

# Exam Preparation Notes

## B2.2 Organelles and Compartmentalization

### What this PDF helps you master

How organelles are adapted to their functions, why compartmentalization improves cell efficiency, and how to answer IB/A level questions using precise structure-function language.

Area	Included
Core focus	Organelles, compartmentalization, cell research methods, nucleus/cytoplasm, ribosomes, Golgi apparatus, vesicles and clathrin.
HL / A level depth	Mitochondria, chloroplasts, nuclear envelope, chemiosmosis links, Calvin cycle compartmentalization, and free vs bound ribosomes.
Exam style included	Definitions, diagrams in words, comparison tables, common mistakes, practice questions and mark schemes.

Prepared from the uploaded B2.2 organelles and compartmentalization source material.

# 1. How to use these notes

Use these notes in three passes. First, learn the exact definitions. Second, connect each structure to a function. Third, practise explaining advantages using exam wording such as because, therefore and so that.

## Exam strategy

A high-scoring answer does not only name an organelle. It links a named structure to a named process and then explains how this improves efficiency, protection, transport, secretion or energy production.

## Specification map

Section	What you must be able to explain
IB B2.2.1	Organelles as discrete subunits adapted to specific functions; cell wall, cytoskeleton and cytoplasm are not counted as organelles in this syllabus wording.
IB B2.2.2	Advantage of separating the nucleus and cytoplasm: transcription and post-transcriptional mRNA processing occur before translation.
IB B2.2.3	Cytoplasmic compartmentalization: concentration of enzymes/metabolites and separation of incompatible reactions; lysosomes and phagocytic vacuoles.
HL B2.2.4	Mitochondrion adaptations for ATP production by aerobic respiration.
HL B2.2.5	Chloroplast adaptations for photosynthesis.
HL B2.2.6	Functional benefits of the nuclear double membrane, pores, and nuclear envelope breakdown/reformation.
IB B2.2.7-9	Free and bound ribosomes, rough ER, Golgi processing/secretion, vesicles and clathrin in vesicle formation.
A level overlap	Eukaryotic cell structure, organelle function, protein synthesis/secretion pathway, membranes, endocytosis/exocytosis, mitochondria and chloroplast adaptations.

## Key command words

Command word	How to answer
State	Give a short answer, usually a name or fact. Example: "State the organelle containing cisternae."
Define	Give the precise meaning. Example: "Define compartmentalization."
Describe	Give features or steps. Example: "Describe the role of the Golgi apparatus."
Explain	Give a reasoned link. Example: "Explain how cristae increase ATP production."
Compare	Give similarities and differences. Example: "Compare free and bound ribosomes."

## 2. Big picture: organelles and compartmentalization

Organelles are specialized cell structures that perform specific functions. In eukaryotic cells, many organelles are membrane-bound, which means their internal conditions can be controlled separately from the cytoplasm.

Cell compartmentalization is the division of a cell into separate regions or compartments, often by single or double membranes. This allows different chemical reactions to occur at the same time without interfering with one another.

### Core idea to repeat in exams

Structure is related to function. For example, mitochondria have cristae, which increase membrane surface area for oxidative phosphorylation, allowing more ATP to be produced efficiently.

Advantage	Why it matters	Example
Separates incompatible reactions	Reactions that would interfere with each other can occur in different compartments.	Digestive enzymes are kept inside lysosomes.
Concentrates enzymes and substrates	Metabolites and enzymes are kept close together, increasing the efficiency of pathways.	Krebs cycle enzymes and substrates are in the mitochondrial matrix.
Maintains different conditions	Each compartment can have a specific pH, ion concentration or chemical environment.	Lysosomes are acidic; thylakoid lumens accumulate protons.
Allows division of labour	Different organelles specialize in different parts of cell function.	Ribosomes synthesize proteins; Golgi modifies and packages them.
Improves regulation	Membranes, pumps and carriers control movement between compartments.	mRNA leaves the nucleus through nuclear pores.

