

# Cell Biology & Ultrastructure

IB HL Study Guide

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## How to Use This Guide

- **Cell Theory & Types** — the three tenets, prokaryote vs eukaryote
- **Eukaryotic Ultrastructure** — every organelle, its function, and what IB asks you to draw
- **Cell Division** **HL** — the cell cycle, mitosis stages, mitosis vs meiosis
- **MCQ Practice** — styled like real IB Paper 1 questions
- **Exam Alerts** — the exact traps that cost marks in A1/D1 questions

**A** *ligned to IB Biology 2025 syllabus — A1.1 Unity and Diversity — A1.2 Cell Ultrastructure — D1.1 Cell Division*

**Jump to section:** Cell Theory & Types · Eukaryotic Ultrastructure · Cell Division · Exam Strategy

## Section 1: Cell Theory & Types

### The Three Tenets of Cell Theory

Cell theory is the foundational framework of modern biology. Every IB Biology student must be able to state all three tenets precisely.

#### **MEMORISE THIS**

##### **The Three Tenets of Cell Theory:**

1. All living organisms are composed of one or more cells.
2. The cell is the basic structural and functional unit of life.
3. All cells arise from pre-existing cells.

*Mnemonic: “All Cells Come From Cells” — A, C, C, F, C*

#### **IB TIP**

**IB Language:** The IB mark scheme uses these exact words. “Cells come from pre-existing cells” scores the mark; vague answers like “cells reproduce” typically do not. Memorise the wording, not just the idea.

### Prokaryotes vs Eukaryotes

The most fundamental division in cell biology is between prokaryotic and eukaryotic cells. Expect at least one MCQ on this distinction in every IB Paper 1.

Feature	Prokaryote	Eukaryote
Membrane-bound nucleus	Absent — nucleoid region only	Present
DNA location	Circular DNA in nucleoid region; plasmids possible	Linear DNA in membrane-bound nucleus
Ribosomes	70S (smaller)	80S cytoplasmic (70S in mitochondria/chloroplasts)
Membrane-bound organelles	Absent	Present (mitochondria, ER, Golgi, etc.)
Cell wall	Usually present (peptidoglycan in bacteria)	Present in plants/fungi (different composition); absent in animals
Size	Typically 1–10 $\mu\text{m}$	Typically 10–100 $\mu\text{m}$
Examples	Bacteria, archaea	Animals, plants, fungi, protists

### ⚠️ EXAM ALERT

#### Exam Alert — Two Classic Mistakes:

1. Prokaryotes do **not** have a membrane-bound nucleus. They have a **nucleoid region** — an area of the cytoplasm where the circular DNA is located. There is no nuclear envelope.
2. Prokaryotes do **not** have mitochondria. ATP production occurs at the **plasma membrane** (and mesosome in some bacteria). This is a very common trap in MCQ distractors.

## Prokaryotic Cell Structure (Bacteria)

The following components are testable for IB. You may be asked to label a diagram.

Structure	Description
Nucleoid region	Area containing the circular, naked (no histone) DNA
Plasmid	Small, circular, extra-chromosomal DNA; not always present
Ribosomes (70S)	Site of protein synthesis; smaller than eukaryotic ribosomes
Cell wall	Rigid layer of peptidoglycan providing structural support
Plasma membrane	Phospholipid bilayer controlling substance entry/exit
Capsule	Outer polysaccharide layer; aids attachment and protection (not always present)
Flagella	Long protein filaments used for locomotion
Pili	Short protein projections used for attachment and conjugation

## Scale and Measurement

Cells are measured in micrometres ( $\mu\text{m}$ ) and nanometres (nm).

$$1 \text{ mm} = 1000 \mu\text{m} = 1,000,000 \text{ nm}$$

- Typical bacterial cell: **1–10  $\mu\text{m}$**

- Typical eukaryotic cell: **10–100  $\mu\text{m}$**
- Mitochondrion:  $\sim 1\text{--}10 \mu\text{m}$  (similar to a bacterium — relevant to endosymbiotic theory)

### 💡 IB TIP

**Why size matters:** The small size of prokaryotes gives them a high surface area : volume ratio, allowing efficient diffusion of materials across the plasma membrane. This is why large cells have internal transport systems (ER, vesicles) and prokaryotes do not need them.

