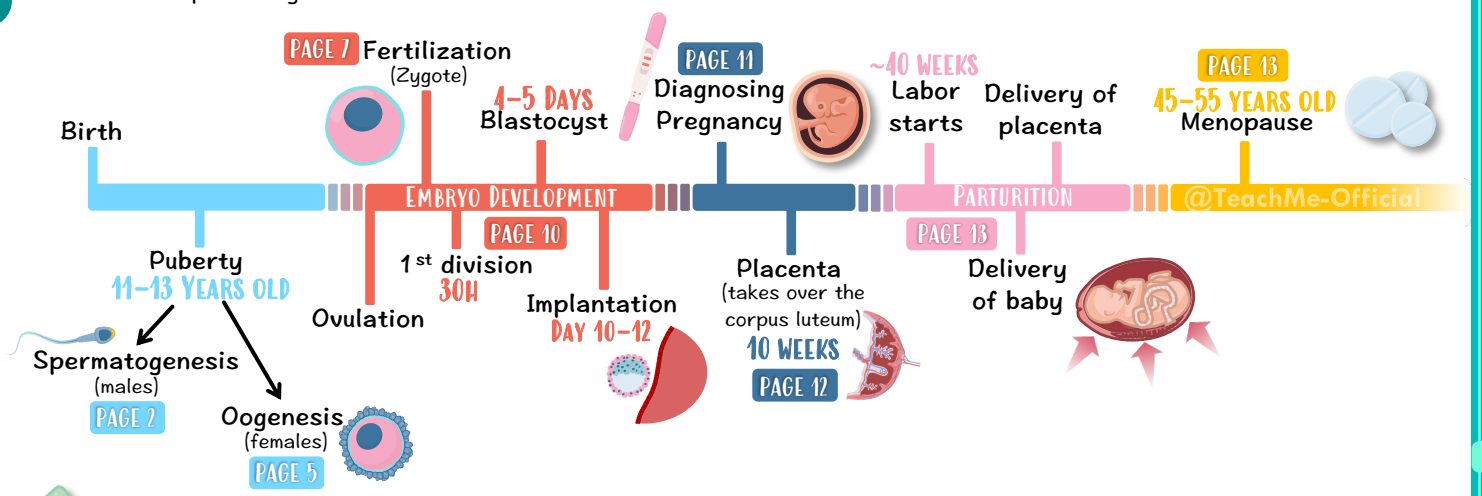
Reproduction (HL)

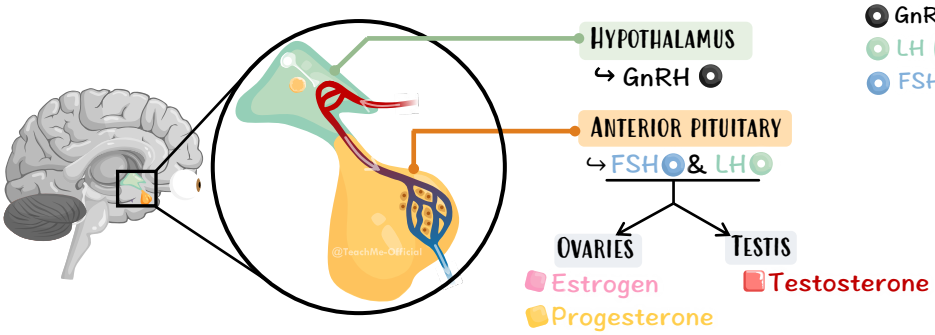
The processes covered in this chapter can be organised on a timeline (mostly representing a woman's life). Bear in mind that it is not perfectly to scale!



PUBERTY

Life stage when an individual becomes sexually mature (see the changes in males and females at the bottom of the page).

Puberty starts on average at 11 years old in females and 12 years old in males. At this time, the **HYPOTHALAMUS** is activated and secretes the hormone GnRH which acts on the **ANTERIOR PITUITARY**, which in turn then releases two hormones (called gonadotropins): **FSH** and **LH**. Both of these are released into the blood and act on the gonads (**OVARIES** in females and **TESTES** in males).



- GnRH (Gonadotropin-releasing hormone)
- LH (luteinizing hormone)
- FSH (Follicle stimulating hormone)

} Gonadotropins

BIG BRAIN TIP!

Gonadotropin

Gonads (ovaries and testes) — Liking

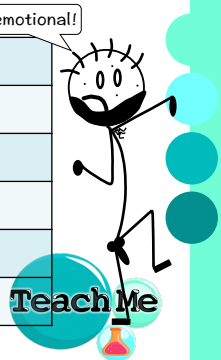
Hormones that act on the gonads!

In females, **FSH** and **LH** stimulate the ovaries to release **ESTROGEN** and **PROGESTERONE**. Both are steroid hormones. They control puberty changes including physical changes, oogenesis, and the menstrual cycle.

In males, **FSH** and **LH** stimulate the testes to release **TESTOSTERONE**, also a steroid hormone. It controls puberty including physical changes, and spermatogenesis.

The body undergoes various changes during puberty which vary between males and females:

FEMALES	MALES
Increase in HEIGHT and body MASS	Increase in HEIGHT and body MASS
HAIR: Underarm & pubic	HAIR: Underarm, pubic, facial & chest
Development of BREASTS	Development of TESTES and PENIS
MENSTRUAL CYCLE begins	ERECTIONS begin
ACNE may begin	ACNE may begin
Hips bone structure WIDENS (for childbirth)	VOICE becomes deeper



Reproduction (HL)

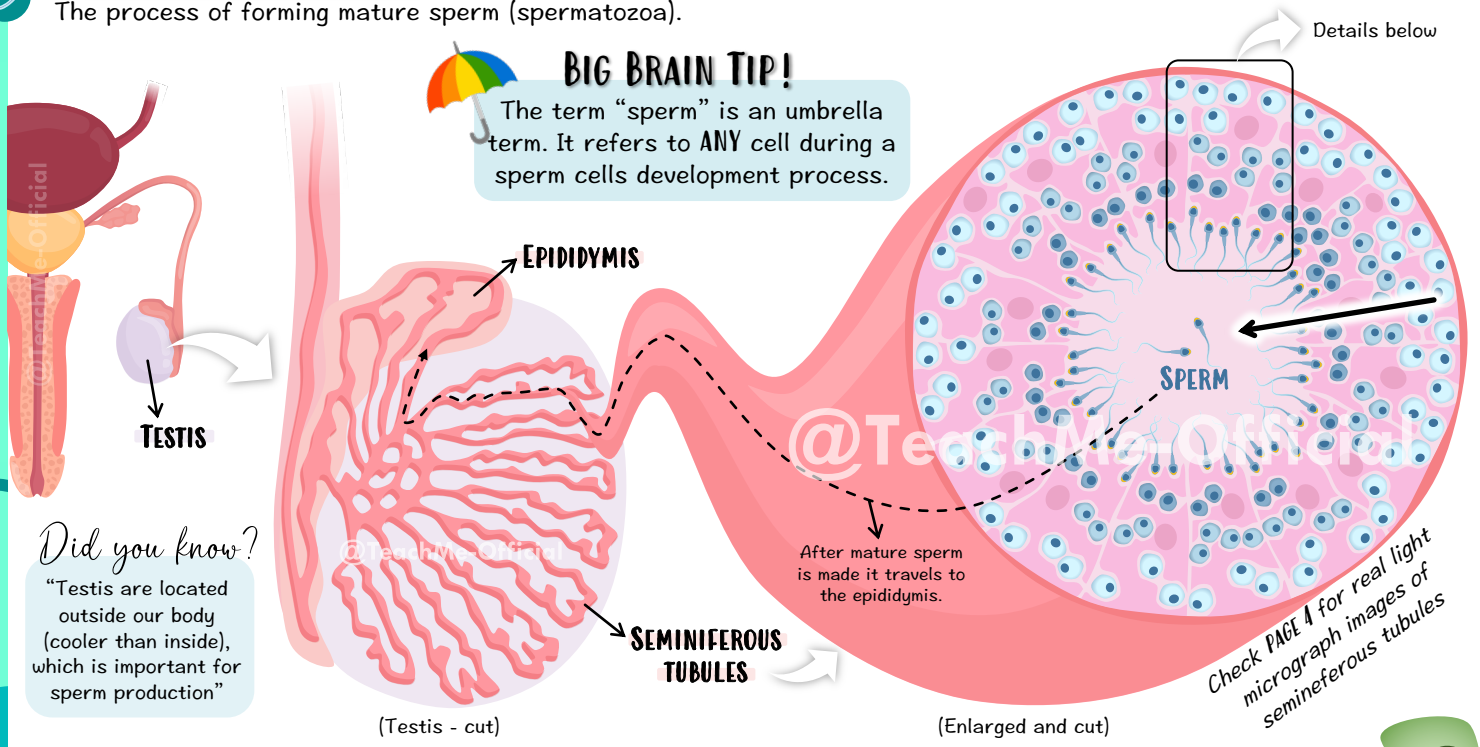
Spermatogenesis

(clear written out steps of this process is on PAGE 3)

The process of forming mature sperm (spermatozoa).

Big Brain Tip!

The term "sperm" is an umbrella term. It refers to ANY cell during a sperm cells development process.