### IB organelle classification trap

Component	Organelle?	Main function
Cell wall	No	Protection and support in plant cells and some other cells.
Cytoskeleton	No	Maintains shape, anchors organelles and helps movement.
Cytoplasm	No	Region where many metabolic reactions occur.
Nucleus	Yes	Genetic control; site of transcription in eukaryotes.
Vesicles	Yes	Storage and transport.
Ribosomes	Yes	Protein synthesis.
Plasma membrane	Yes	Controls exchange, recognition and communication.
Cilia/flagella	Yes	Movement.
Golgi apparatus	Yes	Modifies, stores and packages products from the ER.
Mitochondria	Yes	ATP production by aerobic respiration.
Chloroplasts	Yes	Photosynthesis: conversion of light energy into chemical energy.
Lysosomes	Yes	Digestion of debris, worn organelles and materials taken in by endocytosis.

### 3. Tools for studying cells and organelles

Progress in cell biology often follows the development of new techniques. Microscopy allowed cells and organelles to be visualized, while fractionation and separation methods allowed individual cell components and molecules to be isolated and studied.

#### Nature of Science link

The function of individual organelles became easier to investigate after ultracentrifuges and cell fractionation methods were developed. This is a useful example of technology driving scientific progress.

Technique	What it separates	How it works	Exam link
Cell fractionation / centrifugation	Organelles and cell components.	Cells are broken open and spun. Larger or denser components sediment at lower speeds; smaller components require higher speeds.	Used to isolate organelles for biochemical study.
Ultracentrifugation	Very small organelles, membranes and macromolecular complexes.	Uses extremely high spinning speeds to separate components by size, shape and density.	Explains how individual organelle functions could be studied.
Chromatography	Pure substances such as amino acids, proteins, carbohydrates and plant pigments.	A mixture moves through a medium; components separate according to properties such as size and speed of movement.	Useful for pigments and biochemical molecules.
Gel electrophoresis	Molecules such as DNA fragments and proteins.	An electrical field moves molecules through a gel; separation depends on size and charge.	Commonly used with nucleic acids and DNA fingerprinting.
Fluorescent dyes	Specific labelled molecules.	Dyes absorb light at one wavelength and emit light at a longer wavelength, making tagged molecules visible.	Ethidium bromide can make DNA fragments visible under UV light.

#### Common exam question

**Question: Which technique uses an electrical current to separate molecules?**

Answer: Gel electrophoresis. It is often used to separate nucleic acids, especially DNA fragments, by size and charge.

## 4. Nucleus and cytoplasm: why separation matters

In eukaryotic cells, the nucleus separates DNA from the cytoplasm. This separation allows transcription and RNA processing to occur before mRNA reaches ribosomes for translation.

<b>Eukaryotic cell</b>	DNA is inside nucleus	Transcription occurs in nucleus	mRNA is processed	mRNA exits through nuclear pores	Translation occurs at ribosomes in cytoplasm or rough ER
<b>Prokaryotic cell</b>	No nucleus	Transcription occurs in cytoplasm	Limited/no compartmental separation	mRNA can meet ribosomes immediately	Translation can begin quickly without the same processing stage

### Transcription, translation and mRNA processing

- Transcription: a DNA strand is used as a template to make mRNA.
- Translation: ribosomes use the code carried by mRNA to build a polypeptide/protein.
- Post-transcriptional modification: changes to mRNA before translation. This can reduce the chance of errors in the final protein.
- Key comparison: eukaryotes can process mRNA in the nucleus before it meets ribosomes; prokaryotes cannot separate these processes in the same way because they lack a nucleus.

#### Best exam phrasing

The nuclear envelope separates transcription from translation, so mRNA can be modified before it is translated. This improves control over protein production and reduces the chance of faulty polypeptides being produced.

### Mark-scheme sentence starter

"In eukaryotes, transcription occurs in the nucleus whereas translation occurs in the cytoplasm. Therefore, mRNA can undergo post-transcriptional modification before reaching ribosomes."

## 5. Compartmentalization in the cytoplasm

Eukaryotic cells contain many compartments involved in energy production, metabolism, biosynthesis and degradation. The number and size of organelles vary according to the function of the cell.

