Gametogenesis, Fertilization, and Early Development

GAMETOGENESIS, FERTILIZATION, AND EARLY DEVELOPMENT

Gametogenesis is the production of sperm (spermatogenesis) and egg (oogenesis), which takes place through the process of meiosis.
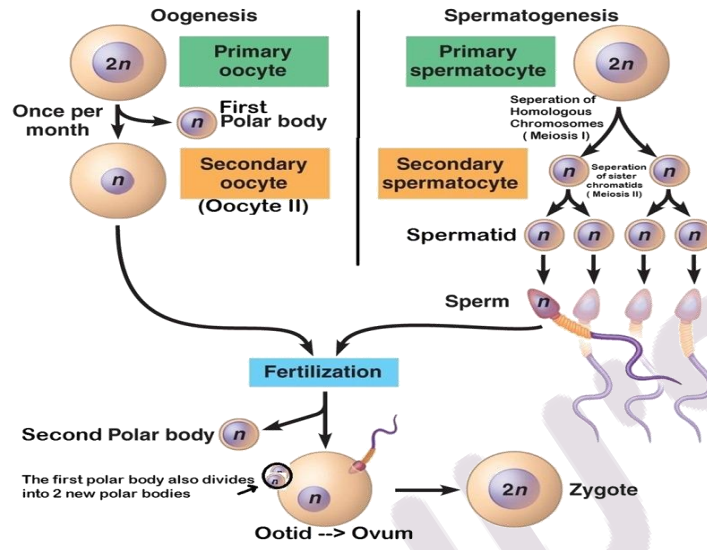

Figure 1. Showing Gametogenesis

Spermatogenesis

Spermatogenesis occurs in seminiferous tubules, in this tubule are diploid, undifferentiated cells, called spermatogonia, go through mitosis and increase in number. Meiosis begins with a cell called the primary spermatocyte. At the end of the first meiotic division, a haploid cell is produced called a secondary spermatocyte. This haploid cell must go through another meiotic cell division. The cell produced at the end of meiosis is called a spermatid. When it reaches the lumen of the tubule and grows a flagellum it is called a sperm cell. Four sperm result from each primary spermatocyte that goes through meiosis. Spermatogonia cells are deposited during gestation and are present at birth through the beginning of adolescence but in inactivation of these cells and the production of visible sperm. This continues into old age. Spermatozoa are later called sperms.
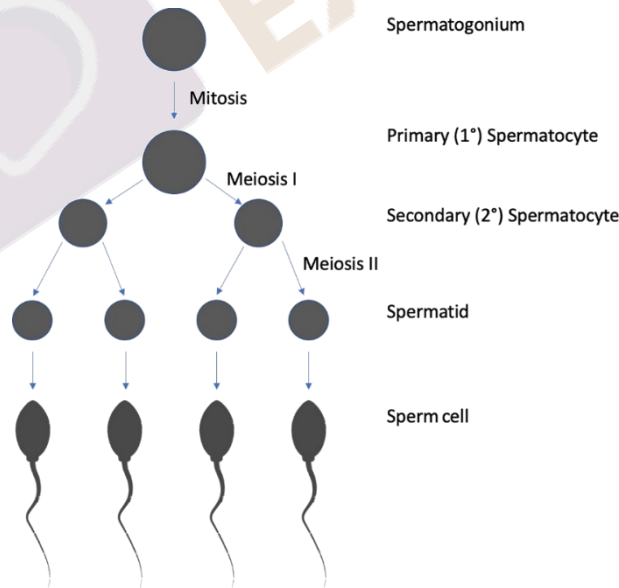

