CHAPTER 4

Cell Division and Cell Cycle

Q.1. Write note on Mitosis.

Ans. Mitosis which is meant for multiplication of cell number and meiosis which help in alternation of generations. Meiotic division always (unless it is abnormal meiosis) reduces the chromosome number to half, which is restored to normal diploid number at the time of zygote formation.

Mitosis

The development of an individual from Zygote to adult stage take place through mitatic cell divisions. Cell division help in growth also by way of increasing surface area of the cells. Therefore mitosis is necessity for maintenance and per petutation of life. S

Growth should be that is should give rise to two daughter cells, which should resemble each other and also the parent cell **qualitatively** and **quantitatively**. The basic outline of such a cell division is the same in all kinds of living forms. It consists of following stages forming a cell cycle. It should be realized that mitotic division is a continuous process and its division into stages is done only for convenience of description.

Cell cycle (Interphase and Mitosis)

In continuously dividing cells, an individual cell passes through four phases, listed in Table 1 and diagrammatically shown in Fig.

Table Different phases of a mitotic cell cycle.

Parts of cell cycle	Phases	Description of phases	Duration in hours		
			Vicia faba	Mouse L Cells	*Human He La Cells*
Interphase	G_1	Pre DNA-synthesis phase	12	12	12
	S	DNA-synthesis phase	6	6–8	10
	G_2	Post DNA-synthesis phase	12	3–4	3
Mitosis	M	Mitotic phase	1	1	1

G_1 is a resting phase; during S phase, DNA synthesis takes place and G_2 phase is again a resting phase following DNA synthesis. These three phases viz. G_1, S and G_2 constitute interphase, while the main mitotic division takes place during **M** phase. Durations of different phases vary not only in different materials, but also in different tissues of the same organism. These **may also vary in cells in culture using different culture media.** The durations of different phases in three materials are given in Table 1. The mitotic phase consists of the following stages :

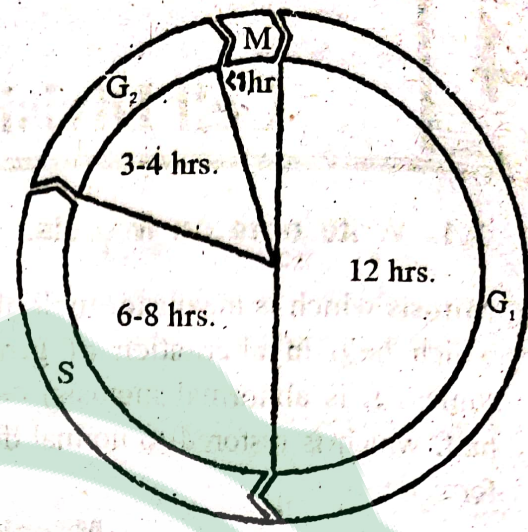


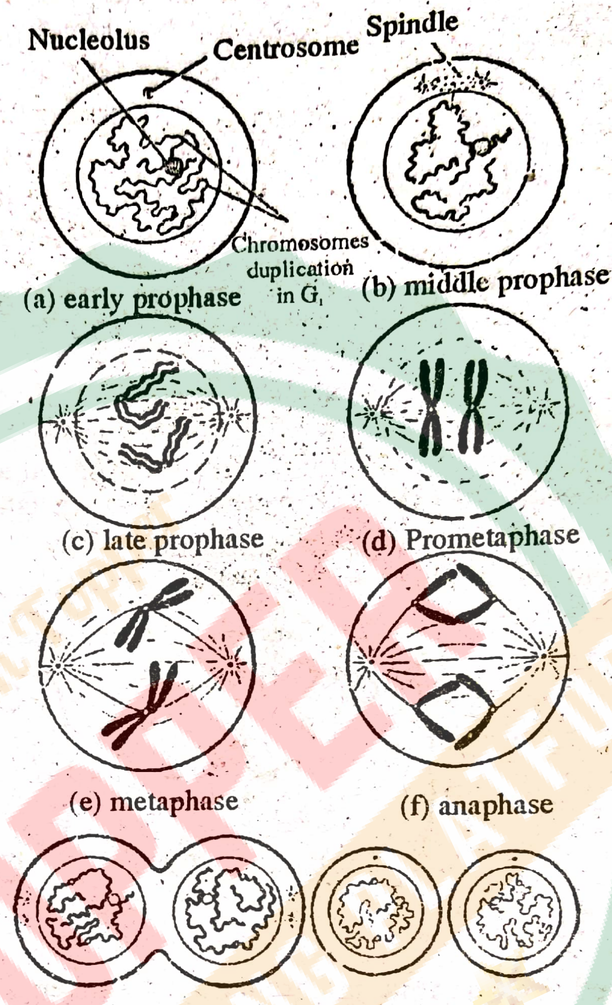
Fig. Diagrammatic representation of cell cycle of mouse L cells doubling every 24 hours (redrawn from Levin's Gene Expression-2

(1) Prophase : At prophase (after DNA synthesis is already completed during interphase), the cell is still preparing for division. At the beginning of prophase chromosomes appear as thin, filamentous uncoiled structures. Chromosomes become **coiled, shortened** and **more distinct** as the mitosis **progresses through prophase,** which is of **much longer duration than other stages.** The durations of different stages of mitosis in four organisms are presented in.

