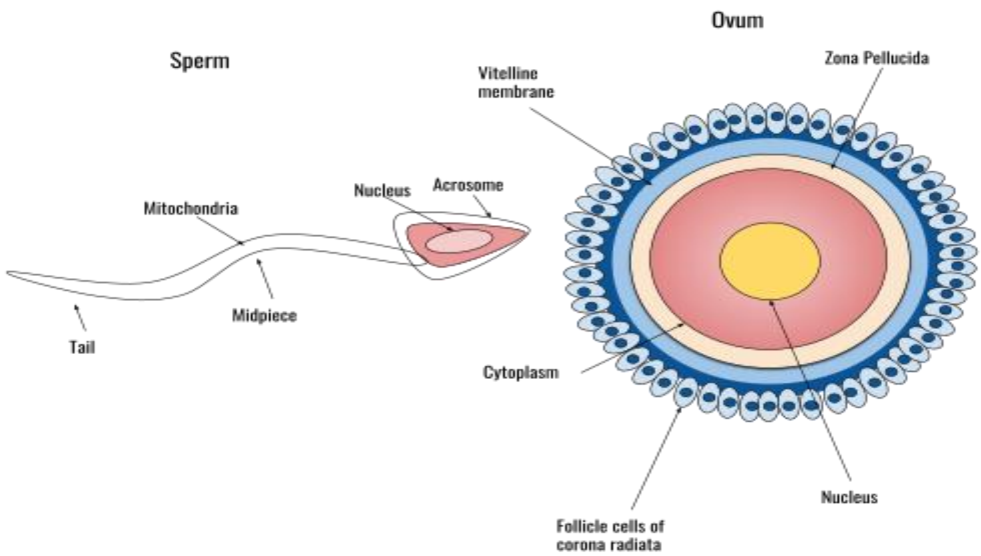
II. Gametogenesis

1. Gametogenesis

Gametogenesis is the biological mechanism by which gametes are formed in the organism. It produces Haploid cells from diploid cells. In mammals, this is known as oogenesis in females and Spermatogenesis in males. The cell division that takes place during gametogenesis and which changes the cell from diploid to haploid is called meiosis.

2. **Gametes:**

A gamete is a haploid reproductive cell that has completed meiosis and cytoplasmic differentiation. In humans, as in most animals, the female gametes are the ovum and the male gametes are the spermatozoa. The gamete-producing organs are called gonads, which are the ovaries in females and the testes in males.



Male and female gamete

I. Spermatogenesis (Male Gametogenesis)

This is the formation of spermatozoa in the male. It takes place in the seminiferous tubules of the testes.

- It is stimulated at puberty by pituitary hormones under the influence of the hypothalamus and by the hormones FSH and LH. Sperm is produced from stem cells (spermatogonia) and millions of sperm are synthesized every day.
- It is permanent and not cyclical like oogenesis.

The stages of spermatogenesis :

Spermatogenesis takes place in the seminiferous tubules and comprises three stages Fig.02.

I.1 The multiplication phase:

This concerns the spermatogonia, diploid stem cells located at the periphery of the tube, against the clean membrane. These cells undergo a succession of mitoses (maintenance of the spermatogonia pool), the last of which results in the formation of primary spermatocytes (spermatocyte I), also diploid.

I.2 The maturation phase:

This corresponds to meiosis and concerns both generations of spermatocytes (primary I or secondary II). A spermatocyte I with 2n chromosomes passes through the first division of meiosis to give 2 spermatocytes II with n chromosomes. Each spermatocyte II makes the second division of meiosis and gives 2 spermatids with n chromosomes. A spermatocyte I was therefore given 4 spermatids at the end of meiosis.

I.3. the differentiation phase: Also known as **spermiogenesis,** is the final stage of spermatogenesis (the process of sperm production), where the immature spermatids undergo a series of morphological changes to become mature, functional sperm cells (spermatozoa). This process primarily involves the transformation of spherical spermatids into streamlined, motile sperm cells capable of fertilizing an egg. Spermiogenesis does not involve cell division, but instead a series of structural changes.

Steps of Spermiogenesis:

1. Condensation of the Nucleus:

- The **nucleus** of the spermatid condenses and elongates to form the **head** of the sperm.
- The chromatin within the nucleus becomes tightly packed, which helps in reducing the size and increasing the density of the genetic material for efficient delivery to the egg during fertilization.

2. Acrosome Formation:

- The **acrosome**, a cap-like structure, forms over the anterior half of the sperm's head. It is derived from the **Golgi apparatus** and contains enzymes that are essential for penetrating the outer layers of the egg during fertilization (e.g., hyaluronidase and acrosin).
- The acrosome helps the sperm "digest" its way through the egg's protective layers during fertilization.

