Course Name- Developmental Biology
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Unit 10: Gametes and fertilization

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Gametogenesis

- Gametogenesis is the general process of gamete formation in both male and females.

- Spermatogenesis and oogenesis are both **forms of gametogenesis**, in which a diploid gamete cell produces haploid sperm and egg cells, respectively.

- Gametogenesis is the process by which gametes, or germ cells are produced in organism. The formation of egg cells, or ova, is technically called oogenisis and formation of spermatozoa, is called spermatogenesis.

Spermatogenesis

- Spermatogenesis is the process of maturation of reproductive cells of the testis in male so as to form the male gametes or sperm is known as spermatogenesis.
- Spermatogenesis occurs in the wall of the seminiferous tubules, with stem cells at the periphery of the tube and the spermatozoa at the lumen of the tube. Immediately under the capsule of the tubule are diploid, undifferentiated cells. These stem cells, called spermatogonia (singular: spermatagonium), go through mitosis with one offspring going on to differentiate into a sperm cell, while the other gives rise to the next generation of sperm.

- The entire process of spermatogenesis can be separated into two subheadings:

A) Formation of spermatids from the cell of germinal epithelium.

B) Metamorphosis of spermatids into sperm, or spermiogenesis.

A) Formation of spermatid:

The process of formation of spermatids from the primary germ cell is distinguished into three phases-

1) Multiplication phase
2) Growth phase
3) Maturation phase

B) Metamorphosis of spermatid or spermiogenisis :

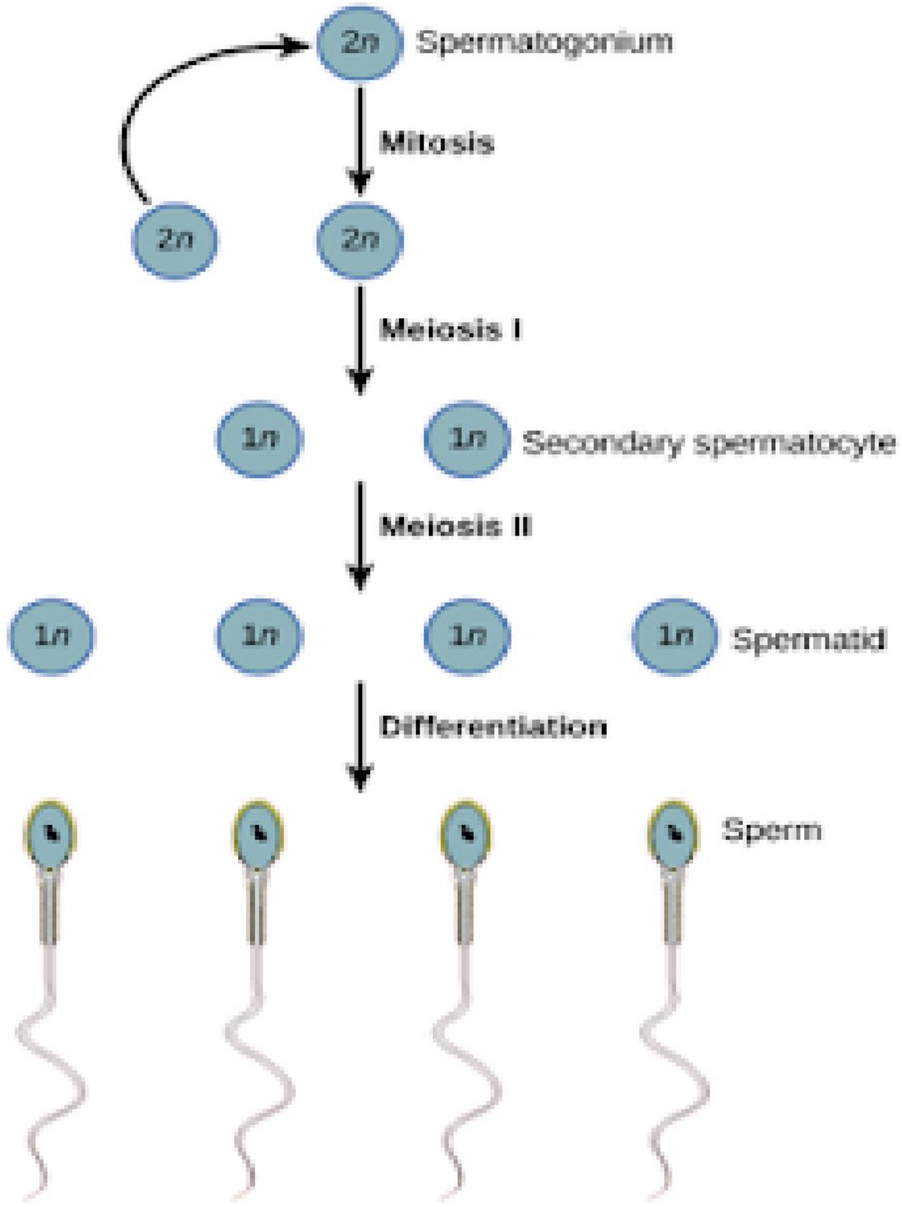
During the spermiogenesis these undergo modification in form and changes in relative position. These changes can be summarized below-