Table 2. Durations of different stages of mitosis in four different materials.

Material	Duration in minutes			
	Pro-phase	Meta-phase	Ana-phase	Telo-phase
1. Mouse (spleen)	21	13	5	4
2. Grasshopper (neuroblasts)	102	13	9	57
3. Onion (root tip)	71	6.5	2.4	3.8
4. Pea (root tip)	78	14.4	4.2	13.2

An important characteristic of mitotic prophase is longitudinal splitting of each chromosome into two sister chromatids. Double structure of each chromosome thus may be conspicuous at late prophase. Sister chromatids at this stage are attached only at **centromere** and it will be at this position that two chromatids will now remain attached to spindle tubule. Soon after the nuclear membrane disappears at late prophase. Similarly, nucleolus also disappears before the cell enters mitotic metaphase. However, there are variations available with respect to the disappearance of nuclear membrane and the nucleolus.



(a) early prophase (b) middle prophase (c) late prophase (d) Prometaphase (e) metaphase (f) anaphase (g) cytokinesis (h) daughter cells

2. Metaphase : At the prophase or early metaphase, spindle tubules start appearing. These tubules get attached to chromosomes at centromeres. The chromosomes begin active movement leading to arrangement of chromosomes in the centre or at equatorial plate. The spindle apparatus, which helps in arrangement of chromosomes at the plate, is formed with the help of centrosome particularly in case of animal cells. As two centrioles separate, astral rays appear radiating outward from each centriole. These will join and form spindle fibres. **In most plants, centrosomes are missing but spindle apparatus is still formed.**

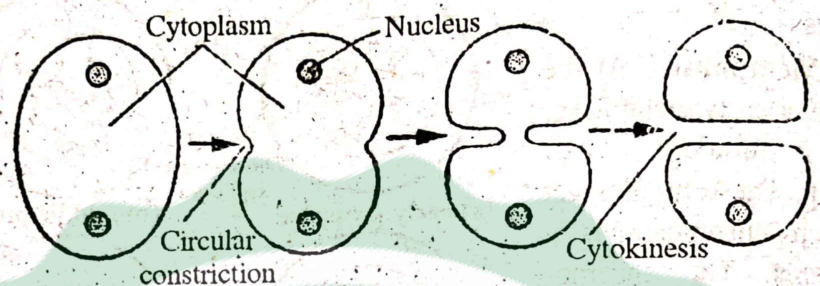
3. Anaphase : After spindle is formed and chromosomes have arranged on equatorial plate, chromosomes split at centromeres also. Sister centromeres separate from each other, so that the two sister chromatids are separate structures and can now be called chromosomes. These sister chromatids or daughter chromosomes now move towards opposite poles of spindle. It seems that there is repulsion between centrosomes and that there is contraction of spindle fibres which helps the movement.

4. Telophase : After anaphase, chromsomes reach the poles, nuclear membrane is reconstructed around each group of chromosomes giving rise to one nucleus at each pole. The nucleoli also reappear at this stage.

Cytokinesis

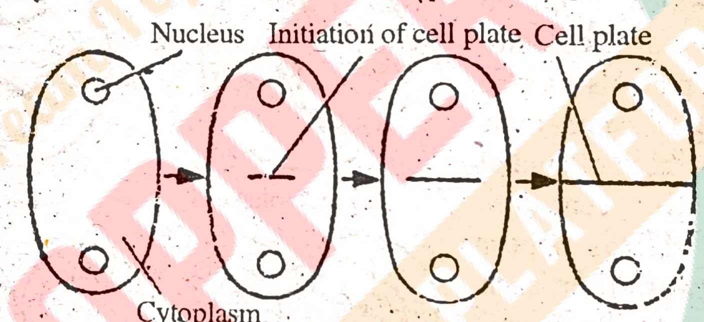
Division of one nucleus into two is often called karyokinesis and is followed by cytokinesis, which divides cytoplasm into two cells and can be brought about in two ways.

Cell furrow : In case of animals, outer layers are more flexible due to absence of cell wall. In such cases, a circular constriction appears at equator and it converges on all sides finally separating two daughter cells.



Cell plate : In plant cells, a more rigid cell plate is usually initiated at centre and is completed towards periphery (Fig). After the cell plate is laid down, primary walls are deposited on either side. The thick secondary cell-walls of cellulose may be laid down later on.

Dfferent stage of mitosis are shown in fig. (a to h). The process takes from 10 mintues to several hours. Metaphase stage of mitosis is often



used for determining chromosome numbers in animals as well as in plants. Chromosomes numbers of some important animals and plants as determined by mitotic metaphase are given in Table.

Q.2. What is significance of meiosis ? Describe all stages of meiosis.

Or

Write a short note on pachytene and diplotene.

Or

Describe the details of Meiosis with particular emphasis on Prophase-I.

Or

Describe the process of meiosis in a euckaryotic cell.

Ans.

