CHAPTER 12

CELL CYCLE AND CELL DIVISION

Topics Discussed

INTRODUCTION
CELL CYCLE
MITOSIS
MEIOSIS
AMITOSIS

1. Introduction

The cell is the skeleton and engine for all the organisms. There are unicellular and multicellular organisms who have cells in their body. The life to exist and continue the cell needs to divide like any other organism. Thus, the cell division is also a fundamental and essential function. Cell division is a long and complex process which involves several steps, common in all the organisms. As unicellular organisms have a single cell which divides in order to increase the population and also continue the species on the planet. Multicellular organisms have several cells in their body which are specialised to perform several functions. Thus, the cell division here ensures that the body is growing, developing, its repair, maintenance and also in the reproduction of the organism. There are various methods for a cell to divide namely Mitosis, Meiosis and Amitosis. There are several processes occurring before the actual cell divides into two. In this chapter we will discuss the processes of the division.

Objectives of this Chapter

At the end of this chapter you will be able to:

- Write about the phases that occur in a cell.
- Arrange the phases of a cell division in order.
- Distinguish between mitosis and meiosis.

2. Cell Reproduction or Cell Cycle

- The cell cycle involves three **major processes** – **Cell growth** (time required by a cell for synthesis and duplication of various components of the cell), **DNA replication** (time when the DNA replicates) and **cell division** (an adult mature cell finally divides into two daughter cells).
- A typical eukaryotic cell cycle is represented with a human cell in various culture methods. These cells divide once in approximately every 24 hours.
- Yeast cell has ability to finish the cell cycle in about 90 minutes.

2.1 Cell Cycle and Its Phase

The cell cycle is divided into two basic phases. **Howard and Pelc classified interphase** into **three sub stages.**

- **Interphase**
- **M-phase (Mitosis phase)**

2.1.1 Interphase

- The **preparatory phase, resting phase, beginning phase** and also a phase involving great metabolic activity. The intermediate stage between the two consecutive cell divisions where no cell division or even chromosomes division takes place. However, the **nucleus** and **cytoplasm** are **metabolically** and **synthetically** very **active** in order to get prepared for the division. The **length** of this phase is **90% - 95%** of the **total** cell **cycle**. The series of **events** occurring in the cell in this particular phase are: **replication** of DNA, **synthesis** of nuclear histones, **division** of centrioles to form a new pair of centrioles, **synthesis** of energy rich compounds, RNA and proteins. The **nuclear envelope remains intact,** however, the **nucleolus** show **genetic DNA** as long, coiled, indistinctly visible chromatin fibres in the **chromosomes**. Also, there are rRNA and ribosomal proteins accumulated in nucleolus which greatly increases its size.

  Interphase is further divided into three phases:

  (i) G_1-phase

  (ii) S or Synthesis Phase

  (iii) G_2-Phase

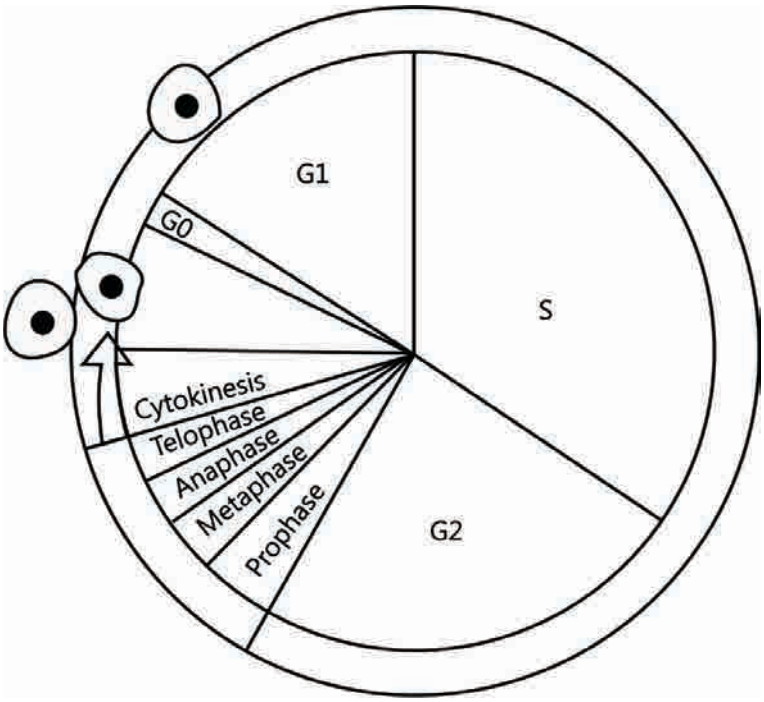

Figure 12.1: Cell cycle involved in cell growth and division

(i) G_1-Phase

It occurs at the end of a mitotic division (pro-mitotic gap phase). The initiation of DNA replication is major function. Following biochemical changes are common during this sub-stage.

- The cell **grows** until its **maximum size** as the normal metabolic activity occurs for the DNA replication preparation, and DNA contents of the cell remains unchanged.
- The new proteins are **translation** and RNA: **rRNA**, **tRNA** and **mRNA** transcription occurs during this phase.
- Also **Nucleotides**, **amino acids** and **ATPs** are formed.
- The **most variable phase** which **differs** in **time affecting** the **cell division** duration for each cell. **G_1** under certain stimuli can be **terminated.** Once G_1 is completed in a cell and 'S' phase has started with the replication of DNA, it cannot be terminated.
- There are cells which do **not** exhibit **division** usually in animal adults (e.g., heart cells) and also some which divide occasionally, as and when required to replace the lost or injured cells. Once replacement is complete, these cells stop further division and exit G_1 phase. Then they enter an inactive stage called as the quiescent stage (G_0) in the cell cycle. The cells are metabolically active, however, do not proliferate till the requirement. Hence, this phase of G_0 can be temporary or permanent in the organism.

Antephase, the end of G_1 phase where the cell will divide in all the conditions even under stress conditions.

(ii) S or Synthesis Phase

- The synthesis or replication of DNA on the template or the existing DNA takes place.
- The amount of DNA in a cell doubles (means the cell has twice the normal set of genes). However, the chromosome number remains the same (Ploidy level remains same). Assume: the initial amount of DNA as 2C, then the DNA amount increases to 4C, and the cell has 2n number of chromosomes at G_1, which remains the same even after S-phase.
- The replication occurs inside the nucleus along with centriole doubling in the cytoplasm.
- Histone proteins are also synthesised in S-phase. This phase is called as invisible phase of the cell cycle as the replicated chromosomes are invisible.

(iii) G_2 Phase

The phase just before the mitosis (pre-mitotic gap phase).

- The cytoplasmic organelles multiply like mitochondria, chloroplast and Golgi complex.
- Transcription of RNA and then translation protein continues. Spindle tubulin synthesis and aster formation starts.
- A cell contains double the number (4C) of DNA present in the original diploid (2N) cell.
- The cell is now prepared to enter into “M” or Mitotic phase.
- The main part is the synthesis of some protein kinases used in the regulation of cell division. Kinases regulating the cell cycle are called as Cdks (cyclin dependant kinases) because they get activated after combination with the key protein called as cyclin.
- The kinase enzyme along with cyclin moves the cell cycle in forward direction. S-kinase is capable of the DNA replication initiation after it combines with S-cyclin. After some time S-cyclin gets destroyed and S-kinase loses its activeness.

Cell cycle in the meristem cells are with a special protein “Cyclin and Cdks” (discovered by Nurse, T. Hunt & Hartmann 2001 during the experiment on yeast cell). The cyclin protein triggers the DNA replication.

2.1.2 M-Phase

The phase when the actual cell division or mitosis is initiated. The steps involve nuclear division, the separation of daughter chromosomes (Karyokinesis) and ends in the division of cytoplasm (cytokinesis). The 24 hour is the average duration of cell cycle in a human cell, where the cell division, i.e., M-phase lasts for about an hour.

KNOWLEDGE BUILDER

Regulation of Cell Cycle:

- Decision of a cell to divide occurs in G_1-phase. If a cell is not to divide it will enter into G_0-phase or Quiescent phase. When the conditions change, the cell can enter back into G_1-phase. $G_1 \rightarrow S$ transition in the cell cycle is called as Restriction point or check point. This is the major check point. Once the cell crosses the restriction point rest of the cell cycle is completed. Another minor check point is $G_2 \rightarrow M$ transition.
- Cell cycle is regulated by cyclin-dependent protein kinase.
- Cyclins are proteins that activate protein kinases to regulate eukaryotic cell cycle.
- G_1 to S transition is triggered by maturation promoting factor (MPF) formed by mitotic cyclin + cdc 2 kinase. Nucleus attains the maximum size.

3. Mitosis

- Mitosis produce **genetically identical cells**. The chromosomes undergo division and replicate to form duplicates which are similar to mother cell chromosome number (equational division).
- The division is also called as **somatic cell division** or **equational division** or indirect division.
- Mitosis was coined by **Fleming** in 1882.
- **Establishment: Strasburger** observed mitosis in **plants**. While **Boveri** and **Fleming** observed the same in **animals**.
- **Duration**: Dependent on the type of the cell involved and its species. It takes **30 minutes to 3 hours**. The various factors affecting the duration are type of the tissue, its location, temperature and species of the organism. The actual cell division is for one hour from the 24 hour average duration.
- **Occurrence**: A common division method for both the **somatic** or **body cells** and the **germ cells** in the sex organs. There are phases and specific location where it is common and a regular method. Plant meristematic tissues (root and shoot tips) and animal skin, bone marrow, even the embryonic developmental stages have the mitotic division.
- **Cause of mitosis:** Kern plasm theory: Hertwig proposed kern plasm theory. According to this theory mitosis occur due to disturbance in Karyoplasmic index (KI) or nucleocytoplasmic ratio of cell.

  V_n = Volume of nucleus

  V_c = Volume of cell

  V_c-V_n = Volume of cytoplasm

  Karyoplasmic Index (KI) of small cell is high as they have less cytoplasm. Nucleus efficiently controls the activity of cytoplasm in small cells, so these cells are metabolically more active

During cell growth, cytoplasm increases, thus K.I. decreases. In a large cell, nucleus fail to control the activity of cytoplasm. To attain the control of nucleus on metabolism a large cell divides into two cells.

- **Surface-volume Ratio:** A cell draws all the materials needed for its maintenance and growth from its surface. When a cell grows in size its volumes increases more than its surface. So a stage will reach when the surface area becomes insufficient to draw the material. At such critical stage, division of cell started.

3.1 Phases of Mitosis

The phases of mitosis are as follows:

Interphase (as described earlier).

Did You Know

- The **factors responsible** for the **cell division** to occur or not occur are as:
  - **Surface area to** the **volume ratio**: in order to undergo division a cell should have low surface area to volume ratio.
  - **Karyoplasmic index**: Also a cell should have low karyoplasmic index (explained later in the chapter).
- **Ideal** examples for the mitosis study is onion root tips or other **meristematic** tissues.
- **Mitogens** are mitosis inducing substances. E.g., Auxin, Cytokinin, Gibberellin, Insulin etc.
- Mitosis in animal cell is called as **Amphiastral** division as it has the spindle formation associated with 2 asters at each pole.
- Mitosis in plant cells is called as **Anastral** division where there are no aster and no centriole.
- The mitosis when occurs in a cell which has lost its nuclear membrane and is extra nuclear, it is called as **Eumitosis**.
- The mitosis is intranuclear where it occurs in the nuclear membrane while it is still in the cell, it is called as **Premitosis**.
- The centrioles when form the spindle complex in the cell it is called as **centric** division.

