Embryology

2nd lecture
Alaa Hachem (DPhil)

☒ OOGENESIS:

Maturation of Oocytes Begins Before Birth

Once primordial germ cells have arrived in the gonad of a genetic female, they differentiate into **oogonia**. These cells undergo a number of mitotic divisions and, by the end of the third month, are arranged in clusters surrounded by a layer of flat epithelial cells known as **follicular cells,** originate from surface epithelium covering the ovary.

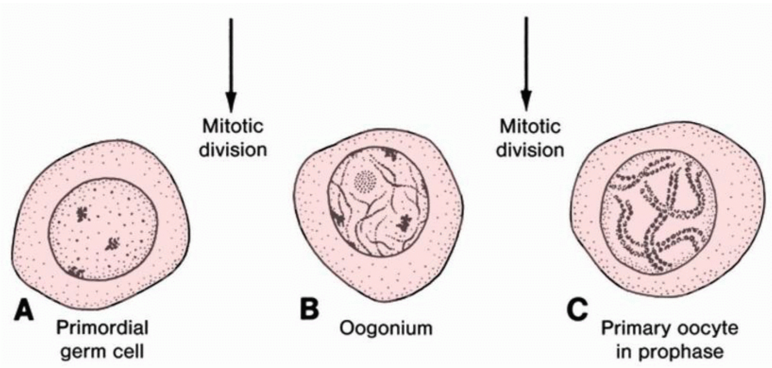


Figure 1.16 Differentiation of primordial germ cells into oogonia begins shortly after their arrival in the ovary. By the third month of development, some oogonia give rise to primary oocytes that enter prophase of the first meiotic division. This prophase may last 40 or more years and finishes only when the cell begins its final maturation. During this period it carries 46 double-structured chromosomes.

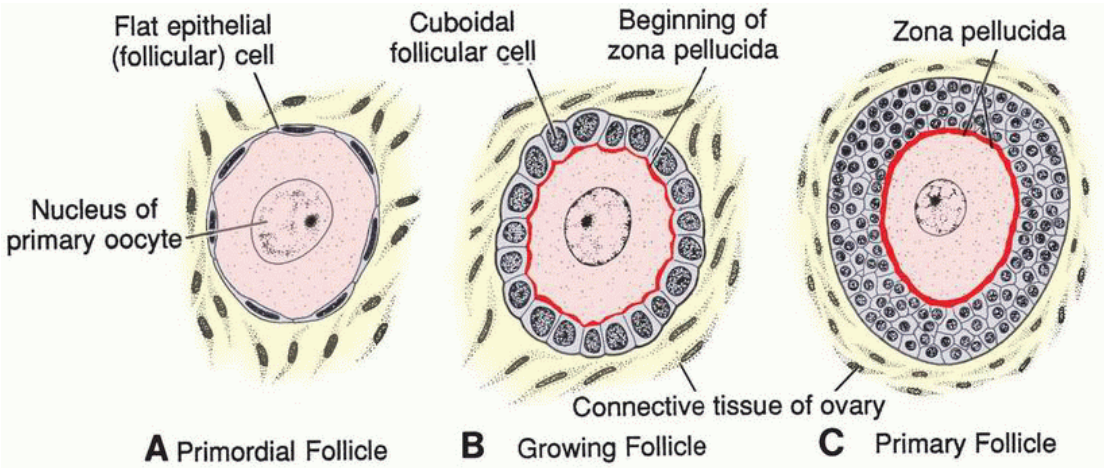
The majority of oogonia continue to divide by mitosis, but some of them arrest their cell division in prophase of meiosis I and form **primary oocytes**. During the next few months, oogonia increase rapidly in number, and by the fifth month of prenatal development, the total number of germ cells in the ovary reaches its maximum, estimated at 7 million. At this time, cell death begins, and many oogonia as well as primary oocytes become atretic. By the seventh month, the majority of oogonia have degenerated except for a few near the surface of the ovary. **All surviving primary oocytes** have entered prophase of meiosis I, and most of them are individually surrounded by a layer of flat epithelial cells. A primary oocyte, together with its surrounding flat epithelial cells, is known as a **primordial follicle**.