Meiosis

Significance of meiosis

It is obvious from the study of mitosis that daughter cells resulting from a mitotic division have same chromosome number as the parent cell had. This is necessary for growth and reproduction, if only asexual method is present. However, in sexual method of reproduction, fusion of sex cells (male and female) is required. If sex cells have the same chromosome number as the somatic cells have, the zygote will have double the chromosome number. **For instance**, if an individual has four chromosomes in each cell including the sex cells, the zygote resulting from fusion of the two sex cell will have eight chromosomes and an individual having eight chromosomes in each cell would result. This cycle will repeat in each generation and with each cycle of

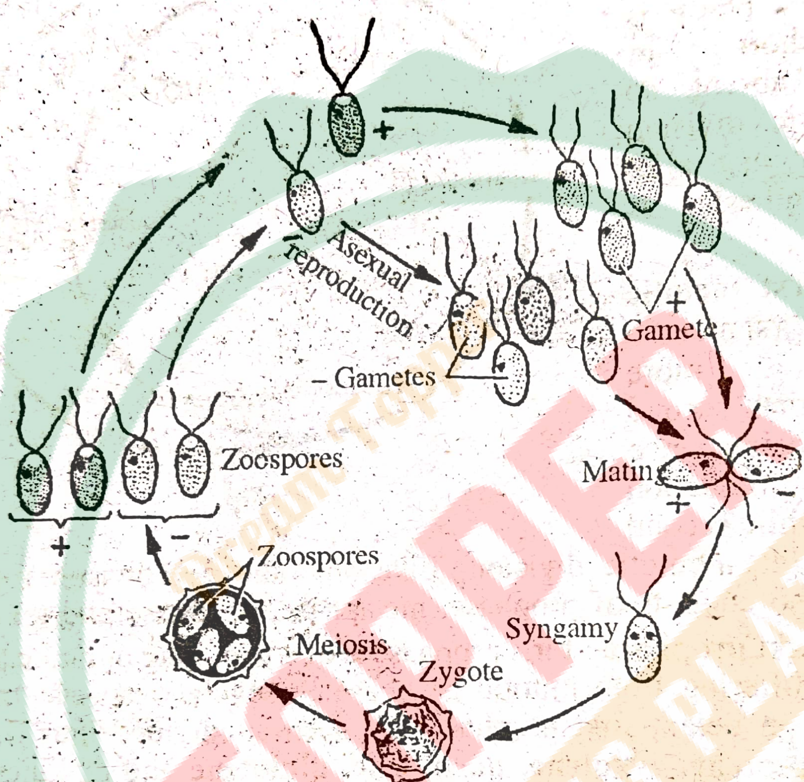


Fig. Chiamydomonas

sex cells fusion, chromosome number will be doubled again and again. This will be a difficult situation.

It is also known that despite **sexual** reproduction involving fusion of sex cells, chromosome number remains constant from one generation to the other. This is possible only when the chromosome number in the sex cells is half that in the somatic cells. It would mean that during formation of sex cells, reduction of chromosome number takes place. This reduced chromosome number, whether reduced at the time of formation of the sex cells (higher plants and animals) or at any other time during life cycle (formation of spores in Bryophytes and Pteridophytes), is called haploid condition. When two haploid cells fuse, diploid condition will be restored (Fig. I and II).

Stages of meiosis

Meiotic division consists of two successive divisions of a cell, so that as a result of one complete meiotic division, four cells will result. First division is accompanied with reduction in chromosome number without any division of chromosomes, while second division involves separation of chromatids of the chromosomes. **Consequently**, number of chromosomes which is reduced in first division remains constant (haploid) during second division. For convenience, therefore, meiosis can be described in two parts (i) first meiotic division, and (ii) second meiotic division.

Preceding meiosis, there is an interphase just like the one found in mitosis, consisting of G_1 phase, S phase and G_2 phase. However in meiosis G_2 phase is very short or altogether absent, so that meiotic division takes over just after DNA synthesis is complete.

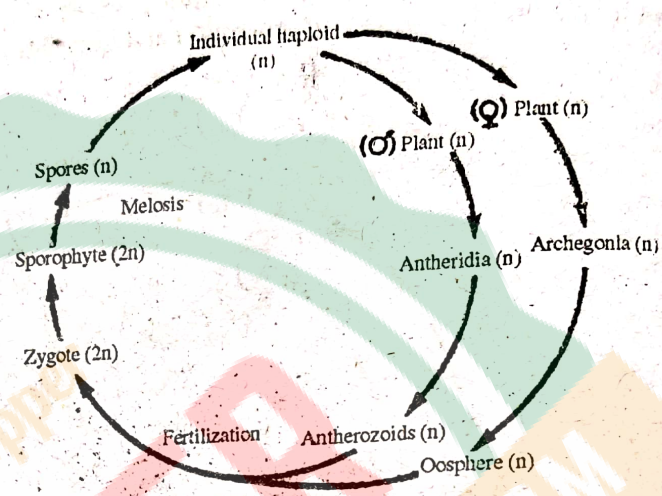


Fig. 2

1. First meiotic division : First meiotic division is more important than second meiotic division, since it is the reduction division, while second division is like a mitotic division. Like any other cell divison, first meiotic division also consists of prophase, metaphase, anaphase and telophase.

