

7. Cell Division



Can you recall?

1. How do your wounds heal?
2. What is the difference between growth of non-living material and living organism?

Life of all multicellular organisms starts from single cell i.e. zygote. Growth of every living organism depends on cell division. As stated in the cell theory, every cell arises from the pre-existing cell.

7.1 Cell cycle :

Sequential events occurring in the life of a cell is called cell cycle. There are two phases of cell cycle as interphase and M-phase. During interphase, cell undergoes growth or rest as per the need. During M-phase, the cell undergoes division. Interphase alternates with the period of division.

Interphase : Interphase is the stage between two successive cell divisions. It is the longest phase of cell cycle during which the cell is highly active and prepares itself for cell division. The interphase is divisible into three sub-phases as G_1 -phase, S-phase and G_2 -phase.

G_1 -phase : This is also known as first gap period or first growth period. It starts immediately after cell division. Cell performs RNA synthesis (mRNA, rRNA and t-RNA), protein synthesis and synthesis of membranes during this phase.

S-phase : It is synthesis phase in which DNA is synthesized or replicated, so that amount of DNA per cell doubles. Histone proteins are also synthesized during this phase.

G_2 phase : G_2 is the second growth phase, during which nucleus increases in volume. Metabolic activities essential for cell division occur during this phase. Various proteins necessary for cell division are synthesized during this phase. Besides, RNA synthesis also occur during this phase. In animal cells, a daughter pair of centrioles appear near the pre-existing pair.

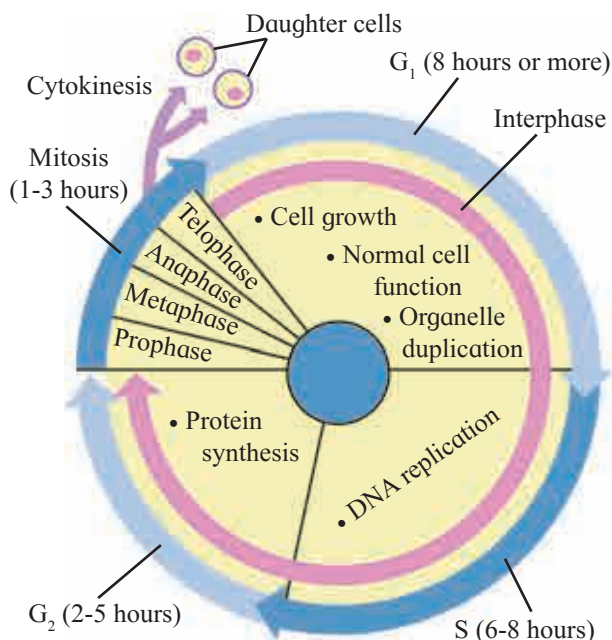


Fig. 7.1 Cell cycle



Discuss with Teacher

Some cells do not have gap phase in their cell cycle whereas some cells spend maximum part of their life in gap phase. Search for such cells. Some cells are said to be in their G_0 phase. What is this G_0 phase?

M-phase or period of division : 'M' stands for mitosis or meiosis. M-phase involves karyokinesis and cytokinesis. Karyokinesis is the division of nucleus into two daughter nuclei whereas cytokinesis is division of cytoplasm resulting in two daughter cells.

7.2 Types of cell division :

Three kinds of cell division are found in animal cells. They are amitosis or direct division, mitosis or indirect division and meiosis or reductional division. Mitosis can be performed by haploid as well as diploid cells but meiosis can be performed by diploid cells only. In honey bee, drones develop from haploid unfertilized eggs whereas in *Marchantia*, haploid spores form gametophyte by mitosis.

A. Amitosis : It is the simplest mode of cell division. During amitosis, nucleus elongates and a constriction appears somewhere along its length. This constriction deepens and divides the nucleus into two daughter nuclei. This is followed by the division of the cytoplasm which results in the formation of two daughter cells. This division occurs in unicellular organisms, abnormal cells, old cells and in foetal membrane cells.



Internet my friend

What is Karyogram or Karyotype?