Division phase or M-phase or mitotic phase (duration 1hr) is the most dramatic period of the cell cycle. **Karyokinesis** – Division of nucleus; and **Cytokinesis** – Division of cytoplasm.

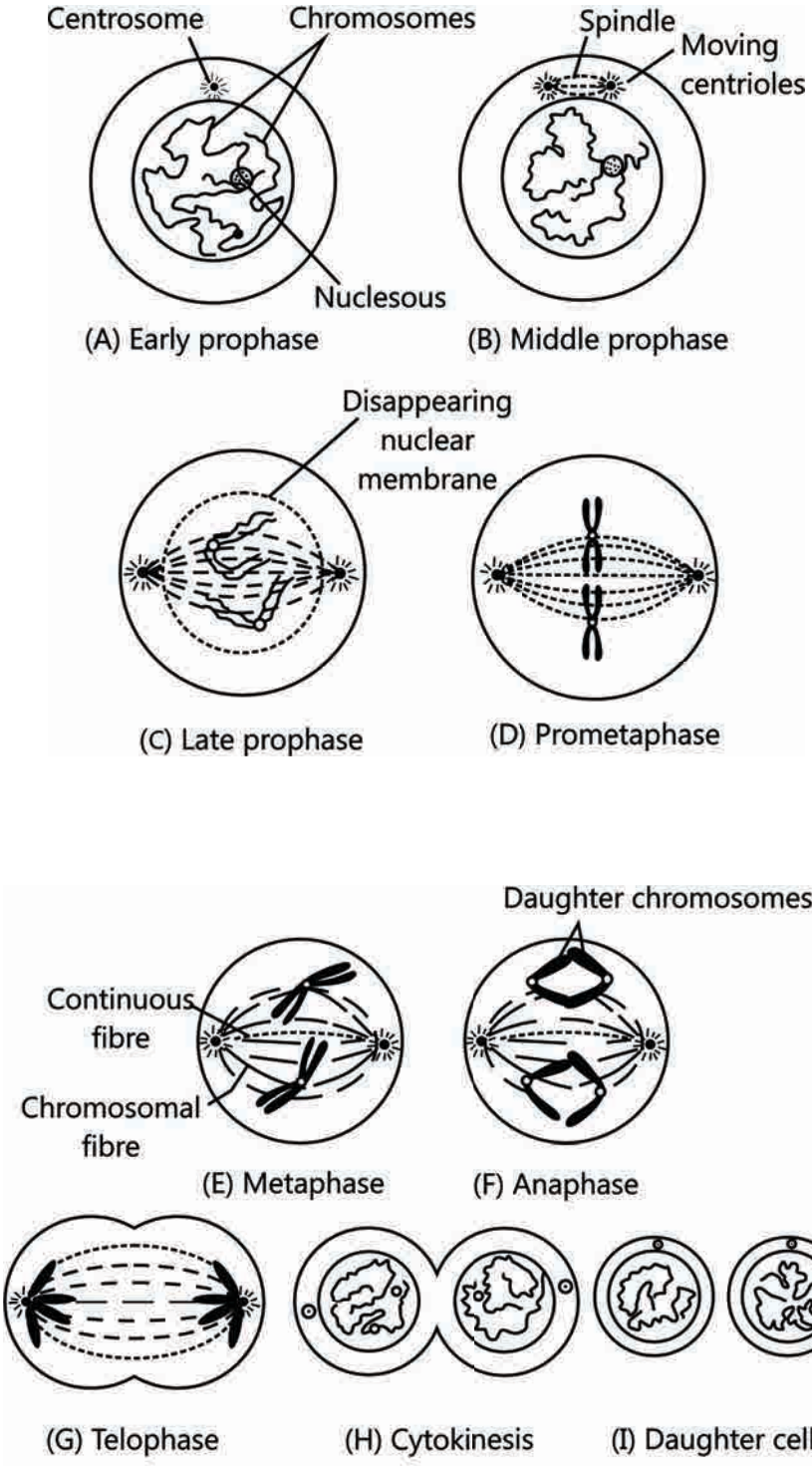

Figure 12.2: Different stages of mitosis

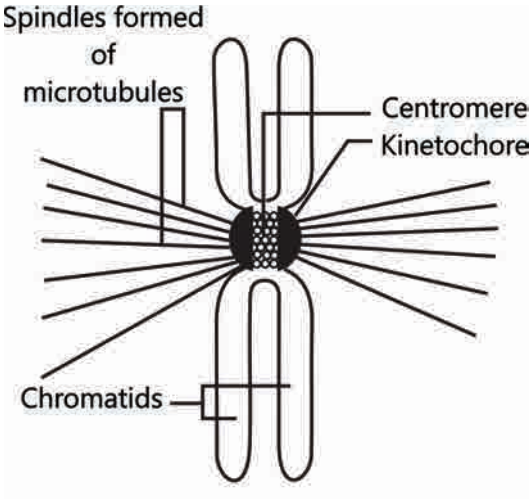

Figure 12.3: Chromosome showing spindle formation

3.1.1 Karyokinesis

Division of nucleus occurs by sequential changes (Indirect division) Karyokinesis has 4 stages:

(i) Prophase (longest stage)

- Chromatin threads get condensed to form the chromosomes.
- Centrioles get aligned towards the opposite poles.
- Astral ray formation from the proteins gelatinised around the centrioles (initiation of the assembly of mitotic spindle).
- Cells do not show Golgi complexes, ER, Nucleolus and nuclear membrane at the end of the prophase.

(ii) Metaphase

- The nuclear **envelope** is completely disintegrated which highlights the start of the second phase in mitosis. The **chromosomes spread** throughout the cytoplasm. Spindle fibres attach to the chromosomes at their kinetochores.
- The condensation of chromosomes is complete. This is the stage where **morphology** of **chromosomes** is easily visible.
- The chromosome is compiled in two sister chromatids, held together with the centromere.
- Each chromosome splits as per length upto the centromere (division of matrix of chromosome). Thus, replicated chromatids are clearly visible at metaphase stage.
- Chromosomes spilt up and arrange themselves on the equator to form metaphase plate (equatorial plate).

- Spindle fibres are microtubules. Chromosomal fibres, (discontinuous and run from pole to centromere) and supporting fibres, (continuous and run from pole to pole), arrange in a cell.
- The centromere lies at the equator with arms facing the poles.

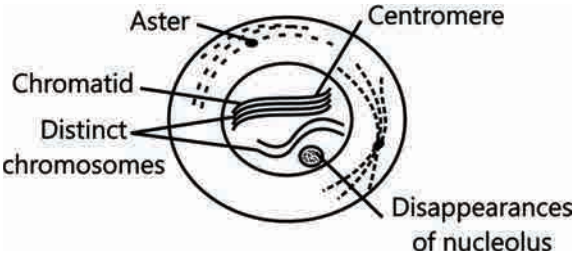

Figure 12.4: Metaphase stage

(iii) Anaphase (smallest stage)

- The early anaphase have inter zonal fibres appearing at the equator.
- Chromosome centromere splits lengthwise (division of centromere).
- Chromosomes double inside a cell during mitotic anaphase. Every chromosome has one chromatid.
- Expansion of Inter zonal fibres and the chromosomes are pushed towards the opposite poles (pushing)
- Contraction of chromosomal fibres such that they pull them towards opposite poles (pulling)

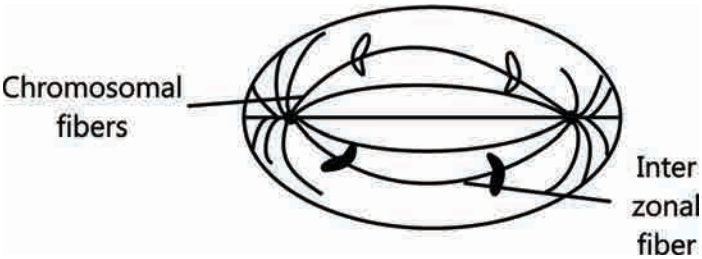

Figure 12.5: Anaphase stage

(iv) Telophase (reverse of prophase)

- Nuclear membrane, Nucleolus, Golgi complex and ER now surround each of the chromosomal pole.
- The chromatin net is formed after the chromosomes decondense. Chromosomes lose their individuality which means the individual chromosomes are not present.

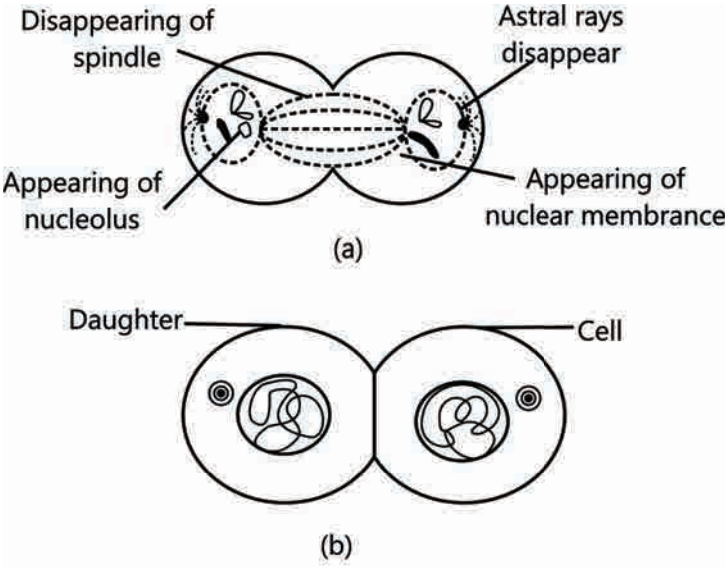

Figure 12.6: A. Early telophase and B. Late telophase stage

3.1.2 Cytokinesis

- Cytokinesis is initiated in late the anaphase. It is different for plants and animals.

(i) Cytokinesis in animals

- It occurs **through constriction** and **furrow formation** in the cell membrane.
- A mid-body equator is formed when the microtubules arrange in the middle while the microfilaments arrange in the peripheral ring just below the plasma membrane.
- The cell organelles arrange themselves at either side of the equator.
- The contraction occurs as the attraction occurs between mid-body and peripheral ring, forming a furrow from the outside of the cell to inside.

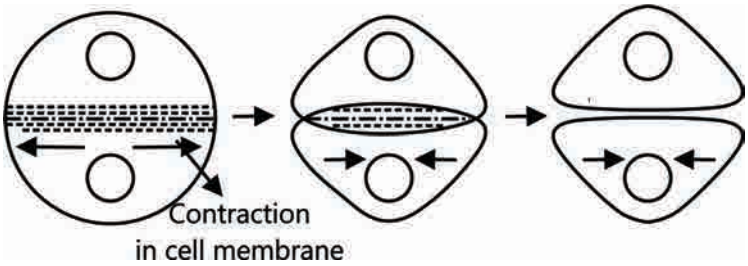

Figure 12.7: Cell membrane division in animals

- The furrow formed deepens continuously and finally the cell divides into two daughter cells.
- The cytokinesis in animal cell occurs in the **centripetal** order.

(ii) Cytokinesis in plants

- The **cell plate formation** takes place because the constriction or even furrow is not possible as the cell wall is rigid.