(a) First prophase : First prophase is of a very long duration and is also complex, differing from mitotic prophase in several respects. In order to describe it in detail, first prophase has been subdivided into five stages, namely, **leptotene, zygotene, pachytene, diplotene** and diakinesis. These five stages are established for convenience of description. Otherwise such a distinction is not possible and one stage very gradually passes on into the next stage.

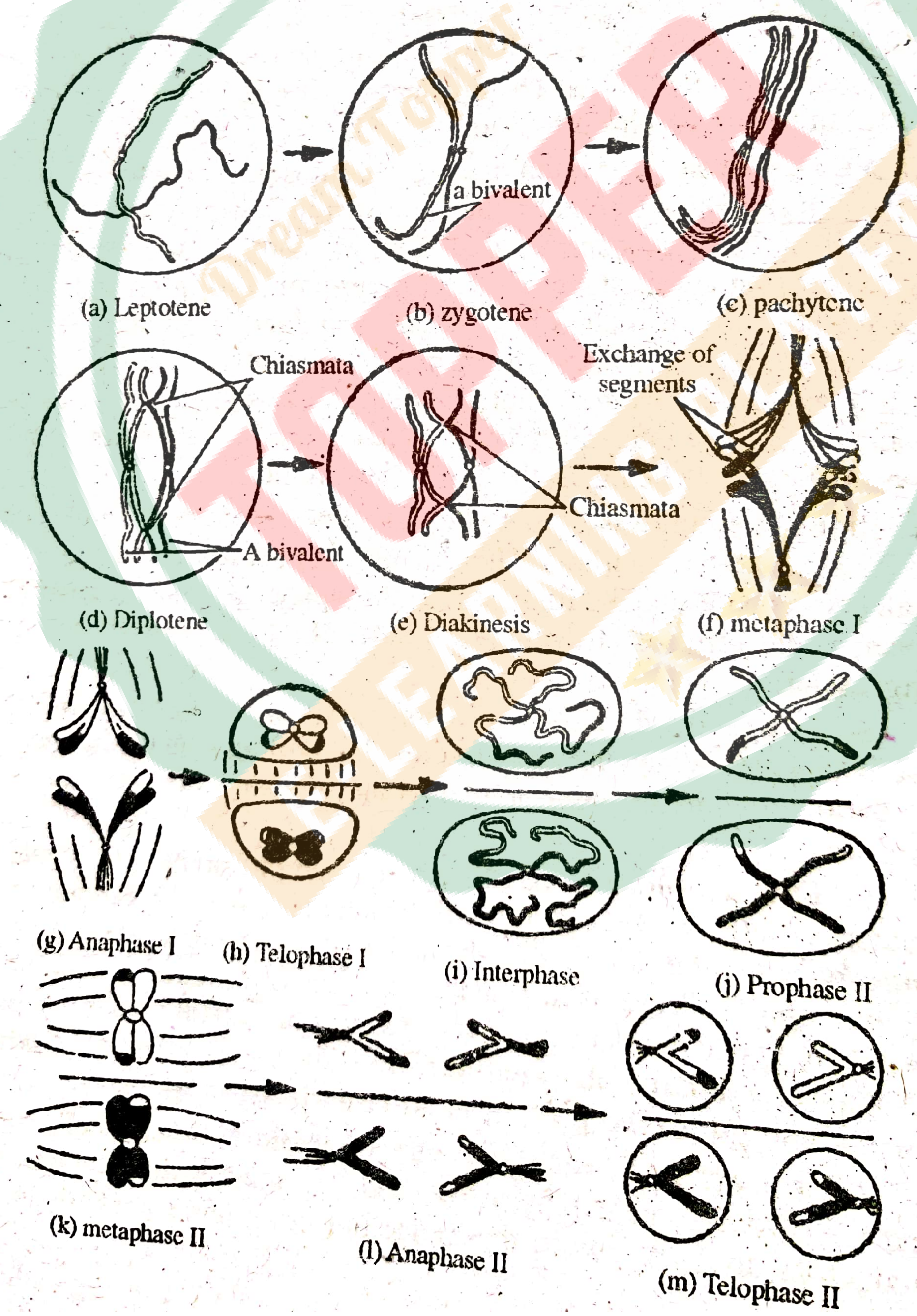
These five stages are explain separately.

(i) Leptotene (leptonema) : This is the first stage of meiosis following interphase. Chromosomes at this stage appear as **long thread-like structures**, which are loosely interwoven. On these thread-like chromosomes, bead-like structures called chromomeres are found all along the length of chromosomes. However, in certain plants like *Lilium*, the chromosomes are densely clumped to one side, no chromatin material being seen in the rest of the nucleus. This phenomenon is called synizesis and its significance is not clearly understood.

(ii) Zygotene (zygonema) : Zygotene is characterized by pairing of homologous chromosomes (synapsis). The pairing is brought about in a zipper-like fashion and may start at centromere, at chromosome ends or at any other position.