## MCQ Practice — Section 1

**Question 1.** Which of the following is a feature found in prokaryotic cells but NOT in eukaryotic cells?

- A. Ribosomes
- B. Plasma membrane
- C. Circular DNA with no associated histones
- D. Cell wall

▶ Reveal answer

**Question 2.** A student views a cell under the electron microscope and observes ribosomes, a nucleoid region, and peptidoglycan in the cell wall. What type of cell is this?

- A. Plant cell
- B. Fungal cell
- C. Animal cell
- D. Bacterial cell

▶ Reveal answer

## Section 2: Eukaryotic Ultrastructure

### Animal vs Plant Cell — Key Differences

Feature	Animal Cell	Plant Cell
Cell wall	Absent	Present (cellulose)
Chloroplasts	Absent	Present
Large central vacuole	Absent (small vacuoles only)	Present — provides turgor pressure
Centrioles	Present	Absent in most plants
Shape	Irregular	More regular, often rectangular

## Organelle Functions — Testable Table

This table is frequently tested. Know the function of every organelle listed.

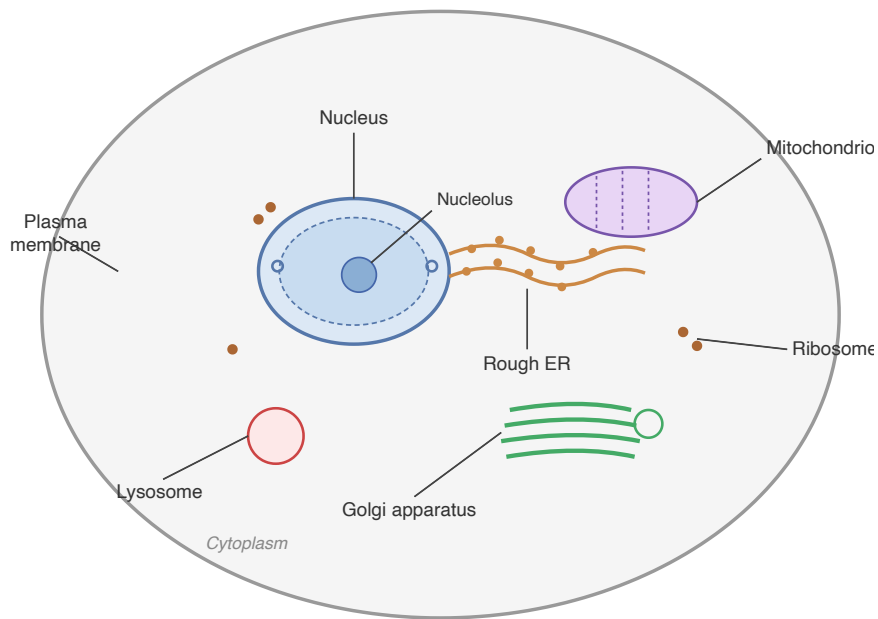
Organelle	Key Function	IB Detail
Nucleus	Stores DNA; directs protein synthesis	Double membrane (nuclear envelope) with nuclear pores; contains nucleolus (rRNA synthesis)
Mitochondria	ATP production via aerobic respiration	Double membrane; inner membrane folded into <b>cristae</b> ; matrix contains enzymes for Krebs cycle
Rough ER (RER)	Protein synthesis and transport	Covered with 80S ribosomes; continuous with outer nuclear membrane
Smooth ER (SER)	Lipid synthesis; detoxification	No ribosomes; prominent in liver cells and steroid-producing cells
Golgi apparatus	Modifies, packages, and routes proteins	Receives vesicles from RER; sorts proteins to lysosomes, plasma membrane, or secretion
Ribosomes (80S)	Protein synthesis	Free in cytoplasm or bound to RER; <b>70S</b> in mitochondria and chloroplasts
Lysosomes	Intracellular digestion	Contain hydrolytic enzymes; bud from Golgi; digest old organelles (autophagy) and pathogens
Large central vacuole	Turgor pressure; storage	Plant cells only; filled with cell sap; pushes cytoplasm against cell wall
Chloroplasts	Photosynthesis	Plant cells only; double membrane; thylakoid membrane + stroma; 70S ribosomes
Cell wall	Structural support; prevents over-expansion	Plants: cellulose; Fungi: chitin; Bacteria: peptidoglycan
Centrioles	Organise spindle fibres during cell division	Animal cells only; absent in most plant cells; found in pairs (centrosome)

