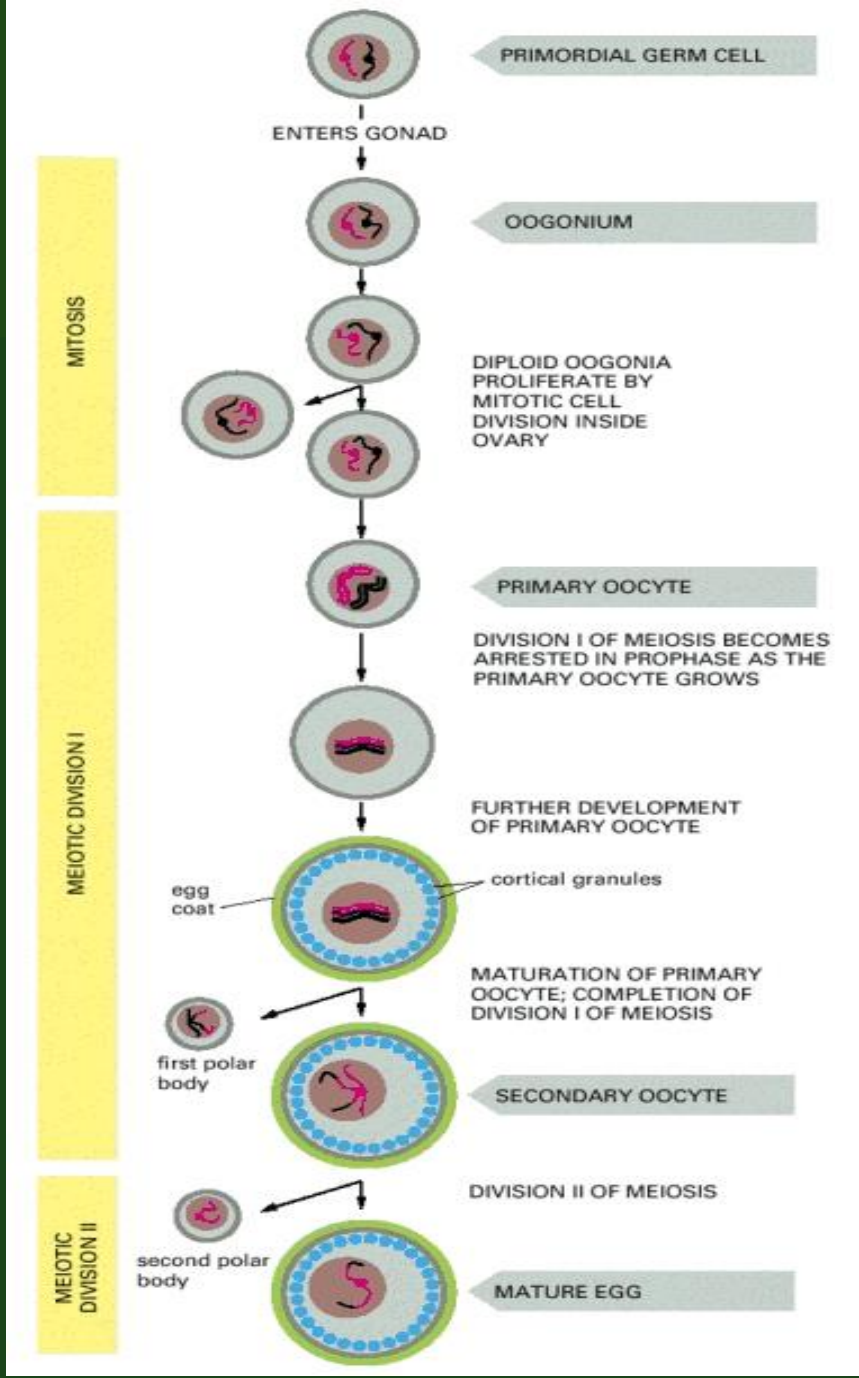
Gametogenesis

Department of Biology, Medical Faculty,
Medical University of Sofia

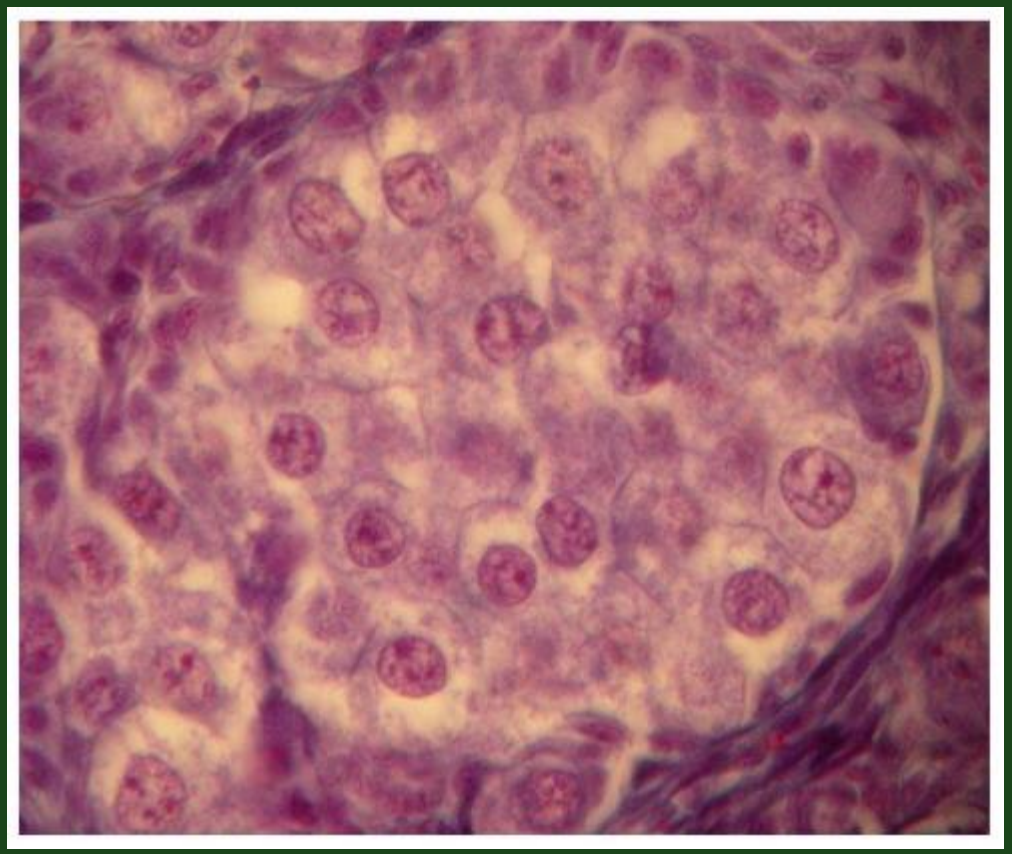
Oogenesis

- Oogenesis is prolonged process which starts in the fetal ovaries. In the embryonic life, stem cells (oogonia) start to divide by mitosis. Around the 10-th week of embryonic development mitosis stops and oogonia start meiosis. When meiosis starts, the cells are called oocytes. In the first meiosis they are primary oocytes, in the second – secondary oocytes. Meiosis progresses to prophase I where it stops. The newborn girl has primary oocytes arrested at prophase I. The process remains arrested to the puberty. At puberty, because of hormonal signals, meiosis of individual oocytes resume and progresses to metaphase II. At metaphase II oogenesis stops for second time. Meiosis is arrested at this stage to the moment of fertilization. When it is fertilized, meiosis of the oocyte finishes. Without fertilization the egg would die at metaphase II.
- During the first arrest at prophase I maturing oocyte grows in size. It accumulates ribosomes, yolk, glycogen, lipids and mRNA, necessary for the future embryonic development. The egg synthesizes its envelopes and cortical granules. Maturing oocyte is still diploid at prophase I. The cell uses diploid genome for its intensive synthetic processes.
