CELL DIVISION

Cell division is the process by which cells replicate in order to replace cell loss, repair tissue damage and reproduce the organism.
Two types of cell division are encountered in the Eukaryotic cell viz. Mitotic and Meiotic divisions.

MITOSIS

In mitotic division (Mitosis) two genetically identical daughter cells are produced from the original cell. The daughter cells, which are identical structurally and in genetic content, could be used to replace dead cells or to repair a damaged tissue. All cells of the body with the exception of the fully differentiated nerve cells undergo mitotic division.

MEIOSIS

In meiotic division (Meiosis), two genetically none identical daughter cells are produced from the mother cell. The product of meiotic division are involved in the duplication of the organism (Reproduction) hence this division only occurs in reproductive cells called Germ cells. In the human the product of meiotic division of the male germ cell is the Spermatozoon while that of the female germ cell is the Ovum. The union between the male and female germ cells in the process called fertilization results in the formation of a new organism.

Mitosis and Meiosis proceed in two phases viz. nuclear division (Karyokinesis) in which genetic materials are shared and cytoplasmic division (Cytokinesis) in which other organelles of the cell are shared.

STAGES OF MITOTIC DIVISION (Diag. C1)

A cell which is not actively dividing is said to be in **INTERPHASE.** As the cell prepares to divide, it replicates its DNA. This leads to elongation and thickening of the chromosomes. Subsequent to this, the cell proceeds to the first stage of Mitosis.
Mitotic division proceeds through 5 stages which include: (See Diagram)

- **Prophase:**
  a. Chromosomes condense, shorten thicken and become visible

- **Prometaphase**
  a. Centrioles separate and migrate in opposite directions
  b. Mitotic spindles (derived from Microtubules) are formed
  c. Nuclear envelope disintegrates (karyokinesis)
  d. Chromosomes are attached to mitotic spindle and are organized by the spindles and centrioles

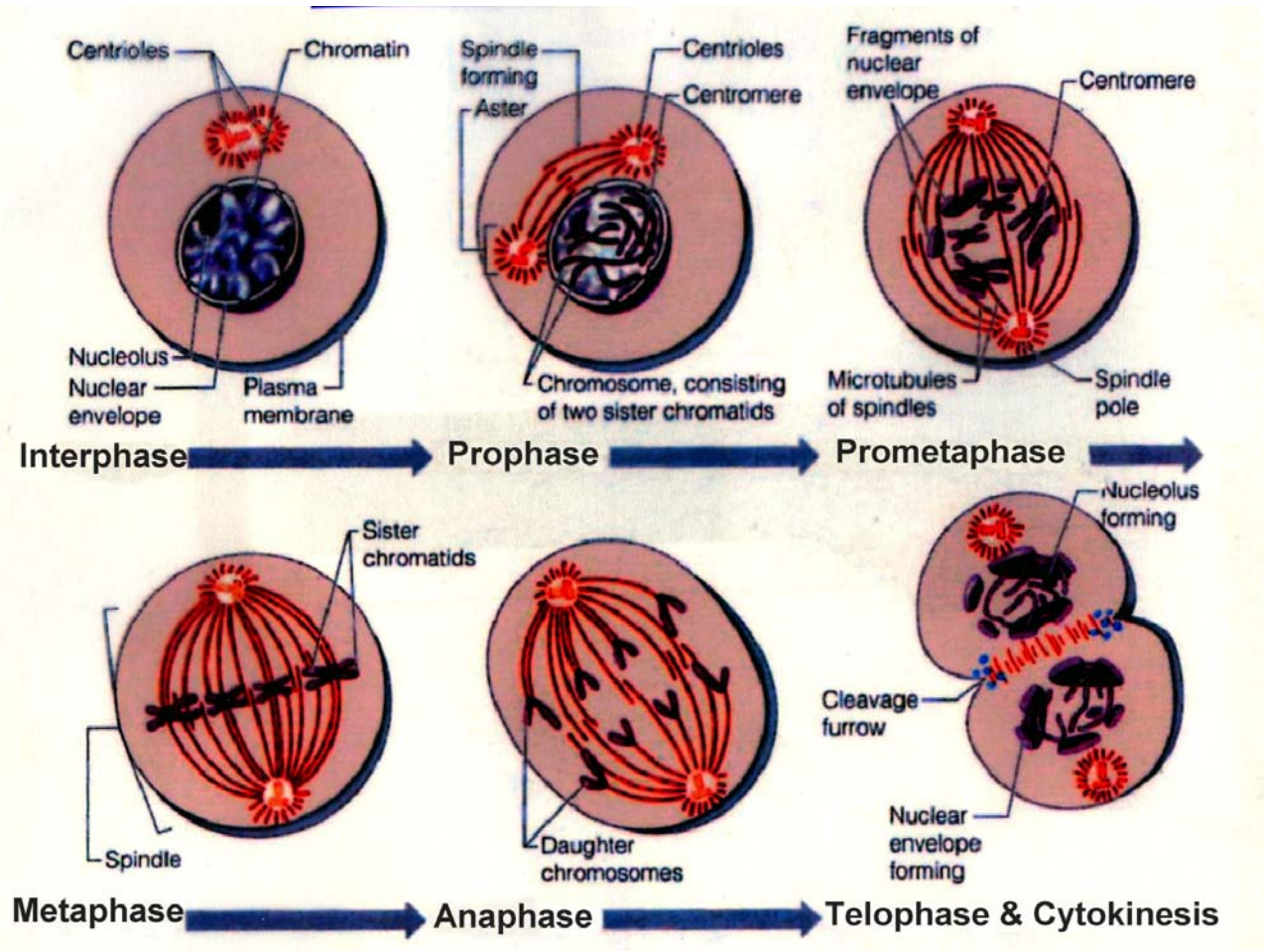
- **Metaphase:**
  a. Chromosomes are arranged along the equatorial plane of the cell by mitotic spindles

