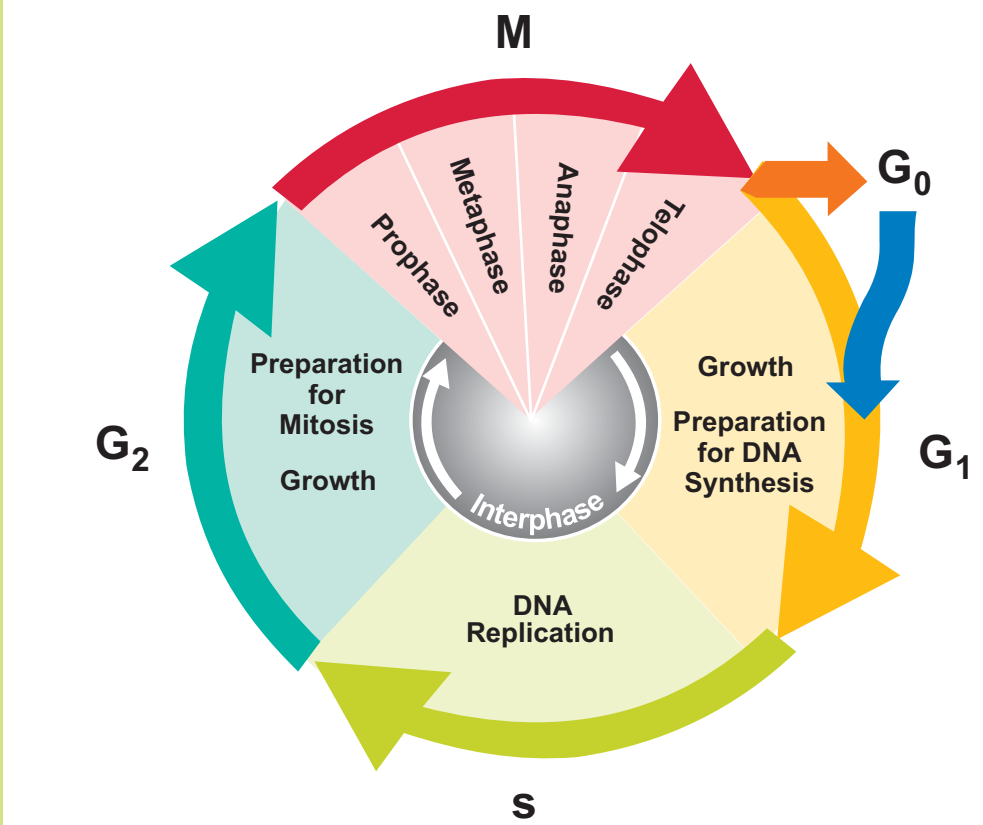
CELL CYCLE

Chapter 5

Major Concept

In this Unit you will learn:

- Chromosomes Structure and Functions
- Cell Cycle (Interphase and Division)
- Mitosis
  - Phases of Mitosis
  - Significance of Mitosis
- Necrosis and Apoptosis
- Meiosis
  - Phases of Meiosis



5.1 CHROMOSOMES

The term Chromosomes is given by German embryologist *Walter Fleming* in 1882 when he was examining the rapidly dividing cells of salamander larvae after treating with Perkin's Aniline. He observed that chromosomes colour is much darker than the rest of organelles. The term chromosomes is misnomer because its means coloured body later it was found that chromosomes are colourless bodies

Fig: 5.1 structure of chromosome

Chromosomes are thread like structure appear at the time of cell division includes found in specific numbers, made up of chromatin material in eukaryotic cell. They contain heredity units called **Genes**.

Chromosomes are made up of DNA and basic protein, Histones, appear during the cell division in the shape of rod. It has two parts arms and centromere.

The chromosomes are of different types, depending upon position of centromere. These types are:

(i) **Metacentric:** Chromosomes with equal arms.

(ii) **Sub-meta centric:** Chromosomes with un equal arms

(iii) **Acrocentric or sub-telocentric:** Rod like chromosomes with one arm very small and other very long. The centromere is subterminal.