3. Midpiece Development:

- The **midpiece** of the sperm develops next. It contains a large number of **mitochondria**, which provide the energy required for the sperm's motility as it swims toward the egg.
- The mitochondria gather around the **axoneme** (the core structure of the sperm's tail) and generate ATP, which powers the sperm's movement.

4. Formation of the Tail (Flagellum):

- The **tail** (or **flagellum**) forms from the **microtubules** of the cytoskeleton and extends from the posterior part of the spermatid.
- The tail is responsible for the sperm's movement, allowing it to swim toward the egg. The tail's structure is composed of the **axoneme**, a central core of microtubules surrounded by a plasma membrane.

5. Loss of Excess Cytoplasm:

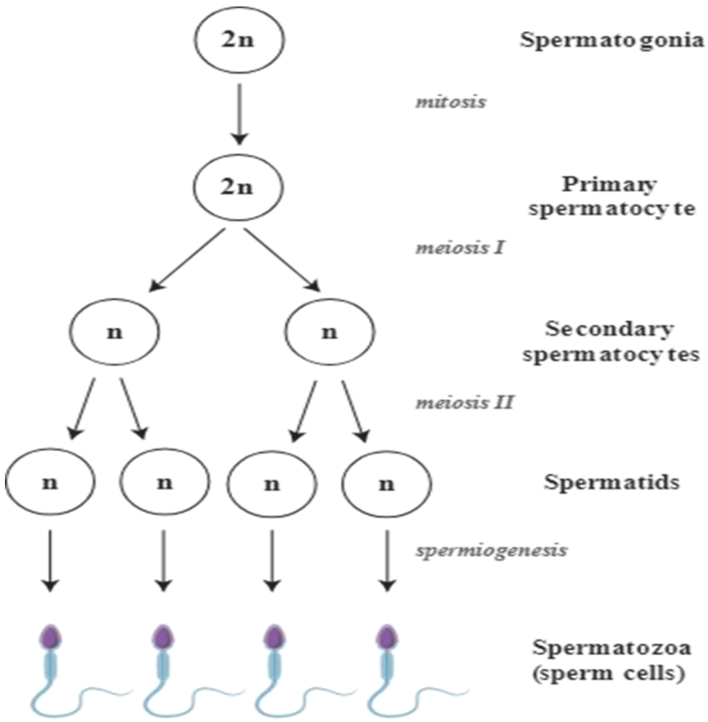
- As the spermatid undergoes transformation into a spermatozoon, it sheds most of its cytoplasm. This results in the sperm becoming more streamlined and efficient for motility.
- The excess cytoplasm is phagocytosed by **Sertoli cells**, which are supportive cells in the testes.

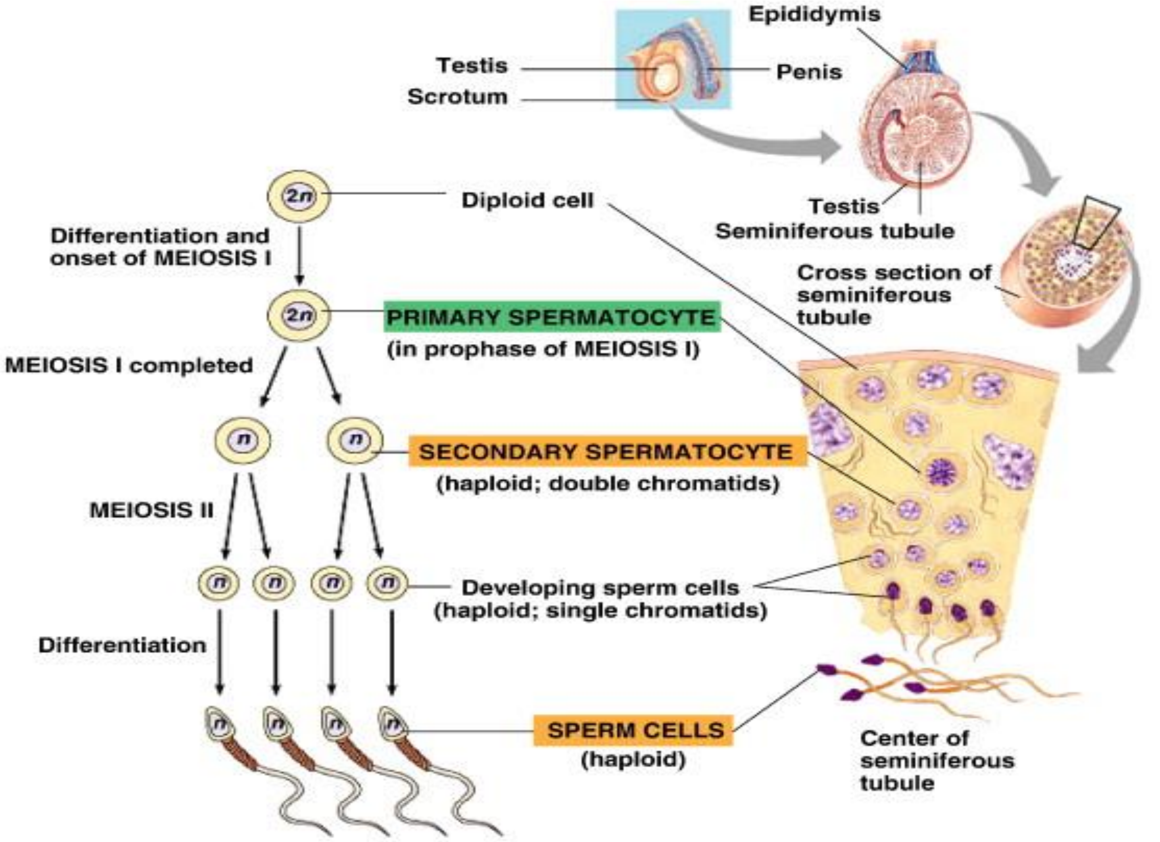
6. Mature Sperm Structure:

- The final result of spermiogenesis is a mature **spermatozoon**, which consists of three main parts:

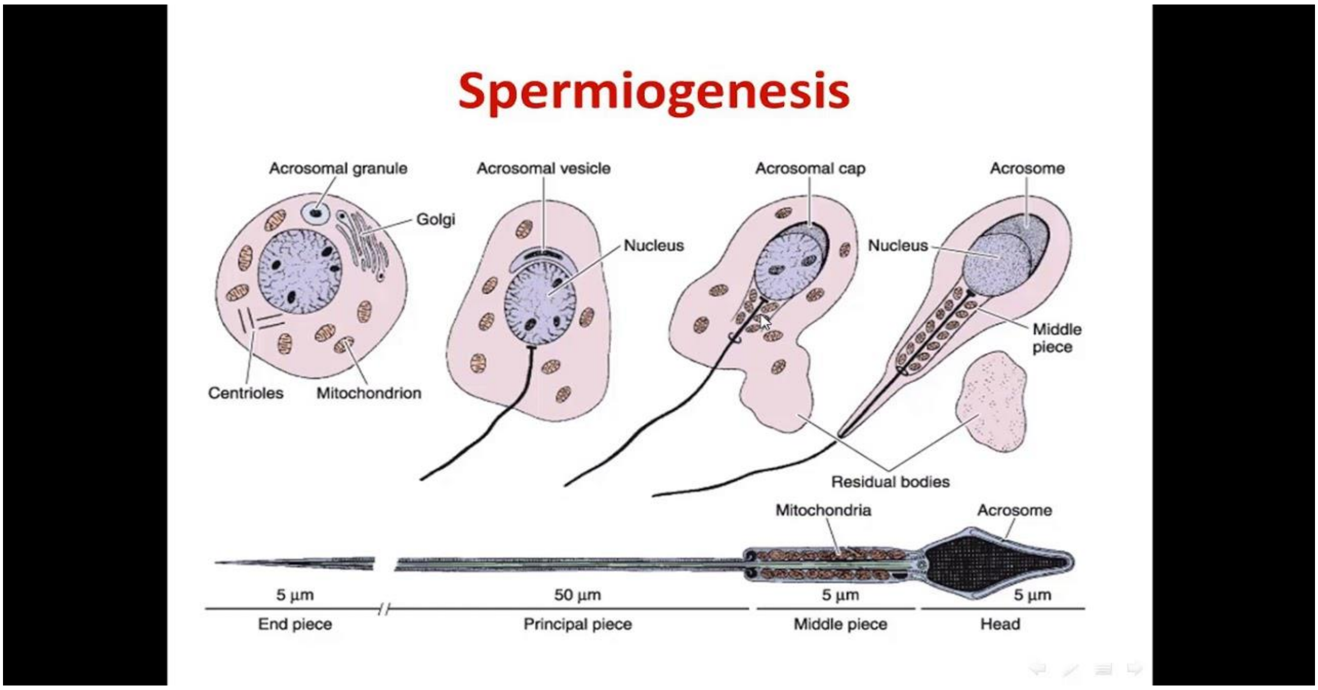
1. **Head**: Contains the tightly packed nucleus and acrosome, which carries the enzymes necessary for fertilization.
2. **Midpiece**: Packed with mitochondria to produce energy for movement.
3. **Tail (Flagellum)**: A long, whip-like structure that propels the sperm toward the egg.

- Spermatids elongate and develop a tail (flagellum) for motility.
- The nucleus becomes condensed and forms the head of the sperm.
- The mitochondria gather in the midpiece to provide energy for swimming.

