Class 9th Biology — Unit 4

Cell Cycle, Mitosis & Meiosis

Complete Study Booklet

✓ 20 Solved MCQs with Answer Key

✓ Descriptive (Long) Questions & Answers

✓ Short Answer Questions

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Part 1 — Multiple Choice Questions

1. In which phase of the cell cycle does maximum growth occur in the cell?

(A) M phase

(B) G_2 phase

(C) ✓ G_1 phase

(D) S phase

2. In which phase of the cell cycle do the chromosomes duplicate?

(A) Mitosis

(B) G_1 phase

(C) G_2 phase

(D) ✓ S phase

3. At which stage do chromosomes line up in the center of the cell?

(A) Prophase

(B) ✓ Metaphase

(C) Anaphase

(D) Telophase

4. If you observe a cell in which the nuclear membrane is reforming around two sets of chromosomes, what stage of the cell cycle is this?

(A) Anaphase

(B) ✓ Telophase

(C) Prophase

(D) Metaphase

5. How does the centrosome contribute to mitosis?

(A) Initiates DNA replication

(B) ✓ Makes mitotic spindle

(C) Forms the nuclear envelope

(D) Duplicates organelles

6. Centrosomes make mitotic spindles in:

(A) ✓ Animal cells

(B) Plant cells

(C) Prokaryotic cells

(D) All of these

7. An organism has 4 pairs of chromosomes. After meiosis-I, how many chromosomes and chromatids will be present in each daughter cell?

(A) 8 chromosomes and 16 chromatids

(B) ✓ 4 chromosomes and 8 chromatids

(C) 4 chromosomes and 4 chromatids

(D) 8 chromosomes and 8 chromatids

8. Which one is the feature of mitosis but NOT of meiosis II?

(A) Daughter cells with the same number of chromosomes

(B) ✓ Separation of homologous chromosomes

(C) Crossing over

(D) Separation of sister chromatids

9. Which event is unique to meiosis but not mitosis?

(A) DNA replication

(B) Chromosome alignment

(C) ✓ Crossing over

(D) Nuclear division

10. Why is meiosis II necessary after meiosis I?

(A) To replicate chromosomes

(B) To reduce chromosome number

(C) ✓ To separate sister chromatids

(D) To ensure genetic recombination

Additional MCQs

11. Substance and energy required for DNA replication are accumulated in the cell during:

(A) G_1

(B) G_2

(C) ✓ S-Phase

(D) M-Phase

12. During cell division, spindle fibers attach to a chromosome at:

(A) ✓ Centromere

(B) Telomere

(C) Upper arm of chromosome

(D) Lower arm of chromosome

13. Some students of SSC observed a thin cross-section from the root tip of an onion plant under the microscope. They found dividing cells at different stages of their life cycle. One of the students found a cell at late prophase and counted 28 chromosomes in it. The number of chromosomes in daughter cells should be:

(A) 14

(B) ✓ 28

(C) 56

(D) 07

14. The spindle apparatus of plants differs from that of animals in not having:

(A) Microtubules

(B) Equator of spindle

(C) ✓ Centrioles

(D) Centromere

Meiosis

15. Crossing over results in genetic recombination. It occurs between:

(A) Two chromatids of the same chromosome

(B) Two chromatids of any two nonhomologous chromosomes

(C) Two chromatids of opposite gametes

(D) ✓ Two chromatids of homologous chromosomes

16. The cell shown in the diagram is passing through:

(A) ✓ Prophase I of meiosis

(B) Prophase of mitosis

(C) Telophase of meiosis I

(D) Anaphase of meiosis II

17. The longest phase of meiosis is:

(A) Interphase I

(B) ✓ Prophase I

(C) Interphase II

(D) Prophase II

18. What causes the number of chromosomes to reduce to half when a cell divides by meiosis?

(A) Replication of DNA during interphase I

(B) ✓ Separation of homologous chromosomes during meiosis I

(C) Separation of sister chromatids of all the chromosomes during meiosis I

(D) Crossing over during meiosis I

19. The chromosomal number of the fruit fly is 8. The gametes of the fruit fly contain:

(A) 2 chromosomes

(B) ✓ 4 chromosomes

(C) 8 chromosomes

(D) 16 chromosomes

20. All of the following events take place in both mitosis and meiosis EXCEPT:

(A) Condensation of chromatin to form chromosomes

(B) Formation of spindle apparatus

(C) Nuclear envelope and nucleolus disappear

(D) ✓ Chromosomes pair for crossing over

Answer Key — MCQs

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	**C**	5	**B**	9	**C**	13	**B**	17	**B**
2	**D**	6	**A**	10	**C**	14	**C**	18	**B**
3	**B**	7	**B**	11	**C**	15	**D**	19	**B**
4	**B**	8	**B**	12	**A**	16	**A**	20	**D**

Part 2 — Descriptive Questions

Q.1 Define cell cycle. Enlist its phases.

Definition: It is the series of events that take place in a eukaryotic cell from its formation to its division into two daughter cells.

Phases of Cell Cycle: The cell cycle can be divided into two main phases, i.e., interphase and the mitosis (division) phase.

Q.2 Define interphase. Explain the stages of interphase.

Introduction: Interphase makes up the major portion of the total time of the cell cycle. During interphase, the cell performs its life functions according to its specialty and prepares itself for the next division.

Stages of Interphase: Interphase consists of the following three phases:

- **G1 Phase (First Gap Phase):** Starts from the end of the mitosis phase; also called the growth phase. The cell makes proteins and organelles and grows in size, and also makes enzymes required in S-phase for DNA replication.
- **S Phase (Synthesis Phase):** The DNA of each chromosome is replicated (copied), resulting in the duplication of chromosomes (each chromosome now consists of two sister chromatids). The total number of chromosomes in the cell remains the same.
- **G2 Phase (Second Gap Phase):** The cell continues to grow and produces proteins necessary for cell division. It checks for any DNA damage from replication, makes repairs, and reorganizes its contents in preparation for mitosis.

G0 Phase:

1. Many cells stop dividing and start performing their specific functions. This phase is called the G0 phase — a so-called non-dividing phase.
2. Many cells (e.g., neurons) remain in G0 for indefinite periods.
3. Some cells (e.g., cells of liver and kidney) remain in G0 phase temporarily.
4. Other cells (e.g., epithelial cells) do not enter G0 and continue to divide throughout life.

Division Phase: After interphase, the cell enters the division phase and divides into two daughter cells. The events of the cell cycle are controlled by special genes, and all phases occur in sequence.

Table 4.1: Main Phases in Eukaryotic Cell Cycle

Phase	Description
Interphase	The cell prepares for division and goes through growth in size and DNA replication.
Gap (G1) Phase	The cell grows and carries out normal functions, preparing for DNA replication.
Synthesis (S) Phase	The cell replicates its DNA, making an exact copy of its genetic material.
Gap 2 (G2) Phase	The cell grows further, ensuring all preparations are complete for division.

Phase	Description
Gap 0 (G0) Phase	The cell exits the cycle and stops dividing, often to carry out specialized functions (not all cells enter this phase).
M Phase	The cell divides its genetic material equally into two new, identical cells.

Q.3 Define mitosis and describe the events that occur during its phases.

Definition: Mitosis is the type of cell division in which a cell divides into two daughter cells, each with the same number of chromosomes as the parent cell.

Occurrence: Mitosis occurs in the somatic cells of eukaryotes. Prokaryotes also divide into identical cells, but the events of their division differ from mitosis — this is called binary fission.

Phases of Mitosis: German biologist Walther Flemming discovered the events of mitosis in the 1880s. Mitosis has two major phases: karyokinesis (division of the nucleus) and cytokinesis (division of the cytoplasm).