B. Mitosis : This is a type of cell division in which a cell divides to form two similar daughter cells which are identical to the parent cell. It is completed in two steps as karyokinesis and cytokinesis.

Karyokinesis is nuclear division which is sub-divided into prophase, metaphase, anaphase, and telephase. Although for the sake of convenience above mentioned steps are used, it must be remembered that mitosis is a continuous process that starts with the disappearance of nuclear membrane in prophase and ends with separation of two fully formed cells after cytokinesis.

1. Prophase : This phase involves condensation of chromatin material, migration of centrosomes, appearance of mitotic apparatus and disappearance of nuclear membrane.

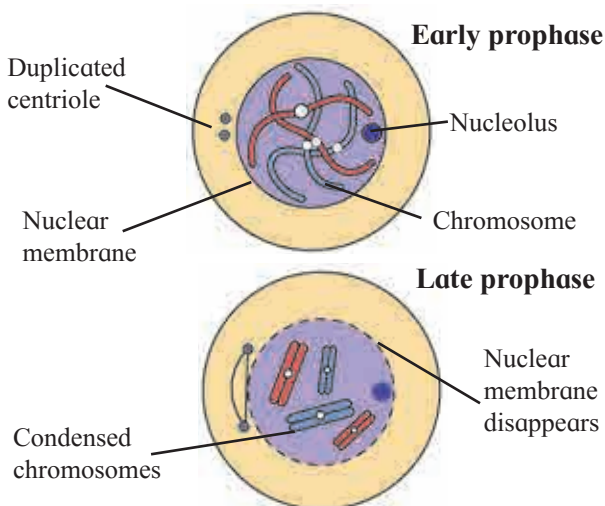


Fig. 7.2 Prophase

Due to condensation, each chromosome becomes visible under light microscope which can be seen with its sister-chromatids connected by centromere. The nucleolus starts to disappear. Nuclear membrane disintegrates and disappears gradually. Centrosome which had undergone duplication during interphase begins to move towards opposite poles of the cell. Mitotic apparatus is almost completely formed.

2. Metaphase : In this phase, chromosomes are completely condensed so that they appear very short. Sister-chromatids and centromere become very prominent. All the chromosomes lie at equatorial plane of the cell. This is called metaphase plate. Mitotic spindle is fully formed. Centromere of each chromosome divides into two, each being associated with a chromatid.

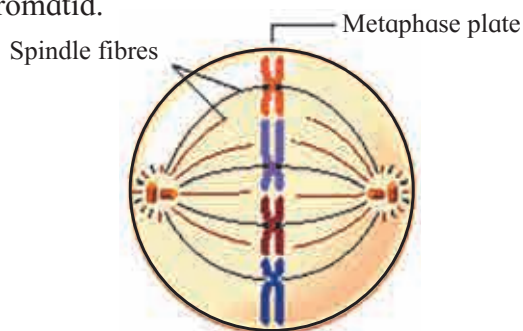


Fig. 7.3 Metaphase

3. Anaphase : The chromatids of each chromosome separate and form two chromosomes called daughter chromosomes. The formed chromosomes are pulled away in opposite direction by spindle apparatus. Chromosomes being pulled away appear like a bunch of banana during midway of anaphase. Each set of chromosomes reach at opposite poles of the cells marks the end of anaphase.

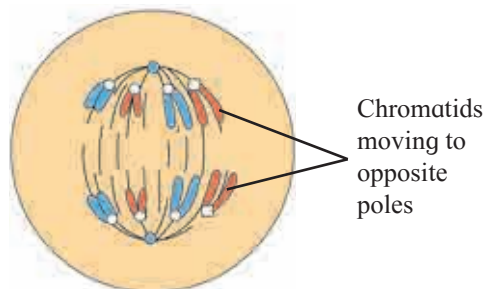


Fig. 7.4 Anaphase

4. Telophase : The telophase is the final stage of karyokinesis. The chromosomes with their centromeres at the poles begin to uncoil, lengthen and lose their individuality. The nucleolus begins to reappear. The nuclear membrane begins to appear around the chromosomes. Spindle fibres break down and get absorbed in the cytoplasm. Thus two daughter nuclei are formed in a cell.