For example, secretory pancreatic acinar cells have enlarged rough ER, Golgi apparatus and storage granules because they produce and secrete large amounts of digestive enzymes.

Feature	Importance	Example
Division of labour	Different organelles specialize in different processes.	Ribosomes synthesize proteins; Golgi modifies and packages them.
Concentration of enzymes and metabolites	Pathways run faster and are easier to control when reactants are localized.	Krebs cycle enzymes are held in the mitochondrial matrix.
Separation of destructive enzymes	Potentially damaging reactions are isolated from the rest of the cell.	Lysosomal digestive enzymes are enclosed by a membrane.
Protection during endocytosis	Materials brought into the cell are held in vesicles/vacuoles until processed safely.	A phagocytic vacuole forms around a pathogen or food particle.
Integration through transport	Membrane pumps, carriers and vesicles move products between compartments.	Proteins move from rough ER to Golgi in transport vesicles.

### Lysosomes and phagocytic vacuoles

A lysosome contains hydrolytic digestive enzymes. These enzymes can break down worn-out organelles, cellular debris and material taken in by endocytosis. Because the enzymes could damage cell structures, they are isolated inside a membrane-bound compartment.

Step	What happens	Why it matters
1. Entrapment	The plasma membrane surrounds a food particle or pathogen.	The foreign material is kept separate from the cytoplasm.
2. Phagocytic vacuole formation	The membrane encloses the material inside a vacuole.	Potentially harmful material is isolated.
3. Fusion with lysosome	A lysosome fuses with the vacuole.	Digestive enzymes are delivered only where needed.
4. Digestion	The contents are broken down and useful products may be reused.	The rest of the cell is protected from destructive enzymes.

#### Do not forget the challenge

Compartmentalization also creates a problem: compartments must communicate. Cells solve this using vesicles, membrane channels, carriers and pumps.

## 6. HL / A level: mitochondrion adaptations for ATP production

The mitochondrion is adapted for aerobic respiration. Its structure allows reactions of the link reaction, Krebs cycle, electron transport chain and chemiosmosis to occur efficiently in specific compartments.

Overall aerobic respiration equation:  $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$

Structure	Function	ATP link
Outer membrane	Separates the mitochondrion from the cytoplasm.	Creates a controlled internal environment.
Intermembrane space	Small space between the inner and outer membranes.	Protons accumulate quickly, producing a steep concentration gradient for chemiosmosis.
Inner membrane	Contains electron transport chain carriers and ATP synthase.	Provides the site of oxidative phosphorylation.
Cristae	Folded regions of the inner membrane.	Increase surface area for electron transport chains and ATP synthase, allowing more ATP to be produced.
Matrix	Fluid interior containing enzymes and substrates for the link reaction and Krebs cycle.	Allows early mitochondrial stages of respiration to occur efficiently in one compartment.
Mitochondrial DNA and ribosomes	Allow some mitochondrial proteins to be produced inside the organelle.	Supports partial independence and is evidence linked to endosymbiosis.

### Mitochondrion diagram in words

Cytoplasm
Outer membrane: controls boundary of the organelle
Small intermembrane space: proton reservoir
Inner membrane folded into cristae: electron transport chain + ATP synthase
Matrix: link reaction + Krebs cycle enzymes and substrates

#### Common exam trap

Do not say cristae are in chloroplasts. Cristae are folds of the inner mitochondrial membrane. Thylakoids and grana are chloroplast structures.

## 7. HL / A level: chloroplast adaptations for photosynthesis

The chloroplast is adapted for photosynthesis. It contains membrane systems for the light-dependent reactions and a fluid stroma where the Calvin cycle occurs.