### MEMORISE THIS

#### Quick Associations — “Which organelle does what?”

- **Energy** → Mitochondria (ATP via aerobic respiration)
- **Protein synthesis** → Ribosomes (all) + Rough ER (secreted/membrane proteins)
- **Protein packaging** → Golgi apparatus
- **Lipids** → Smooth ER
- **Digestion** → Lysosomes
- **Photosynthesis** → Chloroplasts (plants only)
- **Cell division spindle** → Centrioles (animals only)

## Generalised Eukaryotic Cell Diagram



Generalised eukaryotic cell (not to scale)

### EXAM ALERT

#### Drawing Requirements — Exam Alert:

IB Paper 2 frequently asks students to draw and label cell organelles. Marks are awarded for:

- **Nucleus:** show the **double membrane** (two parallel lines for the nuclear envelope) and indicate **nuclear pores** (gaps in the double membrane)
- **Mitochondria:** show the **outer membrane** and the **inner membrane folded into cristae** — draw wavy internal lines
- **Rough ER:** show as a system of **folded membranes continuous with the outer nuclear membrane**, with dots (ribosomes) on the cytoplasmic surface
- **Golgi apparatus:** show as a stack of flattened, curved **cisternae** with vesicles budding from the edges

Proportions matter — a nucleus drawn smaller than a ribosome will lose marks.

## Magnification and Scale

IB Paper 1 and Paper 2 both test magnification calculations.

$$\text{Magnification} = \frac{\text{image size}}{\text{actual size}}$$

Rearranged:

$$\text{Actual size} = \frac{\text{image size}}{\text{magnification}}$$

## WORKED EXAMPLE

### Worked Example — Scale Bar Calculation

A photograph shows a mitochondrion with a scale bar of  $1\ \mu\text{m}$  that measures 20 mm on the printed image. The mitochondrion image length is 48 mm. What is the actual length of the mitochondrion?

#### Step 1 — find magnification from the scale bar:

$$\text{Magnification} = \frac{\text{scale bar image length}}{\text{scale bar actual length}} = \frac{20\ \text{mm}}{0.001\ \text{mm}} = \times 20,000$$

(Note:  $1\ \mu\text{m} = 0.001\ \text{mm}$ )

#### Step 2 — find actual mitochondrion length:

$$\text{Actual size} = \frac{48\ \text{mm}}{20,000} = 0.0024\ \text{mm} = 2.4\ \mu\text{m}$$

**Answer:** The mitochondrion is **2.4  $\mu\text{m}$**  long.

### IB TIP

**Unit conversion reminder:** Always convert image size and actual size to the **same unit** before calculating. The most reliable approach is to work in millimetres throughout, then convert the answer to  $\mu\text{m}$  at the end ( $\times 1000$ ).

## MCQ Practice — Section 2

**Question 1.** Which of the following correctly identifies a structural difference between rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER)?

- A. RER has a double membrane; SER has a single membrane.
- B. RER is covered with ribosomes; SER has no ribosomes.
- C. RER produces lipids; SER synthesises proteins.
- D. RER is found only in animal cells; SER is found in all eukaryotes.

► Reveal answer

**Question 2.** A cell was treated with a drug that destroys the Golgi apparatus. Which process would be MOST directly impaired?

