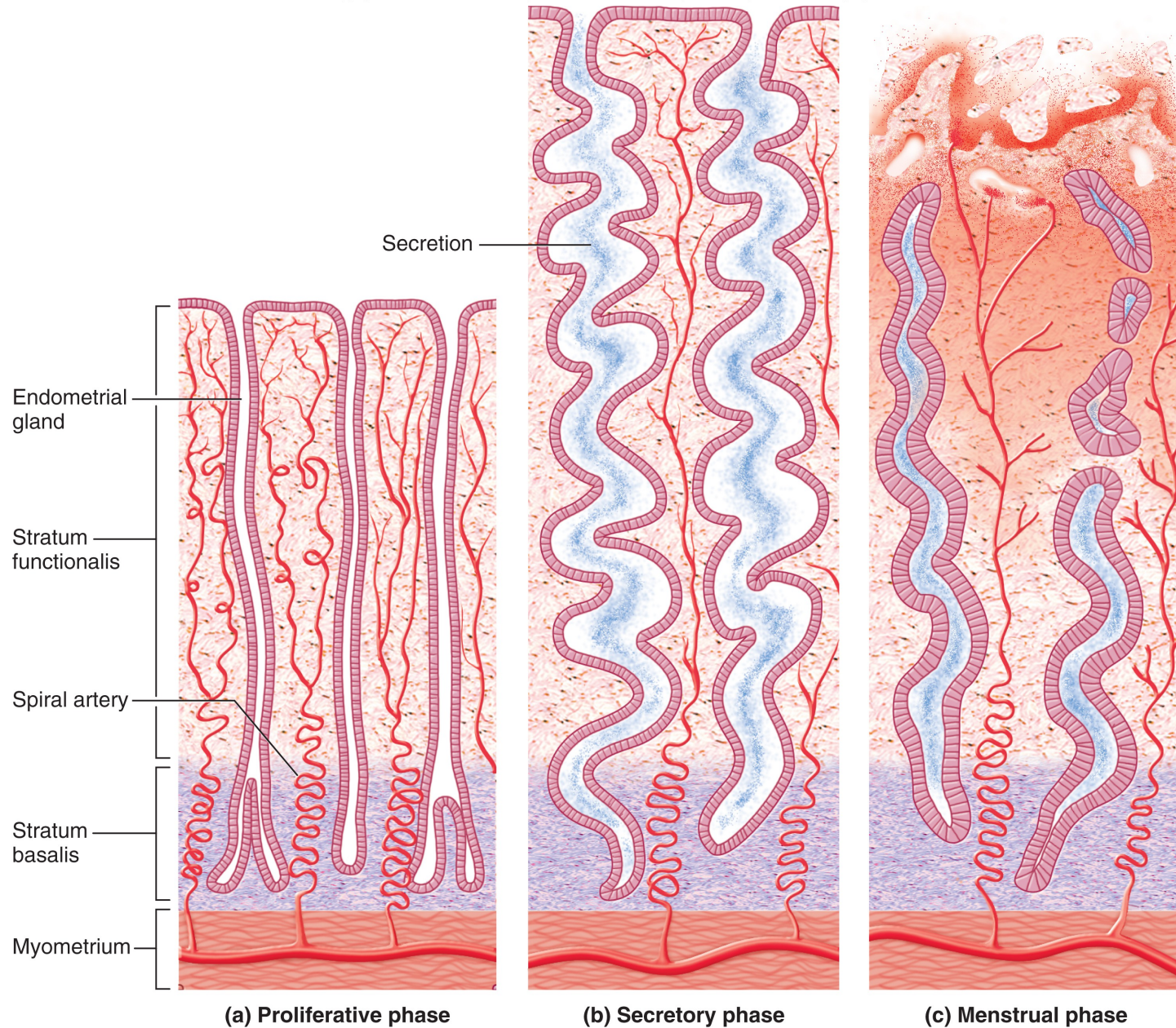
**endometrium** = the mucosa of the uterus

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

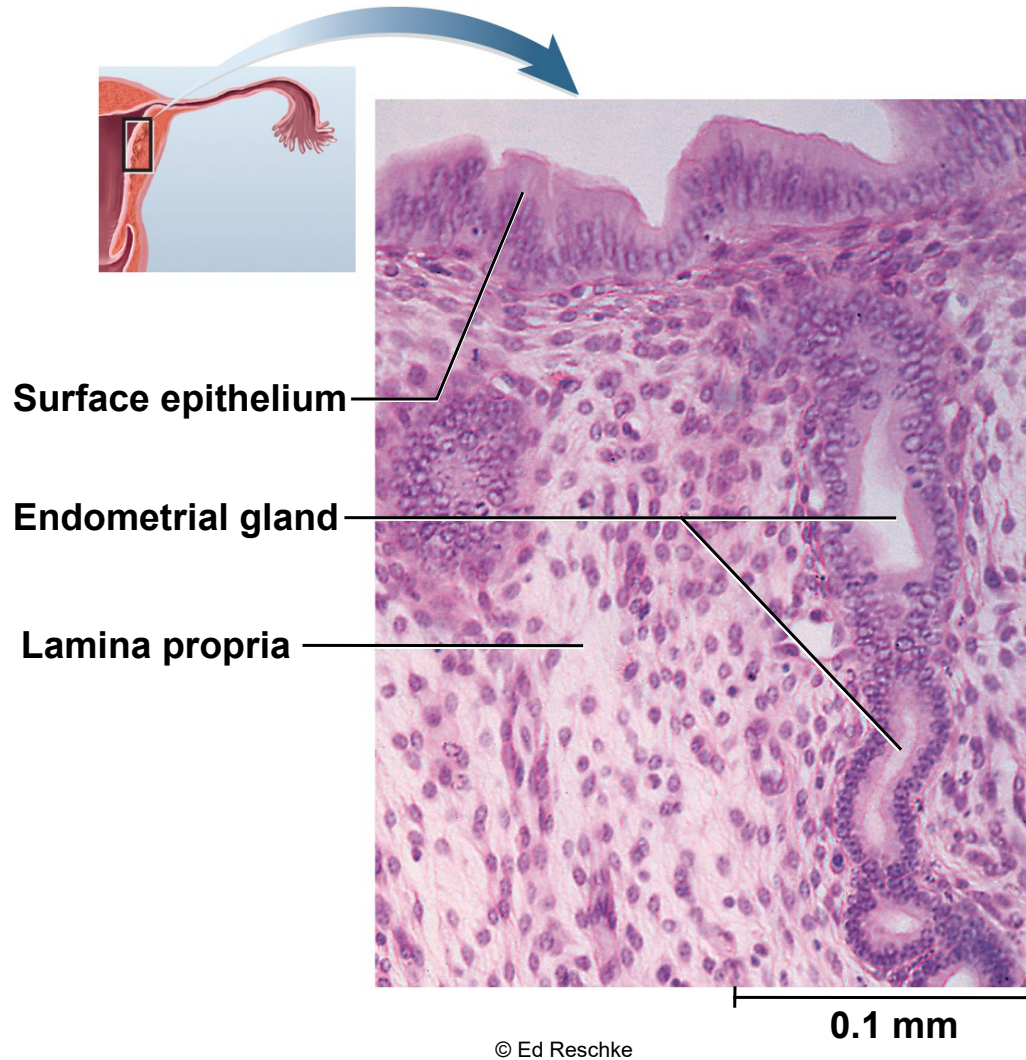
**stratum functionalis** – superficial half, shed each menstrual period

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

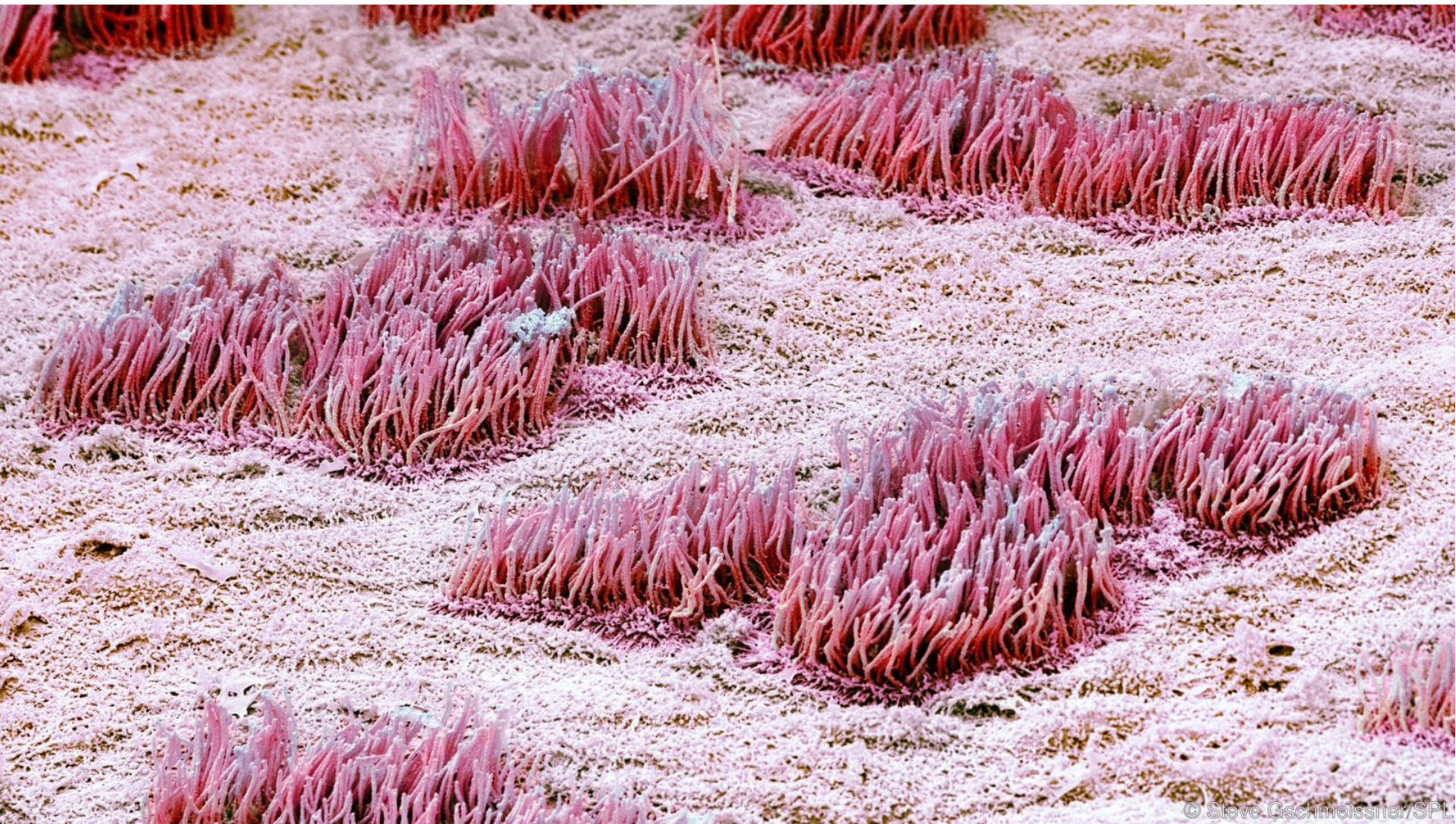
during pregnancy, the endometrium is the site of attachment of the conceptus /// the placenta grows “out of the conceptus” /// forms interface between maternal tissue and conceptus // the placenta is the organ that exchanges nutrients and waste products between conceptus and mother



# Histology of Endometrium



# Endometrium





# 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.



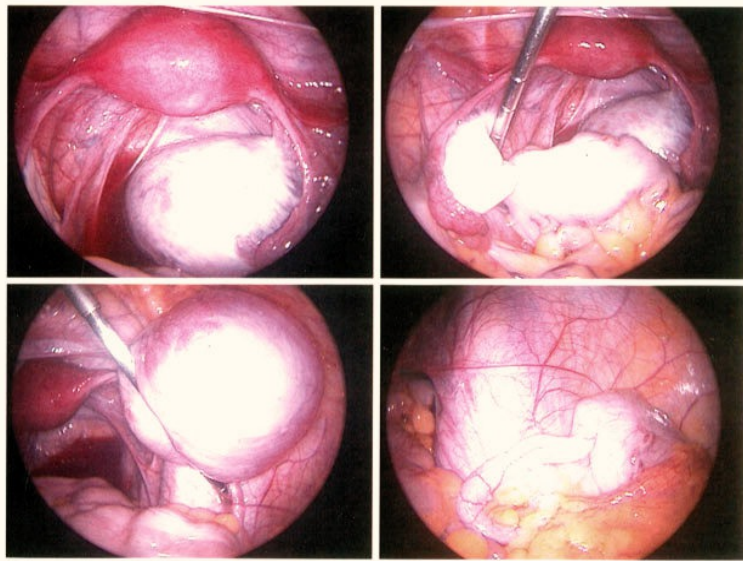


- Blastocyte attaches to endometrium at **day 10** to initiate the formation of the placenta
- Placenta is the organ used to **exchange nutrients and metabolic waste between mother and conceptus** // nicknamed the fetus first organ
- Placenta fully developed at week 8 – before this time the conceptus 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

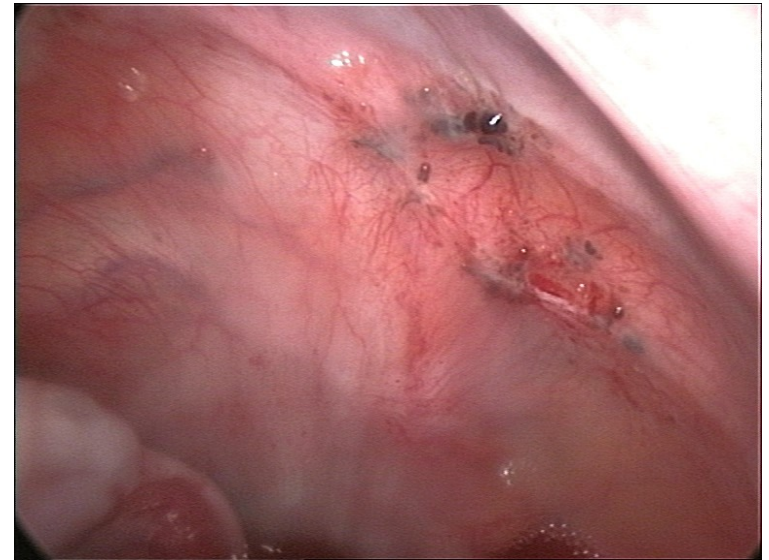
# Endometriosis

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.

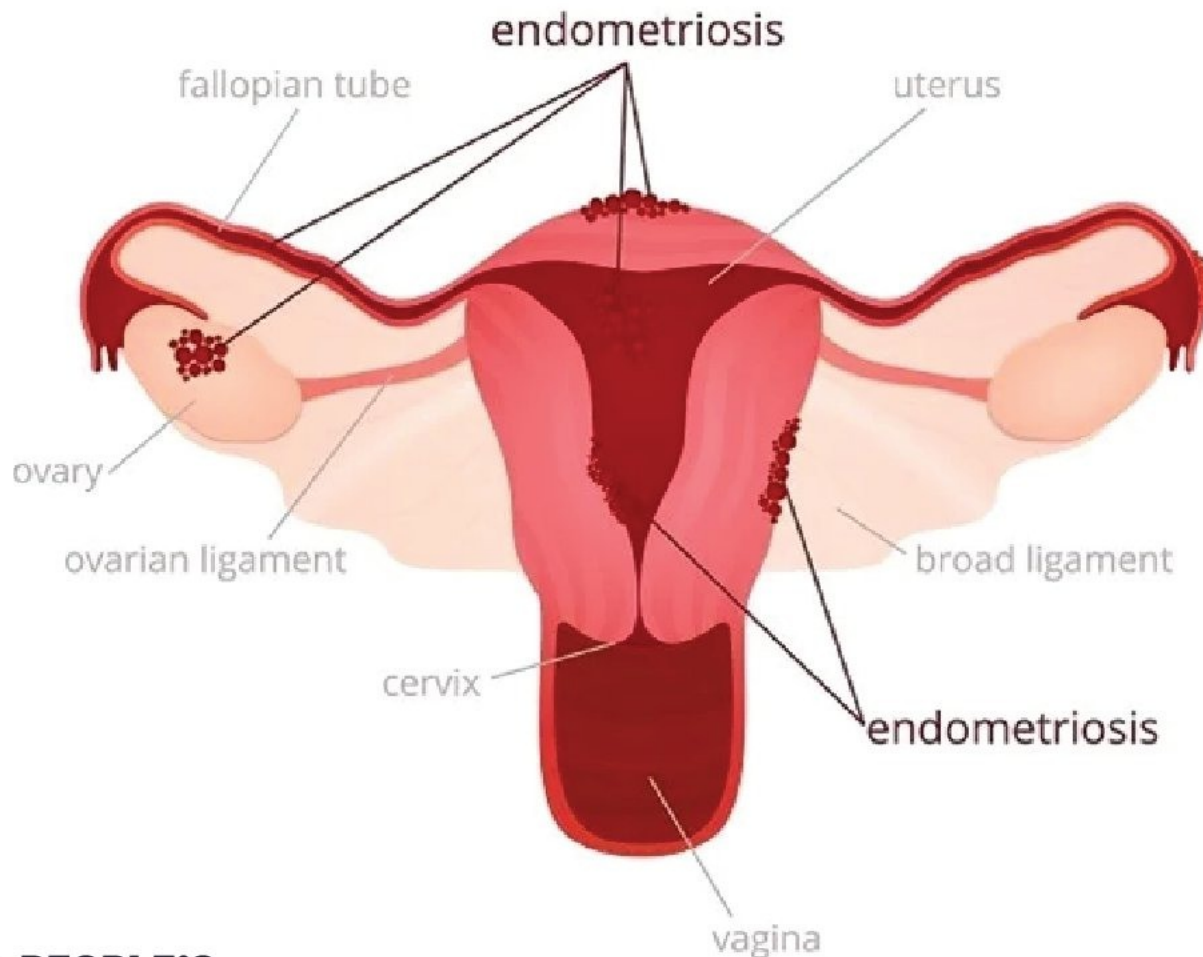


Endometriotic cyst on ovary

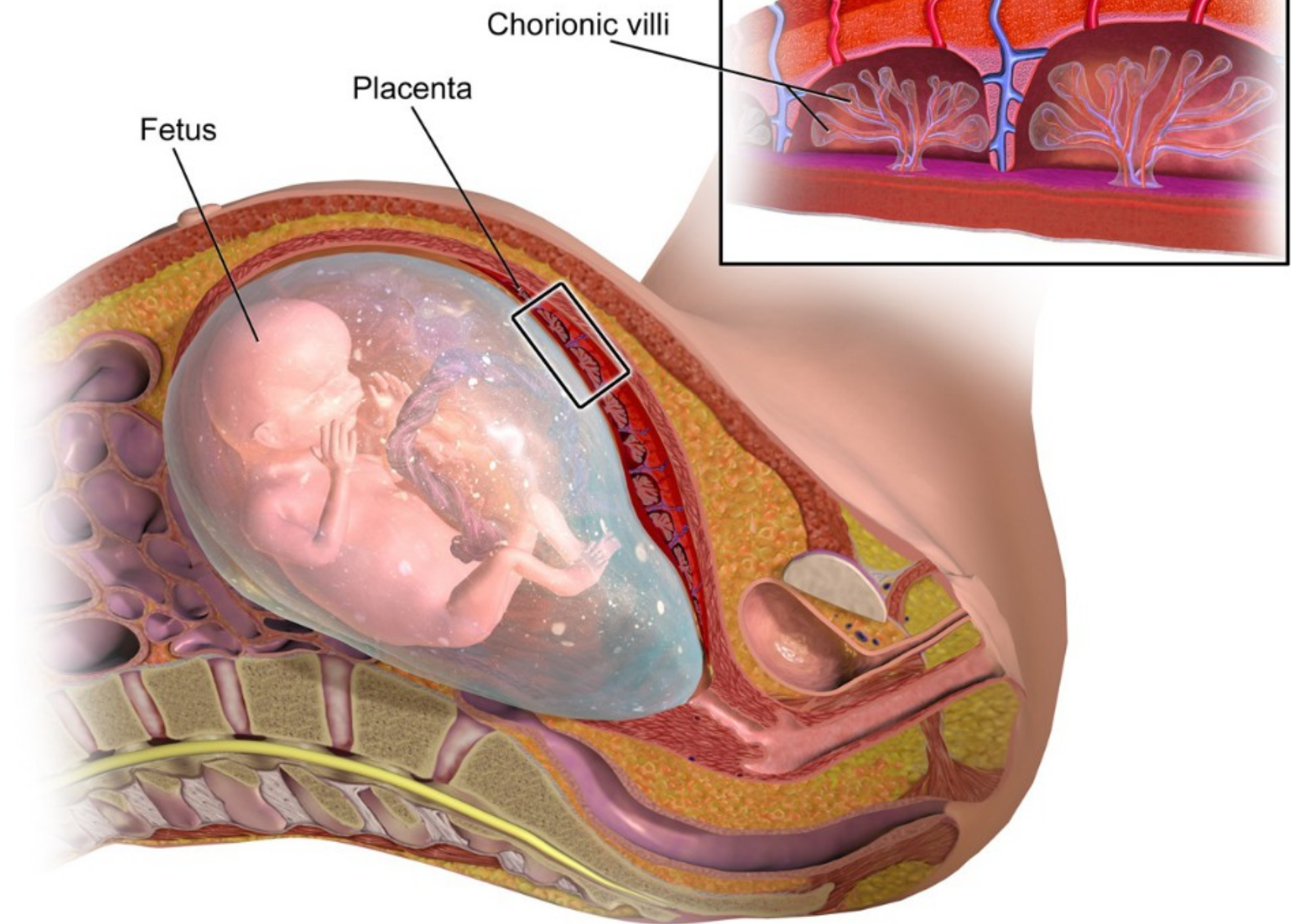


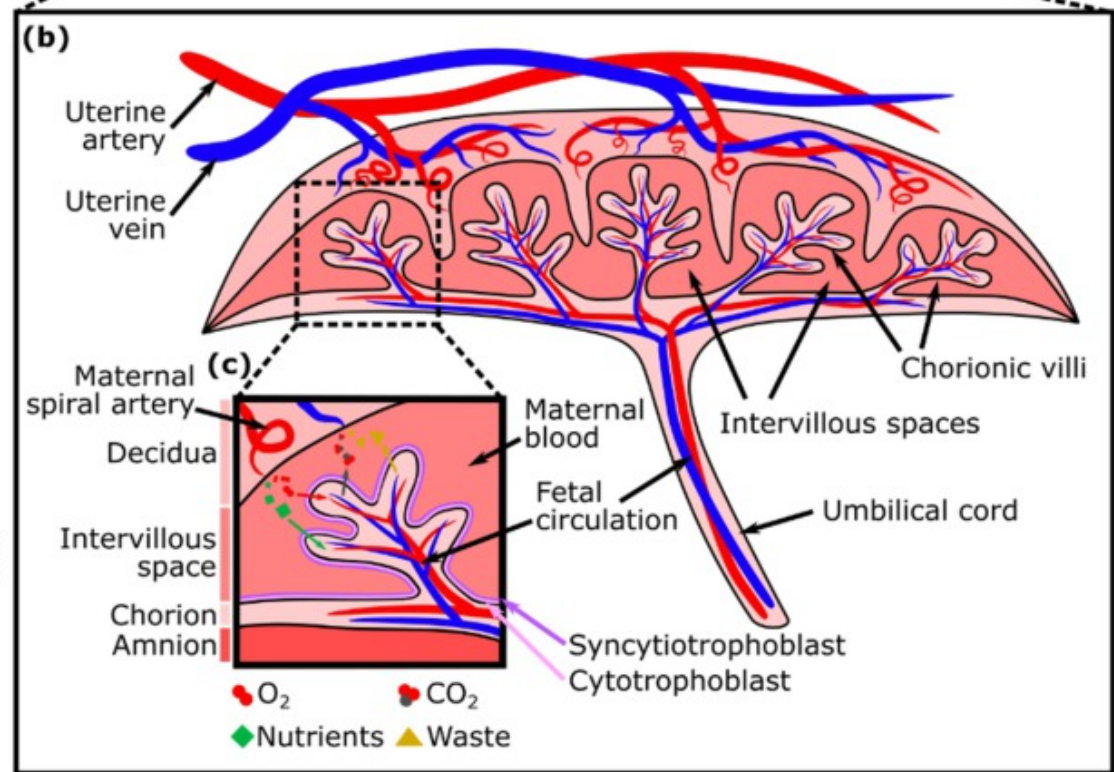
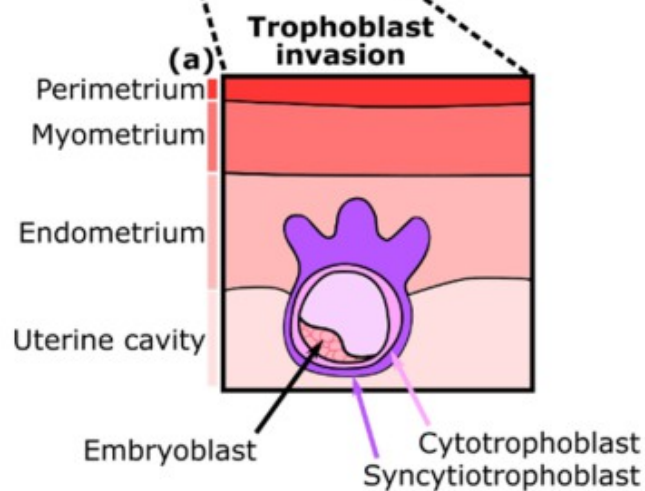
Endometriotic lesions at the peritoneum of the pelvic wall