Overall photosynthesis equation:  $6\text{CO}_2 + 12\text{H}_2\text{O} + \text{light} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O} + 6\text{O}_2$

Structure	Function	Photosynthesis link
Double outer membrane	Separates chloroplast contents from the cytoplasm.	Allows a controlled internal environment for photosynthesis.
Thylakoid membranes	Contain photosystems and electron carriers.	Large membrane surface area increases light absorption and light-dependent reaction capacity.
Grana	Stacks of thylakoids.	Increase the amount of photosynthetic membrane in a compact space.
Thylakoid lumen	Small internal fluid volume.	Protons accumulate quickly, creating a gradient for ATP production.
Stroma	Fluid region containing enzymes and substrates for the Calvin cycle.	Allows carbon fixation and synthesis of carbohydrate to occur in one compartment.
Chloroplast DNA and ribosomes	Allow some proteins to be produced in the chloroplast.	Supports endosymbiotic evidence and partial independence.

### Chloroplast diagram in words

Outer + inner membranes: isolate chloroplast reactions from cytoplasm
Stroma: Calvin cycle enzymes and substrates
Grana: stacks of thylakoids
Thylakoid membranes: photosystems absorb light
Thylakoid lumen: small volume for rapid proton accumulation

### Mitochondria vs chloroplasts

Feature	Mitochondrion	Chloroplast
Main process	Aerobic respiration.	Photosynthesis.
Energy transformation	Energy from glucose is used to make ATP.	Light energy is converted into chemical energy.
Folded/internal membranes	Cristae increase inner membrane surface area.	Thylakoid membranes/grana increase photosynthetic membrane surface area.
Fluid compartment	Matrix contains enzymes/substrates for link reaction and Krebs cycle.	Stroma contains enzymes/substrates for Calvin cycle.
Small proton space	Intermembrane space allows rapid proton gradient formation.	Thylakoid lumen allows rapid proton gradient formation.
Evidence for endosymbiosis	Own DNA, ribosomes, double membrane, size similar to prokaryotes.	Own DNA, ribosomes, double membrane, size similar to prokaryotes.

## 8. HL / A level: nuclear envelope and pores

The nucleus is surrounded by a double membrane called the nuclear envelope. This separates DNA from the cytoplasm while still allowing controlled exchange through nuclear pores.

Feature	Function	Exam explanation
Double membrane / nuclear envelope	Separates nucleoplasm from cytoplasm.	Allows DNA-related processes to occur without direct interference from cytoplasmic reactions.
Nuclear pores	Control movement between nucleus and cytoplasm.	mRNA exits to ribosomes; proteins and RNA-protein complexes can enter or leave.
Outer nuclear membrane	Continuous with the endoplasmic reticulum and may have ribosomes attached.	Links nuclear structure to the endomembrane system.
Inner nuclear membrane	Interacts with chromatin and helps maintain nuclear shape.	Contributes to nuclear organization and gene regulation.
Nucleolus	Produces ribosomal RNA and assembles ribosomal subunits/RNA-protein complexes.	Supports ribosome production.
Nuclear envelope breakdown	During mitosis and meiosis, the envelope breaks into vesicles.	Allows chromosomes to move and be separated; vesicles later reform envelopes around daughter nuclei.

### Chromatin and chromosomes

- Chromatin is DNA associated with proteins. It is usually elongated and less visible during most of the cell cycle.
- Before cell division, chromatin condenses into visible chromosomes.
- Chromatin structure can influence gene expression because it affects how accessible DNA is to enzymes. Such changes are epigenetic when the DNA sequence itself is not changed.

#### Common exam trap

Nuclear pores do not mean the nucleus is open. They are controlled passageways for specific molecules such as mRNA, proteins and RNA-protein complexes.

## 9. Ribosomes, rough ER and protein destination

Ribosomes are organelles made of ribosomal RNA and proteins. Each ribosome has a large and a small subunit, with binding sites for mRNA and amino-acid-carrying molecules. Their function is protein synthesis.

Ribosomes are found in both prokaryotic and eukaryotic cells, although prokaryotic ribosomes are smaller.

Ribosome type	Protein produced	Destination	Exam wording
Free ribosomes in cytoplasm	Proteins that remain inside the cell.	Used in cytoplasm, nucleus, mitochondria, cytoskeleton or other internal locations.	"Free ribosomes synthesize proteins for retention in the cell."
Ribosomes bound to rough ER	Proteins that enter the ER system.	Transported through ER and often sent to Golgi for modification, secretion or membrane insertion.	"Bound ribosomes synthesize proteins for transport within the cell or secretion."

