(Meiosis)

- **Meiosis** is a specialized type of cell division that reduces the chromosome number by half, creating **four haploid cells**, each genetically distinct from the parent cell that gave rise to them.

- This process occurs in all sexually reproducing single-celled and multicellular eukaryotes, including animals, plants, and fungi.

- In meiosis, DNA replication is followed by two rounds of cell division to produce four daughter cells, each with half the number of chromosomes as the original parent cell.

- The two meiotic divisions are known as **Meiosis I** and **Meiosis II**.

- Meiosis occurs in eukaryotic life cycles involving **sexual reproduction**, consisting of the constant cyclical process of meiosis and fertilization.

- In some cases all four of the meiotic products form **gametes** such as **sperm**, **spores**, or **pollen**. In female animals, three of the four meiotic products are typically eliminated by extrusion into **polar bodies**, and only one cell develops to produce an **ovum**.

- Because the number of chromosomes is halved during meiosis, gametes can fuse (**fertilization**) to form a diploid **zygote** that contains two copies of each chromosome, one from each parent.

- For example, **diploid human cells** contain 23 pairs of chromosomes including 1 pair of sex chromosomes (46 total), half of maternal origin and half of paternal origin.

- The preparatory steps that lead up to meiosis are identical in pattern and name to interphase of the mitotic cell cycle.

- **Interphase** is divided into three phases:

❖ **Growth 1 (G1) phase**: In this very active phase, the cell synthesizes its vast array of proteins, including the enzymes and structural proteins it will need for growth. In G1, each of the chromosomes consists of a single linear molecule of DNA.

❖ **Synthesis (S) phase:** The genetic material is replicated; each of the cell's chromosomes duplicates to become two identical sister chromatids attached at a centromere. The identical sister chromatids have not yet condensed into the densely packaged chromosomes visible with the light microscope. This will take place during prophase I in meiosis.

❖ **Growth 2 (G2) phase:** G2 phase as seen before mitosis is not present in meiosis. Meiotic prophase corresponds most closely to the G2 phase of the mitotic cell cycle.

Meiosis I:

Prophase I:

- Prophase I is typically the longest phase of meiosis.
- During **prophase I**, homologous chromosomes pair and exchange DNA (homologous recombination). This often results in **chromosomal crossover** and this process happened at the first meiosis division.
- The new combinations of DNA created during crossover are a significant source of **genetic variation**.
- The paired and replicated chromosomes are called bivalents or tetrads, which have two chromosomes and four chromatids, with one chromosome coming from each parent.
- The process of pairing the homologous chromosomes is called **synapsis**.
- Prophase I has been divided into a series of sub stages which are named according to the appearance of chromosomes:
  1- Leptotene.
  2- Zygotene.
  3- Pachytene.
  4- Diplotene.
  5- Diakinesis.

Metaphase I:

- Homologous pairs move together along the metaphase plate.
- As **kinetochore microtubules** from both centrosomes attach to their respective kinetochores, the paired homologous chromosomes align along an equatorial plane that bisects the spindle.

Anaphase I:

- Kinetochore microtubules shorten, pulling homologous chromosomes (which consist of a pair of sister chromatids) to opposite poles.

Telophase I:

- The first meiotic division effectively ends when the chromosomes arrive at the poles.
- Each daughter cell now has half the number of chromosomes but each chromosome consists of a pair of chromatids.
- The microtubules that make up the spindle network disappear, and a new nuclear membrane surrounds each haploid set.
- The chromosomes uncoil back into chromatin.
- **Cytokinesis**, the pinching of the cell membrane in animal cells or the formation of the cell wall in plant cells, occurs, completing the creation of two daughter cells. Sister chromatids remain attached during telophase I.
- Cells may enter a period of rest known as **interkinesis** , no DNA replication occurs during this stage.

Meiosis II:

Prophase II:

- Disappearance of the **nucleoli** and the **nuclear envelope** again as well as the shortening and thickening of the chromatids.
- Centrosomes move to the polar regions and arrange spindle fibers for the second meiotic division.