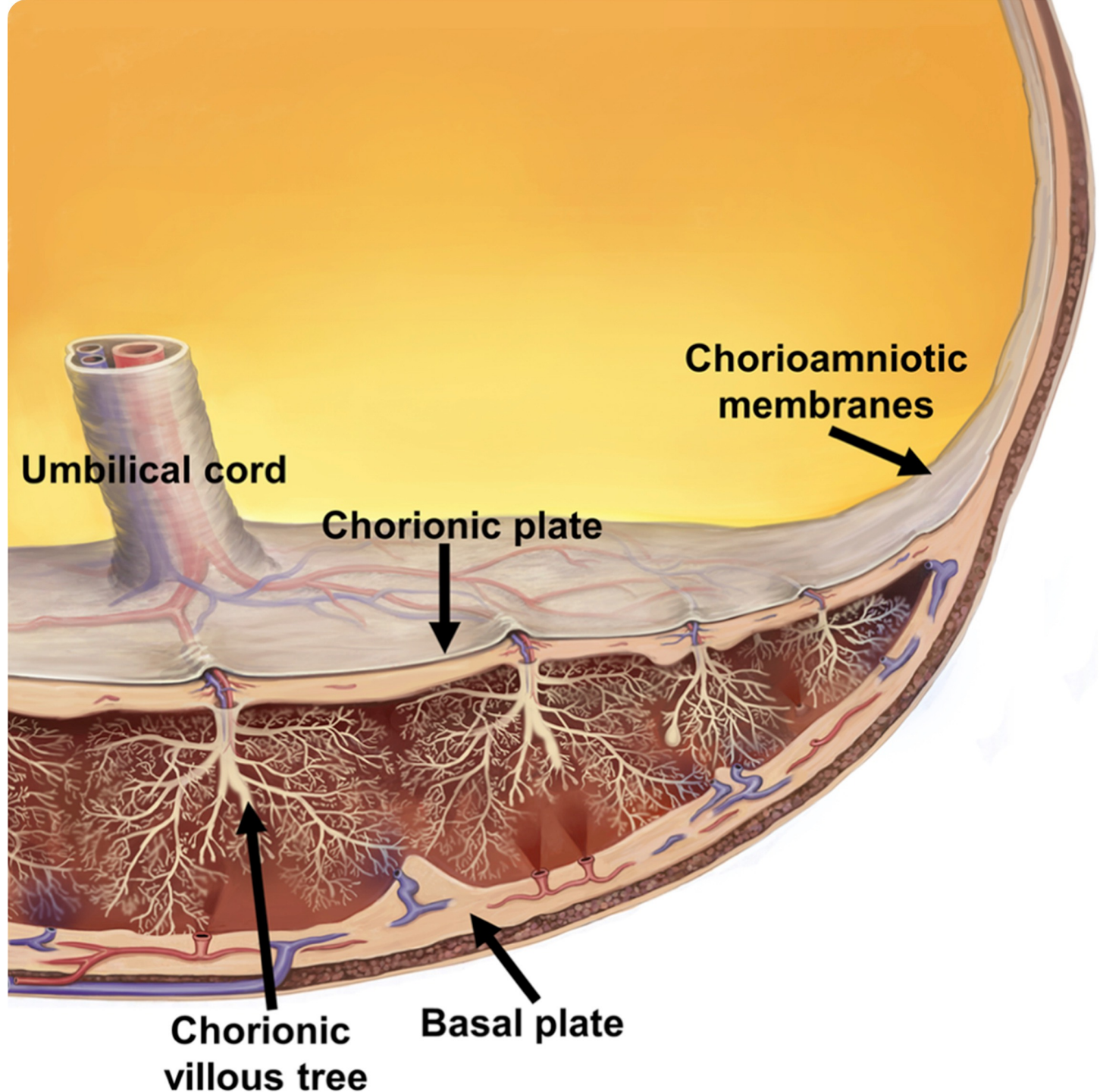
# ENDOMETRIOSIS

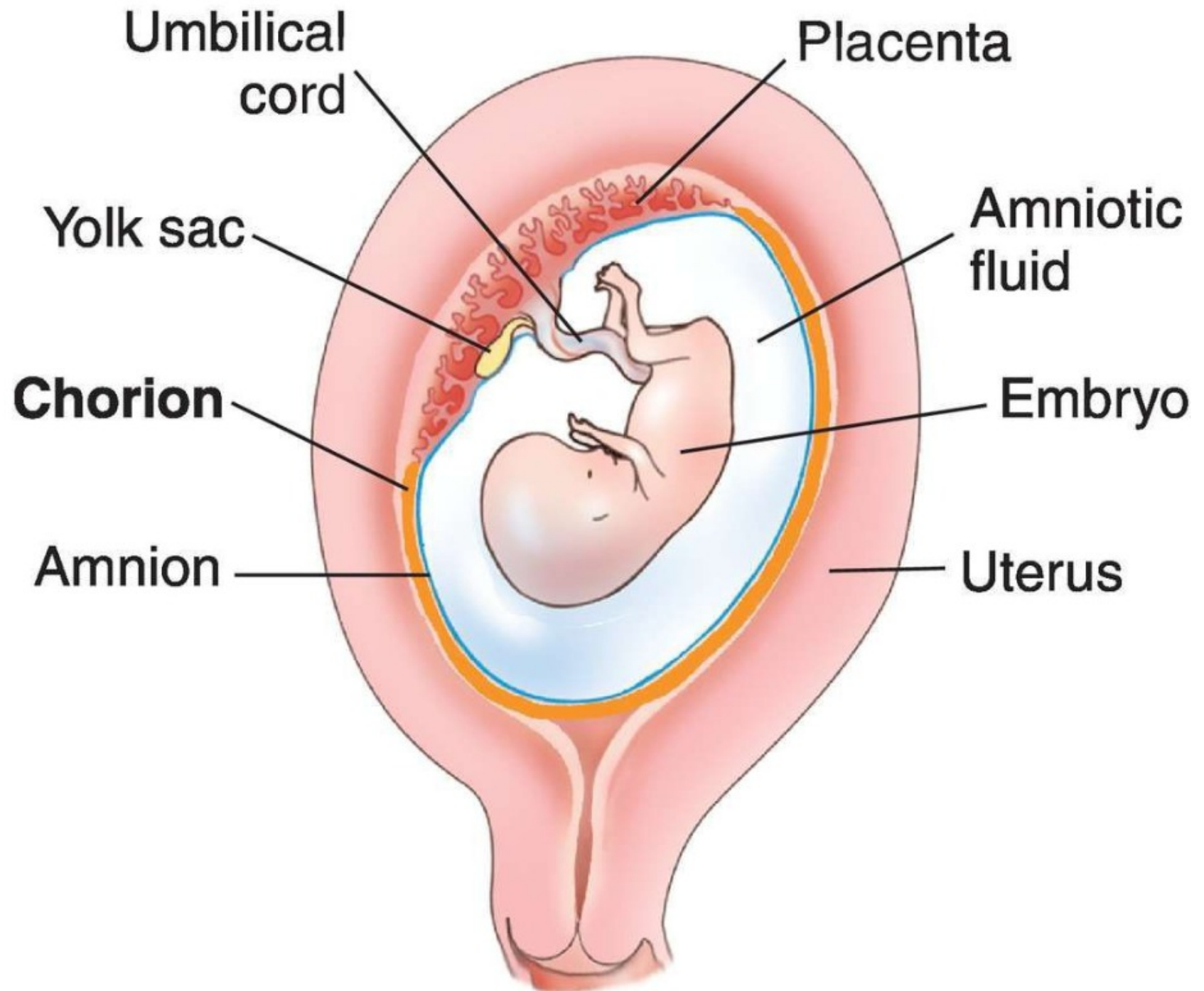


# Chorionic Villi









## 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.

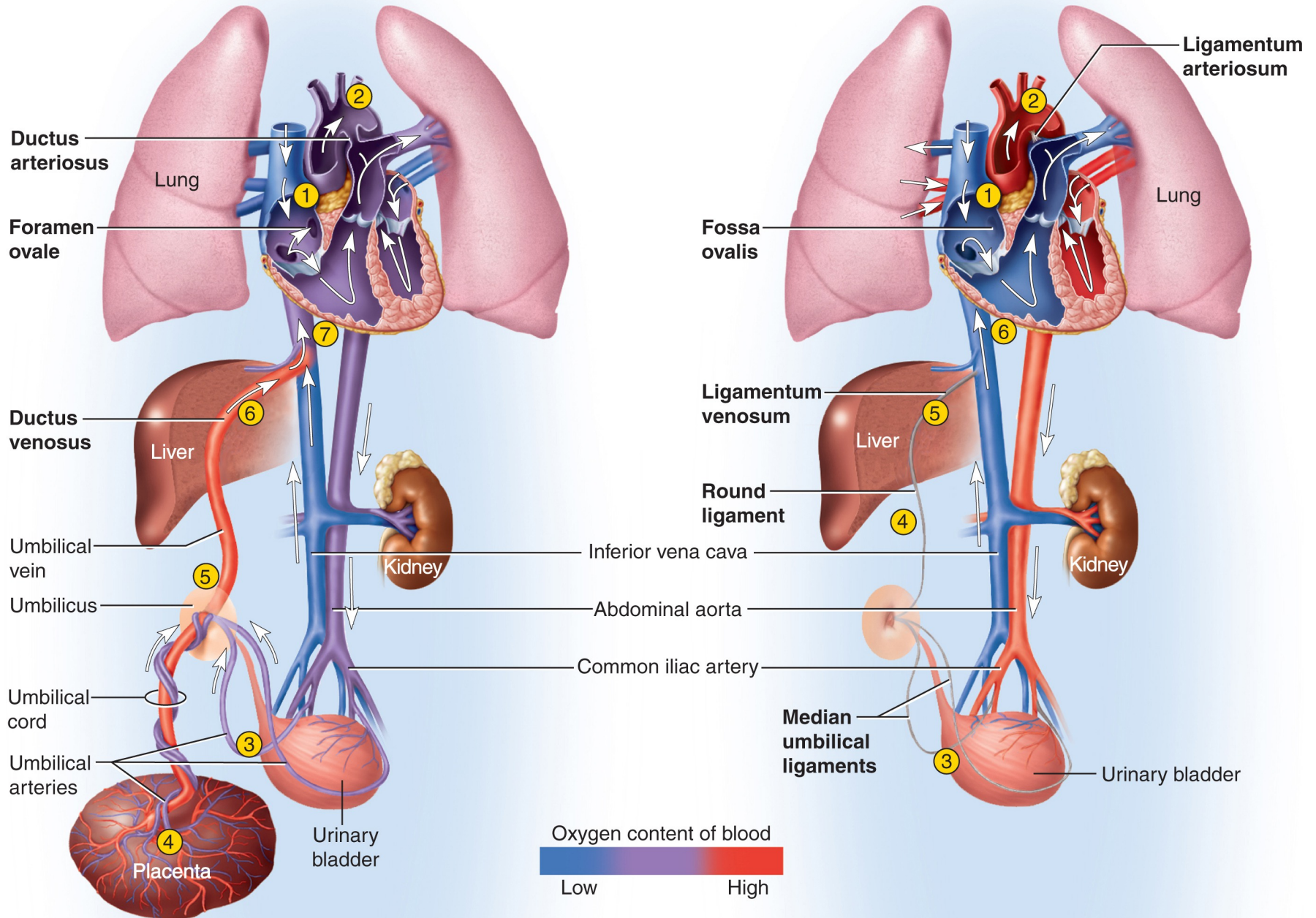
A similar role is played by placental growth hormone, which predominates during pregnancy due to suppression of growth hormone produced by the maternal pituitary gland.

## What hormones are produced by the placenta?

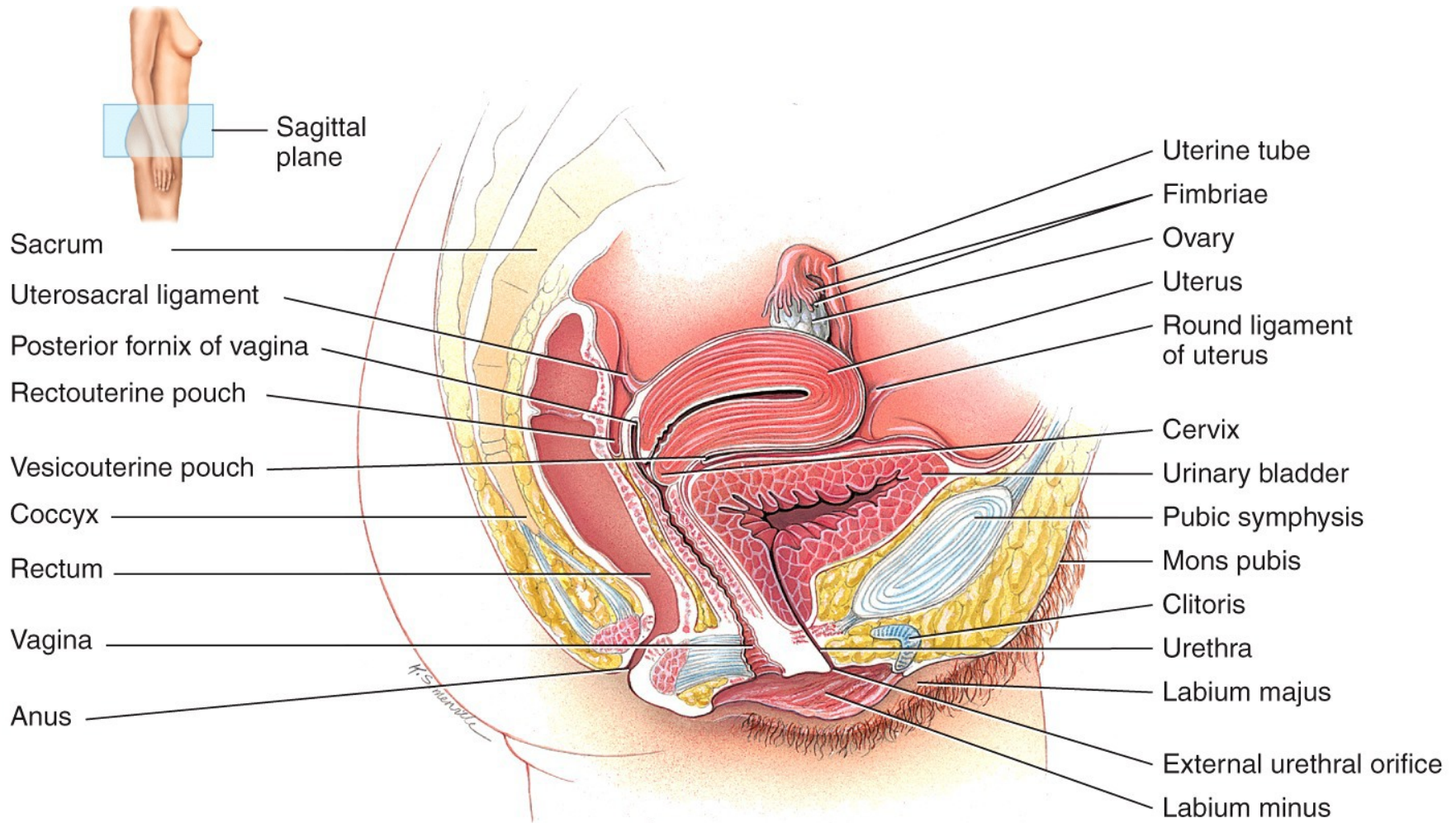
Relaxin causes the relaxation of pelvic ligaments and softening of the cervix at the end of pregnancy, which aids the process of labor

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).

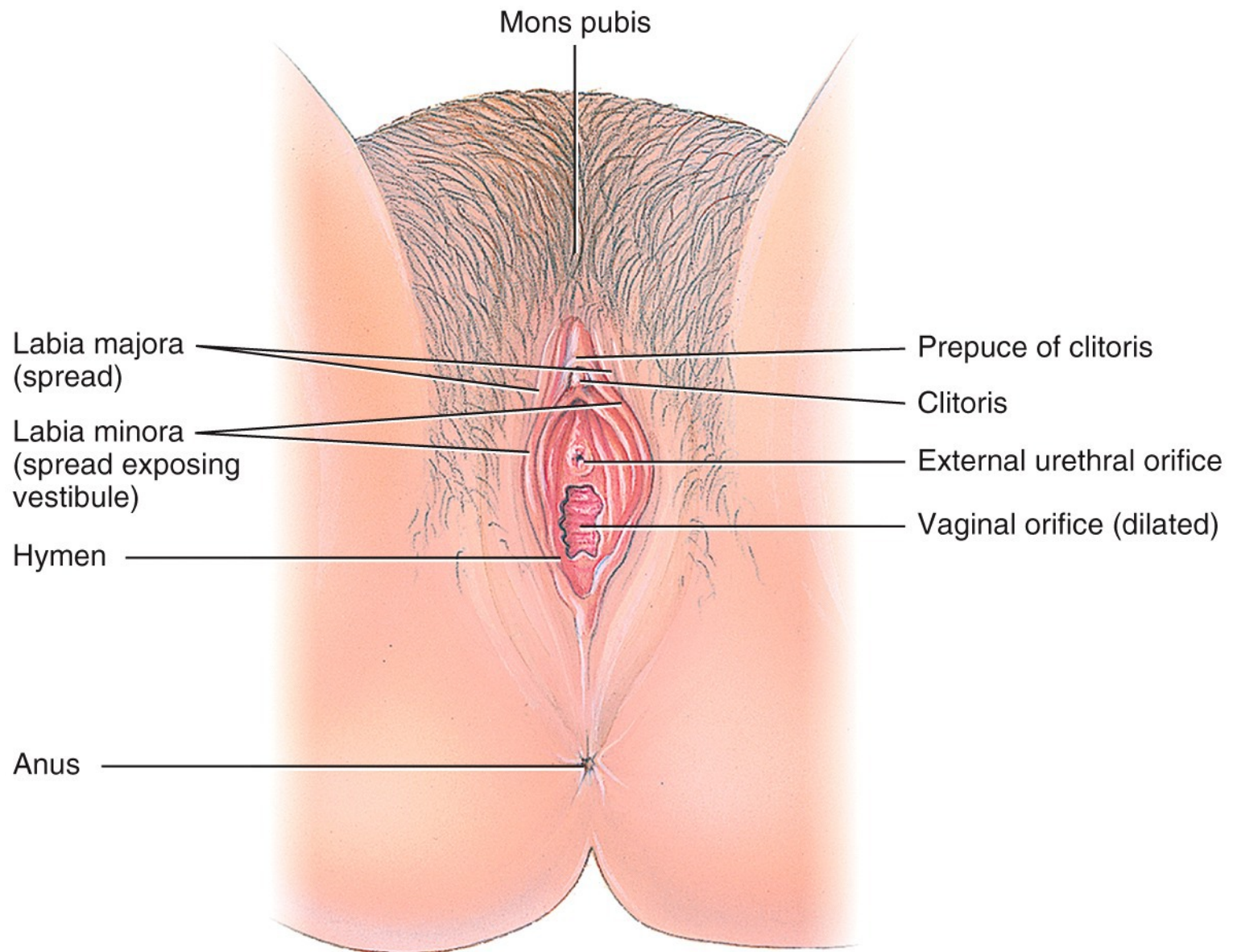
A number of other peptide hormones have been recently identified to regulate blood vessel formation within the placenta, which is crucial in allowing the placenta to exchange nutrients from the mother to baby; these peptide hormones include soluble endoglin (sEng), soluble fms-like tyrosine kinase 1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