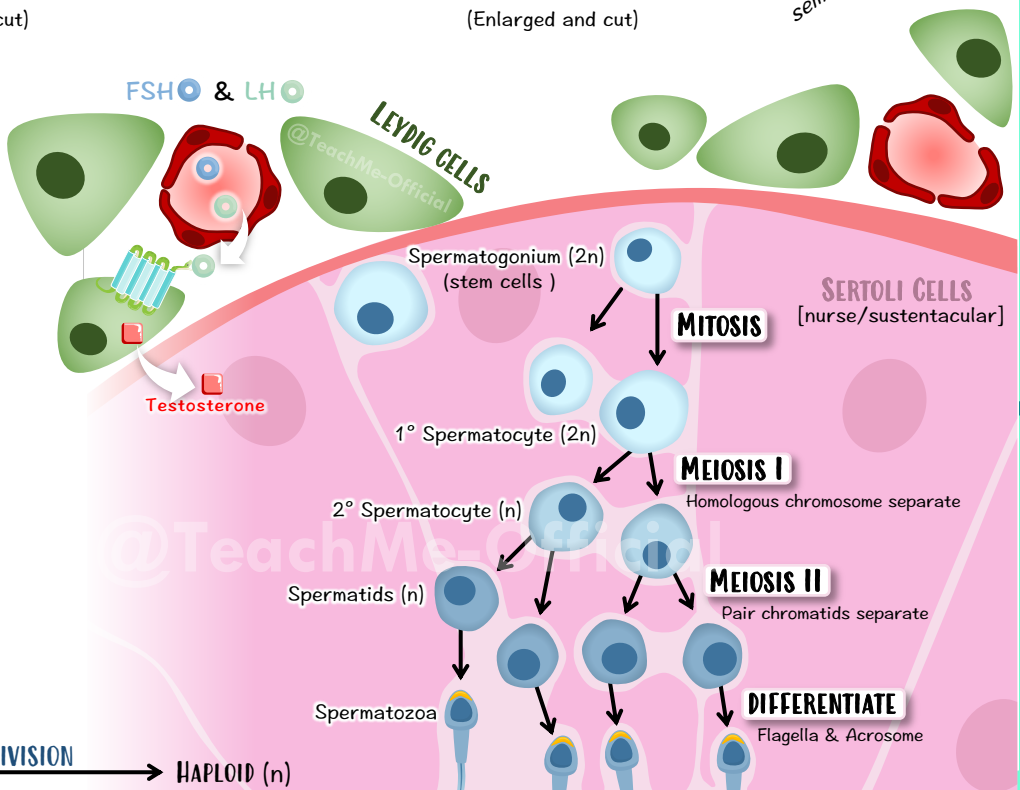


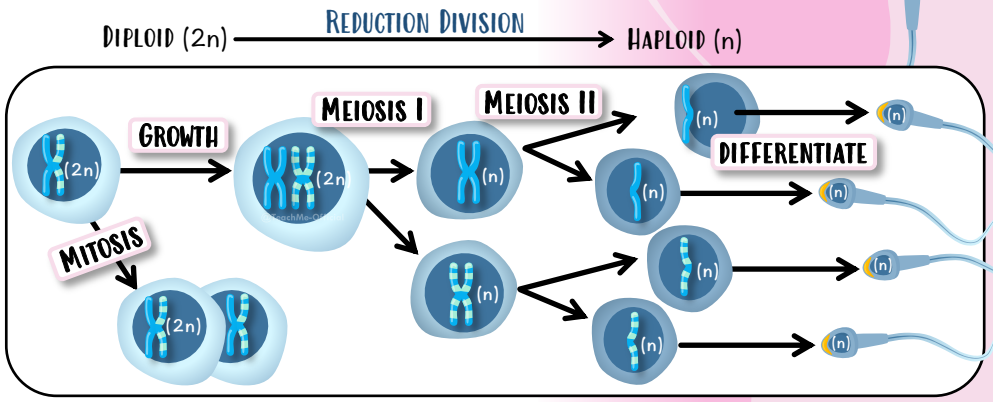
Did you know?

"Testis are located outside our body (cooler than inside), which is important for sperm production"

Overall Process

SPERM is produced in the SEMINIFEROUS TUBULES in the testes. Here stem cells differentiate from spermatogonium (2n) into spermatozoa (n), which are not motile (cannot swim yet). The spermatozoa then travel to the EPIDIDYMIS where they learn how to swim. During EJACULATION, millions of sperm are moved from the epididymis, through the VAS DEFERENS and out through the URETHRA (remember the pathway of sperm learned in D3.1 SL).





Reproduction (HL)

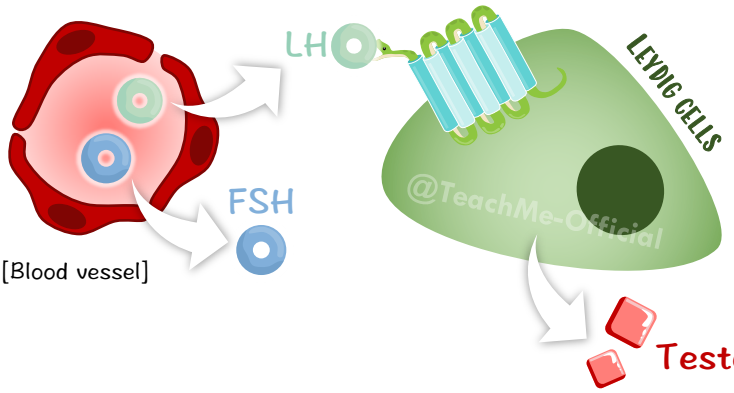
WORD SUMMARY FOR SPERMATOGENESIS *(refer back to the diagrams on PAGE 2)*

The process of forming **MATURE SPERM** (spermatozoa) in the **SEMINIFEROUS TUBULES** of the **TESTES**. This process starts at **PUBERTY** and continues throughout life until death. Millions of sperm cells are produced daily.

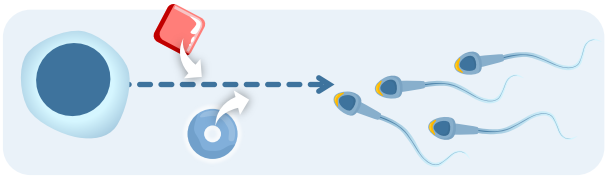
How is Spermatogenesis regulated?

BIG BRAIN TIP TIP!
Leydig - LH Sertoli = Serve

At puberty, when the **HYPOTHALAMUS** is activated and releases **GnRH**, the **ANTERIOR PITUITARY** starts releasing the gonadotropins **FSH** and **LH** into the blood stream.



LH (Luteinizing hormone) stimulates the **LEYDIG CELLS** to make the hormone **TESTOSTERONE**. **FSH** (Follicle Stimulating Hormone) works together with **testosterone** to stimulate the process of spermatogenesis.



Three main processes take place:

I. MITOSIS & GROWTH

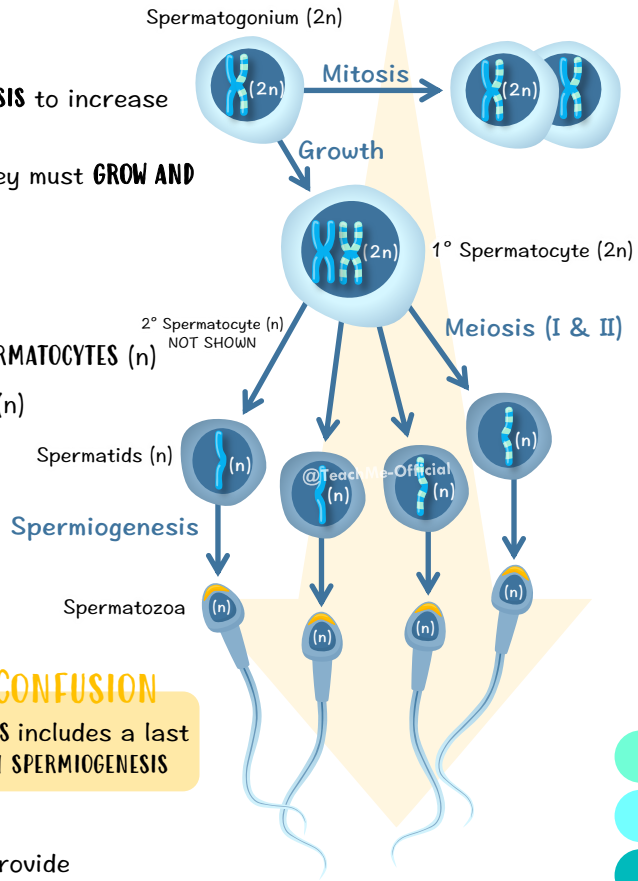
1. A **SPERMATOGONIUM** (stem cell - undifferentiated) can undergo **MITOSIS** to increase the supply of stem cells.
2. A Spermatogonium may also enter **MEIOSIS**, but before doing so they must **GROW AND REPLICATE** their diploid nucleus.
   One Spermatogonium (2n) → One **PRIMARY SPERMATOCYTE** (2n)

II. MEIOSIS

1. **Meiosis I:** One Primary Spermatocyte (2n) → Two **SECONDARY SPERMATOCYTES** (n)
2. **Meiosis II:** Two Secondary Spermatocyte (n) → Four **SPERMATIDS** (n)

III. SPERMIOGENESIS (DIFFERENTIATION)

1. Four **SPERMATIDS** (n) → Four **SPERMATOZOA** (n)
   + Flagellum for motility and Acrosome (destructive enzymes).



NOTE
Spermatogonia is plural for **spermatogonium**
Spermatozoa is plural for **spermatozoon**