1) Changes in the nucleus
2) Changes in centrioles
3) Changes in mitochondria
4) Formation of acrosome
5) Loss of cytoplasm

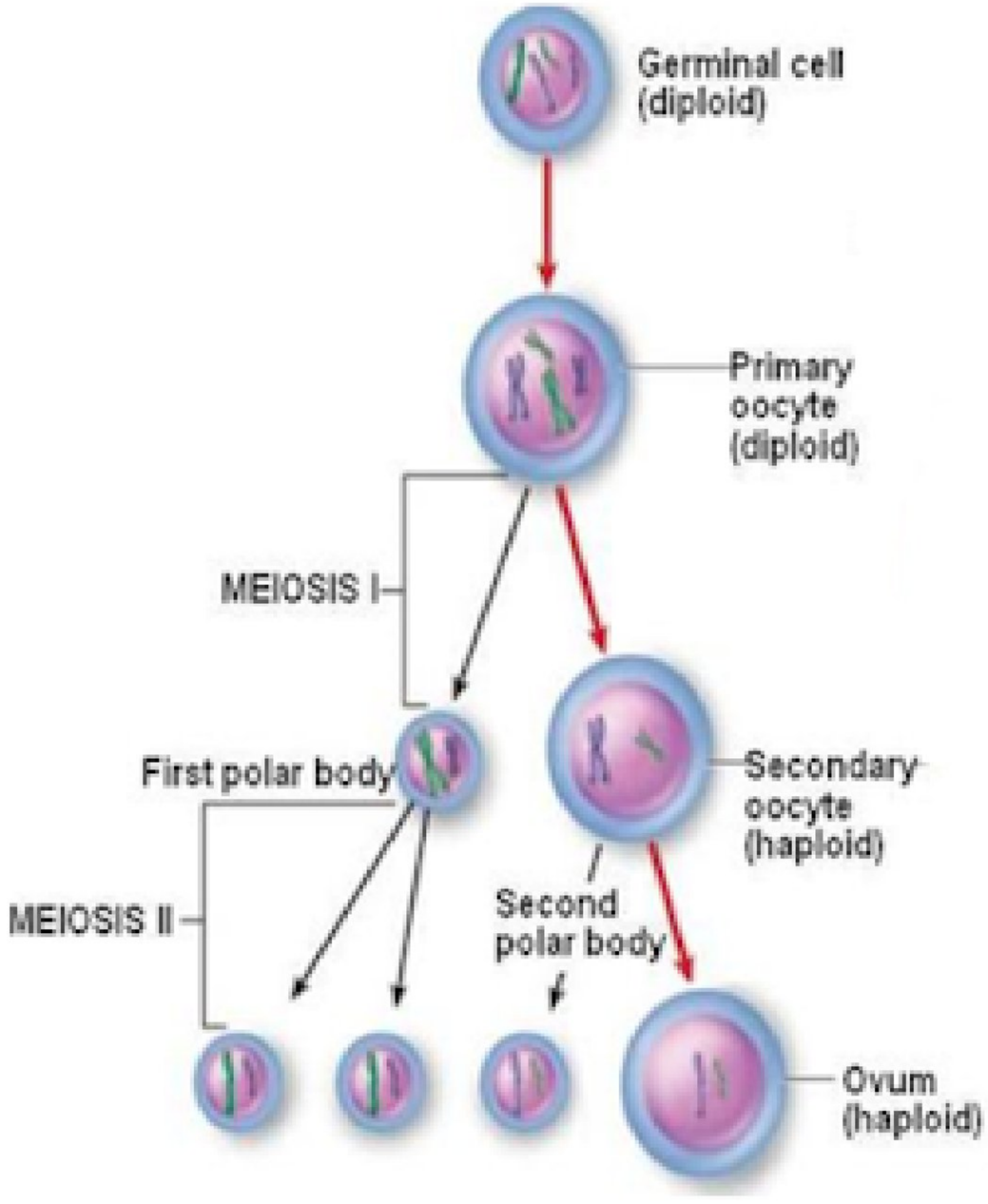
Significance of spermatogenesis