- At puberty ovulation, begins because of Follicle stimulating hormone produced by hypophysis. The ovary responds to the hormonal signal and it produces estrogen. The estrogen resumes meiosis of a group of oocytes (3 – 4). Because the dose of hormones is insufficient for all of responded oocytes, only one of them mature. The other oocytes degenerate. From the hundred thousand maturing oocytes only 400 reach ovulation.

- Oocytes mature in follicles. The follicle contains maturing egg surrounded by layers of follicle cells. Those cells protect and nourish developing oocyte. Follicle cells secrete estrogen to resume meiosis of the oocyte. The oocyte finishes first meiosis. At this moment first polar body is emitted. After that the egg starts second meiosis immediately and it reaches metaphase II. At this stage meiosis is arrested again to fertilization. The aim of this second arrest is to prevent parthenogenesis (development without spermatozoa).
- During oogenesis one mature oocyte and two polar bodies are produced by one stem cell.This cell division is asymmetric. The oocyte is large (one of the largest human cells) and polar bodies are small. The purpose is to keep the whole cytoplasm for the oocyte. Future embryo relies on the maternal cytoplasm, because spermatozoa loses almost all of cytoplasmic organelles. Polar bodies remove the excess of chromosome to produce haploid cell form diploid stem cell.



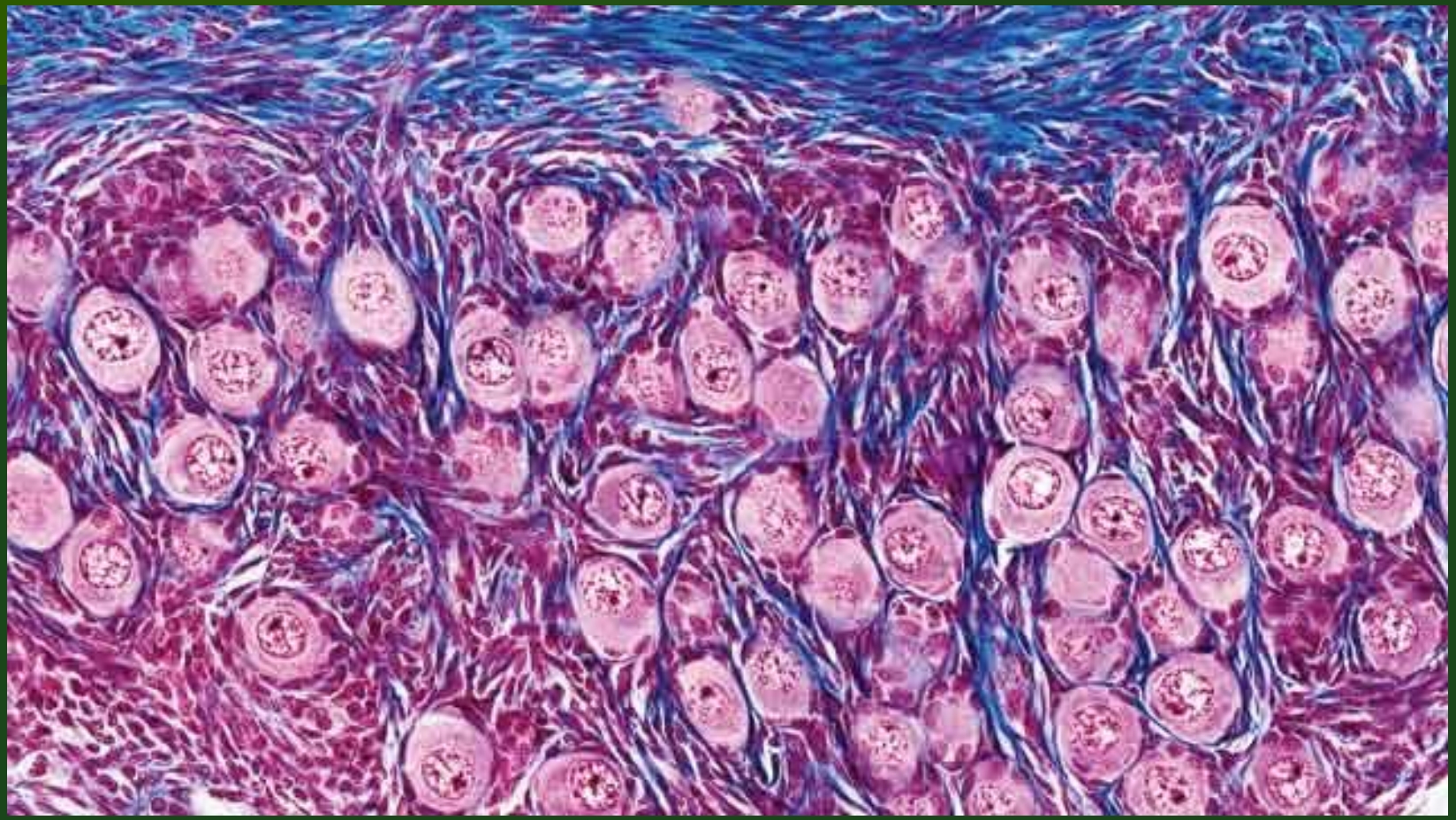
Oogenesis starts in the fetal ovary.
Diploid germ cells called oogonia divide by mitosis



(SlidePlayer)