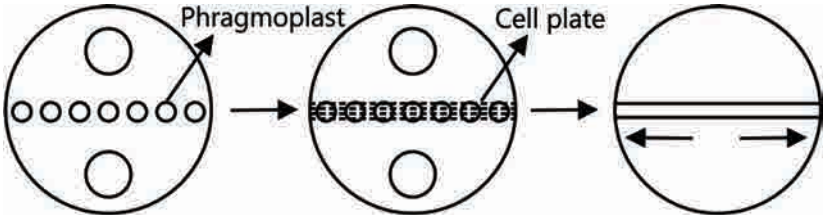

Figure 12.8: Cell division in plants

- Many Golgi vesicles and spindle microtubules arrange themselves on equator and the cell has a **Phragmoplast**. It may also have the deposits of fragments of ER. Golgi vesicles membranes fuse and form a plate like structure which is called as the cell plate. Golgi vesicles then secret pectates of calcium and magnesium. The cell plate modifies into the middle lamella. The cytokinesis of plant cells occur in the **centrifugal order** (cell plate formation is from centre to periphery).

3.2 Significance of Mitosis

- **Mitosis**: The **equational division** is a common division method for the **diploid** cells only. However, some lower plants and social insects which have **haploid** cells, also use **mitosis** for division. The **significance** of this division is **essential** to **understand** in the **life** of an organism.
- Mitosis results in the production of diploid daughter cells which have identical genetic chromosome number. The multicellular organisms grow due to the mitosis.
- Cell growth often results in disturbing the usual ratio of the nucleus and the cytoplasm. Thus, the cell divides and restores the **nucleo-cytoplasmic ratio**.
- A very significant contribution is that a cell is repaired. Best examples are the cells of the upper epidermis layer, cells of the gut lining, and blood cells being replaced constantly.

TRY IT YOURSELF

1. Fill in the blanks:

a. _____ are proteins that activate kinases to regulate eukaryotic cell cycle.

b. The morphology of chromosome is best studied in _____

c. Cell plate is first laid down in _____ and then proceeds towards _____

2. Which one of the following is not a mitotic poison?

(A) Chalones (B) Cytokinin (C) Ribonuclease (D) Mustard gas

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Mitotic Poisons:

All the substances or chemicals which affect the **mitotic process** in a cell or prevent the cells completely from dividing normally are called as mitotic poisons. The various **mitotic poisons** are:

- **Enzyme ribonuclease**, **Azide** and **cyanide** acts as a poison during prophase.
- **Mustard gas** reaching a cell results in the agglutination of the chromosomes.
- **Chalones** are small peptides or glycoproteins present in the extracellular fluid also inhibit mitosis.
- The **alkaloid colchicine** targets and inhibits the formation of mitotic spindle (inhibits polymerization of microtubules) and freezes the cell in the metaphase. Though chromosomes and DNA replicate they remain intact in the same cell. The nucleus division dies not occur. This increases the chromosome sets in a cell. This process leads to **endopolyploidy** or **endomitosis** in which nucleus contains multiple sets of chromosomes, more than the normal two sets in a normal diploid cell. Such cells are called as **polyploidy** cells.
- **X-rays** induce uncontrolled mitosis as they energize the cells and thus cause breakage of chromosomes.

Abnormal Mitosis:

- **Intranuclear mitosis (pre-mitosis)**: In *Amoeba*, *Yeast*, fungi and many algae, during the mitotic division, the nuclear envelope fails to degenerate. Spindle formation is intranuclear.
- **Dino mitosis**: **Dinoflagellates** possess **condensed chromosomes** even in non-dividing nuclei. Nuclear envelope does not degenerate. Division of chromosomes occur when the nucleus develop special channels.
- **Free Nuclear Division**: Sometimes, there are repeated mitosis without the subsequent cytokinesis in a cell which results in multinucleated conditions, e.g., *Rhizopus*, *Vaucheria*, *Slime moulds*, etc.

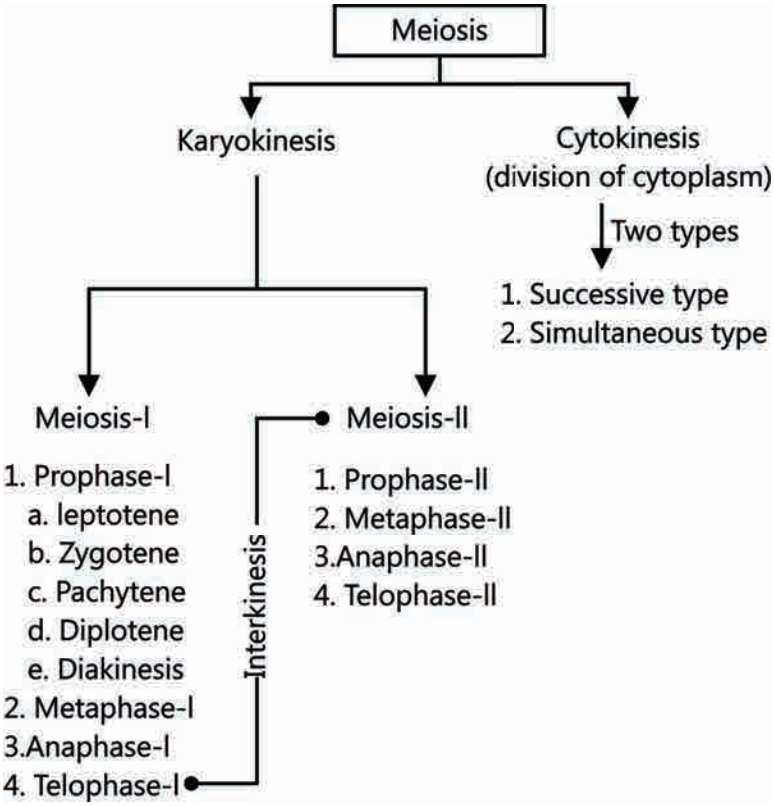
4. Meiosis

- Meiosis is a method where the **division produces genetically different** type of cells. All the four daughter cells produced with meiosis have genetic differences among each other and also are different from the mother cell. Gametogenesis the formation of gametes is a common factor for meiosis to occur.

4.1 Phases of Meiosis

There are two different phases in the division of cell:

- **Meiosis I: Heterotypic division** or **reduction division**. It leads to reduction in chromosome number to half in daughter cells. Division of chromosome does not occurs in meiosis-I, only segregation of homologous chromosomes takes place.
- **Meiosis II**: **Homotypic division** or **equational division**. It does not lead to any change in chromosome number. Division of nucleus occurs twice, however, the DNA replication and chromosome division occurs only once.



Flowchart 12.1: Phases of Meiosis

4.1.1 Stages of Meiosis I

(i) Prophase - I: The longest and most complex stage of the meiosis. Prophase I is further divided in five sub stages as:

(a) Leptotene – Chromatin threads are condensed so that they form chromosomes which are longest and thinnest fibers. There are **bead** like structures present on it called as **chromomeres**. All the **chromosomes** move **towards centrioles** in **nucleus**, so **group** of chromosomes in nucleus appears like a **bouquet** in animal cell. (Bouquet stage).

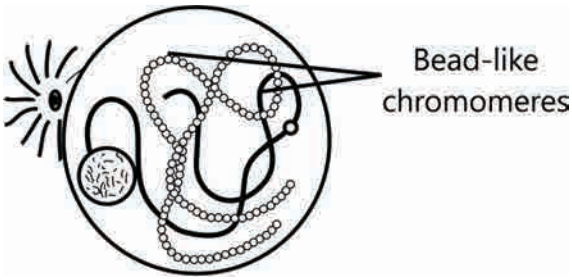


Figure 12.9: Leptotene stage

(b) Zygotene or Synaptotene – There is pairing of homologous chromosomes (Synapsis). The pairs of homologous chromosomes which are formed here, are called as **Bivalents** or **Tetrads**, and are clearly identified in the next stage. A structure is developed in between the **homologous chromosomes**, is called as **synaptonemal complex**. It has three thick lines made up of DNA and proteins. The complete set helps in pairing of the DNA.

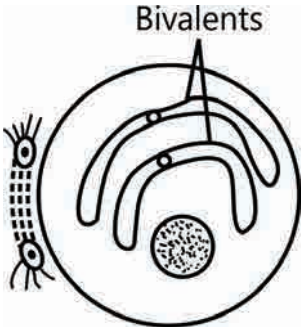


Figure 12.10: Zygotene stage

(c) Pachytene (thick thread) – There is increased attraction which causes **homologous chromosomes** to coil tightly around each other. Both the chromatids in the chromosome are clear and distinct and now the pair or **bivalent** is found as a **tetrad**. Both the **chromosome chromatids** are called as **sister chromatids**. **Non-sister chromatids** present in the bivalent develop into **recombination nodules** and exchange their parts called as the **crossing over**. This is an **enzyme-mediated process** and the enzyme is **recombinase**.

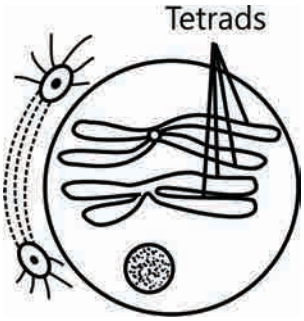


Figure 12.11: Pachytene stage

(d) Diplotene – The diplotene starts with the **dissolution** of the **synaptonemal complex**. There is also the tendency in the bivalent **recombined homologous chromosomes** to separate from each other while still joint at the cross-overs. These X-shaped structures formed are called as **chiasmata**. The diplotene can last for months or years, in **some vertebral oocytes which** is called as **dictyotene**.

Figure 12.12: Diplotene stage

(e) Diakinesis – The meiotic prophase I ends in diakinesis. There is markable **terminalisation** of the **chiasmata**. The chromosomes gets fully condensed and then the meiotic spindle assembles to prepare the homologous chromosomes which separate. When **diakinesis ends**, the **nucleolus disappears** and the **nuclear envelope breaks** down. Diakinesis ends and metaphase starts.

Figure 12.13: Diakinesis stage

(ii) Metaphase I:

- **Bivalents** form **metaphase plate** after arranging on the equator of cell such that the centromeres face the poles while arms face the equator.
- Spindle fibres now attach to the pair of homologous chromosomes.
- There are in all 3 types of spindle fibres in the cell:
    - Chromosomal / Kinetochore Spindle fibres
    - Supporting / Continuous Spindle fibres
    - Inter zonal Spindle fibres.

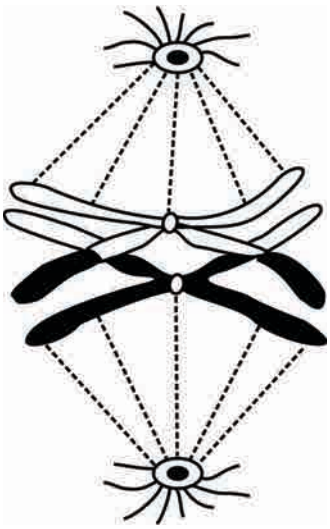


Figure 12.14: Metaphase I stage

(iii) Anaphase I:

- There is contraction of chromosomal fibres and expansion of **inter zonal fibres**. The homologous chromosomes move towards the opposite poles after they segregate from each other.
- Anaphase I has segregation or disjunction of the homologous chromosomes. There is no division of centromere.

Figure 12.15: Anaphase I stage

(iv) Telophase I:

- The nuclear membrane and nucleolus reappear.
- This is followed by the cytoplasm division or the cytokinesis and two daughter cells together are called as **diad** of cells. The **chromosomes** in some situations undergo some **dispersion**, and are thus fail to reach the extremely extended state of the **interphase nucleus**.