This pairing takes place between homologous segments even if they are present in non-homologous chromosomes. Another important feature of this pairing is that pairing is allowed only between two chromosomes in one region. **For instance**, in an autotetraploid, where there will be four homologous chromosomes, in a particular region only two chromosomes will pair. It seems that as soon as two chromosomes come in contact, their attraction forces are neutralized. In *Drosophila.* In this case, if there are three or more homologous chromosomes, these will pair throughout their length, but this is not meiotic pairing.

(iii) Pachytene (pachynema) : Once homologous chromosomes have undergone pairing at zygotene, the cell enters the stage of pachytene, where chromosomes become shortened and coiled. The chromosomes appear as thickened thread-like structures, haploid, in number. Each thread, however, if carefully examined has two homologous chromosomes closely appressed



(a) Leptotene (b) zygotene (c) pachytene (d) Diplotene (e) Diakinesis (f) metaphase I (g) Anaphase I (h) Telophase I (i) Interphase (j) Prophase II (k) metaphase II (l) Anaphase II (m) Telophase II against each other. These pairs of homologous chromosomes are called bivalents. Each chromosome in a bivalent at this stage has two chromatids, as a result of which a bivalent really consists of four chromatids and is called a tetrad. At this stage, crossing over or exchange of segments of chromatids is brought about. The nucleolus still persists. Attached to nucleolus can be seen the nucleolar organizing bivalent.

(iv) Diplotene (diplonema) : At diplotene, further thickening and shortening of chromosomes take place. Homologous chromosomes start separating from one another. This separation starts at centromeres, and travels towards the ends. This kinds of repration from contromer towards the ends is known as terminalization. Due to such repration, dual nature of bivalent become distinct and hence the name diplatene. Homologous chromosome are now held together only at certain paints along the length. Such paint of contact between homologous chromosome are known as chiasmata (singular chiasma) and represent the place of crossing over (actual exchange of chromosome segment). As terminalization occur, these chiasmata move towards the ends of chromosome.

(v) Diakinesis : At diakinesis, chromosomes continue to undergo further contraction. Ordinarily the only distinction between diplotene and diakinesis is the more contracted state of bivalents at diakinesis. Nucleolus may not be seen at this stage. Due to further terminalization and contraction, bivalents appear as rounded bodies darkly stained (with acetocarmine) and evenly scattered throughout the cell. Consequently, chiasmata are mainly terminal and chromosome counting is easy at this stage. In cases of longer chromosomes with intercalary chiasmata, all chiasmata are not terminalized, some of them still being in the intercalary region.

(b) First metaphase : At metaphase, chromosomes are most condensed and have a smooth outline. The spindle **apparatus** starts appearing and bivalents become attached to spindle through centromeres. Bivalents then appear in the form of an equatorial plate, due to the movement known as **congression.**

Some workers describe a prometaphase stage between diakinesis and first metaphase. Whenever, it is described, it will include the period between the dissolution of the nuclear membrane and the full appearance of the spindle.

(c) First anaphase : The movement of chromosomes of a bivalent from equatorial plate to poles constitute first anaphase. While in mitotic anaphase, centrosome divides longitudinally and two sister chromatids pass to two different poles, in case of first anaphase of meiosis, sister chromatids do not separate but go to the same pole. When sister chromatids go to same pole, it is called a **reductional** or **disjunctional** division; on the other hand, when they separate and go to two poles it is an **equational** division.

After anaphase I, each pole has a haploid number of chromosomes. Thus the chromosome number is reduced. The meiotic division is also called a reduction division, due to this reduction in chromosomes number.

(d) First telophase and interphase : At first telophase, nuclear membranes are formed around the groups of chromosomes at the two poles. After formation of nuclei, chromosomes pass into a small interphase before the second meiotic division will start. In some cases, the first telophase and the subsequent interkinesis may be absent. In such cases, chromosomes at the two poles after anaphase will directly pass to metaphase of the second division.

First meiotic division, which is completed at first telophase, may be followed by cytokinesis giving rise to a dyad. Such a division is called **successive division.** However, cytokinesis may be postponed till the end of second division, when four cells are formed due to **simultaneous division.**

2. Second meiotic division : First meiotic division is followed by a second meiotic division with or without the intervening interphase. The second division is essentially a mitotic division. And is sometimes referred to as meiotic mitosis. Since mitosis has already been discussed, only a brief account of second meiotic division will be given here.

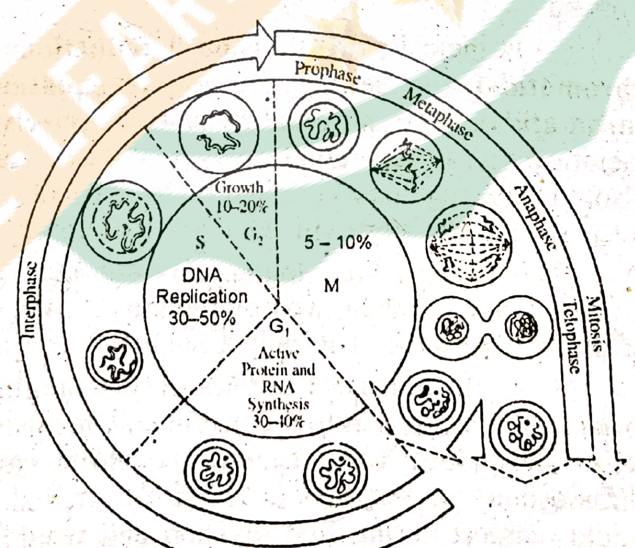
At second prophase, chromosome are already double, each having two sister chromatids with a single functional centromere. These chromosome soon arrange at metaphase plate during second metaphase. The centromere the split and two chromatids, which may now be called chromosomes, Pass to two pales during second and phase. This is soon followed by second telophase, and cytokinesis As indicated earlier, cytokinesis may be successive or of simultaneous type and will give rise to four haploid cells.