Metaphase II:

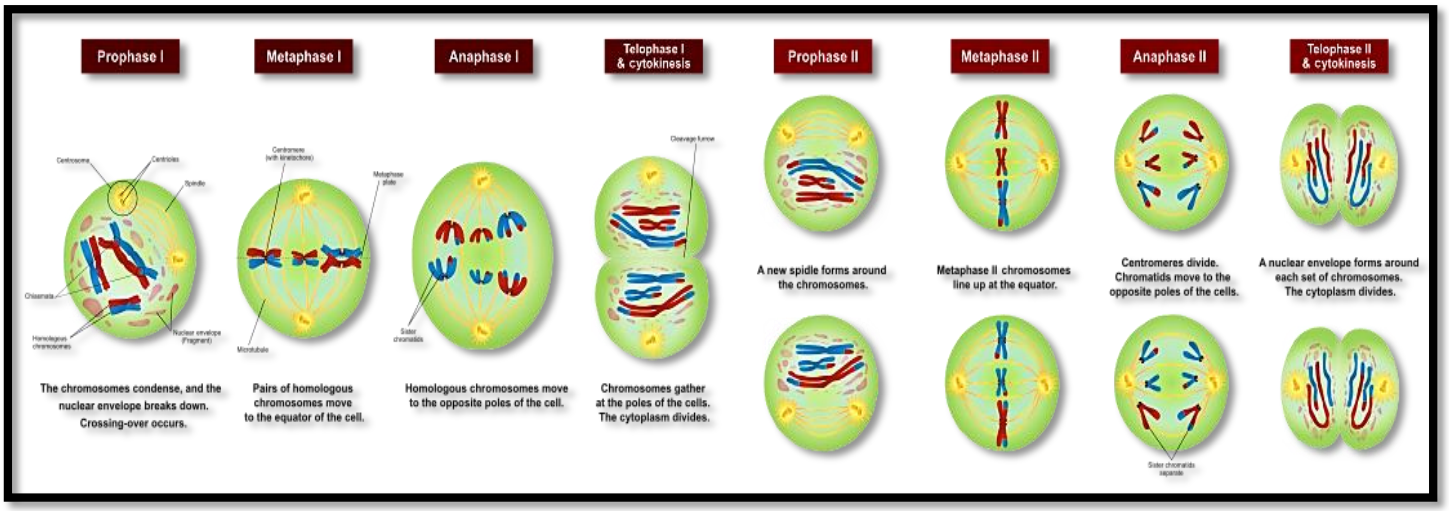
- The centromeres contain two kinetochores that attach to spindle fibers from the centrosomes at opposite poles.

Anaphase II:

- The remaining centromeres is cleaved allowing the sister chromatids to segregate.
- The sister chromatids by convention are now called sister chromosomes as they move toward opposing poles.

Telophase II:

- Is similar to telophase I, and is marked by decondensation and lengthening of the chromosomes and the disassembly of the spindle.
- Nuclear envelopes reform and cleavage or cell plate formation eventually produces a total of four daughter cells.



(Human Reproduction)

- The formation of sperms and eggs are referred as Spermatogenesis and Oogenesis, respectively. Like all other higher animals, in man also, the egg and sperm are developed by the process of meiosis.
- A gamete, haploid (X) in number gets diploid (2X) after its fusion with a female one (X). It denotes the formation of a zygote (2X) after fertilization.