- A. DNA replication
- B. ATP production
- C. Secretion of proteins to the cell exterior
- D. Transcription of mRNA

► Reveal answer

## Section 3: Cell Division HL

Syllabus reference: D1.1 Cell Division

### The Cell Cycle

The cell cycle describes the ordered series of events a cell undergoes from formation to division. It has two major phases:

1. **Interphase** — the cell grows and replicates its DNA
2. **Mitotic phase (M phase)** — the cell divides

#### Interphase Sub-stages

Sub-stage	What Happens
G1 (Gap 1)	Cell grows; organelles replicate; proteins are synthesised
S (Synthesis)	DNA replication — each chromosome is duplicated to form two sister chromatids
G2 (Gap 2)	Further growth; cell prepares for division; DNA checked for errors

#### ⚠ EXAM ALERT

**Exam Alert:** DNA replication occurs during **S phase of interphase** — NOT during mitosis itself. In prophase (the first stage of mitosis), the chromosomes are already replicated; they condense into visible structures consisting of two sister chromatids joined at the centromere.

### Stages of Mitosis

Mitosis produces two genetically identical daughter cells from one parent cell ( $2n \rightarrow 2n$ ).

#### 📖 MEMORISE THIS

**PMAT** — the four stages of mitosis:

Stage	Key Events
Prophase	Chromosomes condense and become visible; spindle fibres form from centrioles (animals) or MTOCs (plants); nuclear envelope breaks down
Metaphase	Chromosomes align along the <b>cell equator</b> (metaphase plate); spindle fibres attach to centromeres
Anaphase	Spindle fibres shorten; <b>sister chromatids separate</b> and are pulled to opposite poles of the cell
Telophase	Nuclear envelopes re-form around each set of chromosomes; chromosomes decondense; spindle breaks down

**Cytokinesis** follows telophase — the cytoplasm divides, producing two daughter cells.

- In animals: cleavage furrow (actin ring pinches inward)
- In plants: cell plate forms from Golgi vesicles at the equator

### 💡 IB TIP

**Visualising mitosis:** In a root tip squash preparation viewed under a light microscope, you can identify each mitotic stage by chromosome arrangement. Metaphase is the easiest to identify — chromosomes are aligned in a single plane at the equator. This is the stage used for karyotyping.

## Mitosis vs Meiosis — Key Differences

Feature	Mitosis	Meiosis
Purpose	Growth; repair; asexual reproduction	Production of gametes (sexual reproduction)
Number of divisions	1	2 (Meiosis I + Meiosis II)
Starting cell	Diploid ( $2n$ )	Diploid ( $2n$ )
Daughter cells produced	2	4
Ploidy of daughter cells	Diploid ( $2n$ )	Haploid ( $n$ )
Genetic outcome	Genetically identical to parent	Genetically varied (crossing over + independent assortment)
Crossing over	Does not occur	Occurs in prophase I (between homologous chromosomes)
Homologous pairs align at equator?	No	Yes — in metaphase I

### ⚠️ EXAM ALERT

#### Anaphase Distinction — A Classic Exam Trap:

- In **mitosis anaphase**: **sister chromatids** separate. Each former chromatid becomes an individual chromosome pulled to a pole. The cell as a whole transiently contains  $4n$  chromosome strands ( $2n$  moving toward each pole), before cytokinesis restores  $2n$  per daughter cell.
- In **meiosis I anaphase**: **homologous chromosomes** separate (not sister chromatids — those remain joined). Each chromosome still consists of two chromatids.
- In **meiosis II anaphase**: sister chromatids now separate (same mechanism as mitotic anaphase).

The question will show you a diagram and ask what is separating. Count: if chromosomes are still double-stranded (two chromatids), it is meiosis I anaphase. If single-stranded, it is mitotic anaphase or meiosis II anaphase.

## MCQ Practice — Section 3

**Question 1.** During which phase of the cell cycle does DNA replication occur?

- A. G1 phase
- B. G2 phase
- C. S phase
- D. Prophase

► Reveal answer

**Question 2.** A cell has a diploid number of 8 ( $2n = 8$ ). After completing meiosis, what is the chromosome number in each daughter cell?