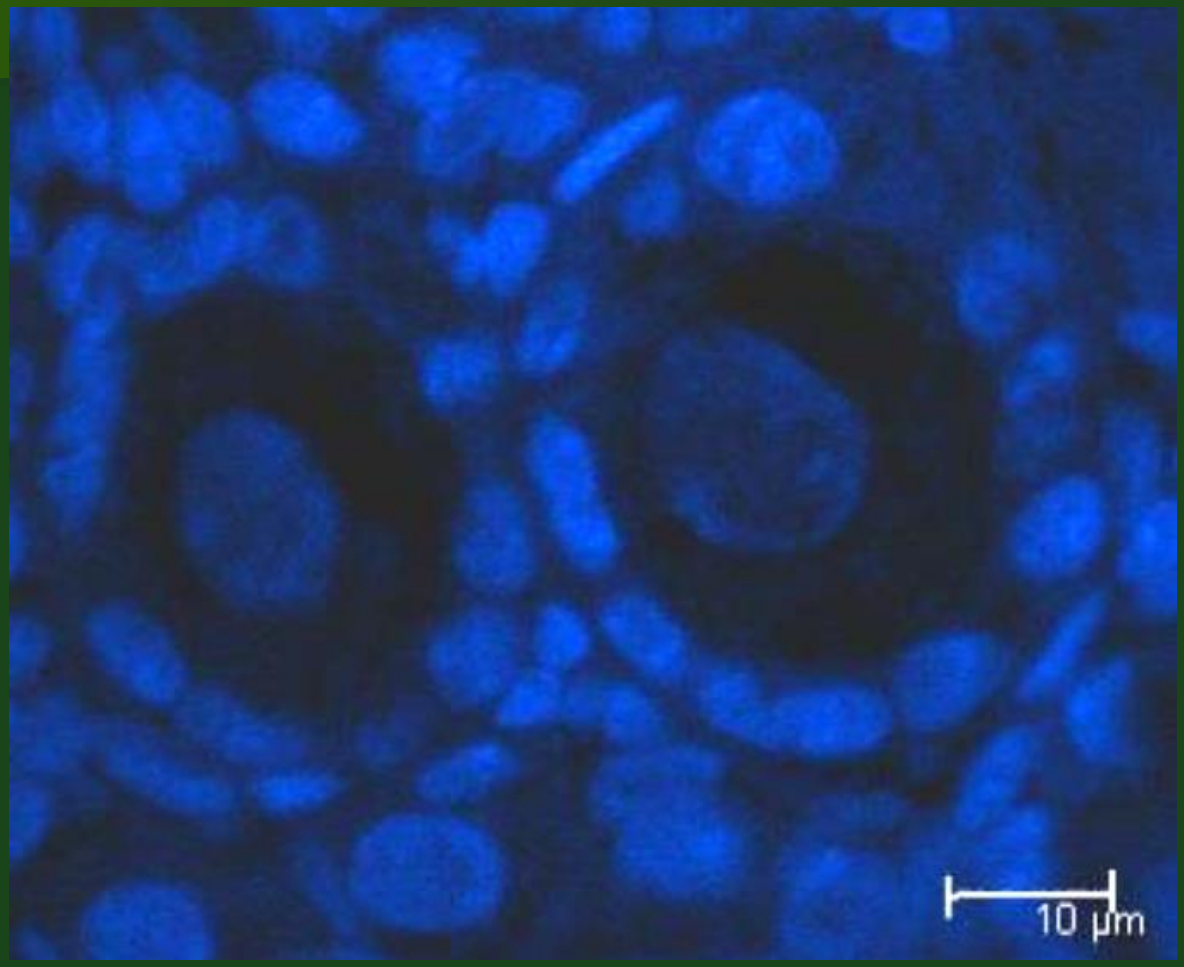
Then, still in the fetal ovary, oogonia stop mitosis and start meiosis, becoming primary oocytes

They reach late prophase I and get arrested – until puberty.



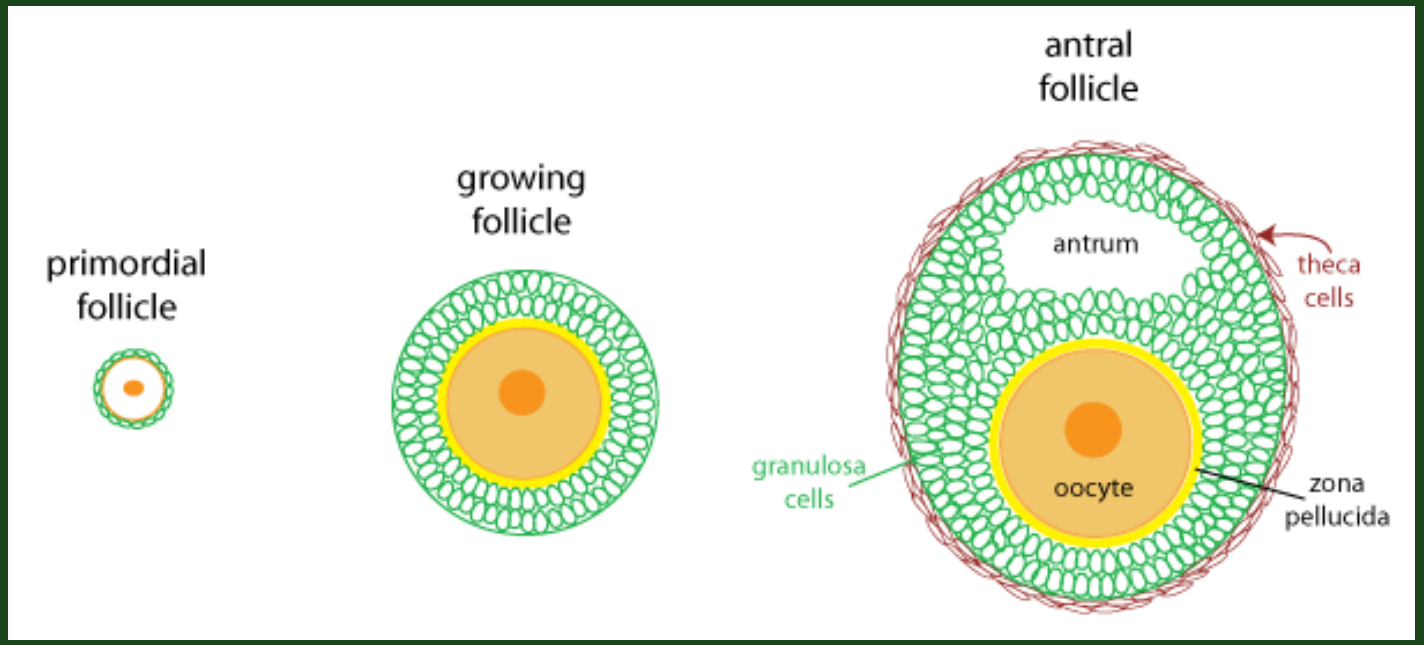
A light micrograph of a section of fetal ovary shows primordial follicles (light pink ovals) with oocytes (dark pink spots).© TISSUEPIX/SCIENCE SOURCE
https://www.the-scientist.com/features/a-scrambled-mess-33626