- **Anaphase:**
  a. Chromosomes split at the centromere

b. Chromatids are pulled apart by mitotic spindles/centrioles in opposite directions

- **Telophase:**
  a. Chromatids which are now new Chromosomes are assembles and enclosed in nuclear membrane on either side of the centre of the cell.
  b. Cytoplasm is divided into two (Cytokinesis) leading to the formation of two daughter cells from one mother cell.

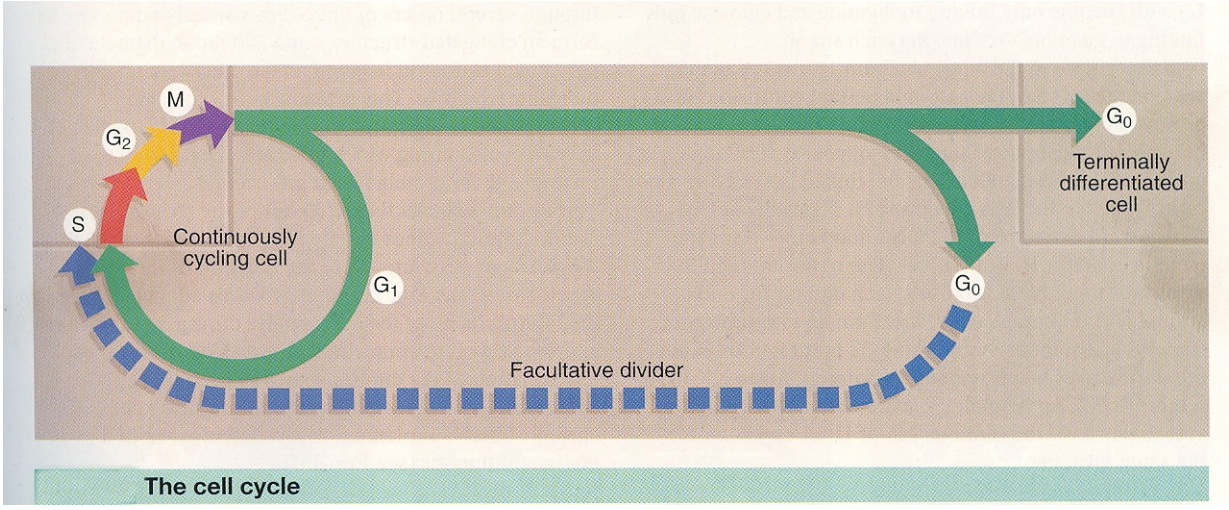
Stages of Mitosis (Diag. C1)



Cell Life Cycle: The lifespan of a cell entails two periods from the time the cell is formed to the time it undergoes cell division. The first period is referred to as the Interphase period during which the cells carries out all its metabolic activities including growth. This period is also referred to as the metabolic phase of cell cycle. The second period is the period of cell division, which terminates the life of the cell but often results in the production of daughter cells. Somatic and germ cells proceed through the two periods of cell cycle. The interphase period is the longer of the two periods and it is further subdivided into phases (See chart).