A. Karyokinesis — division of the nucleus, further divided into four phases:

- **i. Prophase — Condensation of Chromatin:** The thread-like chromatin condenses and forms thick chromosomes; each chromosome has two sister chromatids joined at a single centromere.
- **Disappearance of Nucleolus and Nuclear Membrane:** The nuclear envelope and nucleolus break down during prophase.
- **Duplication of Centrosome and Spindle Fibres:** The centrosome duplicates and the two centrosomes migrate to opposite sides of the nucleus, forming a network of microtubules called spindle fibres (together, the mitotic spindle). Plant cells lack a centrosome; their spindle forms from fibres aggregating in the cytoplasm.
- **ii. Metaphase — Binding of Spindle Fibres:** Spindle fibres bind to chromosomes at the centromere, where kinetochore proteins are present.
- **Formation of the Metaphase Plate:** Spindle fibres from both poles attach to each chromosome, which then aligns along the equator of the cell, forming the metaphase plate.
- **iii. Anaphase:** Spindle fibres pull the chromosomes toward the poles, causing sister chromatids to separate. Two similar sets of chromatids move toward opposite poles.
- **iv. Telophase:** A new nuclear envelope forms around each set of separated chromosomes, which unfold back into chromatin.

B. Cytokinesis — division of the cytoplasm:

- **In Animal Cells:** A furrow develops at the equator. The cytoplasm there has a ring of microfilaments; the ring contracts and the furrow moves inward, pinching the parent cell into two.
- **In Plant Cells:** The Golgi apparatus produces vesicles that move to the middle of the cell and fuse to form a plate called the phragmoplast. The plate grows outward and fuses with the cell membrane, resulting in two daughter cells.

Q.4 Describe the significance of mitosis.

- **Growth:** Growth means an increase in size and number of cells. Mitosis produces new cells identical to the original cell, driving growth.

- **Cell Replacement:** Many cells constantly die in our bodies — e.g., red blood cells and cells of the intestinal walls and skin. These are replaced by exact copies formed through mitosis.
- **Regeneration:** Some animals regenerate body parts by carrying out mitosis in remaining cells. Example: a starfish can regenerate its lost arms.
- **Asexual Reproduction:** Mitosis enables asexual reproduction. Example: Hydra reproduces by budding — mitosis forms a bud on its surface that grows into a new individual.
- **Formation of the Body:** The human body has about 200 trillion cells, all formed from a single zygote through millions of mitotic divisions, with genetic material equally distributed each time.

Q.5 Which errors are associated with mitosis?

i. Failure in Separation of Sister Chromatids: Sometimes mitosis goes wrong — during anaphase, sister chromatids of a chromosome may fail to separate. As a result, one daughter cell receives both sister chromatids and the other receives none.

ii. Tumor Formation: Chromosomes may be damaged during mitosis. If genes that regulate mitosis are mutated, cells divide uncontrollably, forming masses of cells called tumors.

- **Benign Tumor:** The tumor remains at its original location in the body.
- **Malignant Tumor:** The tumor is cancerous and capable of spreading (invading) into neighbouring tissues — this spreading is called metastasis.

Q.6 Describe the events that occur during the phases of meiosis-I and meiosis-II.

Introduction: Meiosis is the type of cell division in which each daughter cell receives half the number of chromosomes compared to the parent cell. A diploid parent cell divides to produce four haploid daughter cells. (Diploid = chromosomes in homologous pairs; haploid = no such pairs.) Meiosis occurs in germline cells during gamete formation.

Discovery: Meiosis was discovered in 1876 by the German biologist Oscar Hertwig.

Phases of Meiosis: Meiosis consists of two divisions — Meiosis-I and Meiosis-II.

1. Meiosis-I — homologous chromosomes in a diploid cell separate, producing two haploid daughter cells. Subdivided into prophase-I, metaphase-I, anaphase-I and telophase-I.

