Fertilization

Edited by: Abdelhadi Okasha

Anything written in red is from outside

Topics of this lecture

1- Parts of female reproductive system

→ Know parts of uterine tube, especially the ampulla
→ Functions of this tube:
1- route for sperm to reach an ovum
2- Transport secondary oocytes and fertilized ova (*the dividing zygote*) from the ovaries to the uterus
→ cells of tube contains cilia, and it contains smooth muscles

2- Process of ovulation

→ Cumulus oophorous Consists of: Granulosa cells/ Zona pellucida/ Secondary oocyte arrested in metaphase stage of meiosis II/ First polar body!
→ effects of LH: **The surface of ovary bulges locally/ Digestion of collagen around the follicle/ local muscular contraction in ovarian wall**
→ **Ovulation occurs in day 14**
→ Some of the granulosa cells will arrange themselves around the zona pellucida to form Corona radiata

3- Corpus luteum

→ granulosa cells remaining in the wall of the ruptured follicle, together with cells from the theca interna, are vascularized by surrounding vessels. Under the influence of LH, these cells develop a yellowish pigment and change into lutein cells, which form the corpus luteum and secrete estrogens and progesterone

4- Fertilization

→ A process by which haploid male gamete fuse with female gamete to give single diploid nucleus.

5- Changes in sperm in fertilization

(1) Capacitation
(2) Acrosome reaction: both binding and the acrosome reaction are mediated by the ligand ZP3**, a zona protein Release of acrosomal enzymes** (acrosin) allows sperm to penetrate the zona. Permeability of the zona pellucida changes when **the head of the sperm comes in contact with the oocyte surface,** This contact results in **release of**: **lysosomal enzymes**from **cortical granules lining the plasma membrane of the oocyte.** These enzymes alter properties of the zona pellucida(**zona reaction**) to prevent sperm penetration and inactivate **species-specific receptor sites for spermatozoa on the zona surface**

6- Changes in oocyte in fertilization

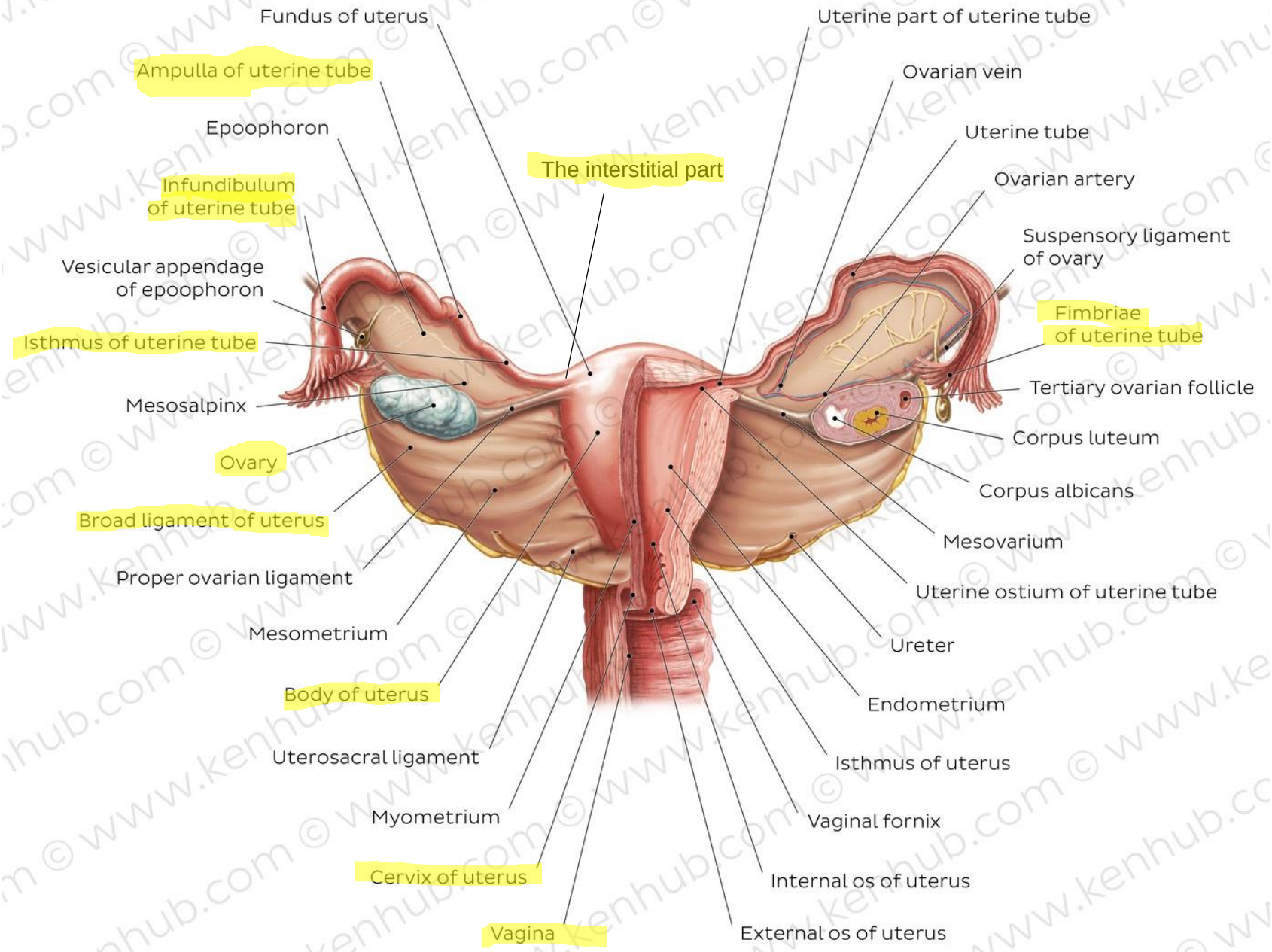
A) Cortical and zona reactions / B) Resumption of the second meiotic division/ C) Metabolic activation of the egg

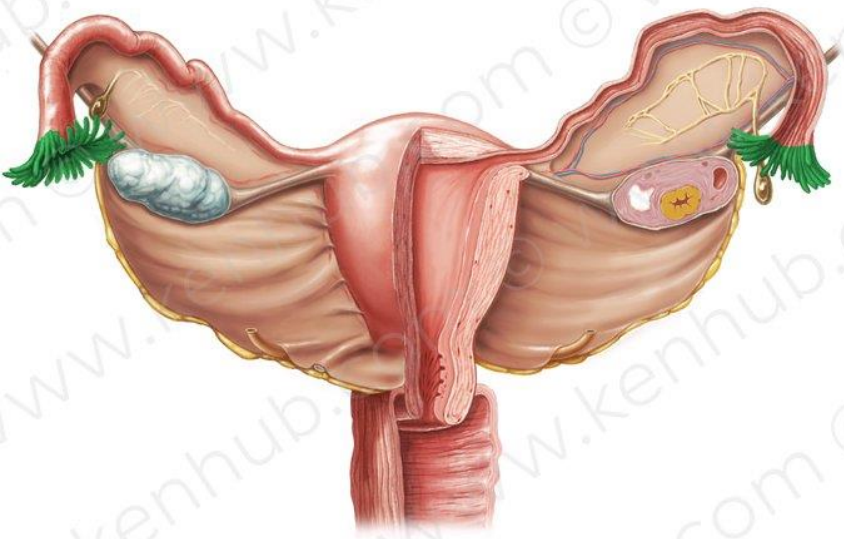
7- Result of fertilization

Restoration of the diploid number of chromosomes/ Determination of the sex of the new individual/ Initiation of cleavage