G_o Phase is the period of continuous differentiated function. Some cell undergoing this phase may have the option of coming out of it to undergo mitosis. Such cells are called **Facultative dividers.**

G_1 Phase (Also called First Gap) is the period of specialization and execution of all special functions of the cell
S Phase is the period of replication of DNA preparatory to mitotic division
G_2 Phase (Also call second Gap) is the period immediately preceding mitotic division



MEIOSIS (Diag. C2)

Meiotic division occurs only in germ (reproductive) cells and consists of two successive phases, viz. Meiosis I and Meiosis II each of which further proceeds in several stages.

Meiosis I:

This is also referred to as the reduction division in which the chromosome content of the daughter cell is reduced to half of that of the mother cell. As in mitotic division, meiosis I is preceded by replication of the DNA content of the dividing cell. The first phase of Meiosis I is the prophase. This goes through 5 stages as follows:

First Meiotic Prophase:

- Leptotene: Chromosomes condense, thicken and begin to coil up and become visible. Alternating thick areas called **chromomeres** begin to appear on each chromosome.
- Zygotene: At this stage, homologous chromosomes pair up (Synapsis) to form bivalents. Homologous sex chromosome do not form bivalent but are only joined at the tips of their short arms
- Pachytene: Chromosomes are much thicker and more pronounced. The chromatids of pairing chromosomes are also visible as a tetrad of four strands.
- Diplotene: Paired chromosomes begin to disengage and move apart. Areas at which exchange of materials would have occurred between homologous pairs **(Chiasmata)** are also becoming visible. At the end of this stage the Chiasmata terminalize i.e. Draw to the end of the chromosome arm.

- Diakinesis: Final terminalization of Chiasmata occur bringing prophase of first meiotic division to an end.

First Meiotic Metaphase:

The nuclear membrane disintegrates and chromosomes migrate to the equatorial plane of the dividing cell.

First Meiotic Anaphase:

Bivalent chromosomes disjoin and each member migrates randomly to opposite poles of the cell. This is the stage at which random and independent assortment of paternal and maternal chromosomes occurs.

First Meiotic Telophase:

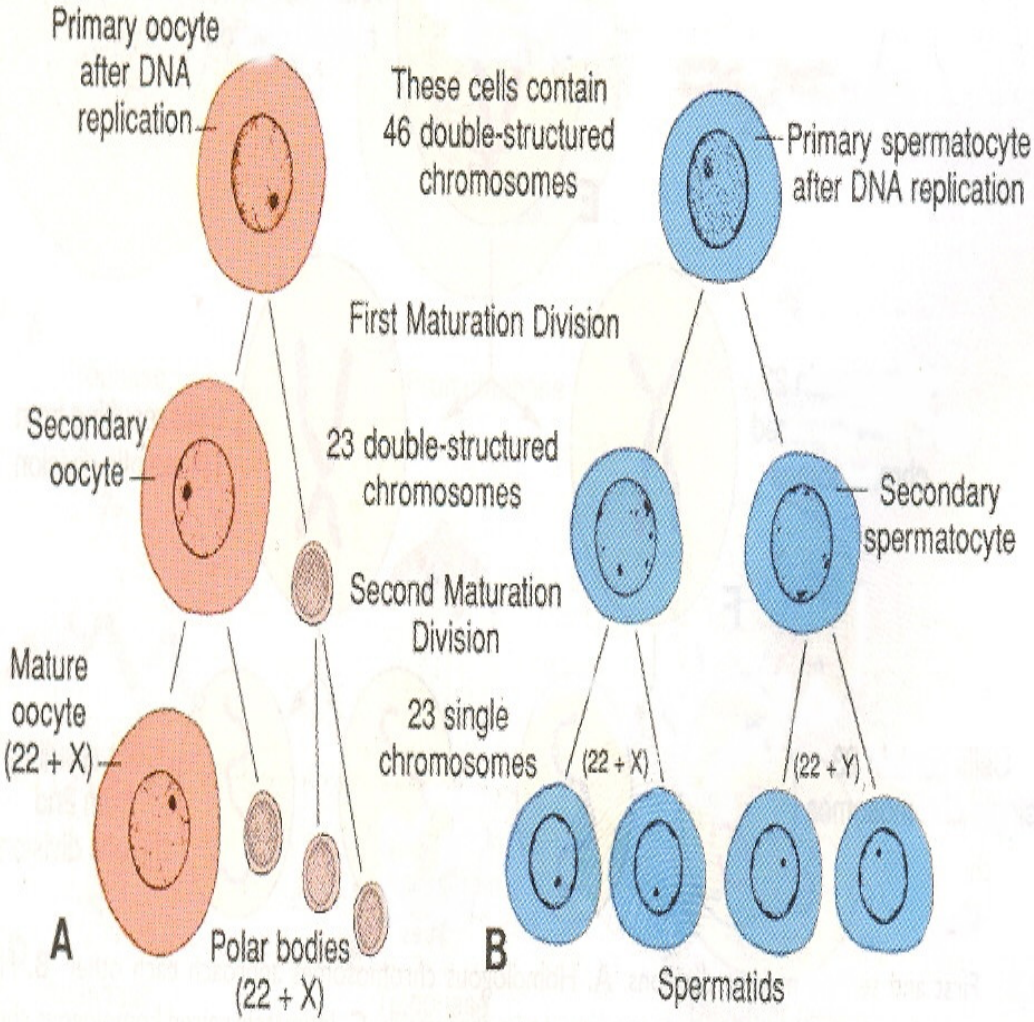
Chromosomes are assembles and enclosed in nuclear membrane on either side of the centre of the cell. The cytoplasm is divided into two (Cytokinesis) leading to the formation of two daughter cells from one mother cell. Each daughter cell now has the haploid number of chromosome (23 in the human).