(iv) **Telocentric:** Location of centromere at the end of chromosomes.

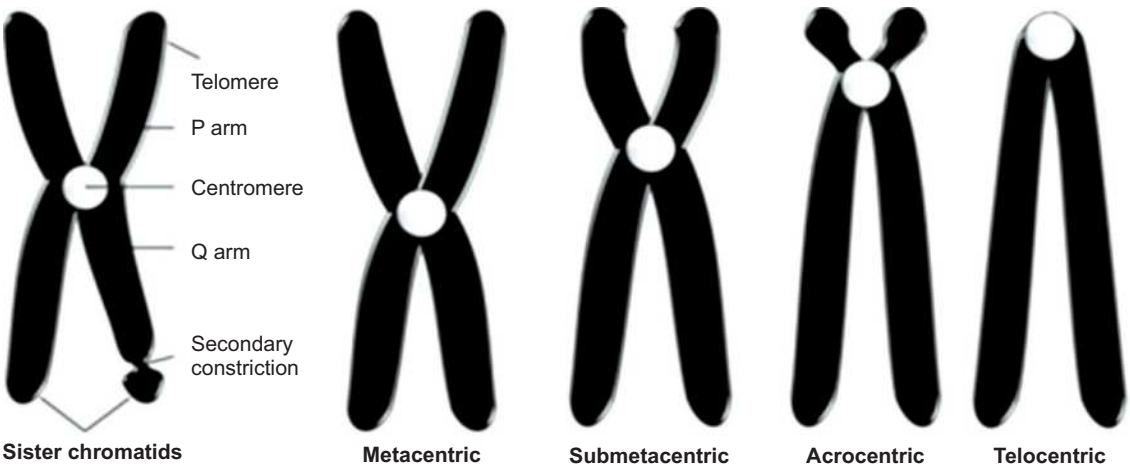


Fig: 5.2 Types of chromosomes

In the beginning of cell-division each chromosome is consist of two genetically identical copies of thread attach with each other called chromatids or sister chromatids.

Formation of chromosome:

Each chromosomes in eukaryotes are composed of chromatin fiber, which is made of nucleosomes. Chromatin fibers are packaged by proteins into a condensed structure called chromatin.

Chromatin allows the very long DNA molecules to fit into the cell nucleus. During cell division chromatin condenses further to form microscopically visible chromosomes. The structure of chromosomes varies through the cell cycle.

During cell cycle chromatin material replicate, divide and passed successfully to their daughter cells for survival of their progeny. Some time cell-division is also responsible for genetic diversity.

5.2 CELL CYCLE

The sequence of changes which occurs between one cell division and the next is called Cell Cycle." It has two phases, **Interphase**, which is the period of non-division and **M-phase**, which is a period of cell division.

The cell cycle undergoes a sequence of changes, which involve period of growth, replication of DNA followed by cell division. This sequence of changes is called **cell cycle**.

Interphase:

The period of cell cycle between two consecutive divisions is called Interphase. It is a period of growth and synthesis of DNA. During this period the cell prepares itself for the M- phase.

The Interphase is divided further into three sub-phase, G_1- phase, S-phase and G_2-phase.

G_1-(Gap one) phase: It is the period of extensive metabolic activity, in which:

Cell grows in size, specific enzymes are synthesized and DNA base units are accumulated for the DNA synthesis.

At a point in G_1, the cell may enter into a phase called G_0 (G-knot) where cell cycle stop. It remains for days, weeks or in some cases even for the life time of the organism.

S-(Synthesis) phase: During this phase, replication of DNA occurs. As a result of it chromatin material is duplicated.

G_2– (Gap two) phase: (Pre-Mitotic Phase): The following changes occur during this phase: Cell grows in size, cell organelles are replicate in numbers as well as enzyme require for cell-division also synthesized during this phase.

5.3 MITOSIS

In this type of cell division a parent cell divides into two daughter cells in a way that the number of chromosomes in the daughter cells remains the same as in the parent cell.