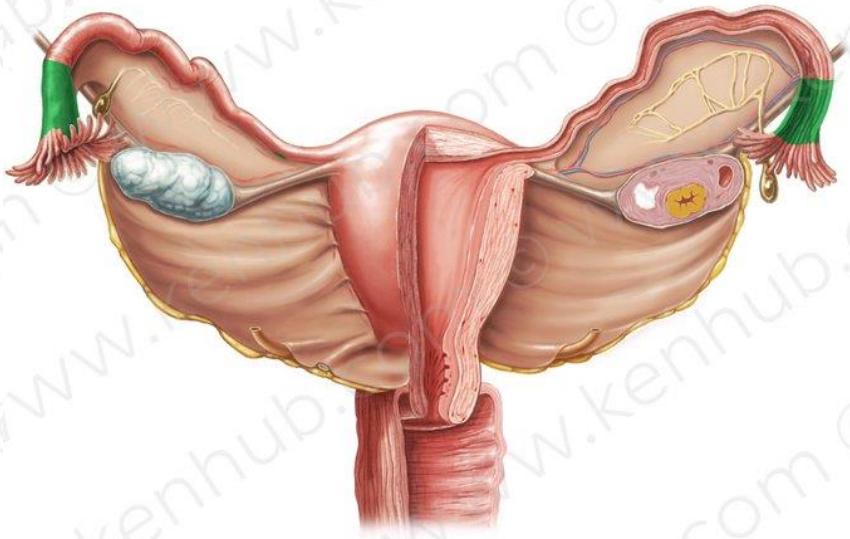
8- summary of oogenesis

1- Parts of female reproductive system

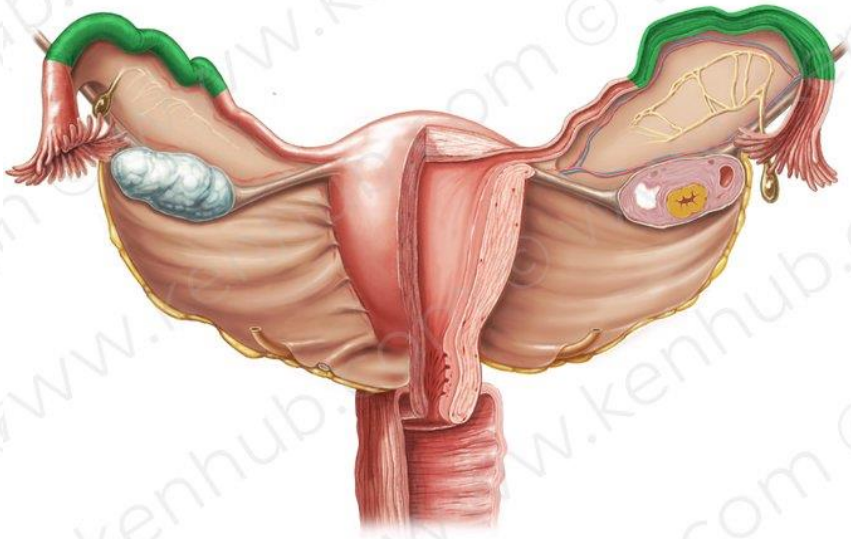




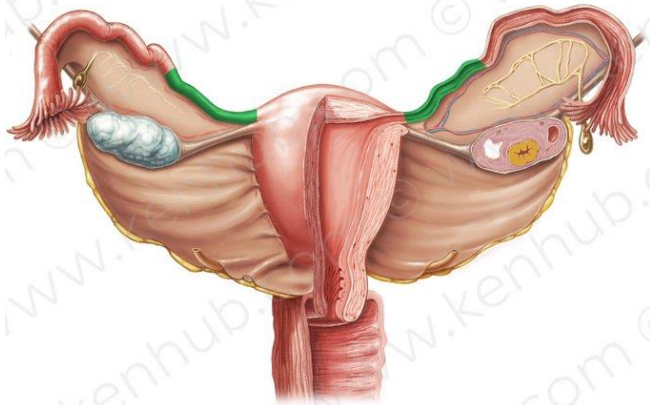
Fimbria (part of infundibulum)



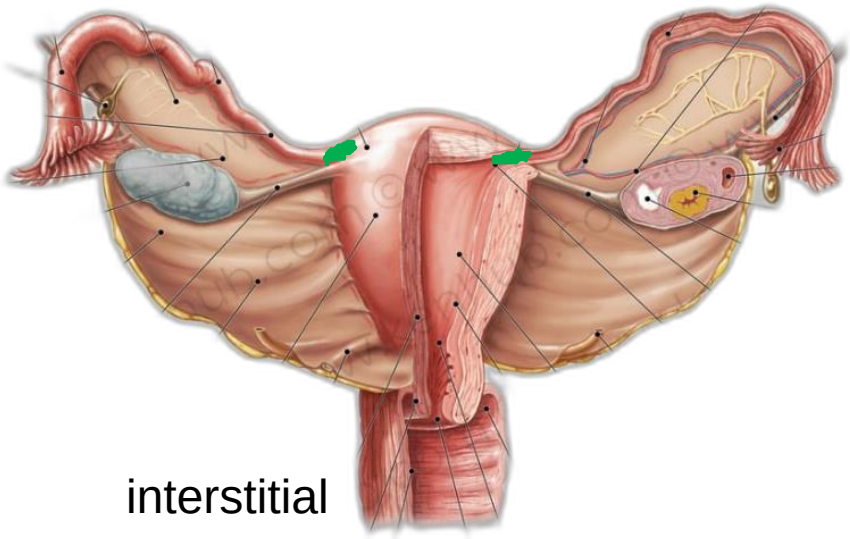
infundibulum



ampulla



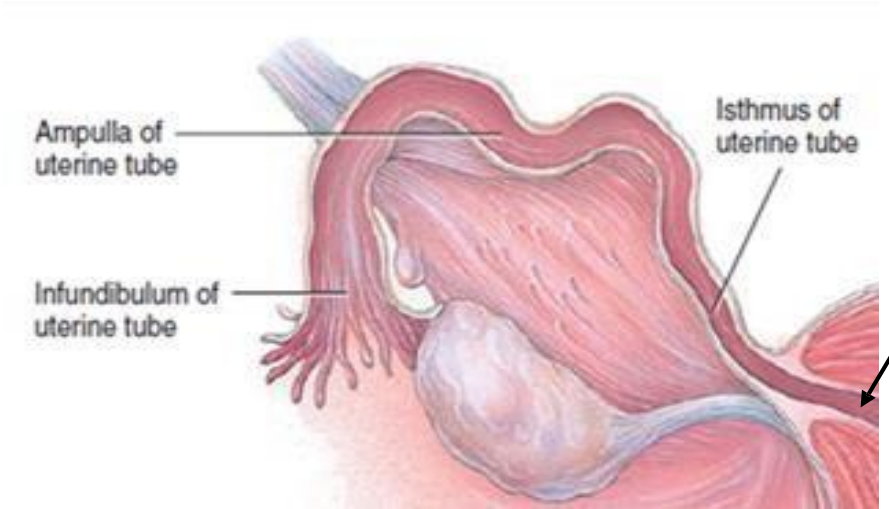
isthmus

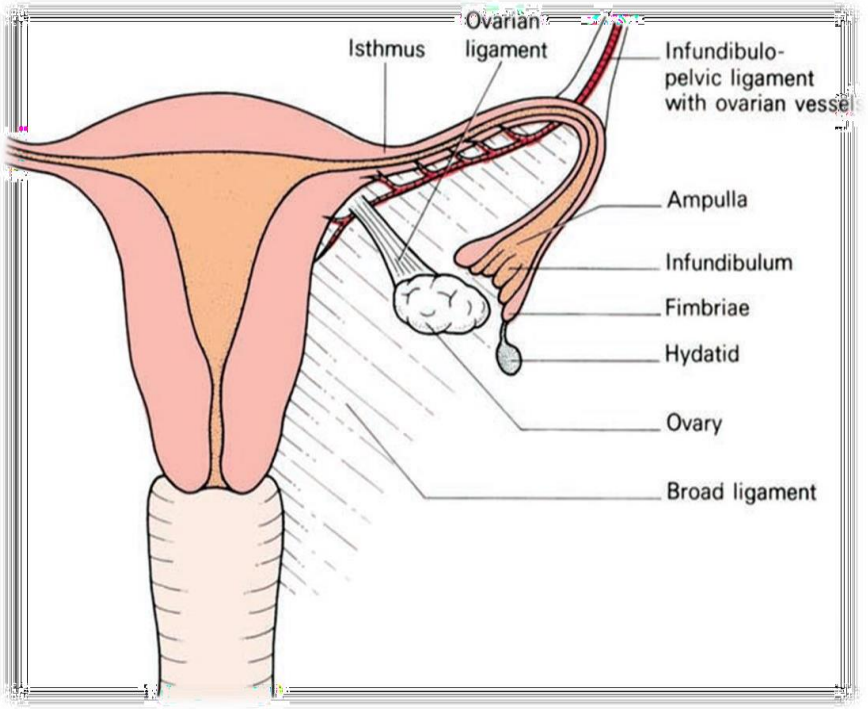


interstitial

1- Parts of female reproductive system

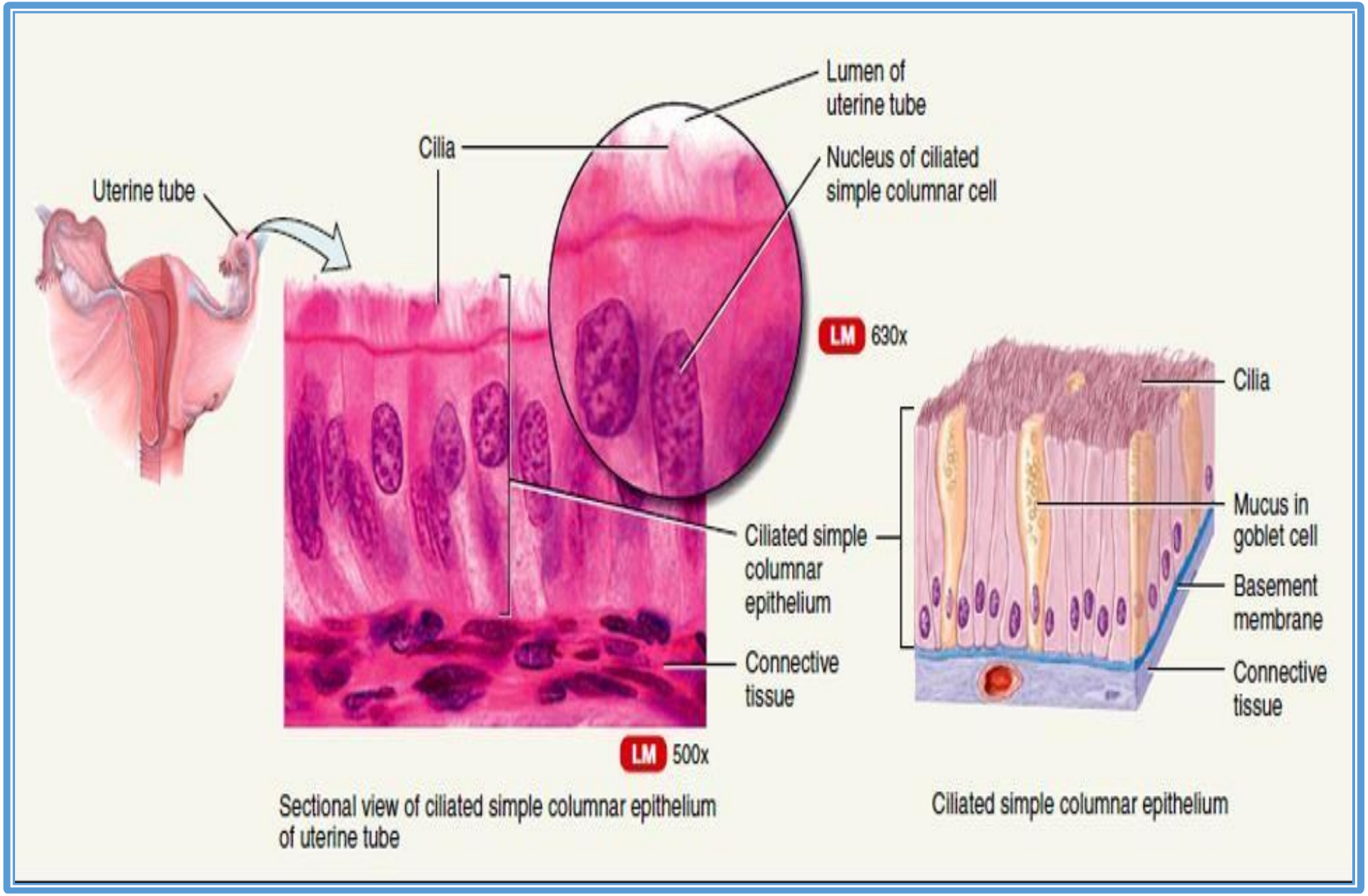
- The uterine tubes (Fallopian) or oviducts are about 4 in (10 cm) long
- they lie in the *free edge of the broad ligaments*
- open into the *cornu of the uterus*.
- They provide
  1- a route for sperm to reach an ovum
  2- Transport secondary oocytes and fertilized ova (*the dividing zygote*) from the ovaries to the uterus.
- Each comprises four parts:
  1-The infundibulum : the bugle-shaped extremity extending beyond the broad ligament and opening into the peritoneal cavity by the ostium. Its mouth is fimbriated and overlies the ovary, to which one long fimbria actually adheres (fimbria ovarica)
  2-The ampulla: wide, thin-walled and tortuous.
  3-The isthmus: narrow, straight and thick-walled.
  4-The interstitial part: which pierces the uterine wall