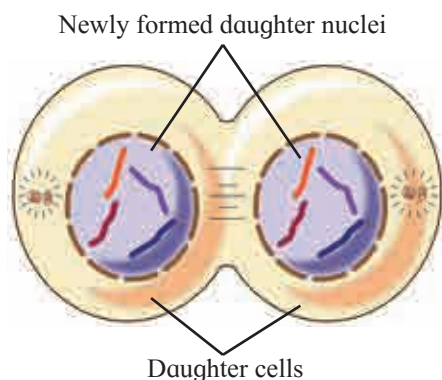


Fig. 7.5 Telophase



Do you know ?

Pulling away of daughter chromosomes is achieved by elongation and shortening of two types of spindle fibres. Spindle fibre present between centriole and centromere, called as kinetochore fibres contract and the spindle fibres present between two opposite centrioles, called as polar fibres elongate.

Cytokinesis : The division of the cytoplasm into two daughter cells is called cytokinesis. The division starts with a constriction. This constriction gradually deepens and ultimately joins in the centre dividing into two daughter cells. This process of division of cytoplasm is perpendicular to the spindle. This mechanism of cytokinesis is characteristic of animal cells.

However, plant cells are covered by a relatively non-flexible cell wall. Due to this, furrow can not be formed. Instead, cell wall/partition starts to appear at the centre of the cell and grows outward to meet the existing lateral walls. The formation of the new cell wall begins with the formation of a simple precursor, called the 'cell-plate' that represents the middle lamella between the walls of two adjacent cells.

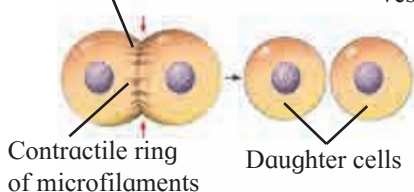
At the time of cytoplasmic division, organelles like mitochondria and plastids get distributed between the two daughter cells.

Significance of mitosis : As mitosis is equational division, the chromosome number is maintained constant. It ensures equal distribution of the nuclear and the cytoplasmic content between the daughter cells, both quantitatively and qualitatively. The hereditary material (DNA) is also equally distributed. It helps in the growth and development of organisms.

Cytokinesis in animal cell



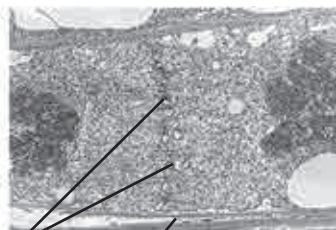
Cleavage furrow



Contractile ring of microfilaments

Daughter cells

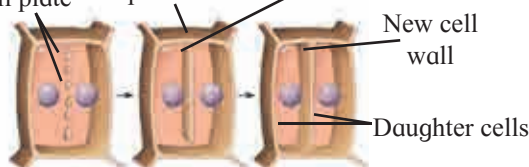
Cytokinesis in plant cell



Vesicles forming cell plate

Wall of parent cell

Cell plate



New cell wall

Daughter cells

Fig. 7.6 Cytokinesis

Old and worn-out cells are replaced through mitosis. It helps in the asexual reproduction of organisms and vegetative propagation in plants. The process of mitosis also maintains the nucleo-cytoplasmic ratio. Although mitosis is a very reliable process for preserving the genetic make-up of cells or organisms, it cannot introduce variation or new combination of existing genes.



Can you tell?

1. What is cell cycle?
2. Which processes occur during interphase?
3. Which are the steps of mitosis?



Internet my friend

How the life span of a cell is decided?

Death of cell : You may think of it as a bad for cells in your body to die. In many cases, that's true: it's not good for cells to die because of an injury (for example, due to scrape or a harmful chemical), which is called necrosis. However, some cells of our body die; not randomly but in a carefully controlled way. For example, during the embryonic development, the cells between the embryonic fingers died in a process called apoptosis to give a definite shape to the fingers. This is a common form of programmed cell death where cells undergo "cellular suicide" when they receive certain signals. Apoptosis involves the cell death, but it benefits the organism as a whole (for instance, by letting fingers develop or by eliminating potential cancer cells).