Maturation of Oocytes Continues at Puberty

Near the time of birth, all primary oocytes have started prophase of meiosis I, but instead of proceeding into metaphase, they enter the **diplotene stage,** a resting stage during prophase.

Primary oocytes remain in prophase and **do not finish their first meiotic division before puberty is reached,** apparently because of **oocyte maturation inhibitor** (OMI), a substance secreted by follicular cells.

Each month, 15 to 20 follicles selected begin to mature, passing through three stages: 1) **primary** 2) **secondary** or **antral** (also called **vesicular** or **Graafian);** and 3) **preovulatory.** The antral stage is the longest, whereas the preovulatory stage encompasses approximately 37 hours before ovulation. As the primary oocyte begins to grow, surrounding follicular cells change from flat to cuboidal and proliferate to produce a stratified epithelium of **granulosa cells,** and the unit is called a **primary follicle.**



Granulosa cells rest on a basement membrane separating them from surrounding stromal cells that form the **theca folliculi.** As follicles continue to grow, cells of the theca folliculi organize into an inner layer of secretory cells (steroid secretion), the **theca interna,** and an outer fibrous capsule, the **theca externa.** Also, granulosa cells and the oocyte secrete a layer of glycoproteins on the surface of the oocyte, forming the **zona pellucid**.

As development continues, fluid-filled spaces appear between granulosa cells. Coalescence of these spaces forms the **antrum,** and the follicle is termed a **secondary (vesicular, Graafian) follicle.** Initially, the antrum is crescent shaped, but with time, it enlarges. Granulosa cells surrounding the oocyte remain intact and form the **cumulus oophorus.**

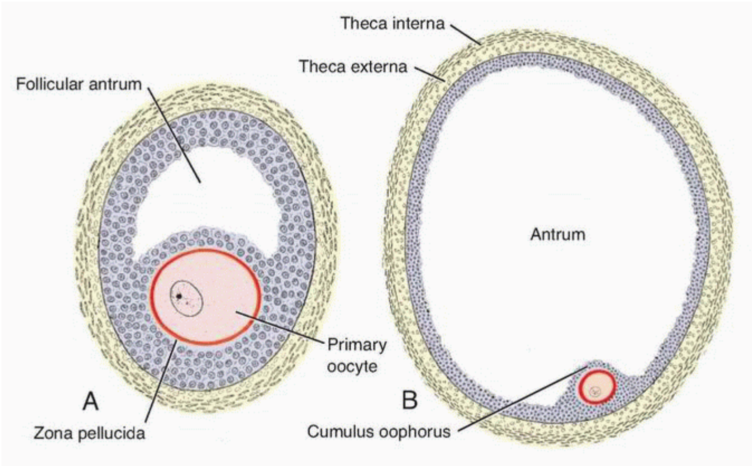


Figure 1.19 A. Secondary (antral) stage follicle. The oocyte, surrounded by the zona pellucida, is off-center; the antrum has developed by fluid accumulation between intercellular spaces. Note the arrangement of cells of the theca interna and the theca externa. **B.** Mature secondary (graafian) follicle. The antrum has enlarged considerably, is filled with follicular fluid, and is surrounded by a stratified layer of granulosa cells. The oocyte is embedded in a mound of granulosa cells, the cumulus oophorus.

With each ovarian cycle, a number of follicles begin to develop, but usually only one reaches full maturity. The others degenerate and become atretic. When the secondary follicle is mature, a surge in **luteinizing hormone (LH)** induces the preovulatory growth phase. Meiosis I is completed, resulting in formation of two daughter cells of unequal size, each with 23 double structured chromosomes (Fig. 1.20, *A* and *B*). One cell, the **secondary oocyte,** receives most of the cytoplasm; the other, the **first polar** body, receives practically none (Fig. 1.20*B*).

The cell then enters meiosis II but arrests in metaphase approximately 3 hours before ovulation. Meiosis II is completed only if the oocyte is **fertilized**; otherwise, the cell degenerates approximately 24 hours after ovulation.

