BIOLOGY

Chapter 10: Cell Cycle And Cell Division

CELL CYCLE AND CELL DIVISION

Cell cycle

The sequence of events by which a cell duplicates its genome, synthesizes the other constituents of cells and eventually divides into two daughter cells is called cell cycle.

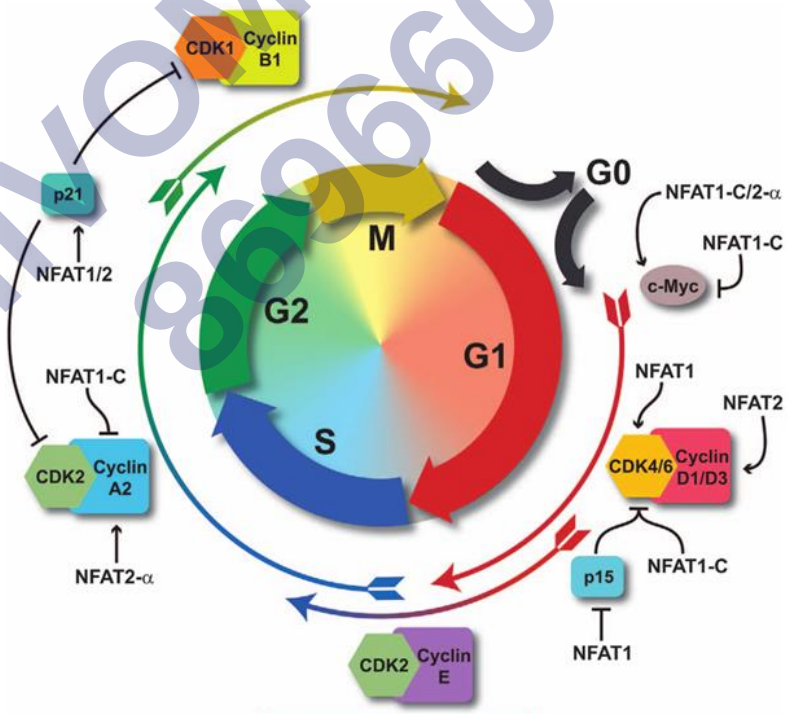
G_1 Phase: Cell metabolically active and grows continuously but does not replicate DNA

S Phase: DNA synthesis occurs, DNA content increases from 2C to 4C, but the number of chromosomes remains same i.e., 2n.

G_2 Phase: Proteins are synthesized in preparation for mitosis while cell b growth continues.

M Phase (Mitosis Phase): Starts with nuclear division, corresponding to separation of daughter chromosomes (karyokinesis) and usually ends with division of cytoplasm, (cytokinesis).

Quiescent stage (G_0): In adult animals cells that do not divide and exit G1 phase to enter an inactive stage called G0. Cells at this stage remain metabolically active but do not proliferate. e.g., Heart cells.



Cell Cycle

Difference between Mitosis and meiosis

Mitosis	Meiosis
Takes place in the somatic cells.	Takes place in reproductive cells.
It is a single division which produces two cells.	It is a double division which produces four cells.
Haploid and diploid both kind of cells may undergo mitosis.	Only diploid cells undergo in meiosis cell division.
Crossing over absent.	Crossing over takes place.
Pairing of chromosome does not occur.	Pairing of homologous chromosome occurs.

Stages of Mitosis

Since the number of chromosomes in the parent and progeny cells is the same, it is called as equational division.

Mitosis is divided into four sub stages:

Prophase:

- Replicated chromosomes, each consisting of 2 chromatids, condense and become visible.
- Microtubules are assembled into mitotic spindle.
- Nucleolus and nuclear envelope disappear.
- Centriole moves to opposite poles.

Metaphase:

- Spindle fibers attached to kinetochores (small disc-shaped structures at the surface of centromere) of chromosomes.
- Chromosomes line up at the equator of the spindle to form metaphase plate.

Anaphase:

- Centromeres split and chromatids separate.
- Chromatids move to opposite poles due to shortening of spindle fibers.

Telophase:

- Chromosomes cluster at opposite poles.
- Nuclear envelope assembles around chromosomes clusters'.
- Nucleolus, Golgi Complex, E.R. reforms.