- A. 8
- B. 4
- C. 2
- D. 16

► Reveal answer

## Section 4: Exam Strategy

### Top 5 Mistakes on A1/D1 Questions

1. **Writing “nucleus” instead of “nucleoid region” for prokaryotes.** Prokaryotes have no membrane-bound nucleus. The IB mark scheme will not accept “nucleus” for a prokaryotic cell. Use the correct term: nucleoid region.
2. **Confusing 70S and 80S ribosomes.** Remember: prokaryotes, mitochondria, and chloroplasts all use 70S ribosomes. Eukaryotic cytoplasmic ribosomes are 80S. The endosymbiotic theory uses this fact as evidence.
3. **Stating that DNA replication happens during mitosis.** It does not — replication is complete before mitosis begins (S phase of interphase). During mitosis, the already-replicated chromosomes are simply sorted and separated.
4. **Confusing what separates in anaphase.** In mitotic anaphase: sister chromatids. In meiosis I anaphase: homologous chromosomes. Drawing a quick sketch and counting chromatid strands often resolves the confusion.
5. **Losing drawing marks for incorrect proportions or missing double membranes.** The nucleus and mitochondria both have double membranes — always draw two lines, not one. A nucleus should be drawn as roughly 10–20% of the cell’s diameter.

 **IB TIP**

**IB Drawing Mark Strategy:**

When asked to “draw and label a [organelle]”, IB mark schemes award marks for:

- Correct overall shape
- Internal structures labelled (e.g., cristae for mitochondria, nuclear pores for nucleus)
- Label lines that touch the structure, not floating beside it
- Correct proportions relative to other named structures

Practice drawing each major organelle from memory until you can produce a labelled diagram in under two minutes. This is a skill that requires repetition, not just reading.

### **MEMORISE THIS**

#### **Fast-Recall Checklist — A1/D1 Key Facts:**

- Cell theory: 3 tenets (all organisms = cells; cell = basic unit; cells from pre-existing cells)
- Prokaryote: no membrane-bound nucleus; 70S ribosomes; no membrane-bound organelles
- Eukaryote: membrane-bound nucleus; 80S ribosomes; membrane-bound organelles
- Magnification formula:  $\text{Image size} \div \text{Actual size}$
- Cell cycle:  $G1 \rightarrow S \rightarrow G2 \rightarrow \text{Mitosis (PMAT)} \rightarrow \text{Cytokinesis}$
- Mitosis:  $2n \rightarrow 2n$ , 2 identical cells
- Meiosis:  $2n \rightarrow n$ , 4 varied cells
- Anaphase of mitosis: sister chromatids separate
- Anaphase I of meiosis: homologous chromosomes separate

## **Virtual Lab Alignment: Labster Simulations**

### **IB TIP**

**Using Labster in IB Biology?** The simulations below map directly to IB Biology HL syllabus topics covered in this guide. Use them before your internal assessments (IAs) or to build intuition for experimental questions in Paper 3.

<b>Labster Simulation</b>	<b>IB HL Topic</b>	<b>What It Covers</b>
Cell Organelles: Be a Cell Biologist	A1: Ultrastructure of eukaryotic cells	Organelle function, endosymbiosis evidence
Cell Division: Observe Mitosis	A1/A2: Cell cycle and mitosis	Cell cycle stages, mitosis, cytokinesis
Cell Membrane: The Gatekeeper	A1: Fluid mosaic model	Phospholipid bilayer, membrane proteins, transport mechanisms
Confocal Microscopy: Imaging the Cell	A1: Techniques for visualising cell structure	Resolution, microscopy methods

**HL**

**How to use these simulations for IB exam prep:**

- The Cell Organelles simulation tests whether you can match structure to function — exactly what Paper 1 MCQs test
- Use the Cell Membrane simulation to visualise facilitated diffusion vs active transport before answering Paper 2 data-based questions
- The microscopy simulation helps with Paper 3 questions on experimental methods