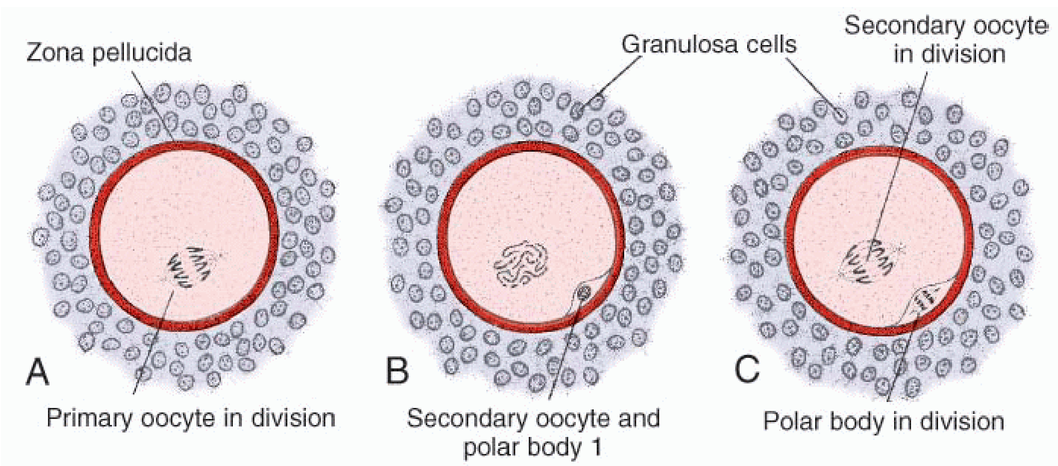


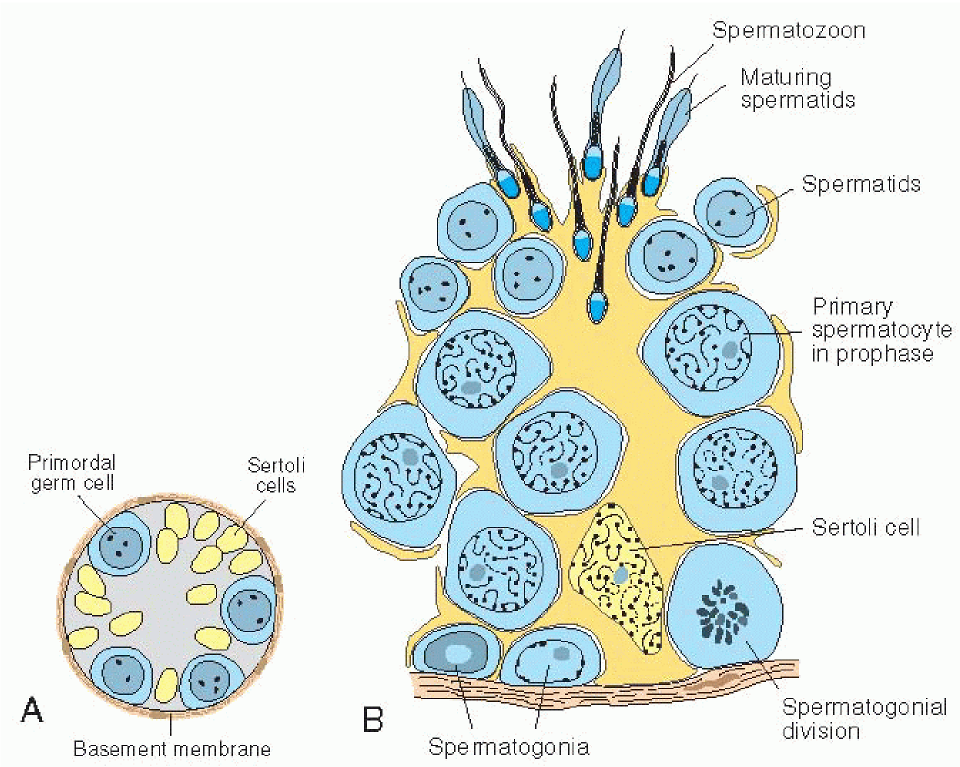
Figure 1.20

☒ SPERMATOGENESIS:

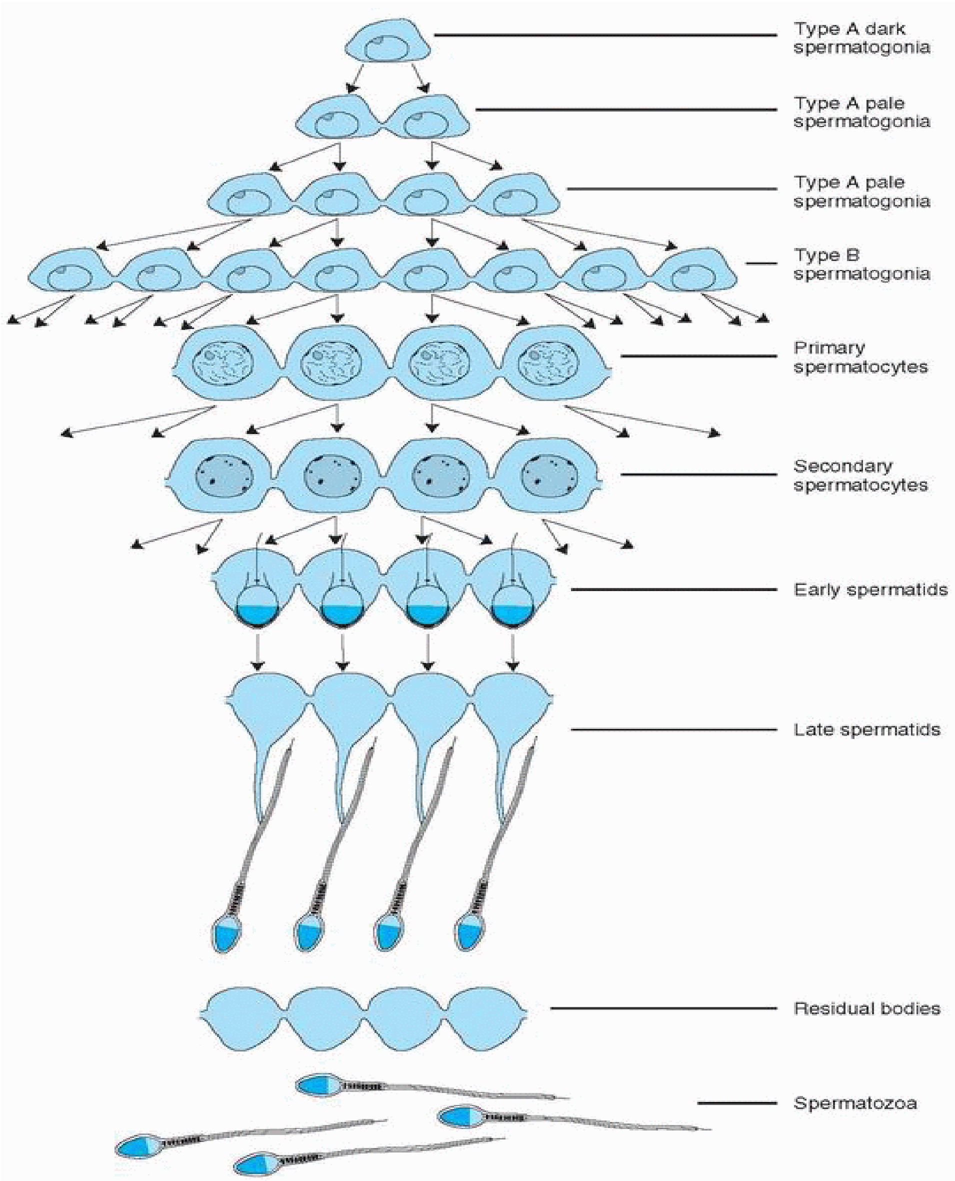
Maturation of Sperm Begins at Puberty:

Spermatogenesis, begins at puberty, includes all of the events by which **spermatogonia** are transformed into **spermatozoa.** At birth, germ cells in the male can be recognized in the sex cords of the testis as large, pale cells surrounded by supporting cells. Supporting cells, which are derived from the surface epithelium of the gland in the same manner as follicular cells, become **sustentacular cells,** or **Sertoli cells**.