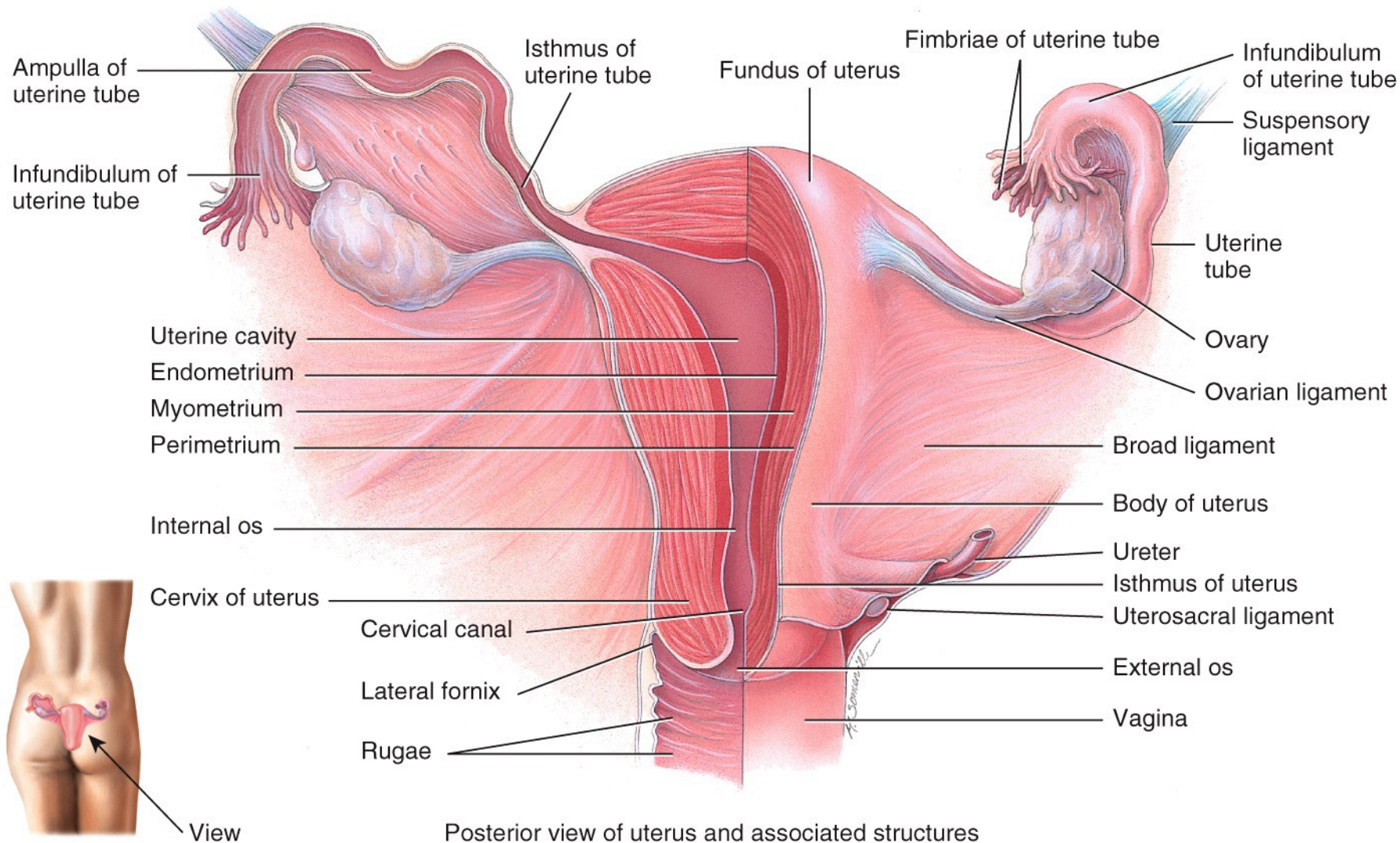
# Female Reproductive Organs

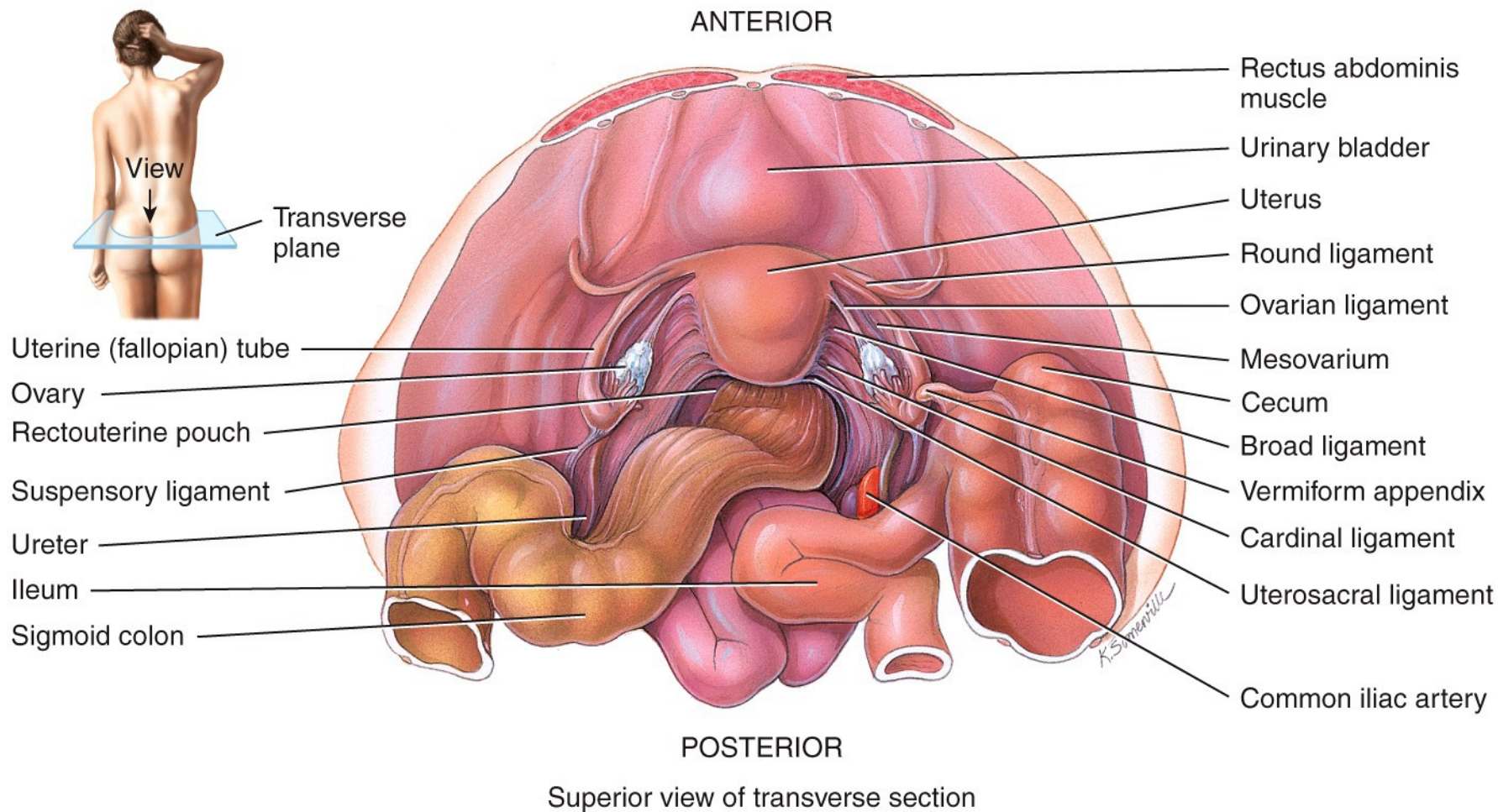


(a) Sagittal section



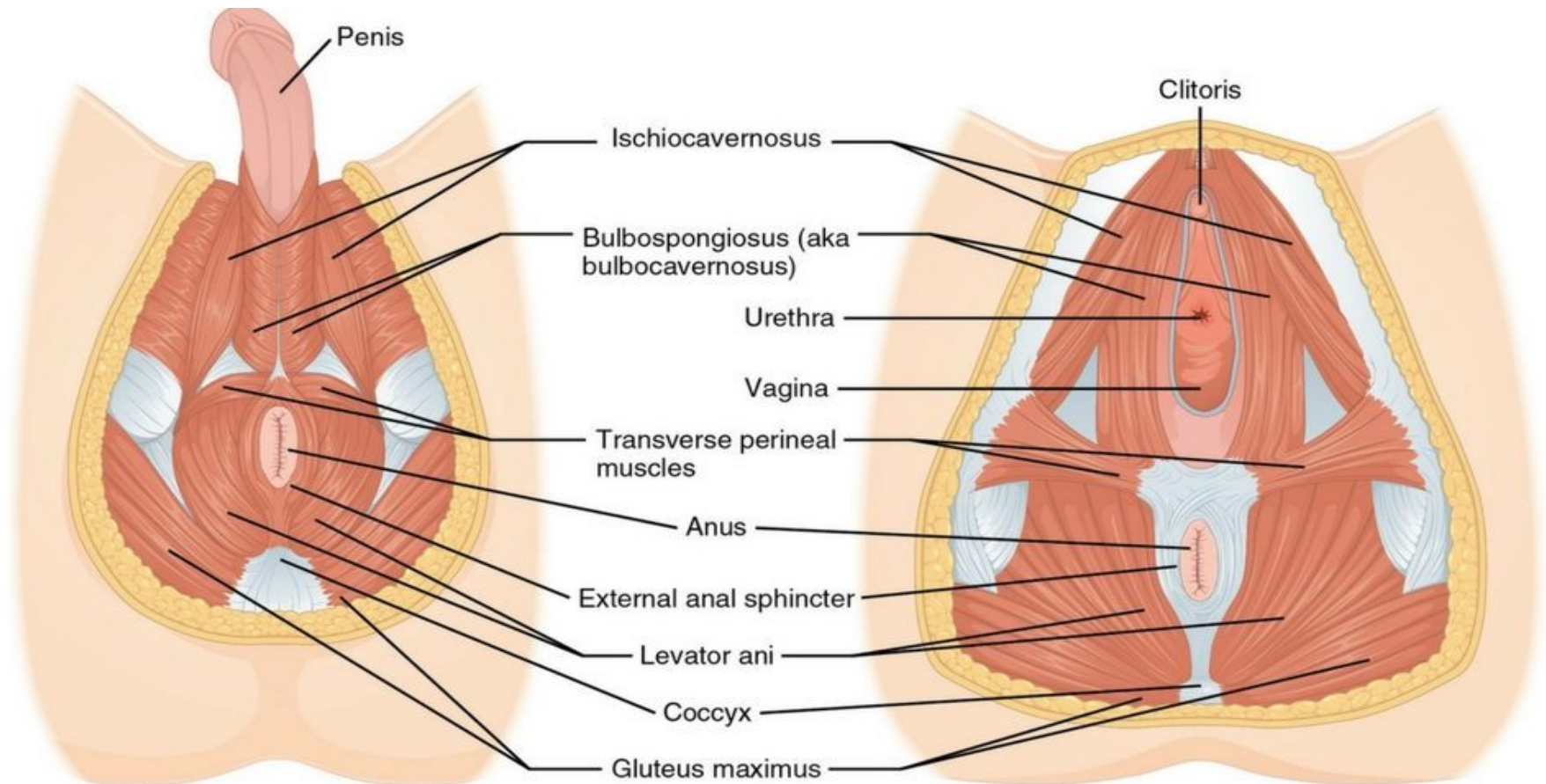
(c) Inferior view





# 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.



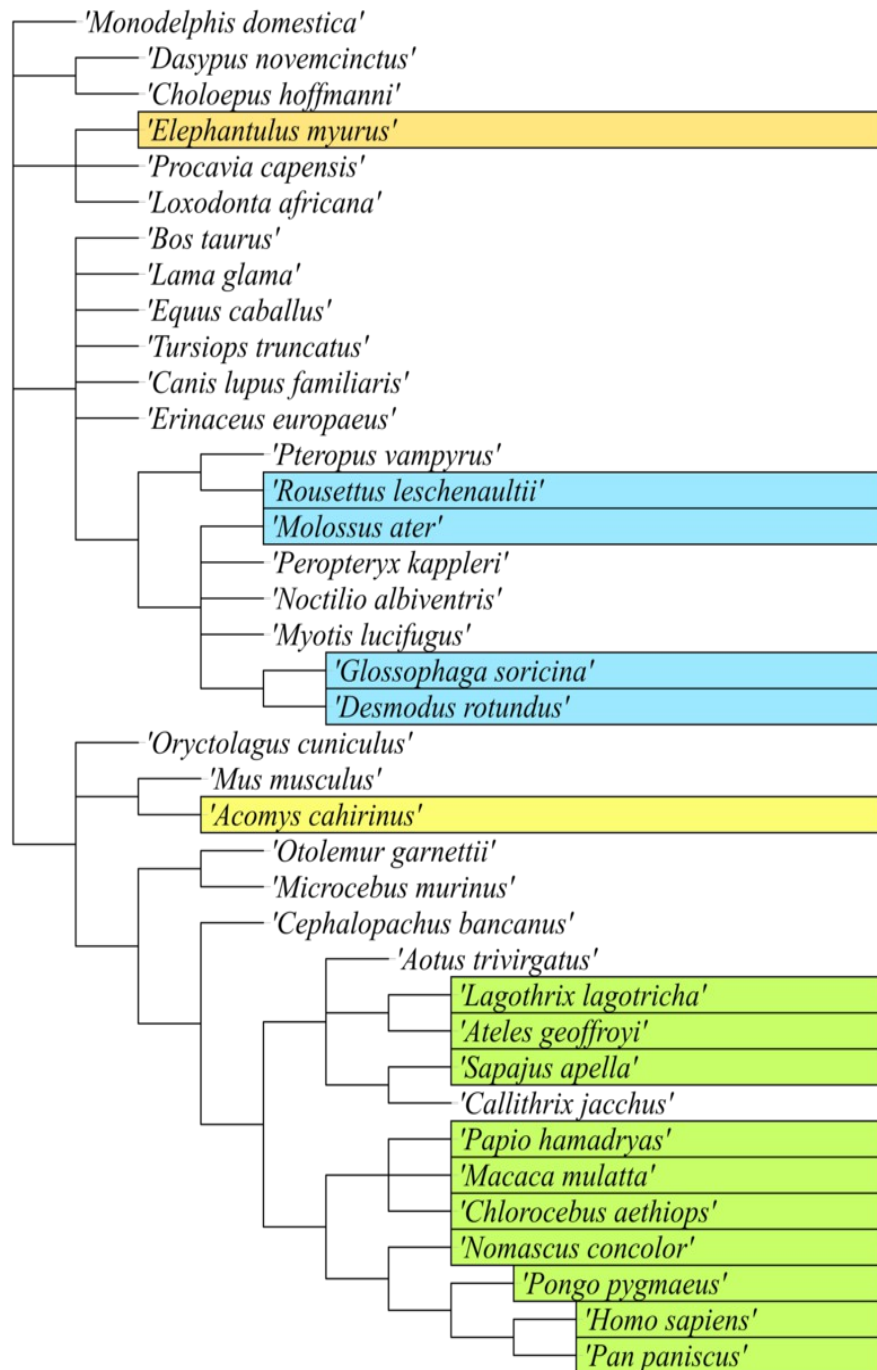
Male perineal muscles: inferior view

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. menses) !***
- *All other mammals reabsorb their endometrium. Evolutionary physiologist study menses to understand what might be the adaptive advantage of the period. (see The Point of a Period – Scientific American)*

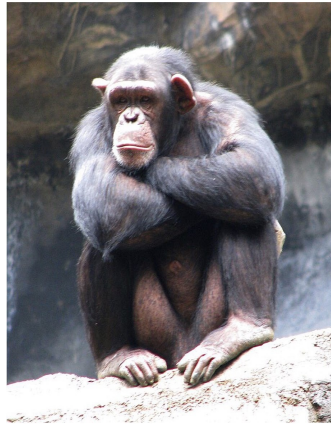


Phylogeny tree of menstruating and select non-menstruating mammals. Each color indicates a convergent evolutionary event: green, Primates; blue, Chiroptera; orange, Afrotheria; yellow, Rodentia.

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.



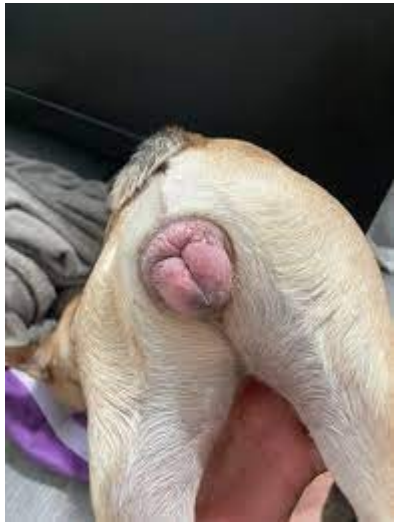
These animals are the only animals to have periods and shed their endometrium.

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.



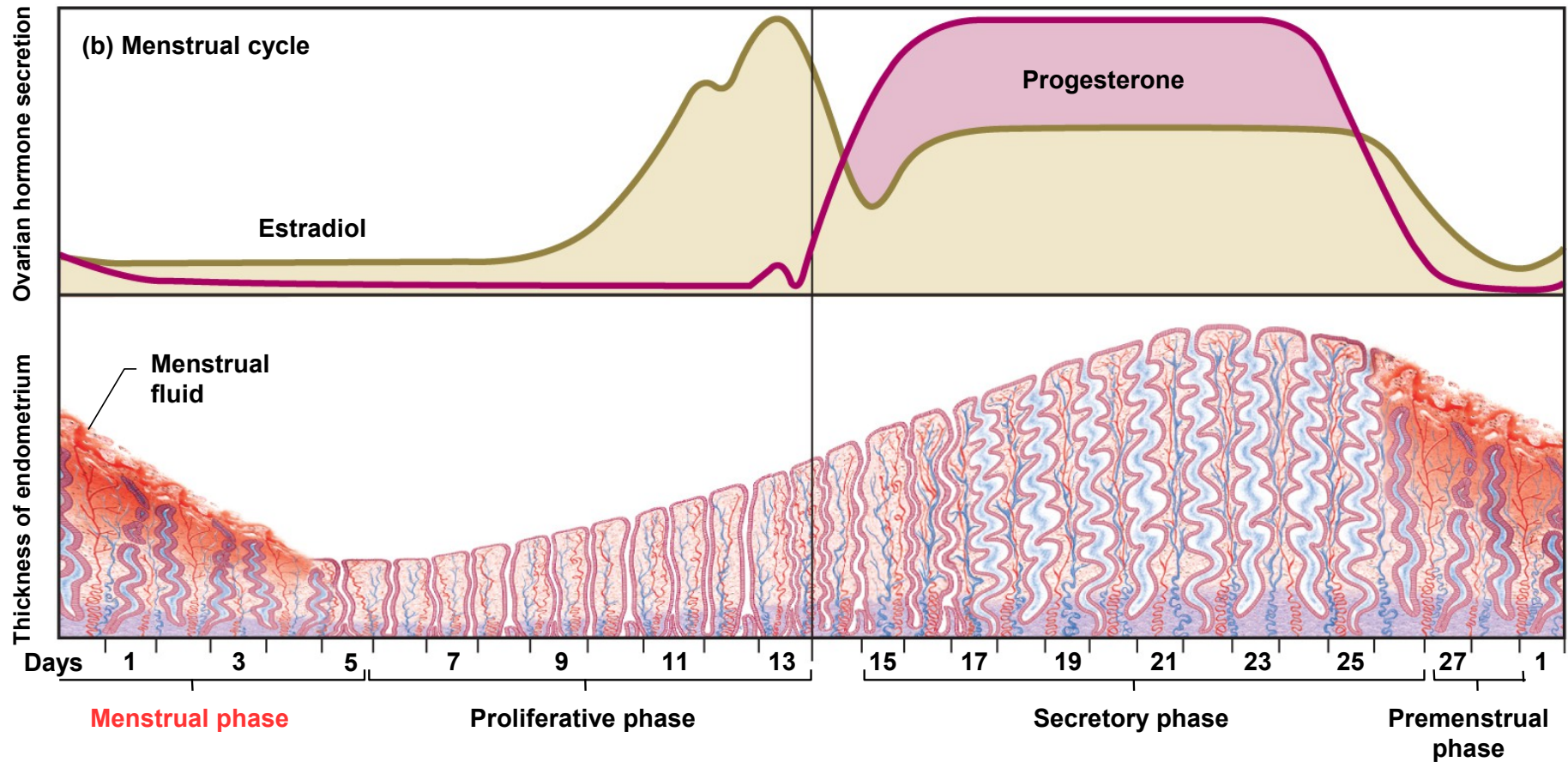
Dog



Horse

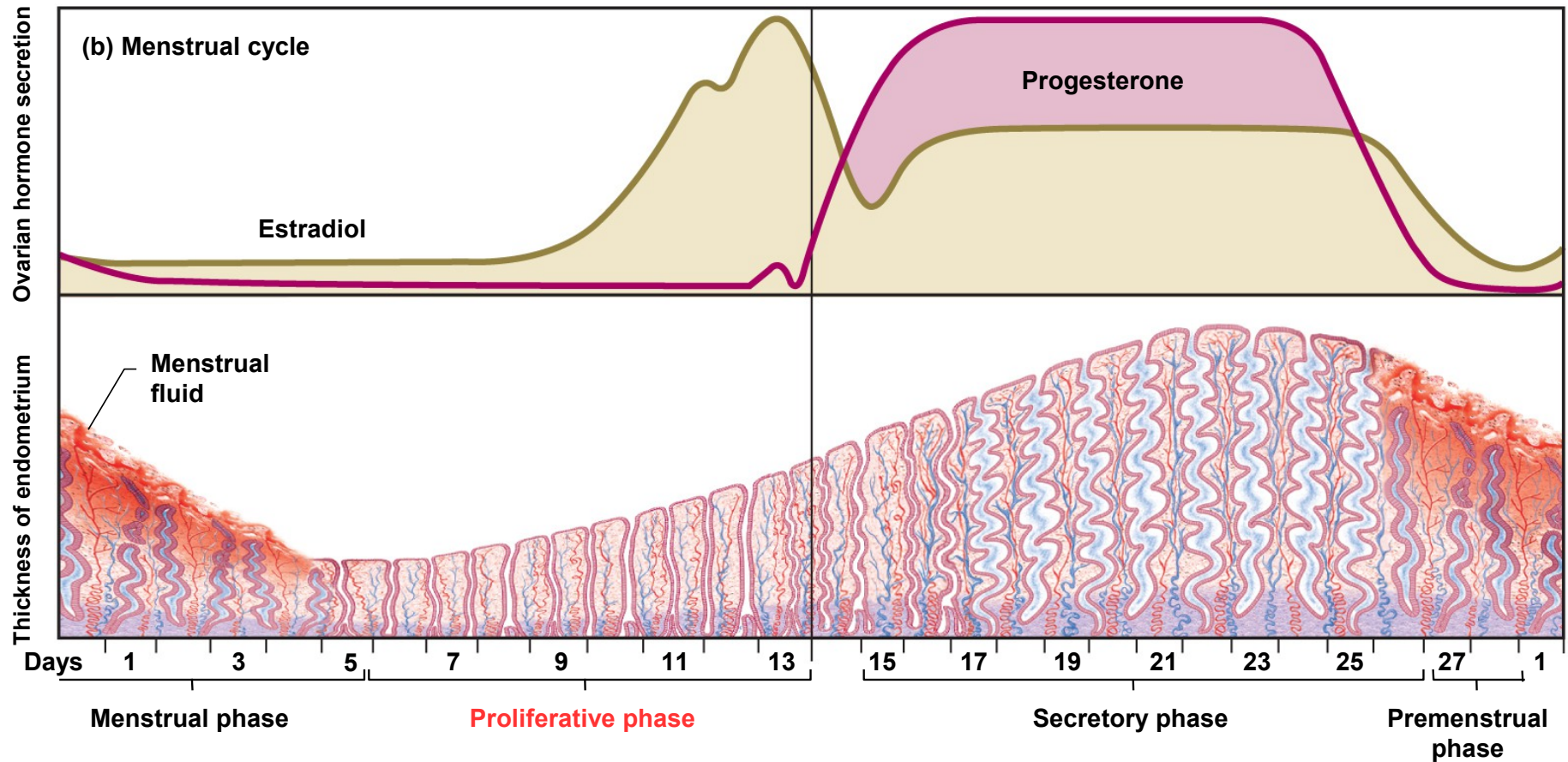


# First Phase = Menstrual Phase



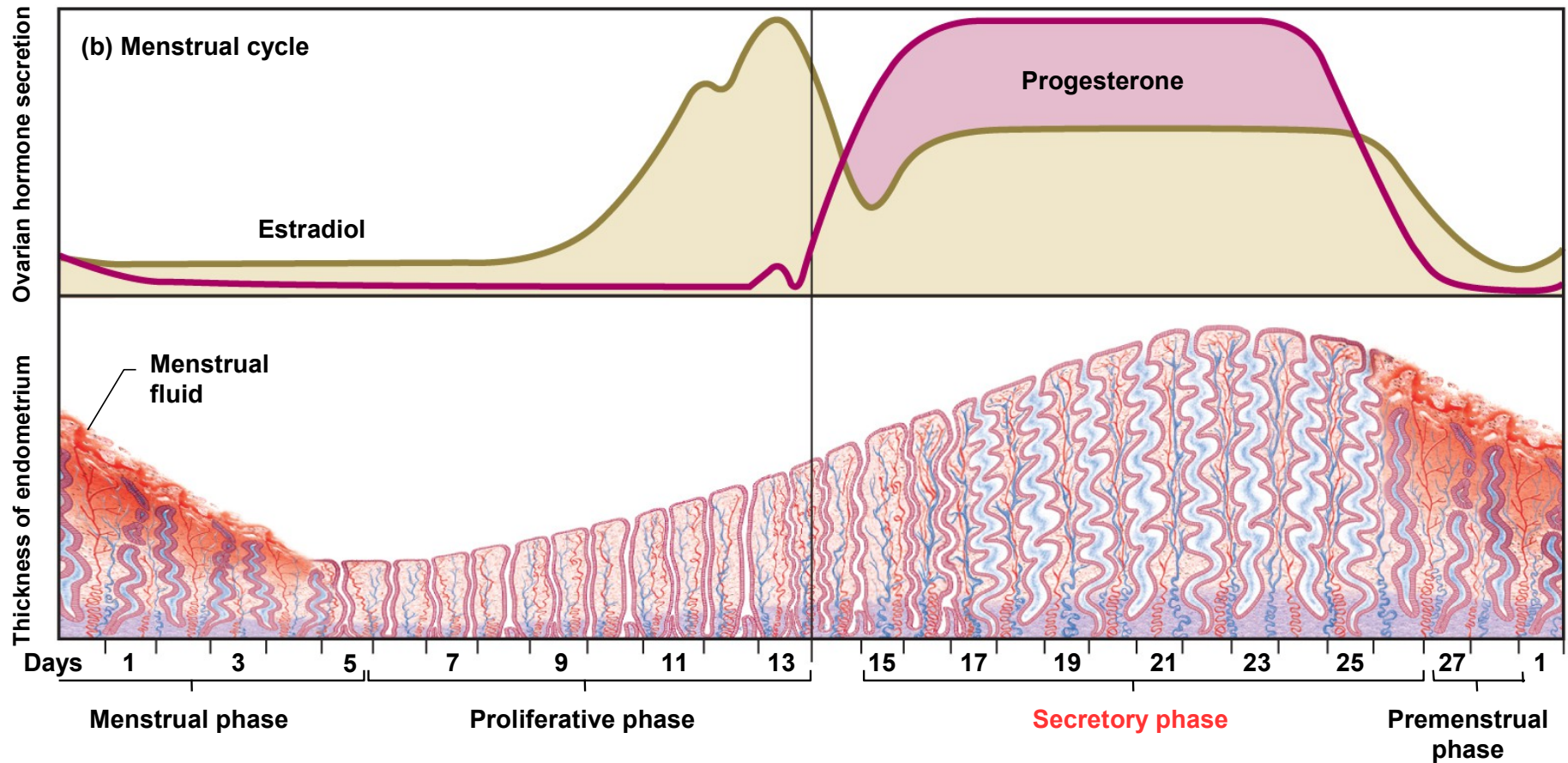
- Beginning of new cycle /// first discharge of endometrium from previous cycle