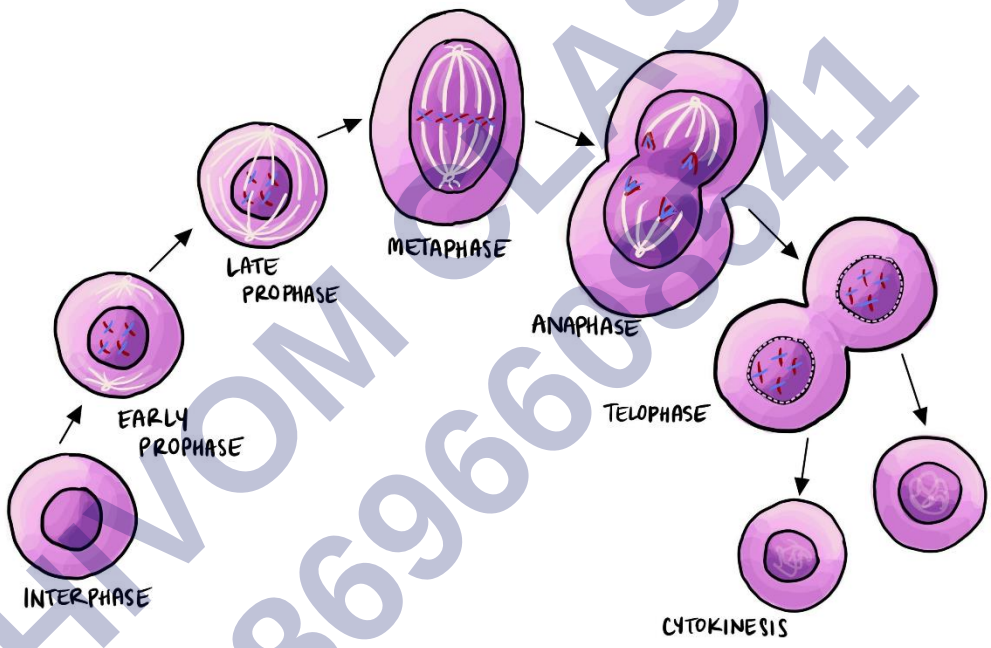
Cytokinesis

Is the division of protoplast of a cell into two daughter cells after karyokinesis (nuclear division).

Animal Cytokinesis: Appearance of furrow in plasma membrane which deepens and joins in the center, dividing cell cytoplasm into two.

Plant cytokinesis: Formation of new cell wall begins with the formation of a simple precursor cell plate which represents the middle lamella between the walls of two adjacent cells.

Syncytium: When karyokinesis is not followed by cytokinesis, a multinucleated condition arises. This is called syncytium.



Significance of Mitosis:

- Growth-addition of cells.
- Maintenance of surface/ volume ratio. Maintain Nucleo –cytoplasmic ratio.
- Maintenance of chromosomes number.
- Regeneration.
- Reproduction in unicellular organisms, lower plants and some insects.
- Repair and wound healing.
- Vegetative reproduction in plants takes place by mitosis.

Meiosis

- Specialized kind of cell division that reduces the chromosomes number by half.

hence it is called reductional division.

- Occurs during gametogenesis in plants and animals.
- Involves two sequential cycles of nuclear and cell division called Meiosis I and Meiosis II.
- It results in 4 haploid daughter cells.
- Interphase occurs prior to meiosis which is similar to interphase of mitosis except the S phase is prolonged.

Meiosis I

Prophase I: Subdivided into 5 phases.

Leptotene:

- Chromosomes make their appearance as single stranded structures.
- Compaction of chromosomes continues.

Zygotene:

- Homologous chromosomes start pairing and this process of association is called synapsis.
- Chromosomal synapsis is accompanied by formation of Synaptonemal complex.
- Complex formed by a pair of synapsed homologous chromosomes is called bivalent or tetrad.

Pachytene: Crossing over occurs between non-sister chromatids of homologous chromosomes. The enzymes involved in the process is 'recombinase'. Recombination between homologous chromosomes is completed. Exchange of genetic material.

Diplotene: Dissolution of synaptonemal complex occurs and the recombined chromosomes separate separate from each other except at the sites of crossing over. These X-shaped structures are called chaismata. In oocytes of some vertebrates diplotene can last for month or years.

Diakinesis: Terminalization of chaismata.

- Chromosomes are fully condensed and meiotic spindles assembled.
- Nucleolus disappear and nuclear envelope breaks down.

Metaphase I

Bivalent chromosomes align on the equatorial plate.

Microtubules from opposite poles of the spindle attach to the pair of homologous chromosomes.

Anaphase I

Homologous chromosomes, separate while chromatids remain associated at their centromeres.

Telophase I:

- Nuclear membrane and nucleus reappear.
- Cytokinesis follows (diad of cells).

Interkinesis

Stage between two meiotic divisions, (meiosis I and meiosis II) generally short lived.

Meiosis II: (It resembles the normal mitosis).

Prophase II

- Nuclear membrane disappears.
- Chromosomes again become compact.