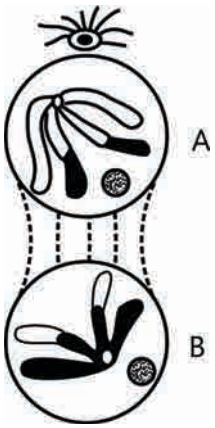


Figure 12.16: Telophase I stage A. and B. are daughter cells

- The connecting stage of the two **meiotic divisions** is called as **interkinesis** which is short in duration. DNA does not replicate in this stage. **Interkinesis** ends with the start of prophase II, which is simpler than prophase I.

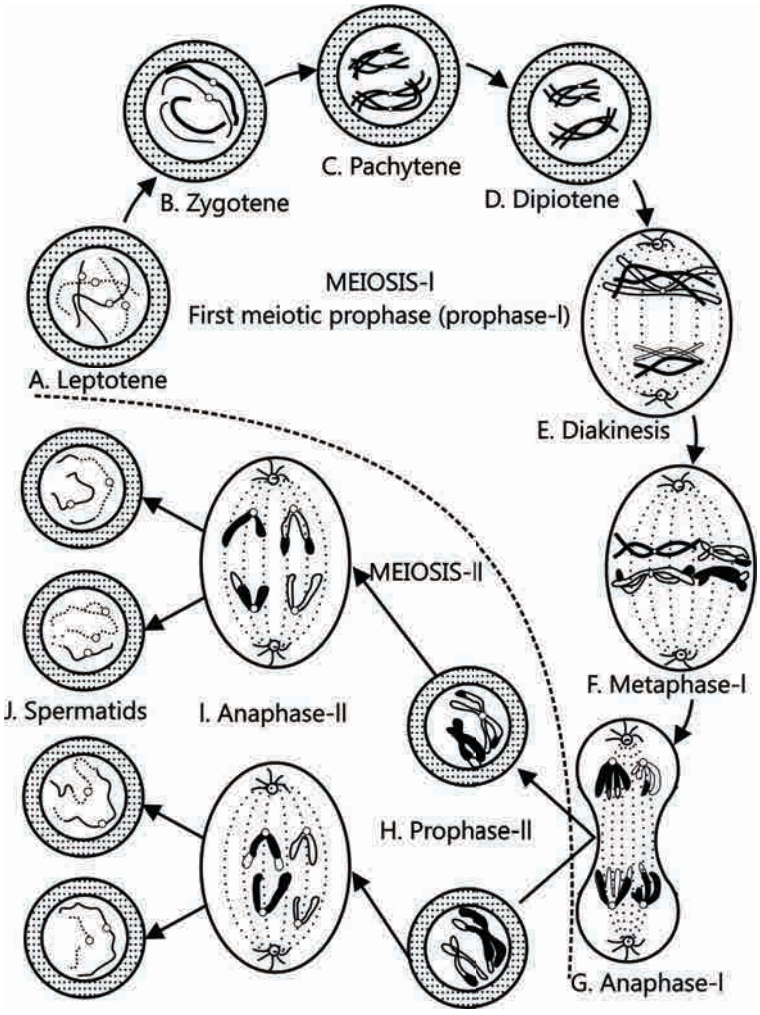


Figure 12.17: All stages involved in Meiosis

4.1.2 Stages of Meiosis – II

(i) Prophase II:

- Meiosis II is an intermediate step which starts immediately after cytokinesis, and before the chromosomes have elongated fully. Meiosis II is similar to a normal mitosis, in contrast to meiosis I. The nuclear membrane disappears and chromosomes are compact again in the end of this stage.

(ii) Metaphase II:

- The chromosomes get aligned at the equator while at the opposite poles the spindle microtubules are in close contact with the kinetochores of the sister chromatids.

(iii) Anaphase II:

- The simultaneous **splitting** of the **chromosome centromere** occurs (which was holding the sister chromatids together), which moves the **chromosomes** toward the **opposite poles** of the cell.

(iv) Telophase II:

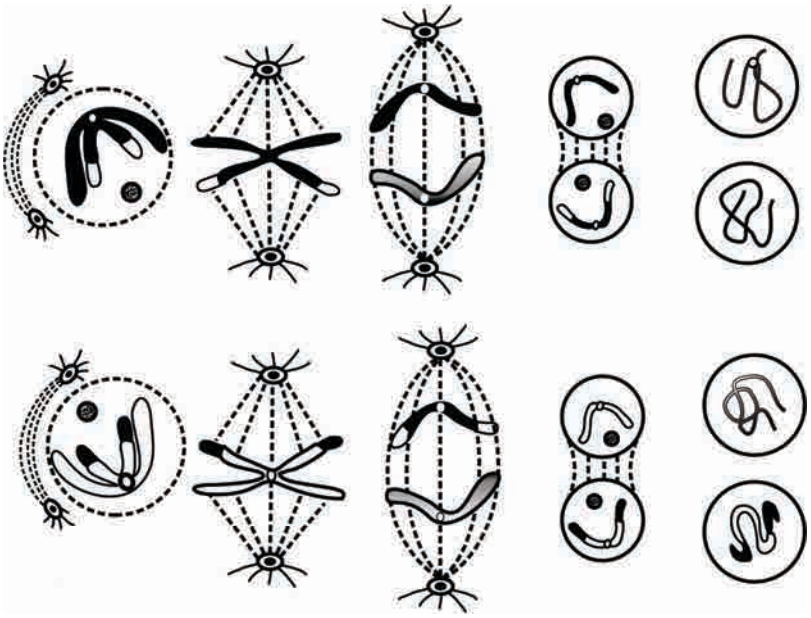


Figure 12.15: Different stages in Meiosis II

- The two sets of chromosomes are again enclosed in a nuclear envelope and cytokinesis begins. There is formation of tetrads (four haploid daughter cells).

4.2 Significance of Meiosis

- Meiosis is the division in which specific chromosome number in each species is conserved. This is achieved in sexually reproducing organisms across several generations, even though there is reduction of chromosome number by half in the whole process.

- The genetic variation increases in the population of organisms over various generations. Evolution is due to variations which is a very important factor that is progressive with time.

Did You Know

- Onion buds (Sambhar onions) are common Meiotic study cells.
- Van Beneden first demonstrated Meiosis and Winiwarter described it.
- Gametic meiosis in the gametic cells is also called as terminal meiosis.
- Zygotic meiosis when the zygote formation is initiated is also called as initial meiosis.
- Sporogenic meiosis is also called as intermediate meiosis.
- Cytokinesis: Cytokinesis can be of two types, successive and simultaneous. Cytokinesis occurs after every nuclear division in successive division. The four cells formed after the successive cytokinesis can be arranged linearly or isobilateral in tetrads.

  When cytokinesis occurs at the end of both the divisions it is the simultaneous division. The nuclei arrangement is in the form of a tetrahedron.

Knowledge Builder

The best theory to explain crossing over is **Darlington's theory** of breakage and union:

- The enzyme endonuclease develops breaks called as nicking.
- The gap formation in the nicks is due to exonuclease.
- The chromatid segments separate in the gaps due to the U-protein or helicase enzyme.
- Re-annealing (rejoining) is a result from the R-protein or Re-annealing protein.

The newly formed chromosomes, are different from the parent cell chromosomes. The formation of new characters (recombinants) and ultimately variations are the obvious results in the population which result in the evolution.

Try It Yourself

1. If a pollen grain contains 30 chromosomes and 50 Pg DNA, then what will be the number of chromosomes and DNA amount in microspore mother cell in G_2-phase, meiosis-I products and meiosis II products respectively?

2. Fill in the blanks:

a. Darkly stained bead like structures called _____ appear along the entire length of chromatin fibre in _____stage of meiosis.

b. Number of bivalents formed in Ophioglossum (Adder's tongue fern) meiocyte is _____.

c. Desynapsis phase is _____.

3. Intrameiotic interphase is characterised by

(A) Genes duplication

(B) replication of DNA

(C) Centrioles duplication in animals

(D) Disappearance of nucleolus

5. Amitosis

- The most primitive type of cell division. Condensation of chromosomes not occurs in **amitosis**. Chromosomes are not visible during division. The process of division does not have any recognizable chromosomes in the cell.
- **Amitosis** is without the **spindle formation**. Nucleus division is direct i.e. without sequential changes (prophase, metaphase, anaphase and telophase).
- The division of **cytoplasm** and **nucleus** is simultaneously through the constriction.
- The division may be **equal** or **unequal** in the chromosome number.
- **Amitosis** is the **fastest** cell division method which can be completed in just **20** to **30 minutes**. Amitosis is the cell division method of **prokaryotes**. However, exceptionally it also occurs in some **eukaryotes**, e.g. in **budding Yeast**.

Table 12.1: Some formulae related to cell division

Formulae Chart	
1. Number of mitotic divisions for the formation of n number of cells. Example: For getting 100 cells 99 mitotic divisions are required	n – 1
2. Number of generations (n) of mitosis for producing 'x' cells.	$x = 2^n$
3. Number of meiosis for the formation of 'n' seeds/grains/fruits.	$n + \frac{n}{4}$

Summary

- According to the cell theory, all the cells arise from the pre-existing cells. The process which involves cell to continue existing is called as the cell division.
- Any sexually reproducing organisms starts the life cycle from a single celled zygote to the whole new organism.
- Cell division is a continuous process from the formation of the mature or adult organism to the death of the organism.
- The stages a cell passes in the life from one division to the next is called as the cell cycle.
- Cell cycle is divided in two phases called (i) Interphase – A period of preparation for cell division, and (ii) Mitosis (**M phase**) – The actual period of cell division
- Interphase has subdivisions: G_1, S and G_2 .
- G_1 phase is the period of the cell growth and its normal metabolism. The organelles get duplicated during this phase.
- S-phase is the period of the DNA replication and chromosome duplication.
- G_2 phase is the period of cytoplasmic growth and also the cell size growth.
- Mitosis is also divide into four stages namely prophases, metaphase, anaphase and telophase.
- Chromosome gets condense during prophase.
- Simultaneously, the centrioles occupy the opposite poles.
- The nuclear envelop and nucleus disappear and the spindle fibers start appearing.
- Metaphase has chromosomes aligned at the equatorial plate.
- The chromatids after the centromere division starts moving towards the two opposite poles.
- The chromosomal elongation starts after the chromatids reach the two pole, the nucleolus and the nuclear membrane reappear. This stage is called the telophase.
- Nuclear division ends and the cytoplasmic division begins called as cytokinesis.
- Mitosis is the equational division in which the chromosome number is conserved through various generations of the cell.
- Meiosis takes place in the diploid cell, majorly cells which form gametes.
- Meiosis is divided into two phases: meiosis-I and meiosis- II.
- Meiosis I has a long prophase, including the phases: Leptotene, Zygotene, Pachytene, diplotene and diakinesis. The homologous chromosomes form pairs and bivalents, and undergo crossing over which causes changes in the new cell different from the parent cell.
- Meiosis-II is similar to mitotic division. Thus, meiosis yield four haploid cells at the end of the division.