Shortly before puberty, the sex cords acquire a lumen and become the **seminiferous tubules.** At about the same time, primordial germ cells give rise to spermatogonial stem cells. At regular intervals, cells emerge from this stem cell population to form **type A spermatogonia,** and their production marks the initiation of spermatogenesis. Type A cells undergo a limited number of mitotic divisions to form a clone of cells. The last cell division produces **type B spermatogonia,** which then divide to form **primary spermatocytes**.



Primary spermatocytes then enter a prolonged prophase (22 days) followed by rapid completion of meiosis I and formation of **secondary spermatocytes.** During the second meiotic division, these cells immediately begin to form haploid **spermatids**. Throughout this series of events, from the time type A cells leave the stem cell population to formation of spermatids, cytokinesis is incomplete, so that successive cell generations are joined by cytoplasmic bridges. Thus, the progeny of a single type A spermatogonium form a clone of germ cells that maintain contact throughout differentiation.



Sertoli cells support and protect the germ cells, participate in their nutrition, and assist in the release of mature spermatozoa.

Spermatogenesis is regulated by **luteinizing hormone (LH)** production by the pituitary. LH binds to receptors on **Leydig cells** and stimulates testosterone production, which in turn binds to **Sertoli cells** to promote spermatogenesis. **Follicle stimulating hormone (FSH)** is also essential because its binding to Sertoli cells **stimulates testicular fluid production** and synthesis of **intracellular androgen receptor proteins.**

☒ Spermiogenesis

<u>The series of changes resulting in the transformation of spermatids into spermatozoa is **spermiogenesis**.</u> These changes include:

(*a*) formation of the **acrosome,** which covers half of the nuclear surface and contains enzymes to assist in penetration of the egg and its surrounding layers during fertilization;

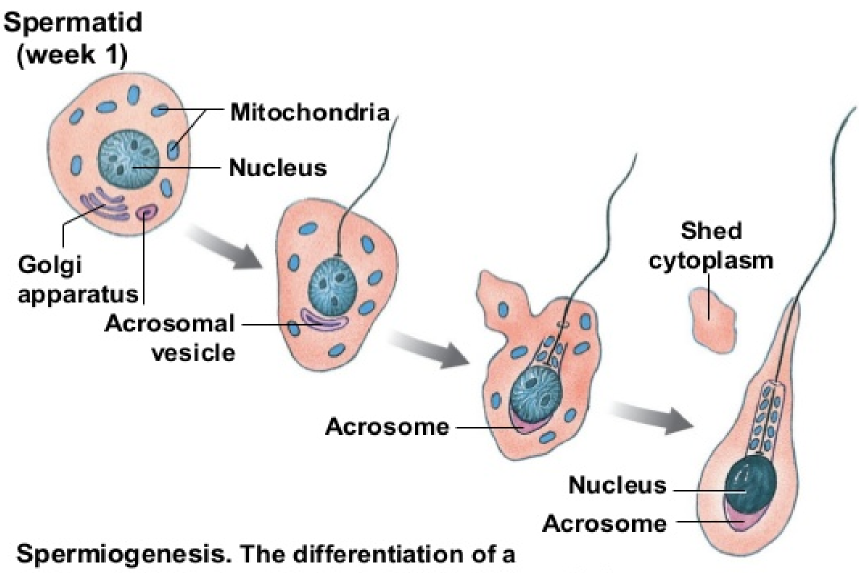
(*b*) condensation of the nucleus;

(*c*) formation of neck, middle piece, and tail; and

(*d*) shedding of most of the cytoplasm.

In humans, the time required for a spermatogonium to develop into a mature spermatozoon is approximately 64 days. When fully formed, spermatozoa enter the lumen of **seminiferous tubules**. From there, they are pushed toward the epididymis by contractile elements in the wall of the seminiferous tubules. Although initially only slightly motile, **spermatozoa obtain full motility in the epididymis.**

Figure 28-8 Spermiogenesis and Spermatozoon Structure



Spermiogenesis. The differentiation of a spermatid into a spermatozoon. This differentiation process is completed in approximately 5 weeks.