Figure 2. Showing Spermatogenesis stages

Oogenesis

Oogenesis occurs in the ovaries. Oogenesis starts with a germ cell, called an oogonium, but this cell undergoes mitosis to increase the number, eventually resulting in up to one to two million cells in embryo. The cell's starting meiosis is called primary oocyte. This cell will begin the first meiotic division but be arrested in its progress in the first prophase stage (Prophase I). At the time of birth, all future eggs are in prophase stage. At adolescence, another pituitary hormone causes the development of a number of follicles in an ovary. This results in the primary oocyte finishing the first meiotic division. The cell divides unequally, with most of the cellular and organelles going to one cell, called a secondary oocyte. Only one set of chromosomes and a small amount of cytoplasm going to another cell. This second cell is called polar body. A secondary meiotic arrest occurs, this time at the metaphase 11 stage. At ovulation, this secondary oocyte will be released and travel toward the uterus through the oviduct. If the secondary oocyte is fertilized, the cell continues through the meiosis 11, completing meiosis, producing a second polar body and fertilized egg containing all 46 chromosomes of human being, half of them coming from sperm. Arrest is due to lack of sufficient cell cycle proteins to allow meiotic progression.
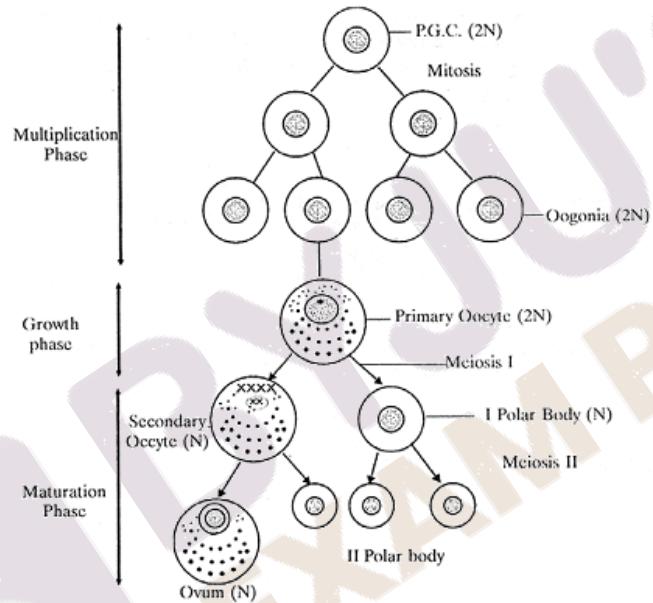

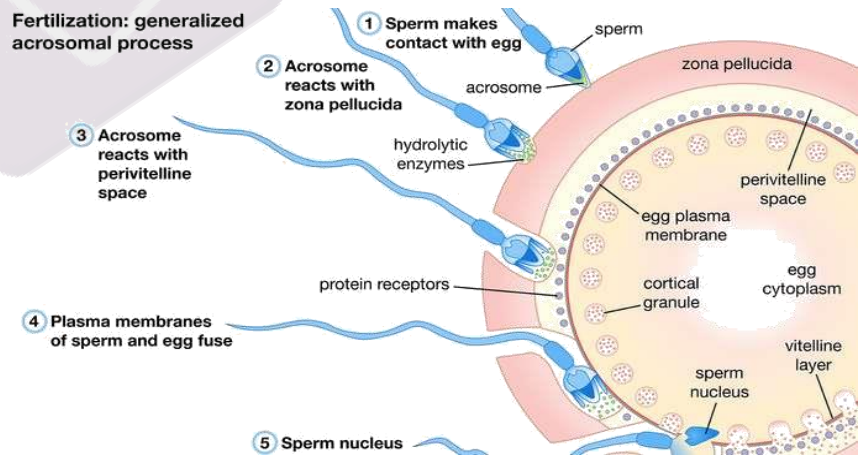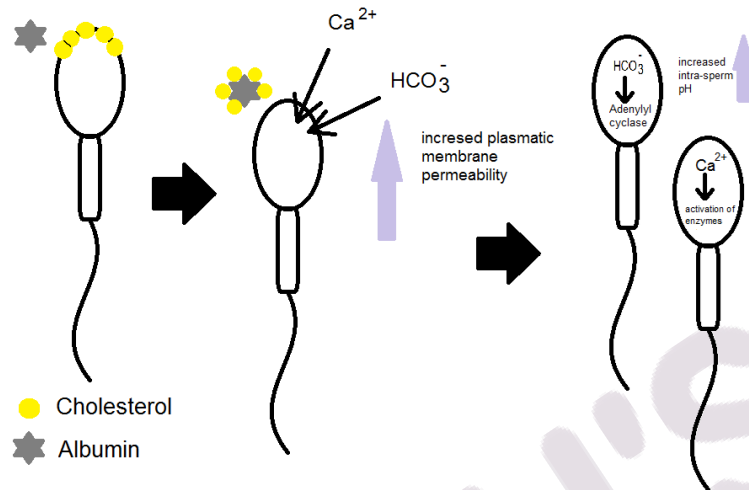**Figure 3. Showing Stages of Oogenesis**