### Protein secretion pathway

Step	Protein secretion pathway
1	Membrane-bound ribosome on rough ER synthesizes a secretory protein.
2	The protein enters the rough ER and is transported in the endomembrane system.
3	Transport vesicles carry protein from ER to the cis side of the Golgi apparatus.
4	The Golgi modifies, sorts and packages the protein.
5	Secretory vesicles leave the trans side of the Golgi and move to the plasma membrane.
6	Vesicles fuse with the plasma membrane and release contents by exocytosis.

#### A level/IB linking point

Cells that secrete many proteins, such as enzyme-secreting cells, usually contain abundant rough ER and Golgi apparatus because they must synthesize, process and export large amounts of protein.

## 10. Golgi apparatus, vesicles and clathrin

The Golgi apparatus is made of flattened sacs called cisternae. It receives products from the ER, modifies them, sorts them and packages them into vesicles.

Feature	Function
Golgi feature	Function
Cisternae	Flattened sacs where proteins and lipids are processed and modified.
Cis side	Receiving side, usually near the ER; transport vesicles arrive here.
Trans side	Shipping side, directed toward the plasma membrane; secretory vesicles leave here.
Modification	Proteins/lipids may be chemically altered and given signal molecules that direct their destination.
Packaging	Products are packed into vesicles for secretion, lysosome formation, return to ER or transport elsewhere.

### Vesicle types

Vesicle type	Role
Vesicle type	Role
Transport vesicles	Move molecules between organelles, such as ER to Golgi.
Secretory vesicles	Carry materials to be released from the cell, such as hormones or neurotransmitters.
Lysosomes	Contain enzymes for digestion of debris, pathogens or damaged organelles.
Peroxisomes	Contain enzymes involved in reactions such as fatty acid breakdown.

### Clathrin and receptor-mediated endocytosis

Clathrin is a protein involved in forming coated pits and coated vesicles during receptor-mediated endocytosis. This allows cells to take in specific molecules efficiently.

Step	What happens
1. Specific binding	A target molecule binds to a specific receptor protein on the plasma membrane.
2. Coated pit formation	Clathrin proteins help form a coated pit beneath the membrane.
3. Vesicle formation	The pit deepens and pinches off to form a coated vesicle.
4. Selective uptake	Because receptors are specific, the cell takes in selected molecules efficiently.

#### Why this matters

Receptor-mediated endocytosis is more selective and efficient than ordinary endocytosis. The specificity is important when cells need to take in particular molecules rather than large amounts of surrounding fluid.

# 11. High-yield comparison tables

Use these tables for quick revision before a test or exam.

## Structure-function pairs

Structure	Function	Exam phrase
Structure	Function	Exam phrase
Cristae	Increase inner mitochondrial membrane surface area.	More space for electron transport chains and ATP synthase.
Small mitochondrial intermembrane space	Allows rapid proton accumulation.	Steep proton gradient drives ATP synthesis.
Mitochondrial matrix	Contains Krebs cycle enzymes and substrates.	Keeps pathway components concentrated.
Thylakoid membranes	Contain photosystems.	Large surface area improves light absorption.
Small thylakoid lumen	Allows rapid proton accumulation.	Supports ATP production in photosynthesis.
Stroma	Contains Calvin cycle enzymes and substrates.	Compartment for carbon fixation reactions.
Nuclear pores	Control exchange between nucleus and cytoplasm.	Allow mRNA to leave and proteins/RNA complexes to move in/out.
Rough ER ribosomes	Synthesize proteins for transport/secretion.	Proteins move through ER and Golgi.
Golgi trans face	Sends vesicles toward destinations.	Modified products are packaged for secretion or delivery.
Clathrin coated pit	Forms selective endocytosis vesicles.	Allows receptor-mediated uptake of specific molecules.