Oocytes encircle themselves with somatic cells of the ovary, forming follicles



V. Hadzhinesheva

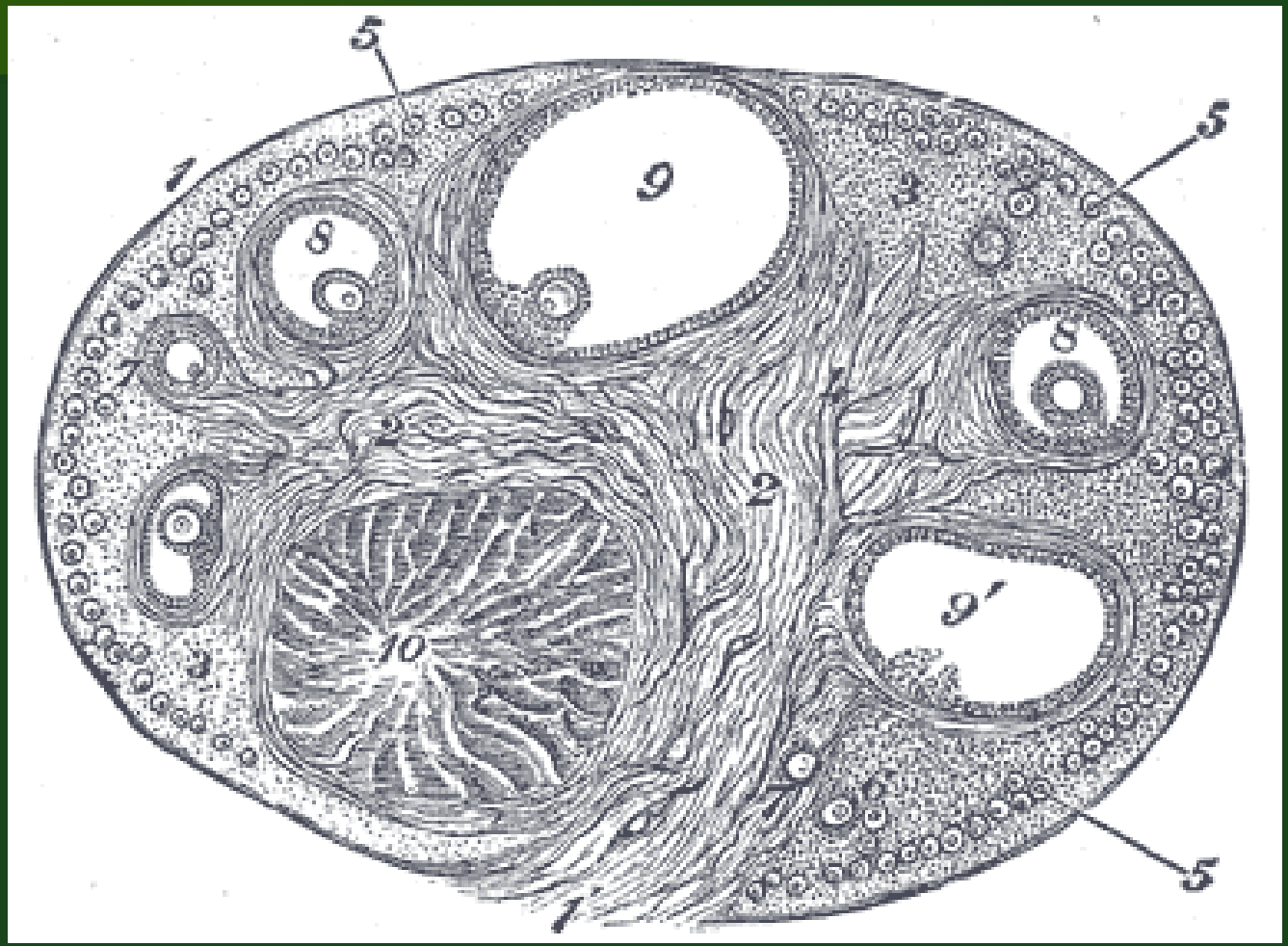
From puberty to menopause, groups of oocytes start to mature in every menstrual / oestrus cycle



https://courses.washington.edu/conj/bess/female/female.html

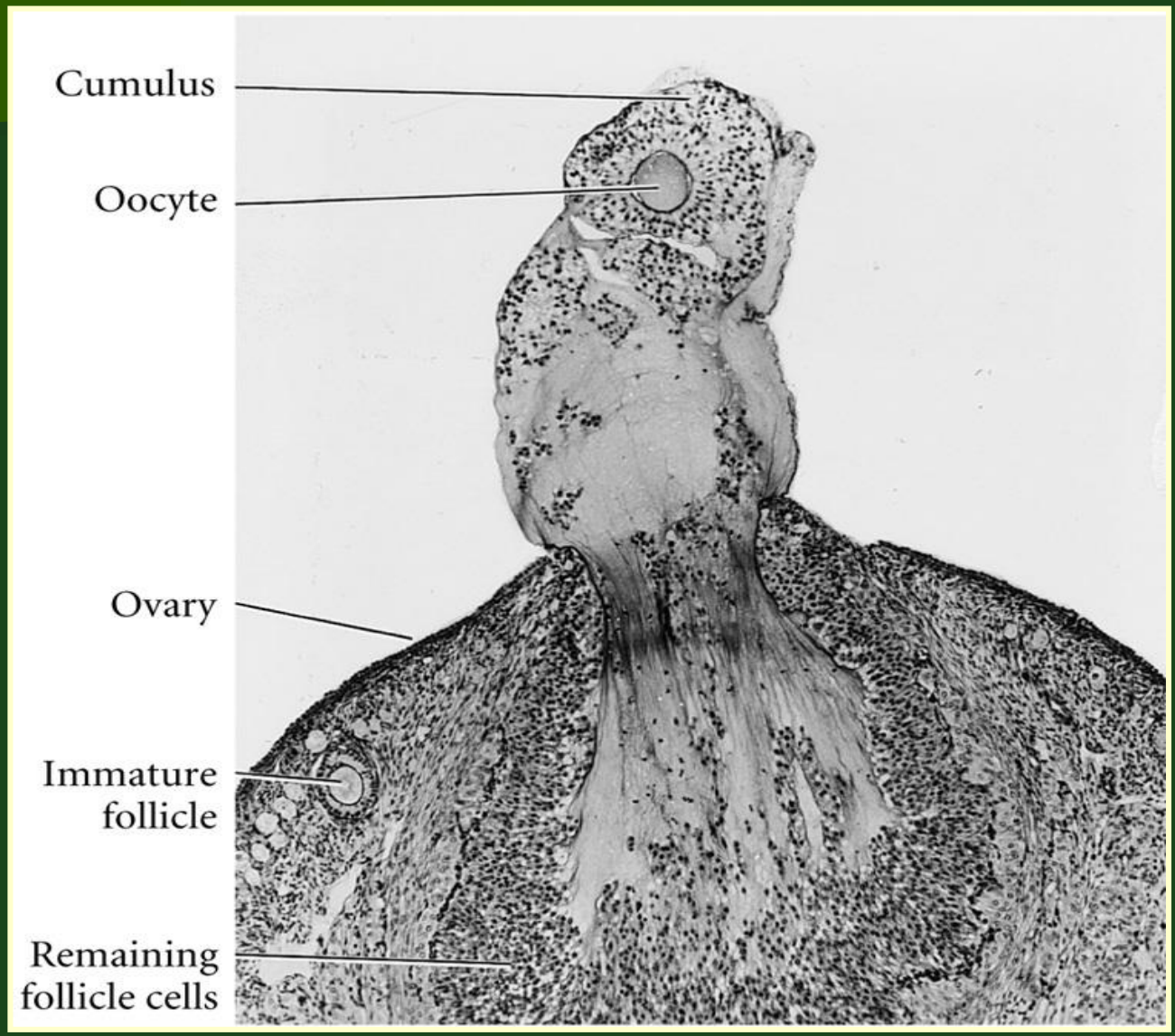
As the oocyte matures, its follicle grows and acquires a fluid-filled cavity

The adult ovary contains numerous follicles at different maturation stages



(Gray's Anatomy)