Meiosis II

There is no intervening interphase and no DNA replication between Meiosis I and II. The two daughter cells proceed straight into Meiosis II. The stages of Meiosis II are similar to those of Mitosis, culminating in the production of two daughter cells from each of the two daughter cells of first Meiotic division. However, the chromosomes of the two daughter cells are not genetically identical.

The end result of Meiosis is the production 4 daughter cells, each with haploid number of unidentical chromosomes

Diag. C2

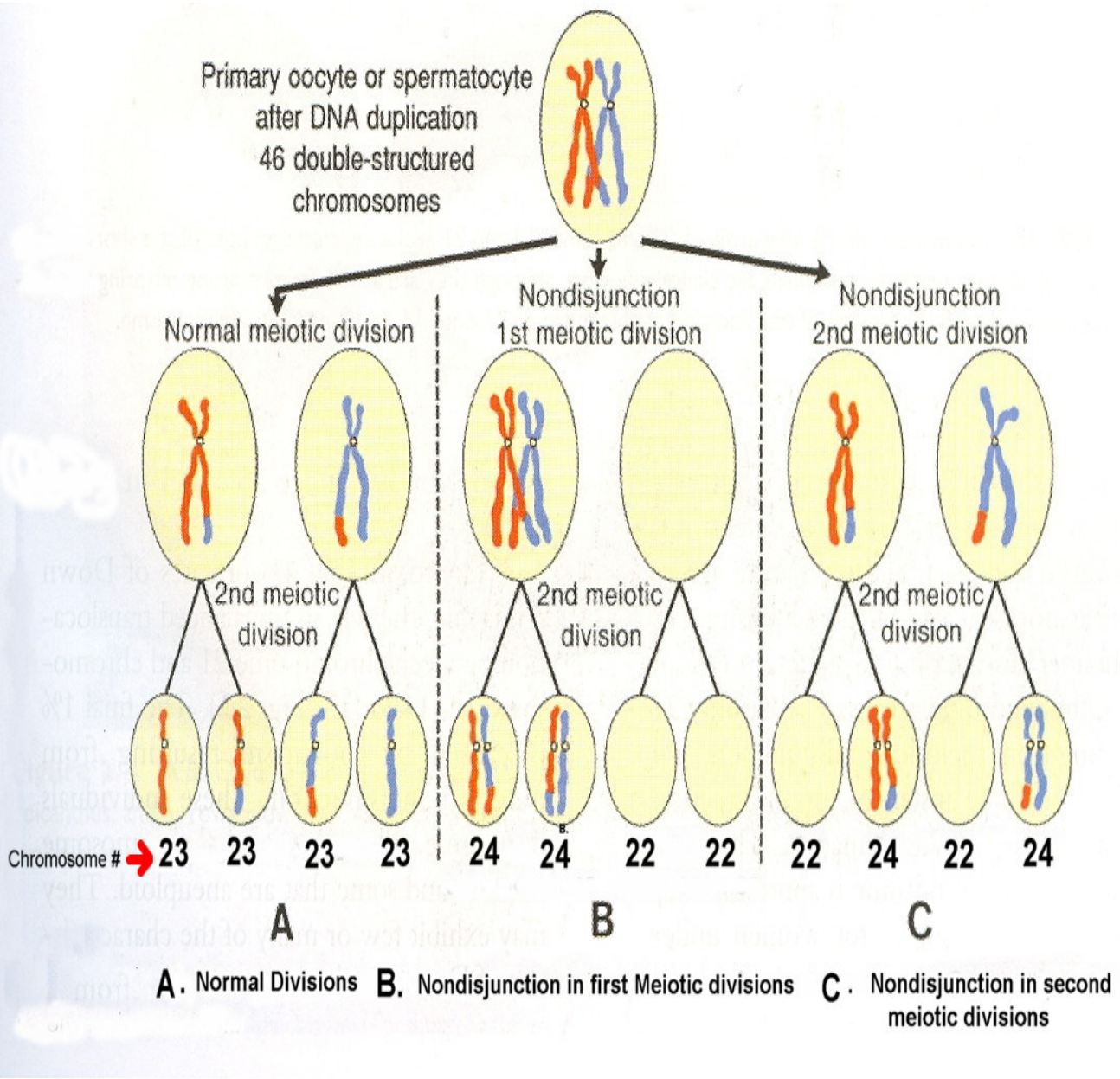


Events occurring during the first and second maturation divisions. **A.** The primitive female germ cell (primary oocyte) produces only one mature gamete, the mature oocyte. **B.** The primitive male germ cell (primary spermatocyte) produces four spermatids, all of which develop into spermatozoa.

Defective Meiotic Division (Diag. C3)

Defective meiotic divisions usually result in the production gametes with chromosomal numerical abnormalities as illustrated in the diagrams below:

Diag. C3



Clinical Correlates

Genetic diseases associated with chromosomal numerical abnormalities:

Down Syndrome (Trisomy 21): This characterized by

- 3 chromosomes in set 21
- Incidence is 1 in 2000 conceptuses for mothers under 25 years
- Growth retardation
- Mental retardation
- Upward slanting of the eyes
- Flat face
- Small ears
- Large tongue
- Extra epicanthal fold
- Semian crease in the palm
- Cardiac defects
- Hypotonia

Trisomy 18:

- 3 chromosomes in set 18
- Incidence is 1 in 5,00 births