## Common confusions

Trap	Correct version
Confusion	Correct distinction
Vesicle vs vacuole	Both are membrane-bound sacs, but vacuoles are generally larger; vesicles are usually smaller transport/storage sacs.
Cristae vs thylakoids	Cristae are mitochondrial inner membrane folds; thylakoids are chloroplast membrane sacs containing photosystems.
Matrix vs stroma	Matrix is in mitochondria; stroma is in chloroplasts.
Free vs bound ribosomes	Free ribosomes make proteins retained in the cell; bound ribosomes make proteins for transport/secretion or membranes.
Endocytosis vs exocytosis	Endocytosis brings material into the cell; exocytosis releases material from the cell.
Cis vs trans Golgi	Cis receives vesicles from ER; trans sends vesicles to destinations such as plasma membrane.
Cell wall/cytoplasm/cytoskeleton as organelles	For this IB topic, these are not considered organelles; do not list them as organelles in a direct question.

## 12. Exam answer templates

Use these sentence structures to build mark-worthy explanations.

Question type	Template
Question type	Answer template
Explain an adaptation	"[Structure] has [feature], which [immediate effect], so [process] occurs more efficiently."
Explain compartmentalization	"The membrane separates [reaction/material] from [other cell contents], preventing interference/damage and allowing [condition/enzyme/substrate] to be controlled."
Compare organelles	"Both [A] and [B] have [similarity]. However, [A] is adapted for [process] by [feature], whereas [B] is adapted for [process] by [feature]."
Link nucleus to protein synthesis	"The nuclear envelope separates transcription from translation, allowing mRNA processing before mRNA reaches ribosomes."
Protein secretion pathway	"Bound ribosomes synthesize the protein, ER transports it, Golgi modifies and packages it, and secretory vesicles release it by exocytosis."

### Model paragraph: 4 marks

#### Explain the advantage of compartmentalization in eukaryotic cells.

Compartmentalization separates different biochemical processes into membrane-bound regions. This allows enzymes and substrates for a pathway to be concentrated in one place, increasing efficiency. It also prevents incompatible or damaging reactions from interfering with the rest of the cell, for example digestive enzymes are kept inside lysosomes. Membranes, vesicles, pumps and carriers then allow products to be moved between compartments in a controlled way.

### Model paragraph: 4 marks

#### Explain how the mitochondrion is adapted for aerobic respiration.

The inner mitochondrial membrane is folded into cristae, increasing the surface area for electron transport chains and ATP synthase. The intermembrane space has a small volume, so protons can accumulate quickly and form a steep concentration gradient. The matrix contains enzymes and substrates for the link reaction and Krebs cycle. These features allow oxidative phosphorylation and ATP production to occur efficiently.

### Model paragraph: 4 marks

#### Explain how the chloroplast is adapted for photosynthesis.

Thylakoid membranes provide a large surface area for photosystems, increasing light absorption. The thylakoid lumen has a small volume, so protons accumulate quickly to form a gradient for ATP production. The stroma contains enzymes and substrates for the Calvin cycle. The double membrane helps isolate chloroplast reactions from the surrounding cytoplasm.

## 13. Practice questions

Answer these without looking first. Then compare with the mark scheme on the next pages.

### Section A: short answer

- 1 Define cell compartmentalization.
- 2 State two cell components that are not considered organelles in this IB topic.
- 3 Explain why post-transcriptional modification is possible in eukaryotes but not in prokaryotes in the same way.
- 4 Name the cell fractionation process that uses electrical current to separate molecules by size and charge.
- 5 Describe one advantage of using ultracentrifugation in cell biology research.
- 6 Explain why lysosomes are membrane-bound.
- 7 Contrast free ribosomes and ribosomes bound to rough ER.
- 8 State the function of the cis side and trans side of the Golgi apparatus.
- 9 Describe the role of clathrin in receptor-mediated endocytosis.
- 10 Explain why pancreatic acinar cells have extensive ER and Golgi apparatus.

