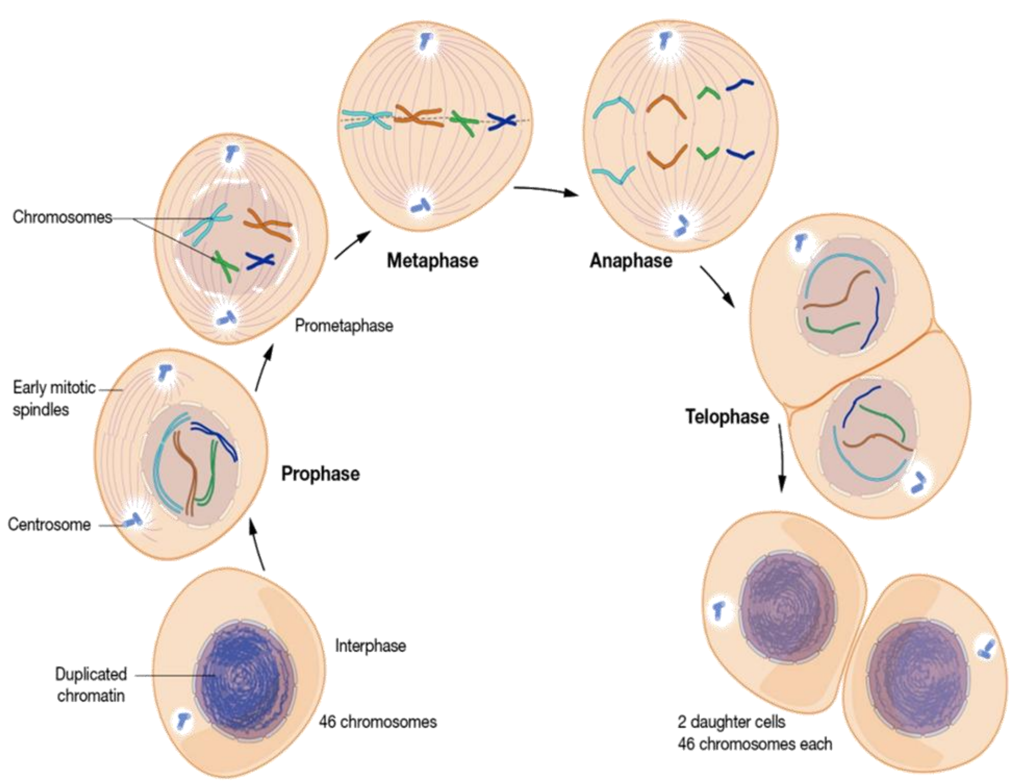
- **Cell division** is a crucial process that increases the number of cells, permits renewal of cell populations, and allows wound repair.

Mitosis

- **Mitosis is a process of chromosome segregation and nuclear division followed by cell division that produces two daughter cells with the same chromosome number and DNA content as the parent cell.**



- The term *mitosis* is used to describe the equal partitioning of replicated chromosomes and their genes into two identical groups.
- The process of cell division includes division of both the nucleus (karyokinesis) and the cytoplasm (cytokinesis).
- Before entering mitosis, cells duplicate their DNA in *synthesis phase*. At the beginning of S phase, the chromosome number is **(2n)**, and the DNA content is also **(2d)**; at the end, the chromosome number remains the same **(2n)**, and the DNA content doubles to **(4d)**.

Mitosis follows the S phase of the cell cycle and is described in four phases.

1. **Prophase** begins as the replicated chromosomes condense and become visible. Each of the four chromosomes can be seen to consist of two **chromatids**. The sister chromatids are held together by the ring of proteins called **cohesins** and the **centromere**.

In **late prophase** or **prometaphase,** the nuclear envelope begins to disintegrate. The nucleolus, also completely disappeared. In addition, a highly specialized protein complex called a **kinetochore** appears on each chromatid opposite to the centromere. Microtubules of the developing mitotic spindle attach to the kinetochores and thus to the chromosomes.

2. **Metaphase** begins as the mitotic spindle, consisting of three types of microtubules **(astral microtubules, polar microtubules, kinetochore microtubules)** becomes organized around the microtubule-organization centers (MTOCs) centrosomes located at opposite poles of the cell.

Kinetochore microtubules and their associated motor proteins direct the movement of the chromosomes to a plane in the middle of the cell, the **equatorial** or **metaphase plate**.