Although mitosis is a continuous process, but for the study point of view we can divide it into two phases; (a) Karyokinesis - nuclear division (b) Cytokinesis - cytoplasmic division.

(a) The karyokinesis can be divided further for convenience into four phases which are **Prophase**, **Metaphase**, **Anaphase** and **Telophase**. Let us study mitosis in an animal cell.

(i) Prophase:

During early prophase chromatin material condenses and become visible as thick coiled, thread like structures called **chromosomes**. Each chromosome at this stage is already double, consists of two **chromatids**. The chromatids are attached to each other at **centromere**. The nuclear membrane gradually disappears and at the same time centrosome divides to form two centrioles, each moves towards the opposite pole of the animal cell and forms the spindle fibres. The centrioles are absent in plant cells.

(ii) Metaphase:

During this phase each chromosome arranges itself on the equator of the spindle. Each chromosome is attached to separate spindle fibre by its centromere.

(iii) Anaphase:

In this phase the spindle fibre contract, centromere of a chromosome divides and the chromatides of each chromosome separates from each other and begin to move towards the other poles. In this way one set of the chromatids (each chromatid is now an independent chromosome) move towards one pole while the other set towards the other pole.

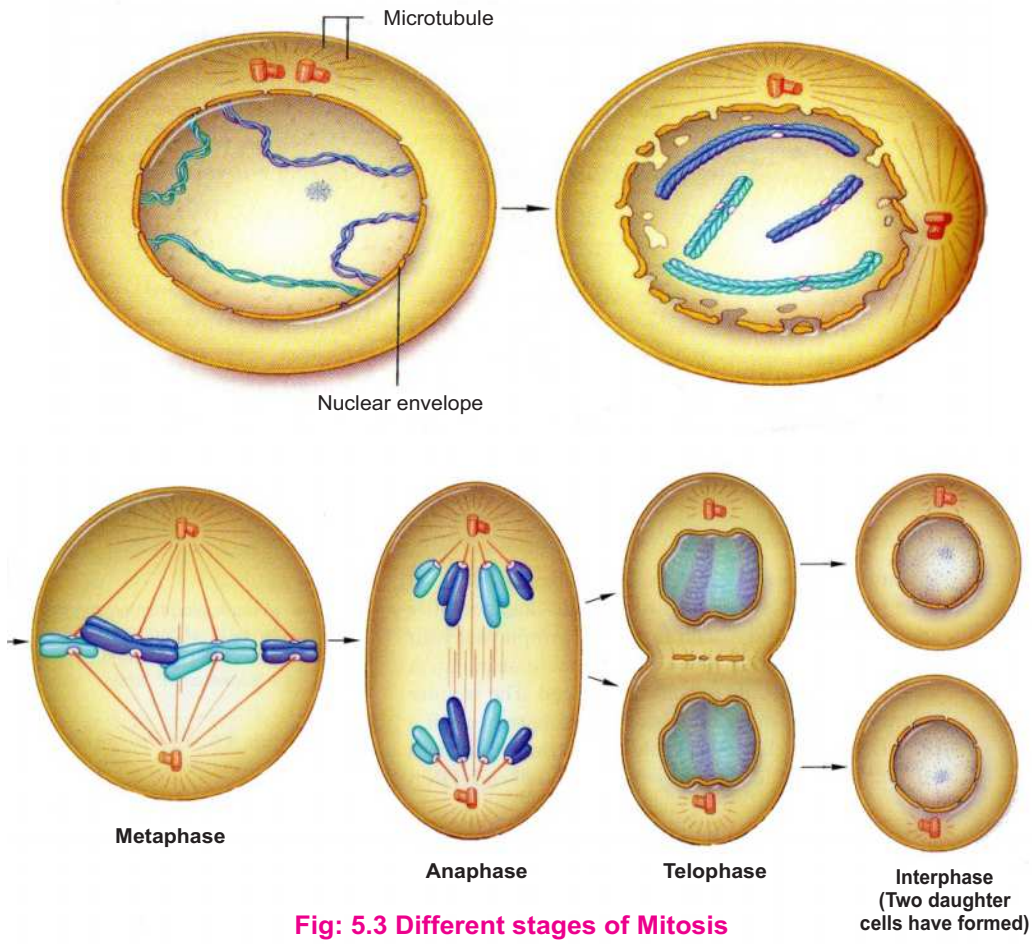


Fig: 5.3 Different stages of Mitosis

(iv) Telophase:

This is a stage when the chromatids (now called chromosomes) reach at the respective poles and their movement ceases. Each pole receives the same number of chromosomes as were present in the parent cell. The nuclear membrane is reformed around each set of chromosomes. In this way two daughter nuclei formed in each cell.

(b) Cytokinesis; soon the cytoplasm of the cell also divides and two daughter cells are formed. In animal cell cytokinesis takes place by developing a constriction. This constriction become deep to divide cytoplasm in two equal halves and two daughter cells are formed. In plant cells it occurs by developing cell plate. In this way the daughter cells become the exact copies of their parent cell.

Significance of mitosis:

Mitosis plays an important role in the life of an organism. It is responsible for development and growth of organisms by increasing exact copies of cells. With few exception all kinds of asexual reproduction and vegetative propagation take place by mitosis. The production of new somatic cells, such as blood cells depends on mitosis. The healing of wounds, repair of wear and tear within organism is also dependent upon the mitotic division.

5.4 APOPTOSIS AND NECROSIS (two ways of cell death)

Cell in an organism depends upon various extra cellular signals for its regulated and controlled activities. It means all the activities even the death of cells is programmed.

Is cell death beneficial?

Programmed cell death helps in proper control of multicellular development, which may lead to deletion of entire structure, e.g. the tail of developing human embryo, or some part an organ which is more required like tissue between developing digits.

Two ways of cell death in Multicellular organisms:

Apoptosis or Self - Destruction (Autophagy): "Programed change which lead to sequence of physiological changes in cell by which cells commit suicide collectively called **Apoptosis**".

Necrosis:

This type of cell death which is caused by external factors i.e infection, toxin and tumor i.e accidental cell death.

5.5 MEIOSIS (Reduction Division)

Meiosis is a type of cell division in which single cell divides into four daughter cells and number of chromosomes becomes half in each daughter cell.

In animal meiosis takes place in germ cell to produce gametes i.e. Sperms and Eggs whereas in plants it takes place in spore mother cells (S.M.C) to produce spores.