Metapahse II

- Chromosomes align at the equator.
- Microtubules from opposite poles of spindle get attached to kinetochores of sister chromatids.

Anaphase II

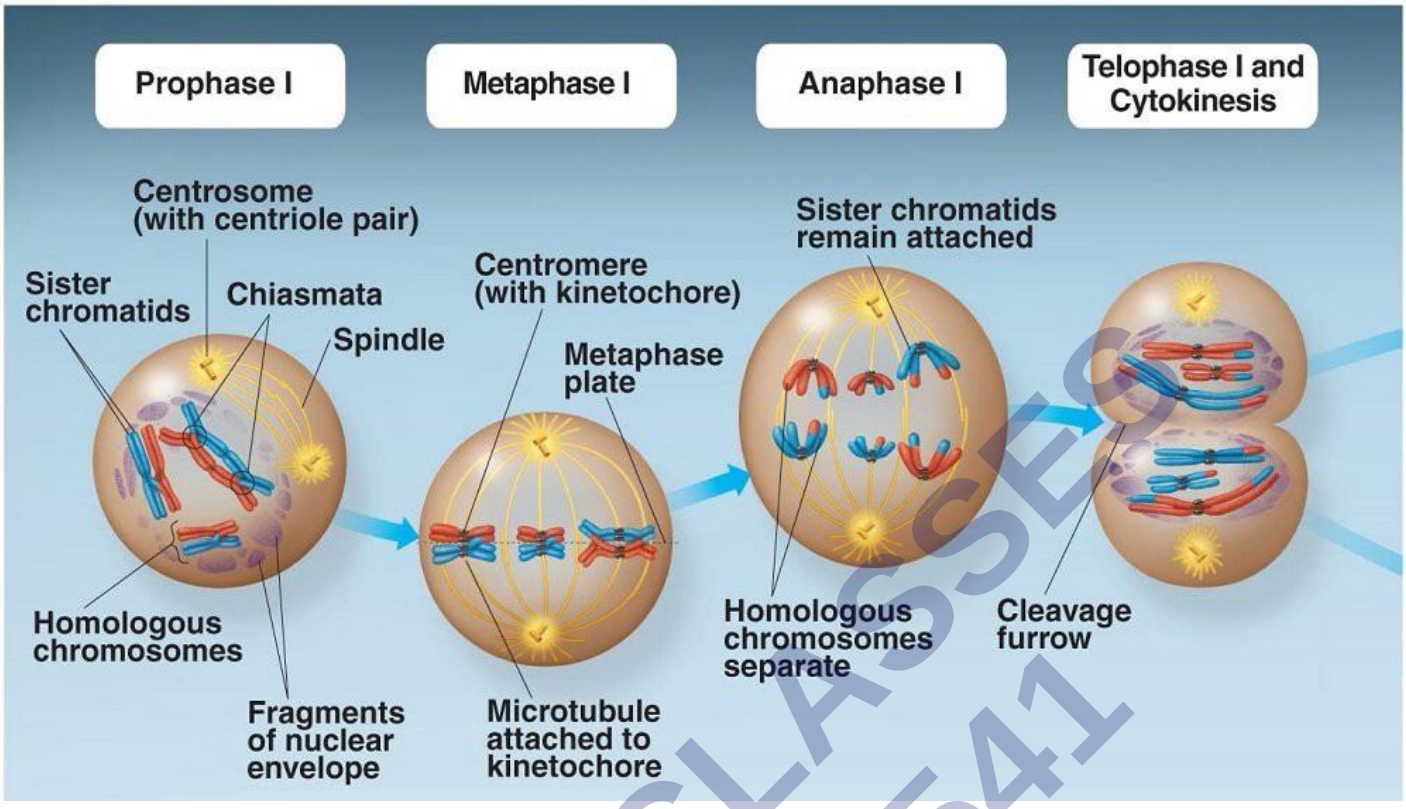
Simultaneous splitting of the centromere of each chromosome, allowing them to move towards opposite poles of the cell.

Telophase II

- Two groups of chromosomes get enclosed by a nuclear envelope.
- Cytokinesis follows resulting in the formation of tetrad of cells i.e., 4 haploid cells.

Significance of Meiosis:

- **Formation of gametes:** In sexually reproducing organisms.
- **Genetic variability:** Variations are very important for evolution.
- **Maintenance of chromosomal number:** By reducing the chromosome number in gametes. Chromosomal number is restored by fertilization of gametes.