# Second Phase = Proliferative Phase



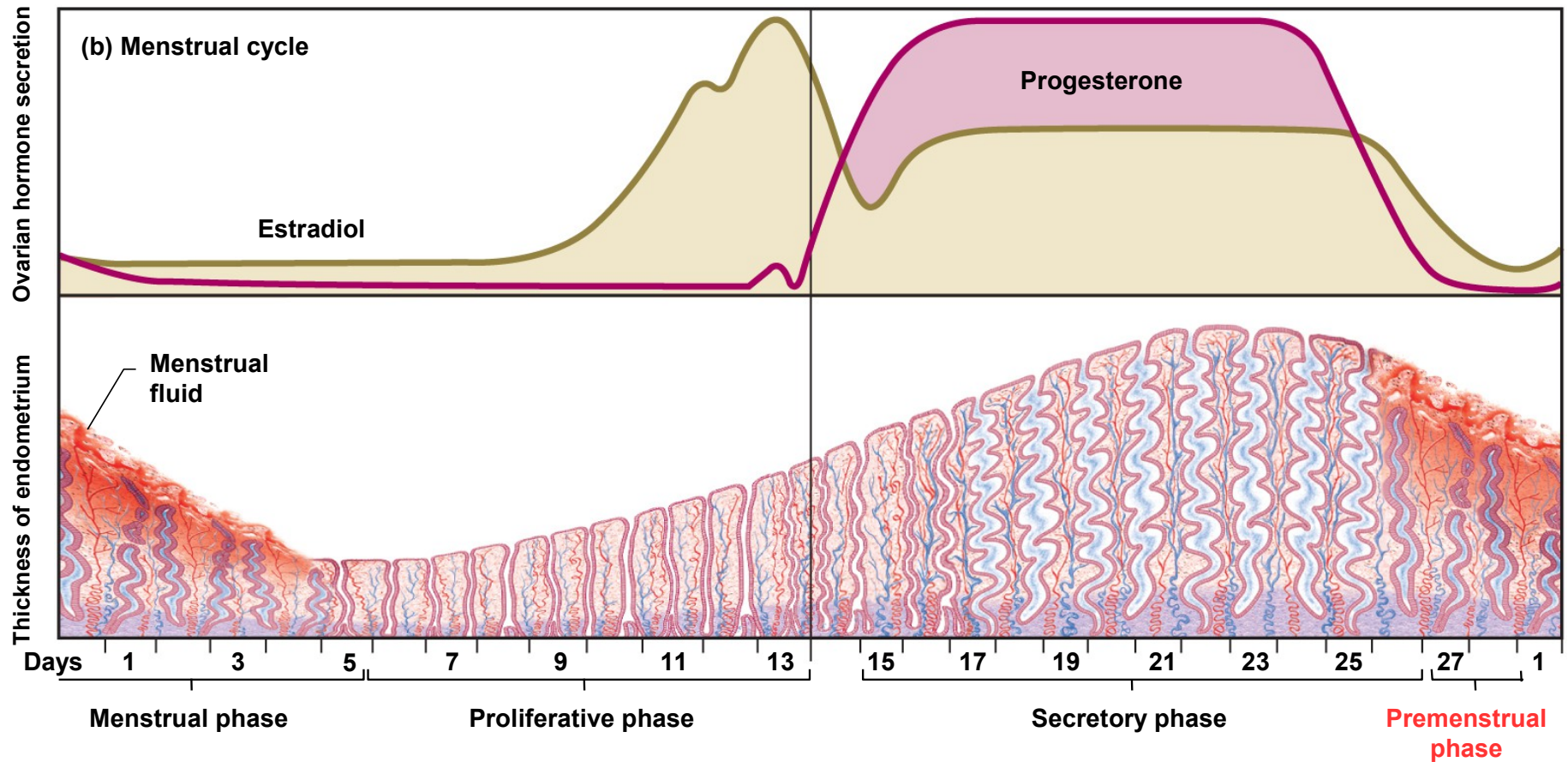
- Hyperplasia of endometrium // under control of estrogen
- Estrogen now also up-regulates endometrium with progesterone receptors

# 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

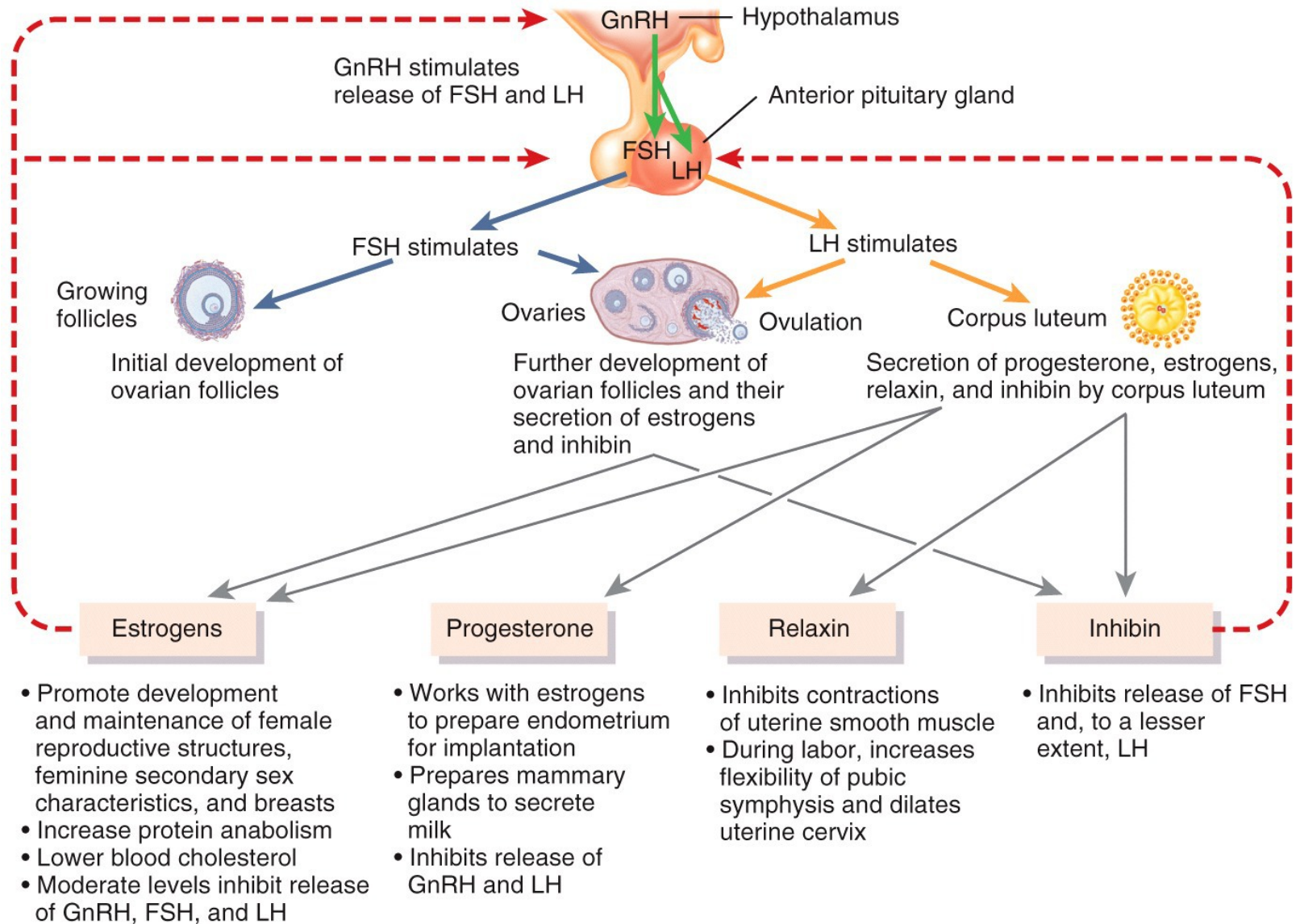
# Fourth Phase = Premenstrual Phase

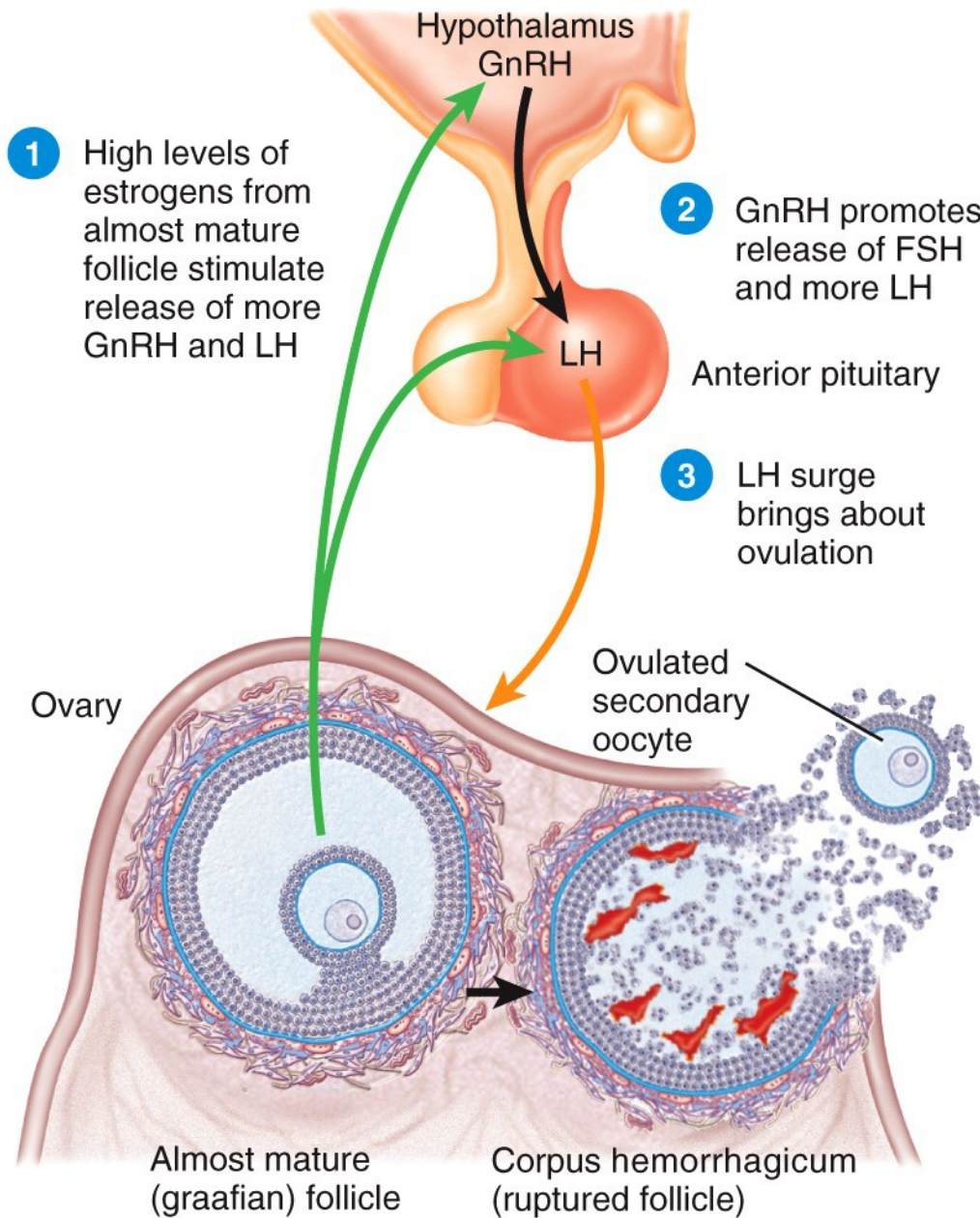


- Corpus luteum stops producing progesterone, conceptus not viable
- Spiral arteries constrict // infarction with loss of endometrium



# Ovarian Cycle

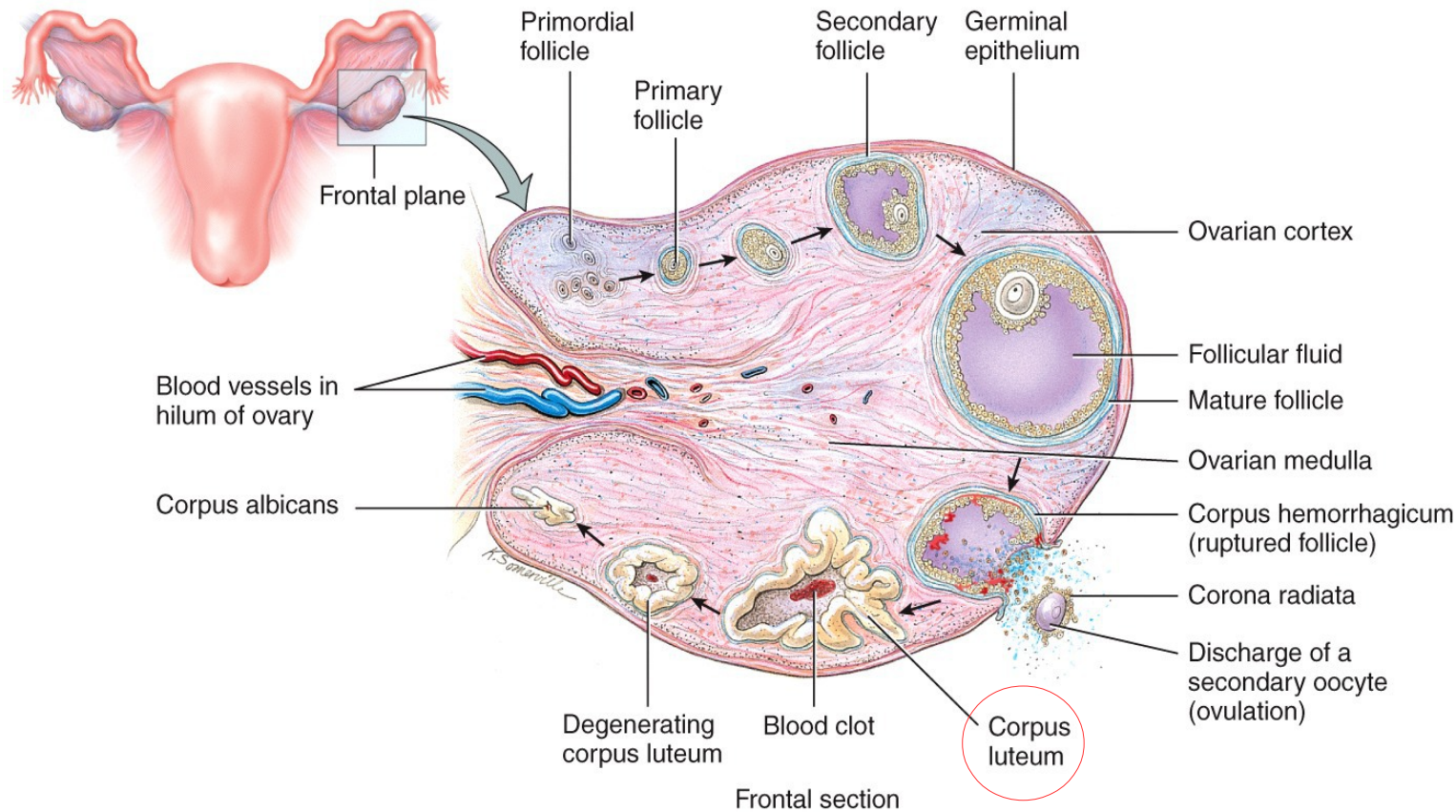




This slide explains how high levels of estrogen secreted by the almost mature follicle has positive feedback on anterior pituitary which causes the LH surge. **The LH surge stimulates ovulation!**

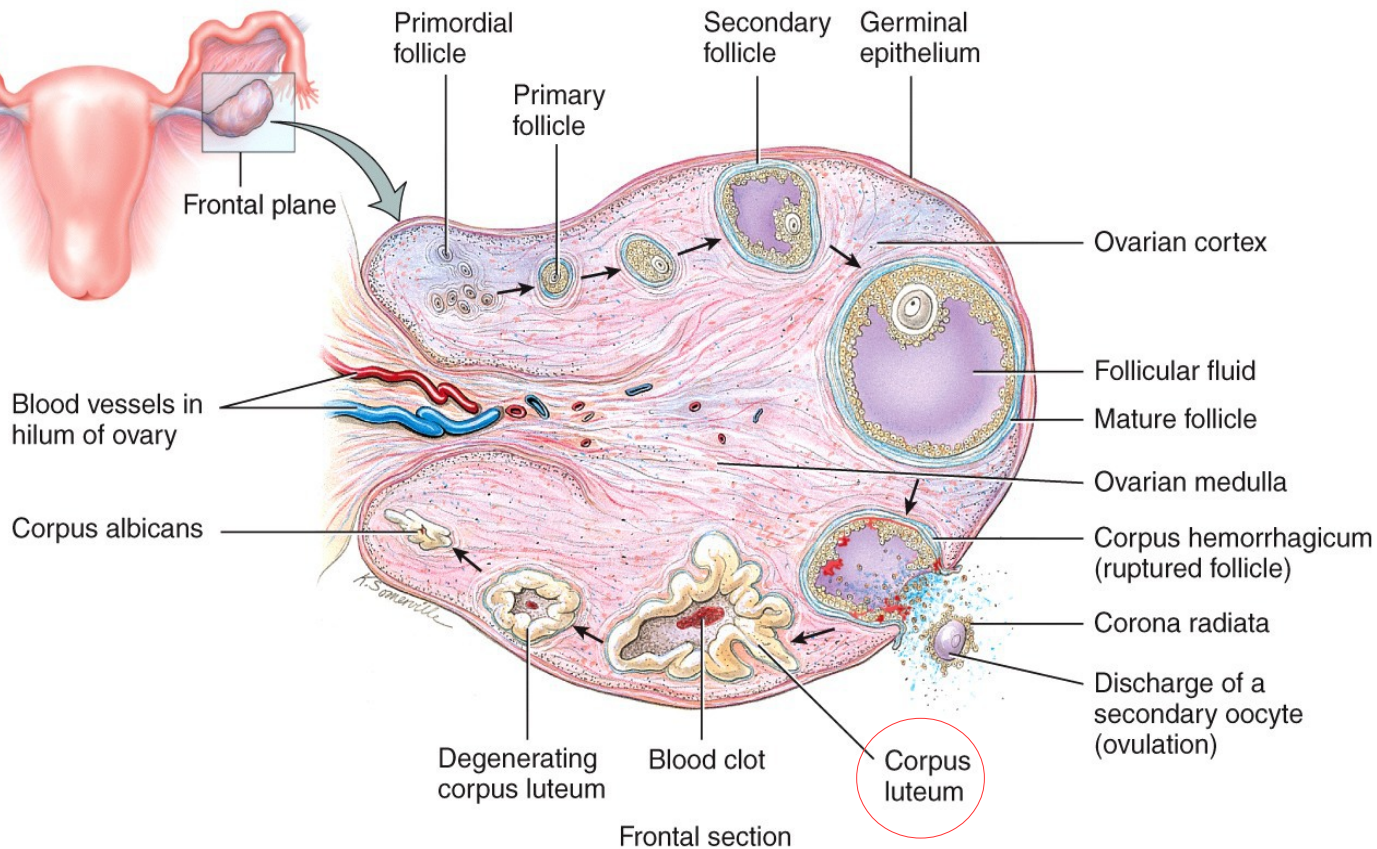
After ovulation, epithelial cells that surrounded follicle stay on surface of ovary and become the corpus luteum

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).

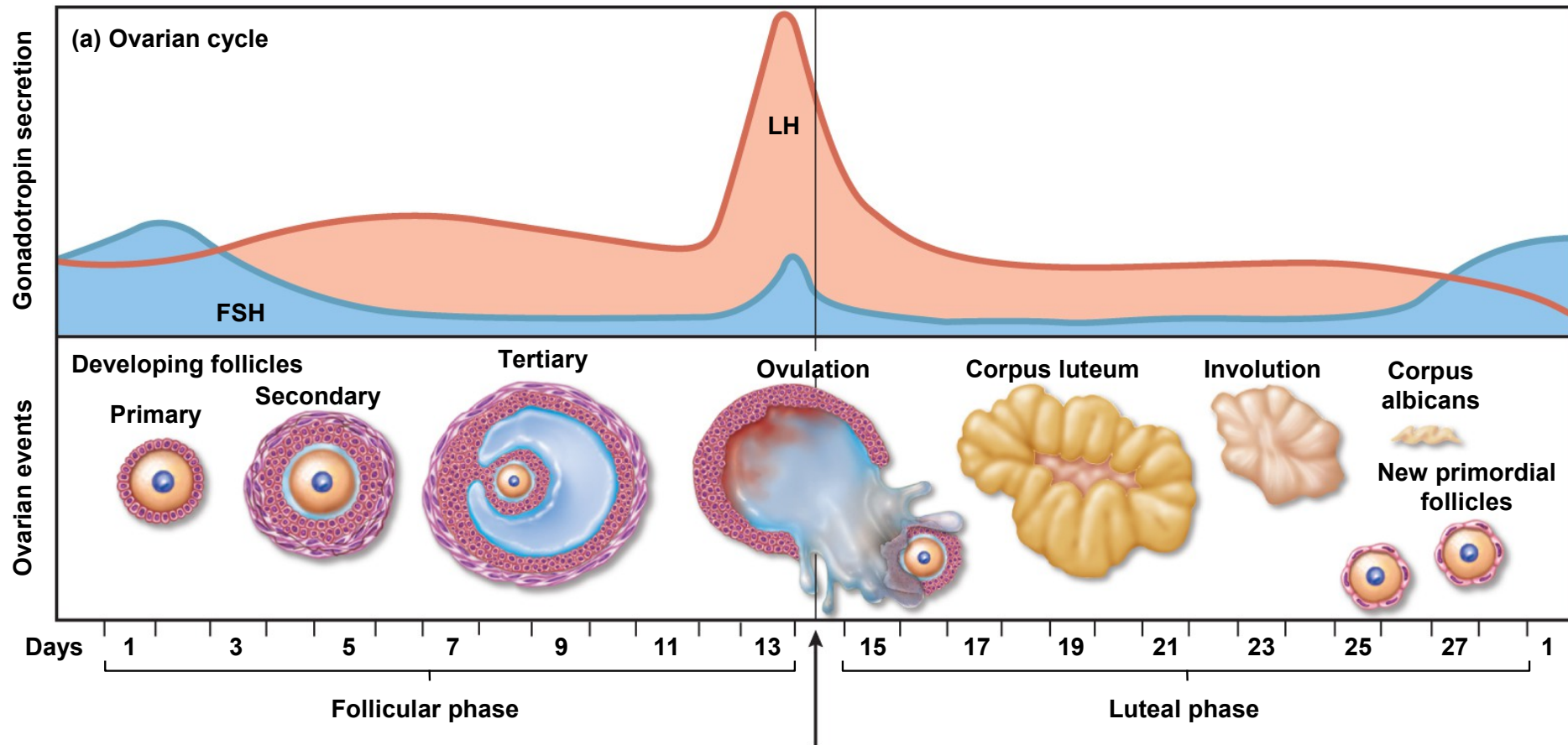
It actually takes 290 days for one of these follicles to develop into a mature oocyte.