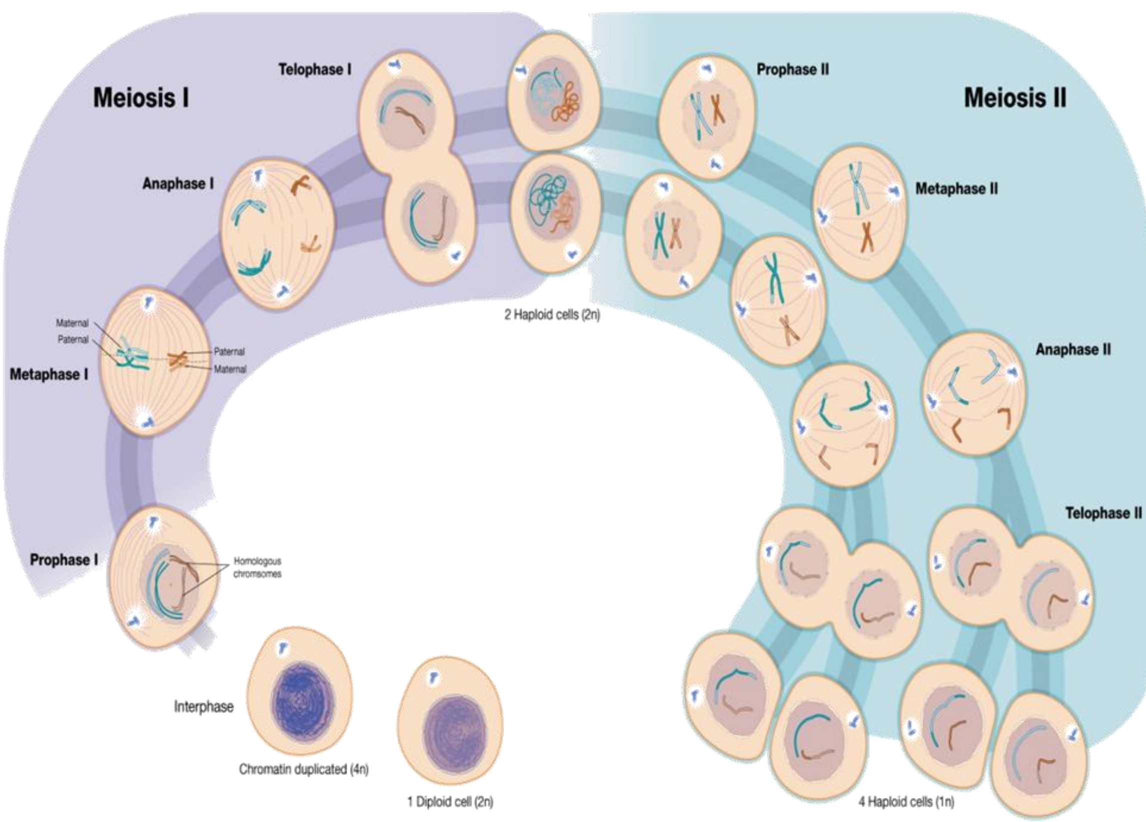
3. **Anaphase** begins at the initial separation of sister chromatids. This separation occurs when the cohesions that have been holding the chromatids together break down. The chromatids then begin to separate and are pulled to opposite poles of the cell by the molecular motors (dyneins) sliding along the kinetochore microtubules toward the (MTOC) centrosomes.
4. **Telophase** is marked by the reconstitution of a nuclear envelope around the chromosomes at each pole. The chromosomes uncoil and the nucleoli reappear, and the cytoplasm divides (cytokinesis) to form two daughter cells.

- **Cytokinesis** begins with the furrowing of the plasma membrane midway between the poles of the mitotic spindle. The separation at the **cleavage furrow** is achieved by a **contractile ring** consisting of a very thin array of actin filaments positioned around the perimeter of the cell. Within the ring, **myosin II** molecules are assembled into small filaments that interact with the actin filaments, causing the ring to contract. As the ring tightens, the cell is pinched into two daughter cells.

❖ Because the chromosomes in the daughter cells contain identical copies of the duplicated DNA, the daughter cells are genetically identical and contain the same kind and number of chromosomes. The daughter cells are **(2d)** in DNA content and **(2n)** in chromosome number.

Meiosis

❖ **Meiosis involves two sequential nuclear divisions followed by cell divisions that produce gametes containing half the number of chromosomes and half the DNA found in somatic cells.**



❖ The **zygote** (the cell resulting from the fusion of an ovum and a sperm) and all the somatic cells derived from it are **diploid (2n)** in chromosome number; thus, their cells have two copies of every chromosome and every gene encoded on this chromosome. These chromosomes are called **homologous chromosomes** because they are similar but not identical; one set of chromosomes is of maternal origin, the other is from the male parent.

