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Biology Class 9 — Punjab Board (PECTAA)

CHAPTER 4

Cell Cycle

Key Concepts · Definitions · Short & Long Questions · MCQs · Diagrams · Exam Tips

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Chapter 4: Cell Cycle

Chapter 4 follows the life of a eukaryotic cell from the moment it is formed until it divides. This sequence is the cell cycle: a long preparation stage called interphase, followed by division. Cells divide in two ways. Mitosis makes two identical cells and is used for growth, repair and asexual reproduction; meiosis makes four cells with half the chromosomes and is used to form gametes and spores.

The notes below explain each stage of interphase, the four phases of mitosis and how cytokinesis differs in plant and animal cells, the two rounds of meiosis with synapsis and crossing over, the importance of both divisions, what happens when they go wrong (tumours and non-disjunction), and a side-by-side comparison of mitosis and meiosis.

Learning Objectives

- Describe the cell cycle and the events of G1, S, G2 and G0.
- Explain the four phases of mitosis and cytokinesis in animal and plant cells.
- State the significance of mitosis and the result of errors in mitosis.
- Explain the phases of meiosis I and meiosis II, including synapsis and crossing over.
- State the significance of meiosis and the result of non-disjunction.
- Compare mitosis and meiosis.

Key Concepts

4.1 The Cell Cycle and Interphase

The cell cycle is the ordered series of events in a eukaryotic cell from its formation to its own division into two daughter cells. It has two main parts: interphase, which takes about 90 percent of the time, and the M (division) phase. Special genes control the cycle so that its stages happen in the right order.

Interphase has three stages. In G1 (first gap) the cell grows, makes proteins and organelles, and produces the enzymes needed to copy DNA. In S (synthesis) each DNA molecule is replicated, so every chromosome now has two identical sister chromatids, though the chromosome count stays the same. In G2 (second gap) the cell keeps growing, makes proteins needed for division, checks and repairs any DNA damage and organises its contents for mitosis.

Some cells leave the cycle after division and enter G0, a resting state in which they do their special job without dividing. Neurons stay in G0 more or less permanently, liver and kidney cells can return to the cycle when needed, while cells such as those of epithelium keep dividing throughout life.

4.2 Mitosis: Karyokinesis

Mitosis is cell division in which one cell forms two daughter cells, each with exactly the same number and kind of chromosomes as the parent. It takes place in body (somatic) cells of eukaryotes; prokaryotes divide by a simpler process called binary fission. Walther Flemming

described the stages of mitosis in the 1880s. Mitosis has two parts: karyokinesis (division of the nucleus) and cytokinesis (division of the cytoplasm).

Prophase: chromatin condenses into visible chromosomes, each made of two sister chromatids joined at a centromere; the nucleolus and nuclear envelope disappear. In animal cells the centrosome duplicates and the two centrosomes move apart, building spindle fibres between them; plant cells, which have no centrioles, build the spindle from fibres in the cytoplasm.

Metaphase: spindle fibres from opposite poles attach to the kinetochore at the centromere of each chromosome, and the chromosomes line up across the middle of the cell, forming the metaphase plate. Anaphase: the spindle fibres shorten, the centromeres split and the sister chromatids are pulled to opposite poles, giving two identical sets. Telophase: a nuclear envelope forms around each set, nucleoli reappear and the chromosomes unwind into chromatin.

4.2 Cytokinesis in Animal and Plant Cells

In animal cells a ring of actin microfilaments under the membrane at the equator contracts, creating a cleavage furrow that deepens until the cell is pinched into two.

In plant cells the rigid wall prevents pinching. Instead, Golgi vesicles carrying wall material gather at the middle of the cell and fuse to form a cell plate, which grows outwards until it joins the existing wall and membrane, separating two daughter cells.

4.2 Significance of Mitosis and Errors

Mitosis allows growth, because organisms grow by adding cells; it replaces cells that wear out, such as red blood cells, skin cells and the lining of the intestine; it allows regeneration of lost parts, as when a sea star regrows an arm; and it is the basis of asexual reproduction, for example budding in Hydra. Every body cell formed from the zygote receives a complete, identical set of chromosomes because of mitosis.