COMMON CONFUSION
SPERMATOGENESIS includes a last stage called **SPERMIOGENESIS**

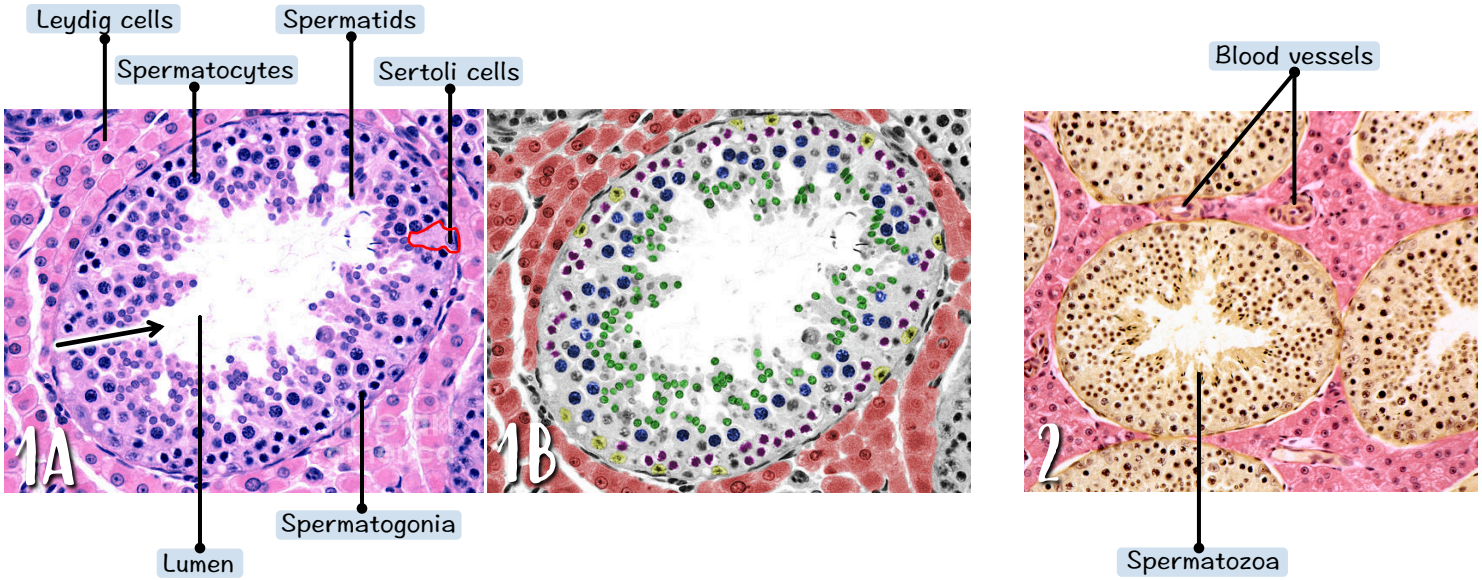
During the process of Spermatogenesis, the **SERTOLI CELLS** provide the **nutrients** to the sperm cells during each stage of development.

Once the spermatozoa have completed their **DIFFERENTIATION**, they will detach from the **SERTOLI CELLS** and travel to the **EPIDIDYMIS** to mature further (learn how to swim).

Reproduction (HL)

Light micrograph: Seminiferous tubules

Each individual structure is difficult to distinguish but dyeing the slide as well as coloring the images allows you to clearly identify all the structures we've learned about. Notice the large number of seminiferous tubules in just one slide!

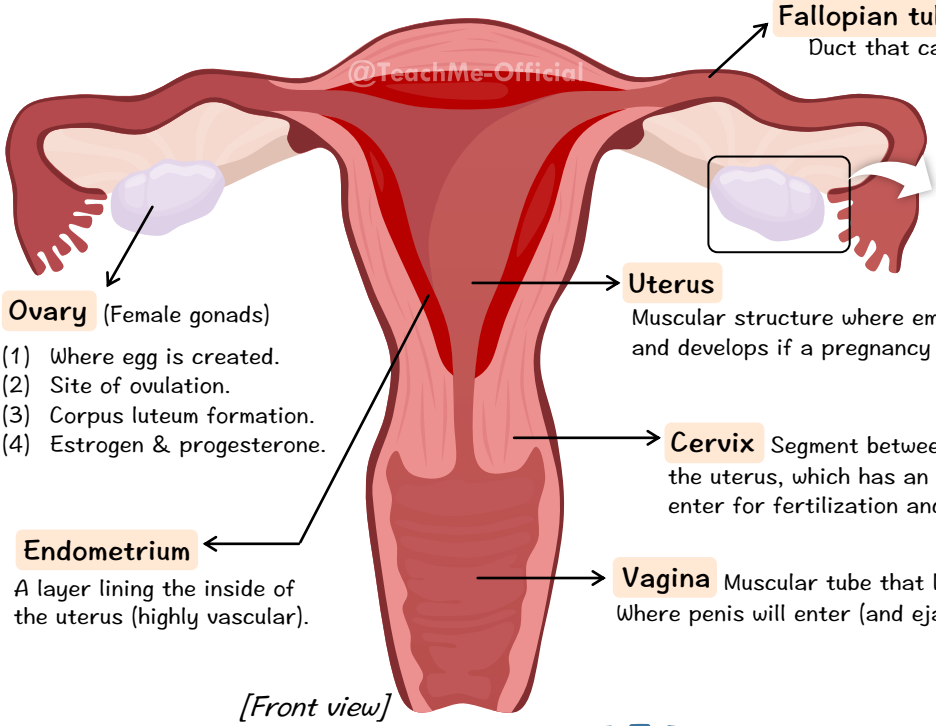


Reproduction (HL)

Oogenesis

(clear steps of the process on PAGE 6)

The process of forming mature egg cells (ovum).



Fallopian tube (oviduct)
Duct that carries the egg (or early embryo to the uterus).

Details below

Review of the female reproductive system structures.
Seen in D3.1 SL / HL

Ovary (Female gonads)

(1) Where egg is created.
(2) Site of ovulation.
(3) Corpus luteum formation.
(4) Estrogen & progesterone.

Uterus
Muscular structure where embryo implants and develops if a pregnancy occurs.

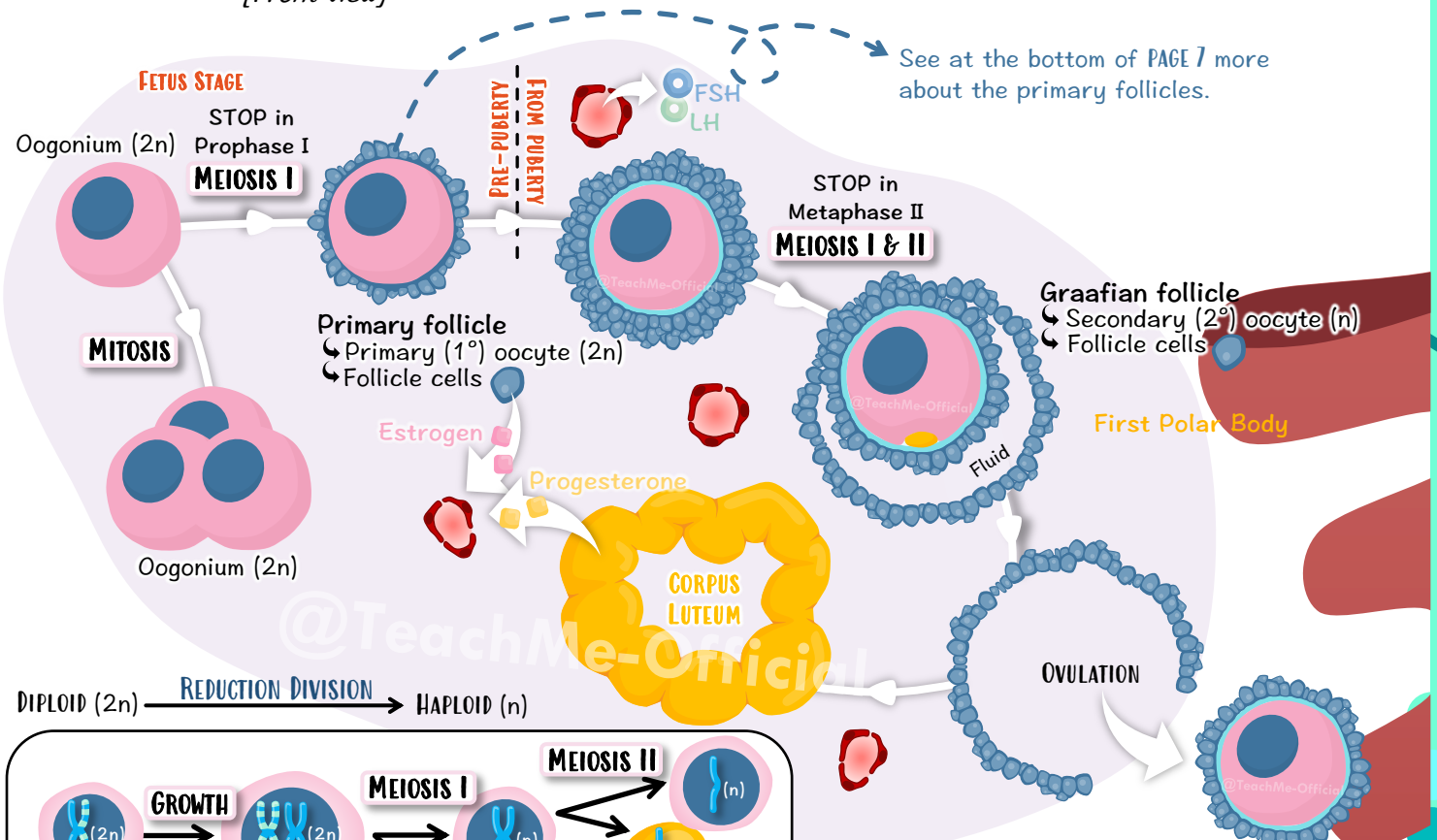
Cervix Segment between the vagina and the uterus. Lower portion of the uterus, which has an opening to the vagina that allows the sperm to enter for fertilization and provides a pathway for childbirth

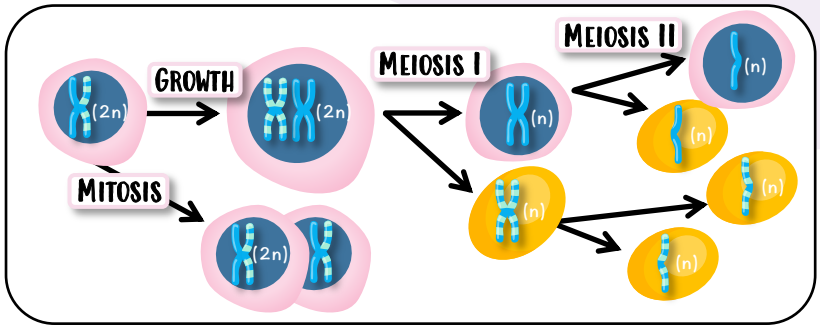
Endometrium
A layer lining the inside of the uterus (highly vascular).