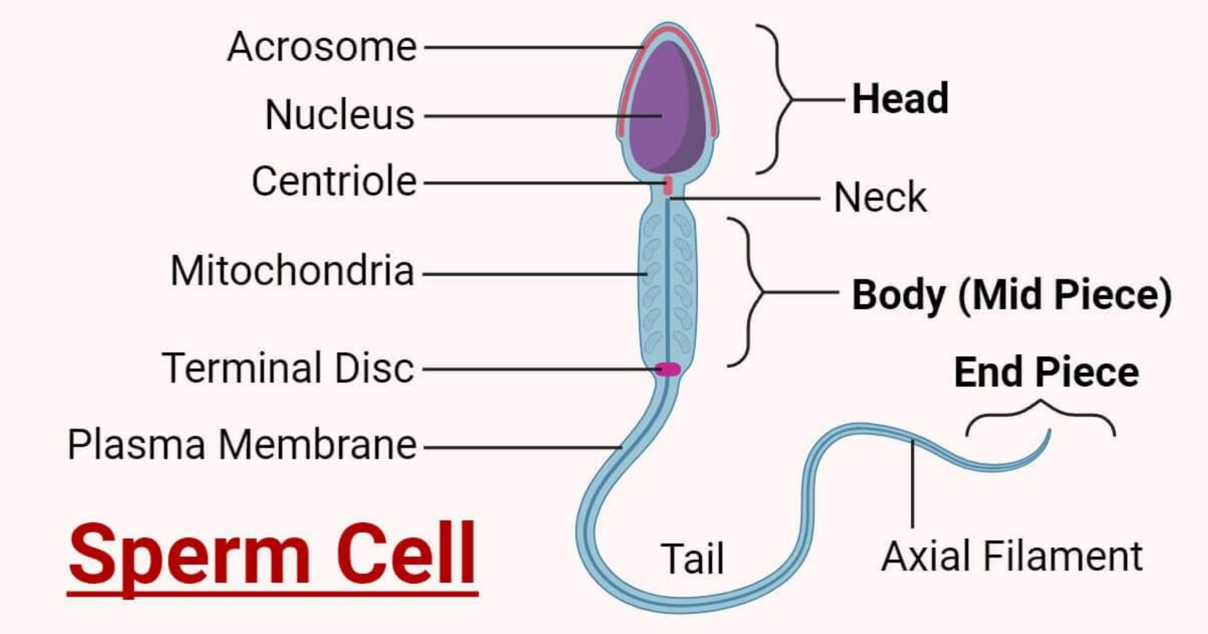




Epididymis
Testis
Penis
Scrotum
Diploid cell
Testis
Seminiferous tubule
Differentiation and onset of MEIOSIS I
Cross section of seminiferous tubule
PRIMARY SPERMATOCYTE
(in prophase of MEIOSIS I)
MEIOSIS I completed
SECONDARY SPERMATOCYTE
(haploid; double chromatids)
MEIOSIS II
Developing sperm cells
(haploid; single chromatids)
Differentiation
SPERM CELLS
(haploid)
Center of seminiferous tubule
2n
n



Spermiogenesis
Acrosomal granule
Golgi
Centrioles
Mitochondrion
Acrosomal vesicle
Nucleus
Acrosomal cap
Acrosome
Nucleus
Middle piece
Residual bodies
Mitochondria
Acrosome
5 μm
50 μm
5 μm
5 μm
End piece
Principal piece
Middle piece
Head



2. Oogenesis (Female Gametogenesis)

Oogenesis is the process by which female gametes (eggs or oocytes) are produced in the ovaries. It begins during fetal development and continues cyclically throughout a female's reproductive years (puberty) until menopause. The process is regulated by hormones, primarily Follicle-Stimulating Hormone (FSH) and Luteinizing Hormone (LH), which are produced by the pituitary gland.

I. The stages of oogenesis

Oogenesis occurs in three distinct phases:

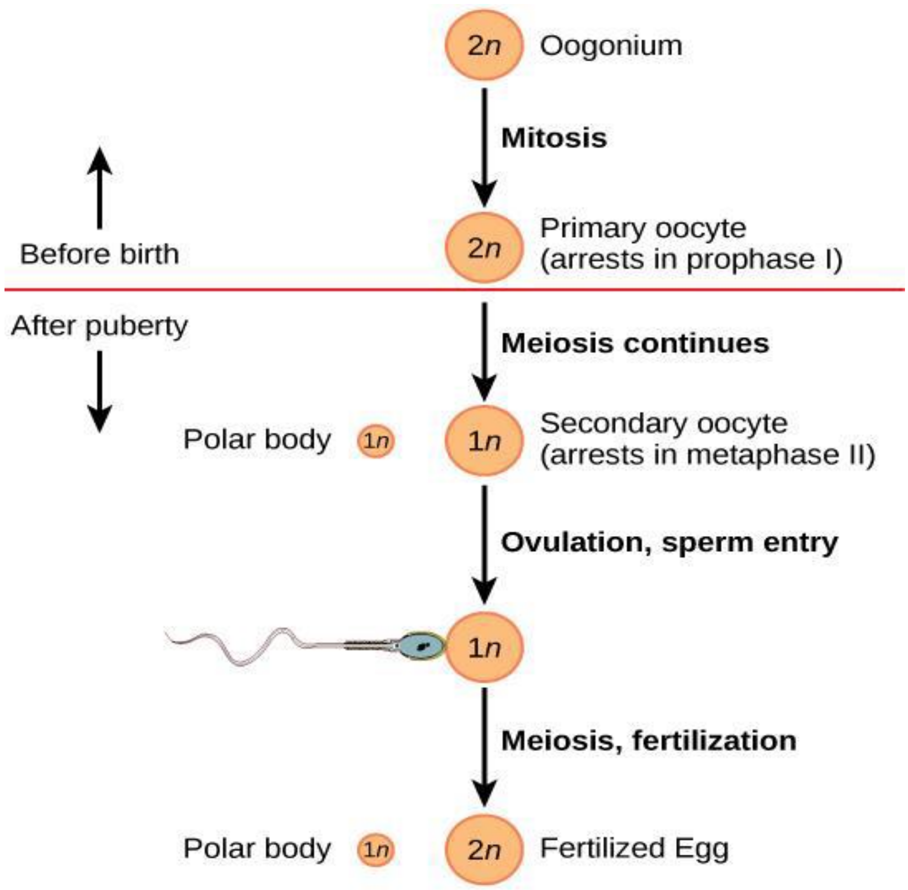
I.1 The multiplication phase: This begins and ends definitively during fetal life. During this phase, the oogonia (2n=46) is multiplied by mitosis.

I.2 Growth phase: This begins during fetal life: all the oogonia (2n=46) increase slightly in volume due to the accumulation of reserves and become oocytes I (2n=46). It stops during infancy. It continues from puberty onward and cyclically at the menopause: a few Oocytes I complete their growth, but only one oocyte I (sometimes two or more) will reach maturity (it is found in a mature follicle or De Graaf follicle).

I.3 The maturation phase: This occurs at the same time as the follicle matures. Each month between puberty and the menopause, in a follicle that is reaching maturity, oocyte I complete the 1st division of meiosis (reduction division), giving two haploid cells (n=23) of unequal size:

a small cell (1st polar globule) and a large cell (oocyte II). The 2nd division of meiosis begins immediately. When it is expelled from the ovary by ovulation, oocyte II is stuck in metaphase of the 2nd division. There are two possible situations:

- If there is no fertilization, oocyte II remains at this stage of meiosis and then rapidly degenerates. - If there is fertilization: oocyte II completes its maturation (the 2nd division of meiosis), giving two haploid cells (n=23): a small cell (2nd polar cell) and a large cell (ovoid or egg cell). During maturation, the oocyte increases in size.



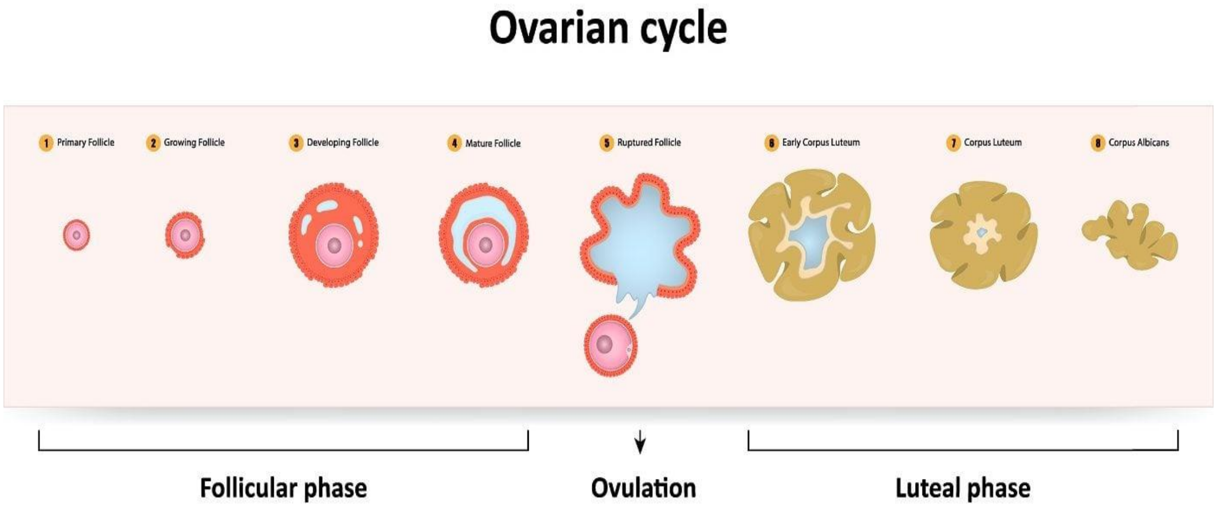
General diagram of oogenesis

III) Menstrual Cycle (Ovarian cycle):

1. Follicular Phase:

2. Ovulation:

3. Luteal Phase:



1. Follicular phase:

The phases of folliculogenesis:

Set of processes by which a **primordial follicle** (small bag located in the ovary and containing the oocyte) will evolve to a **mature follicle,** it ends with ovulation (release, through the ovary, of the female reproductive cell: the egg ready to be fertilized by the sperm).