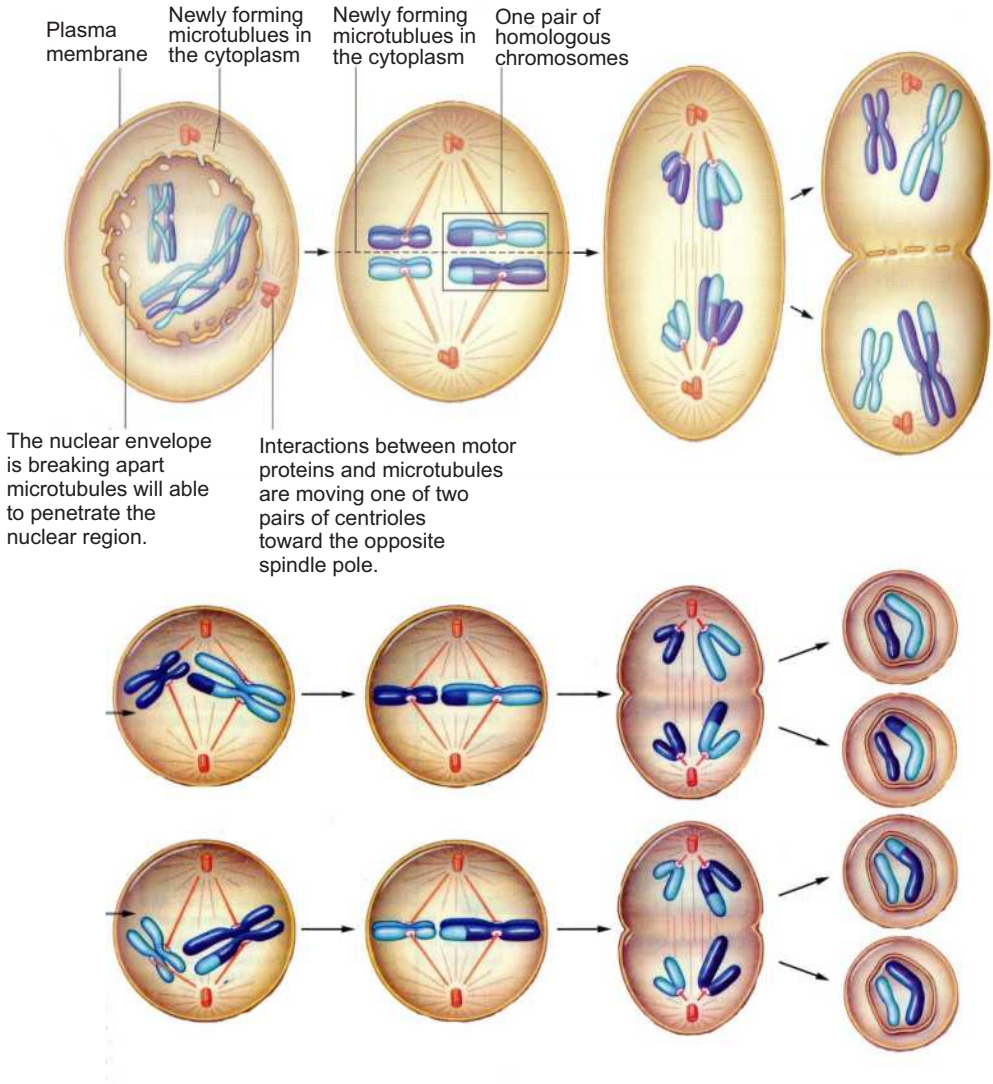


Fig: 5.4 Different stages of Meiosis

Events of Meiosis:

Meiosis is a series of two divisions, MEIOSIS I and MEIOSIS II which result in the formation of four haploid cells.

Meiosis I (First Meiotic Division)

First meiotic division is the reduction division during which the chromosomes number is reduced to half. Meiosis I consists of Prophase I, Metaphase I, Anaphase I and Telophase I.

Prophase I:

It consists of the longest phase of meiosis. It can be subdivided into following sub stages:

(1) Leptotene (2) Zygotene (3) Pachytene
(4) Diplotene (5) Diakinesis

(1) Leptotene:

During this sub stage following changes occur; The chromatin network break into specific number of long thin beaded thread called leptotene. Each thread has two morphologically similar leptene in each cell called homologous structure.

(2) Zygotene:

During this sub stage the Homologous (Similar structure) chromosomes, which comes from the mother (by ovum) and father (by sperm) are attracted towards each other and their lengthwise pairing takes place. The pairing of homologous chromosomes is known as **synapsis**, while the paired homologous chromosomes are known as **bivalent**.

(3) Pachytene:

The synaptic forces of attraction between each bivalent decrease and the chromosomes uncoil and separate. The separation is however incomplete and paired chromosomes are in contact with each other at one or more points, called Chiasmata. Each homologous chromosome split longitudinally except in the centromere region. Now each bivalent is composed of four chromatids and therefore is known as **bivalent tetrad**.

(4) Diplotene:

The homologous chromosomes exchange their parts of chromatid at Chiasmata. This exchange of segments of chromatids at chiasmata between the homologous chromosomes is called Crossing Over.

(5) Diakinesis:

During this sub stage; nucleoli and nuclear membrane are disappeared, whereas Mitotic Apparatus (spindle) is completed. Chiasmata moves from the centromere towards the ends of the chromosomes like a zipper.

This type of movement of chiasmata is known as Terminalization. At the end of Diakinesis chromatids still remain compacted at their ends.