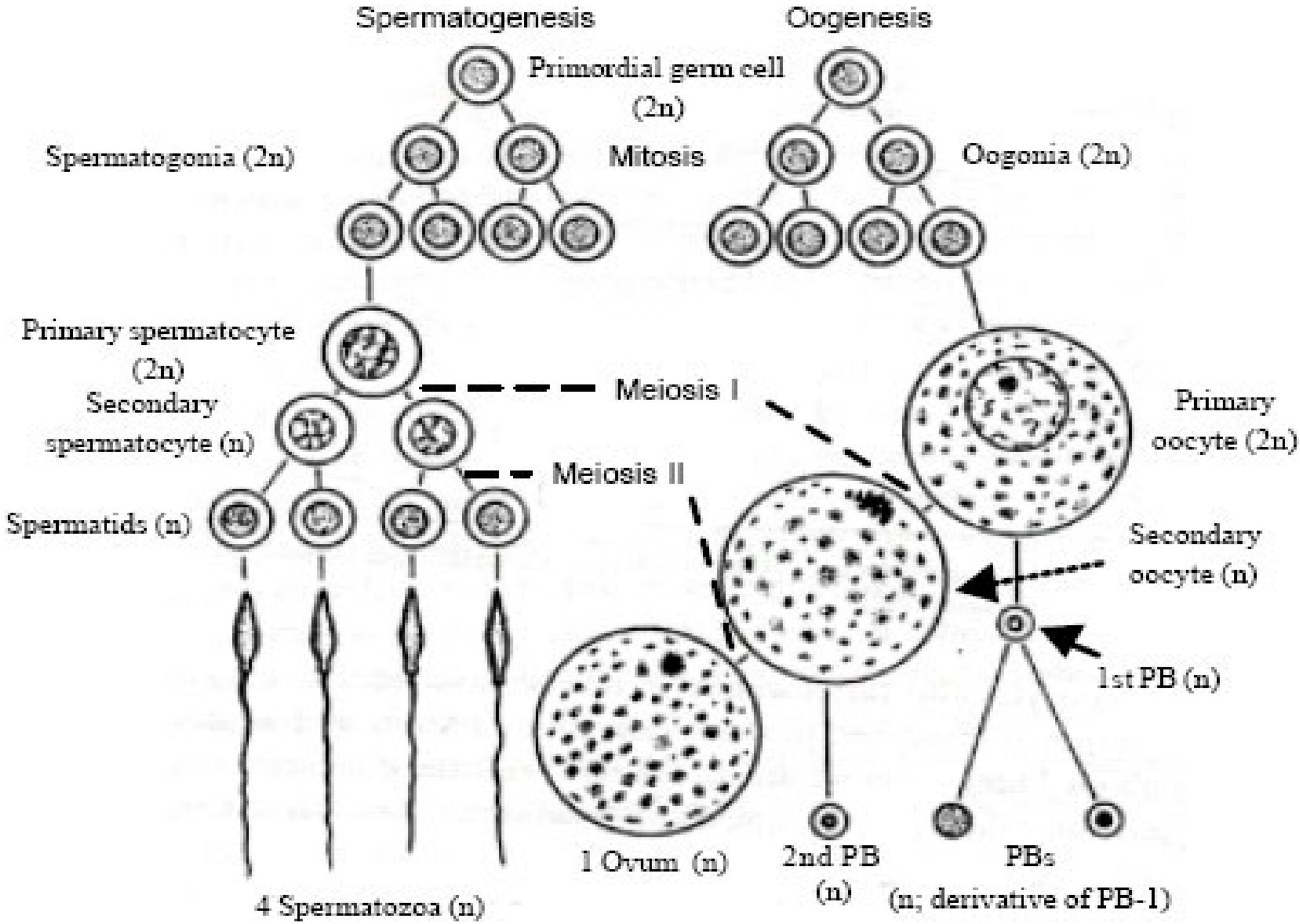
The process of spermatogenesis result in the reduction of chromosome number in the daughter cells which is exactly half of the parental cell. In the end four cells are formed one spermatogonium.