Fertilization

Figure 4. Showing fertilization

Events of fertilization

1. Capacitation

Cholesterol
Albumin

Capacitation occurs in the ampulla of the oviduct. The final maturation of sperm occurs during capacitation. Proteins and carbohydrates are lost in sperm. Removal of cholesterol (as shown above in the diagram). Efflux of K^+ from sperm head. Calcium permeability increases inside sperm.

2. Chemo-attraction

The chemo attraction occurs through thermotaxis i.e. sperm sense heat. There is a thermal gradient of 2°C between the thymus of the oviduct and the warmer ampullary region. This ability to sense temperature differences and preferentially swim from cooler to warmer sites (thermotaxis) is found only in capacitated sperm. Chemotaxis-progesterone has been shown to bind to a receptor that activates Ca^{2+} channels in the cell membrane of the sperm tail, leading to sperm hyperactivity.

3. Binding of sperm to cumulus and acrosomal reaction

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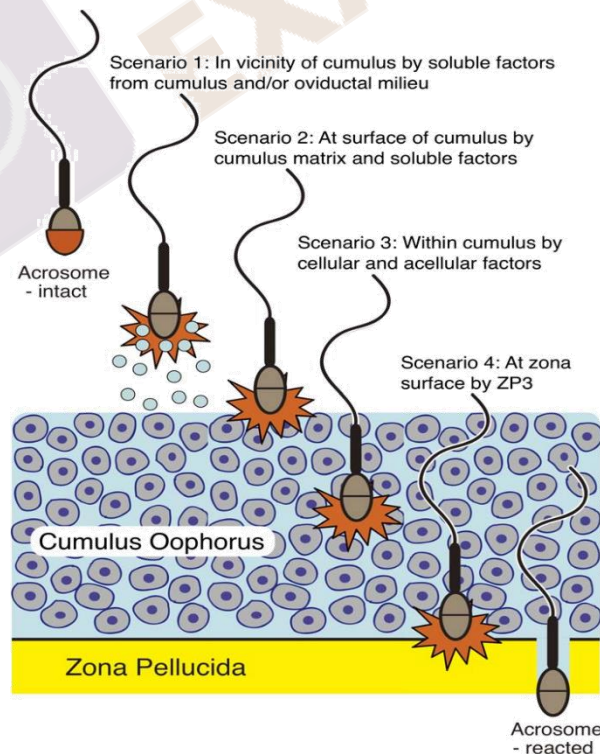
The acrosomal reaction occurs within the cumulus prior to zona pellucida binding (as shown in the above diagram).

4. Binding of sperm to zona pellucida
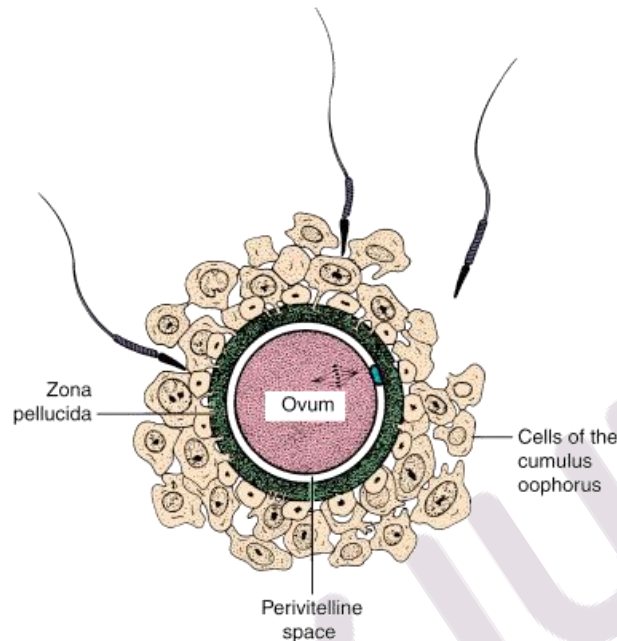
The human zona pellucida has four major glycoproteins- ZPQ, ZP2, ZP3, and ZP4. The binding of sperm to the zona pellucida occurs (as shown in the diagram above).