It is made from the stock of primordial follicles formed during intrauterine life and is associated with oogenesis.

Folliculogenesis begins from the 7th month of pregnancy by the establishment of primordial follicles. At birth the number of primordial follicles is 1 million per ovary on average. From birth to puberty, folliculogenesis is blocked, causing 60% of the initial stock of primordial follicles to degenerate. At puberty their number drops to 400,000 per ovary.

From puberty to menopause, once a month and just after menstruation, (4th day of the cycle) about twenty primordial follicles continue folliculogenesis by secretion, at the hypothalamus, of GnRH (gonadotropin-releasing hormone); the role of this peptide hormone is to stimulate the pituitary gland to increase its secretions of FSH (follicle-stimulating hormone) and LH (luteinizing hormone); these two peptide hormones trigger folliculogenesis and egg maturation in the ovaries. Usually, only one follicle reaches term the others degenerate.

It has several phases.

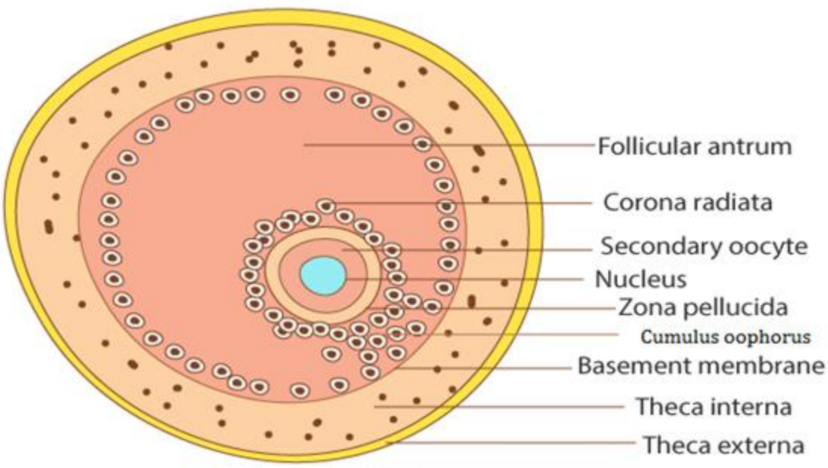
1.Primordial follicle: The primordial follicle is composed of an oocyte I, blocked in prophase I, surrounded by some flattened follicular cells.

2.Primary follicle: It is characterized by an increase in the size of oocyte I, a single layer of cubic follicular cells; a pellucid zone (glycoprotein) between oocyte I and follicular cells; an undifferentiated library; and a Slavjansky membrane between the undifferentiated theca and follicular cells.