Metaphase I:

Following changes occur in this phase:

The bivalent line up at the equatorial plane. The centromere of each chromosome attaches with same fibres of spindle.

Anaphase I:

At this stage one chromosome from each member of homologous pair (bivalent) begins to separate and move towards its respective pole by the contraction of spindle fibers.

The actual reduction occurs at this stage because half the number of chromosomes moves to each pole. Moreover as a result of crossing over the two chromatids of a chromosome do not resemble with each other in the genetic terms.

Telophase I:

The nuclear membrane form around the chromosomes at each pole and chromosomes become uncoil. The nucleolus reappears and thus two daughter nuclei formed.

Cytokinesis: Telophase may or may not be accompanied by cytokinesis and daughter cells formation.

Interphase: Following Telophase I (If this stage occurs), there is a short period called **Interphase** before meiosis II. It is similar to Interphase between Mitotic divisions except that DNA replication does not occur. Replication of DNA is unnecessary because each chromosome already has two chromatids.

Second Meiotic Division (Meiosis II):

The second meiotic division is actually the mitotic division which divides each haploid cell formed during meiosis I into two daughter haploid cells. The second meiotic division includes:

(1) Prophase II (2) Metaphase II (3) Anaphase II (4) Telophase II

(1) Prophase II:

The spindle fibres are formed. The nuclear membrane and the nucleolus disappear.

(2) Metaphase II:

The chromosomes are attached to half spindle fibers by their centromere and get arranged at equatorial plane. Each chromosome attach with separate fiber of spindel.

(3) Anaphase II:

The spindle fibers attached to the centromeres shorten and the chromatids of chromosomes are pulled away from one another. This movement continues until one complete set of chromosomes is positioned at each pole of the cell.

(4) Telophase II:

The spindle fibers disappear completely and chromosomes begin to uncoil. They become longer and indistinct and form group at each pole. Around each group nuclear envelope is formed.

After the kayrokinesis in each haploid meiotic cell the cytokinesis i.e. division of cytoplasm occurs and thus four haploid cells are formed.

What happens in absence of meiosis?
In the absence of meiosis number of chromosomes would have been doubled giving rise to abnormal growth, changes in species characteristics and or may prove fatal.

Significance of Meiosis:

(1) Constant number of chromosomes:

Meiosis maintains chromosome number constant from generation to generation. It is due to the fact that meiosis reduces the diploid number of chromosomes to half i.e. haploid in the gametes.

During fertilization the diploid number of the chromosomes is restored.

(2) Responsible for genetic variation among species:

By crossing over, the meiosis provides an opportunity for the exchange of the genes between homologous chromosome and thus cause the genetic variations among the species. The variations are the raw material of the evolutionary process.

Meiotic errors:

In normal course of meiosis, the two chromosomes of each homologous pair separates and enter into two gametes, but sometimes a pair of homologous chromosomes fails to separate from one another, during meiosis I. this phenomenon is called Non-disjunction.

Non-disjunction produce gametes with abnormal number of chromosome i.e either with less or extra chromosome. If such abnormal gametes fuse with normal gametes, the resulting zygote will also have abnormal number of chromosome.

Summary

- Term chromosome is given by *Fleming* in 1882. These are thread like structures appear at the time of cell- division made up of chromatin material in specific number in Eukaryotic cell.
- Chromosomes are made up of DNA and histone protein.
- There are four types of Chromosome i.e Metacentric, Sub-metacentric Aerocentric and Telocentric.
- Sequences of change occur between two successive Cell division called cell-cycle.
- Cell-cycle is mainly consist of two phases i.e cell-division and inter phase.
- Inter phase is divided further into three sub phases G1, S and G2 phases.
- Mitosis is the type of cell division, where a parent cell divides into two daughter cells, with same number of chromosomes as the parent cell contain.
- Meiosis is the type of cell division in which a single cell divides into four daughter cells and number of chromosomes become half of the parent cell.
- In animal meiosis takes place in the Germ cells while in plant it takes spore mother cells to produce gametes and spores respectively.
- Meiotic error, where a pair of homologous Chromosomes fails to separate form one another called non disjunction. This non disjunction produce gametes with abnormal number of chromosomes with less or extra chromosomes.