Q.3. Give a critical account of the molecular mechanism of cell cycle.

Ans. A cell division cycle have two periods :

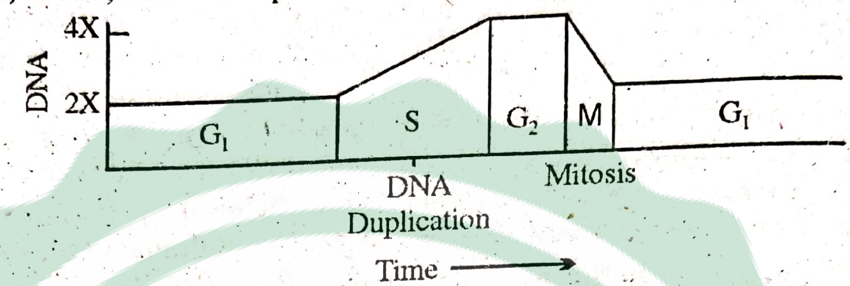
(1) Interphase (Non-dividing period).

(2) Cell division (Mitosis) or period of division.



In fact cell cycle may be considered as a complex series of phenomenon by which cellular material is divided equally between daughter cells microscopically visible phase of an underlying changes that has occurred at the molecular level is called cell cycle.

Prior to the start of mitosis, the main molecular components have been duplicated and during the cell division final separation of already duplicated molecular units found. This entire process makes the interphase of the cell cycle a important period, during which there is duplication of all the main components of their cell *i.e.*, DNA, RNA and proteins.



(1) G_1 *Sub-stage* Period of initial growth-It is resting phase characterized by general growth of cell and synthesis of those substances which are necessary for DNA synthesis e.g., Protein and DNA.

(2) *S Sub-stage Period of DNA Synthesis* : In this chromosomal DNA duplicates itself.

(3) G_2 *Sub-stage* Second growth period : In this cell itself prepares for cell division by synthesizing those proteins.

Duration of cell cycle is variable in different plant and animals. example *Vicia faba* G_1 stage takes 12 hours, S stage 6 hours, G_2 stage 12 hours and Mitosis takes one hour. Thus cell cycle in *Vicia faba* takes 31 hours in completion.

Q.4. Write a comparative account of mitosis and meiosis only with well labelled diagrams.

Ans. Comparison of Meiosis and Mitosis

A comparison between meiosis and mitosis may be drawn as shown in Figure. In this connection the following similarities and differences should be noticed.

(1) In meiosis, first **division is reductional (separation of non-sister chromatids)** and second division is **equational (separation of sister thromatids). The mitotic division is purely equational.** During first meiotic division, separation in first meiotic division may be partly equational also. In these regions where first division becomes equational due to crossing over, second division will now be reductional.

(2) In meiosis, homologous chromosomes undergo pairing. This pairing involves not more than two homologous chromosomes in a particular region of the chromosome. The only exception in salivary gland chromosome.

(3) While mitosis gives rises **to two daughter cells** which are identical to each other as well as to the parent cell, meiosis gives rise to four daughter cells. These **four cells, though resemble each other with respect** to chromosome number, they differ, since paternal and maternal chromosomes would reassort during first division and would also undergo exchange of chromosome segments during crossing over (Fig). The four daughter cells will also differ from the parent cell in having half the chromosome number.