Structure/Histology of the oviduct

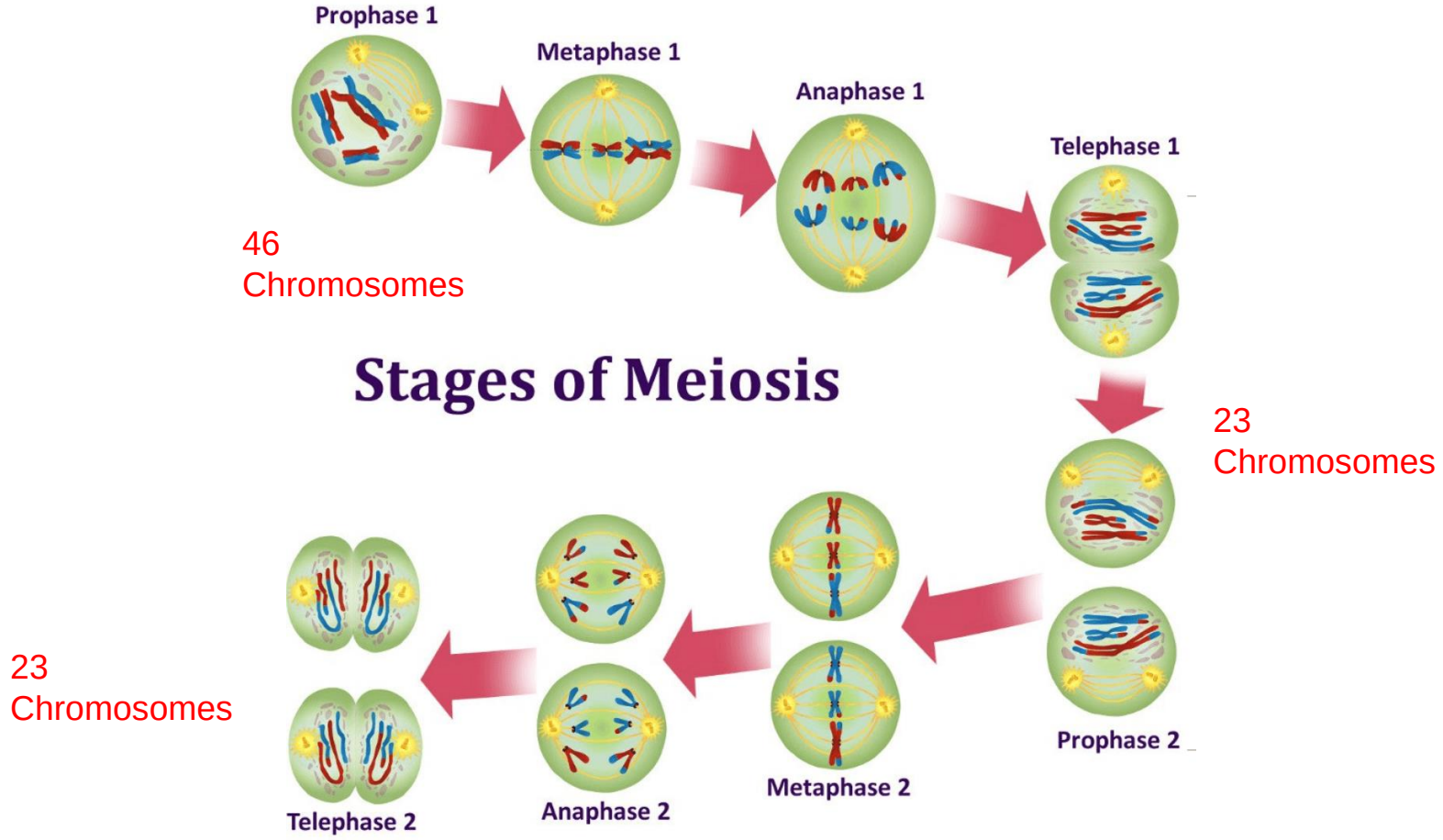
The mucosa is formed of ***columnar,*** mainly ***ciliated cells*** The ova are propelled to the uterus along this tube, partly by ***peristalsis because of the smooth muscle cells and partly by cilial action***



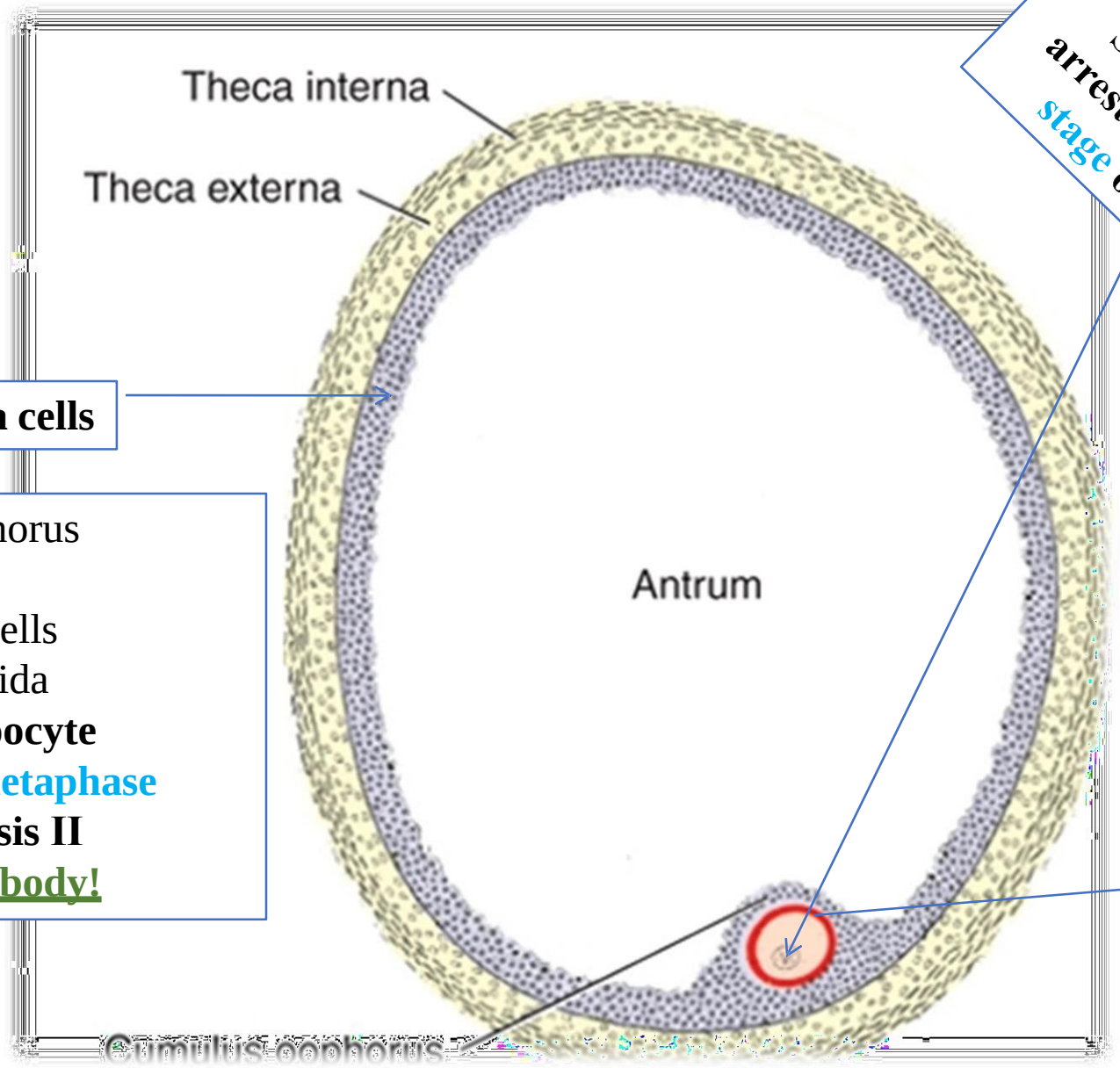
2- Process of ovulation

JUST REMEMBER!

- Remember : the primordial follicle under the influence of FSH it becomes primary follicle (Contains a primary oocyte that is arrested in the prophase of meiosis 1) and this primary follicle becomes secondary follicle and under the influence of LH (luteinizing hormone) it would become a tertiary follicle also called graafian follicle (Preovulatory follicle)



Important slide!