- Cell-death occur in two ways:
  (i) Apoptosis; programmed cell death, which help in proper control of development.
  (ii) Necrosis; cell death occur by external factor or accidental cell-death.

Review Questions

1. Encircle the correct answer:

(i) Which processes involve mitosis?
(a) Growth, reduction division and asexual reproduction.
(b) Growth, repair and asexual reproduction.
(c) Growth, repair and semiconservative replication.
(d) Growth, reduction division and repair

(ii) What occurs in metaphase of mitosis?
(a) Chromosome line up on the equator of the cell.
(b) Chromatids reach the poles of the spindle.
(c) Chromatids separate and move to opposite poles
(d) Chromosomes start to coil up and become visible.

(iii) Select the mismatched
(a) Anaphase → Chromatids move
(b) Prophase → Centriole move
(c) Telophase → Nuclear membrane disappear
(d) Metaphase → Chromosome line up.

(iv) Which process occurs during prophase of mitosis in an animal cell?
(a) Division of centromeres (b) Formation of chromosomes
(c) Replication of DNA (d) Separation of centrioles

(v) Sequence of physiological changes by which cell commit suicide.
(a) Apoptosis (b) Necrosis
(c) Autophagy (d) Both “a” and “b”

(vi) Choose the incorrect statement regarding meiosis.

(a) Maintain chromosome number from generation to generation.

(b) Reduces the diploid number of chromosomes to half

(c) Takes place in germ cell to produce gametes

(d) Production of new somatic cells from germ cells.

(vii) A type of cell division in which spore mother cell produce spores.

(a) Amitosis (b) Mitosis

(c) Meiosis (d) Both "a" and "c"

(viii) Stage of mitosis in which chromatids reach the poles and their movement ceases.

(a) Prophase (b) Metaphase

(c) Anaphase (d) Telophase

(ix) Stage of meiosis in which centromeres shorten and the paired chromatids are pulled away from one another.

(a) Anaphase-II (b) Metaphase-II

(c) Telophase-II (d) Prophase-II

(x) Phenomenon in which pair of homologous chromosome fails to separate called.

(a) Non-disjunction (b) Terminalization

(c) Synapsis (d) Linkage

2. Fill in the blanks:

(i) Chromosomes are thread like structures appear at the time of _____.

(ii) Sequence of changes which occurs between one cell division and the next is called_____.

(iii) The two chromatids are attached to each other at_____.

(iv) Chromosomes in the cell which are similar to each other in shape and size are called_____.

(v) Chromosomes with one arm very small and other very long called_____.

(vi) Chromosomes consist of two genetically identical copies of thread called_____.

(vii) Period of extensive metabolic activity, in which cell grow, enzymes are synthesizes_____.

(viii) In animal meiosis produces_____.

(ix) During metaphase homologous chromosomes arrange themselves on the _____.

(x) Cell death which is caused by external factor called_____.

3. Define the following terms:

(i) Pachytene (ii) Cytokinesis (iii) Bivalent

(iv) Chaismata (v) Chromatids (vi) Diakinesis

(vii) Terminalization (viii) Necrosis (ix) Crossing over

(x) Centromere

4. Distinguish between the following in tabulated form:

(i) Prophase and Prophase-I (ii) Prophase and Telophase

(iii) Apoptosis and Necrosis

5. Write short answers of following questions:

(i) Why meiosis-I is called reduction division?

(ii) Why mitosis is necessary for growth?

(iii) How number of chromosomes remains constant from generation to generation?

(iv) Why interphase is called as phase of high metabolic activities?

(v) Why interphase between meiosis-I and meiosis-II is short?

6. Write detailed answers of the following questions:

(i) Describe various stages of mitosis with suitable diagrams.

(ii) Describe stages of meiosis-I with suitable diagrams.