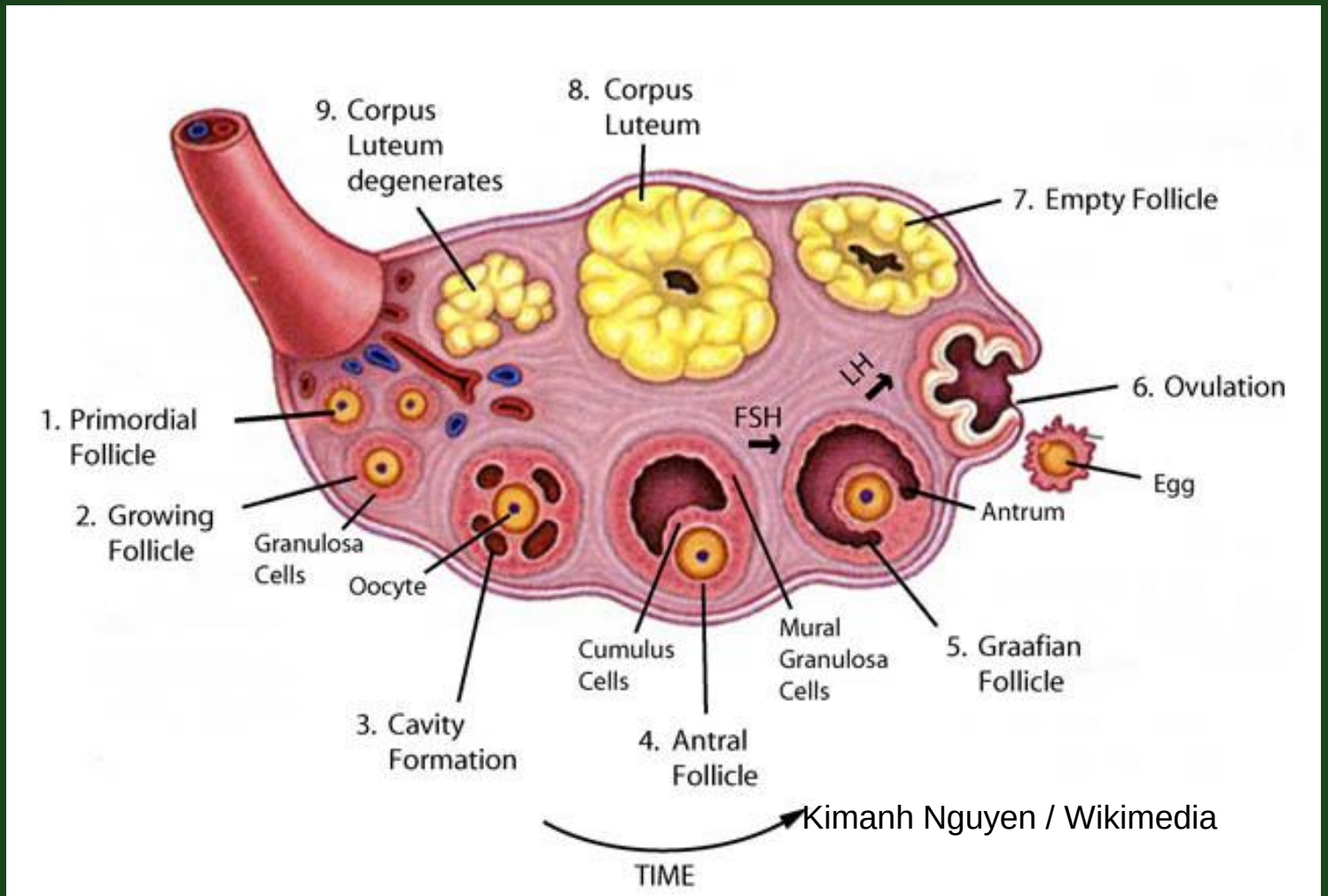
In the middle of the cycle, the oocyte is mature and leaves the ovary



The process is called ovulation. It occurs by rupture of the follicle and the ovary itself, pushing out the oocyte (and the follicular cells surrounding it).

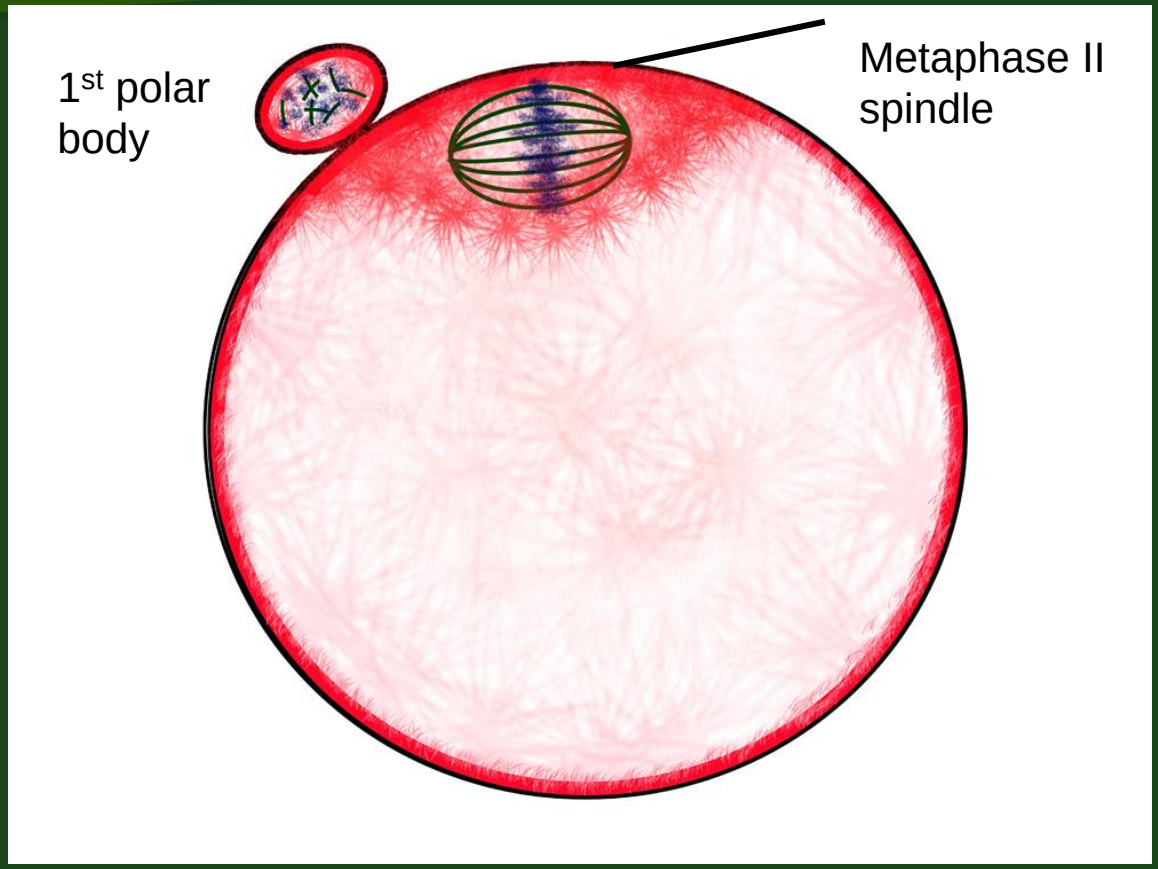
Developmental Biology. 6th edition. Gilbert SF.