- **i. Prophase-I — Condensation of Chromatin:** Chromatin condenses into chromosomes; each has two sister chromatids since DNA replicated before meiosis.
- **Synapsis and Tetrad Formation:** Homologous chromosomes pair up in a process called synapsis; each pair is called a tetrad.
- **Chiasmata and Crossing Over:** Non-sister chromatids of homologous chromosomes join closely, forming X-shaped structures called chiasmata — the sites of crossing over (exchange of chromosome segments), leading to genetic recombination.
- **Other Events:** The nucleoli disappear, the nuclear envelope breaks down, and centrioles migrate to opposite poles forming spindle fibres that attach to the chromosomes.
- **ii. Metaphase-I:** Tetrads attached to spindle fibres align along the equator, forming the metaphase plate. Two spindle fibres — one from each pole — attach to each chromosome of a homologous pair.
- **iii. Anaphase-I — Separation of Paired Chromosomes:** Spindle fibres pull each chromosome of a homologous pair toward opposite poles, forming two haploid sets. Each chromosome still consists of a pair of sister chromatids.
- **iv. Telophase-I:** Spindles disappear and a new nuclear envelope forms around each haploid set; chromosomes uncoil into chromatin. Cytokinesis occurs, forming two daughter cells.

2. Meiosis-II — closely resembles mitosis, with four phases:

- **i. Prophase-II:** The nucleoli and nuclear envelope disappear, and chromatin condenses; centrioles move to the poles, forming spindle fibres.
- **ii. Metaphase-II:** Spindle fibres attach to the kinetochores of chromosomes, aligning them at the cell's equator.
- **iii. Anaphase-II:** Spindle fibres pull the sister chromatids apart toward opposite poles.
- **iv. Telophase-II:** Chromosomes uncoil back into chromatin and nuclear envelopes reform. Cytokinesis produces four daughter cells, each with half the chromosome number of the parent cell.

Q.7 Describe the significance of meiosis.

1. Meiosis Maintains the Number of Chromosomes

(a) In Animals:

1. Special cells in reproductive organs undergo meiosis. The daughter cells, called gametes, have half the number of chromosomes (with no pairs).
2. During sexual reproduction, male and female gametes join to form the first cell (zygote) of the new generation.
3. The original chromosome number is restored in the zygote.
4. The zygote undergoes mitosis many times and develops into the new animal.

(b) In Flowering Plants:

1. Specialized cells in the flowers undergo meiosis. The daughter cells, called spores, have half the number of chromosomes.
2. These spores grow into a new generation inside the flowers.
3. This generation produces gametes by mitosis.
4. The gametes join to form a zygote with the full chromosome set, which develops into a new plant through mitosis.

2. Meiosis Brings Genetic Diversity: Crossing over creates new combinations of genes on chromosomes. Each gamete carries a unique set of genes, so when gametes from two parents combine, the resulting zygote is genetically different from both parents — contributing to genetic diversity in populations.

Q.8 Which errors are associated with meiosis?

During meiosis-I, homologous chromosomes normally separate, and during meiosis-II, sister chromatids normally separate — this correct separation is called **disjunction**.

Non-Disjunction: Sometimes non-disjunction occurs, where daughter cells (gametes) receive more or less than the normal number of chromosomes. If such gametes fuse to form a zygote with an abnormal chromosome number, the resulting offspring may suffer from severe medical problems.

Q.9 Describe the comparison between meiosis and mitosis.

Similarities:

1. DNA replication occurs during interphase (S phase) before both divisions.
2. Both divisions begin with a parent cell that has chromosomes in pairs.
3. In both, chromatin condenses and chromosomes become visible during prophase.