### Section B: multiple choice

- 1 Which organelle contains cisternae involved in modification and transport of substances? A. Golgi apparatus B. Nucleus C. Chloroplast D. Ribosome
- 2 Which substance is most likely to be found in vesicles leaving smooth ER? A. Proteins B. Carbohydrates C. Nucleic acids D. Lipids
- 3 Which structure is most directly associated with receptor-mediated endocytosis? A. ATP synthase B. Clathrin C. Cristae D. Stroma
- 4 Which organelle is most likely to have pores in its surrounding membrane? A. Ribosome B. Vesicle C. Chloroplast D. Nucleus
- 5 Which matching pair is correct? A. Chloroplast - matrix B. Chloroplast - cristae C. Ribosome - membrane D. Mitochondrion - double membrane
- 6 A damaged mitochondrion is broken down by which organelle? A. Vacuole B. Lysosome C. Ribosome D. Centrosome

# Practice questions continued

## Section C: structured response

- 1 6 marks: Explain the advantages of compartmentalization in eukaryotic cells. Include examples.
- 2 5 marks: Explain how the structure of the mitochondrion is adapted for aerobic respiration.
- 3 5 marks: Explain how the structure of the chloroplast is adapted for photosynthesis.
- 4 4 marks: Describe the pathway followed by a secreted protein from synthesis to release from the cell.
- 5 4 marks: Compare the nucleus of a eukaryotic cell with the genetic region of a prokaryotic cell in relation to transcription and translation.
- 6 3 marks: Explain the benefit of a small intermembrane space in the mitochondrion.
- 7 3 marks: Explain the benefit of a small thylakoid lumen in the chloroplast.
- 8 4 marks: Describe receptor-mediated endocytosis and explain why it is selective.

## Section D: data/diagram style prompts

- 1 A diagram shows a chloroplast with labels for stroma, grana, thylakoid membrane and double membrane. Identify the site of the Calvin cycle and explain your answer.
- 2 A TEM image shows an organelle with many inner membrane folds. Identify the organelle and explain how the folds support its function.
- 3 A cell secretes large quantities of enzyme. Predict which organelles would be abundant and justify your prediction.
- 4 A scientist isolates cell components using centrifugation. Explain why larger and denser components are usually separated at lower speeds.

## 14. Mark scheme: short answer and multiple choice

Use these mark schemes to check whether your answers contain enough precise biological detail.

Q	Indicative answer
1	Division of a cell into separate regions/compartments, usually by membranes, allowing different processes to occur separately.
2	Any two: cell wall, cytoskeleton, cytoplasm.
3	Eukaryotes have a nucleus, so transcription occurs in the nucleus and translation occurs in the cytoplasm. mRNA can be modified before leaving the nucleus. Prokaryotes lack a nucleus, so mRNA can contact ribosomes immediately.
4	Gel electrophoresis. Often used for nucleic acids/DNA fragments; can also separate proteins depending on context.
5	It separates organelles/cell components by size, shape and density, allowing individual organelles to be isolated and studied.
6	They contain digestive/hydrolytic enzymes that could damage cell structures if released; the membrane isolates and controls these enzymes.
7	Free ribosomes make proteins retained within the cell. Bound ribosomes on rough ER make proteins for transport within the endomembrane system, secretion or membranes.
8	Cis side receives vesicles from ER; trans side sends modified/packaged products in vesicles toward destinations such as the plasma membrane.
9	Clathrin forms/lines coated pits and helps the membrane invaginate and pinch off into coated vesicles during receptor-mediated endocytosis.
10	They secrete digestive enzymes, so they need extensive rough ER for protein synthesis, Golgi for modification/packaging, and vesicles/granules for storage and secretion.

### Multiple choice answers

Q	Answer
1	A - Golgi apparatus
2	D - Lipids
3	B - Clathrin
4	D - Nucleus
5	D - Mitochondrion - double membrane
6	B - Lysosome

## 15. Mark scheme: structured response

Award credit for clear structure-function links. Equivalent wording is acceptable if the biological meaning is correct.