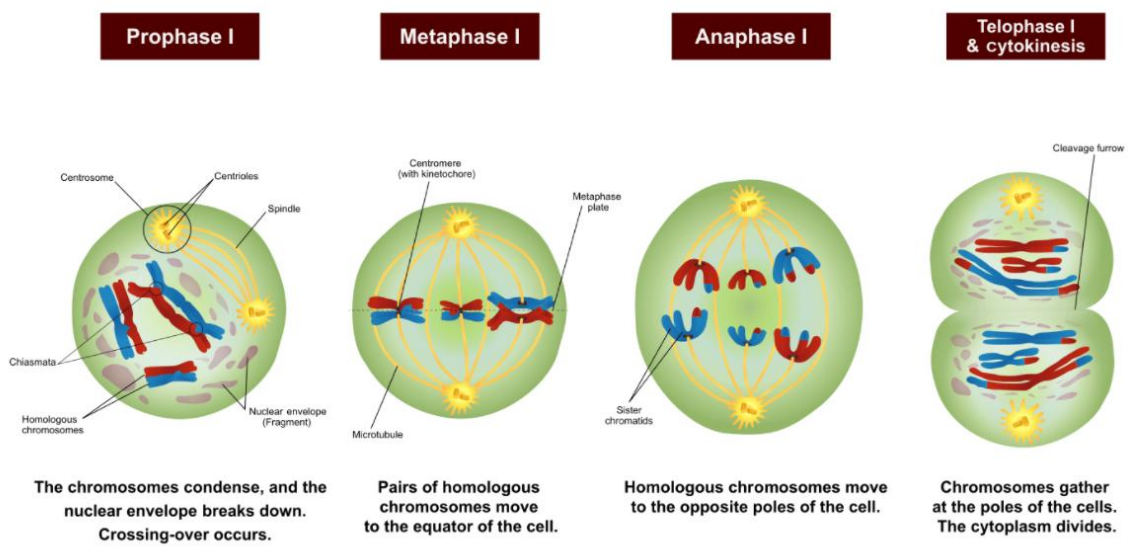
- The **gametes**, having only one member of each chromosome pair, are described as **haploid (1n)**. During gametogenesis, reduction in chromosome number to the haploid state (23 chromosomes in humans) occurs through **meiosis**, a process that involves two successive divisions, the second of which is not preceded by an S phase.

This reduction is necessary to maintain a constant number of chromosomes in a given species.

- During meiosis, the chromosome pair may exchange chromosome segments, thus altering the genetic composition of the chromosomes. This genetic exchange, called **crossing over**, and the random assortment of each member of the chromosome pairs into haploid gametes give rise to infinite genetic diversity.

Meiosis consists of two successive mitotic divisions without the additional S phase between the two divisions.

Meiosis I phases



Prophase I is subdivided into the following five stages

1. **Leptotene**. This stage is characterized by the condensation of chromatin and by the appearance of chromosomes.

2. **Zygotene**. The close association of homologous chromosomes (Synapsis) begins at this stage to form pairs of chromosomes (bivalent) consist of four chromatids (tetrads).
3. **Pachytene**. **Crossingover** occurs early in this phase and involves transposition of DNA strands between two different chromosomes to form chiasmata.
4. **Diplotene**. Homologous chromosomes begin to separate from each other and appear to be connected by newly formed junctions between chromosomes called **chiasmata** (*sing.*, chiasma).
5. **Diakinesis**. The homologous chromosomes condense and shorten to reach their maximum thickness, the nucleolus disappears, and the nuclear envelope disintegrates.

Metaphase I is similar to the metaphase of mitosis except that the paired chromosomes are aligned at the **equatorial plate** with one member on either side. At late metaphase, chiasmata are cleaved and the chromosomes separate. Once the nuclear envelope has broken down, the spindle microtubules begin to interact with the chromosomes through the multilayered protein structure, the **kinetochore**, which is usually positioned near the centromere. The chromosomes undergo movement to ultimately align their centromeres along the equator of the spindle.

Anaphase I and Telophase I are similar to the same phases in mitosis except that the centromeres do not split. The sister chromatids, held together by cohesin complexes and by the centromere, remain together. A maternal or paternal member of each homologous pair, now containing exchanged segments, moves to each pole. **Segregation** or **random assortment** occurs because the maternal and paternal chromosomes of each pair are randomly aligned on one side or the other of the metaphase plate, thus contributing to genetic diversity. At the completion of meiosis I, the cytoplasm divides. Each resulting daughter cell (a **secondary spermatocyte** or **oocyte**) is haploid in chromosome number **(1n)** and contains one member of each homologous chromosome pair. The cell is still diploid in DNA content **(2d)**.