EXERCISE

Objective Questions

Q.1 DNA synthesis takes place in

(A) S phase (B) G_1 phase (C) G_2 phase (D) None

Q.2 When pairing occurs in chromosomes (meiosis)

(A) Leptotene (B) Zygotene (C) Pachytene (D) Dikinesis

Q.3 Most active stage of cell cycle is

(A) Prophase (B) Metaphase (C) Telophase (D) Interphase

Q.4 What happens in interkinesis

(A) DNA-replication (B) Chromosome duplication

(C) Preparation of second meiotic div (D) Resting stage

Q.5 Which can be observed in an interphase nucleus under the light microscope

(A) Chromosomes (B) Nucleosomes (C) Centromere (D) Heterochromatin

Q.6 How much part of cell cycle formed by interphase

(A) 50% (B) 70% (C) 10% (D) 95%

Q.7 In cell cycle, changes of which stage are not visible under microscope

(A) Interphase (B) Prophase (C) Metaphase (D) Anaphase

Q.8 Which type of division leads to polyploidy

(A) Cryptomitosis (B) Meiosis (C) Endomitosis (D) Amitosis

Q.9 Which of the following not occurs in Anaphase – I but occurs in Anaphase- II

(A) Condensation of chromosomes (B) Poleward movement of chromosome

(C) Contraction of spindle fibers (D) Splitting of centromere

Q.10 During G_2 –phase a diploid cell contains the amount of DNA equal to a

(A) Diploid cell (B) Tetraploid cell (C) Haploid cell (D) Nothing can be said

Q.11 Crossing over takes place in

(A) Zygotene (B) Pachytene (C) Diplotene (D) Diakinesis

Q.12 Which type of chromosome will appear 'L'-shaped during anaphase

(A) Telocentric (B) Acrocentric (C) Metacentric (D) Submetacentric

Q.13 In which order, cytokinesis occurs in plants

(A) Centripetal (B) Centrifugal (C) Oblique (D) Equatorial

Q.14 Meiosis not occurs in

(A) Ovule (B) Anther (C) Microsporangia (D) Shoot tip

Q.15 Which of the two events restore the normal number of chromosomes in life cycle

(A) Mitosis and meiosis (B) Meiosis and fertilization

(C) Fertilization and mitosis (D) Only meiosis

Q.16 Division of nucleus is indirect in

(A) Mitosis (B) Meiosis (C) Amitosis (D) A and B both

Q.17 Which protein is key regulator of cell cycle

(A) Histone (B) Interleukine (C) Intereferone (D) Cycline

Q.18 Which part of plant is suitable for the study of meiosis

(A) Root apex (B) Ovary (C) Anther (D) Shoot apex

Q.19 Colchicines, a mitotic poison, arrests the cell division in

(A) G_1 phase (B) G_2 phase (C) Anaphase (D) Metaphase

Q.20 Nuclear envelope reappears at

(A) Metaphase (B) Prophase (C) Anaphase (D) Telophase

Q.21 Slipping of chiasmata towards the ends of bivalent is called

(A) Terminalisation (B) Diakinesis (C) Interkinesis (D) Heteropycnosis

Q.22 The cellular structure which disappear during mitosis is

(A) Plasma membrane (B) Nuclear membrane

(C) Mitochondria (D) Nuclear membrane and nucleolus

Q.23 Meiosis takes place in

(A) Apical meristem (B) Inter calary meristem

(C) Reproductive cells (D) Vegetative cells

Q.24 How many chromosome shall be present in a diploid cell at mitotic anaphase if its egg cell has ten chromosome

(A) 10(Ten) (B) 20(Twenty) (C) 30(Thirty) (D) 40(Forty)

Q.25 Chromosome exhibit high level of coiling at which phase of karyokinesis

(A) Prophase (B) Metaphase (C) Telophase (D) Interphase

Q.26 “Bouquet-stage” occur in which sub stages of prophase –I

(A) Leptotene (B) Zygotene (C) Pachytene (D) Diplotene

Q.27 The synaptonemal complex appears

(A) Between homologous chromosomes (B) In zygotene stage

(C) Composed of DNA + protein (D) All the above

Q.28 At anaphase – II of meiosis each chromosome contains

(A) 4-DNA (B) 3-DNA (C) 2-DNA (D) 1-DNA

Q.29 In human cell how many chromosome present in mitotic metaphase plate

(A) 23 (B) 46 (C) 22 (D) 44

Q.30 Which one of the following statements is not true for meiosis

(A) It occur in reproductive tissue only

(B) Chromosome undergo pairing in early prophase –I

(C) Chromosome do not exchange part

(D) Centromere do not divide during anaphase-I

Q.31 In which stage of mitosis, the chromosomes are composed of two chromatids

(A) Prophase and metaphase (B) Anaphase and telophase

(C) Prophase and telophase (D) Metaphase and anaphase

Q.32 In Anaphase–I each chromosome composed of

(A) One chromatid (B) Two chromatid

(C) Four chromatid (D) Many chromatid

Q.33 Gap between division phase and start of DNA – replication is called

(A) G_1-phase (B) G_2-phase (C) M-phase (D) Interkinesis

Q.34 In meiosis, division of centromere occurs during

(A) Interphase (B) Anaphase-I (C) Anaphase –II (D) Metaphase-I

Q.35 In animals , active mitosis can be observed

(A) At the base of nails (B) At the apex of hairs

(C) Dermis of skin (D) Glans

Q.36 In meiosis, nuclear membrane and nucleolus disappear during

(A) Zygotene (B) Pachytene (C) Diakinesis (D) Metaphase-I

Q.37 Cell cycle can remain arrested at

(A) G_1 (B) S (C) G_2 (D) M

Q.38 Which of the following are mitotic poisons

(A) Colchicines (B) Mustard gas and Azides

(C) Cyanides (D) All the above

Q.39 Spindle fibers which extend from pole to kinetochores are

(A) Chromosomal or tractile fibers (B) Interzonal fibers

(C) Supporting fibers (D) Astral rays

Q.40 The longest phase in meiotic division is

(A) Prophase – I (B)Metaphase –I (C) Prophase –II (D) Anaphase –I

Q.41 In tetrad, the number of non cross over chromatids is normally

(A) Four (B) Two (C) One (D) None

Q.42 In mitosis, splitting of chromatids upto the centromere takes place in

(A) Prophase (B) Metaphase (C) Anaphase (D) Telophase

Q.43 In which stage of cell division the chromosomes are most condensed

(A) Prophase (B) Meta phase (C) Anaphase (D) Telophase

Q.44 Karyoplasmic index (K.I.) is

(A) Vn/Vn-Vc (B) Vn/Vc-Vn (C) Vc/Vn (D) Vn/Vc+Vn

Q.45 What happens during growth of a cell

(A) K.I. decreases (B) K.I. increases

(C) K.I. fluctuates (D) K.I. remaine constant

Q.46 Synthesis of proteins occurs during

(A) G_1 (B) G_2 (C) S (D) All the above

Q.47 During which stage a diploid cell becomes tetraploid in mitosis

(A) G_2 (B) Prophase (C) Metaphase (D) Anaphase

Q.48 Each chromosome composed of one chromatid in

(A) Anaphase –I (B) Anaphase –II (C) Metaphase –I (D) Metaphase –II

Q.49 Phase of shortest duration is

(A) Prophase (B) Metaphase (C)Anaphase (D) S-phase

Q.50 Which of the following not occurs in Anaphase – I

(A) Segregation of homologous chromosomes

(B) Contraction in spindle

(C) Poleward movement of chromosomes

(D) Division of centromere

Q.51 In meiosis

(A) Division of nucleus twice but replication of DNA only once

(B) Division of nucleus twice and replication of DNA twice

(C) Division of nucleus once and replication of DNA is also once

(D) Division of nucleus once and DNA–replication is twice

Q.52 After meiosis-I the two chromatids of a chromosome are

(A) Genetically similar (B) Genetically different

(C) Only one chromatid in each chromosome (D) None of the above

Q.53 Chiasmata appears during

(A) Diakinesis (B) Synaptotene (C) Diplotene (D) Leptotene

Q.54 Meiosis can take place in

(A) Prokaryotic cell (B) Haploid cell (C) Dikaryotic cell (D) Diploid cell

Q.55 Reappearance of nuclear membrane and nucleolus along with thining and elongation in chromosomes are diagnostic characters for the phase

(A) Anaphase (B) Metaphase (C) Interphase (D) Telophase

Q.56 What happens in crossing over

(A) Duplication of chromosomes (B) Linkage in chromosomes

(C) Minimization in genetic material (D) Exchange of genetic material

Q.57 In mitosis, the spindle is

(A) Bipolar (B) Multipolar (C) Apolar (D) Random

Q.58 Condensation of chromosomes and appearance of astral rays occur during

(A) Prophase (B) Metaphase (C) Anaphase (D) Telophase

Q.59 During telophase

(A) Nuclear membrane is formed (B) Nucleolus appears

(C) Astral rays disappear (D) All the above

Q.60 Chromosoma morphology (structure) is best observed at

(A) Prophase (B) Metaphase (C) Interphase (D) Anaphase

Q.61 Which stage of cell cycle is characterized by DNA replication, synthesis of Histones and formation of new nucleosomes

(A) S-phase (B) G_1-phase (C) G_2-phase (D) M-phase

Q.62 In anaphase, a metacentric chromosome appears

(A) I shaped (B) J –shaped (C) V –shaped (D) L –shaped

Q.63 The correct sequence of prophase –I of meiosis is

(A) Leptotene, pachytene, zygotene, diplotene, diakinesis

(B) Leptotene, diplotene, pachytene, zygotene, diakinesis

(C) Leptotene, zygotene, pachytene, diplotene, diakinesis

(D) Leptotene, zygotene, diakinesis, diplotene, pachytene

Q.64 M-pahse of cell cycle consist

(A) G_1, S and G_2 phase

(B) Prophase, Metaphase, Anaphase, Telophase

(C) Interphase, Prophase, Metaphase, Anaphase, Telophase

(D) Only prophase

Q.65 Longest phase of mitosis is

(A) Prophase (B) Metaphase (C) Anaphase (D) Telophase

Q.66 Crossing over takes place on

(A) Two stranded stage (B) Three stranded stage
(C) One stranded stage (D) Four stranded stage

Q.67 Pre-DNA synthesis phase is

(A) G_1-phase (B) G_2-phase (C) S-phase (D) Prophase

Q.68 Which of the following is called heterotypic division

(A) Meiosis-I (B) Meiosis-II (C) Mitosis (D) Amitosis

Q.69 DNA replication is found in

(A) Mitosis and meiosis-I
(B) Mitosis and meiosis –I and meiosis –II
(C) Meiosis only
(D) Mitosis ony

Q.70 Thick–thread stage occured in

(A) Leptotene (B) Zygotene (C) Pachytene (D) Diplotene

Q.71 Smallest phase of mitosis is

(A) Prophase (B) Metaphase (C) Anaphase (D) Telophase

Q.72 Synthesis of proteins for formation of spindle fibres takes place in

(A) G_1-phase (B) S-phase (C) G_2-phase (D) M-phase

Q.73 Which type of cell division heals the wound

(A) Amitosis (B) Mitotic (C) Meiosis (D) Free nuclear

Q.74 The significance of meiosis is that it

(A) Produce four cells having chromosomal number equal to mother cell
(B) Occurs in all types of cells
(C) Maintains the constant Chromosomes number to a particular species
(D) Growth of animal body organs

Q.75 Cell cycle of an ordinary animal cell

(A) Has cytokinesis only

(B) Has karyokinesis only

(C) Has karyoinesis followed by cytokinesis

(D) Has cytokinesis followed by karyoniesis

Q.76 Mitosis is not found in

(A) Cartilage cells (B) Bone cells (C) Nerve cells (D) All of the above

Q.77 Which one of the following statement in incorrect for interphase stage?