4 Both involve the formation of a spindle apparatus.

5 Both involve prophase, metaphase, anaphase and telophase — however, meiosis has two rounds (meiosis-I and meiosis-II).

6 In both, sister chromatids separate — in mitosis during anaphase; in meiosis during anaphase-II.

7 Cytokinesis occurs at the end of both divisions, forming two new cells.

Differences:

Difference between Mitosis and Meiosis

Mitosis	Meiosis
A parent cell divides only once; two daughter cells are produced.	A parent cell undergoes two divisions; four daughter cells are produced.
Chromosome number in daughter cells remains the same as the parent cell.	The chromosome number is reduced by half in daughter cells.
Variations do not occur.	Variations occur due to crossing-over.
Occurs in somatic cells.	Occurs in germline cells.
Homologous chromosomes do not form pairs.	Homologous chromosomes form pairs.
No crossing over occurs during prophase.	Crossing over occurs during prophase-I.
A single chromosome aligns to form the metaphase plate.	Homologous pairs align to form the metaphase plate.
During anaphase, sister chromatids separate and move towards the poles.	During anaphase-I, whole homologous chromosomes move towards the poles (chromatids stay joined).
Occurs for growth, development and maintenance of multicellular organisms.	Occurs for producing gametes (animals) and spores (plants) for sexual reproduction.

Part 3 — Short Answer Questions

Q.1 Enlist the events that occur during the G1 phase of interphase.

1 The cell makes proteins and organelles and so grows in size.
2 The cell also makes enzymes required in S-phase for the replication of DNA.

Q.2 What is the main purpose of the S phase in the cell cycle?

During this phase, the DNA of each chromosome is replicated (copied). It results in the duplication of chromosomes (each chromosome now consists of two sister chromatids). The total number of chromosomes in the cell remains the same.

Q.3 During which phase of mitosis do sister chromatids separate?

During anaphase, spindle fibres attached to the chromosomes pull towards the poles, causing the sister chromatids of each chromosome to separate.

Q.4 How does crossing over contribute to genetic variation in meiosis?

During crossing over, segments of non-sister chromatids of homologous chromosomes are exchanged. This leads to recombination of genetic material and increases genetic diversity.

Q.5 What is the role of spindle fibres in mitosis?

Spindle fibres attach to chromosomes at the centromere and ensure the accurate separation of sister chromatids, pulling them to opposite poles by telophase.

Q.6 How is cytokinesis in animal cells different from plant cells?

Animal cells: A furrow develops at the equator. The cytoplasm there has a ring of microfilaments; the ring contracts and the furrow moves inward, pinching the parent cell into two.

Plant cells: The Golgi apparatus makes vesicles that move to the middle of the cell and fuse to form a plate called the phragmoplast. The plate grows outward and fuses with the cell membrane, resulting in two daughter cells.

Q.7 What is the difference between prophase of mitosis and prophase-I of meiosis-I?

Prophase of Mitosis	Prophase-I of Meiosis-I
Pairing of homologous chromosomes does not take place.	Pairing of homologous chromosomes (synapsis) takes place.
Crossing over is absent.	Crossing over occurs, leading to genetic recombination.

Q.8 How does meiosis differ from mitosis in terms of chromosome number?

The number of chromosomes remains the same during mitosis. Example: a diploid (2n) parent cell produces two diploid (2n) daughter cells.

During meiosis, the chromosome number is reduced by half compared to the parent cell. Example: a diploid (2n) parent cell produces four haploid (n) daughter cells.

Q.9 What are the key events of anaphase in mitosis?

1. Spindle fibres contract, pulling towards their respective poles.
2. Sister chromatids of each chromosome separate equally and move to opposite poles.

Q.10 What is the function of the centrosome during cell division?

The centrosome duplicates into two. These two centrosomes migrate to opposite sides of the nucleus and form a network of microtubules called spindle fibres, which ensure the accurate separation of chromosomes.

Q.11 What are sister chromatids, and when do they separate in meiosis?

Sister chromatids are identical copies of a single chromosome, joined at the centromere. They separate during anaphase-II of meiosis.

Q.12 How is mitosis related to the process of regeneration?

Some animals can regenerate parts of the body. To do this, they form new cells by carrying out mitosis in the cells of the remaining parts.

Q.13 What is the G0 phase?