- ❖ **The nuclear events of meiosis I are similar in males and females, but the cytoplasmic events associated with meiosis differ in the male and female.**

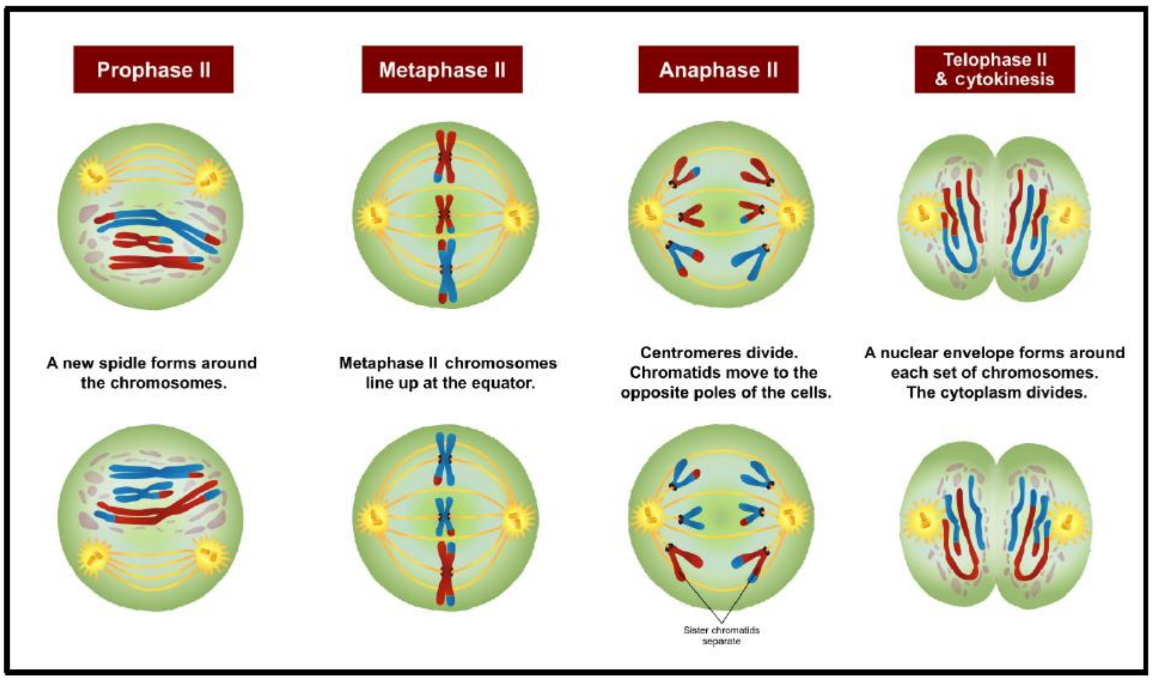
The nuclear and cytoplasmic events of meiosis occur in spermatogenesis and oogenesis. The events of meiosis through metaphase I are the same in both sexes. Therefore, the differences in the process diverge after metaphase I.

In males, the two meiotic divisions of a **primary spermatocyte** yield four structurally identical, although genetically unique, haploid **spermatids**. Each spermatid has the capacity to differentiate into a **spermatozoon**.

In contrast, in females, the two meiotic divisions of a **primary oocyte** yield one haploid **ovum** and three haploid **polar bodies**.

The ovum receives most of the cytoplasm and becomes the functional gamete. The polar bodies receive very little cytoplasm and degenerate.

Meiosis II



After meiosis I, the cells quickly enter meiosis II without passing through an S phase. **Meiosis II** is an equatorial division and resembles mitosis. During this phase, the proteinase enzyme **separase** cleaves the cohesion complexes between the sister chromatids. Cleavage of the cohesin complexes in the region of the centromere releases the bond between both centromeres. This cleavage allows the sister chromatids to separate at anaphase II and move to opposite poles of the cell. During meiosis II, the cells pass through prophase II, metaphase II, anaphase II, and telophase II. These stages are essentially the same as those in mitosis except that they involve a haploid set of chromosomes **(1n)** and produce daughter cells that have only haploid DNA content **(1d)**. Unlike the cells produced by mitosis, which are genetically identical to the parent cell, the cells produced by meiosis are genetically unique.