Secondary oocyte arrested in metaphase stage of meiosis II

Granulosa cells

Cumulus oophorus
Consists of:
1 Granulosa cells
2 Zona pellucida
3Secondary oocyte arrested in metaphase stage of meiosis II
4 **First polar body!**

Zona pellucida

PREOVULATORY FOLLICLE To **OVULATION**

secreted from the anterior lobe of the pituitary gland

(LH) increases

The surface of ovary bulges locally

Digestion of collagen around the follicle

Local muscular contraction In ovarian wall

All this will help in extruding

The cumulus Oophours

BREAK FREE (ovulation) and float out of the ovary

Cumulus oophorus

Consists of:

1 Granulosa cells

2 Zona pellucida

3Secondary oocyte arrested in metaphase stage of meiosis II

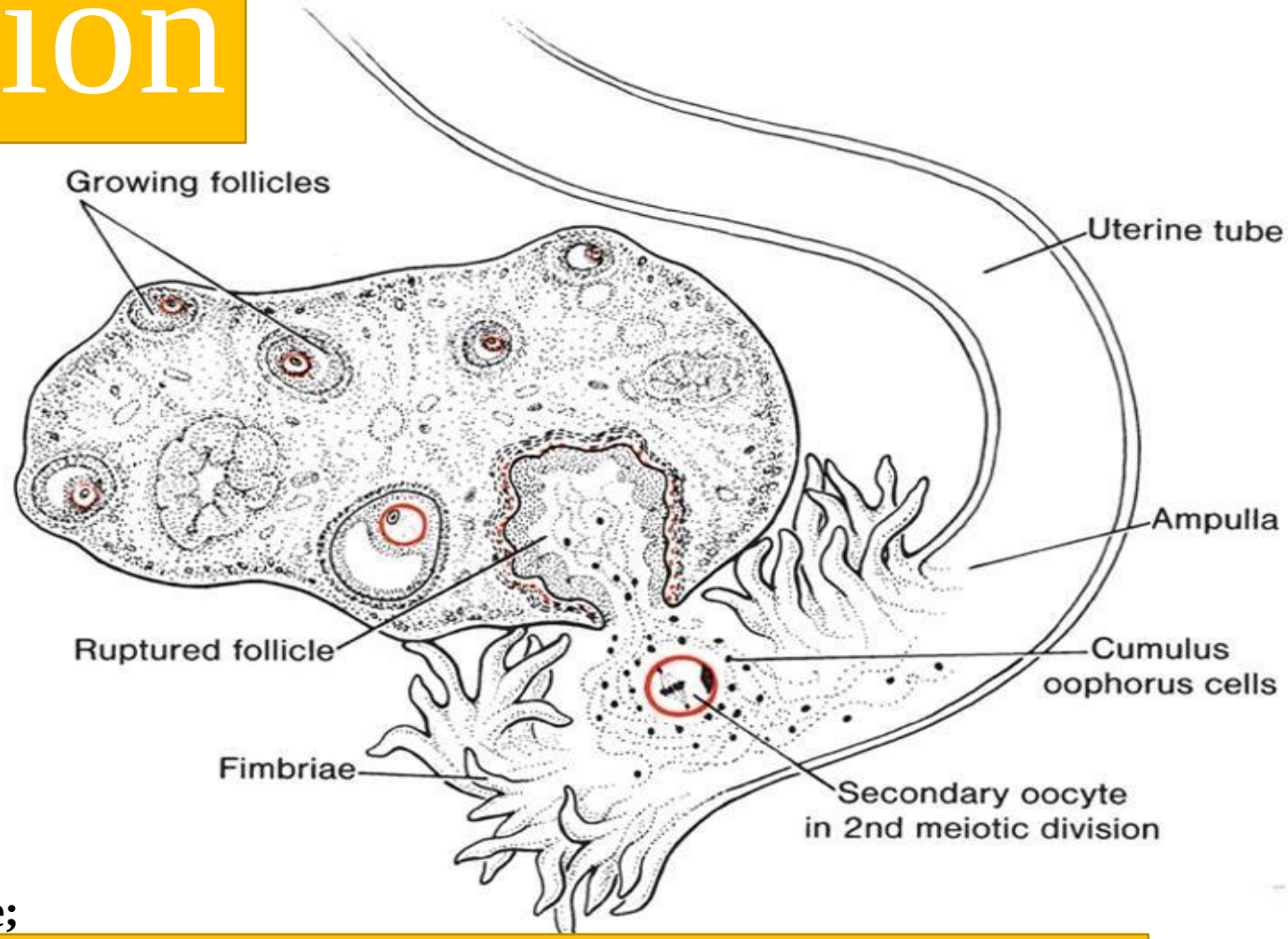
4 First polar body!

Notice that only the **cumulus oophorus** is ovulated from the Preovulatory Follicle (Graafian Follicle)

Ovulation

Day 14 of a 28 days menstrual cycle

Or mid-cycle in other normal Cycles (not 28 days)



Note;

From the region of *cumulus oophorus* the oocyte with its surrounding granulosa cells breaks free (Ovulation), leaving behind them the theca interna , externa and granulosa cells

Cumulus oophorus

Consists of:

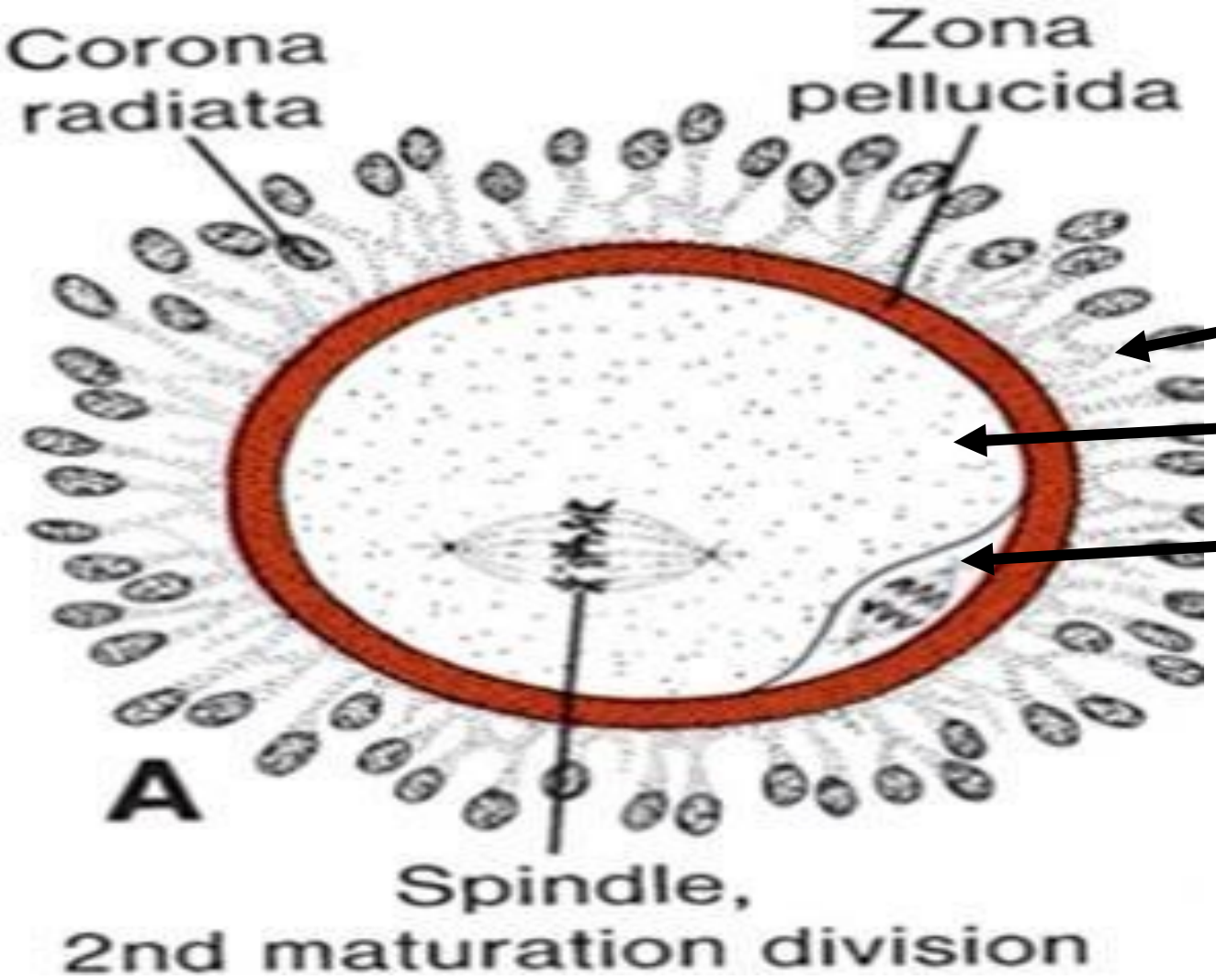
1-Granulosa cells

2-Zona pellucida

3Secondary oocyte arrested in metaphase stage of meiosis II

4 First polar body!

Some of the granulosa cells will arrange themselves around the zona pellucida to form Corona radiata