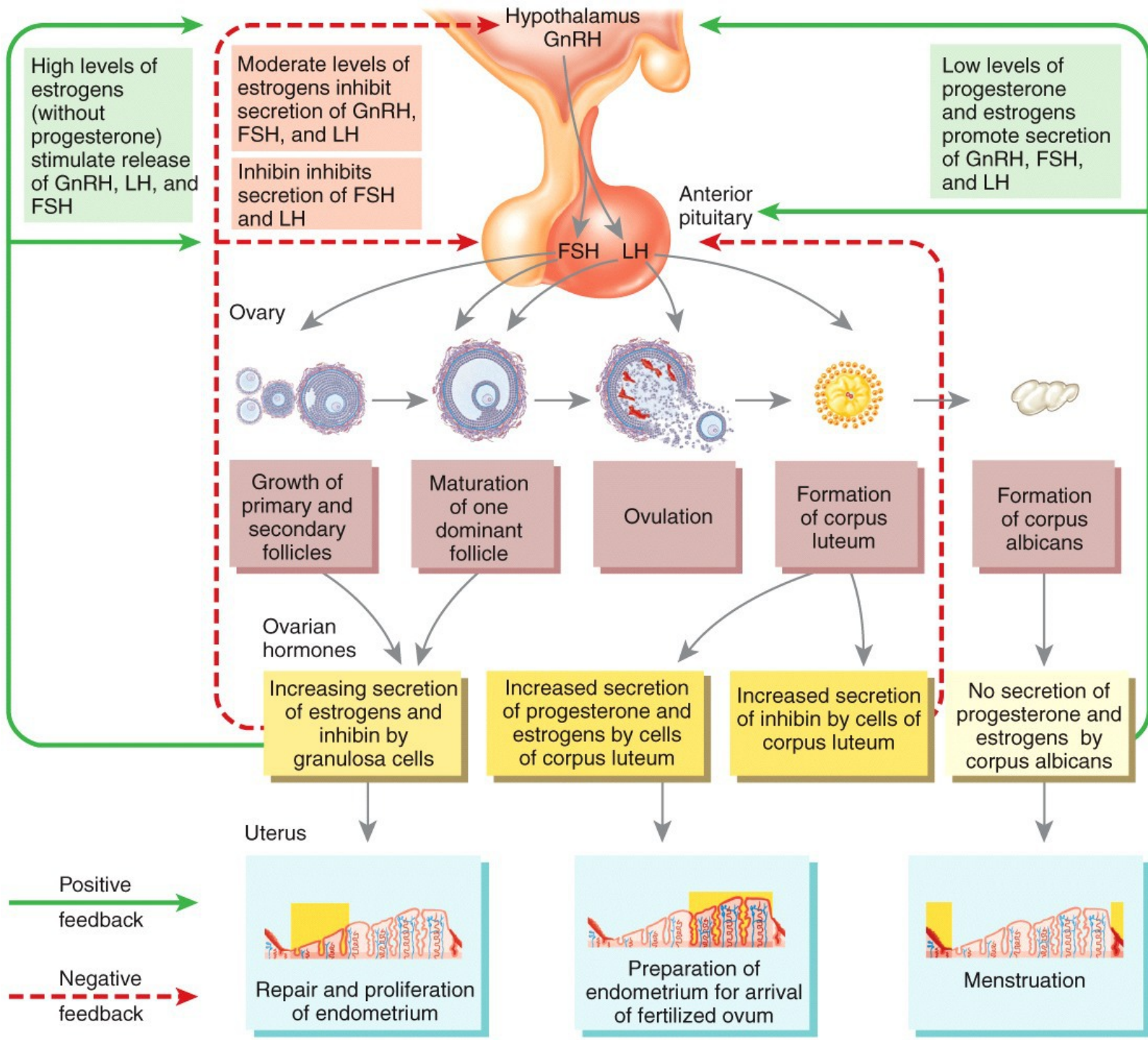
But there are always “waves” of follicles, separated by 28 days in their development /// developing at different stages within the ovary

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

# Ovarian Cycle

## Follicular & Luteal Phases







**Pituitary-Ovarian-  
Uterine Axis**

② Estradiol stimulates hypothalamus and anterior pituitary

GnRH Hypothalamus

③ Hypothalamus secretes GnRH

Anterior pituitary

LH  
FSH

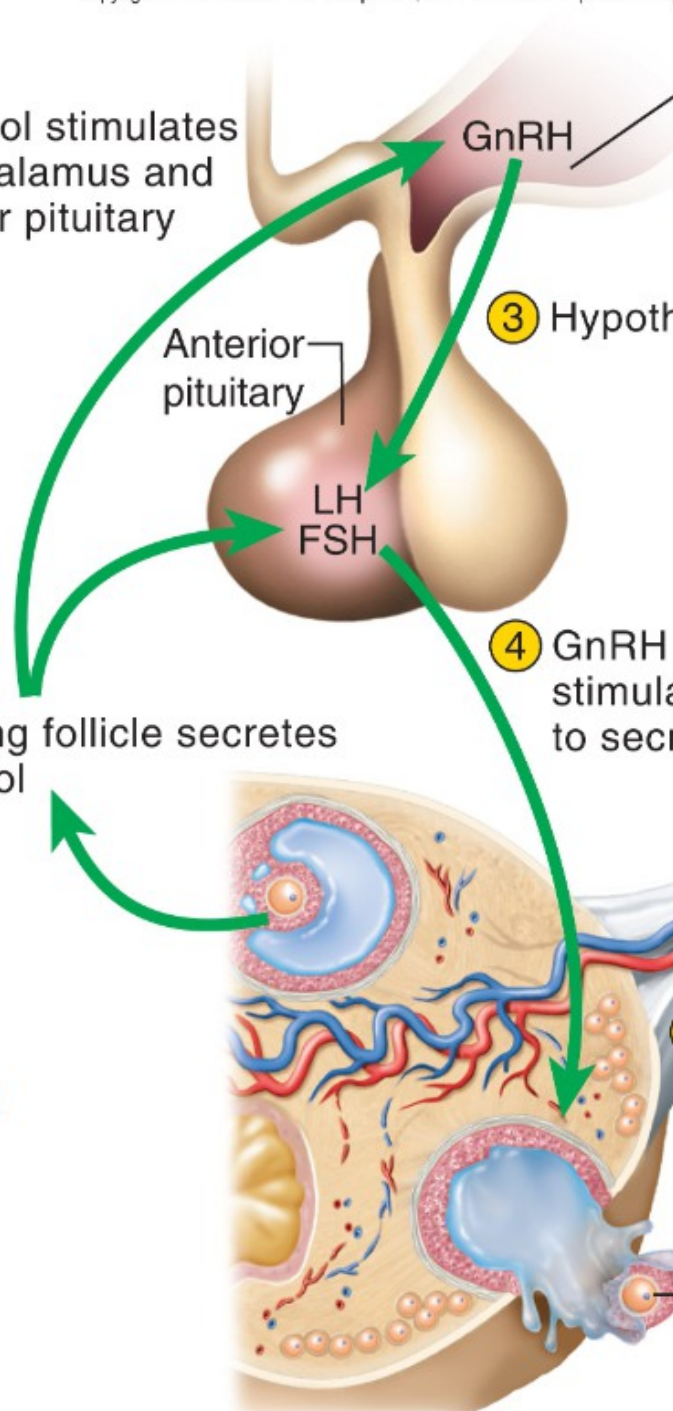
④ GnRH and estradiol stimulate pituitary to secrete LH and FSH

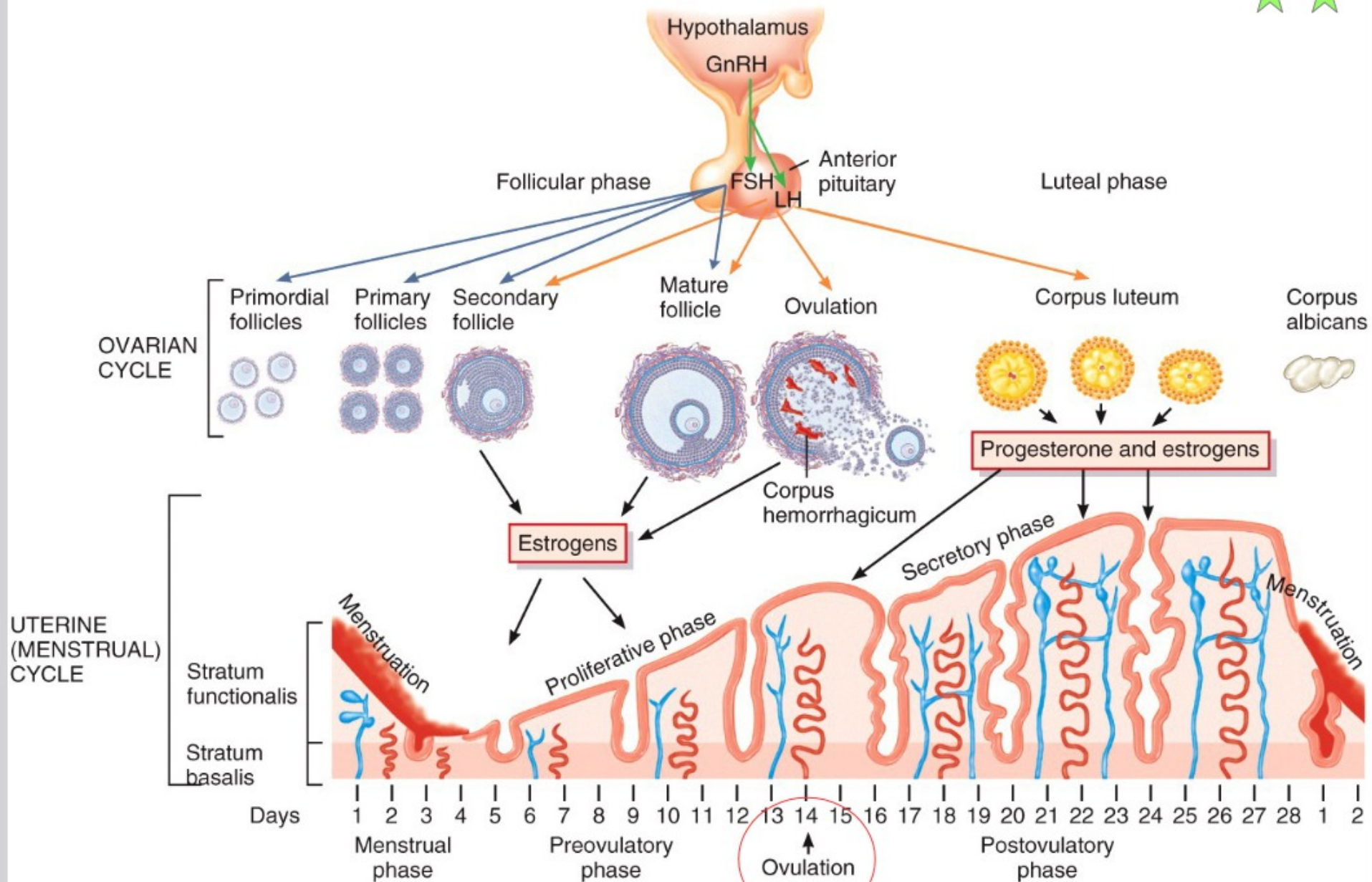
① Maturing follicle secretes estradiol

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

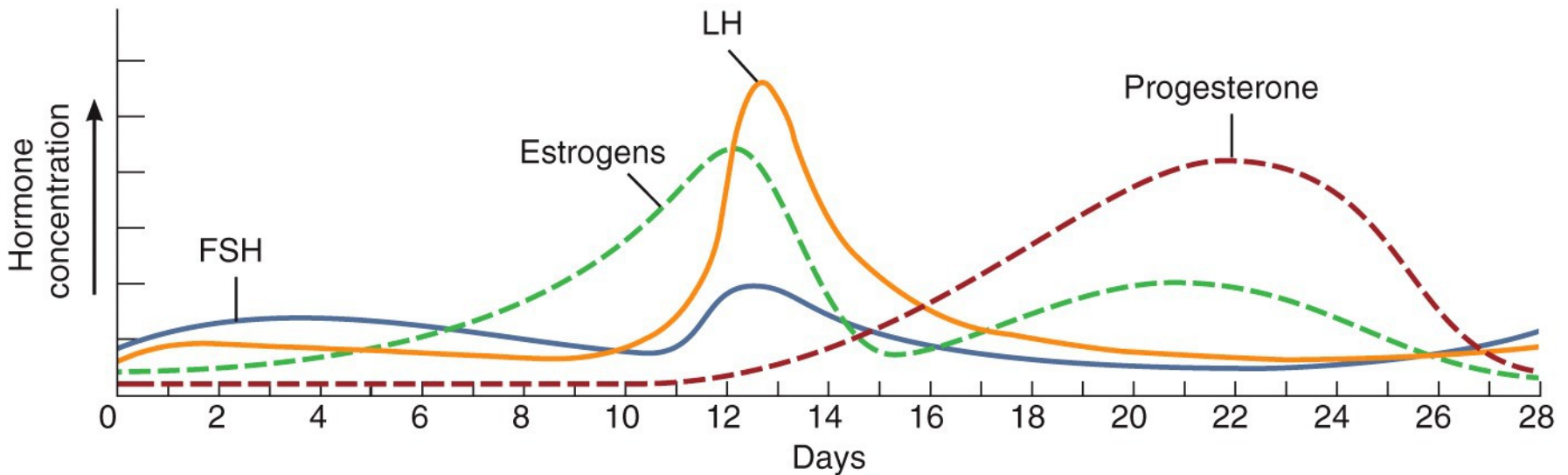
⑤ Oocyte completes meiosis I; follicle rapidly enlarges and then ovulates

Ovulated secondary oocyte





(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

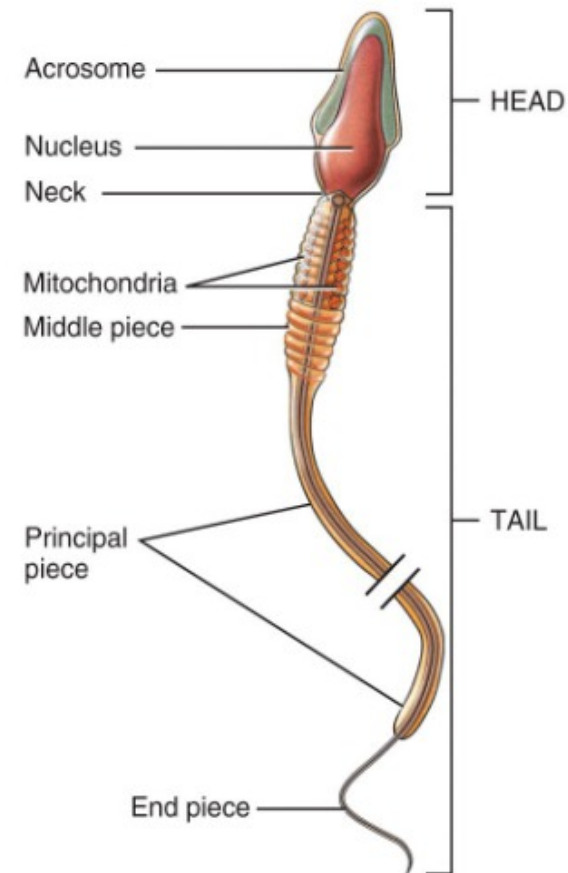
Egg is only viable for 24 hours

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.

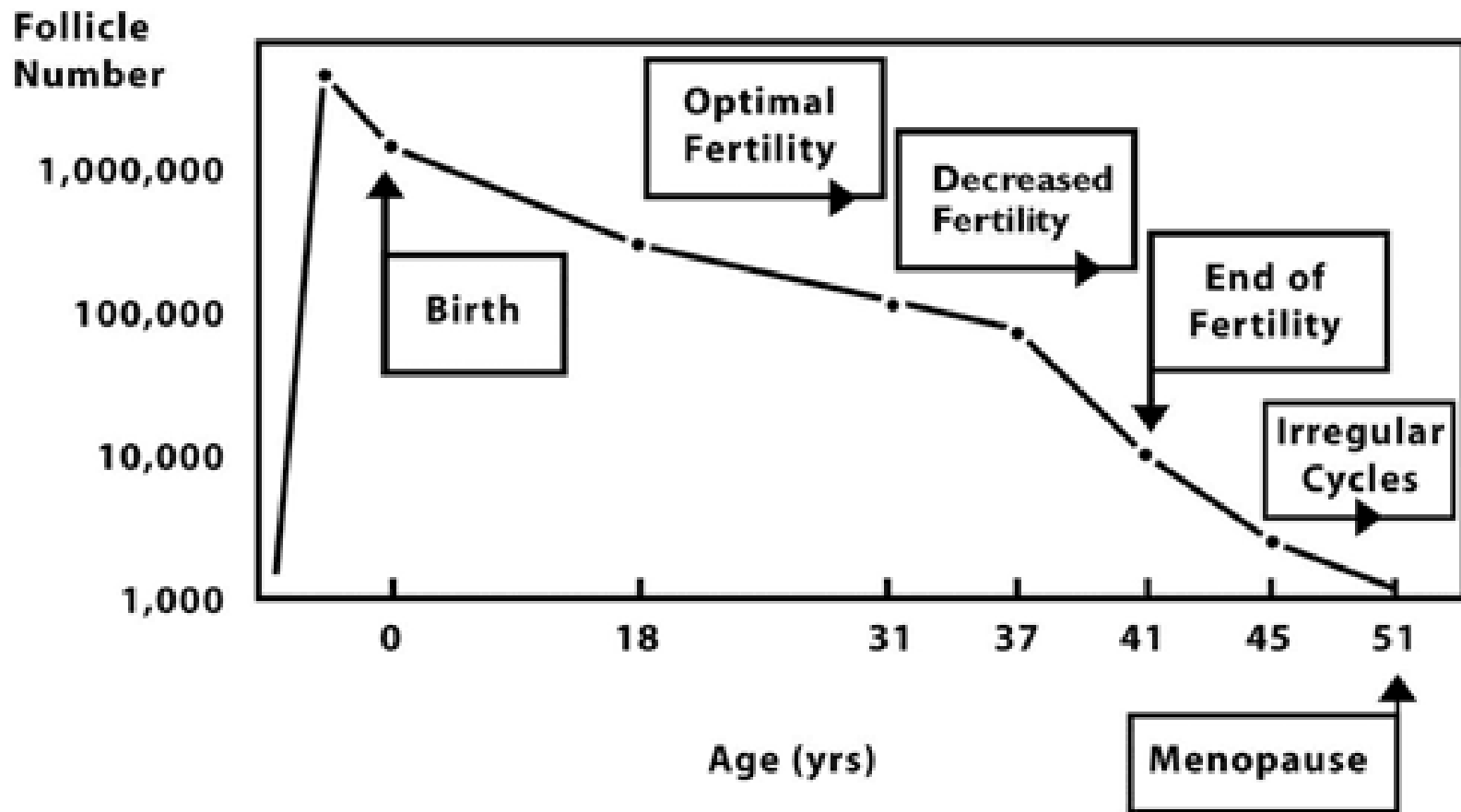
Progesterone negative feedback decreases the pulse frequency of gonadotropin-releasing hormone (GnRH) release by the hypothalamus, which decreases the secretion of follicle-stimulating hormone (FSH) and greatly decreases the secretion of luteinizing hormone (LH) by the anterior pituitary.

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.

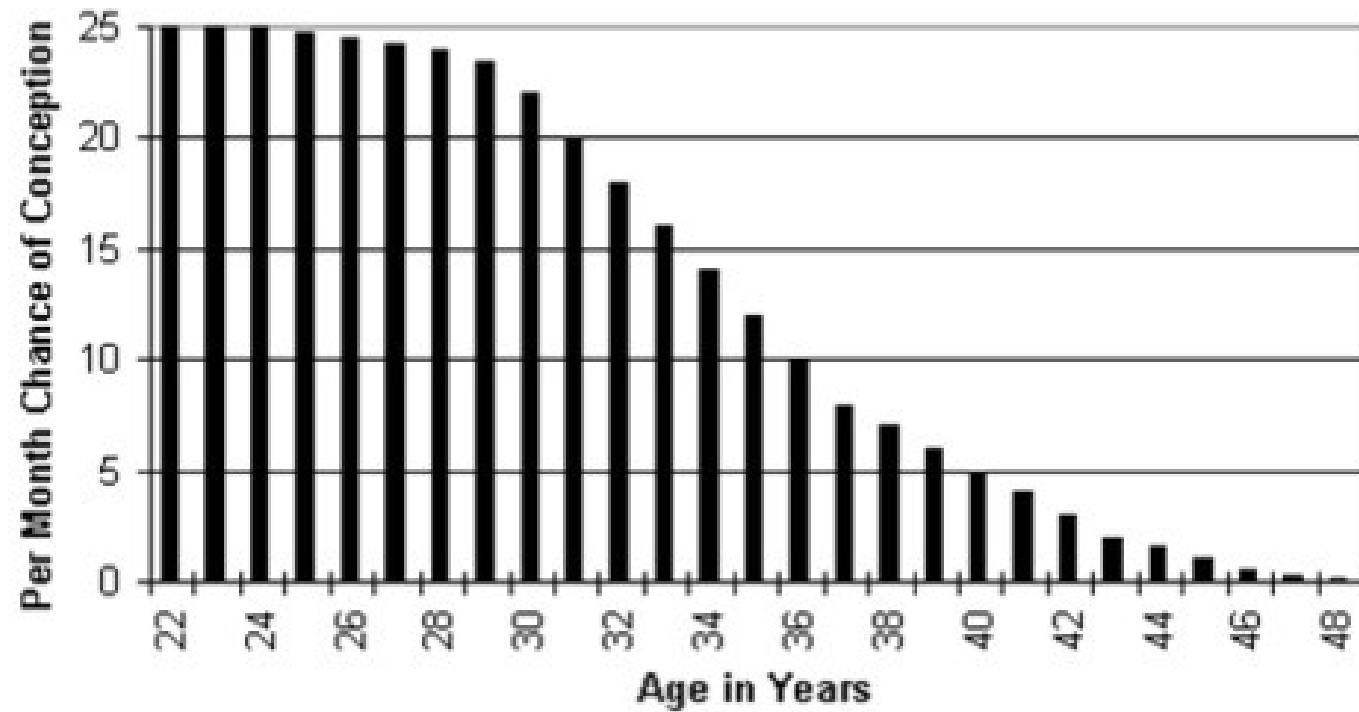
Estrogen was originally included in oral contraceptives for better cycle control (to stabilize the endometrium and thereby reduce the incidence of breakthrough bleeding), but was **also found to inhibit follicular development and help prevent ovulation**. Estrogen negative feedback on the anterior pituitary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

# Female Fertility

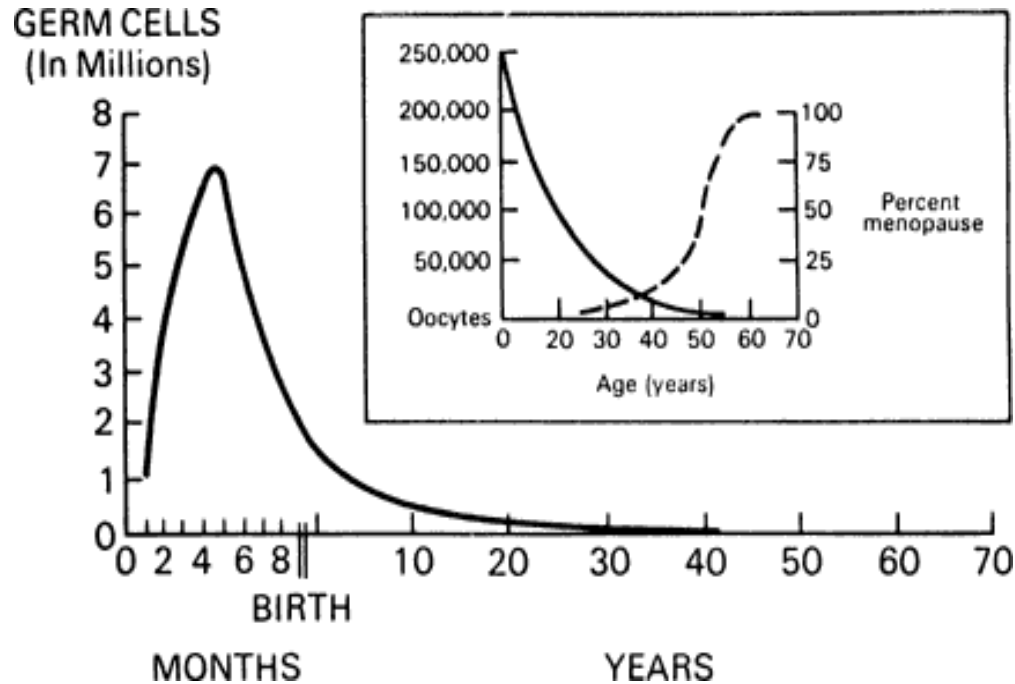


E.R. TE VELDE ET AL., 1998

## AGE AND FEMALE FERTILITY



# Female Oogenesis



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

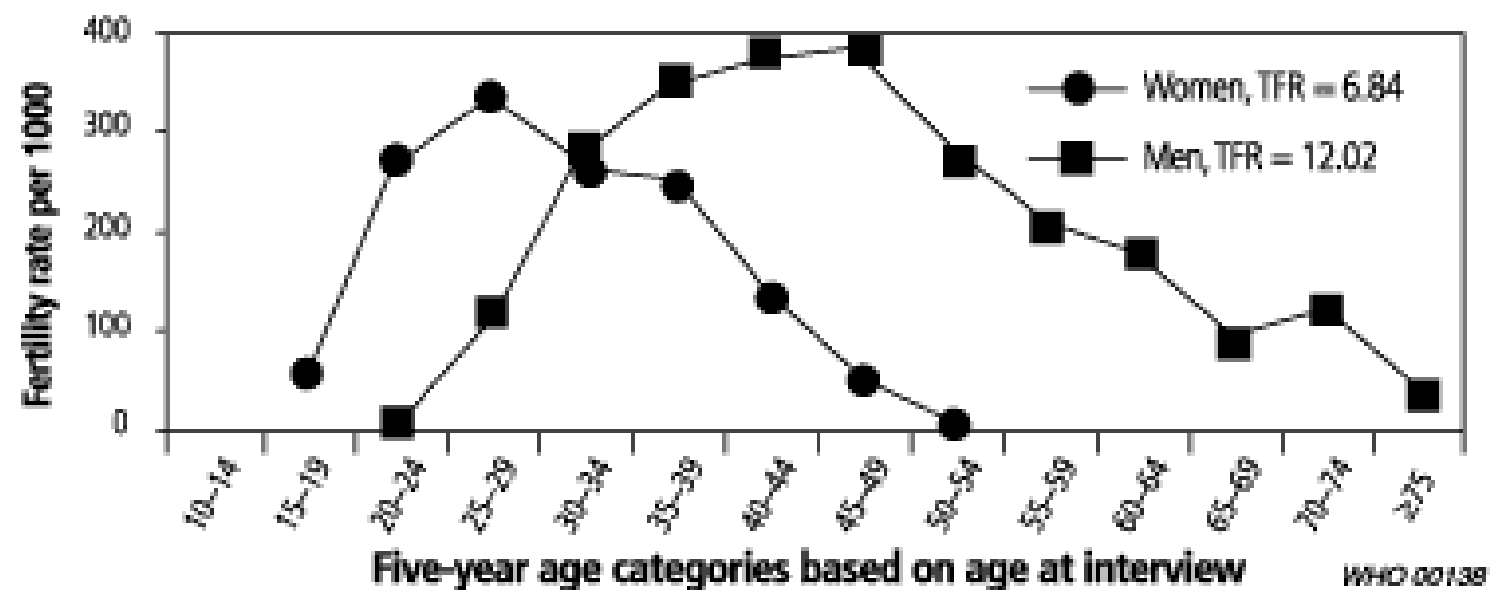
Called oogonia and continue to develop until fifth month.