C. Meiosis : The term meiosis was coined by J. B. Farmer in 1905. It takes place only in reproductive cells during the formation of gametes. By this division, the number of chromosomes is reduced to half, hence it is also called reductional division. The cells in which meiosis take place are termed as meiocytes. Meiosis produces four haploid daughter cells from a diploid parent cell. Meiosis is of two subtypes :

1. **First meiotic division or Heterotypic division – (Meiosis I)**
2. **Second meiotic division or Homotypic division (Meiosis II)**

A. First meiotic division or Heterotypic division (Meiosis I)

During 1st meiotic division, diploid cell is divided into two haploid cells. The daughter cells resulting from this division are different from the parent cell in chromosome number. Hence this division is also called heterotypic division.

It consists of the phases like prophase-I, metaphase-I, anaphase-I, telophase-I and cytokinesis-I

Prophase-I : This phase has longer duration. Significant features which are peculiar to meiosis occurs in this phase. This phase can be sub-divided into five sub-stages as Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

Leptotene : The volume of nucleus increases. The chromosomes become distinct, long thread-like and coiled. They take up a specific orientation- the 'bouquet stage' inside the nucleus. This is characterised with the ends of chromosomes converged towards that side of the nucleus where the centrosome lies. The centriole divides into two and migrate to opposite poles.

Zygotene : Intimate pairing of non-sister chromatids of homologous chromosomes takes place by formation of synaptonemal complex. This pairing is called synapsis. Each pair consists of a maternal chromosome and a paternal chromosome. Chromosomal pairs are called bivalents or tetrads.

Pachytene : Each individual chromosome begins to split longitudinally into two similar chromatids. At this stage, tetrads become more clear in appearance because of presence of four visible chromatids. The homologous chromosomes of each pair begin to separate from each other. However, they do not completely separate but remain attached together at one or more points.

These points appear like a cross (X) known as chiasmata. Chromatids break at these points and broken segments are exchanged between non-sister chromatids of homologous chromosomes. This is called as crossing-over or recombination.

Diplotene : Though chiasmata are formed in pachytene, they become clearly visible in diplotene due to the beginning of repulsion between synapsed homologous chromosomes. This is called desynapsis. It involves disappearance of synaptonemal complex.

Diakinesis : In this phase, the chiasmata beings to move along the length of chromosomes from the centromere towards the ends of chromosomes. The displacement of chiasmata is termed as terminalization. The terminal chiasmata exist till the metaphase.

The nucleolus disappears and the nuclear membrane also begins to disappear. Spindle fibres starts to appear in the cytoplasm.

Do yourself

Write down the explanation of prophase I in your words.

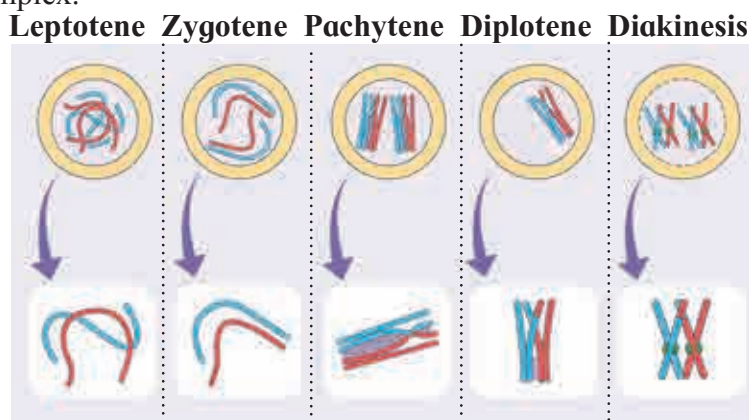


Fig. 7.7 Prophase I

Metaphase-I : The spindle fibres become well developed. The tetrads move towards the equator and they orient themselves on the equator in such a way that centromeres of homologous tetrads lie towards the poles and arms towards the equator. Due to increasing repulsive forces between homologous chromosomes, they are ready to separate from each other.