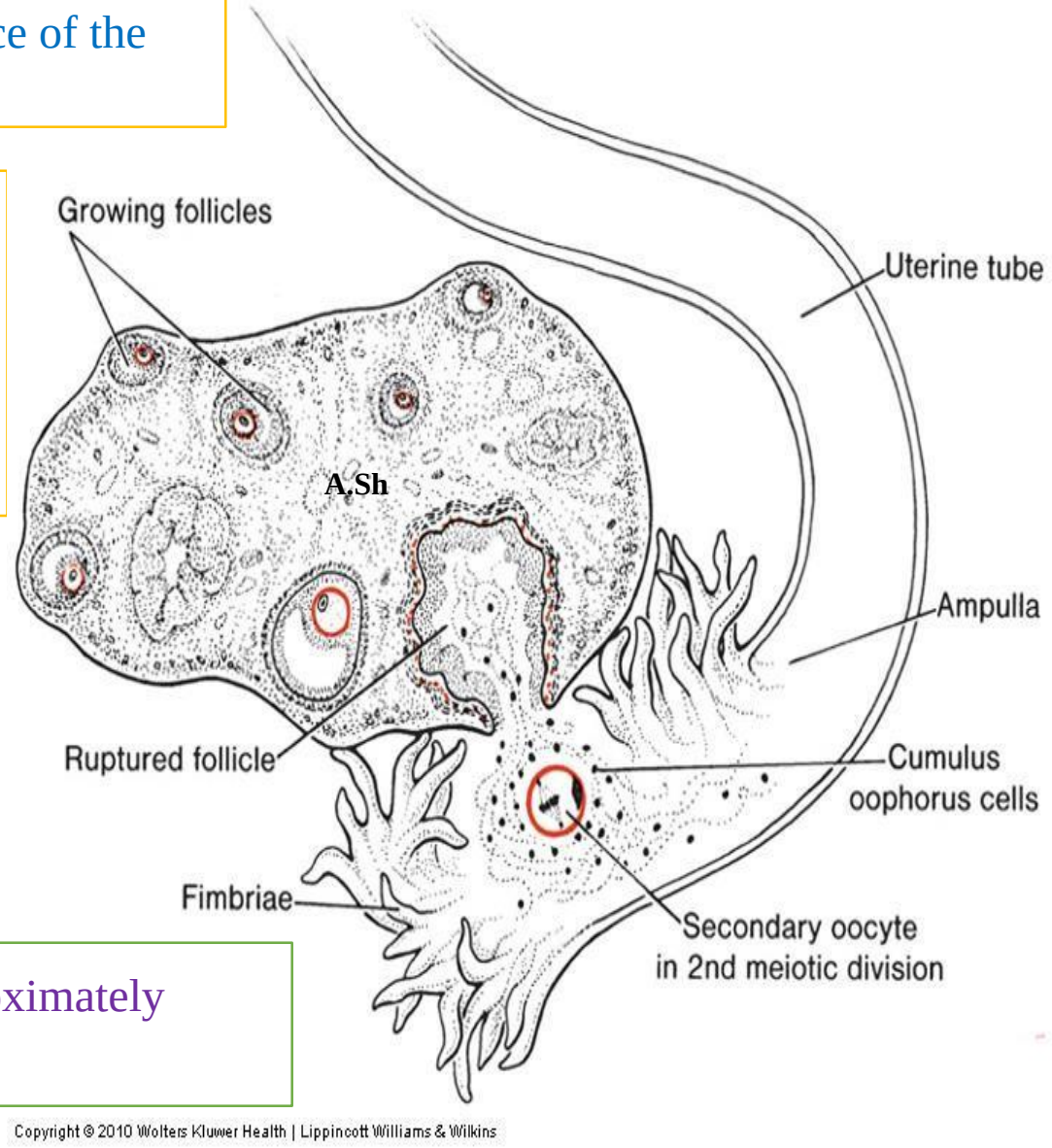
1 Granulosa cells (Corona radiata)
2 Zona pellucida
3Secondary oocyte arrested in metaphase stage of meiosis II
4-First polar body!

- **Before ovulation, fimbriae** of the uterine tube **sweep over** the surface of the ovary, and the tube itself begins to **contract rhythmically**

Oocyte Transport

- These **sweeping movements** of the fimbriae and **motion of cilia** on the epithelial lining **carry** the oocyte to the uterine tube

Once the oocyte is in the uterine tube, it is **propelled by peristaltic muscular contractions** of the tube and **by cilia in the tubal mucosa**



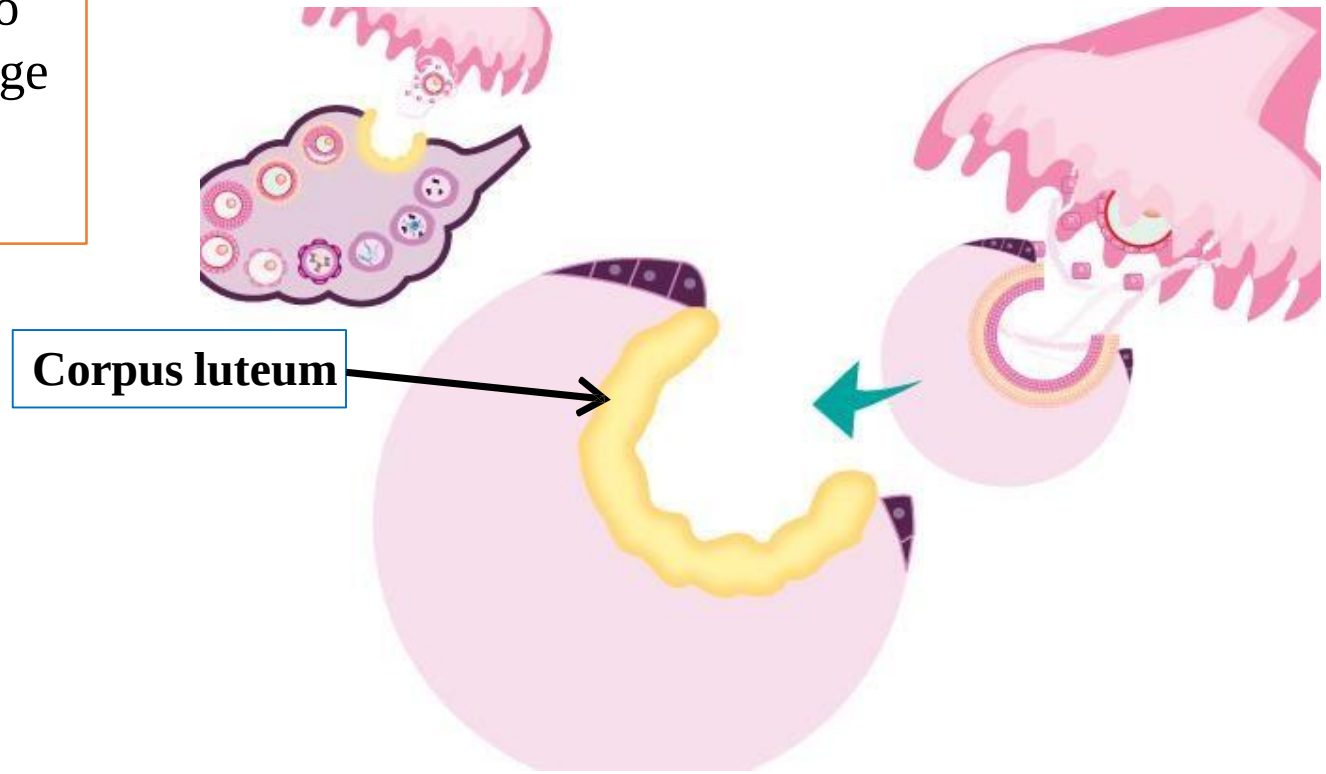
- In humans, the fertilized oocyte reaches the uterine lumen in approximately **3 to 4 day**.

3- Corpus luteum

CORPUS LUTEUM

After ovulation, granulosa cells remaining in the wall of the ruptured follicle, together with cells from the theca interna, are vascularized by surrounding vessels. Under the influence of LH, these cells develop a yellowish pigment and change into lutein cells, which form the corpus luteum and secrete estrogens and progesterone

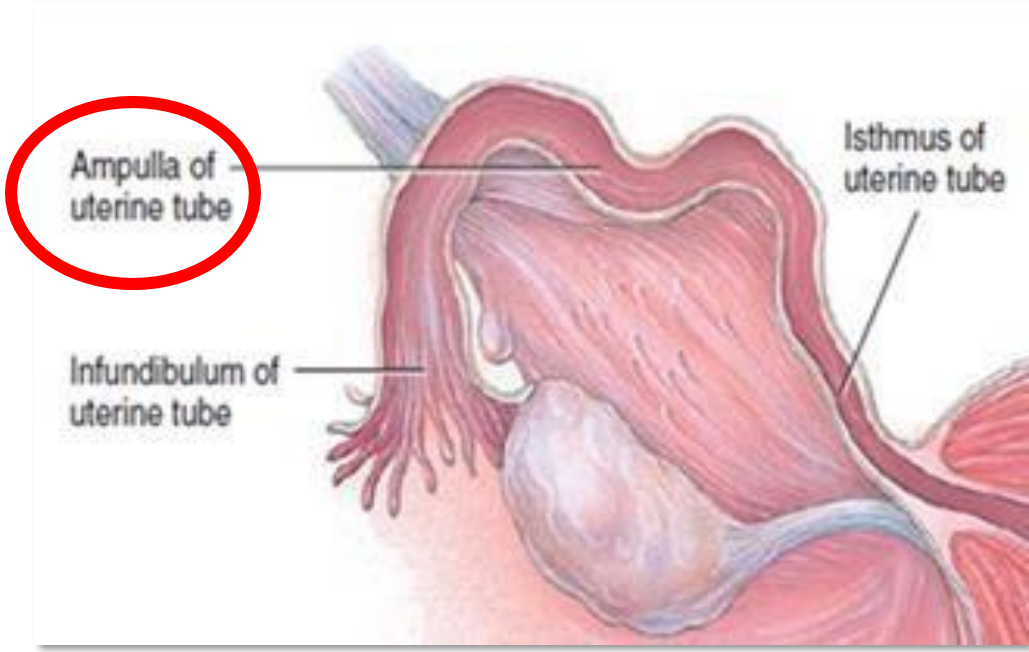
Progesterone, together with some **estrogen**, causes the uterine mucosa to enter the progestational or secretory stage in preparation for implantation of the embryo.



4- Fertilization

Fertilization

A process by which haploid male gamete fuse with female gamete to give single diploid nucleus.