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

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Reproductive system consists of primary and secondary sex organs

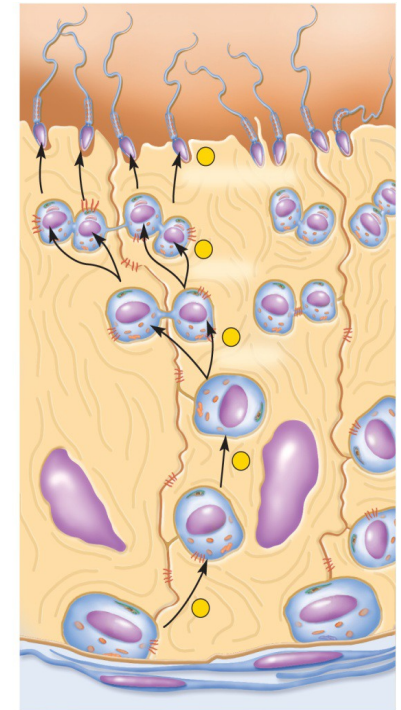
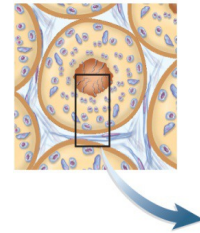
primary sex organs (the gonads) //  
produce gametes (testes)

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



## **Luteinizing hormone (LH)** **(also called interstitial cell stimulating hormone (ICSH))**

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



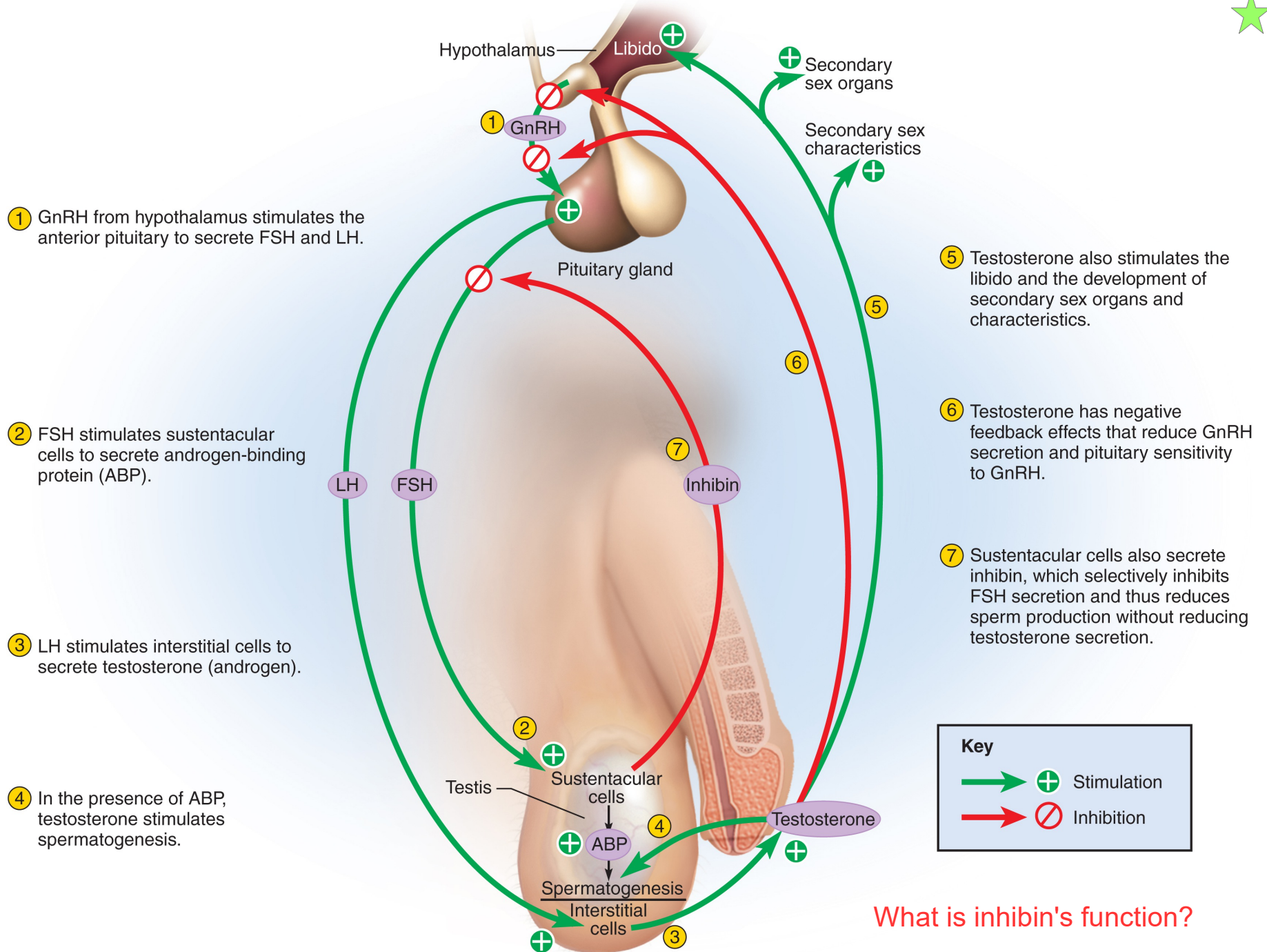
# Testosterone

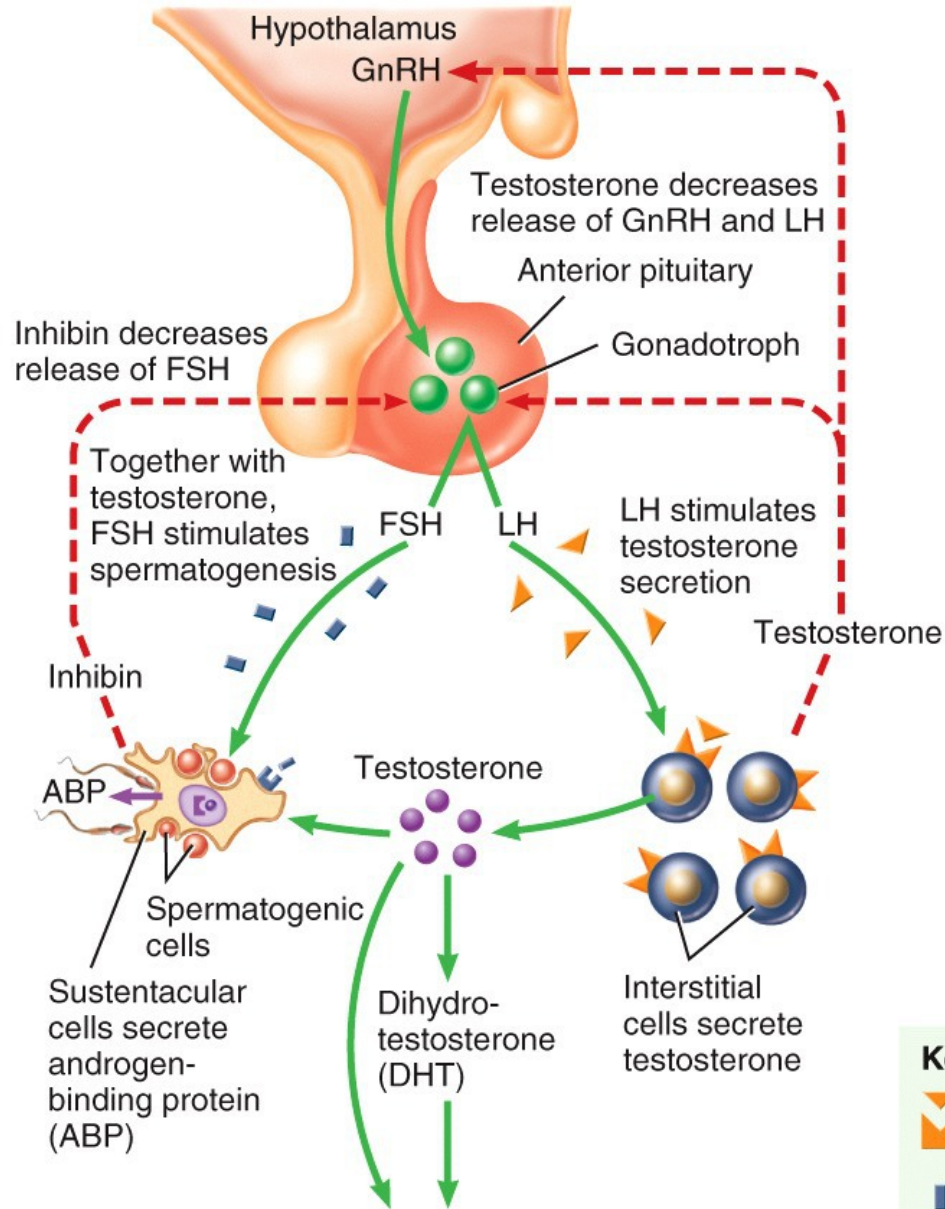
- Produced by interstitial cells of the testes
  - LH receptors on interstitial cells
  - Interstitial cells produce testosterone
  - Testosterone responsible for secondary sexual characteristics
  - Testosterone also required for spermatogenesis
  - Testosterone must be concentrated by ABP within seminiferous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



# Inhibin

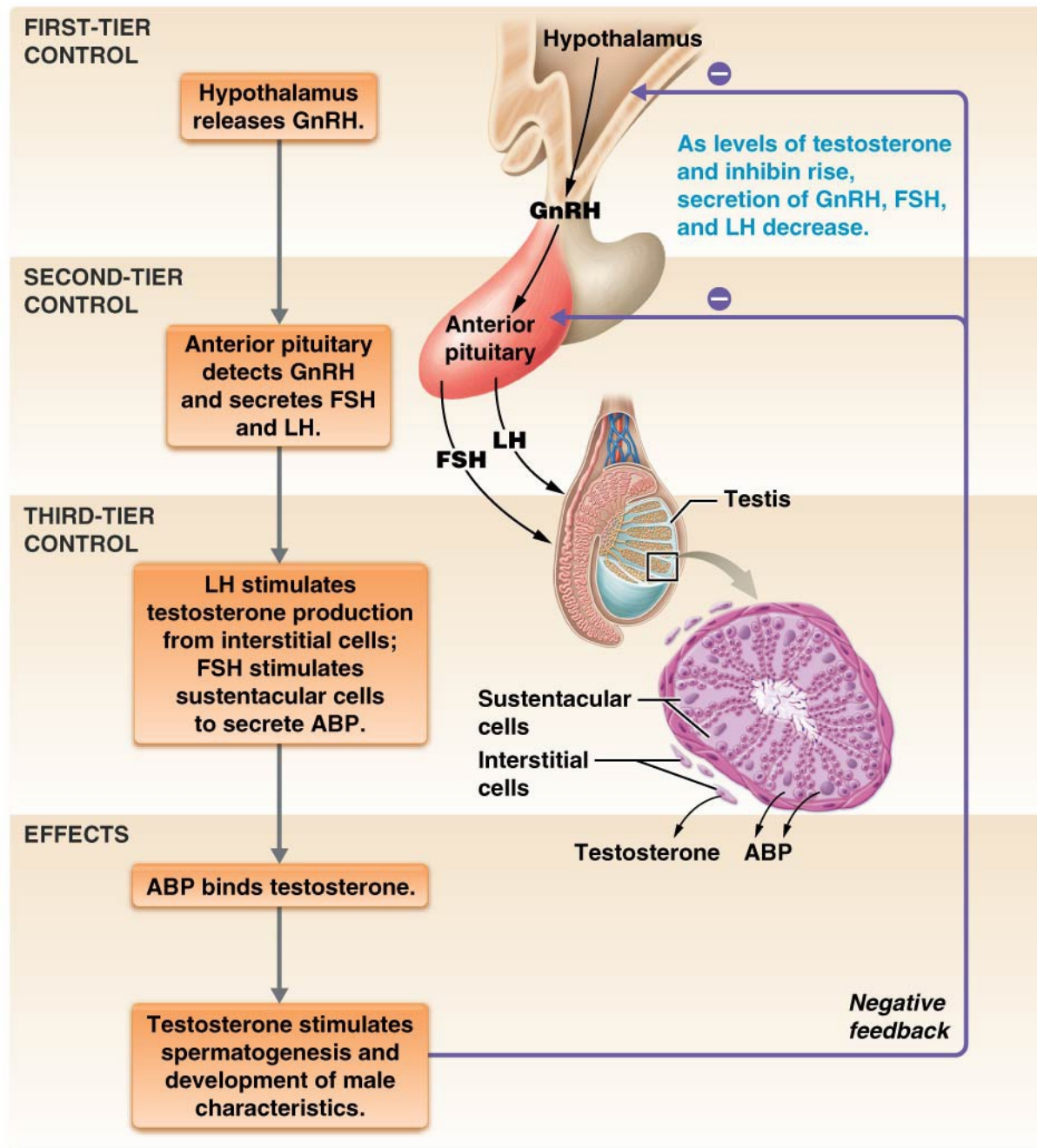
- Released by sustentacular cells of testes
  - Inhibits FSH release
  - By stopping FSH - prevents SC from producing ABP // this results in testosterone not being concentrated in testes which stops spermatogenesis
  - LH secretions continues to stimulate interstitial cells /// production of testosterone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



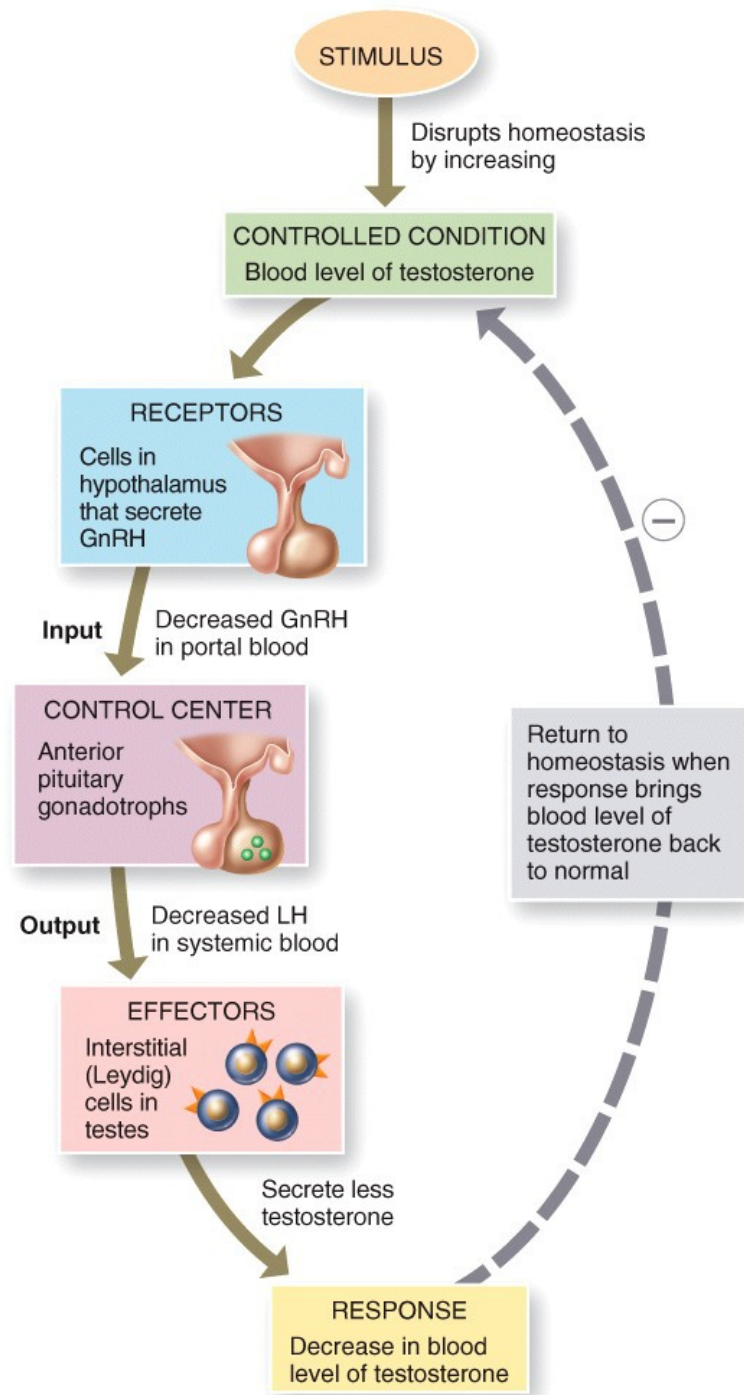


- Male pattern of development (before birth)
- Enlargement of male sex organs and expression of male secondary sex characteristics (starting at puberty)
- Anabolism (protein synthesis)

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



# Response to Excess Testosterone



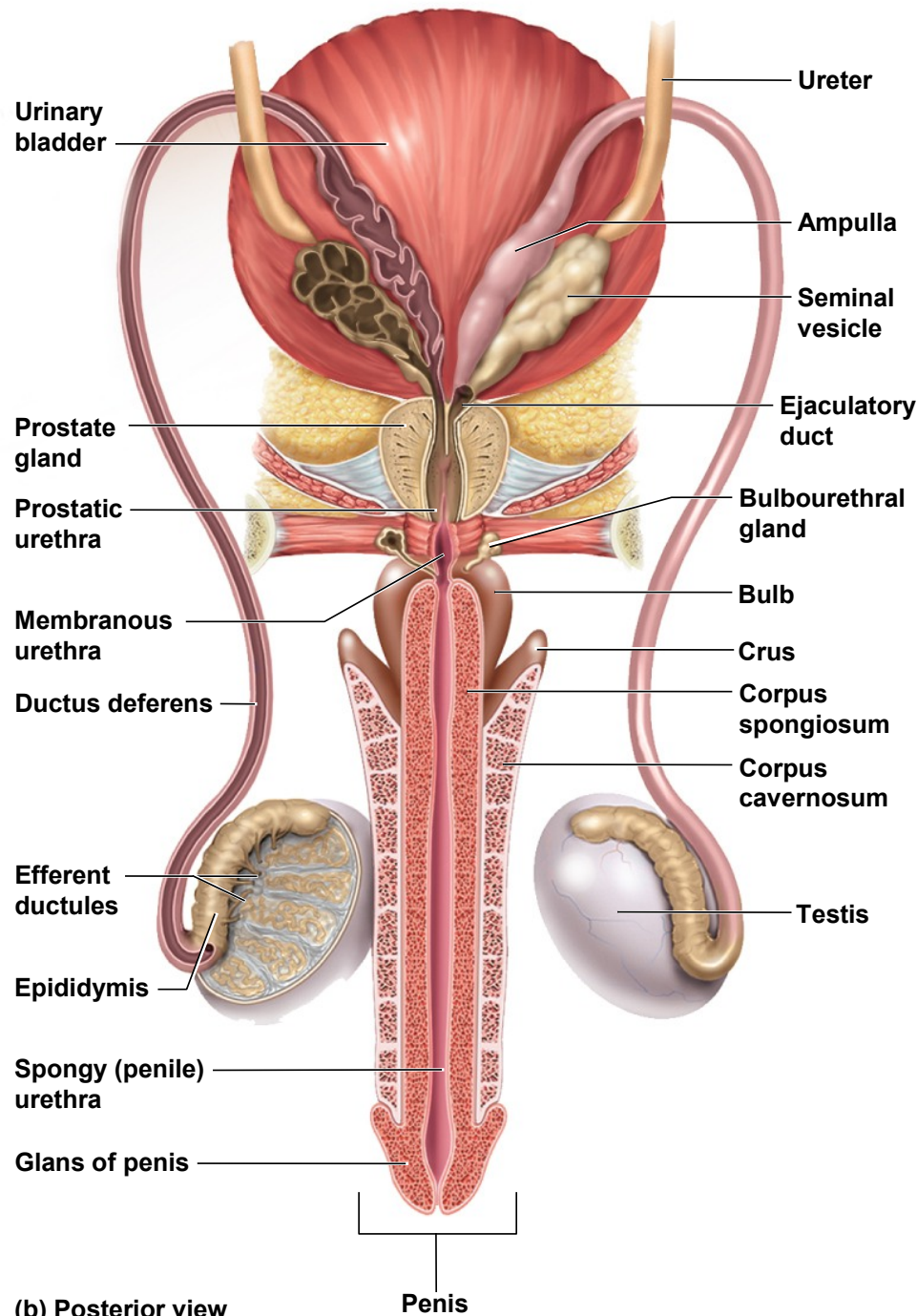


## Why is male testes outside the abdominal cavity?

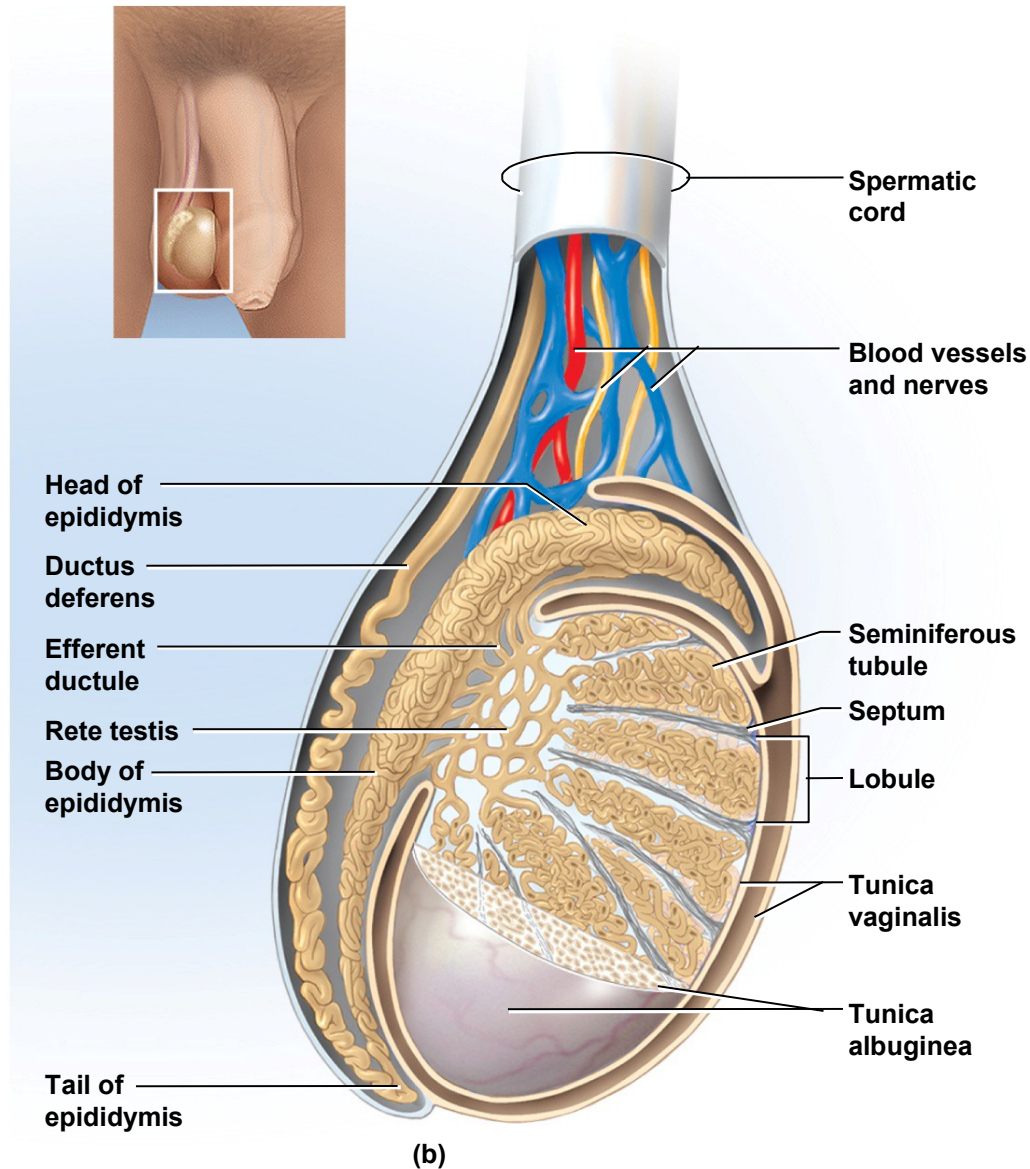
Testis must be outside abdominal cavity for spermatogenesis

Elevated temperature within the abdominal cavity will inhibit spermatogenesis.