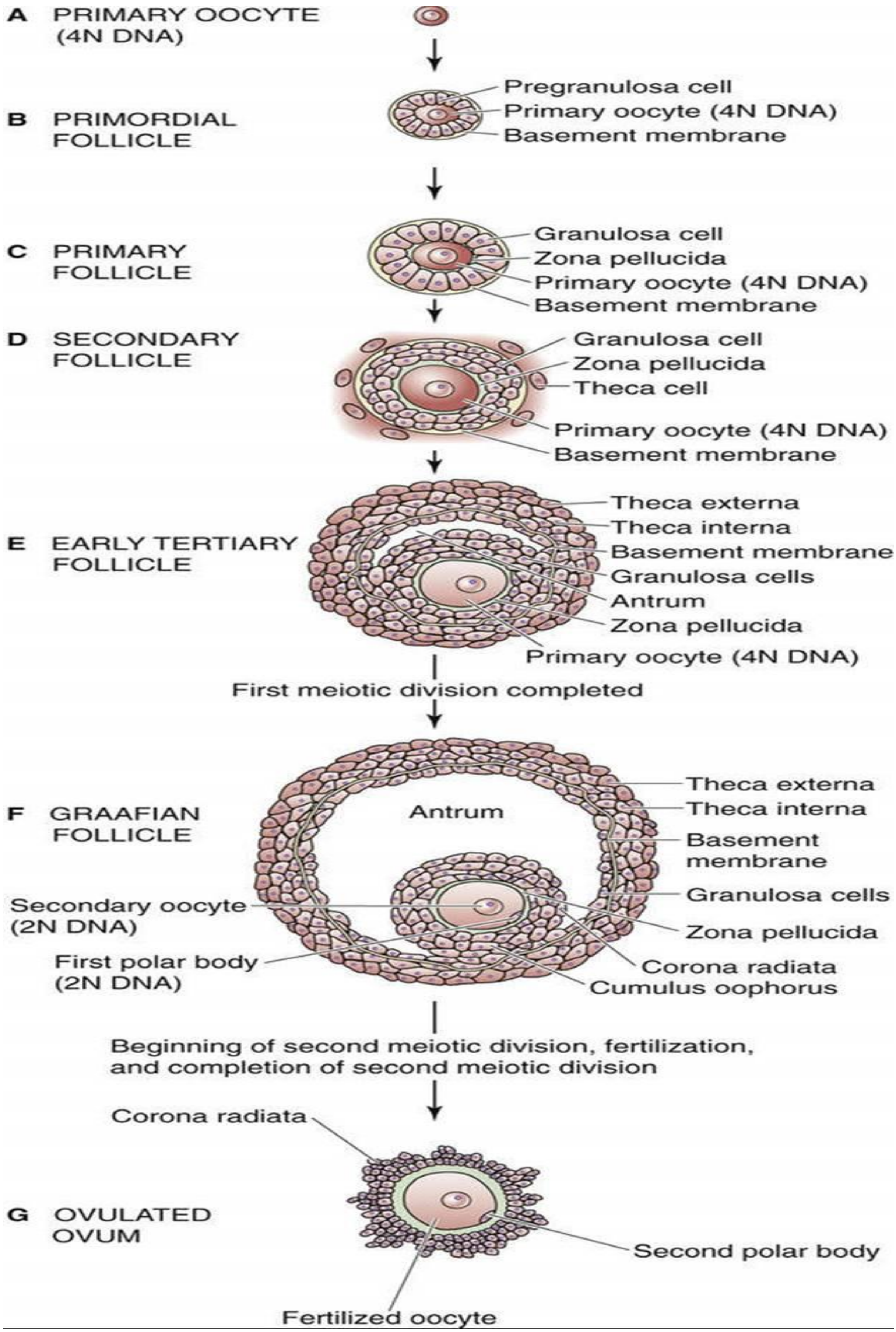
3.Secondary follicle: The number of layers of follicular cells is greater orequal to two. All follicular cells are called granulosa. At this stage, the library has been differentiated into two distinct libraries: one internal cellular and the other external fibrous.

4.Tertiary or cavitary follicle: There are several cavities within follicular cells. These cavities gather together into a single large cavity, or antrum (crescent-shaped), which closes the follicular fluid.

5.Wall or follicle of De Graaf: The oocyte, voluminous, reaches its mature size, which is of the order of 2.5 cm. The follicular cells directly surrounding the oocyte from the corona radiata. A few hours before ovulation, oocyte I completes its reductional division and gives oocyte II (n chr.) blocked in metaphase 2 and the first polar globule (G.P.) that remains in the pellucid zone. The whole corona radiata, the oocyte II connected to the rest of the granulosa, forms the cumulus oophorus. In women, egg laying or ovulation is cyclical and spontaneous. It takes place on the 14th day of an ideal 28-day cycle: there is an increase in the blood level of LH, and 37 to 38 hours after, the follicle ruptures and the oocyte is released.