Spermatogenesis



Oogenesis





Oogenesis

- Oogenesis is the process of maturation of ova from the primary germ cells of the germinal epithelium in the ovary.
- Oogenesis occurs in the outermost layers of the ovaries. As with sperm production, oogenesis starts with a germ cell, called an oogonium (plural: oogonia), but this cell undergoes mitosis to increase in number, eventually resulting in up to one to two million cells in the embryo.
- There are three phase to oogenesis namely-
  1) Multiplication phase
  2) Growth phase
  3) Maturation phase.

Multiplication phase

- In multiplication phase the primordial germ cells of the germinal epithelium which line the ovary, undergo repeated mitotic division to form a large number of diploid daughter cells these are known as oogonia. Before entering the next phase the oogonia cease to divide.

Growth phase

- Since the egg cytoplasm is stuffed with reserve food needed during development, the growth phase of oocyte is long and elaborate. The differentiation and the first maturation division of the egg takes place simultaneously with the growth. The growth phase varies and may extend to many years.

Maturation phase

- The primary oocyte thus formed undergo two successive divisions. The first maturation division is a reduction division or meiotic cell division which results in the formation of two haploid daughter cells.
- Each haploid daughter cell contains only one member of each homologous pair. Due to unequal division of cytoplasm, the cells are unequal. One with almost no cytoplasm is termed as first polar body or polocyte. The other cell is large and practically with all the cytoplasm. It represents the secondary oocyte.
- The secondary oocyte undergoes, secondary maturation division with unequal division of the cytoplasm, resulting in the formation of a large ovum and a small secondary polar body. The first polar body may or may not divide mitotically into two , but every single case all of them degenerate. Thus the products of oogenesis are a single ovum and two or three haploid polar bodies found on the periphery of the ovum.