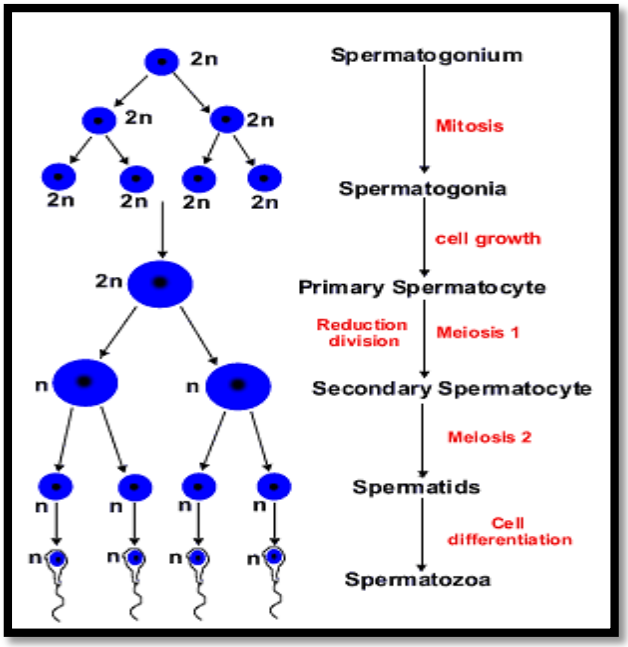
- The germ cell contains only one set of the 23 chromosomes. But, at the time of fertilization, a sperm with its 23 chromosomes being fused with an ovum having 23 chromosomes results in the formation of a zygote containing 46 chromosomes.

- Maturation of the gamete is the process, which is known as Gametogenesis, This gamete is basically a germ cell, which is divided, mitotically in repeated successions to develop into **spermatogonia** and **oogonia**, the producers of the sperms and the ova respectively.

- The **spermatogonia** at the beginning is called as **primary spermatocyte**. This is the stage when the pairs of chromosomes engage themselves in synapsis.

- The **primary spermatocyte** divides itself into **two secondary spermatocytes** by meiotic division. Each of two halves contains haploid number of chromosomes.

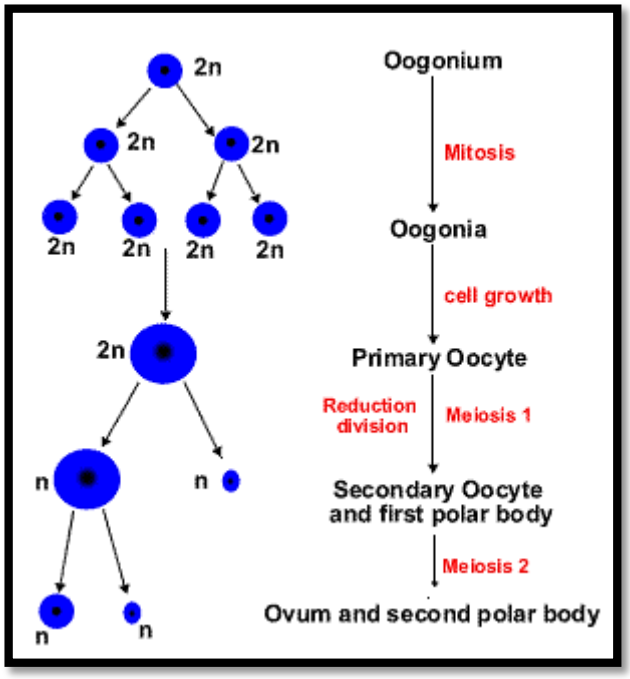
- These **secondary spermatocytes** divide again mitotically to give rise **four spermatids**, which are finally grown into **sperms**. The total process has been termed as **Spermatogenesis**.



- **Oogenesis** or the formation of ova follows a more or less same process as like Spermatogenesis. For example, germ cell divides mitotically and develops **oogonia** which gives rise to **primary oocyte**. In turn, the **secondary oocytes** develop through **meiotic division I** with one polar body and haploid number of chromosomes.

- Each of the **secondary oocytes** also undergoes an unequal **meiotic division II** to form an ovum and (3) secondary polar body .

- The **ovum** develops into an embryo after fertilization, but the polar bodies are incapable to take part in fertilization and ultimately they are lost.



Comparison between spermatogenesis and oogenesis

Aspect	Spermatogenesis	Oogenesis
Site of process	In the testes	In the ovaries
Cells produced	Sperm	Ova or egg
Size of cells	Small	Big
Cell structure	Consist of the head, middle pieces and tail.	Round
Number of gametes produced	4 functional cells.	1 functional cell and 3 non-functional polar bodies
Meiosis	Occurs continuously	Not continues, stop at meiosis I. Meiosis II occurs only if sperm penetrates the secondary oocyte.
Parent cells	Infinity number of cells can become sperm.	Limited number of cells can become ova.