If sister chromatids fail to separate in anaphase, one daughter cell gets an extra chromosome and the other gets one too few. If the genes controlling division are mutated, cells divide without stopping and form a lump called a tumour. A benign tumour stays where it formed; a malignant tumour (cancer) invades other tissues and spreads, a process called metastasis.

4.3 Meiosis I

Meiosis is cell division in which a diploid cell (chromosomes in homologous pairs) gives rise to four haploid cells (one chromosome from each pair). It was first described by Oscar Hertwig in 1876 and consists of two divisions, meiosis I and meiosis II, after a single round of DNA replication.

Prophase I: chromosomes condense, each already made of two chromatids. Homologous chromosomes come together side by side in synapsis, forming a group of four chromatids called a tetrad (bivalent). Non-sister chromatids touch at points called chiasmata, where they exchange segments; this crossing over recombines genes. The nuclear envelope and nucleolus disappear and the spindle forms.

Metaphase I: homologous pairs, not single chromosomes, line up at the equator. Anaphase I: the members of each homologous pair are pulled to opposite poles; sister chromatids stay together. Telophase I: nuclear envelopes may re-form and cytokinesis produces two haploid cells, each

chromosome still having two chromatids.

4.3 Meiosis II

Meiosis II looks like mitosis but starts with haploid cells. In prophase II the chromosomes condense again and a spindle forms; in metaphase II they line up singly at the equator; in anaphase II the sister chromatids finally separate and move to opposite poles; in telophase II nuclei re-form and cytokinesis follows.

The final result is four haploid daughter cells, each genetically different from the parent and from each other because of crossing over and the random way homologous pairs line up in metaphase I.

4.3 Significance of Meiosis and Errors

Meiosis keeps the chromosome number constant from one generation to the next. Gametes made by meiosis carry half the chromosomes, and fertilisation restores the full diploid number in the zygote, which then grows by mitosis. In flowering plants meiosis produces haploid spores inside the flower, which give rise to the gamete-forming stage.

Meiosis also creates genetic variety. Crossing over and independent arrangement of chromosome pairs give every gamete a unique gene combination, so offspring differ from their parents and from each other. If chromosomes or chromatids fail to separate properly (non-disjunction), gametes end up with too many or too few chromosomes, and a zygote formed from them may develop serious disorders.

4.4 Mitosis and Meiosis Compared

Similarities: DNA is copied in the S phase before both; both have prophase, metaphase, anaphase and telophase; both use a spindle; sister chromatids separate in both (anaphase of mitosis, anaphase II of meiosis); both end with cytokinesis.

Differences: mitosis has one division producing two identical diploid cells, while meiosis has two divisions producing four haploid, genetically varied cells. Homologous chromosomes pair and cross over only in meiosis. Mitosis occurs in body cells for growth, repair and asexual reproduction, while meiosis occurs in reproductive (germ-line) cells to form gametes or spores.

Important Definitions

Cell cycle
The sequence of events in a eukaryotic cell from its formation to its division into two daughter cells.

Interphase
The long preparatory stage of the cell cycle made up of G1, S and G2.

G0 phase
A resting state in which a cell leaves the cycle and stops dividing.

Sister chromatids
The two identical copies of a chromosome formed by DNA replication and joined at the centromere.

Centromere
The point where sister chromatids are joined and where spindle fibres attach through the kinetochore.

Spindle fibres
Microtubules that attach to chromosomes and move them during cell division.

Metaphase plate
The plane at the cell's equator where chromosomes line up during metaphase.

Karyokinesis
Division of the nucleus.

Cytokinesis
Division of the cytoplasm to form two separate cells.

Cell plate
The new partition formed from Golgi vesicles at the middle of a dividing plant cell.

Binary fission
The simple division of a prokaryotic cell into two.

Tumour
A mass of cells formed by uncontrolled cell division.

Metastasis
The spread of cancer cells from their original site to other tissues.

Diploid (2n)
Having chromosomes in homologous pairs.

Haploid (n)
Having only one chromosome from each pair.

Homologous chromosomes
A pair of chromosomes, one from each parent, carrying genes for the same characters.

Synapsis
The pairing of homologous chromosomes in prophase I.