After ovulation, remnants of the follicle in the ovary form the corpus luteum which secretes progesterone. This hormone is a defender of the pregnancy. It prepares the uterus for a pregnancy – the uterine wall thicken to accept fertilized egg. If there is no pregnancy, corpus luteum breaks down and menstruation happens.



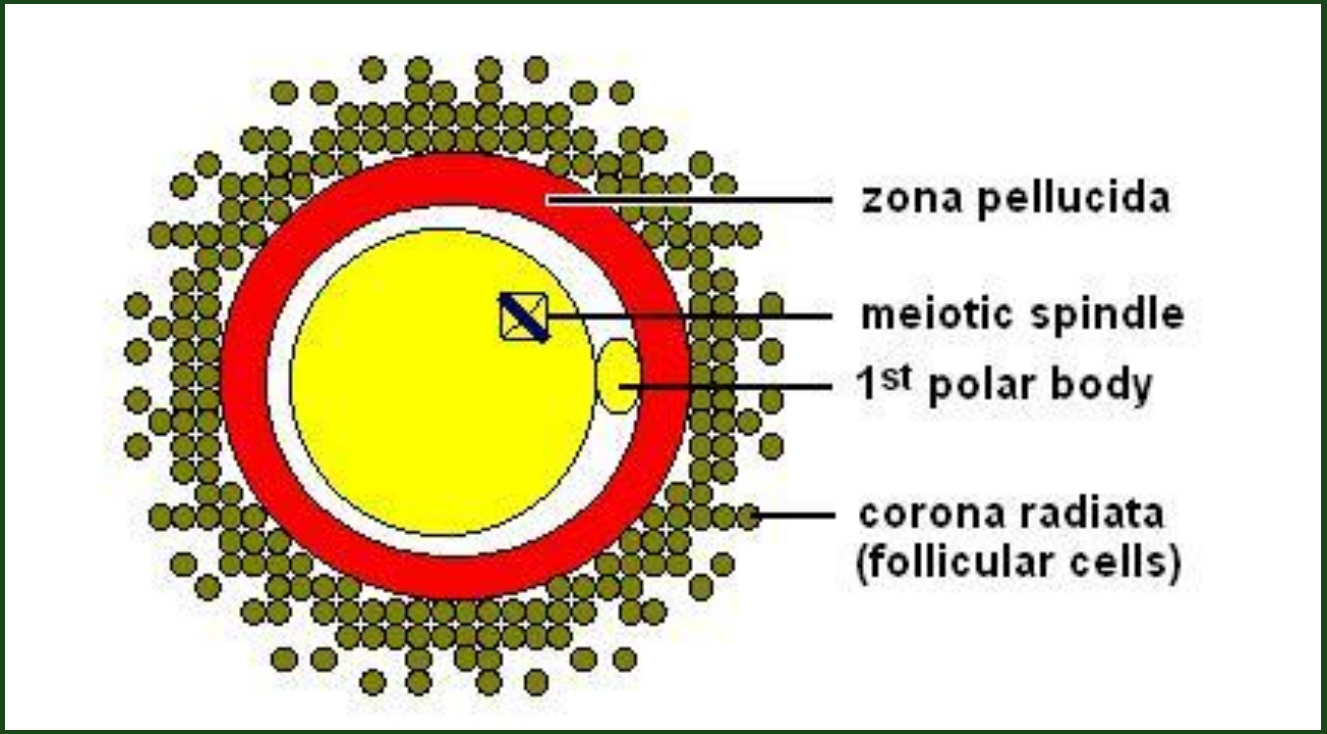
Kimanh Nguyen / Wikimedia

The mature ovulated oocyte is in metaphase II.
It has meiotic spindle close to the cell periphery and a polar body.



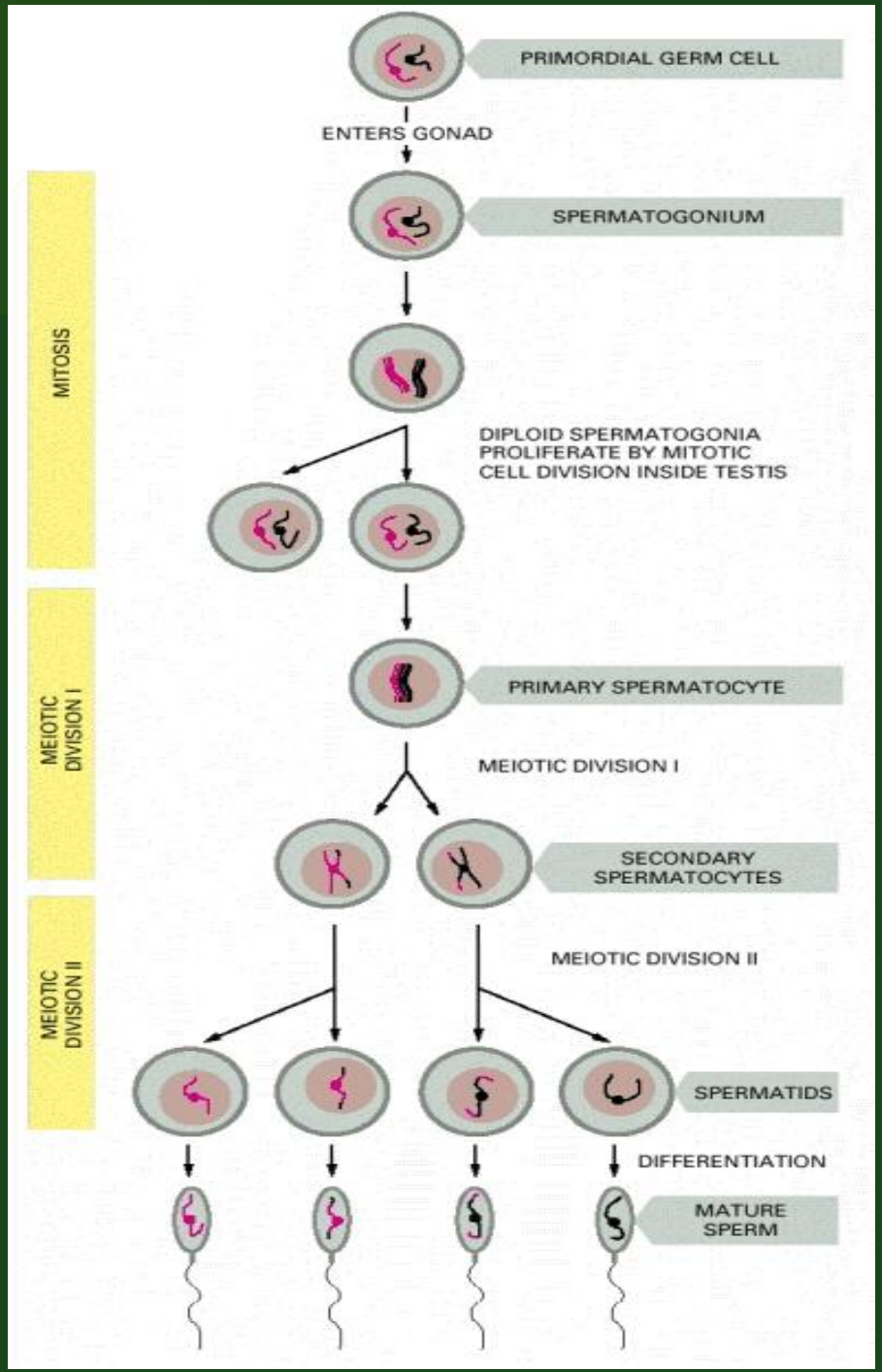
Meiosis is arrested and will be resumed only if fertilization starts. Second polar body is formed only if the egg is fertilized.