Significance of Oogenesis

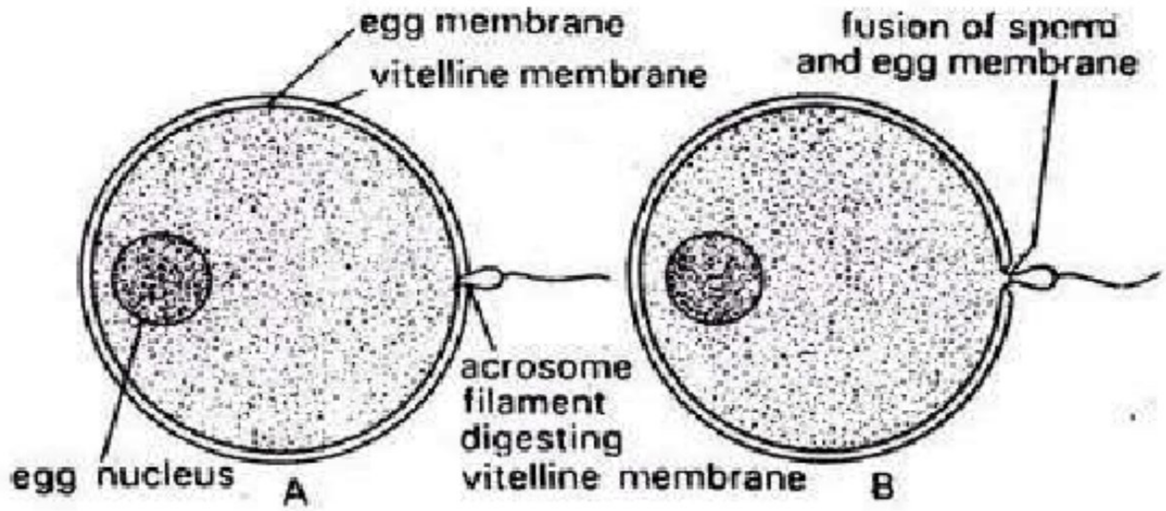
- The ovum formed as a result of oogenesis contains only half the number of chromosomes as present in the parent cell. This reduction in chromosome number helps in restoring the parental chromosomal configuration even after the fusion of gametes at the time of fertilization.