Tetrad

A synapsed pair of homologous chromosomes, made of four chromatids.

Chiasma (plural chiasmata)
The X-shaped point where non-sister chromatids cross and exchange segments.

Crossing over
The exchange of segments between non-sister chromatids of homologous chromosomes.

Non-disjunction
The failure of chromosomes or chromatids to separate properly during division.

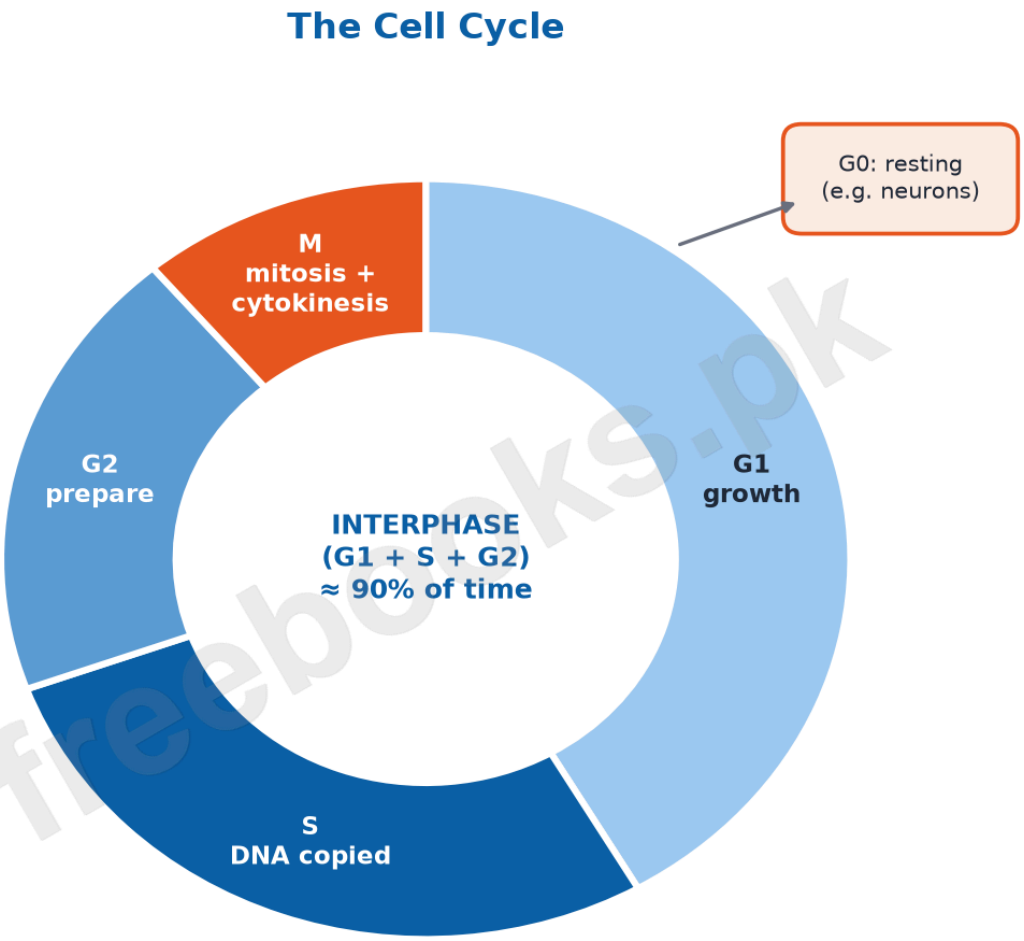
Key Facts at a Glance

Topic	Key point
Interphase share of cycle	About 90%
DNA replication	S phase
Phases of mitosis	Prophase → Metaphase → Anaphase → Telophase (PMAT), then cytokinesis
Mitosis described by	Walther Flemming, 1880s
Meiosis described by	Oscar Hertwig, 1876
Mitosis result	2 identical daughter cells, same chromosome number
Meiosis result	4 haploid, genetically different cells
Crossing over	Prophase I, at chiasmata
Homologues separate	Anaphase I
Sister chromatids separate	Anaphase (mitosis) and anaphase II (meiosis)
Animal cytokinesis	Cleavage furrow by a ring of microfilaments
Plant cytokinesis	Cell plate from Golgi vesicles
Cells that stay in G0	Neurons
Asexual reproduction by mitosis	Budding in Hydra