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

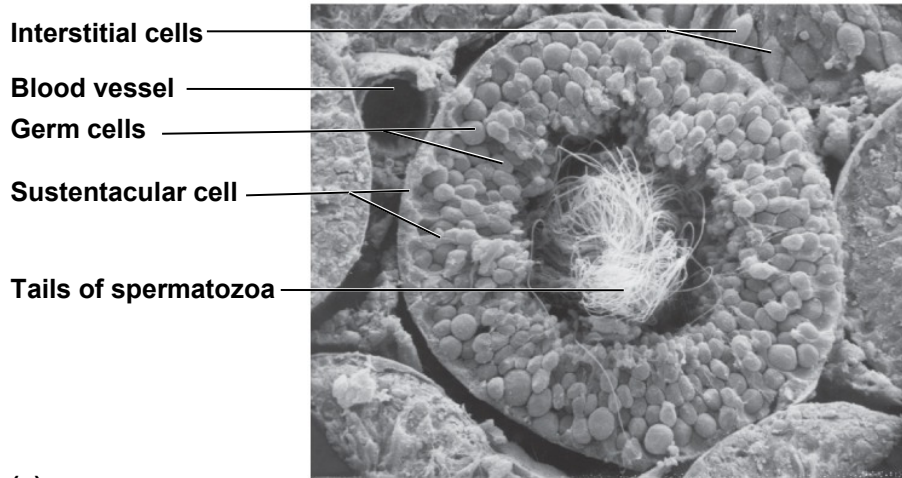


# Testis and Associated Structures

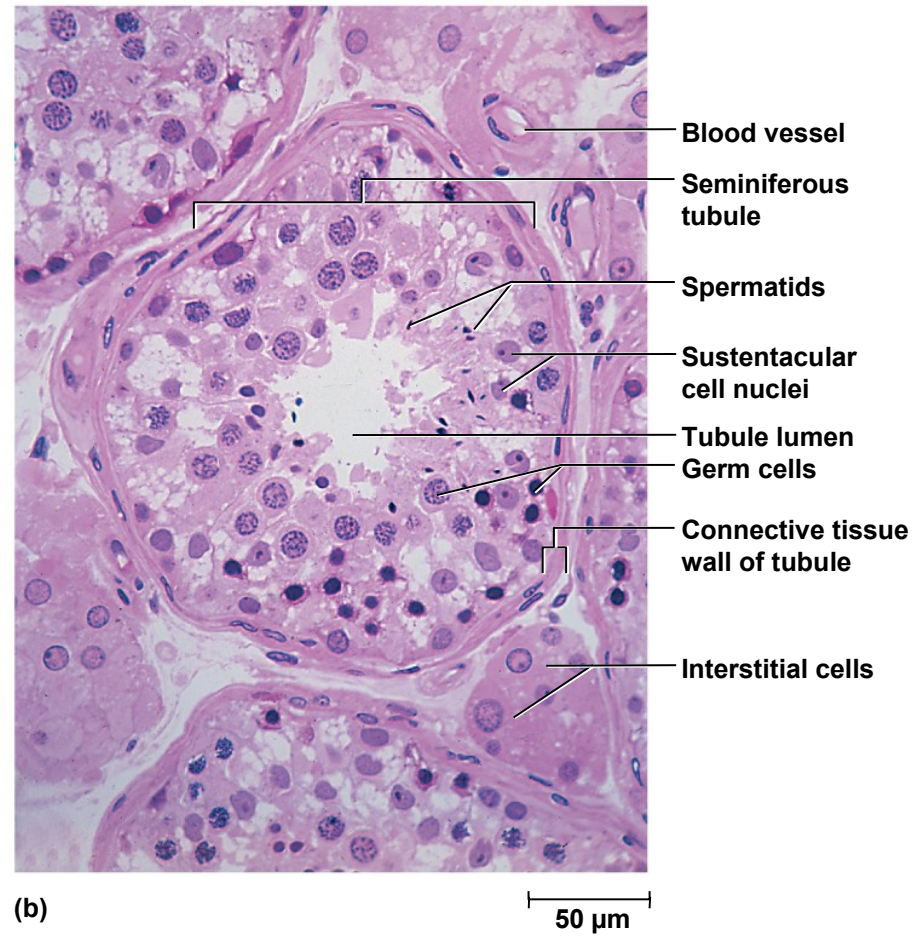


# Cross Section of the Seminiferous Tubule

## 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 sustentacular 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

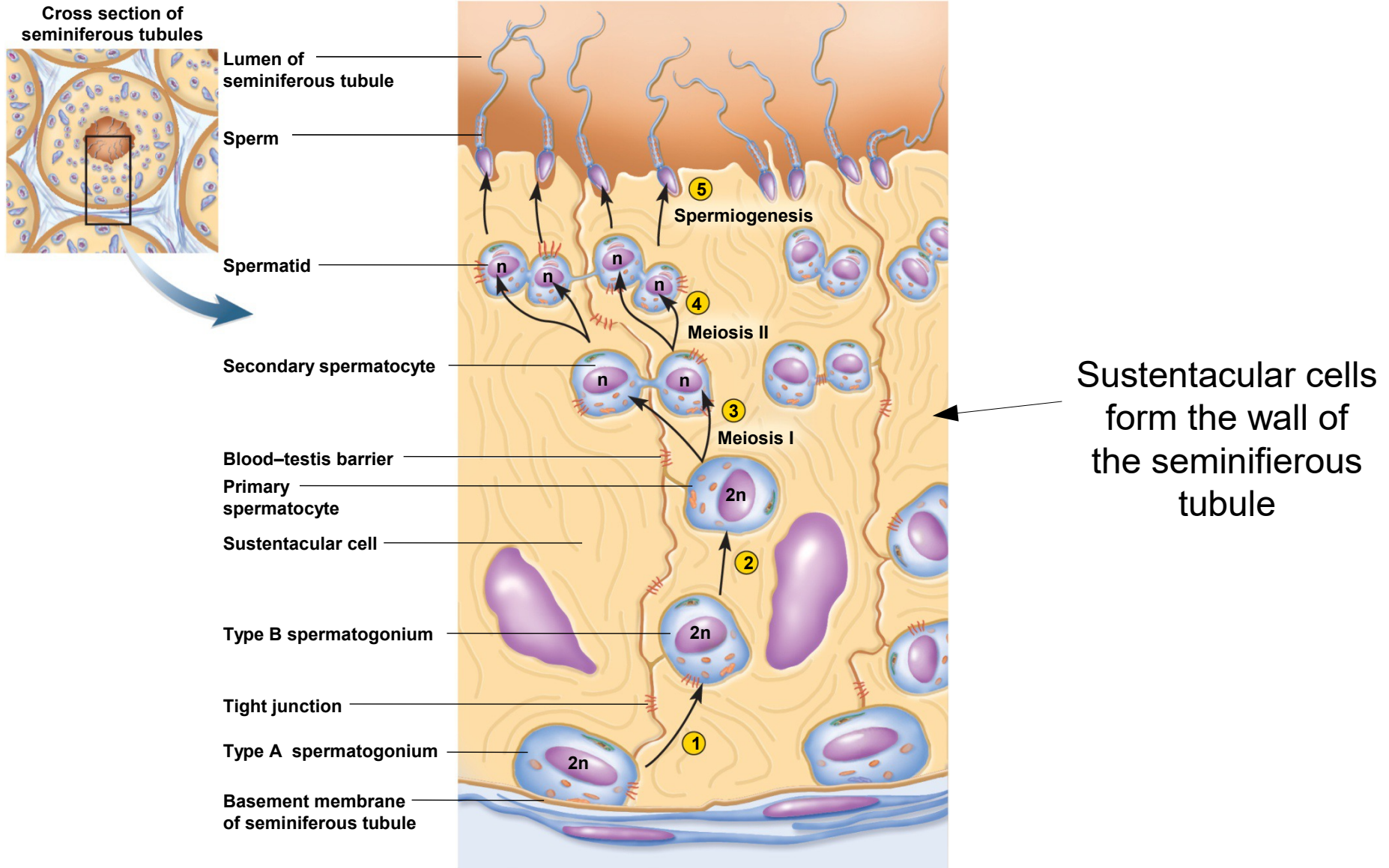
# Spermatogenesis

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- 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





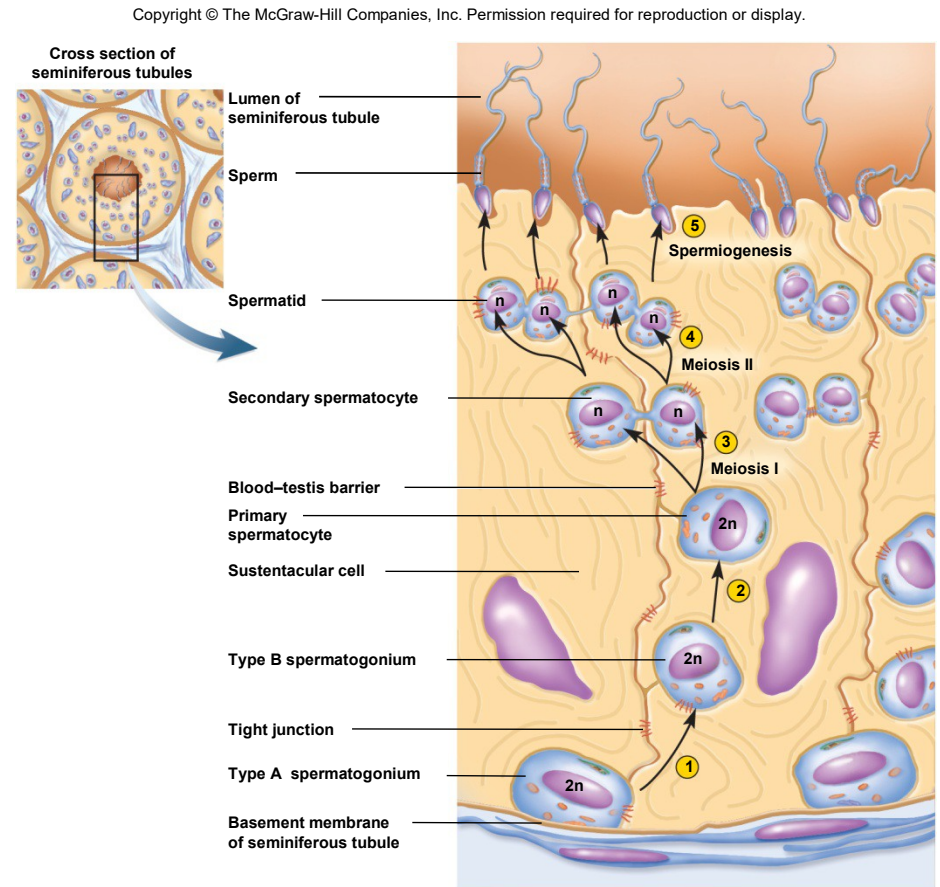
# Spermatogenesis and the Blood-Testis Barrier (BTB)

---

- 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





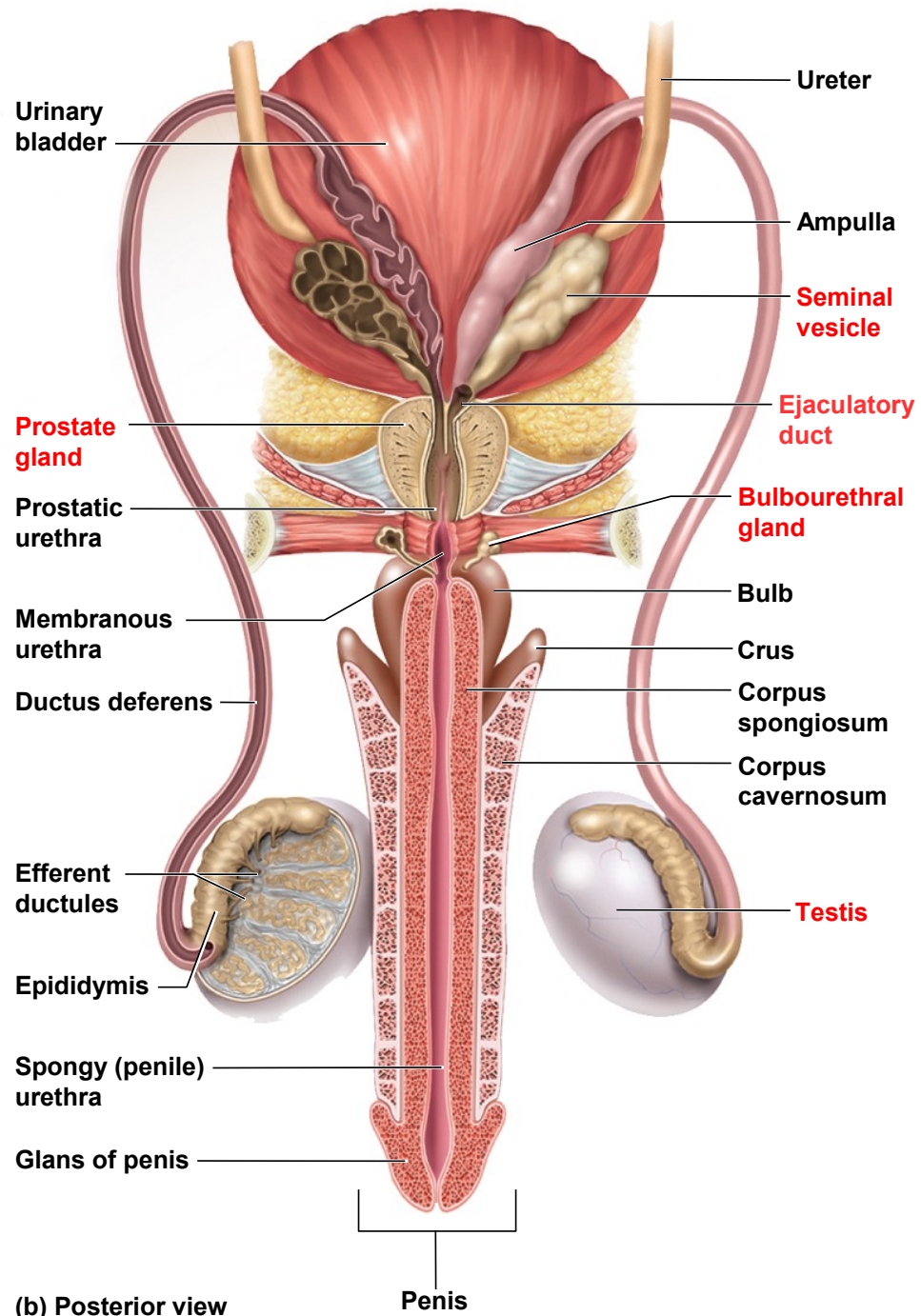
# Contributors to Semen's Volume

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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%
- bulbourethral gland (also called Cowper's gland) // < 0.1

# Male Duct System & Accessory Glands



# Seminal Vesicles

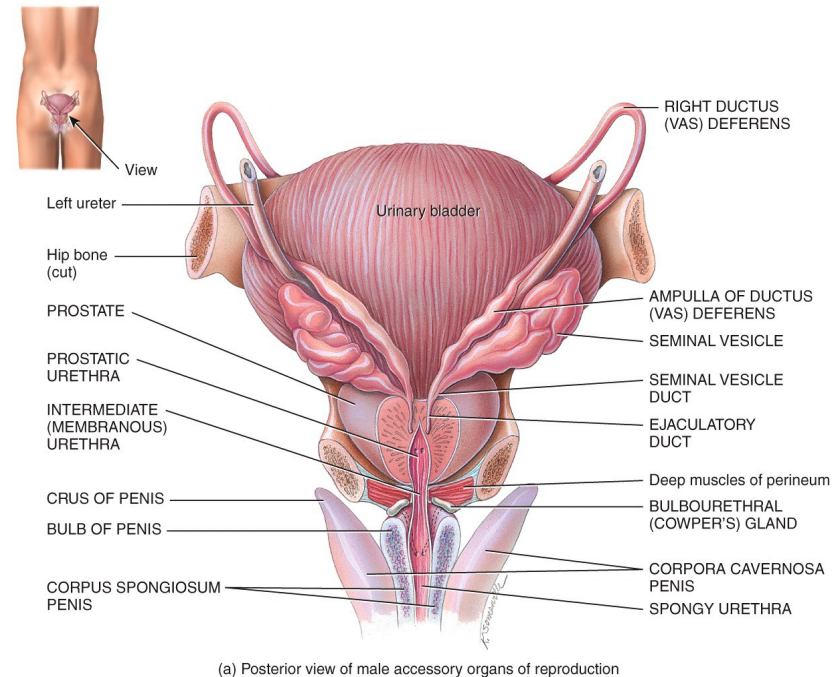
Pair of glands posterior to bladder

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





# Seminal Vesicles

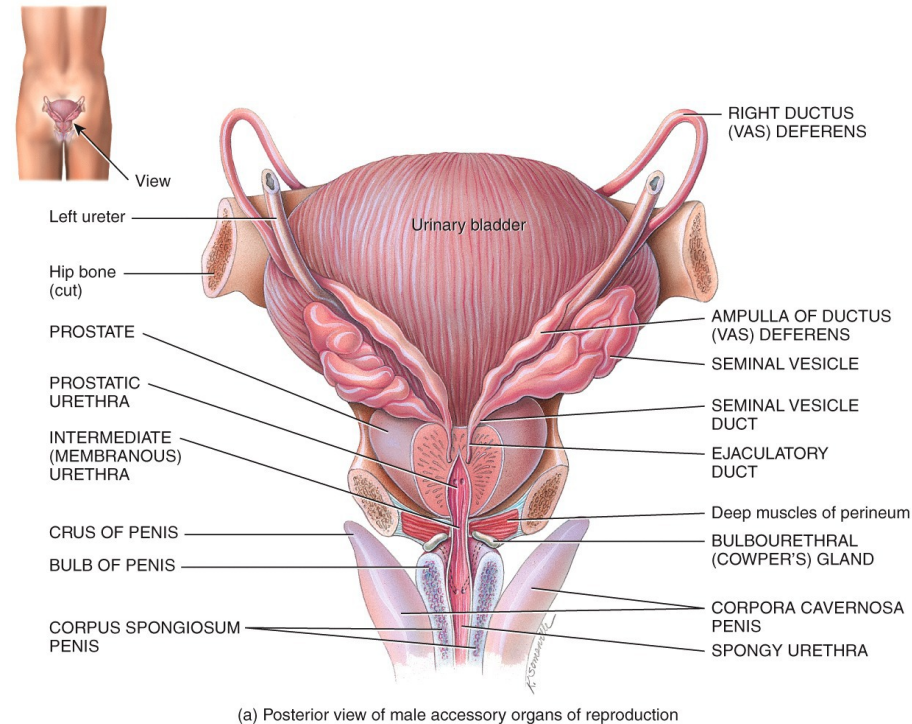
Seminal vesicles contribute viscous yellowish fluid

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

**Pro-seminogelin** is a protein

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

**Seminogelin** is a viscous, sticky molecule // its function is to “stick” sperm near entrance of cervix



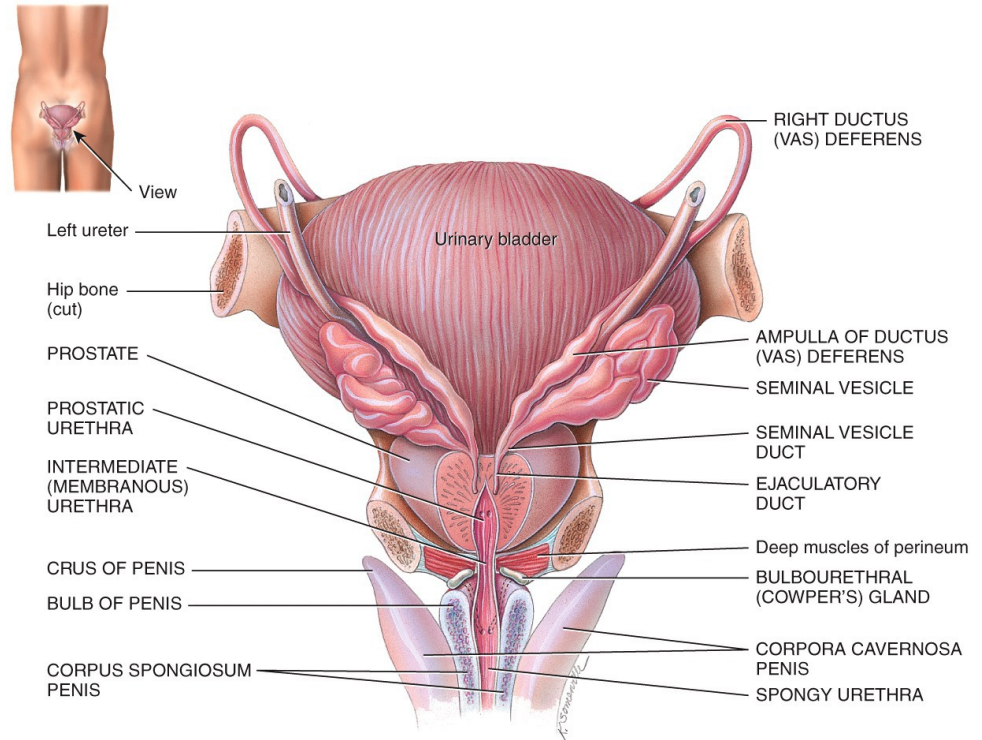
# Prostate Gland



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

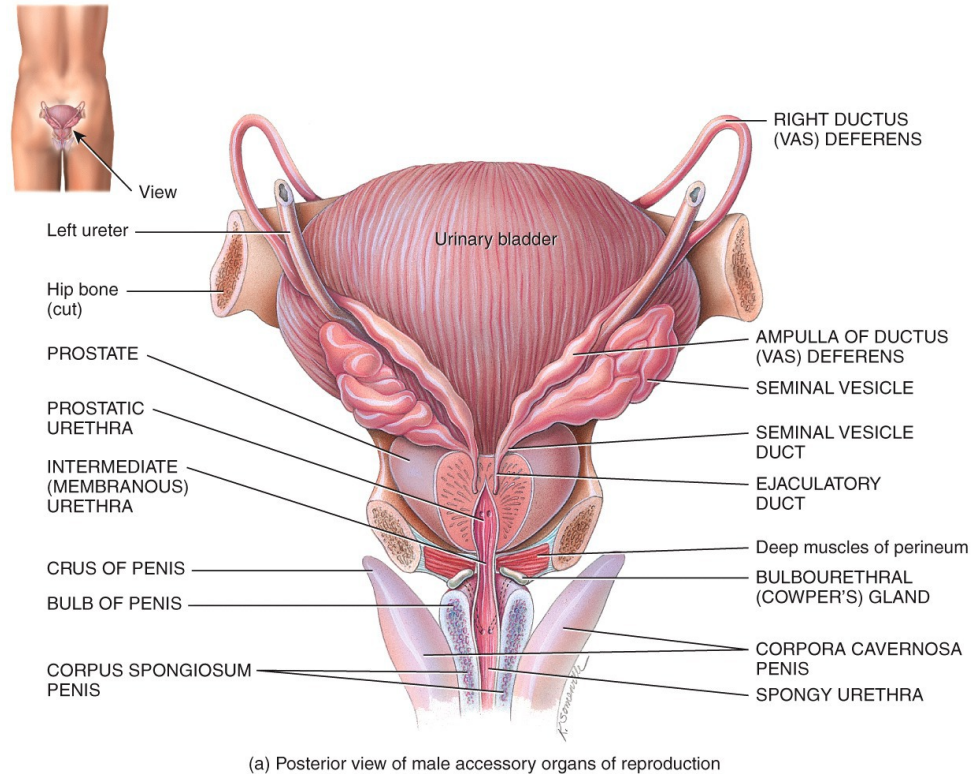
# Prostate Gland

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

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

First enzyme is the “**clotting**  
**enzyme**” – converts  
proseminogelin into seminogelin

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



# Role of Pro-seminogelin in Fertilization

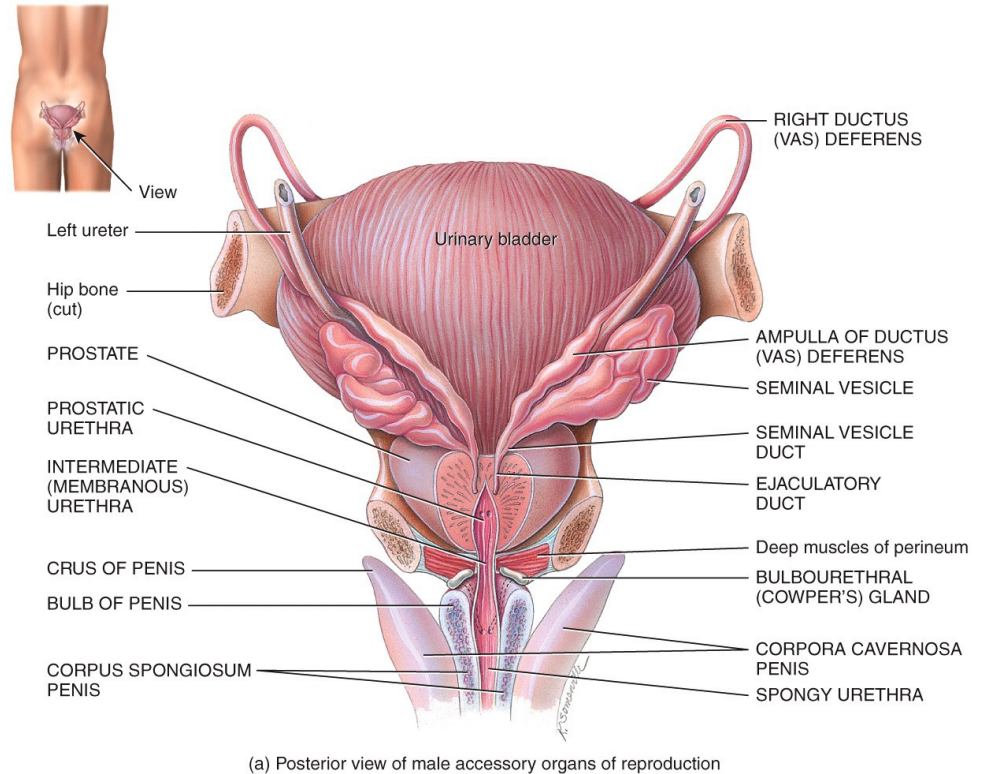
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- “**Stickiness**” of semen promotes fertilization
  - Proseminogelin secreted from seminal vesicles
  - Prostate's clotting enzyme from prostate activates **proseminogelin**
  - Clotting enzyme converts proseminogelin to a sticky fibrin-like protein – **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
  - It is now when the 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%