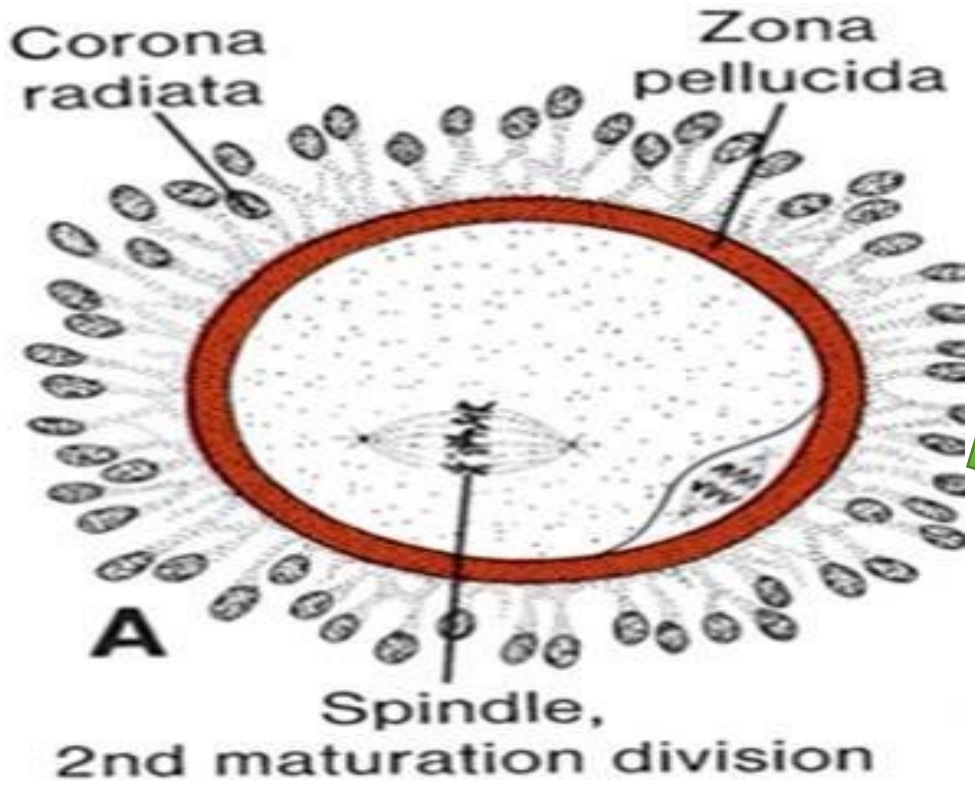
- Occurs **in the ampullary region** of the **uterine tube**.
- This is the widest part of the tube and is close to the ovary.

- Spermatozoa may remain **viable** in the **female reproductive tract for several days**!!!!!!!

- **Only 1% of sperm** deposited in the vagina **enter the cervix**, where they may survive for **many hours.** .
- The trip from cervix to oviduct requires a minimum

of 2 to 7 hours.

SO …..WHAT WE HAVE BEFORE FERTILIZATION



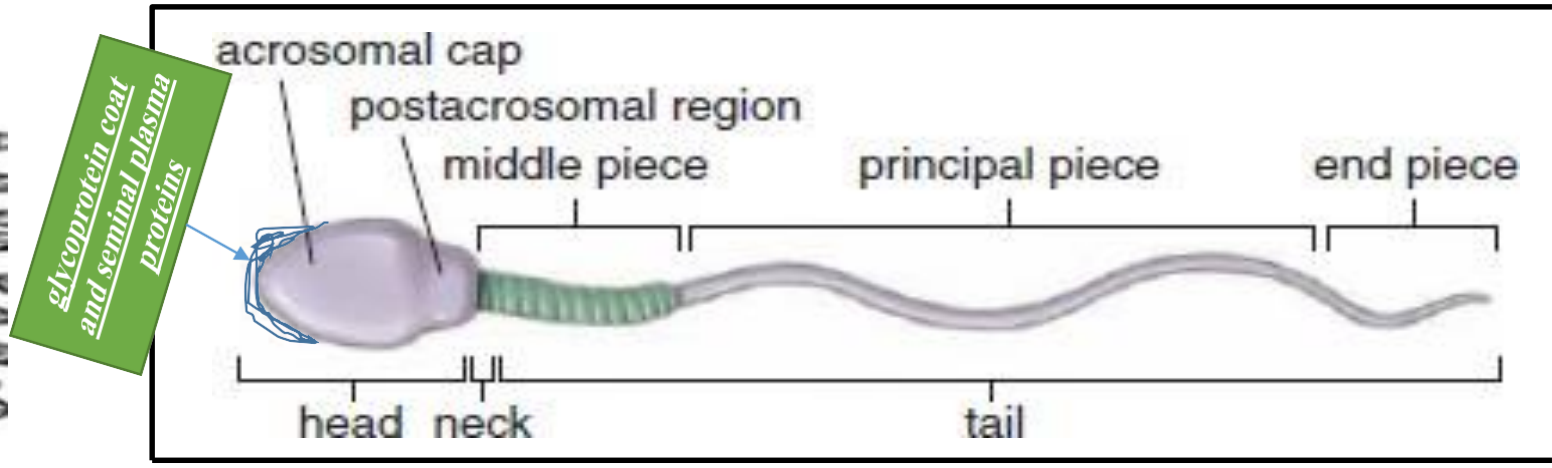
An ovulated egg Made of:

1 **Secondary oocyte arrested in metaphase stage of meiosis II**

2First polar body arrested in metaphase stage of meiosis II

3 **Zona pellucida**

4 **Corona radiata**



A Sperm

that carries **23 chromosomes**

and an **acrosome**

Is it arrested at any stage???!! no

But it has !!!!!!!!!

glycoprotein coat and seminal plasma proteins

They will prevent penetration through corona radita, what to do?

5- Changes in sperm in fertilization

- Spermatozoa are ***not able to fertilize*** the oocyte immediately upon arrival in the female genital tract but must undergo:

(1) Capacitation
(2) Acrosome reaction

1-Capacitation

- is a period of conditioning ***in the female reproductive tract***
- in the human **lasts approximately 7 hours**
- **It** Includes;

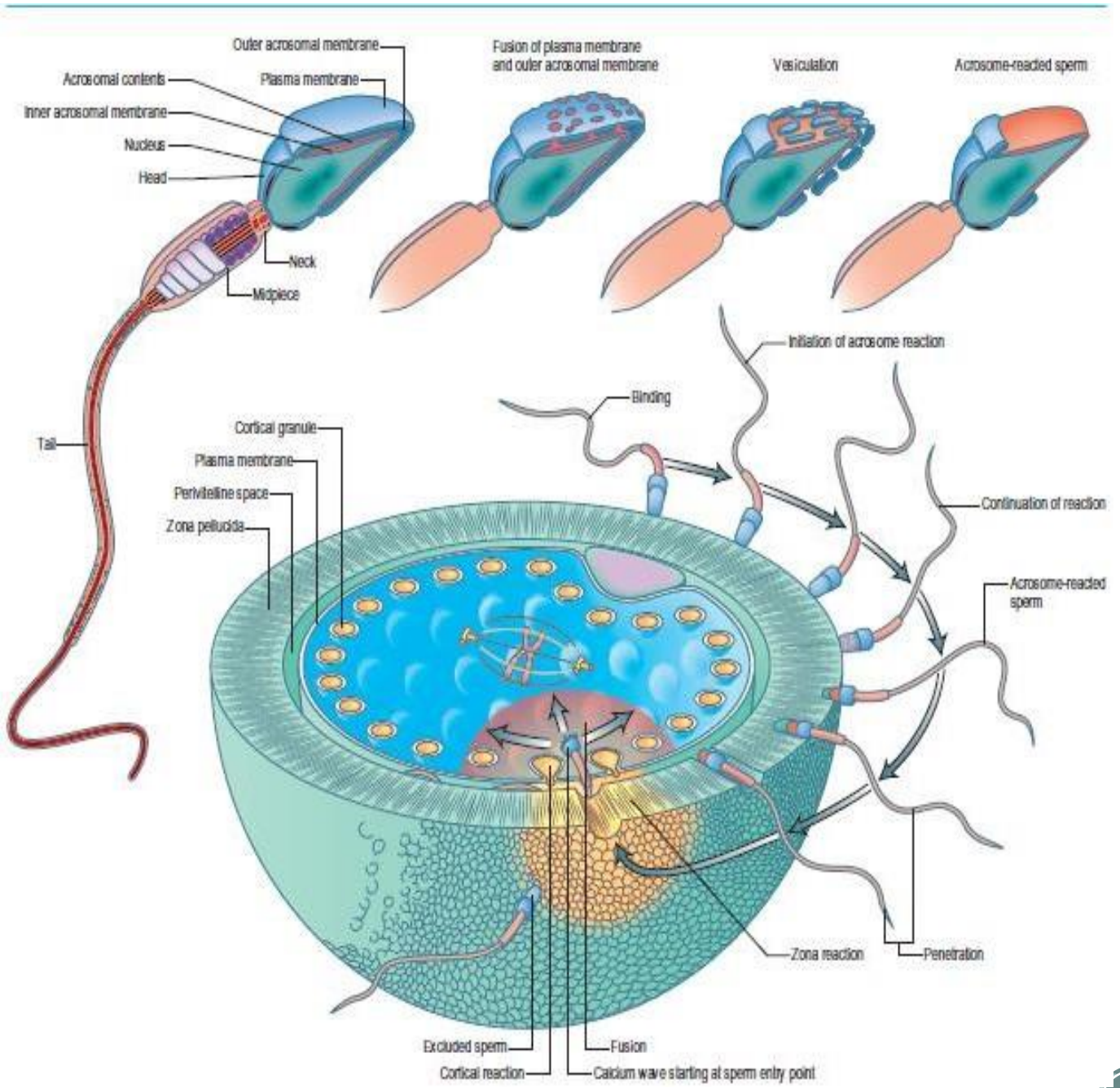
REMOVAL of the glycoprotein coat and seminal plasma proteins from the plasma membrane ***that overlies the acrosomal*** region of the spermatozoa.