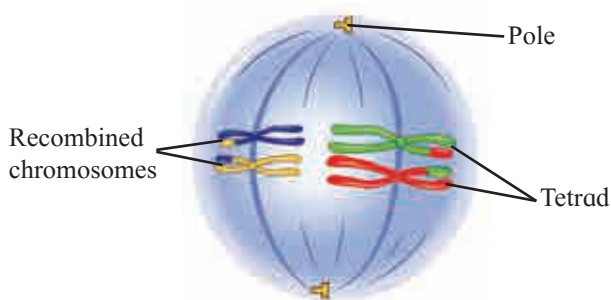


Fig. 7.8 Metaphase-I

Anaphase-I : In this phase, homologous chromosomes are pulled away from each other and carried towards opposite poles by spindle apparatus. This is disjunction. The two sister chromatids of each chromosome do not separate in meiosis-I.

This is reductional division. The sister chromatids of each chromosome are connected by a common centromere. Both sister chromatids of each chromosome are now different in terms of genetic content as one of them has undergone the recombination.

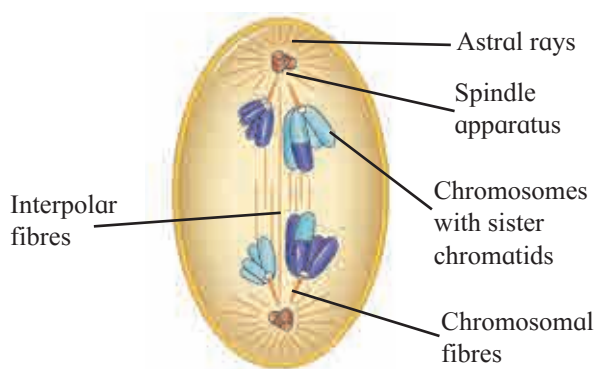


Fig. 7.9 Anaphase-I

Telophase-I : The haploid number of chromosomes after reaching their respective poles, become uncoiled and elongated. The nuclear membrane and the nucleolus reappear and thus two daughter nuclei are formed.

Cytokinesis-I : After the karyokinesis, cytokinesis occurs and two haploid cells are formed.

In many cases, these daughter cells pass through a short resting phase or interphase / interkinesis. In some cases, the changes of the telophase may not occur. The anaphase directly leads to the prophase of meiosis II.

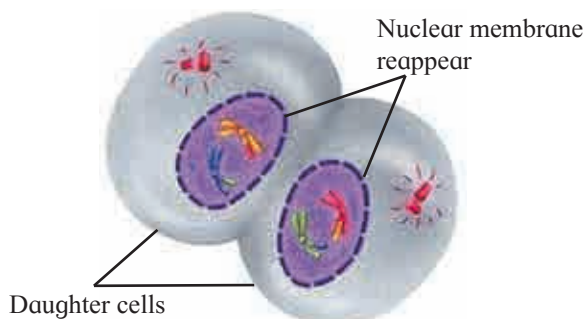


Fig. 7.10 Cytokinesis-I

B. Second meiotic division or Homotypic Division (Meiosis II)

During this division, two haploid cells formed during first meiotic division divide further into four haploid cells. This division is similar to mitosis. The daughter cells formed in second meiotic division are similar to their parent cells with respect to the chromosome number formed in meiosis-I. Hence this division is called homotypic division.

It consists of the following phases : prophase-II, metaphase-II, anaphase-II, telophase-II and cytokinesis-II.

Prophase-II : The chromosomes are distinct with two chromatids. Each centriole divides into two resulting in the formation of two centrioles which migrate to opposite poles and form asters. Spindle fibres are formed between the centrioles. The nuclear membrane and nucleolus disappear.

Metaphase-II : Chromosomes get arranged at the equator. The two chromatids of each chromosome are separated by the division of the centromere. Some spindle fibres are attached to the centromeres and some are arranged end to end between two opposite centrioles.

Anaphase-II : The separated chromatids become daughter chromosomes and move to opposite poles due to the contraction of the spindle fibres attached to centromeres.