# Sperm's Pathway in Male Duct System

Seminiferous tubules

Rete testes

Efferent ductules

Epididymis

Ductus deferens

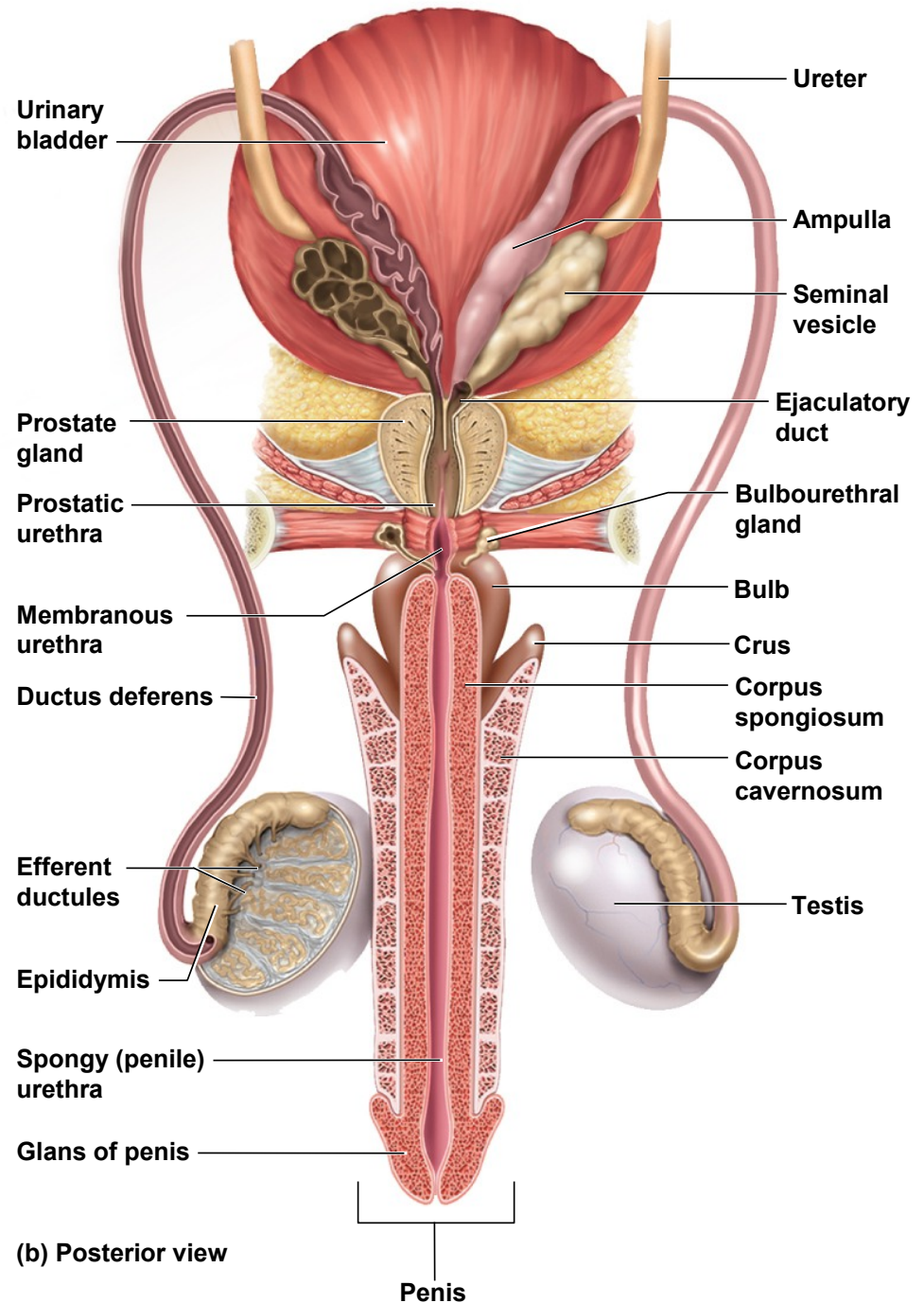
Ampulla of ductus deferens

Ejaculatory duct

Prostatic urethra

Membranous urethra

Spongy (penile) urethra

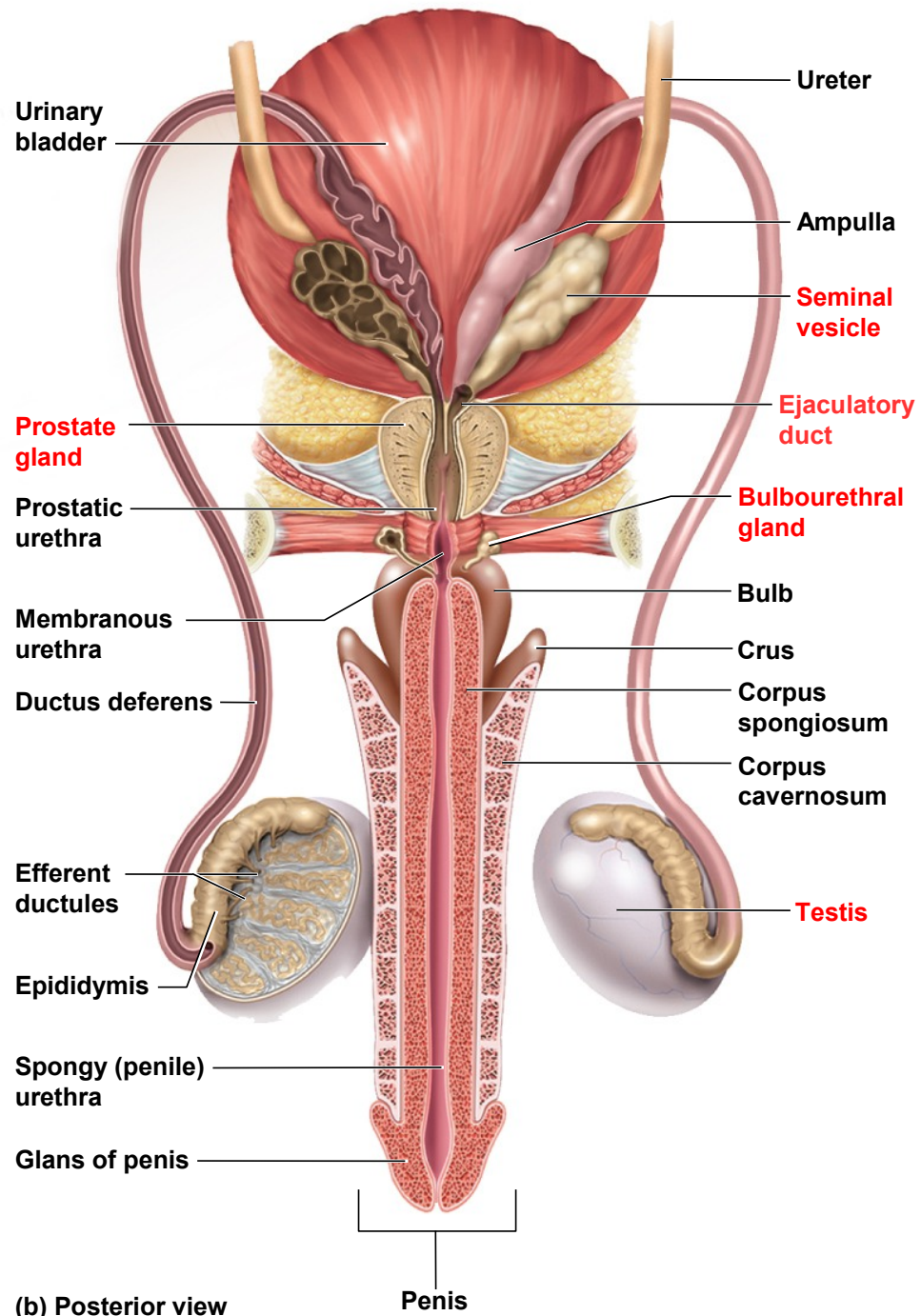


**Where are  
sperm stored?**

**How long may  
sperm be stored?**

Mature sperm is stored in the epididymis – the coil-like structure that runs across the top of each testicle.

Sperm can remain in the epididymis for about **two weeks** before being delivered up as ejaculate, or broken down and reabsorbed by the body.



# 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

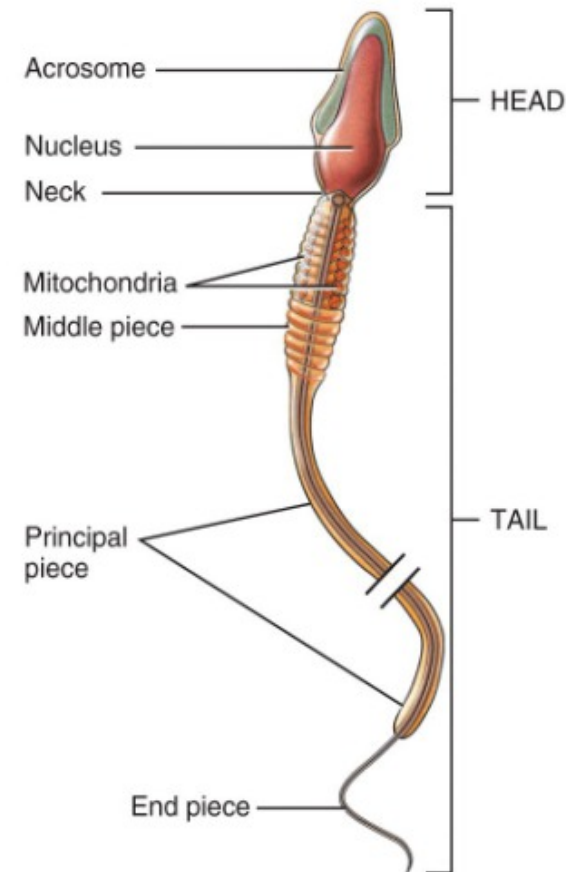
Egg is only viable for 24 hours

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)**



# Male Sexual Response

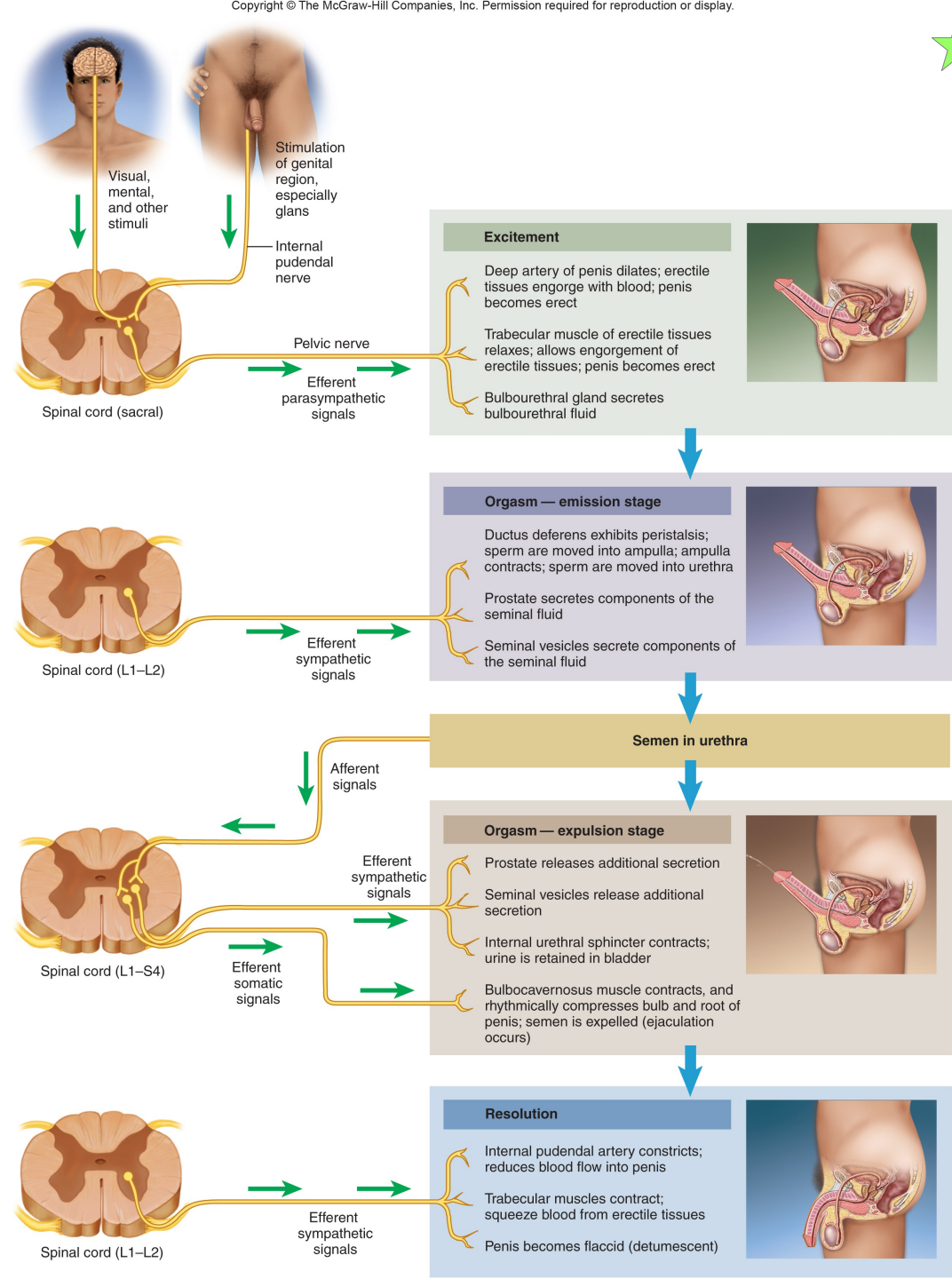
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- Brought to general public by ground breaking publication of research papers by William Masters and Virginia Johnson (1966)
- Sexual Response divided into **four recognizable phases** (see next slide)
  - Excitement
  - Orgasm (event 1) – emission 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

- Excitement (engorgement of penile erectile tissue)
- Emission Stage of orgasm (peristalsis moves sperm from epididymis into penile urethra)
- Secretions enter urethra from prostate and seminal vesicles)
- Expulsion 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

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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 impulses from integrating center to penis.

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

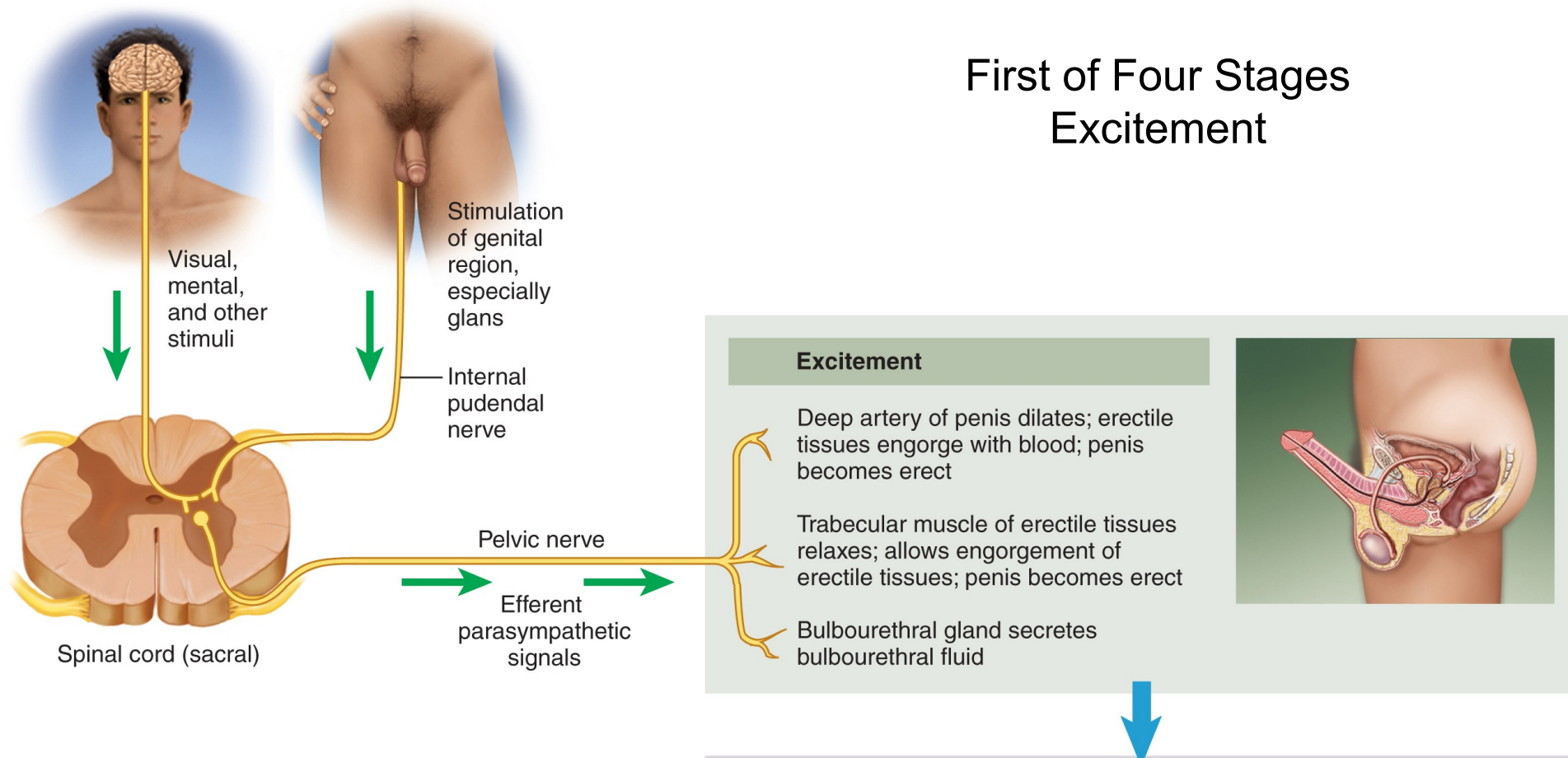
Parasympathetic NS induce an **erection** in response to direct stimulation to the penis.

# Orgasm and Ejaculation

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- **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**

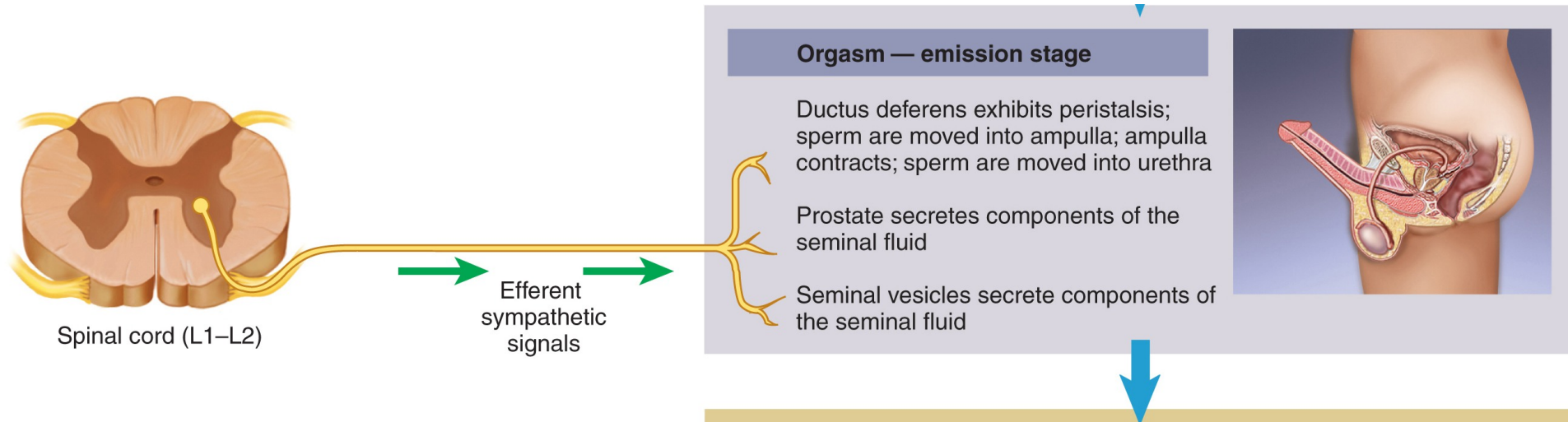
## First of Four Stages Excitement



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

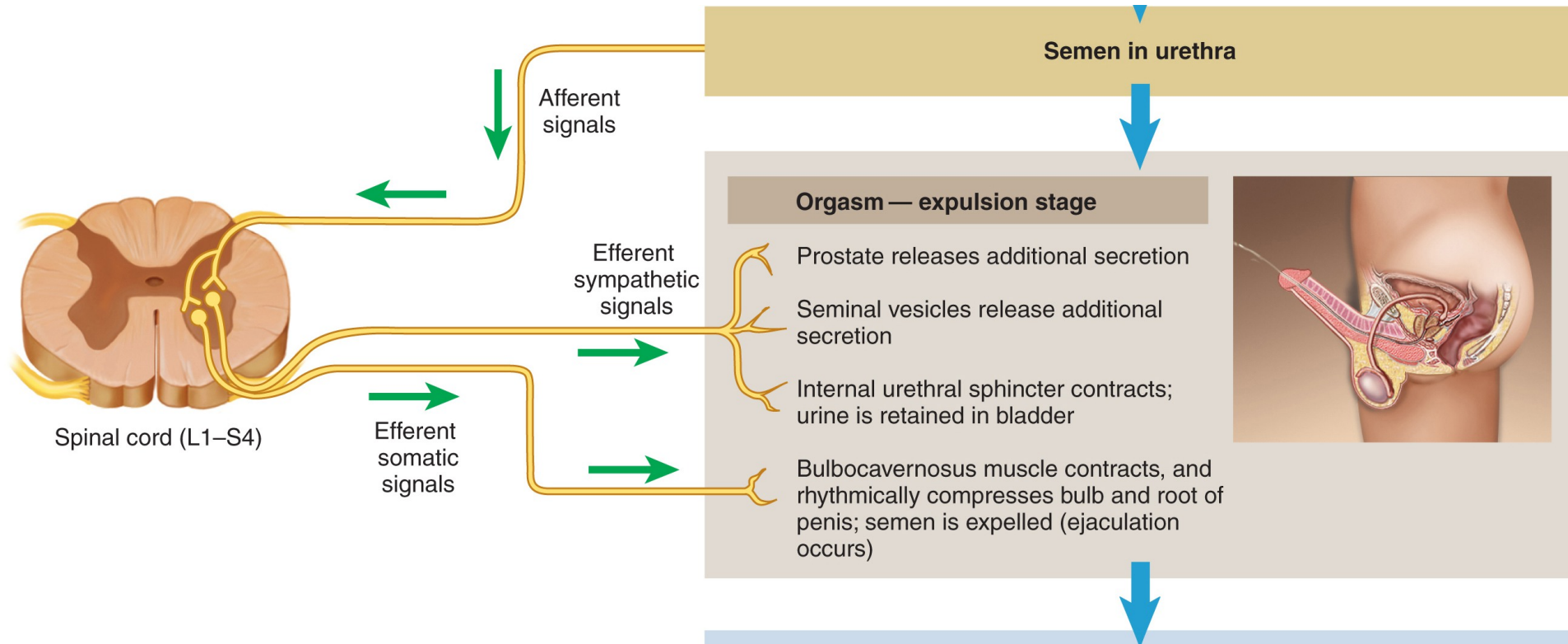
Parasympathetic NS induce an **erection** in response to direct stimulation to the penis.

## Second of Four Stages Emission



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

# Third of Four Stages Expulsion



## Third of Four Stages Resolution