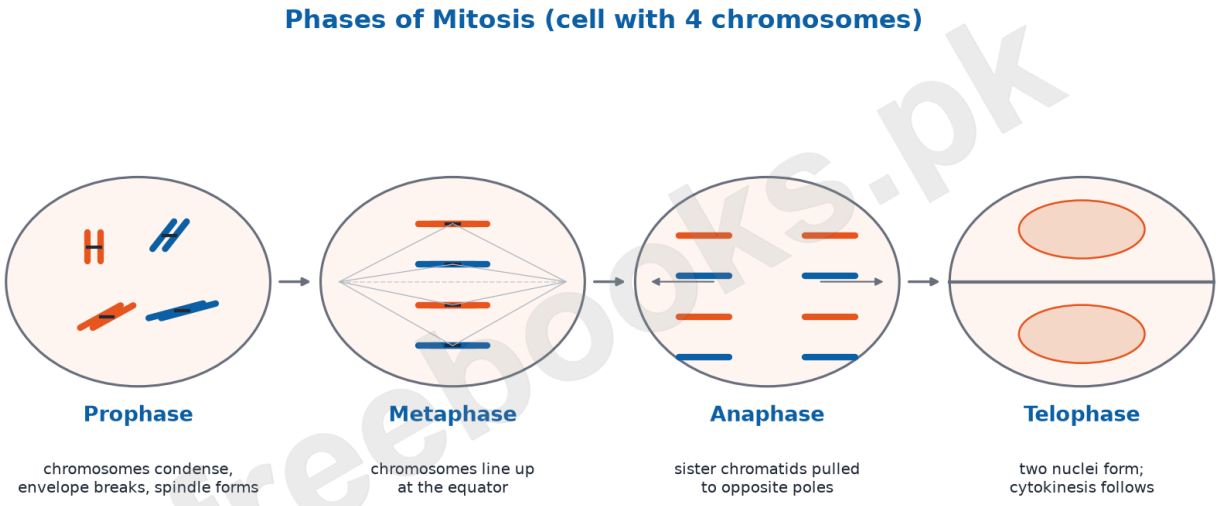
Diagrams

The cell cycle: A circular chart of the cell cycle showing G1, S and G2 of interphase, the M phase

and the exit into G0.