Vagina Muscular tube that leads from the external genitals to the cervix. Where penis will enter (and ejaculate).

[Front view]

See at the bottom of PAGE 7 more about the primary follicles.





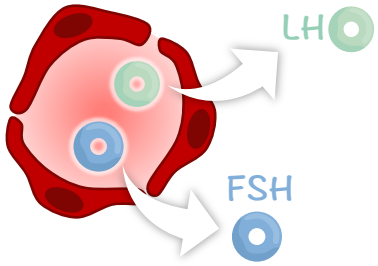
Reproduction (HL)

Oogenesis *(refer back to the diagrams on PAGE 5)*

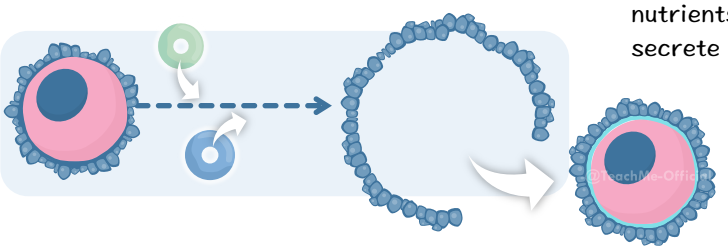
It is the process of forming **MATURE EGG** (ova). This process starts in the **OVARIES** and finishes in the **FALLOPIAN TUBES** (usually). It starts **BEFORE BIRTH**, is **INTERRUPTED TWICE** (once before puberty in prophase I and another time before fertilization in metaphase II) and stops at **MENOPAUSE** (45-55 years old). One egg is created each month.

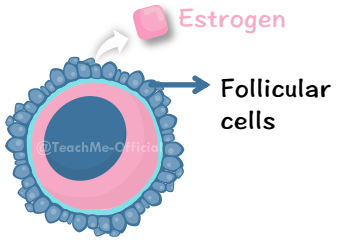
How is Oogenesis regulated ?

At puberty, when the **HYPOTHALAMUS** is activated and releases **GnRH**, the **ANTERIOR PITUITARY** starts releasing the gonadotropins **FSH** and **LH** into the blood stream.



LH (Luteinizing hormone) stimulates the process of oogenesis and ovulation. And **FSH** (Follicle Stimulating Hormone) helps to stimulate the process of oogenesis.





The follicular cells provide nutrients for the ovum and secrete **ESTROGEN**.

Two main processes take place:

I. Mitosis & Growth

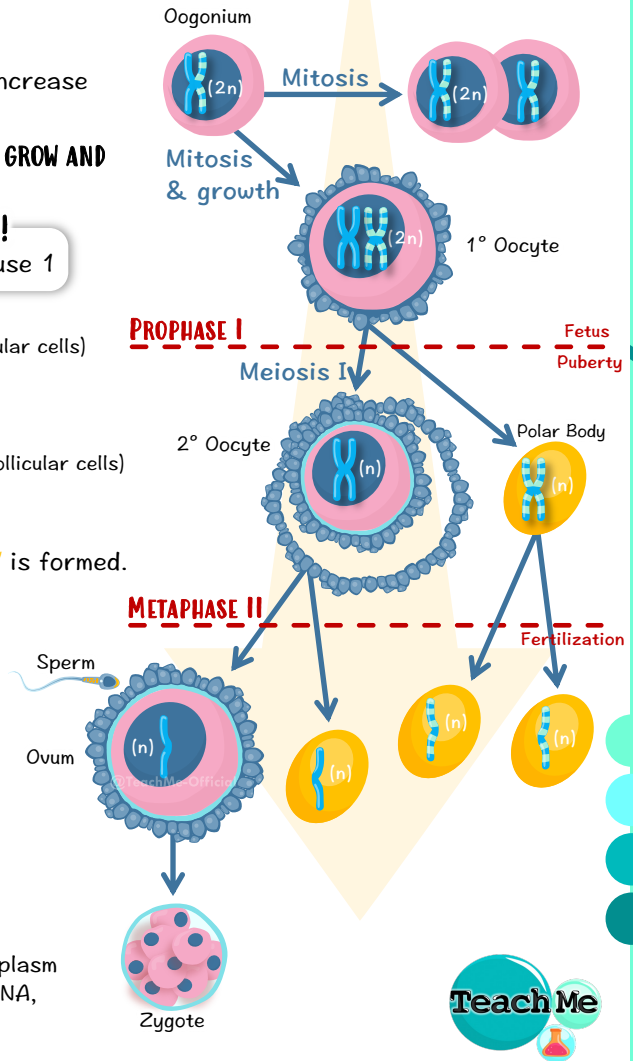
1. An **OOGONIUM** (stem cell - undifferentiated) can undergo **MITOSIS** to increase the supply of stem cells.
2. An oogonium may also enter **MEIOSIS**, but before doing so they must **GROW AND REPLICATE** their diploid nucleus.

BIG BRAIN TIP!
Prophase 1 — Pause 1

II. Meiosis & Differentiation

1. One oogonium (2n) → One **PRIMARY FOLLICLE** (Primary Oocyte (2n) + follicular cells)
   - Meiosis I starts but is **NOT** completed: it **STOPS AT PROPHASE I**.
   - Occurs during fetal stages, does not progress until puberty.
2. One Primary Follicle (2n) → **GRAAFIAN FOLLICLE** (Secondary oocyte (n) + follicular cells)
   - Meiosis I finishes and Meiosis II starts but is **NOT** completed: it **STOPS IN METAPHASE II**.
   - Occurs from puberty (each menstrual cycle). The first **POLAR BODY** is formed.
3. Ovulation releases the secondary oocyte (still arrested in MII) into the fallopian tube.
4. When the secondary oocyte gets fertilized by sperm, meiosis II is completed. A zygote and another **POLAR BODY** is formed.

Details on PAGE 6



NOTE
Oogonia is plural for **oogonium**
Ova is plural for **ovum**

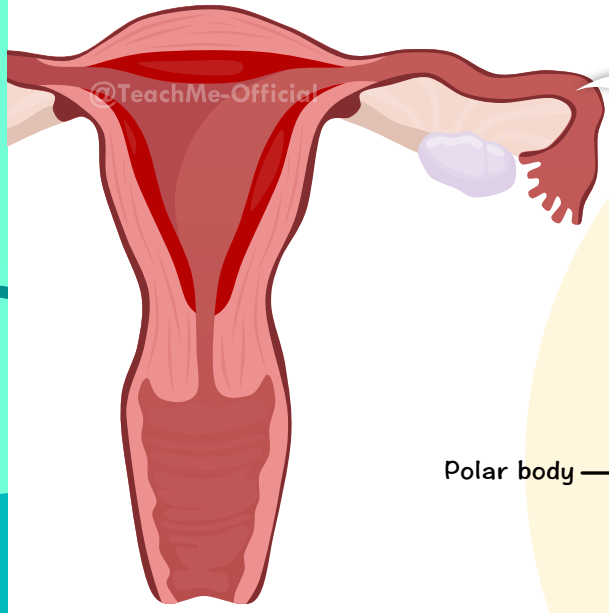
A **POLAR BODY** is a very small cell which contains little cytoplasm and organelles, used as a way to get rid of the surplus DNA, allowing the ovum to be haploid.

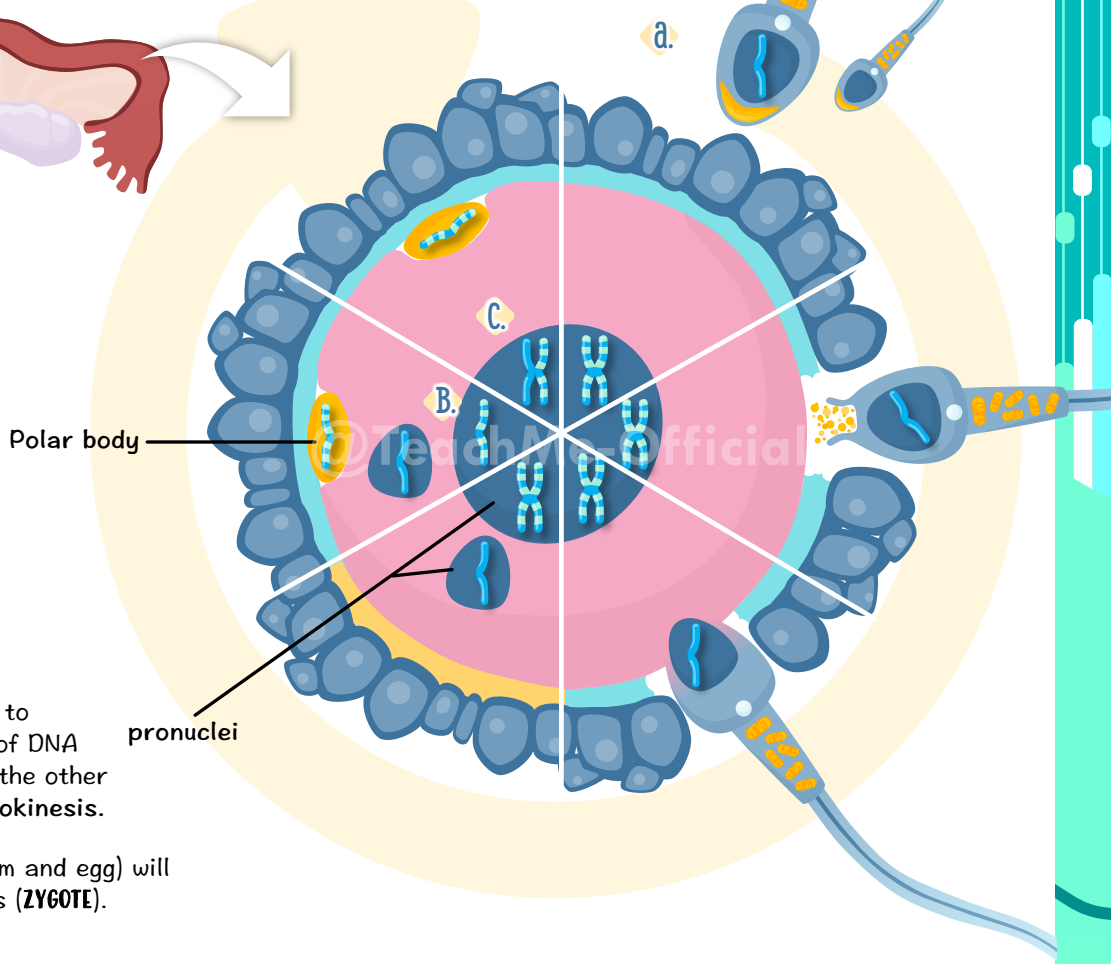
Reproduction (HL)

FERTILIZATION

4. When the secondary oocyte gets fertilized by sperm, meiosis II is completed. A zygote and another POLAR BODY is formed.