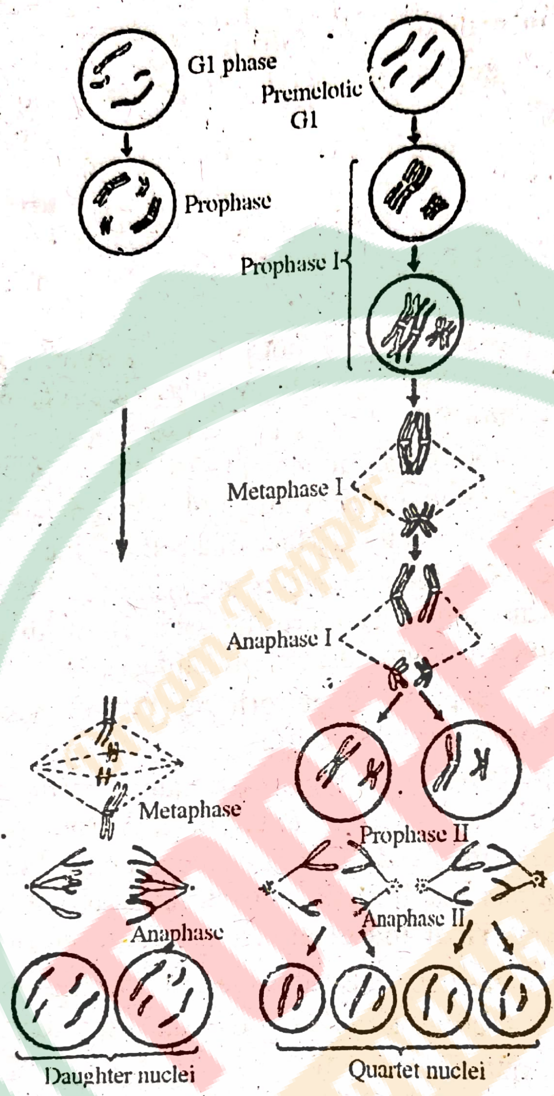


Fig. Diagrammatic representation of comparison between

(4) In meiosis, with each pair of homologous **chromosomes forming a bivalent, a tripartite structure called** *synaptonemal complex* is **observed under electron microscope.** This structure appears at **zygotene,** persists in pachytene and disappears in diplotene. No such structure is observed in mitosis.

Q.5. Describe the main functions of cell.

Ans. The cell is the fundamental unit of life. It has all the chemical and physical factors essential for growth and maintenance so it is a complete unit of metabolism. There are lot of difference in shape and size of many types of cells but there are some basic similarities at the functional level. The similar basic functions are as follows :

1. **Functions as Genetic material**
2. **Functions in Motility**

3. **Functions as Barrier**

4. **Functions in cellular metabolism.**

1. Functions as genetic meterial : Inheritance and transmission of genetic material from one generation to another are performed in the cell through cell divisions. In eukaryotic cells the gene material is occur in the nucleus which remain enclosed by nuclear envelope. Controls the transport of chemical substances from the nucleus to the cytoplasm and vice-versa. The genetic material (DNA) are folded into a compact structure known as **nucleoid.**

The genetic material (DNA) both in prokaryotes and eukaryotes regulate the synthesis of protein on small cytoplasmic structures ribosomes.

2. Functions in motility : Cells can show different types of motility begining from locomotion to the movement of some components of the cell. The movements may be either the movement of cell from one place to another or the movement of liquid over the surface of a cell by cilia and flagella.

In eukaryotic cells smaller filaments are also occur. These are made up of actin proteins and are known as microfilaments. These microfilaments help in muscle contraction and cytoplasmic streaming.

So, the cells are capable of performing all the necessary metabolic activities essential for continuity of life.

3. Functions as Barrier : All cells maintain a barrier that protects the contents of cell from the exterior environment. Both **prokaryotic and eukaryotic cells** are enclosed by a thin membrane known as **plasma membrane**. This barrier maintain the concentration of the solutes in the cell by **regulating transport of materials** from in and out of the cell.

(i) Membranes can selectively allow certain specific molecules against a concentration gradi (active transport) maintainnig higher concentration inside the cell than outside the cell.

(ii) Membranes are selectively permeable allowing certain molecules to pass in and out of cell.

(iii) The cell perform certain specific metabolic activities through the enzymes and proteins present plasma membrane.

(iv) Excess amount of substances present in the cell are thrown out with the formation of vesicles. The vesicles are pinched off and relêased from the cell. This type of movement is called exocyto . The cell receives substances from its environment by the process called endoctosis.

4. Functions in cellular metabolism : All cells carry out series of chemical reactions for the synthesis of macromolecules, trapping energy, degradation of unused molecules, conveting food substances into sugars etc. The initial reactions of the cell begins through the degradation of reserve foods in the fluid phase of the cytoplasm.

In photosynthetic eukaryotes, the energy from sunlight is used after converting the light energy into chemical energy. This conversion is done by some specialized organelles known as chloroplasts.

Q.6. Describe various types of cell adhesion molecules which provide differnetial cell affinity.

Ans. In a developing embryo, different types of cells segregrate to form specific region through a phenomenon known as **cell sorting**. Some type of cells, after cell sorting **adhere** with each other to form a **specific tissue**. The process of cell adhesion is mediated by **cell adhesion molecules** (CAM), **substratum adhesion molecules** and cell junction molecules following categories of cell adhesion molecules (CAMs) are occur in various types of cells.

1. Cadherins : Cadherins are Ca^{2+} dependent cell adhesive molecules. These are **glycoproteins,** those help in organization of animal forms. Twelve different types of cadherins are known but in mammalian embryo only 3 types of cadherins are occur :