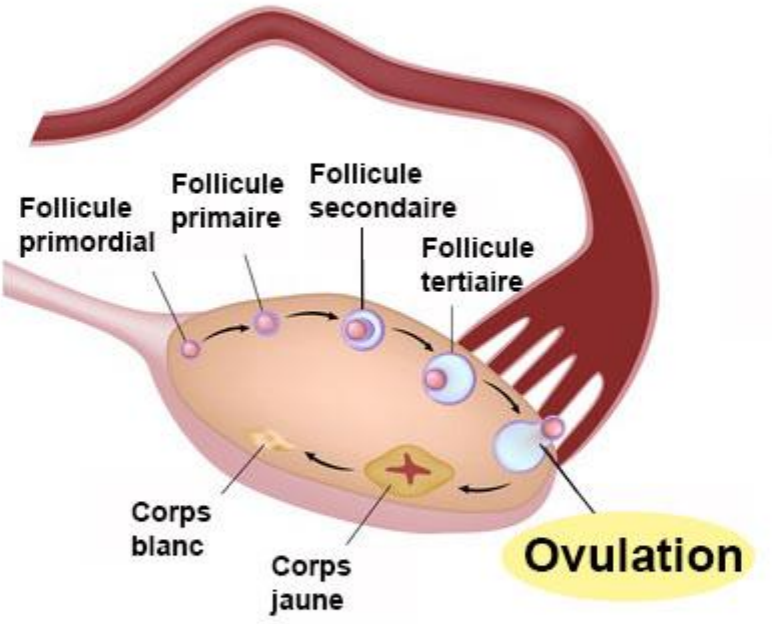


Graafian follicle


A PRIMARY OOCYTE
(4N DNA)
B PRIMORDIAL
FOLLICLE
Pregranulosa cell
Primary oocyte (4N DNA)
Basement membrane
C PRIMARY
FOLLICLE
Granulosa cell
Zona pellucida
Primary oocyte (4N DNA)
Basement membrane
D SECONDARY
FOLLICLE
Granulosa cell
Zona pellucida
Theca cell
Primary oocyte (4N DNA)
Basement membrane
E EARLY TERTIARY
FOLLICLE
Theca externa
Theca interna
Basement membrane
Granulosa cells
Antrum
Zona pellucida
Primary oocyte (4N DNA)
First meiotic division completed
F GRAAFIAN
FOLLICLE
Antrum
Theca externa
Theca interna
Basement
membrane
Granulosa cells
Zona pellucida
Corona radiata
Cumulus oophorus
Secondary oocyte
(2N DNA)
First polar body
(2N DNA)
Beginning of second meiotic division, fertilization,
and completion of second meiotic division
Corona radiata
G OVULATED
OVUM
Second polar body
Fertilized oocyte

2. Ovulation:

Under the action of LH, cumulus oophorus separates from granulosa. Oocyte I completes the first division of meiosis and turns into oocyte II. About 56 hours before its release. Ovarian contractions promote the rupture of the follicle. There remains in the ovary a follicle emptied of its oocyte and follicular fluid: the dehiscent follicle.

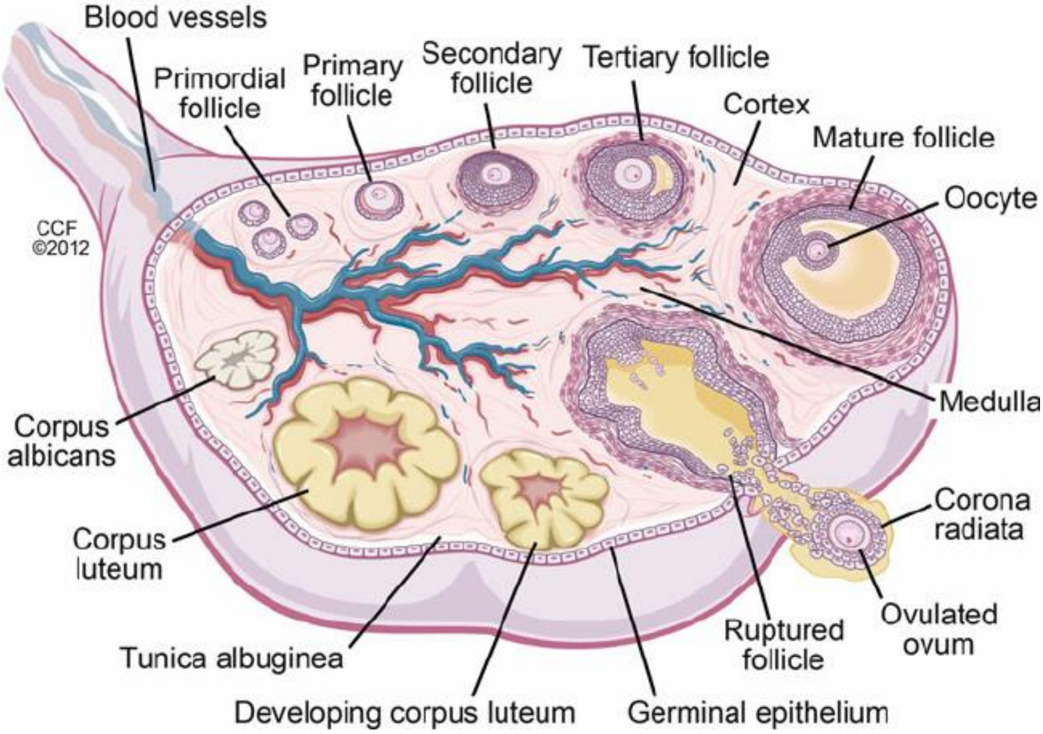


3. Luteal Phase:

1. **The yellow body (corpus luteum):** The dehiscence follicle heals, forming a temporary endocrine gland called yellow body. The yellow body granulosa cells become luteal, capable of synthesizing progesterone. Cells in the internal library always synthesize estrogen. The yellow body can evolve in two different ways:

- **In the absence of fertilization**, the yellow body is called progestin, its lifespan is 14 days
- **In the case of fertilization,** the yellow body is said to be gestative. Its lifespan is 3 months. Then it degenerates and the relay of steroid synthesis is taken by the cells of the placenta.

2. White Body (corpus albicans): In the ovary, the degeneration of the yellow body (gestative or progestin) gives the white body, which will be phagocytized by the phagocytic cells of the ovary.


Blood vessels
Primordial follicle
Primary follicle
Secondary follicle
Tertiary follicle
Cortex
Mature follicle
Oocyte
CCF ©2012
Medulla
Corpus albicans
Corpus luteum
Corona radiata
Ovulated ovum
Ruptured follicle
Tunica albuginea
Developing corpus luteum
Germinal epithelium