- More severe than Trisomy 21, as patients often die at the age of 2 months or could be aborted by 10 weeks of gestation
- Mental retardation
- Low-set ears
- Small tongue (Micrognatha)
- Flexion of fingers and hands
- Syndactyly
- Renal defects
- Skeletal defects

Trisomy 13:

- 3 chromosomes in set 13
- Very rare; 1 in 20,000 but often very severe. Most patient die within first month of birth
- Mental retardation
- Holoprosencephaly
- Anophthalmia (No eyes)
- Microphthalmia (Small eyes)
- Coloboma
- Deafness
- Cleft lip and palate
- Cardiac defects

Klinefelter Syndrome:

- There is an extra X sex chromosome
- Occurs only in males at an incidence rate of 1 in 500 births
- Usually detectable at puberty and characterized by:
- Sterility
- Testicular atrophy
- Hyalinization of the seminiferous tubules
- Gynecomastia (Large mammary gland)
- Occasional occurrence of mental retardation

Turner Syndrome (Gonadal Agenesis); 45,X or XO

- There is only one X chromosome (Monosomy)
- Absence of X chromosome usually linked to paternal gamete
- Barr body negative
- Occurs only in female
- 98% are aborted spontaneously within the first trimester of intrauterine life
- Gonadal agenesis
- Short stature
- Reduced carrying angles at the elbow
- Webbed neck
- Wide chest with broadly spaced nipples
- Sparse Axillary and pubic hair
- Coarctation of the aorta
- Oedema of the feet at birth

XYY Syndrome:

- There is an extra Y chromosome
- Incidence is 1 in 1000 births
- Occurs only in males
- Associated with criminal, aggressive and psychopathic and other antisocial behaviors.