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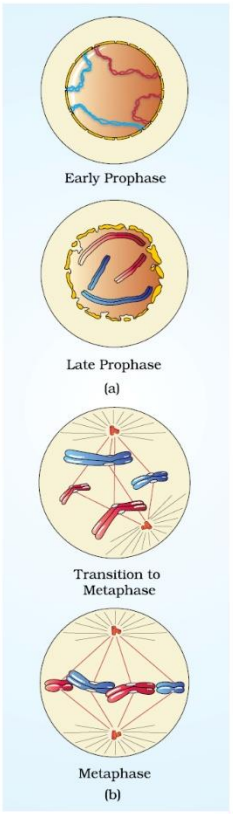
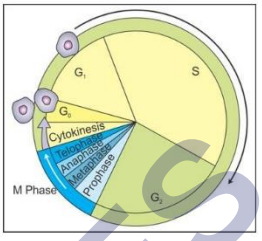
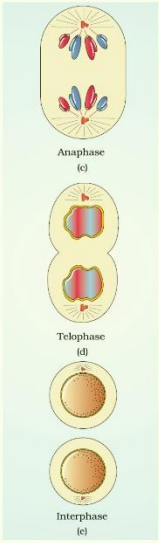
Chapter- 10 : Cell Cycle and Cell Division





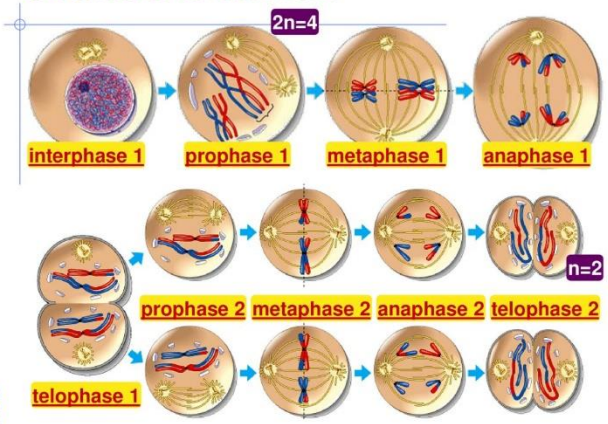
Cell Cycle and Cell Division

- Cell Cycle
  - Interphase
    - G1
    - S
    - G2
  - Inter Phase
  - M-phase
    - Karyokinesis
      - Prophase
      - Metaphase
      - Anaphase
      - Telophase
    - Cytokinesis
      - **Plant Cell** Cell wall formation starts in the centre
      - **Animal cell** Starts with appearance of furrow in the plasma membrane
- **Mitosis- Equational Division**



- Meiosis- Reductional Division
  - Meiosis I
    - Prophase I
      - 1. Leptotene (Duplicated chromosomes start to condense)
      - 2. Zygotene (Synapsis begins)
      - 3. Pachytene (Synapsis complete, Crossing over occurs)
      - 4. Diplotene (Synaptonemal complex starts disappearing, Bchiasma visible)
      - 5. Diakinesis (Bivalent ready for metaphase)
    - Metaphase I
    - Anaphase I
    - Telophase I
  - Meiosis II
    - Prophase II
    - Metaphase II
    - Anaphase II
    - Telophase II

Overview of meiosis



Important Questions

➢ Multiple Choice Questions:

Question 1. Life starts from a single cell in plants and animals called

(a) Cell
(b) Zygote
(c) Tissue
(d) Growth

Question 2. A typical eukaryotic cell cycle is illustrated by human cells in culture, which divide approximately every:

(a) 12 hours
(b) 10 hours
(c) 24 hours
(d) 6 hours

Question 3. Yeast cell can progress through all the four stages of the cell cycle in only about:

(a) 60 minutes
(b) 90 minutes
(c) 30 minutes
(d) 45 minutes.

Question 4. The interphase is divided into.

(a) G1 phase (Gap1)
(b) S phase (Synthesis)
(c) G2 phase (Gap2)
(d) ail of these stages.

Question 5. The S phase marks the period during which replication of DNA takes place. It is during this time that the content of DNA doubles, from

(a) 2C to 4C
(b) 4C to 2C
(c) (1n or 2n)
(d) (2n or 1n)

Question 6. The centrioles, in animal cells, initiate their replication in the cytoplasm during.

(a) G1 phase
(b) G2 phase
(c) S phase
(d) None of these phases.

Question 7. In plants apical cells and the cambium tissue continue to divide all their life,

they are called.

(a) Meristemic tissue
(b) cambium tissue
(c) equational division
(d) syneytium

Question 8. Mitosis is divided into

(a) Prophase
(b) Metaphase
(c) Anaphase
(d) Telophase

(e) All of these phases.

Question 9. The small disc shaped structure at the surface of centromeres is called.