When fertilization occurs, at this point the egg is arrested in METAPHASE II. The rest of oogenesis occurs after the sperm fertilizes the egg (usually in fallopian tube.)



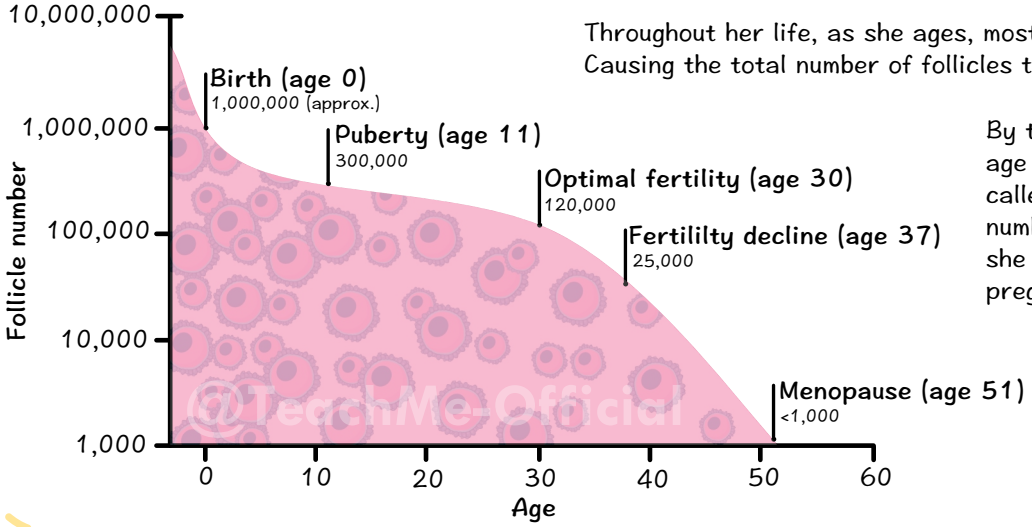


a. Spermatozoa (n) reaches the egg (n) and fertilizes it.

B. Feralization triggers the egg to complete Meiosis II. One set of DNA becomes the pronucleus and the other a polar body: **Incomplete cytokinesis.**

C. The two pronuclei (from sperm and egg) will fuse to form a diploid nucleus (**ZYGOTE**).

A woman is BORN WITH ALL HER PRIMARY OOCYTES.



Throughout her life, as she ages, most of these DEGENERATE (die). Causing the total number of follicles to decrease throughout life.

By the time a woman reaches the age of 45-55, she enters a stage called MENOPAUSE; where the total number of follicles left is so few, she would not be able to get pregnant again.

Reproduction (HL)

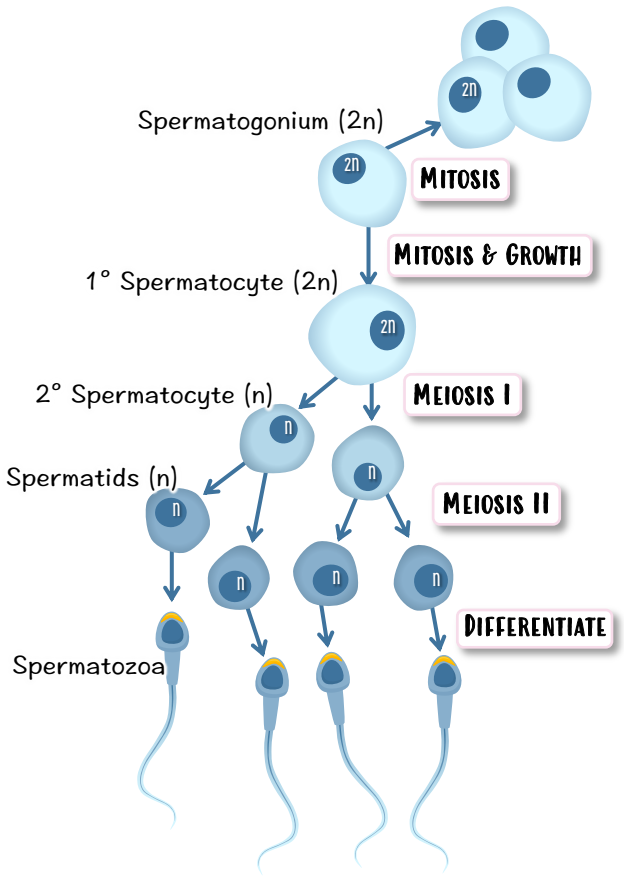
Spermatogenesis & Oogenesis Summary

Summary of similarities and differences between spermatogenesis and oogenesis. Notice there are many differences, for the exam it is recommended to know at least 4 differences, it is a **very common long answer question (in paper 2)**.

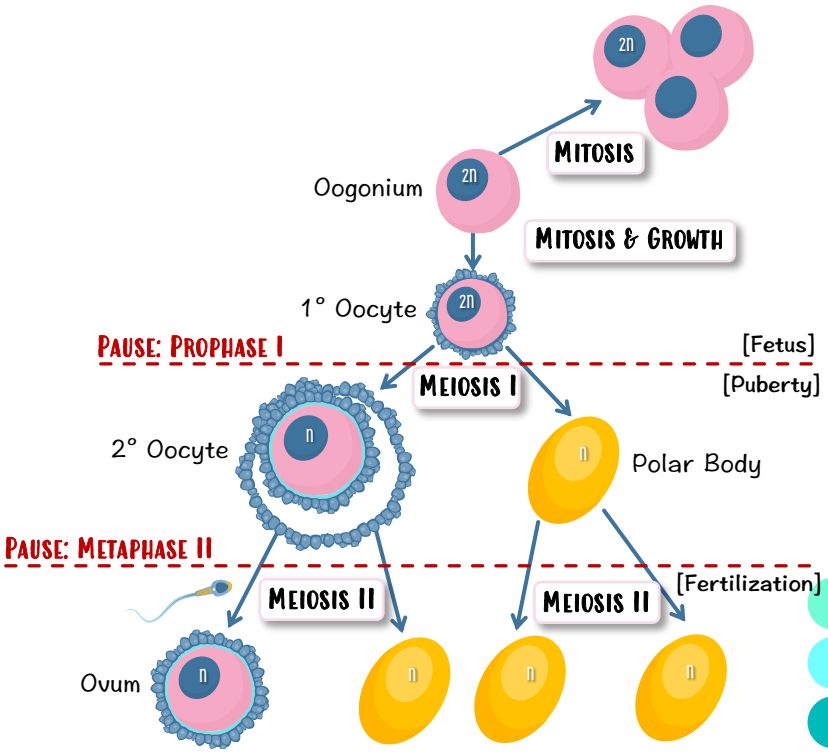
	Spermatogenesis	Oogenesis
Similarities	Both involve the production of haploid (n) cells through meiosis.	
	Both begin with mitosis to produce many stem cells.	
	Both have cell growth (in preparation) before meiosis.	
	Both are differentiation processes	
Differences	Occurs in Testis (seminiferous tubules)	Occurs in ovary (mostly)
	4 gametes (sex cells) produced	1 gamete produced (+ 2 or 3 polar bodies)
	Equal cytokinesis	Unequal cytokinesis
	Produce small, motile gametes with minimal cytoplasm & organelles.	Produce large, non-motile gametes with abundant cytoplasm, organelles and nutrients.
	Begins at puberty	Begins at fetus stage
	Continues throughout life	Stops at menopause
	Sperm is constantly produced (millions daily)	Usually, 1 per menstrual cycle
	No breaks in meiosis	Yes, breaks in meiosis (PI, & MII)

Visual summary of both processes:

Spermatogenesis



Oogenesis



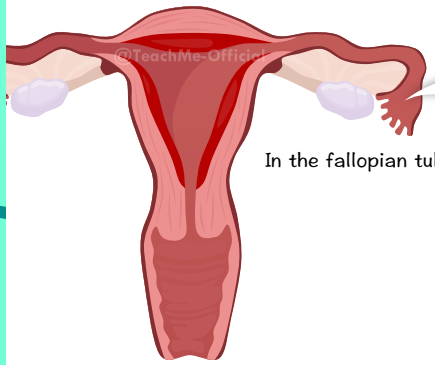
Reproduction (HL)