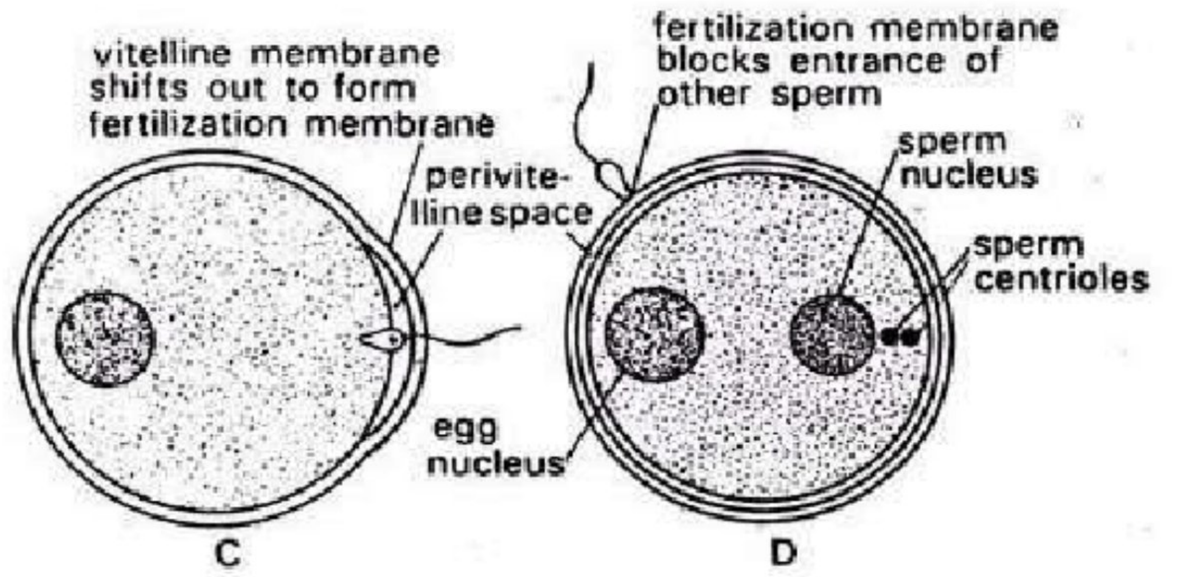
Fertilization

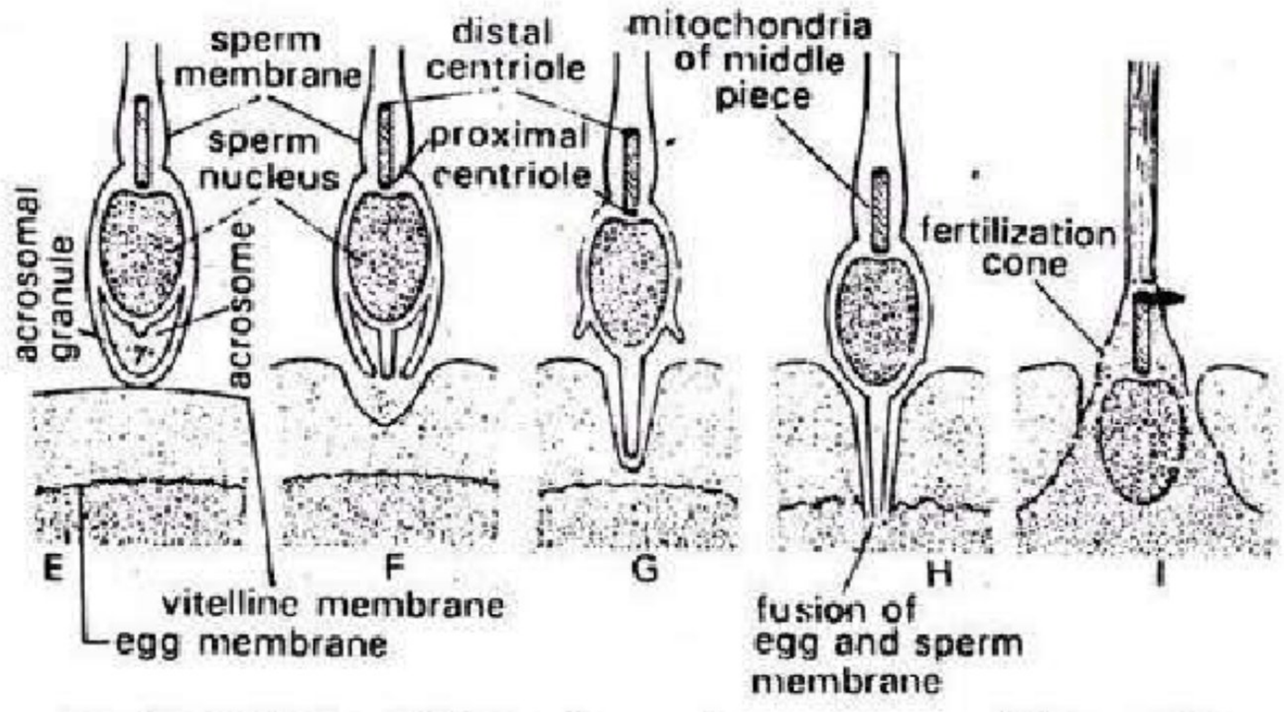
- Fertilization is the fusion of two gametes (sex cells), the male gamete (or sperm) with female gamete (or ovum), followed by the joining together of their nuclei. As a result of fertilization single fertilized cell is formed which is know as zygote or egg.