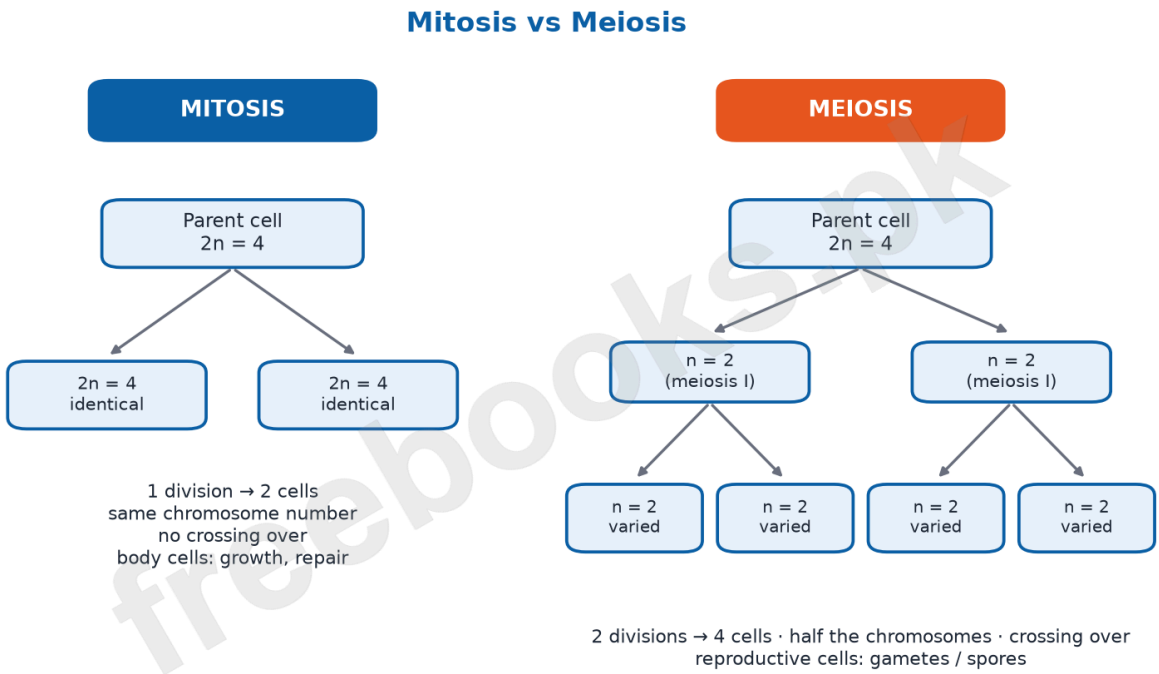


Phases of mitosis: Simplified sketches of prophase, metaphase, anaphase and telophase with the key event of each phase.



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Mitosis vs meiosis: A flow comparison showing one division giving two identical diploid cells against two divisions giving four varied haploid cells.



Short Questions and Answers

Why is interphase not a resting phase?

During interphase the cell is very active: it grows, makes proteins and organelles, copies its DNA in the S phase and checks and repairs it in G2 before dividing.

What happens to the chromosome number in the S phase?

The DNA is copied so each chromosome comes to have two sister chromatids, but the number of chromosomes stays the same.

Name a cell that stays in G0 and one that keeps dividing.

Mature neurons stay in G0 and normally do not divide, while skin epithelial cells keep dividing throughout life.

What is the role of the kinetochore?

It is a protein structure at the centromere to which spindle fibres attach, allowing the chromosome to be moved during division.

Why do plant cells form a cell plate instead of a cleavage furrow?

Their rigid cell wall cannot be pinched inwards, so they build a new wall from Golgi vesicles at the middle of the cell.

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How does a plant cell form a spindle without centrioles?
It assembles spindle fibres from microtubules already present in its cytoplasm.

Give two uses of mitosis in the human body.
Growth of the body by increasing cell number, and replacement of worn-out cells such as red blood cells and skin cells.

How is a malignant tumour different from a benign tumour?
A benign tumour stays in the place where it formed, while a malignant tumour invades nearby tissues and spreads to other parts of the body.

What is the difference between diploid and haploid cells?
Diploid cells have chromosomes in homologous pairs (2n); haploid cells have only one chromosome from each pair (n), as in gametes.

What is a tetrad and when does it form?
A tetrad is a pair of homologous chromosomes lying together, made of four chromatids; it forms during synapsis in prophase I of meiosis.

Why is meiosis called reduction division?
Because its first division separates homologous chromosomes, halving the chromosome number so that the daughter cells are haploid.

How does crossing over create variation?
Non-sister chromatids exchange segments, so each chromosome ends up with a new mixture of genes from both parents.

Why must gametes be haploid?
So that when two gametes fuse at fertilisation the zygote gets the normal diploid number, keeping the chromosome number constant from generation to generation.

What is non-disjunction and what can it cause?
It is the failure of chromosomes or chromatids to separate properly in division; it produces gametes with extra or missing chromosomes, which can lead to serious disorders in the offspring.

Long Questions and Answers

Describe the cell cycle.

What is the cell cycle and what are its main parts?

The cell cycle is the series of events from the formation of a cell to its division into two. It has a long interphase, taking about 90 percent of the time, and a shorter M phase in which the nucleus and cytoplasm divide.

What happens in G1 and S phases?

In G1 the cell grows, makes proteins and organelles and produces enzymes for DNA replication. In the S phase every DNA molecule is copied, so each chromosome comes to have two sister chromatids.

What happens in G2 phase?

The cell continues to grow, makes proteins needed for division, checks the copied DNA for errors and repairs them, and arranges its contents ready for mitosis.

What is G0 phase?

Some cells leave the cycle and enter G0, where they work without dividing. Neurons remain in G0 permanently, liver and kidney cells can return to the cycle, and epithelial cells generally never enter G0.

Describe the phases of mitosis.

What happens in prophase?