(A) Period of great metabolic activity

(B) Also called as preparatory phase

(C) Absence of replication of DNA

(D) It covers over 95% of the total duration of cell cycle

Q.78 Post-mitotic gap phase is characterised by all, except.

(A) Synthesis of histone proteins (B) Synthesis of RNA and nucleotides

(C) Most-variable in length (D) No change in DNA contents

Q.79 Duplication of DNA occurs in

(A) G_1-phase (B) S-phase (C) G_2-phase (D) M-phase

Q.80 In plant cells, mitosis was first observed by

(A) Flemming (B) Strasburger (C) Farmer and Moore (D) Darlington

Q.81 Which of the following is correctly matched?

(A) Spireme stage - late prophase

(B) Congression stage - Metaphase

(C) Interzonal fibres formation - Telophase

(D) Reaooearance of ER and golgi bodies - Anaphase

Q.82 Cebtrifugal cytokinesis

(A) Occurs in animals (B) Occurs by cell furrowing

(C) Occurs by cell plate formation (D) Is characteristics of bacteria and lower plants only

Q.83 What will be the total number of mitotic divisions in the formation of 64 daughter cells?

(A) 6 (B) 32 (C) 63 (D) 16

Q.84 Which one of the following is not a diploid cell?

(A) Zygote (B) Microspore mother cell

(C) Primary oocyte (D) Ovum

Q.85 Ends of chromosomes are attached with nuclear envelope at attachment plate in

(A) Leptotene (B) Zygotene (C) Pachytene (D) Diplotene

Q.86 If there are 30 chromosomes in G_1-phase, then what will be number of bivalents in zygotene stage?

(A) 30 (B) 15 (C) 45 (D) 60

Q.87 Synaptonemal complex formation stage is

(A) Pachytene (B) Zygotene (C) Diplotene (D) Leptotene

Q.88 Match the column I with column II

	Column I		**Column II**
a.	Appearance of recombination nodules	(i)	Diplotene
b.	Desynapsis	(ii)	Pachytene
c.	Disjunction of homologous chromosomes	(iii)	Anaphase – I
d.	Centromere division	(iv)	Anaphase – II

(A) a (ii), b (i), c (iii), d (iv) (B) a (ii), b (i), c(iv), d(iii)

(C) a (i), b (ii), c (iii), d (iv) (D) a (iii), b (ii), c (i), d (iv)

Q.89 Bivalent chromosomes clearly appears as tetrad in

(A) Zygotene (B) Pachytene

(C) Diplotene (D) Diakinesis

Q.90 Chromatids separation and centromere division occur in

(A) Anaphase (B) Anaphase – I

(C) Anaphase – II (D) More than one option is correct

Q.91 What will be the amount of DNA in meiosis-II products if meiocyte contains 30 pg DNA in G_1 – phase?

(A) 30 Pg (B) 60 Pg (C) 15 Pg (D) 120 Pg

Q.92 Interkinesis or intrameiotic interphase shows

(A) Centriole duplication (B) DNA synthesis

(C) Generally short lived (D) More than one option is correct

Q.93 Number of meiotic divisions required to produce 1000 pollen grains in Cyperus is

(A) 250 (B) 500 (C) 1000 (D) 1250

Q.94 The cell cycle of a somatic cell usually consists of all the following except

(A) The first part of interphase is called as G_1 phase. During this, there is maximum increase in cell size and there is active synthesis of RNA and proteins.

(B) In synthesis phase 'S' phase, the DNA molecule of each chromosome replicated by synthesis of a new DNA molecule.

(C) During G_2 phase, a cell contains double the amount (4n) of DNA present in the original diploid cell (2n).

(D) The cell cycle consists of a short interphase and long M-phase

Q.95 Which of the following is most important point in the regulation of cell cycle during which it must decide whether the cell will start a new cycle or will become arrested in G_0 phase?

(A) S-phase (B) G_1-phase (C) G_2-phase (D) Interphase

Q.96 Histone protein synthesis occurs during

(A) G_0-phase (B) G_2-phase (C) S-phase (D) Prophase

Q.97 The sequence of cell cycle is

(A) S, M, G_1 and G_2 (B) G_1, G_2, S and M

(C) M, G_1, G_2 and S (D) G_1, S, G_2 and M

Q.98 During cell cycle, DNA replicates

(A) One (B) Twice (C) Many times (D) Not at all

Q.99 The synthesis of spindle proteins occur during

(A) G_1-phase (B) S-phase (C) G_2-phase (D) M-phase

Q.100 If mitotic division is restricted in G_1 phase of cell, the condition is known as

(A) G_2-phase (B) S-phase (C) G_0-phase (D) M-phase

Q.101 Condensation of chromosomes with visible centromere occurs during

(A) G_1-phase (B) S-phase (C) G_2-phase (D) M-phase

Q.102 The stage of cell cycle when cell has undergone differentiation is

(A) G_0 (B) G_1 (C) G_2 (D) S

Q.103 Phase of cell cycle when DNA polymerase is active

(A) G_1 (B) S (C) G_2 (D) M

Q.104 G_0-phase of cell denotes

(A) Exit of cell from cell type

(B) Check point before entering the next phase

(C) Death of cell

(D) Temporary pause

Q.105 During cell cycle, two molecules of DNA are present in chromosome during

(A) G_1-phase (B) Beginning of S-phase

(C) G_2-phase (D) End of M-Phase

Q.106 Antephase is the phase in which ATP is synthesised during cell division. It refers to

(A) G_0-phase (B) G_1-phase (C) S-phase (D) G_2-phase

Q.107 Which of the following materials you will select to study mitosis?

(A) Anthers (B) Onion root tips (C) Flower bud (D) Pollen

Q.108 Mitosis in animal cell is

(A) Anastral (B) Amphiastral

(C) Pre-mitosis, acentric (D) Eumitosis, acentric

Q.109 Mitosis is found in

(A) Lower animals (B) Higher animals

(C) All plants (D) All living organisms

Q.110 Which of the following is proper sequence of stages in mitosis?

(A) Metaphase, telophase, prophase and anaphase

(B) Prophase, metaphase, anaphase and telophase

(C) Anaphase, metaphase, telophase and prophase

(D) Telophase, anaphase, metaphase and prophase

Q.111 The chromosomes morphology is best studied during

(A) Prophase

(B) Metaphase, as the chromosomes are most condensed

(C) Anaphase, as the chromosomes are most condensed

(D) Telophase

Q.112 The two daughter cells formed during mitosis contains

(A) The same amount of DNA but a set of chromosomes different from those of parental cells

(B) The same amount of DNA and the same set of chromosomes as those of the parent cell

(C) Half the amount of DNA and the same set of chromosomes as those of the parent cell

(D) Double the amount of DNA and a set of chromosome different from those of the parent cell

Q.113 Colchicine is a mitotic poison because it

(A) Causes splitting up of chromosomes (B) Inhibits the formation of mitotic spindle

(C) Causes non-pairing of chromosomes (D) Agglutinates the chromosomes

Q.114 Higher plants differ from animals in having

(A) Spindle microtubule (B) Anastral mitosis

(C) Kinetochores (D) Disappearance of nucleolus during prophase

Q.115 During which phase the centromere splits and chromatids move towards the opposite poles by shortening of spindle fibres attached to centromeres

(A) Prophase (B) Metaphase (C) Anaphase (D) Telophase

Q.116 The region of the attachment of chromosome to spindle fibres is called

(A) Centromere (B) Centriole (C) Chromonemata (D) Centrosome

Q.117 Which of the following phases are longest and shortest in mitosis?

(A) Metaphase, Anaphase (B) Prophase, Anaphase

(C) Telophase, Anaphase (D) Prophase, Telophase

Q.118 Nuclear envelope disappears at

(A) Metaphase (B) Anaphase (C) Early prophase (D) Late prophase

Q.119 When nuclear division takes place without cytoplasmic division it results in the formation of

(A) Polyteny (B) Coenocyte (C) Polyploidy (D) Amitosis

Q.120 The cell would normally proceed to mitosis without interruption

(A) When it has entered S phase (B) Once it has entered G_2 phase

(C) At any time during cell activity (D) Irrespective of any phase

Q.121 Term 'meiosis' was coined by

(A) Flemming (B) Farmer and Moore

(C) Strasburger (D) Hofmeister

Q.122 Meiosis is evolutionarily significant, because it results in

(A) Recombinations (B) Eggs and sperms

(C) Four daughter cells (D) Genetically similar daughter cells

Q.123 All are the essential stages that take place during meiosis, except

(A) Two successive divisions without any DNA replication occurring between them

(B) Formation of chiasmata and crossing over

(C) Segregation of homologous chromosomes

(D) Number of chromosomes in daughter cells after meiosis II is reduced to half but the amount of DNA remains the same

Q.124 Stages in proper of prophase-I are

(A) Zygotene, Leptotene, Pachytene, Diakinesis and Diplotene

(B) Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis

(C) Leptotene, Zygotene, Pachytene, Diakinesis and Diplotene

(D) Leptotene, Pachytene, Zygotene, Diakinesis and Diplotene

Q.125 Intimate pairing between the two members of each homologous chromosome par is initiated by the process called as synapsis, leading to bivalent formation, occurs in

(A) Zygotene (B) Pachytene (C) Diplotene (D) Diakinesis

Q.126 Mitosis differs from meiosis in not having

(A) Duplication of DNA (B) Long prophase

(C) Interphase (D) Synapsis and crossing over

Q.127 Recombination nodules which mediate for chromosome recombination appear during

(A) Zygotene (B) Diplotene (C) Diakinesis (D) Pachytene

Q.128 Crossing over occurs during

(A) Pachytene (B) Diplotene (C) Diakinesis (D) Zygotene

Q.129 In oocytes, which of the following phase can last for month or years, since it is at this stage the chromosomes decondense and engage in RNA synthesis?

(A) Diakinesis (B) Diplotene (C) Pachytene (D) Leptolene

Q.130 Nuclear membrane and nucleoli can be distinctly seen in

(A) Prophase (B) Metaphase (C) Anaphase (D) Interphase

Q.131 In the meiotic cell division, 56 daughter cells are produced by two successive divisions in which

(A) First division is equational, and second is reductional

(B) First division is reductional, and second is equational

(C) Both divisions are reductional

(D) Both divisions are equational

Q.132 Number of chromosomes in primary oocyte is

(A) Same as that of secondary oocyte (B) Half as that of secondary oocyte

(C) Double as that of secondary oocyte (D) Same as that of ovum

Q.133 Terminalization is completed in

(A) Diakinesis (B) Leptotene (C) Zygotene (D) Diplotene

Q.134 Meiosis involves

(A) One nuclear division and one chromosome division

(B) Two nuclear divisions and one chromosome division

(C) One nuclear division and two chromosome divisions

(D) Two nuclear divisions and two chromosome divisions

Q.135 In meiosis, the daughter cells differ from parent cell as well as among themselves due to

(A) Segregation and crossing over

(B) Independent assortment and crossing over

(C) Independent assortment, segregation and crossing over

(D) Segregation and independent assortment

Q.136 The movement of homologous chromosomes towards opposite poles occur by contraction of spindle fibres during

(A) Anaphase (B) Anaphase –I (C) Anaphase – II (D) Metaphase

Q.137 In plant cells, cytokinesis occurs by

(A) Cell plate formation (B) Invagination (C) Cleavage (D) Furrowing

Q.138 If egg on an organism has 10 Pg of DNA in its nucleus. How much DNA would a diploid cell of same organism have G_2 phase of meiosis?