Telophase-II : During this stage the daughter chromosomes uncoil. The nuclear membrane surrounds each group of chromosomes and the nucleolus reappears.

Curiosity box:

1. What is exact structure of synaptonemal complex?
2. What is structure of chiasmata?
3. Which type of proteins are involved in formation of spindle fibres?
4. Why and how some spindle fibres elongate and some contract?
5. What is the role of centrioles in formation of spindle apparatus?
6. What would have happened in absence of meiosis?

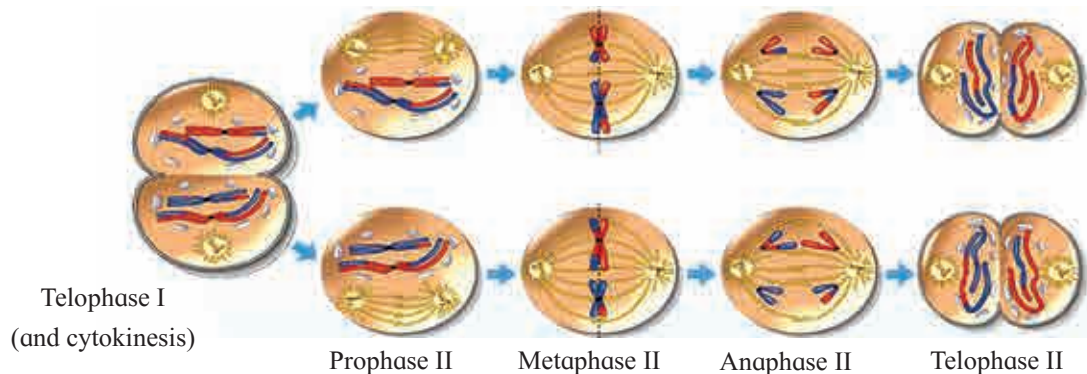


Fig. 7.11 Meiosis II

Cytokinesis-II : Cytokinesis occurs after nuclear division. Two haploid cells are formed from each haploid cell. Thus, in all, four haploid daughter cells are formed. These cells undergo further changes to develop into gametes.

Significance of Meiosis : Meiotic division produces gametes. If it is absent, the number of chromosome would double or quadruple resulting in the formation of monstrosities (abnormal forms). The constant number of chromosomes in a given species across generations is maintained by meiosis. Because of crossing over, exchange of genetic material takes place leading to genetic variations, which are the raw materials for evolution.



Internet my friend

Different types of proteins like cyclins, maturation promoting factor (MPF), cyclosomes, enzymes like cyclin dependent kinases (CDK) play important role in control of cell cycle. Collect more information about these proteins and enzymes from internet, prepare a power-point presentation and present it in the class.



Can you tell?

1. What is difference between mitosis and meiosis?
2. What is difference between meiosis-I and meiosis-II?
3. Elaborate the process of recombination.

Do Yourself

Prepare a concept map on cell division in following box.



Exercise

1. Choose correct option

- A. The connecting link between Meiosis-I and Meiosis-II is
a. interphase-I b. interphase-II
c. interkinesis d. anaphase-I
- B. Synapsis is pairing of
a. any two chromosomes
b. non-homologous chromosomes
c. sister chromatids
d. homologous chromosomes
- C. Spindle apparatus is formed during which stage of mitosis?
a. Prophase. b. Metaphase.
c. Anaphase. d. Telophase.
- D. Chromosome number of a cell is almost doubled up during
a. G_1 -phase b. S-phase
c. G_2 -phase d. G_0 -phase
- E. How many meiotic divisions are necessary for formation of 80 sperms?
a. 80 b. 40 c. 20 d. 10
- F. How many chromatides are present in anaphase-I of meiosis-I of a diploid cell having 20 chromosomes?
a. 4 b. 6 c. 20 d. 40
- G. In which of the following phase of mitosis chromosomes are arranged at equatorial plane?
a. Prophase b. Metaphase
c. Anaphase d. Telophase
- H. Find incorrect statement -
a. Condensation of chromatin material occurs in prophase.
b. Daughter chromatids are formed in anaphase.
c. Daughter nuclei are formed at metaphase.
d. Nuclear membrane reappears in telophase.