(a) Kinetochores
(b) sister chromatids
(c) microtubule
(d) Golgi complex

Question 10. Mitosis accomplishes the segregation of duplicated chromosomes into daughter nuclei (karyokinesis), but the cell itself is divided into two daughter cells by a separate process called.

(a) Cytokinesis
(b) Karyokinesis
(c) Nucleolous
(d) Chromosome clusters.

Question 11. In some organisms karyokinesis is not followed by cytokinesis as a result of which multinucleate condition arises which is called:

(a) Syncytium
(b) Meiosis I
(c) Cell-plate
(d) Meiosis II

Question 12. The cells having more than two complete sets of chromosomes are called

(a) Diploid
(b) Haploid
(c) Polyhybrid
(d) Polyploid.

Question 13. In Meiosis, the chromatids separate during

(a) Metaphase I

(b) Anaphase I
(c) Anaphase II
(d) Metaphase II

Question 14. In the meiotic cell division four daughter ceils are produced by two successive division in which

(a) First division is reductional and second is equationai.
(b) First division is equationai, second is reductional.
(c) Both division are equationai.
(d) Both division are reductional.

Question 15. Meosis is

(a) Reductional division
(b) Equationai division
(c) Multiplicational division
(d) Disjunctional division.

➢ Fill In the Blanks:

1. Meiosis ends with telophase II, in which the …… are once again enclosed by a nuclear envelope, cytokinesis follows, resulting in the formation of tetrad of cells i.e., four haploid ……
2. Anaphase begins with the simultaneous splitting of the …… which hold the sister chromatids together, allowing them to move toward ……
3. Metaphase II the chromosomes align on the equator with micro¬tubules from opposite poles of the spindle get attached to the …… of sister chromatids.
4. Prophase II meiosis II initiates immediately after …… usually before the …… have fully elongated.
5. The stage between the two meiotic divisions is called …… and is generally short lived.
6. Diplotene X-shaped structures are called ……

➢ True or False:

1. All organisms, even the largest, start their life from a single cell.
2. Growth and reproduction are characteristic of cells, indeed of all living organisms.
3. Cell division is a very important process in all organisms.
4. The requence of events by which a cell duplicates its genome, synthesies the other constituent of the cell and eventually divides into two daughter cells is termed cell cycle.
5. Yeast for example, can progress through the cell cycle in only about 24 hours.

6. The cell cycle is divided into two basic phases:
   i. M phase (mitosis phase)
   ii. Interphase.

➢ Very Short Question:

1. Who first described meiosis?
2. What is a genome?
3. What is meant by the non-disjunction of chromosomes?
4. Why is mitosis an equational division?
5. What is crossing over?
6. Why is meiosis a reductional division?
7. What are the two successive divisions in meiosis?
8. Name the two phases of the cell cycle of a somatic cell.
9. During which part of interphase active synthesis of RNA and proteins take place.
10. What amount of DNA is present in the cell during the G_2 phase?

➢ Short Questions:

1. Define cell cycles.
2. What do you understand by homologous chromosomes?
3. Why is mitosis an equational division?
4. Why is meiosis necessary in sexually reproducing organisms?
5. What is the importance of mitosis?
6. What are homologous chromosomes? What happens to homologs during meiosis?
7. What is the significance of meiosis?
8. What do you mean by cell reproduction?

➢ Long Questions:

1. Describe the changes that take place during the prophase and metaphase of mitosis.
2. Explain the main steps in aerobic glycolysis.
3. How cytokinesis is different in an animal and a plant cell?

Assertion Reason Question-

1. In these questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
(c) If Assertion is true but Reason is false.
(d) If both Assertion and Reason are false.

Assertion: Interphase is resting stage.

Reason: The interphase cell is metabolically inactive.

2. In these questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
(c) If Assertion is true but Reason is false.
(d) If both Assertion and Reason are false.

Assertion: Histones are basic proteins of major importance in packaging of eukaryotic DNA. DNA and histones comprise chromatin, forming the bulk of eukaryotic chromosome.

Reason: Histones are 5 major types H_1, H_2A, H_2B, H_3 and H_4.

✓ Answer Key-

➢ Multiple Choice Answers:

1. (b) zygote
2. (c) 24 hours
3. (b) 90 minutes.
4. (d) All of these stages.
5. (a) 2C to 4C.
6. (b) G2 phase.
7. (a) Meristemic tissue.
8. (e) All of these phases.
9. (a) Kinetochores.
10. (a) Cytokinesis
11. (a) Syncytium.