(A) 10 Pg (B) 5 Pg (C) 20 Pg (D) 40 Pg

Q.139 Minimum number of meiotic divisions required to produce 100 wheat grains are

(A) 400 (B) 125 (C) 200 (D) 25

Q.140 Amitosis

(A) Division involving forming of chromosome bridges

(B) Division involving spindle formation

(C) Division in which the chromosomes are unequally distributed

(D) Cleavage of nucleus without recognisable chromosomes distribution

Q.141 Nuclear membrane is formed around the groups of daughter chromosomes during telophase by

(A) Endoplasmic reticulum (B) Golgi apparatus

(C) Lysosomes (D) Microbodies

Q.142 How many generations are required by a cell of meristem to produce 128 cells?

(A) 127 (B) 64 (C) 32 (D) 7

Q.143 To produce 102 pollen grains, how many meiotic divisions are required?

(A) 25 (B) 25.5 (C) 26 (D) 27

Q.144 Find out the wrong statement

(A) Each metaphasic plate in heterotypic division of meiosis contains half the number of diploid set of chromosomes.

(B) Interkinesis is generally short lived

(C) Synaptonemal complex and nuclear membrane completely disappear in diplotene.

(D) Homologous chromosomes move to respective poles in anaphase – I

Q.144 What will be the content of DNA in a somatic cell at G_2 if its meiotic products have 20 picogram of DNA?

(A) 40 Pg (B) 20 Pg (C) 80 Pg (D) 160 Pg

Q.145 Select the correct match

(A) Reformation of ER and golgi complex – Telophase

(B) Invisible movement of cell cycle – Metaphase

(C) Polar movement of chromatids – S-phase

(D) Recombination nodules formation - Zygotene

Q.146 All chromosomes of a cell are directed towards one side and are attached to the nuclear membrane, can be observed in

(A) Leptotene (B) Zygotene (C) Pachytene (D) Diplotene

Q.147 Phragmoplast is formed by golgi complex and grows

(A) Centripetally to form cell plate

(B) Centrifugally to form cell plate

(C) Centripetally to produce a cleavage furrow

(D) Centrifugally to form a cleavage furrow

Q.148 Select an incorrect statement w.r.t. cell cycle

(A) Duplication of genes occurs twice in meiosis

(B) Karyokinesis occurs twice during meiotic division

(C) Cyclins are proteins that activate protein kinases to regulate the cell cycle.

(D) At the end of telophase-I, chromosome number is reduced to half.

Q.149 Diplotene phase of meiosis is also characterised by

a. Desynapsis

b. Complete terminalisation of chiasmata

c. Dictyotene stage

d. Complete disappearance of nuclear membrane and nucleoli

e. Complete development of astral rays and aster

f. Longest phase of prophase – I

(A) a, b, c and e (B) b, d, e and f (C) a, c and f (D) b, d and f

Q.150 Spireme stage of chromosomes is associated with

(A) Early prophase (B) Late prophase (C) Metaphase (D) Telophase

Q.151 Which of the following is correct for mitosis in most of the plants member?

(A) Amphiastral, anastral and eumitosis

(B) Anastral, acentric and premitosis

(C) Anastral, acentric and eumitosis

(D) Astral, centric and eumitosis

Q.152 Maturation promoting factor formation triggers the cell to cross

(A) $G_1 \rightarrow S$ (B) $S \rightarrow G_2$ (C) $G_2 \rightarrow M$ (D) $M \rightarrow G_1$

Previous Years' Questions

Q.1 Best material for the study of mitosis in laboratory ***[CPMT-2002]***

(A) Anther (B) Root tip (C) Leaf tip (D) Ovary

Q.2 Mitosis occurs in ***[RPMT-2002]***

(A) Haploid individuals (B) Diploid individuals

(C) Both A and B (D) In bacteria only

Q.3 The number of DNA in chromosome at G_2 state of cell cycle ***[RPMT-2002]***

(A) One (B) Two (C) Four (D) Eight

Q.4 Which is correct for meiotic metaphase – I ***[RPMT-2002]***

(A) Bivalents are arranged at equator

(B) Univalents are arranged at equator

(C) Non–homologous chromosomes forms pair

(D) Spindle fibers are attached at chromomere

Q.5 Crossing over that results in genetic recombination inhigher organisms occurs between ***[AIPMT-2004]***

(A) Non-sister chromatids of a bivalent

(B) Two daughter nuclei

(C) Two different bivalents

(D) Sister chromatids of a bivalents

Q.6 Is the somatic cell cycle ***[AIPMT-2004]***

(A) DNA replication takes place in S-phase

(B) A short interphase is followed by a long mitotic phase

(C) G_2 phase follows mitotic phase

(D) In G_2 phase DNA content is double the amount of DNA present in the original cell

Q.7 In which stage of meiosis the chromosome number reduces to half ***[RPMT-2004]***

(A) Anaphase –I (B) Anaphase –II

(C) Telophase – I (D) Telophase –II

Q.8 Chiasmata are formed as a result of ***[RPMT-2004]***

(A) Exchange of parts of paired homologus chromosome

(B) Exchange of part of unpaired non-homologus chromosome

(C) Duplication of parts of paired homologus chromosome

(D) Loss of parts of unpaired non-homologus chromosome

Q.9 When synapsis is complete all along the chromosome, the cell is said to have entered a stage called ***[AIIMS-2005]***

(A) Zygotene (B) Pachytene (C) Diplotene (D) Diakinesis

Q.10 Many cells function properly and divide mitotically even through they do not have ***[AIIMS-2005]***

(A) Plasma membrane (B) Cytoskeleton

(C) Mitochondria (D) Plastids

Q.11 Centromere is required for ***[AIPMT-2005]***

(A) Movement of chromosomes towards poles

(B) Cytoplasmic cleavage

(C) Crossing over

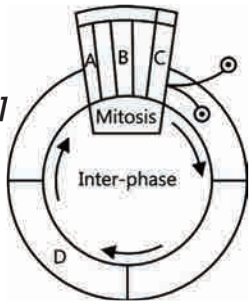
(D) Transcription

Q.12 At what stage of the cell cycle histone proteins are synthesized in a eukaryotic cell ***[AIPMT-2005]***

(A) During telophase (B) During S-phase

(C) During G-2 stage of prophase (D) During entire prophase

Q.13 Given below is a schematic break-up of the phases/stages of cell cycle. Which one of the following is the correct indication? ***[AIPMT-2009]***



(A) A-Cytokinesis (B) B-Metaphase

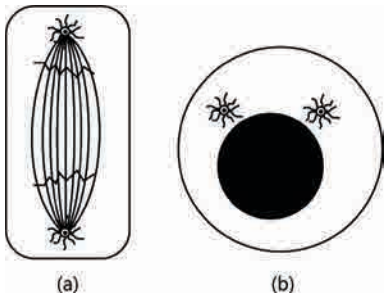
(C) C-Karyokinesis (D) D-Synthetic phase

Q.14 During mitosis ER and nucleolus begin to disappear at ***[AIPMT Pre.-2010]***

(A) Early prophase (B) Late prophase

(C) Early metaphase (D) Late metaphase

Q.15 Which stages of cell division do the following figures A and B represent, respectively? ***[AIPMT Pre.-2010]***



(A) Prophase - Anaphase

(B) Metaphase - Telophase

(C) Telophase - Metaphase

(D) Late Anaphase- Prophase

Q.16 Select the correct option with respect to mitosis ***[AIPMT Pre.-2011]***

(A) Chromatids separate but remain in the centre of the cell in anaphase

(B) Chromatids start moving towards opposite poles in telophase

(C) Golgi complex and endoplasmic reticulum are still visible at the end of prophase

(D) Chromosomes move to the spindle equator and get aligned along equatorial plate in metaphase

Q.17 At metaphase, chromosomes are attached to the spindle fibres y their ***[AIPMT Pre.-2011]***

(A) Centromere (B) Satellites

(C) Secondary constrictions (D) Kinetochores

Q.18 During gamete formation , the enzyme recombinase participates during ***[AIPMT Pre.-2012]***

(A) Prophase –I (B) Prophase –II

(C) Metaphase-I (D) Anaphase-II

Q.19 Give below is the representation of a certain events at particular stage of a type of cell division. Which is this stage? ***[AIPMT Pre.-2010=12]***

(A) Prophase of Mitosis

(B) Both prophase and metaphase of mitosis

(C) Prophase I during meiosis

(D) Prophase II during meiosis

Q.20 Identify the meiotic stage in which the homologous chromosomes separate while the sister chromatids remain associated at their centromeres ***[AIPMT Pre.-2012]***

(A) Anaphase I (B) Anaphase II

(C) Metaphase I (D) Metaphase II

Q.21 Extra nuclear DNA. (genes) are located in ***[AIPMT 2000]***

(A) Lysosomes and chloroplasts (B) Golgi complex and ribosomes

(C) Chloroplasts and mitochondria (D) Ribosomes and mitochondria

Q.22 In an animal cell, protein synthesis takes place ***[AIPMT 2001]***

(A) Only on the ribosomes present in cytosol

(B) Only on ribosomes attached to nuclear envelope and ER

(C) On ribosomes present in the nucleolus as well as in cytoplasm

(D) On ribosomes present in the cytosol as well as in the mitochondria

Q.23 Microtubules absent in ***[AIPMT 2001]***

(A) Mitochondria (B) Centriole (C) Flagella (D) Spindle fibres

Q.24 Extra nuclear chromosomes occur in ***[AIPMT 2001]***

(A) Peroxisome, ribosome (B) Chloroplast, mitochondria

(C) Mitochondria, ribosome (D) Chioroplast, lysosome

Q.25 Mitotic spindle is mainly composed of which protein? ***[AIPMT 2002]***

(A) Actin (B) Myosin (C) Actomyosin (D) Myoglobin

Q.26 Ribosomes are produced in ***[AIPMT 2002]***

(A) Nucleolus (B) Cytoplasm (C) Mitochondria (D) Golgi body

Q.27 In fluid mosaic model of plasma membrane ***[AIPMT 2002]***

(A) Upper layer is non-polar and hydrophilic

(B) Upper layer is polar and hydrophobic

(C) Phospholipids form a bimolecular layer in middle part

(D) Proteins form a middle layer

Q.28 Best material for the study of mitosis in laboratory is ***[AIPMT 2002]***

(A) Anther (B) Root tip (C) Leaf tip (D) Ovary

Q.29 Which of the following occurs more than one and less than five in a chromosome? ***[AIPMT 2002]***

(A) Chromatid (B) Chromosome (C) Centromere (D) Telomere

Q.30 If a diploid cell is treated with colchicine then it becomes ***[AIPMT 2002]***

(A) Triploid (B) Tetraploid (C) Diploid (D) Monoploid

Q.31 In which one of the following is nitrogen not a constituent? ***[AIPMT 2003]***

(A) Pepsin (B) Idioblast (C) Bacteriochlorophyll (D) Invertase

Q.32 Flagella of prokaryotic and eukaryotic cells differ in ***[AIPMT 2004]***

(A) Type of movement and placement in cell

(B) Location in cell and mode of functioning

(C) Microtubular organization and type of movement

(D) Microtubular organization and function

Q.33 If you are provided with root tips of onion in your class and are asked to count the chromosomes, which of the following stages can you most conveniently look into? ***[AIPMT 2004]***

(A) Metaphase (B) Telophase (C) Anaphase (D) Prophase

Q.34 In chloroplasts, chlorophyll, is present in the ***[AIPMT 2004]***

(A) Outer membrane (B) Inner membrane (C) Thylakoids (D) Stroma

Q.35 Which one of the following precedes reformation of the nuclear envelope during M-phase of the cell cycle? ***[AIPMT 2004]***

(A) Decondensation from chromosomes and reassembly of the nuclear lamina

(B) Transcription from chromosomes and reassembly of the nuclear lamina

(C) Formation of the contractile ring and formation of the phragmoplast

(D) Formation of the contractile ring and transcription from chromosomes

Q.36 In the somatic cell cycle ***[AIPMT 2004]***

(A) In G1-phase DNA content is double the amount of DNA present in the originarcell

(B) DNA replication takes place in S-phase

(C) A short interphase is followed by a long mitotic phase

(D) G2-phase follows mitotic phase

Q.37 Crossing over that results in genetic recombination in higher organisms occur between ***[AIPMT 2004]***

(A) Sister chromatids of bivalent (B) Non-sister chromatids of a bivalent

(C) Two daughter nuclei (D) Two different bivalents

Q.38 Extra nuclear inheritance is a consequence of 'presence of genes in ***[AIPMT 2004]***

(A) Mitochondria and chloroplasts

(B) Endoplasmic reticulum and mitochondria

(C) Ribosomes and chioroplast

(D) Lysosomes and ribosomes

Q.39 A student wishes to study the cell structure under a light microscope having 10X eyepiece and 45X objective: He should illuminate the object by which one ot the following colours 0 light so as to get the best possible resolution?