Only capacitated sperm can pass through the corona cells and undergo the acrosome reaction.

so if I asked you how this sperm passes corona radiata the answer should be by capacitation only

➢ The acrosome reaction

Occurs after binding to **the zona pellucida**, is induced by zona proteins. Includes the release of **enzymes** needed to penetrate the zona pellucida, **including acrosin- and trypsin-like substances**



The phases of fertilization

Phase 1: Penetration of the Corona Radiata

Capacitated sperm pass freely through **the corona radiata**

Phase 2: Penetration of the Zona Pellucida

The zona **is a glycoprotein shell surrounding** the egg that **facilitates and maintains** sperm **binding** and induces **the acrosome reaction.**

FROM THE SPERM

- Both binding and the acrosome reaction are mediated by the **ligand ZP3, a zona protein**
- **Release of acrosomal enzymes** (acrosin) allows sperm to penetrate the zona.
- Permeability of the zona pellucida changes when **the head of the sperm comes in contact with the oocyte surface,** This contact results in **release of**:

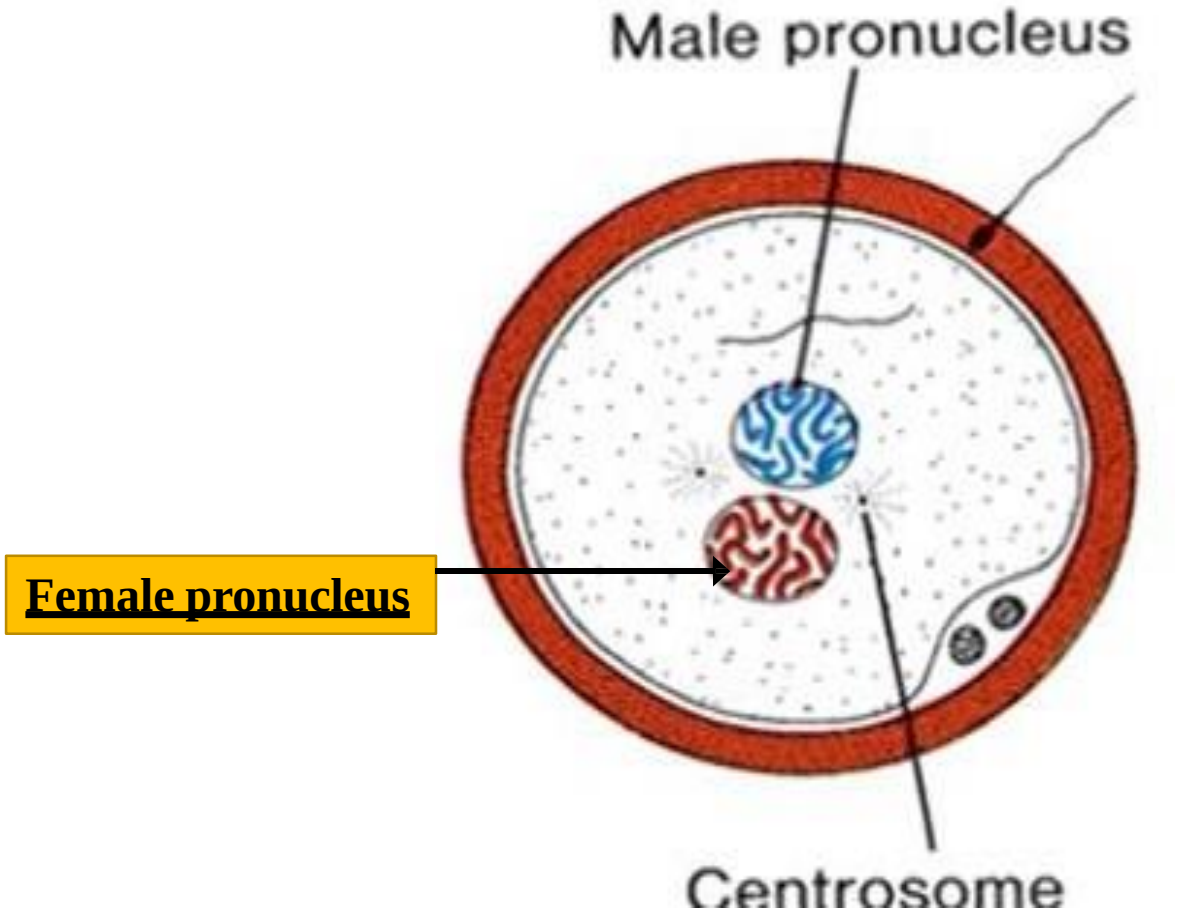
FROM THE OOCYTE

lysosomal enzymes from **cortical granules lining the plasma membrane of the oocyte.**

- These enzymes alter properties of the zona pellucida(**zona reaction**) to prevent sperm penetration and inactivate **species-specific receptor sites for spermatozoa on the zona surface**

Phase 3: Fusion of the Oocyte and Sperm Cell Membranes.

Actual fusion between the oocyte membrane and the membrane that covers the sperm head is
accomplished at the acrosomal reaction
when the plasma membrane covering the head cap disappears during the acrosome reaction.



6- Changes in oocyte in fertilization

The egg responses to the entrance of the spermatozoon in three ways:

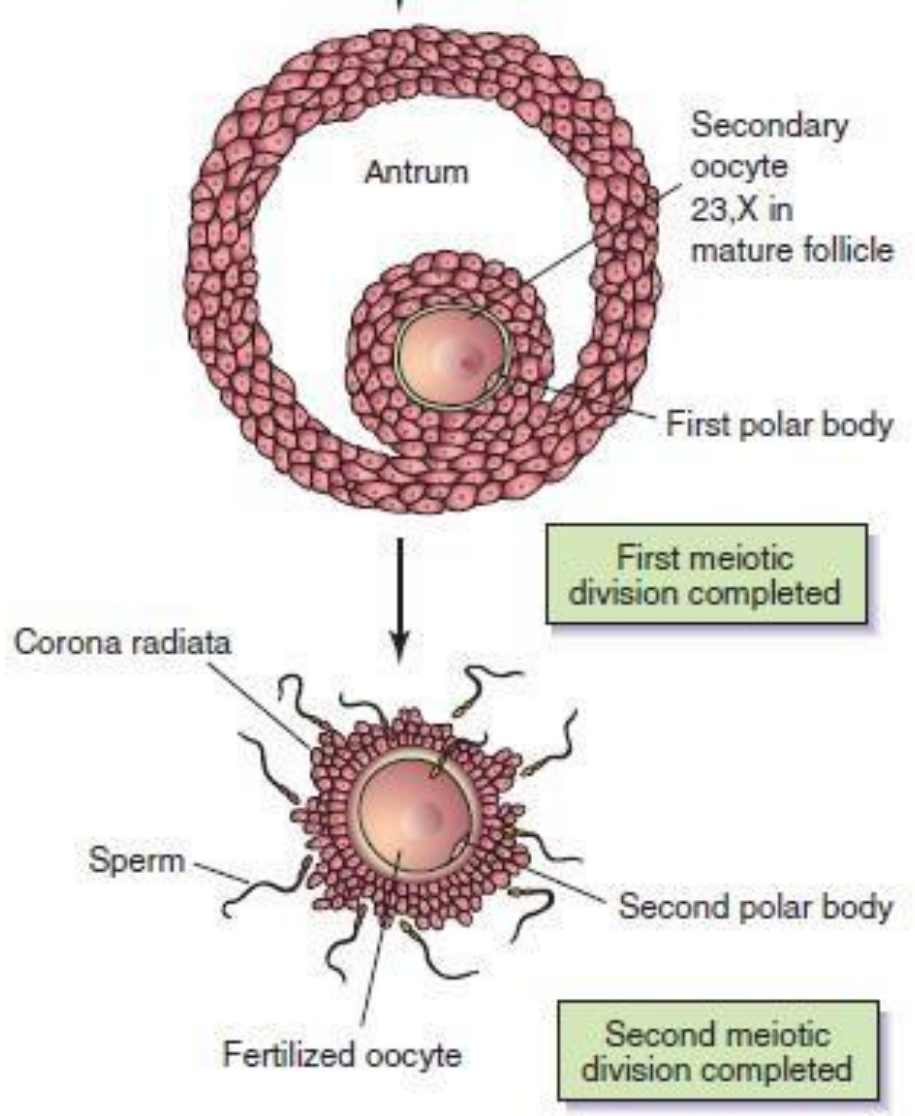
A) Cortical and zona reactions

As a result of the release of cortical oocyte granules

(1) The oocyte membrane becomes **impenetrable** to other spermatozoa.
(2)the zona pellucida alters its structure and composition to prevent **sperm binding and penetration**. These reactions prevent **polyspermy** (penetration of more than one spermatozoon into the oocyte