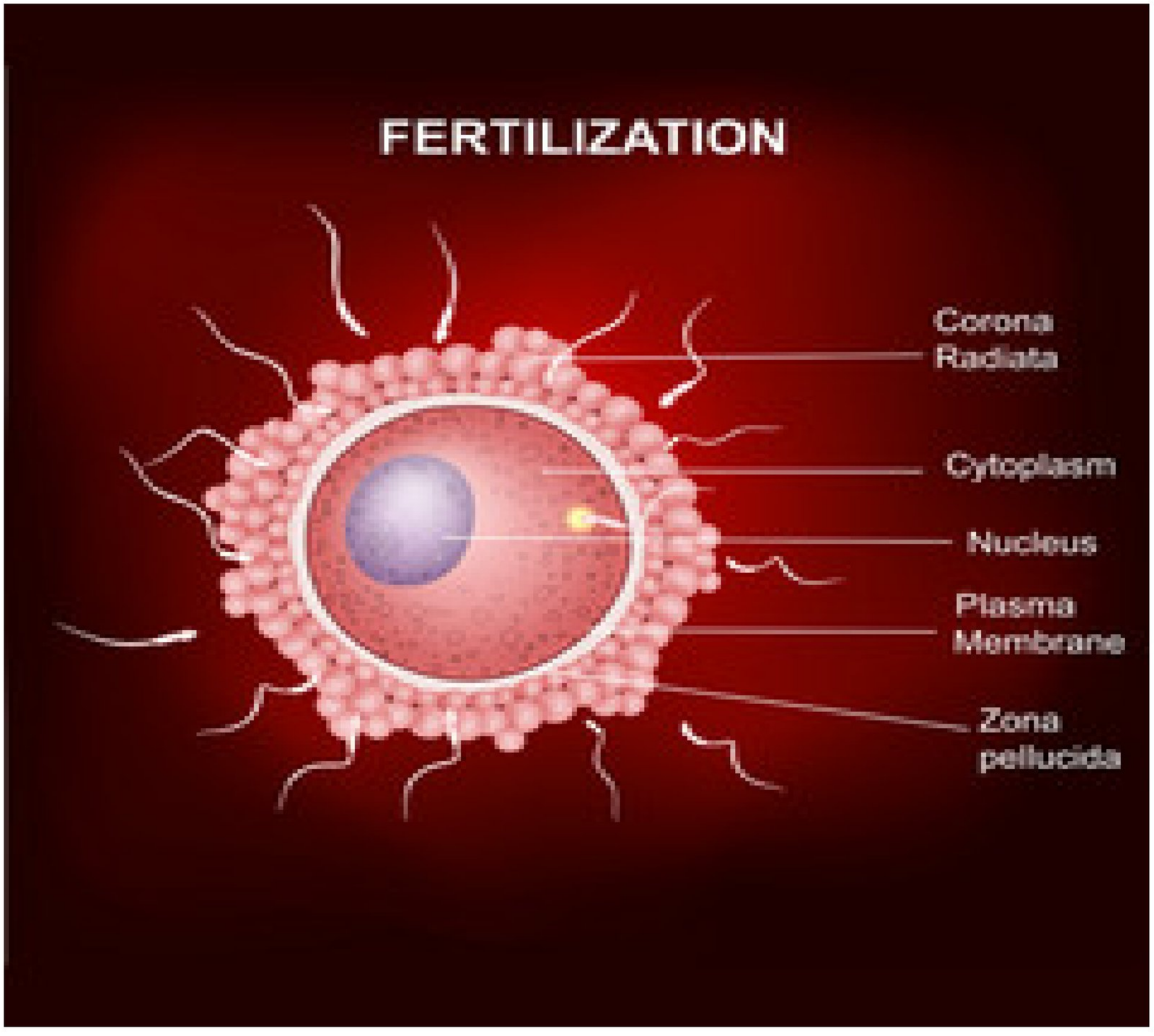
- The act of fertilization includes the union of the nuclei of male and female gametes along with the fusion of their cytoplasm.

- Fertilization occurs outside the body of female in lower non-chordates and chordates but in all the higher chordates and some non-chordate ovum is fertilized within the body of female. The former is external fertilization and latter is internal fertilization. In sea-urchins fertilization is external and sperms and ova are released in water.









Mechanism Of Fertilization

1. Approach of the Spermatozoon to the egg

- Whether fertilization is external or internal, the first step is the encounter of spermatozoon and the ovum, which is brought about by swimming movement of spermatozoa.
- Encounter between the sperm and ovum is purely accidental, because the movements of spermatozoa are entirely at random.