12. (d) Polyploid.
13. (c) Anaphase II.
14. (a) First division is reductional and second is equationai.
15. (a) Reductional division.

➢ Fill In the Blanks:

1. chromosomes, daughter cells
2. centromeres, opposite poles of the cell
3. kinetochores
4. cytokinesis, chromosomes
5. interkinesis
6. chsiamata

➢ True or False:

1. True
2. True
3. True
4. True
5. False
6. True

➢ Very Short Answers:

1. Answer: Strasburger,
2. Answer: It is a full set of DNA instructions or a single set of chromosomes in a cell.
3. Answer: Non-disjunction means failure in the separation of homologous chromosomes during anaphase.
4. Answer: Mitosis is an equational division because the daughter cells get the same number of chromosomes from the parent.
5. Answer: The exchange of segments of chromatids of homologous chromosomes during meiosis is called crossing over.
6. Answer: Meiosis is a reductional division because it reduces the number of chromosomes from diploid number to haploid number in the daughter cells.
7. Answer: The first division is reductional followed by the second equational di¬vision.
8. Answer:

i. Interphase and

ii. M-phase or mitotic phase

9. Answer: G. phase.
10. Answer: Double the amount of DNA present in the original diploid cell.

➢ Short Answer:

1. Answer: The cell cycle is the sequence of events that occur between the formation of a cell and its division into daughter cells.
2. Answer: Homologous chromosomes are pairs of chromosomes that have similar characteristics. They show pairing during meiosis. One chromosome in each pair is inherited from the father and the other one from the mother.
3. Answer: Mitosis is an equational division because the daughter cells have the same number of chromosomes and an equal amount of cytoplasm.
4. Answer: Meiosis is necessary for sexually reproducing organisms because

   i. It maintains the number of chromosomes constant in generation as meiosis is reductional division.

   ii. It causes variations among the progeny because crossing over takes place during meiosis. This variation is important for evolution.
5. Answer: Mitosis is important because

   1. It maintains genetic stability through generations.

   2. It helps in the growth of multicellular organisms.

   3. Many plants and animals multiply by mitosis i.e., asexual repro-duction to regenerate the whole organism.

   4. It helps to regenerate lost parts of an animal's body.

   5. It helps in the regeneration of new cells in place of dead and worn-out cells.
6. Answer: Each diploid nucleus has pairs of similar chromosomes called homologous chromosomes. The two homologous chromosomes each derived from one parent during sexual reproduction come together and form pairs during the zygonema of meiosis I. Individuals of a pair are similar in length and in the position of their centromere.
7. Answer: Significance of meiosis:

   i. Sexual reproduction: Maintains a number of chromosomes constant. Characteristic of a species from generation to generation.

   ii. Genetic variation: Through crossing over, it produces variations of genetic characters of the progeny essential for evolution.

8. Answer: Cell reproduction: Reproduction is an essential phenomenon in the continuity of life. New cells arise by the division of the pre-existing cells. It was proposed by Rudolf Virchow.

   Reproduction is of two types:

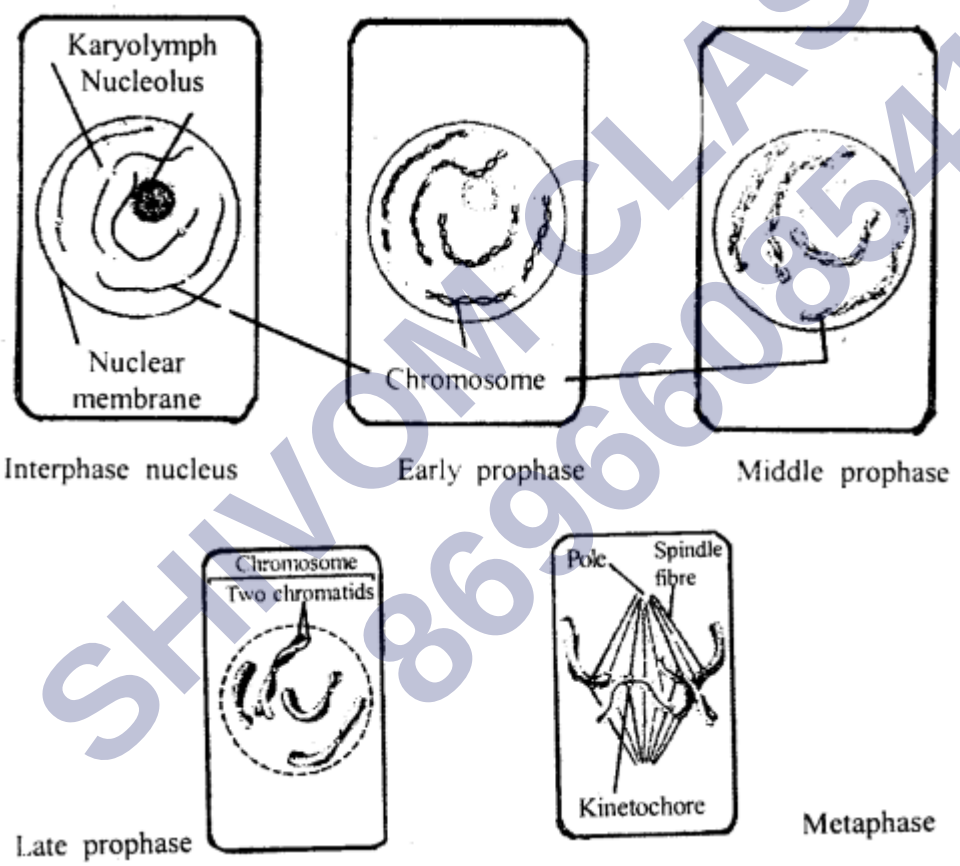
   i. sexual and

   ii. asexual reproduction.

   The growth and development of the living being are dependent on the division of cells. The single-celled zygotes by means of cell division develop into an adult having a large number of cells.

➢ Long Answer:

1. Answer: Following changes take place during prophase



   1. Chromosomes become short and thick and sister chromatids are held at the centromere.

   2. Nucleus and nuclear envelope disappear.

   3. In animal cells, centrioles move to opposite poles.

   4. Chromosomes begin to move towards the equatorial plane.

   Following changes take place in metaphase:

- Chromosomes lie on the equatorial plate.
- Chromatids become attached by spindle fibers.
- Maximum condensation of chromosomes takes place.

2. Answer: Glycolysis is the breakdown of glucose to pyruvic acid, which includes the following:

   (a) Phosphorylation: Transfer of phosphate from ATP to glucose to form glucose – 6 phosphate. One molecule of ATP is consumed enzyme, hexokinase is present.

   (b) Isomerisation: There is internal molecular rearrangement to form fructose 6 phosphates. The enzyme is hexose phosphate isomerase.

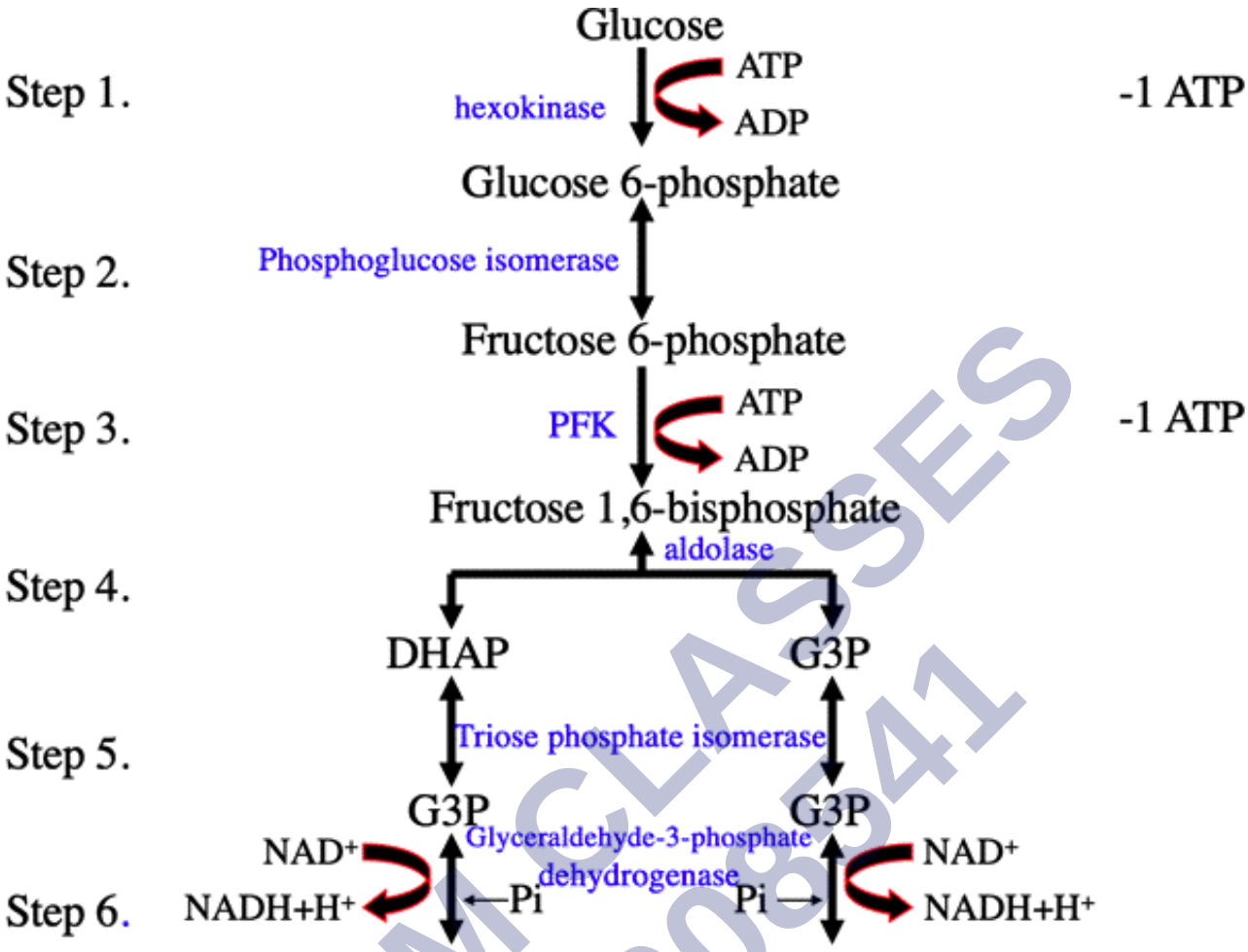
   (c) Second phosphorylation: The fructose – 6-phosphate undergoes phosphorylation to form fructose 1,6 diphosphate. One molecule of ATP is consumed. The enzyme is phosphofructokinase.