Preventing Polyspermy

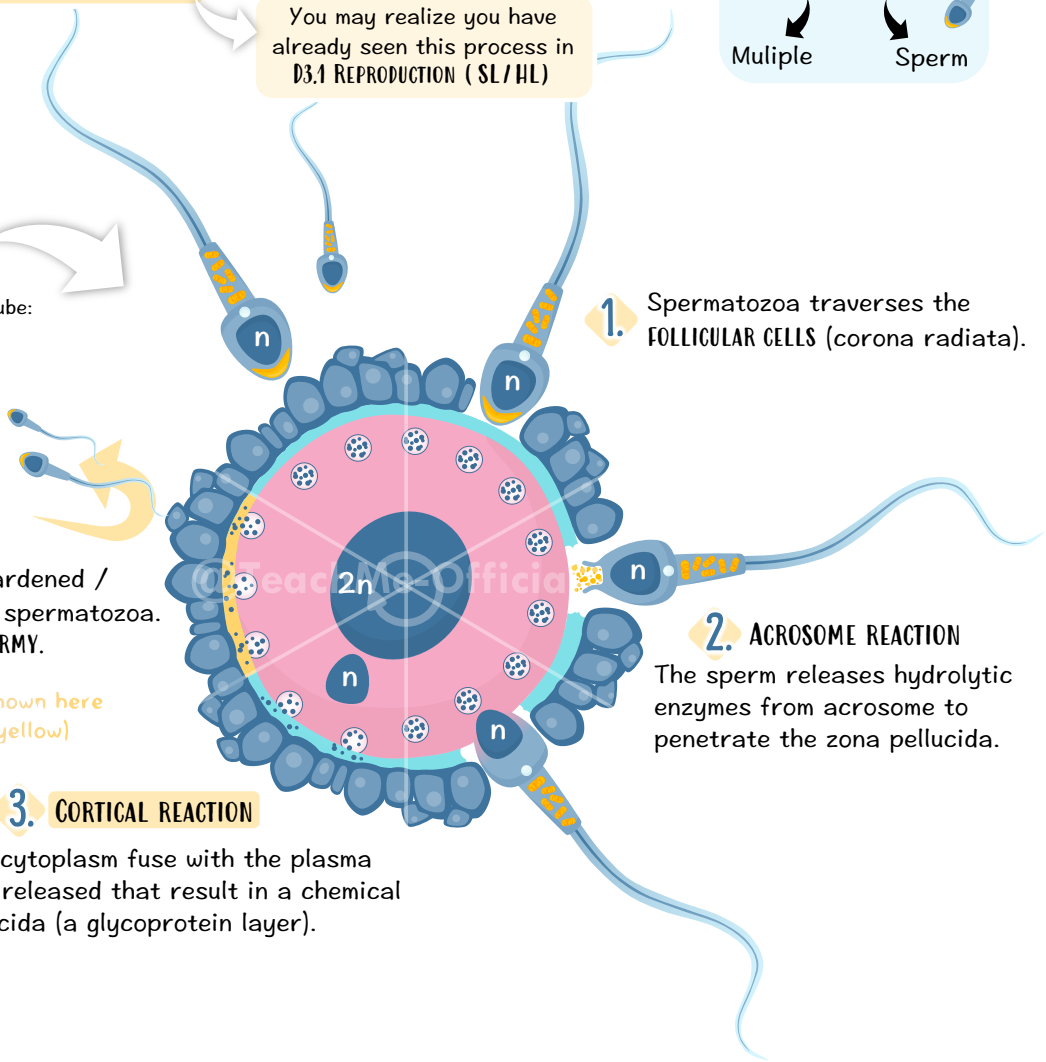
Polyspermy is the rare event of more than one spermatozoon fertilizing the ovum – which results in the ovum not developing into a zygote. Luckily, during the process of fertilization, polyspermy is prevented by the **Cortical Reaction**.

You may realize you have already seen this process in D3.1 Reproduction (SL / HL)

POLYSPERMY
Muliple Sperm



In the fallopian tube:



1. Spermatozoa traverses the **follicular cells** (corona radiata).

2. **Acrosome reaction**
The sperm releases hydrolytic enzymes from acrosome to penetrate the zona pellucida.

3. **Cortical reaction**
Cortical granules in the cytoplasm fuse with the plasma membrane. Enzymes are released that result in a chemical change in the zona pellucida (a glycoprotein layer).

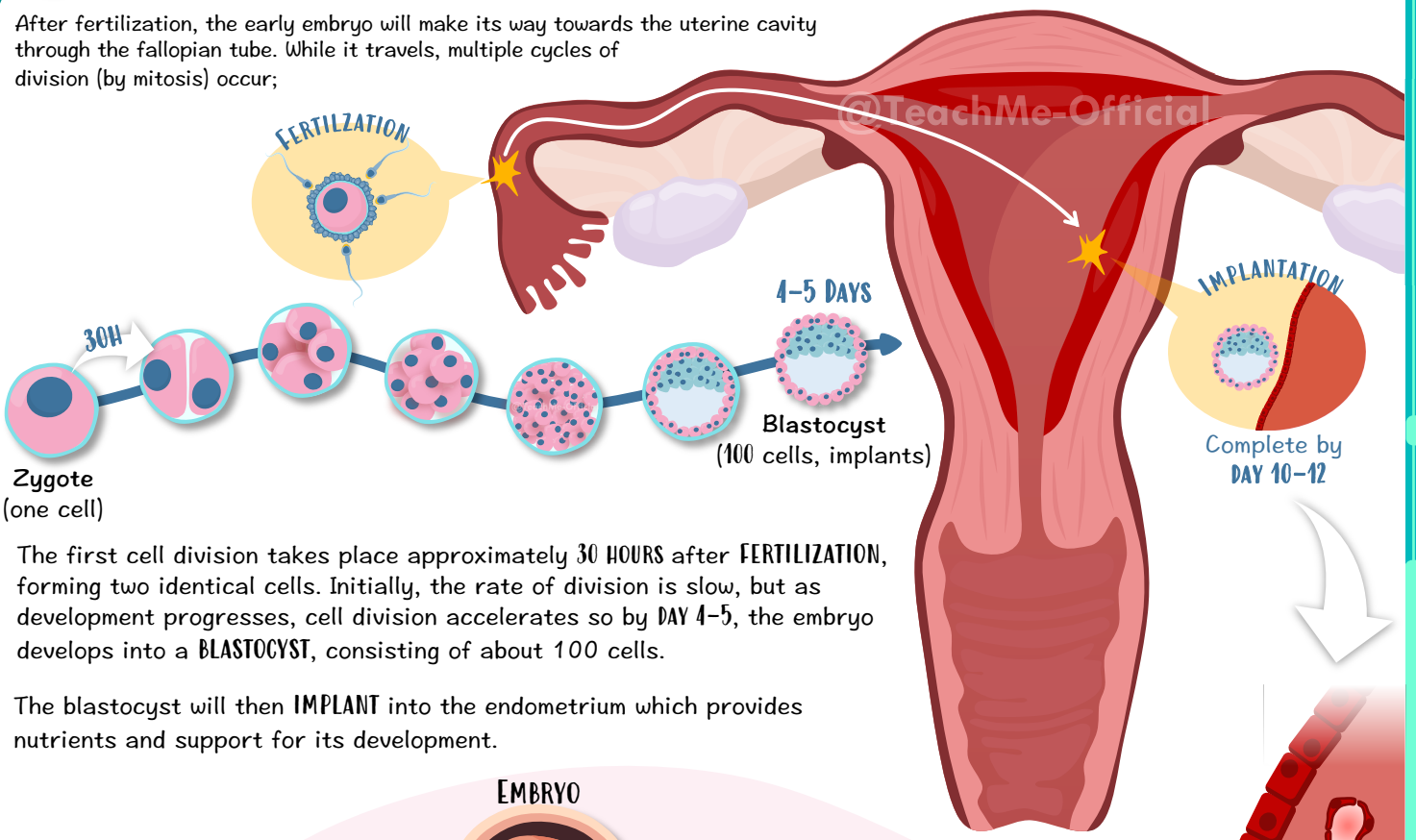
4. Zone pellucida is now hardened / **impermeable** to any more spermatozoa. Thus, preventing **polyspermy**.

(zona pellucida hardening shown here by changing its color to yellow)

Reproduction (HL)

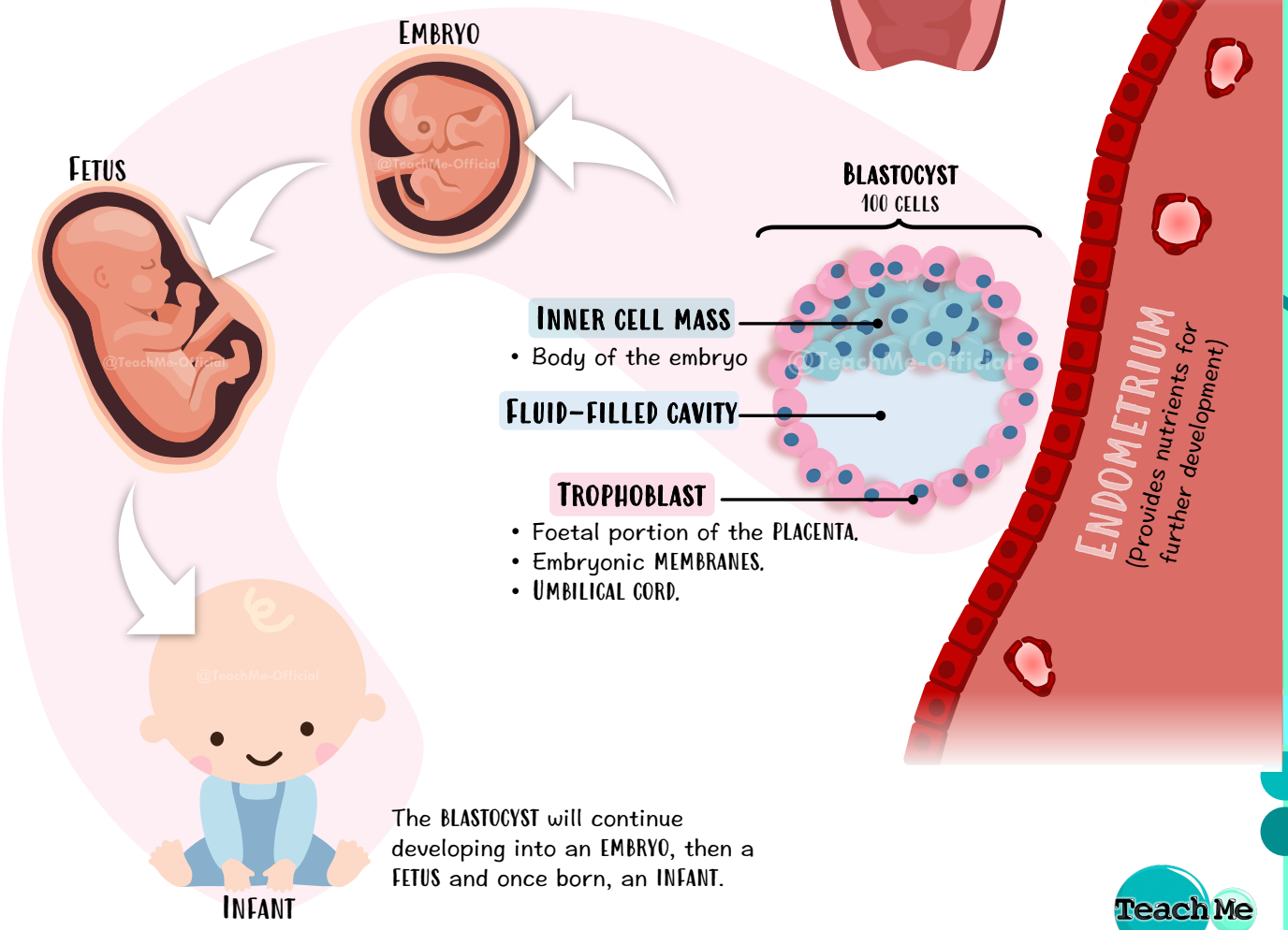
Embryo Development

After fertilization, the early embryo will make its way towards the uterine cavity through the fallopian tube. While it travels, multiple cycles of division (by mitosis) occur;