5. Species interaction

Sperm recognize ZP2 protein on zona pellucida. In the gain of function experiment, ZP2 was shown to be critical for human sperm-egg.

6. Gamete fusion

The acrosome reaction in addition to expelling the enzymatic contents of the acrosome also exposes the inner acrosomal membrane to the outside. The junction between this inner acrosomal membrane and the sperm cell membrane is called the equatorial region.

IZUMO protein

It is originally found in the membrane of the acrosomal granules. However, after the acrosome reaction, IZUMO redistributes along the surface of acrosome reacted sperm, where it is found primarily in the equatorial section, where mammalian sperm-egg binding takes place.

Stages of early development in mammals
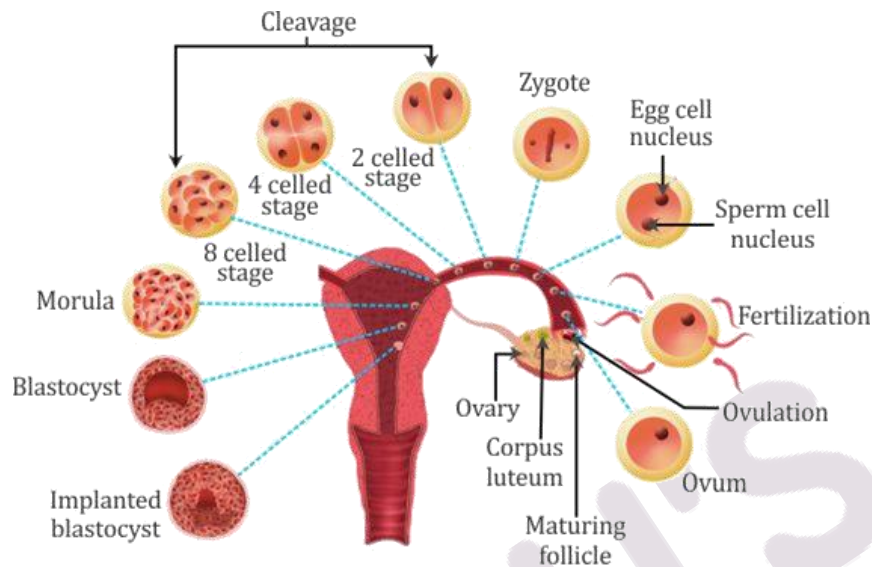
Prior to fertilization the mammalian oocyte, wrapped in cumulus cells, is released from the ovary and swept by the fimbriae into the oviduct. Fertilization occurs in the ampulla of the oviduct, a region close to the ovary, mitosis is completed after sperm entry, and the first cleavage begins about a day later. The cilia in the oviduct push the embryo toward the uterus and, the first cleavages occur along this journey. Following successive stages during embryo development:

a) Zygote
b) 2 celled stage - zygote divide into 2 cells
c) Further 2 celled stages divide to form a 4-celled stage.
d) After 4 celled comes an 8-celled stage
e) Morula - after the 8-celled stage, further division occurs and a ball of cells forms called a morula.
f) Blastula - after the morula stage comes the blastula stage in which a ball of cells divides into trophoblast outer group of cells and inner cell mass (icm).
g) Finally, this gets implanted into the mother's womb (as shown in diagram above).

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