2. Agglutination

- The jelly like substance surrounding the egg produces a chemical substance, the fertilizin, and sperm a chemical which is known as antifertilizin.
- Adhesion of spermatozoa to the surface of eggs is brought about by linking of fertilizin molecules with antifertilizin molecules, which establish an initial bond.

- In addition to this, fertilizin reacts with antifertilizin and cause agglutination of spermatozoa.

3. Penetration of sperm

- Mechanism of penetration is purely chemical. Spermatozoon, on being attached to the surface of ovum, produces chemical substances of enzymatic nature which are known as sperm lysins. These are produced by the acrosome of spermatozoon.
- These dissolve the egg membranes in the local area and clear the path for spermatozoon to reach the surface of egg.

4. Formation of acrosomal filament

- Under the influence of fertilization the central transparent portion of acrosome elongate and gets changed into a thin tubular filament, called acrosomal filament.
- This activated filament penetrates through the jelly coat and vitelline membrane and touches the plasma membrane around the egg cytoplasm.

5. Reaction of egg for sperm

- Coming in contact with the acrosomal filament of spermatozoon, the cytoplasm of the egg bulges forward to produce a conical projection, the fertilization cone.

- It gradually engulfs the spermatozoon and then begins to retract, carrying the spermatozoon inward. Simultaneously, the surface of egg cytoplasm exhibits profound cortical reactions.
- The changes start from the point of attachment of spermatozoon and gradually spread over the whole surface of egg.
- The change affect the organization of egg cortex and in particular the cortical granules. Immediately after fertilization the two layers of plasma lemma of egg become separated from one another and from the surface of egg as fertilization membrane.

- The cortical granules swell up, become liquefied and the liquid is released into the space between egg cytoplasm and the fertilization membrane.

6. Behaviour of sperm within the ovum

- Usually the entire sperm enters the ovum but in the sea urchin the tail is left outside the vitelline membrane and the head and middle piece enter the egg.
- The subsequent behaviour of spermatozoon depends upon the stage of maturation, the egg has reached at the time of fertilization. In sea urchin the egg is laid and fertilized only after it has extruded out both its polar bodies.

- The membrane of sperm dissolves, liberating nucleus and centrosome and mitochondria.
- The sperm nucleus immediately proceed to unite with the egg nucleus.

7. Fusion of male and female pronuclei

- When the spermatozoon first penetrates into egg cytoplasm its acrosome is directed forward and is followed by nucleus and centrosme, and soon the nucleus and centrosome rotate centrosome come ahead of the nucleus turns at 180 degree so that now it come it come forward and move towards the area where fusion with the egg nucleus or female pronucleus is to take place.

- Simultaneously, sperm nucleus or male pronucleus swells up and becomes vesicular. Its chromatin becomes granular. The centrosome becomes surrounded by an aster.
- The female pronucleus also move to the site of fusion. The site is usually present in the centre of cell. The movement of female pronuclei is probably because of force of attraction but the movement is automatic.
- In the last stage when male and female pronuclei actually fuse together, the nuclear membrane breaks off at the points of contact and the contents of the nuclei unite into one mass surrounded by common nuclear membrane. At the approach of first cleavage of the fertilized egg of sea urchin and patrnal line become segregated and arrange on the equator of the achromatic spindle.

Significance of Fertilization

The results of fertilization are:

- The entrance of sperm activates the secondary oocyte to complete its second maturation division.
- Includes the movement of cytoplasm and the pigment granules and marks the fertilization track.
- Introduces the 2^{nd} centriole and induces spindle formation.
- Restore the diploid number of chromosomes and recombines the maternal and paternal genetic traits.
- Indues change in the periphery of egg and this change precludes the entry of other sperm.

6. This cause separation of vitelline membrane which allows the rotation of egg inside.
7. This enhances the metabolic activities and thus renews the vigor and vitality.
8. The amount of cytoplasm lost due to the separation of polocytes is restored.
9. Establishes a new plane of egg axis.
10. Causes rearrangement and organization into distinct ‘organ forming areas’.

Thank you