Cells that have stopped dividing are in the G0 phase. In multicellular eukaryotes, cells enter the G0 phase from G1.

1. Some cells of the liver and kidneys enter the G0 phase temporarily.
2. Neurons remain in the G0 phase for an indefinite period.
3. Other cells, such as epithelial cells, do not enter the G0 phase at all.

Q.14 Describe the G2 phase.

It is the last sub-phase before cell division. During this phase, increased protein synthesis occurs for the production of spindle fibres.

Q.15 What is M-Phase?

In this phase, the cell divides into two daughter cells. This phase is called the M-phase (mitotic phase).

Q.16 Differentiate between benign and malignant tumours; why does each occur?

- **Benign Tumours:** Not all tumours are cancerous. A benign tumour is an abnormal mass of otherwise normal cells that always remains at its original site in the body.
- **Malignant Tumours:** A malignant tumour is cancerous and capable of spreading into neighbouring tissues.

Both occur due to uncontrolled cell division, which forms masses of cells called tumors.

Q.17 Can you distinguish between the following pairs?

(a) Mitosis and meiosis (b) Chromatin and chromosome (c) Chromosome and chromatids (d) Centromeres and centrioles (e) Cytokinesis and karyokinesis (f) Centromeres and kinetochores (g) Haploid and diploid number of chromosomes

(a) Mitosis and Meiosis

Mitosis	Meiosis
Takes place in somatic cells.	Takes place in germline cells of sex organs.
Consists of one division.	Consists of two divisions.
Crossing over does not take place during prophase.	Crossing over takes place during prophase-I.
Sister chromatids separate at anaphase.	Sister chromatids do not separate at anaphase-I (only at anaphase-II).
Individual duplicated chromosomes align at the metaphase plate.	Paired homologous chromosomes align at the metaphase plate during metaphase-I.
Daughter chromosomes move to opposite poles during anaphase.	Homologous chromosomes (each with two sister chromatids) separate and move to opposite poles during anaphase-I.
Two diploid daughter cells are formed.	Four haploid daughter cells are formed.
Daughter cells are genetically identical to each other and to the parent cell.	Daughter cells are not genetically identical to each other or to the parent cell.
Chromosome number remains constant.	Chromosome number becomes half.
Mitotic products can usually undergo additional mitotic divisions.	Meiotic products cannot undergo further meiotic divisions.

(b) Chromatin and Chromosome

Chromatin	Chromosome
At the start of prophase, chromosomes are not visible — they exist as fine thread-like structures called chromatin.	During prophase, chromatin shortens, thickens and coils by a process called condensation, resulting in the appearance of chromosomes.

(c) Chromosome and Chromatids

Chromosome	Chromatid
Formed when chromatin shortens, thickens and coils by condensation; consists of two chromatids joined by a centromere.	An unseparated replica of a chromosome is called a chromatid.

(d) Centromeres and Centrioles

Centromeres	Centrioles
The centromere is a constriction in the chromosome where sister chromatids are joined to each other.	A pair of centrioles is located near the nucleus; each consists of a triplet of microtubules arranged in a hollow cylinder.

(e) Cytokinesis and Karyokinesis

Cytokinesis	Karyokinesis
The process of cytoplasmic division is called cytokinesis.	The process of nuclear division is called karyokinesis.

(f) Centromeres and Kinetochores

Centromeres	Kinetochores
The centromere is a constriction in the chromosome.	Kinetochores are proteins that act as the attachment site for spindle fibres.

(g) Haploid and Diploid Cells

Diploid Cells	Haploid Cells
Diploid means cells having the full number of chromosomes.	Haploid means cells having half the number of chromosomes.
Somatic cells are diploid (2n) cells.	Germline cells (gametes) are haploid (n) cells.
Responsible for growth and maintenance of the organism.	Involved in sexual reproduction.
Produced by mitosis.	Produced by meiosis.
Diploid number of chromosomes in humans is 46.	Haploid number of chromosomes in humans is 23.