- I. Histone proteins are synthesized during
a. G_1 phase b. S-phase
c. G_2 phase d. Interphase

2. Answer the following questions

- A. While observing a slide, student observed many cells with nuclei. But some of the nuclei were bigger as compared to others but their nuclear membrane was not so clear. Teacher inferred it as one of the phase in the cell division. Which phase may be inferred by teacher?
- B. Students prepared a slide of onion root tip. There were many cells seen under microscope. There was a cell with two groups of chromosomes at opposite ends of the cell. This cell is in which phase of mitosis?
- C. Students were shown some slides of cancerous cells. Teacher made a comment as if there would have been a control at one of its cell cycle phase, there wouldn't have been a condition like this. Which phase the teacher was referring to?
- D. Some Mendelian crossing experimental results were shown to the students. Teacher informed that there are two genes located on the same chromosome. He enquired if they will be ever separated from each other?
- E. Students were observing a film on *Paramecium*. It underwent a process of reproduction. Teacher said it is due to cell division. But students objected and said that there was no disappearance of nuclear membrane and no spindle formation, how can it be cell division? Can you clarify?

- F. Is the meiosis responsible for evolution? Justify your answer.
- G. Why mitosis and meiosis-II are called as homotypic division?
- H. Write the significance of mitosis.
- I. Enlist the different stages of prophase-I.

3. Draw labelled diagrams and write explanation

- A. With the help of suitable diagram, describe the cell cycle.
- B. Distinguish between mitosis and meiosis.
- C. Draw the diagram of metaphase.

4. Match the following column-A with column-B

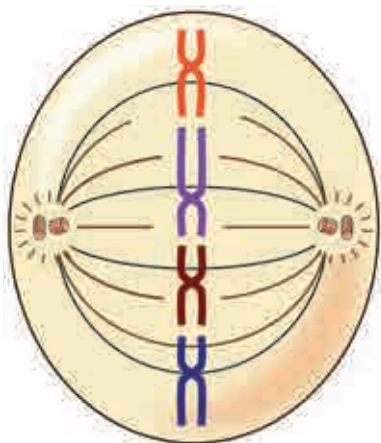
Column-A
(phases)

- a. Leptotene
b. Zygotene
c. Pachytene
d. Diplotene

Column-B
(Their events)

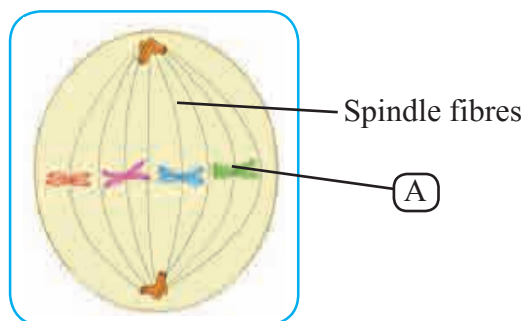
1. Crossing over
2. Desynapsis
3. Synapsis
4. Bouquet stage

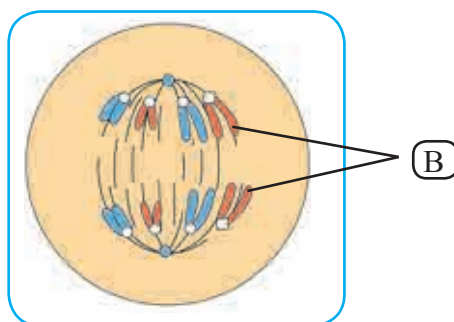
5. Is a given figure correct? why?



6. If an onion has 16 chromosomes in its leaf cell, how many chromosomes will be there in its root cell and pollen grain.

7. Identify the following phases of mitosis and label the 'A' and 'B' given in diagrams





Practical / Project :

Fix the onion root tips at different durations of the day starting from 6am up to 9am at the intervals of half an hour. Prepare the slide of each fixed root tip and analyse the relation between time and phase of mitosis.