The first cell division takes place approximately 30 hours after **fertilization**, forming two identical cells. Initially, the rate of division is slow, but as development progresses, cell division accelerates so by **day 4–5**, the embryo develops into a **blastocyst**, consisting of about 100 cells.

The blastocyst will then **implant** into the endometrium which provides nutrients and support for its development.



The **blastocyst** will continue developing into an **embryo**, then a **fetus** and once born, an **infant**.

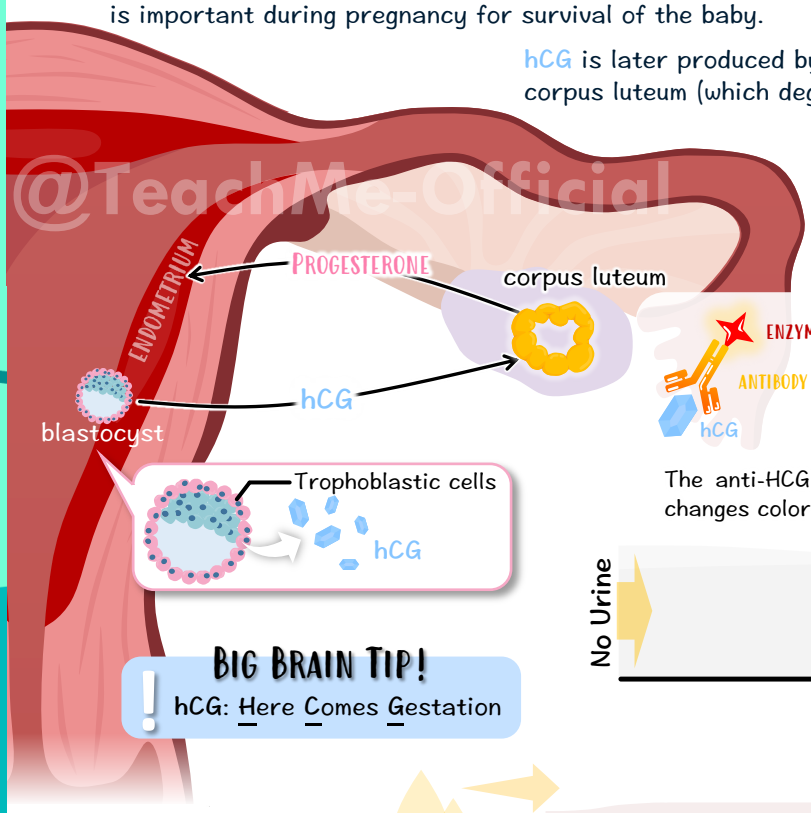
Reproduction (HL)

How to know you're pregnant?

Simply by the detection of hCG in your body.

hCG (human chorionic gonadotropin) is a chemical produced by the trophoblastic cells in the blastocyst. It keeps the corpus luteum alive, which makes progesterone to maintain the vascular tissue of the endometrial lining. This is important during pregnancy for survival of the baby.

hCG is later produced by placental cells once the placenta takes over the corpus luteum (which degenerates) and provides the embryo with nutrients.

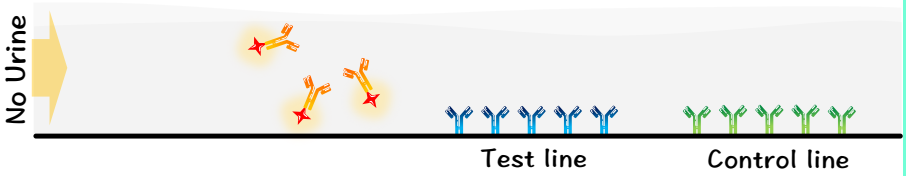


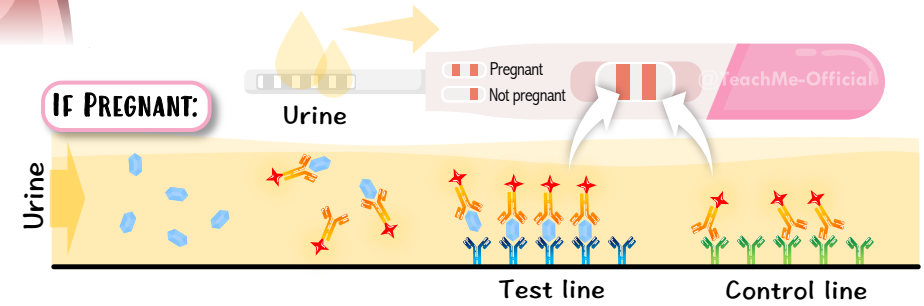
BIG BRAIN TIP!
hCG: Here Comes Gestation

Mechanism of hCG detection:

Culture (grow in a lab) B-lymphocytes (B-cells) that produce only one type of ANTIBODY (monoclonal antibodies). One that recognizes hCG as the antigen (orange one). One that recognizes the complex of anti-hCG bound to hCG (blue one), and one that binds to the anti-hCG alone (green).

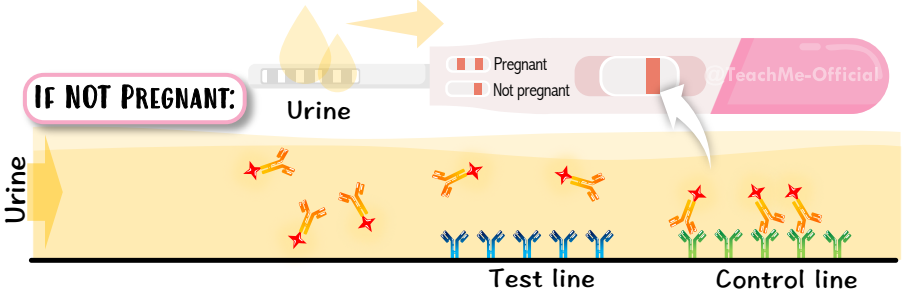
The anti-HCG antibodies are also chemically bonded to an ENZYME that changes color when exposed to a substrate.





NOTE: The control line needs to be present to be able to consider the test reliable.

Urine of a pregnant female will contain hCG. When exposed to a pregnant female's urine, the anti-hCG antibodies will bind to the hCG and the attached enzyme will emit a color. Then they will travel down to the test line and the complex will bind to the blue antibody. This is the location where the first "line" on the pregnancy test will appear. The excess (unbound) anti-HCG antibodies flows down to the control line, binding to the green antibody to emit the second line. This second line shows that the test works (is valid).



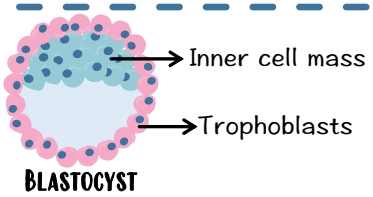
USE OF THE CONTROL LINE:
If something is obstructing the urine to flow all the way to the control line OR if the test was improperly made and is lacking anti-hCG antibodies, the control line would not appear: test is UNRELIABLE.

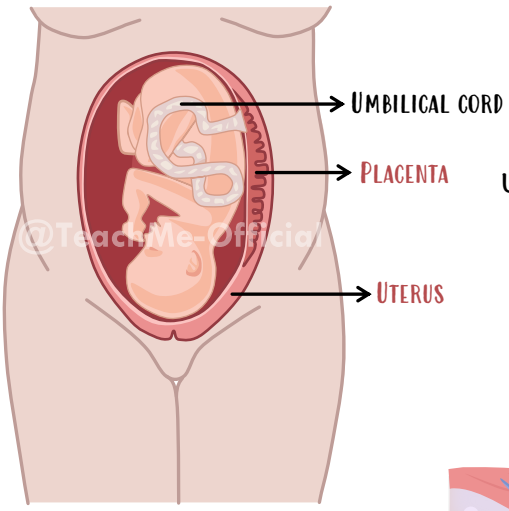
Urine of a non-pregnant female will not contain hCG. When exposed to a pregnant female's urine, the anti-hCG antibodies will have no hCG to bind. Then the anti-hCG antibodies will travel down and beyond the test line (not binding to the blue antibodies). For this reason, the first line will not appear. Instead, they continue to flow down to the control line and bind the green antibody to emit the second line only. Again, this second line is important to show that the test works (is valid).

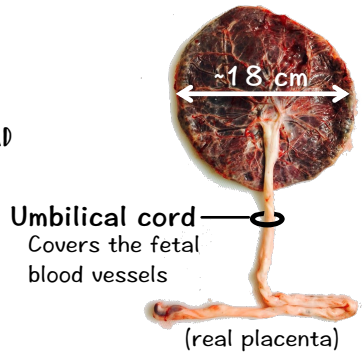
Reproduction (HL)

Placenta

The placenta is a disc/pancake shaped structure weighing approximately 1kg which originates from a combination of the **TROPHOBLASTIC CELLS** of the blastocyst (fetus) and the mother's own tissue.