   (d) Triose phosphates are 3-phosphoglyceraldehyde (PGAL) and dihydroxyacetone phosphate (DHAP). The enzyme phosphorize isomerase maintains the two isomers in equilibrium.

   (e) Phosphorylation and oxidative dehydrogenation: PGAL under¬goes simultaneous phosphorylation and oxidative dehydrogenation to form 1,3 diphosphoglyceric acid.

   (f) ATP generation: 1,3 diphosphoglyceric acid transfers its phosphate with a high energy bond to ADP to form ATP and 3-phosphoric acid. One molecule of ATP is produced from one triose molecule.

   One enzyme is phosphoglyceric kinase Glucose



3. Answer: Cytokinesis in plant and animal cells: The separation of daughter nuclei and cytokinesis or cell cleavage maybe two different processes. The first visible changes consist of an appearance of dense material around the microtubules at the equator of the spindle at either mid or late phase then although spindle the fibre tends to disorganize and disappear during telophase, they usually persist and may even increase in number at the equator, frequently intermingled with a row of vesicles and the dense material.

The entire structure is called the midbody. Simultaneously there is a depression on the cell surface a kind of constriction that deepens gradually until reaching the midbody with the completion of the furrowing, the separation of cells is concluded.

The phragmoplast begins to form in the mid anaphase of plant cells. Under the electron microscope, it is possible to observe that the vesicles are of dense material applied together to their surface. The vesicles are derived from Golgi complexes which are found in the regions adjacent to phrag¬moplast which migrate to the equatorial region to be clustered around the microtubules.

Although phragmoplast is initially found as a ring on the periphery of the cell, with time it grows centripetally by the addition of microtubules and partition until it extends across the entire equatorial plane. The vesicles increase in size and just until the two

cells are separated by a fairly continuous plasma membrane.

All this time the phragmoplast has been transformed into, cell plate. Thin cytoplasmic connection is plasmoids- data transverse the cell plate and remain in place for communication between the adjacent daughter cells.

The formation of the cell plate also leads to the synthesis of the cell wall. The Golgi-vesicles in phragmoplast is already filled with secretory material consisting mainly of the pectin. The fusion of vesicles results in the combining of the pectin in the extracellular space between the two daughter cells thereby forming the main body of the periphery cell wall.

Assertion Reason Answer-

1. (c) If Assertion is true but Reason is false.

   Explanation: Previously interphase was called resting stage because there is no apparent activity related to cell division. The interphase cell is metabolically quite active. Interphase consist of three sub-phases (G1, G2 and S). Synthesis of DNA occurs in S phase. G1 is the period between the end of mitosis and the start of S phase. G2 is the interval between S phase and start of mitosis. As the synthesis of DNA occurs in S phase so, it is considered as metabolically active phase.

2. (b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

   Explanation: Chromosome contains equal amounts of DNA and histone. The DNA and histone octamer forms a nucleosome. Histone is the protein found in eukaryotic chromosomes. There are 5 types of histone namely H_1, H_2A, H_2B, H_3 and H_4.