Question	Mark points
1. Compartmentalization - 6 marks	Membranes divide the cell into compartments; enzymes/substrates can be concentrated; incompatible reactions are separated; destructive enzymes are isolated in lysosomes; different conditions such as pH/ion concentration can be maintained; vesicles/pumps/carriers integrate compartments; examples such as mitochondria, chloroplasts, lysosomes or phagocytic vacuoles.
2. Mitochondrion - 5 marks	Double membrane creates compartments; cristae increase surface area; inner membrane has ETC and ATP synthase; small intermembrane space allows proton gradient to form quickly; matrix contains enzymes/substrates for link reaction and Krebs cycle.
3. Chloroplast - 5 marks	Double membrane isolates contents; thylakoid membranes contain photosystems; grana/thylakoids provide large surface area; small thylakoid lumen allows proton gradient to form quickly; stroma contains enzymes/substrates for Calvin cycle.
4. Secreted protein pathway - 4 marks	Bound ribosome on rough ER synthesizes protein; protein enters/transported through ER; vesicle transports to Golgi; Golgi modifies/sorts/packages; secretory vesicle fuses with plasma membrane; protein released by exocytosis.
5. Eukaryote vs prokaryote - 4 marks	Eukaryotes have nuclear envelope; transcription in nucleus; mRNA can be processed before leaving nucleus; translation occurs in cytoplasm/rough ER. Prokaryotes lack nucleus, so transcription and translation are not separated and mRNA can meet ribosomes immediately.
6. Small intermembrane space - 3 marks	Protons pumped into it; small volume means concentration rises quickly; steep proton gradient drives ATP synthase/chemiosmosis efficiently.
7. Small thylakoid lumen - 3 marks	Protons accumulate inside lumen; small volume forms gradient quickly; proton movement through ATP synthase supports ATP production in light-dependent reactions.
8. Receptor-mediated endocytosis - 4 marks	Specific molecule binds receptor; clathrin forms coated pit; membrane invaginates and pinches off as coated vesicle; selectivity occurs because only molecules fitting receptors are taken in.

# 16. Last-minute revision sheet

Memorise these statements and practise expanding each one into a full explanation.

Topic	Must-know points
Topic	Must-know points
Compartmentalization	Separates processes; concentrates enzymes/substrates; maintains different conditions; protects cell from destructive reactions; requires controlled transport between compartments.
Nucleus	Double membrane; nuclear pores; transcription in nucleus; mRNA processing before translation; envelope breaks into vesicles during mitosis/meiosis and reforms later.
Mitochondrion	Double membrane; cristae; small intermembrane space; matrix; inner membrane with ETC/ATP synthase; adapted for ATP production by aerobic respiration.
Chloroplast	Double membrane; thylakoid membranes with photosystems; grana; small thylakoid lumen; stroma for Calvin cycle; adapted for photosynthesis.
Ribosomes	Made of rRNA and proteins; two subunits; free ribosomes make internal proteins; bound ribosomes make proteins for transport/secretion.
Golgi apparatus	Cisternae; cis side receives from ER; modifies/sorts/packages; trans side sends vesicles; important in secretion and lysosome formation.
Vesicles	Transport/storage sacs; secretory vesicles release materials; lysosomes digest; clathrin helps receptor-mediated endocytosis.
Research techniques	Centrifugation separates organelles by size/density; chromatography separates biochemical substances; gel electrophoresis separates molecules by size/charge; fluorescent dyes reveal specific molecules.

## Top 10 exam traps

- 1 Calling cytoplasm, cytoskeleton or cell wall organelles in this IB topic.
- 2 Saying translation happens in the nucleus.
- 3 Confusing matrix with stroma.
- 4 Confusing cristae with thylakoids.
- 5 Writing "more surface area" without saying what occurs on that surface.
- 6 Forgetting that small spaces help concentration gradients form quickly.
- 7 Saying all ribosomes make secreted proteins; only bound ribosomes on rough ER usually do this.
- 8 Reversing Golgi cis and trans sides.
- 9 Describing clathrin as a receptor; it forms/supports coated pits and vesicles.
- 10 Only naming an organelle without linking structure to function.

### Final exam reminder

For every organelle question, write in this order: name the structure, describe the feature, link it to the process, then explain the advantage.