It has envelopes above the cell membrane for support and protection



Spermatogenesis

- In contrast of oogenesis, spermatogenesis is continuous process. Spermatogenesis starts at puberty and goes on continuously in seminiferous tubules of the testis.
- In order to produce million spermatozoa, stem cells (spermatogonia) divide by mitosis all the time. After that some of them start meiosis to be primary and later secondary spermatocytes.
- Cell division during spermatogenesis is symmetrical. Four mature spermatozoa are formed from a single precursor cell.



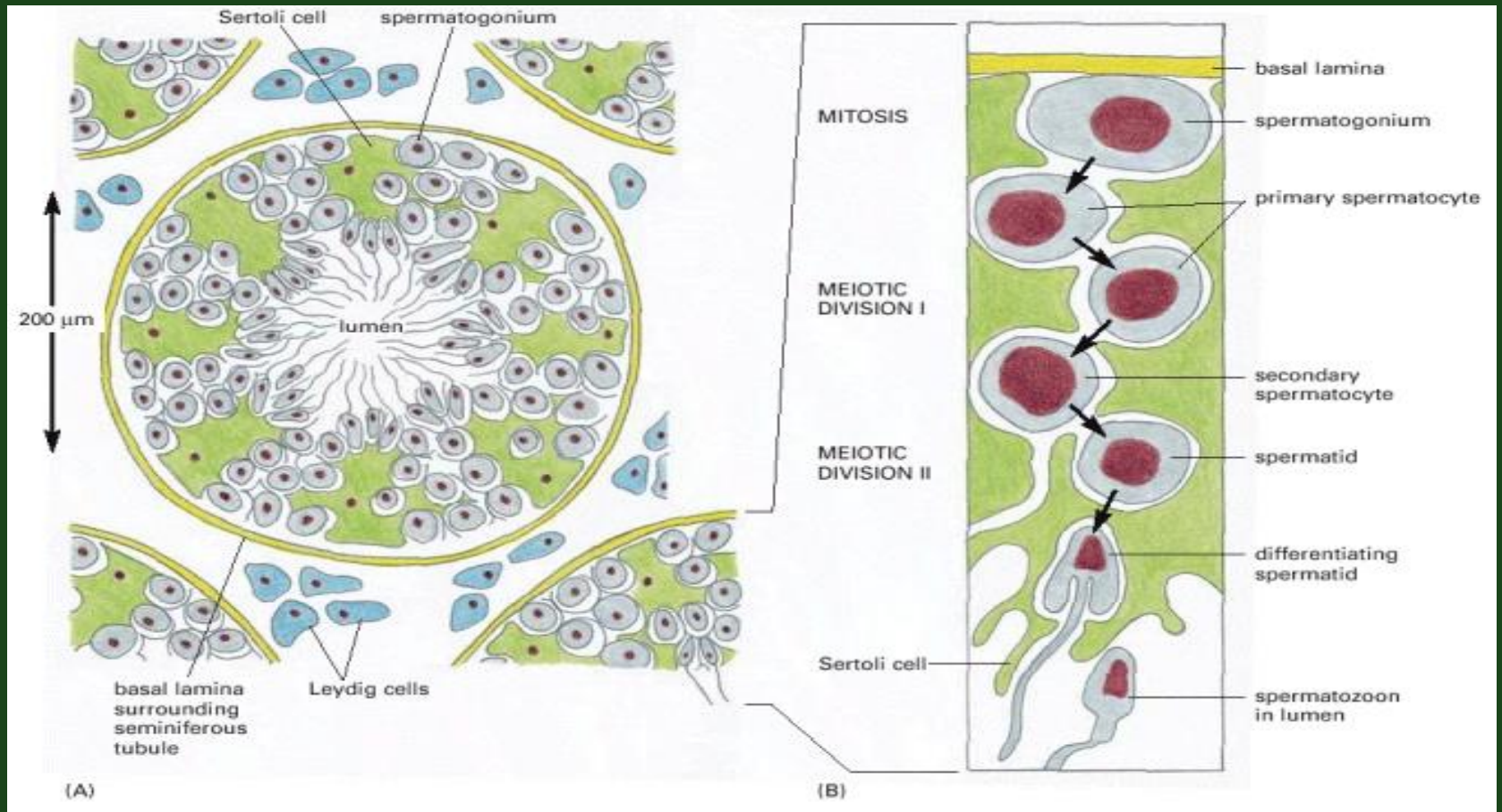
Spermatogenesis takes place in seminiferous tubules of the testis

A seminiferous tubule in a cross section

Differentiation advances from the periphery to the center.

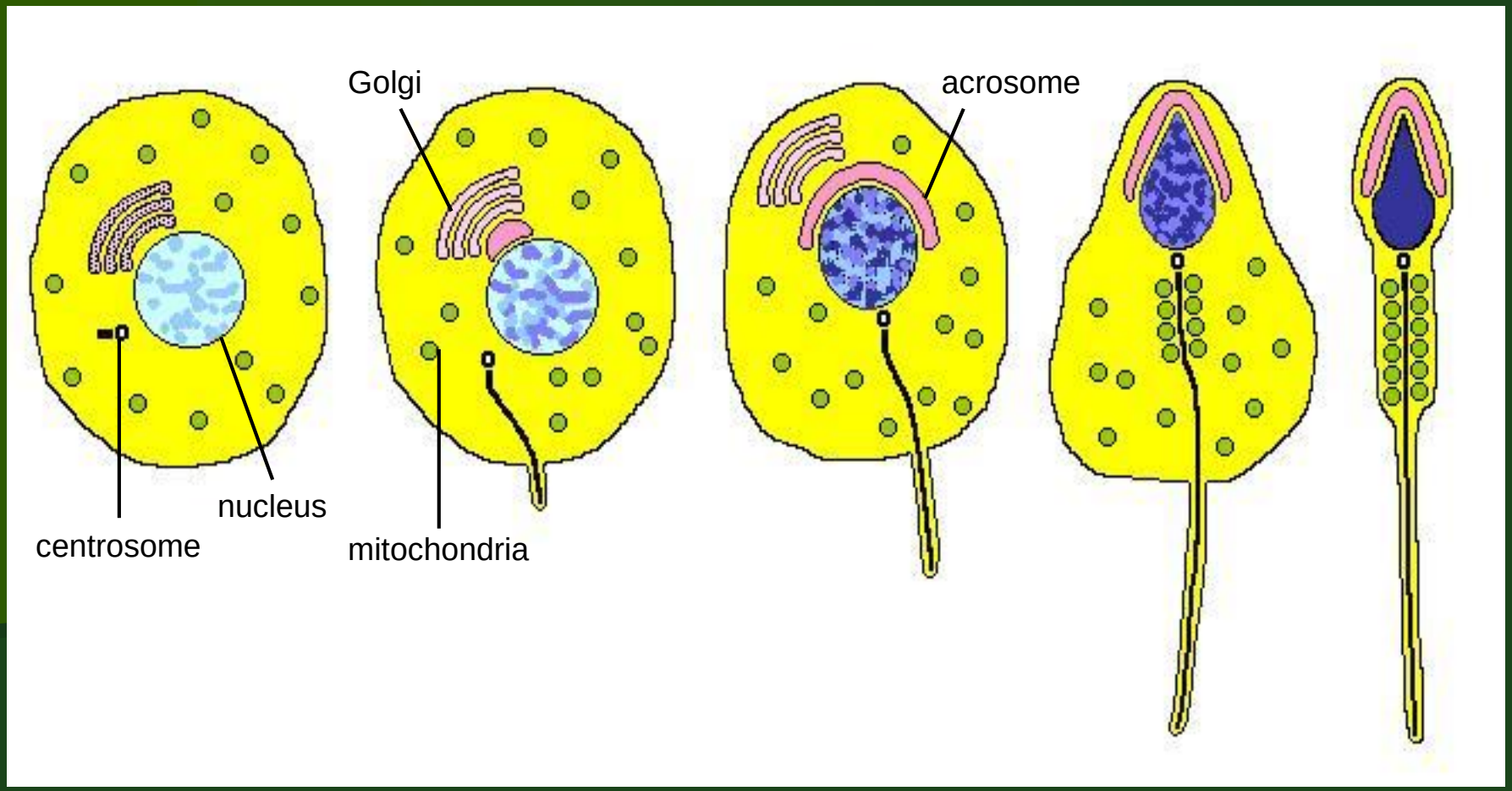
Stages of spermatogenesis and their position