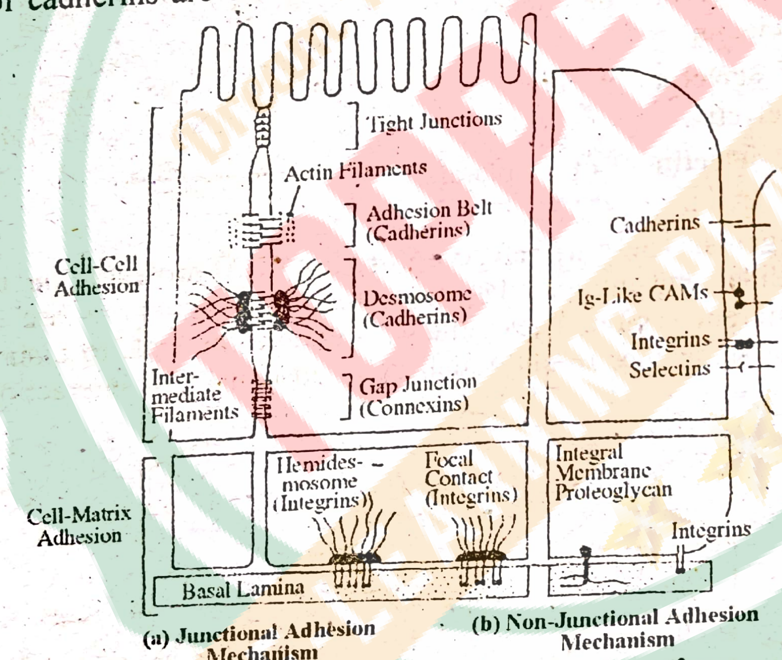


Fig. Different types of adhesive mechanisms from shown by animal cells.

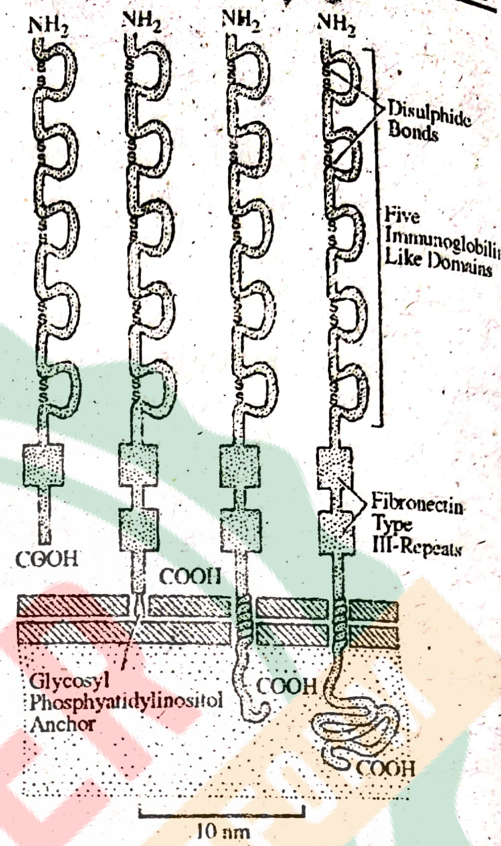
(i) **E-Cadherins** : These are epithelial cadherins and are also called L-CAM.

(ii) **P-cadherins** : These are placental cadherins.

(iii) **N-cadherns** : These are neural cadherns and are also known A-CAM.

Cells with particular type of cadherins adhere preferentially to other cells expressing the same cadherins. The adhesion found due to clustering of cadherins, catchins and microfilaments of cytoskeleton.

2. Immunioglobulin super-family CAM : These are Ca^{2+} independent cell-cell adhesives. The structure of these CAMs resembles with that of **immunoglobulins** (antibodies) molecules. The most abundant Ca^{2+} independent adhesive molecules are neural cell adhesive molecules (N-CAM). These molecules bring the cells together by homophillic binding.



3. Selectins : Selectins help in cell-cell (leukocyte-endothelial cell) adhesion during regional inflammation. Three known selections are.

(i) **L-selectin** or leucocyte selectin.

(ii) **E-selectin** or endothelial selectin.

(iii) **P-selectin** or platelet selectin.

4. Integrins : These are **cell receptors for ECM molecule** and integrate the extracellular and intracellular structures. These integrins are occur in plasma membrane region. These integrins enable the cells to bind specific extra-cellular molecules to allow cell-cell and cell-ECM interactions.

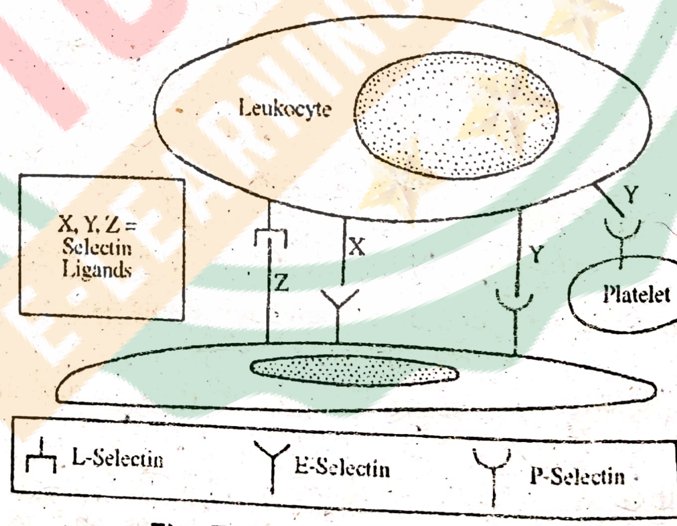


Fig. Three types of selectins

5. Glycosyltransferases : These are the cell receptors for ECM molecules. They recognize the carbohydrate acceptors on the **ECM proteins** like lamin in leading to adhesion. It also help in fertilization. These are also involved in migration of cells.