Chromatin condenses into chromosomes made of two sister chromatids, the nuclear envelope and nucleolus disappear, and the spindle begins to form between the two centrosomes in animal cells or from cytoplasmic microtubules in plant cells.

What happens in metaphase?

Spindle fibres from both poles attach to the kinetochore of each chromosome, and the chromosomes line up at the equator to form the metaphase plate.

What happens in anaphase and telophase?

In anaphase the centromeres split and sister chromatids are pulled to opposite poles. In telophase a new nuclear envelope forms around each set, the nucleoli reappear and the chromosomes unwind.

How does cytokinesis complete mitosis?

In animal cells a contracting ring of microfilaments forms a furrow that pinches the cell in two. In plant cells Golgi vesicles fuse at the centre to form a cell plate that grows outward to divide the cell.

Explain the significance of mitosis and what happens when it goes wrong.

How does mitosis help in growth and repair?

It increases the number of cells, which makes an organism grow, and it replaces cells that die or wear out, such as skin and blood cells, with exact copies.

How does mitosis help in regeneration and asexual reproduction?

Animals such as sea stars regrow lost parts by mitosis in the remaining cells, and Hydra produces buds by repeated mitosis that grow into new individuals.

What can go wrong in mitosis?

Sister chromatids may fail to separate, giving one cell an extra chromosome and the other one

less, or chromosomes may be damaged. Mutations in the genes that control division can make cells divide without stopping.

How do tumours and cancer form?

Uncontrolled division forms a mass called a tumour. If it stays in place it is benign; if its cells invade other tissues and spread through the body (metastasis) it is malignant, which is cancer.

Describe meiosis and explain its significance.

What happens in prophase I?

Chromosomes condense and homologous chromosomes pair up in synapsis to form tetrads. Non-sister chromatids cross at chiasmata and exchange segments in crossing over; the nuclear envelope breaks down and the spindle forms.

What happens in the rest of meiosis I?

In metaphase I homologous pairs line up at the equator; in anaphase I the members of each pair move to opposite poles; in telophase I two haploid cells form, each chromosome still having two chromatids.

What happens in meiosis II?

Each haploid cell divides again like mitosis: chromosomes line up singly, sister chromatids separate in anaphase II, and four haploid daughter cells are formed.

Why is meiosis important?

It halves the chromosome number in gametes so that fertilisation restores the normal number, and crossing over plus random arrangement of chromosome pairs create genetic variety in the offspring.

Compare mitosis and meiosis.

How are mitosis and meiosis similar?

In both, DNA is copied beforehand, chromosomes condense in prophase, a spindle forms, sister chromatids separate at some stage, and cytokinesis divides the cytoplasm.

How do they differ in the number of divisions and products?

Mitosis has one division and gives two identical cells with the parent's chromosome number. Meiosis has two divisions and gives four cells with half the chromosome number.

How do they differ in pairing and variation?

Homologous chromosomes pair and cross over only in meiosis, so meiosis creates variation while mitosis produces genetically identical cells.

Where and why does each occur?

Mitosis occurs in body cells for growth, repair and asexual reproduction. Meiosis occurs in reproductive cells to form gametes in animals and spores in plants.

Multiple Choice Questions (MCQs)

In which phase is DNA replicated? (A) G1 (B) S (C) G2 (D) M
Correct answer: (B) S. DNA synthesis happens in the S phase.

A nerve cell that no longer divides is in the: (A) G1 phase (B) S phase (C) G0 phase (D) M phase
Correct answer: (C) G0 phase. Cells that leave the cycle enter G0.

Chromosomes line up at the equator during: (A) Prophase (B) Metaphase (C) Anaphase (D) Telophase
Correct answer: (B) Metaphase. Metaphase forms the metaphase plate.

Sister chromatids move to opposite poles during: (A) Prophase (B) Metaphase (C) Anaphase (D) Interphase
Correct answer: (C) Anaphase. Centromeres split and chromatids separate in anaphase.

The nuclear envelope re-forms during: (A) Telophase (B) Metaphase (C) S phase (D) Prophase
Correct answer: (A) Telophase. Nuclei rebuild in telophase.