Stem cells are attached to the outer membrane of seminiferous tubules. Sertoli cells which nourish and protect developing sperm are also attached to the membrane of the tubule. Inside are the cells in meiosis – first primary spermatocytes, secondary spermatocytes and deeper spermatids and spermatozoa. Mature spermatozoa detach from the tubule and go to the cavity of the canal. In the space between the tubules are Leydig cells producing testosterone.



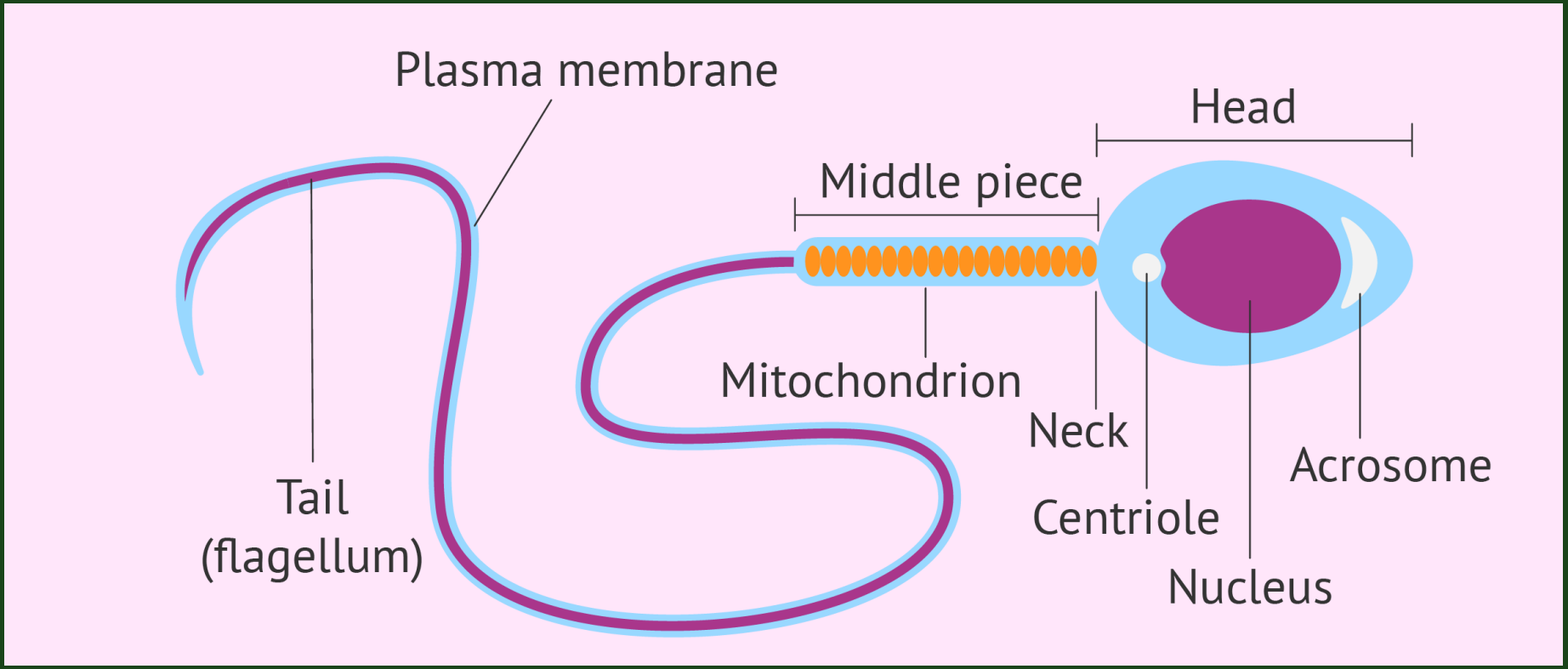
Final (post-meiotic) stages of spermatogenesis

When meiosis finishes, a cell named spermatid is produced. It is haploid, but is very large and immotile. This cell undergoes post-meiotic transformations to become functional spermatozoon. To acquire the proper shape for swimming, spermatozoa leave behind most of their cytoplasm. Golgi complex modifies to form the acrosome. Mitochondria wrap around middle piece to supply energy for movement. Centriols modify to form the tail. These transformations of spermatid to spermatozoon are called SPERMIOGENESIS.



Mature spermatozoon (sperm cell)

Mature spermatozoa has an acrosome – a structure like a cap covering the nucleus. The acrosome contains lytic enzymes to penetrate the oocyte. Nucleus is packaged by special proteins to be small and motile. The neck has a centriole crucial for the embryonic development. Middle piece and a tail follow.



https://www.invitra.com/sperm-cell/structure-and-parts-of-a-sperm-cell/

Oogenesis vs. spermatogenesis

	Spermatogenesis	**Oogenesis**
Location	Testis	Ovary
Number of gametes produced	Life long production (millions)	Fixed amount (only ~ 400 mature)
Gametes per germ cell	Four	One
Beginning of process	Begins at puberty	Begins during fetal development
Timing of gamete formation	Continuous (any time)	Once a month (menstrual cycle)
End of process	Fertility is life long but reduces	Fertility stops at menopause
Timing of gamete release	Any time	Monthly cycle
Meiotic divisions	Uninterrupted	Arrested
Germ line epithelium	Involved in gamete production	Not involved in gamete production