B) Resumption of the second meiotic division

➢The oocyte **finishes its second meiotic division.**



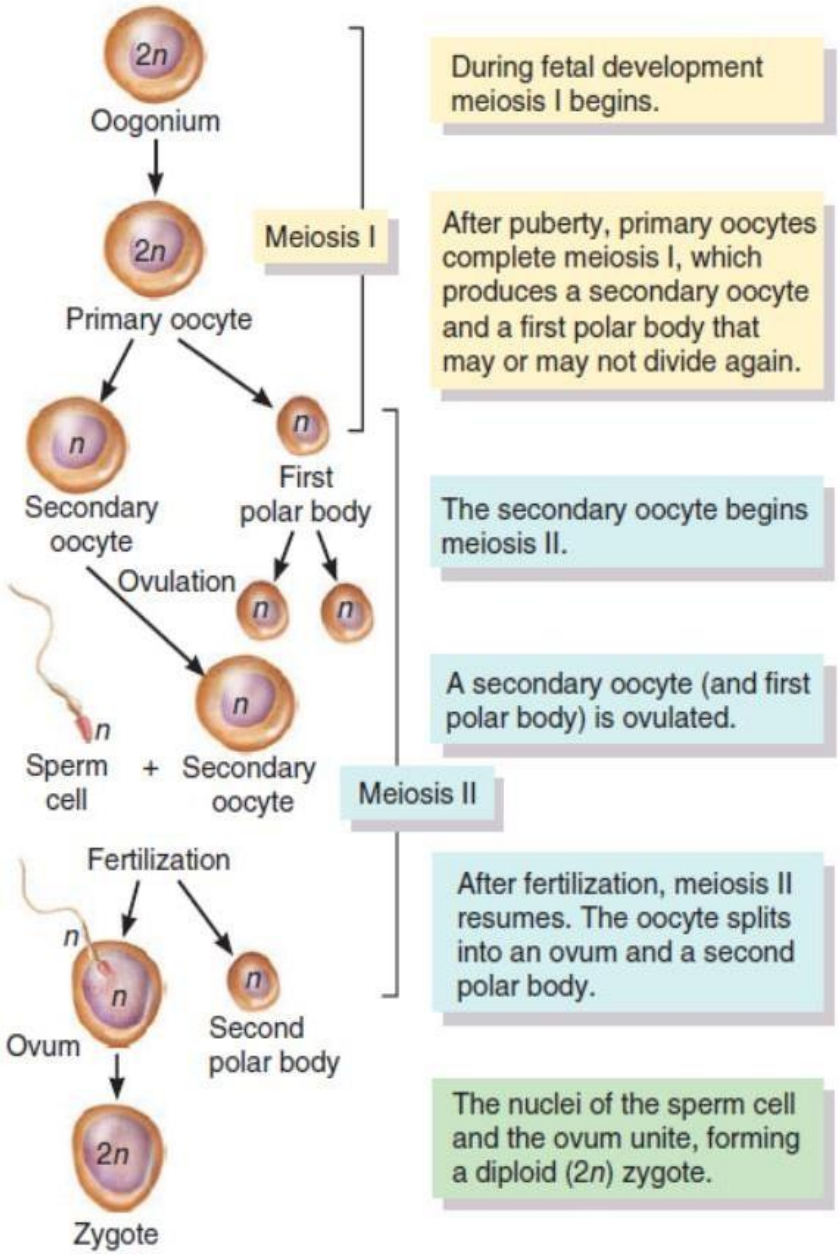
➢One of the daughter cells, receives hardly any cytoplasm, is known as the **second polar body**; the other daughter cell is the definitive oocyte (fertilized egg).

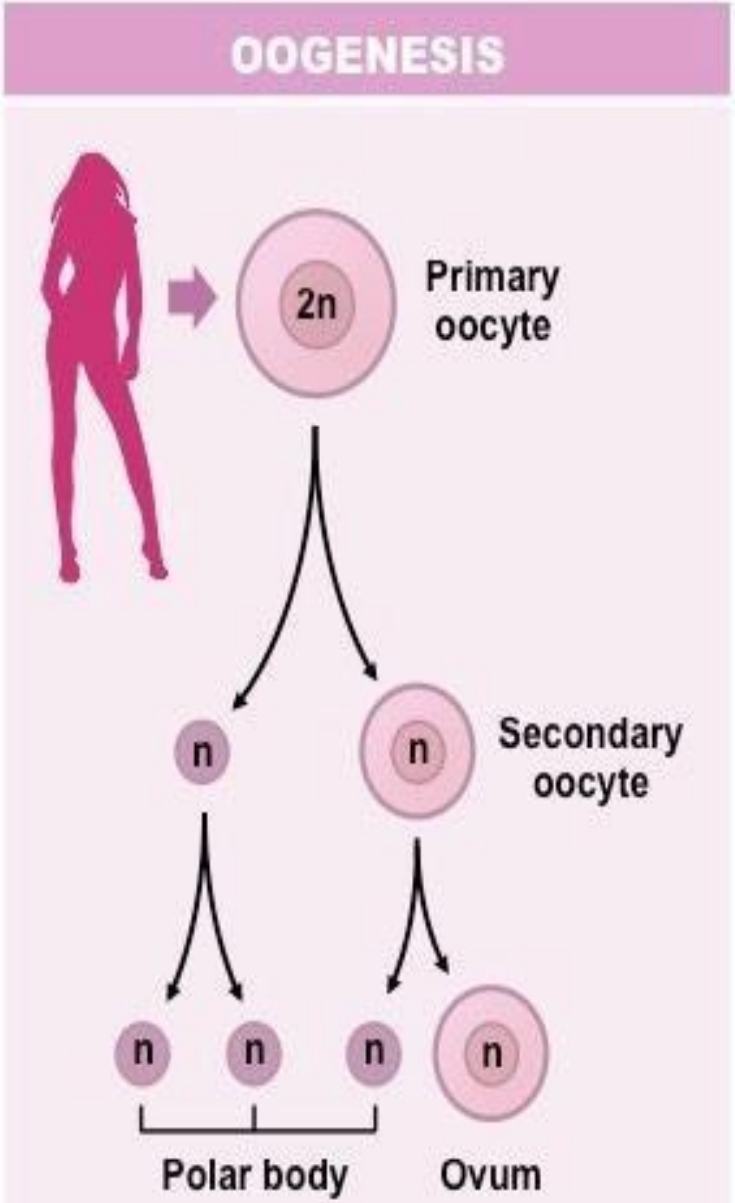
➢ Its chromosomes **(22plus X)** arrange themselves in a vesicular nucleus known as the **female pronucleus**.

➢The spermatozoon, meanwhile, moves forward until it lies close to the female pronucleus. Its nucleus becomes swollen and forms the **male pronucleus**.

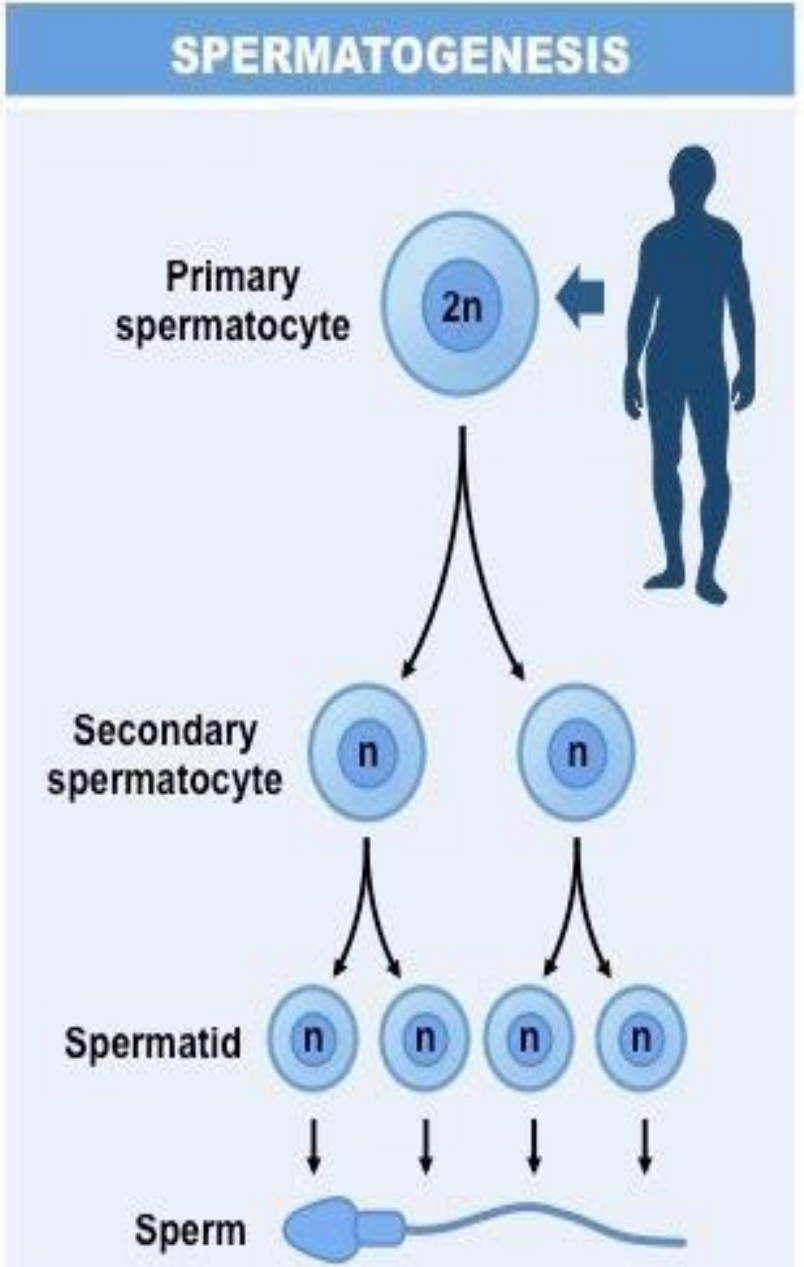
➢Number of secondary polar bodies can be 1 or three (if the primary polar body divided)

Only now the oogenesis of this oocyte has come to its end





DIFFERENT SIZE



SAME SIZE

C) Metabolic activation of the egg

- The activating factor is probably carried by the spermatozoon

- Activation encompasses the initial cellular and molecular events associated with early embryogenesis.

7- Result of fertilization

The main results of fertilization are as follows:

- ***Restoration of the diploid number of chromosomes***, half from the father and half from the mother. Hence, the zygote contains a new combination of chromosomes different from both parents.

- ***Determination of the sex of the new individual***.
An X-carrying sperm produces a female (XX) embryo, and a Y-carrying sperm produces a male (XY) embryo. Therefore, the chromosomal sex of the embryo is determined at fertilization

Initiation of cleavage (Division of the fertilized egg).
Without fertilization, the oocyte usually degenerates 24 hours after ovulation.

8- summary of oogenesis

OOGENESIS

- Primordial germ cells arrive in the indifferent gonad at week 4 and differentiate into oogonia.
- Oogonia enter meiosis I to form **primary oocytes**. All primary oocytes are formed by **month 5 of fetal life** and are **arrested the first time in prophase (diplotene) of meiosis I** and remain arrested until puberty.
- Primary oocyte arrested in meiosis I are present at birth.
- When a girl reaches puberty, during each monthly cycle a primary oocyte becomes unarrested and completes meiosis I to form a secondary oocyte and polar body.
- The secondary oocyte becomes **arrested the second time in metaphase of meiosis II** and is ovulated.
- At fertilization within the uterine tube, the secondary oocyte completes meiosis II to form a **mature oocyte** and **polar body.**