(A) Blue (B) Green (C) Yellow (D) Red

Q.40 The main organelle involved in modification and routing of newly synthesized proteins to their destinations is ***[AIPMT 2004]***

(A) Chloroplast (B) Mitochondria (C) Lysosome (D) Endoplasmic reticulum

Q.41 Centromere is required for ***[AIPMT 2005]***

(A) Movement of chromosomes towards poles

(B) Cytoplasmic cleavage

(C) Crossing over

(D) Transcription

Q.42 According to widely accepted "fluid mosaic model" cell membranes are semi-fluid, where lipids and integral proteins can diffuse randomly. In recent years, this model has been modified in several respects. In this regard, which of the following statements is incorrect? ***[AIPMT 2005]***

(A) Proteins in cell membranes can travel within the lipid bilayer

(B) Proteins can also undergo flip-flop movements in the lipid bilayer

(C) Proteins can remain confined within certain domains of the membrane

(D) Many proteins remain completely embedded within the lipid bilayer

Q.43 "Protein synthesis in an animal cell occurs ***[AIPMT 2005]***

(A) Only on the ribosomes present in cytosol

(B) Only on ribosomes attached to the nuclear envelope and endoplasmic reticulum

(C) On ribosomes present in the nucleolus as well as in cytoplasm

(D) On.ribosomes present in cytoplasm as well as in mitochondria

Q.44 At what stage of the cell cycle are histone proteins synthesized in a eukaryotic cell? ***[AIPMT 2005]***

(A) Dtiring G2-siage of prophase (B) During S-phase

(C) During entire prophase (D) During telophase

Q.45 Genes for cytoplasmic male sterility in plants are generally located in ***[AIPMT 2005]***

(A) Mitochondrial genome (B) Cytosol

(C) Chloroplast genome (D) Nuclear genome

Q.46 Chlorophyll in chloroplast is located in ***[AIPMT 2005]***

(A) Grana (B) Pyrenoid (C) Stroma (D) Both (A) and (C)

Q.47 The salivary gland chromosomes in the dipteran larvae are useful in gene mapping because ***[AIPMT 2005]***

(A) These are much longer in size (B) These are easy to stain

(C) These are fused (D) They have endoreduplicated chromosomes

Q.48 Which of the following statements regarding mitochondrial membrane is not correct? ***[AIPMT 2006]***

(A) The enzymes of the electron transfer chain are embedded in the outer membrane

(B) The inner membrane is highly convoluted forming a series of infoldings

(C) The outer membrane resembles a sieve

(D) The outer membrane is permeable to all kinds of molecules

Q.49 During photorespiration, the oxygen consuming reaction occurs in ***[AIPMT 2006]***

(A) Stroma of chloroplasts and mitochondria

(B) Stroma of chloroplasts and peroxisomes

(C) Grana of chloroplasts and peroxisomes

(D) Stroma of chloroplasts

Q.50 A major breakthrough in the studies of cells came with the development of electron microscope. This is because ***[AIPMT 2006]***

(A) The resolving power of the electron microscope is 200nm to 350nm as compared to 0.1-0.2 for the light microscope

(B) Electron beam can pass through thick materials, whereas light microscopy required thin sections

(C) The electron microscope is more powerful than the light microscope as it uses a beam of electrons which has wavelength much longer than that of photons

(D) The resolution power of the electron microscope is much higher than that of the light microscope

Q.51 Select the wrong statement from the following ***[AIPMT 2007]***

(A) Both chloroplasts and mitochondria contain an inner and an outer membrane

(B) Both chloroplasts and mitochondria have an internal compartment, the thylakoid space bounded by the thylakoid membrane

(C) Both chloroplasts and mitochondria contain DNA

(D) The chloroplasts are generally much larger than mitochondria

Q.52 Keeping itiview the 'fluid mosaic model' for the structure of cell membrane, which one of the following statements is correct with respect to the movement of lipids and proteins from one lipid monolayer to the other (described as flip-flop movement)? ***[AIPMT 2008]***

(A) Both lipids and proteins can flip-flop

(B) While lipids can rarely. flip-flop, proteins cannot

(C) While proteins can flip-flop, lipids cannot

(D) Neither lipids, nor proteins can flip-flop

Q.53 The two subunits of ribosome remain united at a critical ion level of ***[AIPMT 2008]***

(A) Copper (B) Manganese (C) Magnesium (D) Calcium

Q.54 Vacuole in a plant cell ***[AIPMT 2008]***

(A) Is membrane-bound and contains storage proteins and lipids

(B) Is membrane-bound and contains water and excretory substances

(C) Lacks membrane and contains air

(D) Lacks membrane and contains water and excretory substances

Q.55 In germinating seeds fatty acids are degraded exclusively in the ***[AIPMT 2008]***

(A) Proplastids (B) Glyoxysomes (C) Peroxisomes (D) Mitochondria

Q.56 There is no DNA in ***[AIPMT 2009]***

(A) An enucleated ovum (B) Mature RBCs

(C) A mature spermatozoan (D) Hair root

Q.57 Middle lamella is mainly composed of ***[AIPMT 2009]***

(A) Hemicellulose (B) Muramic acid

(C) Calcium pectate (D) Phosphoglycerides

Q.58 Plasmodesmata are ***[AIPMT 2009]***

(A) Lignified cemented layers between cells

(B) Locomotory structures

(C) Membranes connecting the nucleus with plasmalemma

(D) Connections between adjacent cells

Q.59 Cytoskeleton is made up of ***[AIPMT 2009]***

(A) Calcium carbonate granules (B) Callose deposits

(C) Cellulosic microfibrils (D) Proteinaceous filaments

Q.60 Synapsis occurs between ***[AIPMT 2009]***

(A) A male and a female gamete (B) mRNA and ribosomes

(C) Spindle fibres and centromere (D) Two homologous chromosomes

Q.61 Semiconsenrative replication of DNA was first demonstrated in ***[AIPMT 2009]***

(A) Drosophila melanogaster (B) Escherichia coli

(C) Streptococcus pneumonia (D) Salmonella typhimurium

ANSWER KEY

Objective Questions

Q.1 A	**Q.2** B	**Q.3** D	**Q.4** C	**Q.5** D	**Q.6** D
Q.7 A	**Q.8** C	**Q.9** D	**Q.10** B	**Q.11** B	**Q.12** D
Q.13 B	**Q.14** D	**Q.15** B	**Q.16** D	**Q.17** D	**Q.18** C
Q.19 D	**Q.20** D	**Q.21** A	**Q.22** D	**Q.23** C	**Q.24** D
Q.25 B	**Q.26** A	**Q.27** D	**Q.28** D	**Q.29** B	**Q.30** C
Q.31 A	**Q.32** B	**Q.33** A	**Q.34** C	**Q.35** A	**Q.36** C
Q.37 A	**Q.38** D	**Q.39** A	**Q.40** A	**Q.41** B	**Q.42** B
Q.43 B	**Q.44** B	**Q.45** A	**Q.46** D	**Q.47** D	**Q.48** B
Q.49 C	**Q.50** D	**Q.51** A	**Q.52** B	**Q.53** C	**Q.54** D
Q.55 D	**Q.56** D	**Q.57** A	**Q.58** A	**Q.59** D	**Q.60** B
Q.61 A	**Q.62** C	**Q.63** C	**Q.64** B	**Q.65** A	**Q.66** D
Q.67 A	**Q.68** A	**Q.69** A	**Q.70** C	**Q.71** C	**Q.72** C
Q.73 B	**Q.74** C	**Q.75** C	**Q.76** C	**Q.77** C	**Q.78** A
Q.79 B	**Q.80** B	**Q.81** B	**Q.82** C	**Q.83** C	**Q.84** D
Q.85 A	**Q.86** B	**Q.87** B	**Q.88** A	**Q.89** B	**Q.90** D
Q.91 C	**Q.92** D	**Q.93** C	**Q.94** D	**Q.95** B	**Q.96** C
Q.97 D	**Q.98** A	**Q.99** C	**Q.100** C	**Q.101** D	**Q.102** A
Q.103 B	**Q.104** A	**Q.105** C	**Q.106** B	**Q.107** B	**Q.108** B
Q.109 D	**Q.110** B	**Q.111** B	**Q.112** B	**Q.113** B	**Q.114** B
Q.115 C	**Q.116** A	**Q.117** B	**Q.118** D	**Q.119** B	**Q.120** A
Q.121 B	**Q.122** A	**Q.123** D	**Q.124** B	**Q.125** A	**Q.126** D
Q.127 D	**Q.128** A	**Q.129** B	**Q.130** D	**Q.131** B	**Q.132** C

Q.133 A **Q.134** B **Q.135** C **Q.136** B **Q.137** A **Q.138** D
Q.139 B **Q.140** D **Q.141** A **Q.142** D **Q.143** C **Q.144** C
Q.145 C **Q.146** A **Q.147** A **Q.148** B **Q.149** A **Q.150** C
Q.151 A **Q.152** C **Q.153** C

Previous Years' Questions

Q.1 B **Q.2** C **Q.3** B **Q.4** A **Q.5** A **Q.6** A
Q.7 A **Q.8** A **Q.9** B **Q.10** D **Q.11** A **Q.12** B
Q.13 D **Q.14** B **Q.15** D **Q.16** D **Q.17** D **Q.18** A
Q.19 C **Q.20** A **Q.21** C **Q.22** D **Q.23** A **Q.24** B
Q.25 A **Q.26** A **Q.27** C **Q.28** B **Q.29** D **Q.30** B
Q.31 B **Q.32** C **Q.33** A **Q.34** C **Q.35** A **Q.36** B
Q.37 B **Q.38** A **Q.39** A **Q.40** D **Q.41** A **Q.42** B
Q.43 D **Q.44** B **Q.45** A **Q.46** A **Q.47** D **Q.48** A
Q.49 B **Q.50** D **Q.51** B **Q.52** B **Q.53** C **Q.54** B
Q.55 B **Q.56** A **Q.57** C **Q.58** D **Q.59** D **Q.60** D
Q.61 B