The placenta holds TWO main functions:

1. Maternal/Fetal Blood Exchange

Exchange of essential nutrients, oxygen, and waste products between the mother and the fetus through the blood supply.

2. Endocrine

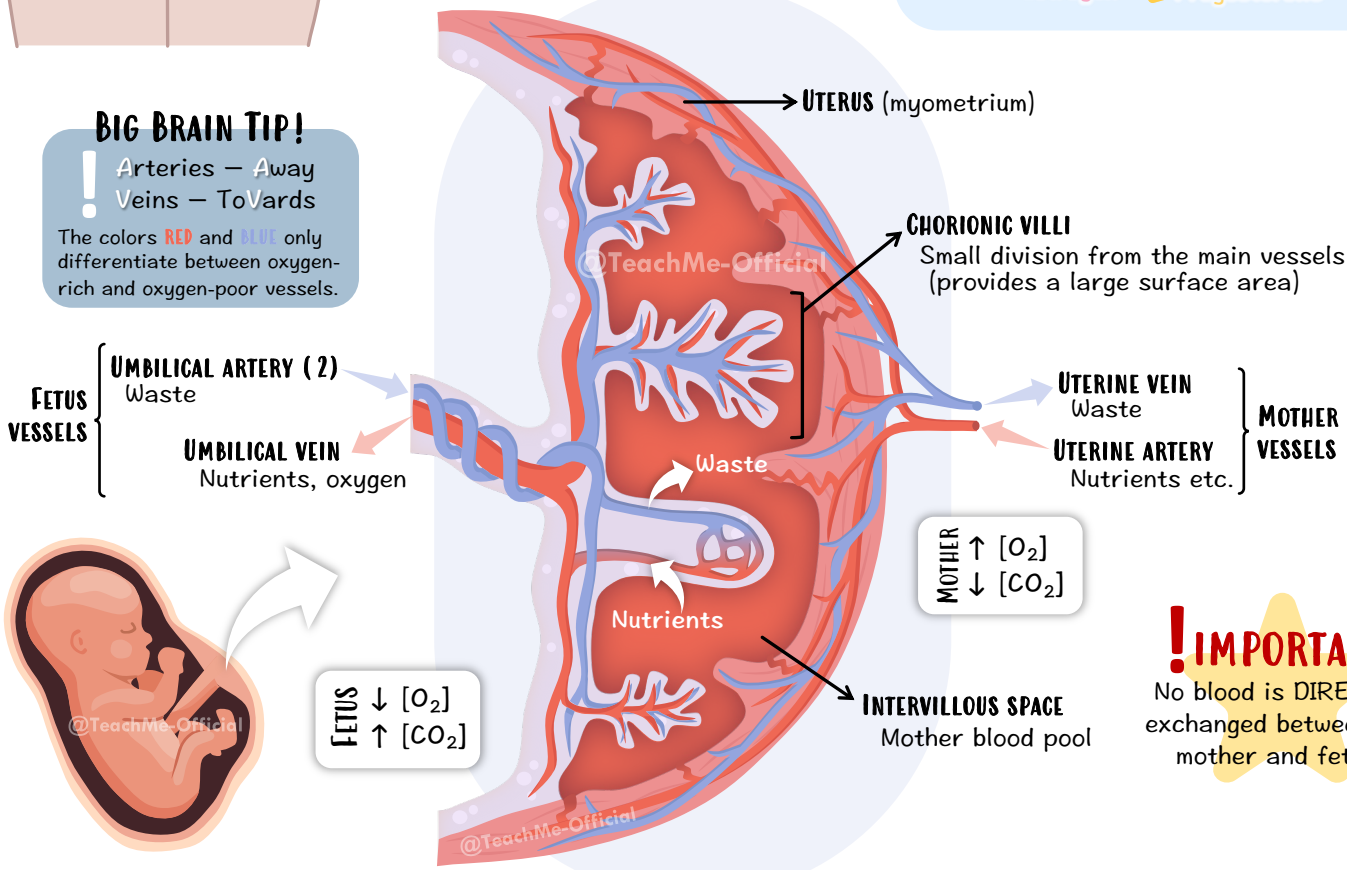
Acts as an endocrine organ by producing hormones such as hCG, progesterone, and estrogen. These hormones help maintain pregnancy etc...

Estrogen Progesterone

BIG BRAIN TIP!

Arteries – Away
Veins – ToVards

The colors RED and BLUE only differentiate between oxygen-rich and oxygen-poor vessels.



IMPORTANT

No blood is DIRECTLY exchanged between the mother and fetus!

Nutrient and waste exchange in the placenta relies on **CONCENTRATION GRADIENTS**:

- For example, oxygen moves from maternal to fetal blood due to the low oxygen content in the fetus (which cannot carry out gas exchange).
- Inversely the high carbon dioxide concentration in the fetus allows it to easily move to the maternal side down its concentration gradient as waste.

Mother To Fetus	Fetus To Mother
Oxygen	Carbon Dioxide
Nutrients: Glucose, amino acids, vitamins, minerals	Urea
Water	Water
Hormones	hCG
Alcohol, nicotine & other drugs	(Any other waste)
Viruses (e.g., HIV)	

Reproduction (HL)

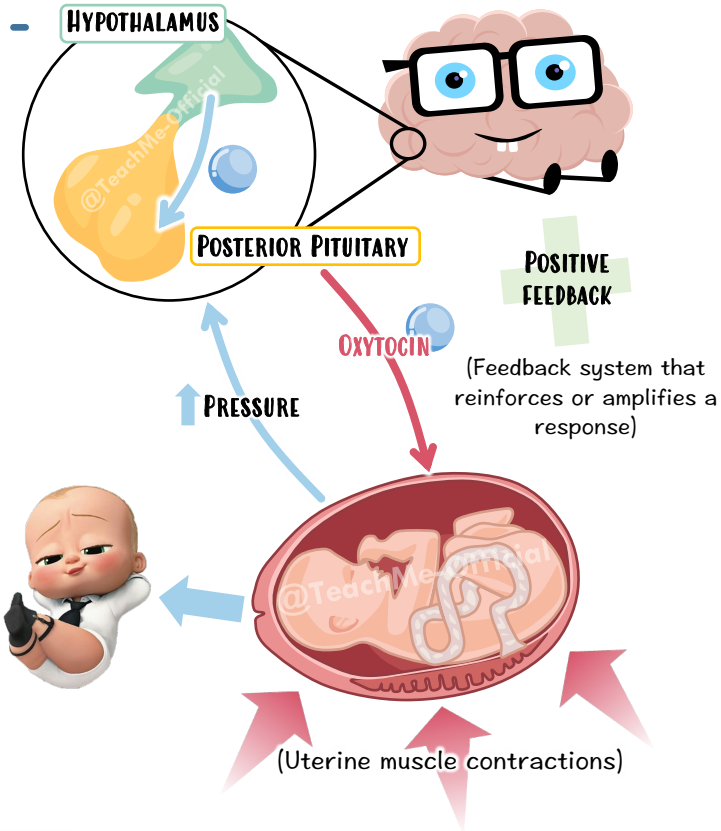
Labor and Birth

Labor is the series of regular uterine contractions which result in the expulsion of the infant and placenta.

Birth (also called parturition)

"Progesterone maintains the placenta."

1. When the fetus matures, the placenta secretes less and less progesterone.
2. Deceasing progesterone stimulates **oxytocin** production by the **posterior pituitary**.
3. Receptors in the muscle of the uterus respond with **contractions**.
4. Pressure from contractions results in **positive feedback** with the pituitary to release more oxytocin.
6. Cycle repeats until the uterine contraction are very intense and very frequent.
5. Loop only terminates with birth, since pressure is gone once the baby is out.

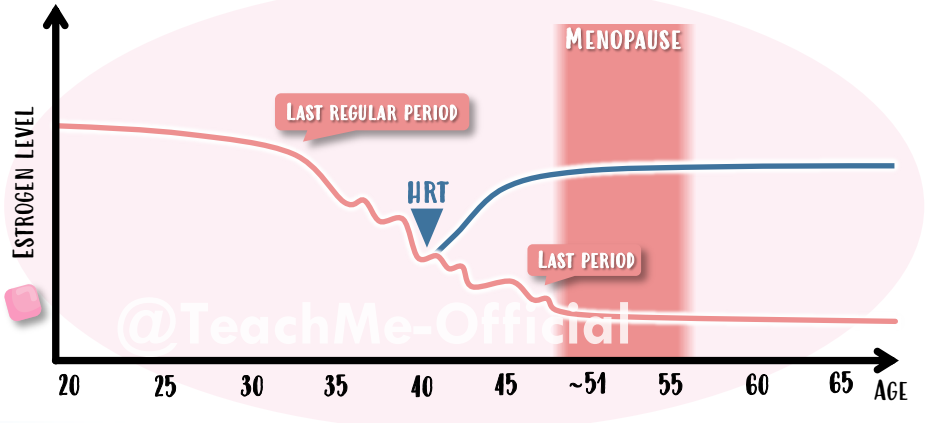


Hormone Replacement Therapy (HRT)

Menopause is the period in a female's life when her menstrual cycle ends.

Commonly ages 45-55, but the age at which it happens can vary significantly.

Why? Occurs because the ovaries stop producing oestradiol and progesterone.



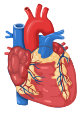
How to treat it?

HRT (hormone replacement therapy) in the form of **oestradiol** (oestrogen) to alleviate symptoms.

The effects of menopause can include trouble sleeping, hot flushes, some loss of musculature and other symptoms.

Health risks of HRT?

- Early reports shows **reduced** incidence of coronary heart disease (CHD) with HRT!
- Later studies indicated that HRT led to a small **increase** in the risk of CHD...
- Now believed, there is **no connection**!



notes