In a dividing onion root cell, the cytoplasm divides by: (A) A cleavage furrow (B) A cell plate (C) Binary fission (D) Budding
Correct answer: (B) A cell plate. Plant cells form a cell plate from Golgi vesicles.

Bacteria divide by: (A) Mitosis (B) Meiosis (C) Binary fission (D) Budding only
Correct answer: (C) Binary fission. Prokaryotes use binary fission.

A tumour whose cells spread to other organs is: (A) Benign (B) Malignant (C) Haploid (D) Dormant
Correct answer: (B) Malignant. Malignant tumours invade and spread (metastasis).

If a body cell has 46 chromosomes, a gamete formed by meiosis has: (A) 92 (B) 46 (C) 23 (D) 12
Correct answer: (C) 23. Meiosis halves the number: 46 / 2 = 23.

Crossing over takes place during: (A) Prophase I (B) Metaphase II (C) Anaphase I (D) Telophase II
Correct answer: (A) Prophase I. It occurs between synapsed homologues in prophase I.

Homologous chromosomes separate during: (A) Anaphase of mitosis (B) Anaphase I (C) Anaphase II (D) Telophase II
Correct answer: (B) Anaphase I. Anaphase I separates the members of each pair.

How many daughter cells are formed by one complete meiosis? (A) One (B) Two (C) Four

(D) Eight
Correct answer: (C) Four. Two divisions give four cells.

Which process produces genetically identical cells? (A) Meiosis (B) Mitosis (C) Crossing over (D) Fertilisation
Correct answer: (B) Mitosis. Mitosis copies the parent's chromosome set exactly.

Hydra reproducing by budding is an example of: (A) Meiosis (B) Mitosis in asexual reproduction (C) Non-disjunction (D) Crossing over
Correct answer: (B) Mitosis in asexual reproduction. The bud forms by repeated mitosis.

Gametes with an extra chromosome usually result from: (A) Crossing over (B) Non-disjunction (C) Cytokinesis (D) Synapsis
Correct answer: (B) Non-disjunction. Failure of separation gives abnormal chromosome numbers.

Quick Revision Summary

- Cell cycle = interphase (G1 → S → G2, ~90% of time) + M phase. G0 = resting, non-dividing state.
- S phase: DNA copied, each chromosome gets two sister chromatids; number of chromosomes unchanged.
- Mitosis: PMAT. Prophase (condense, envelope breaks, spindle) → Metaphase (plate) → Anaphase (chromatids separate) → Telophase (nuclei re-form).
- Cytokinesis: furrow (animal, actin ring) vs cell plate (plant, Golgi vesicles).
- Mitosis uses: growth, replacement, regeneration, asexual reproduction. Uncontrolled division → tumour; malignant tumour spreads (metastasis).
- Meiosis: 2n → four n cells. Prophase I: synapsis, tetrads, chiasmata, crossing over. Anaphase I: homologues separate. Anaphase II: chromatids separate.
- Meiosis keeps chromosome number constant and creates variation; non-disjunction gives abnormal gametes.

Exam Tips

- Remember PMAT for the phases, and add 'I' or 'II' for meiosis.
- The commonest mistake: in anaphase I homologous chromosomes separate, not sister chromatids. Chromatids separate in anaphase II and in mitosis.
- Practise drawing a cell with 4 chromosomes (2 pairs) through each phase; it makes the difference between mitosis and meiosis obvious.
- In comparison questions, write at least five differences in a table: number of divisions, number of cells, chromosome number, pairing/crossing over, where it occurs.
- Link each error to its result: mitosis error → tumour/cancer; meiosis error (non-disjunction) → abnormal chromosome number in offspring.

Note on Facts

The textbook says the human body has about 200 trillion cells, while Chapter 1 and Chapter 3 of the same book say over 30 trillion. Current scientific estimates are about 30 to 37 trillion human cells.

The key points of the textbook say anaphase I forms 'two diploid sets'. The sets formed in anaphase I are haploid (one chromosome from each pair), as the main text of the chapter correctly states.

The textbook calls the structure formed from Golgi vesicles in a dividing plant cell the phragmoplast. Strictly, the vesicles fuse to form the cell plate; the phragmoplast is the framework of microtubules that guides them there.