



Organelles and compartmentalization

Revision notes · IB Biology B2.2: organelles, cell fractionation, compartmentalization, and HL structure and function of mitochondria, chloroplasts, ER and Golgi.

For IB Diploma Biology, Standard Level and Higher Level (first assessment 2025). **HL only** is additional higher level content, for HL students only.

Organelles and compartmentalization **Spec B2.2**

Organelles, the nucleus and compartments **Spec B2.2.1-B2.2.3**

Organelles are discrete subunits of cells that are adapted to perform specific functions. Nuclei, mitochondria, chloroplasts, the endoplasmic reticulum, the Golgi apparatus, vesicles, ribosomes and the plasma membrane are all organelles.

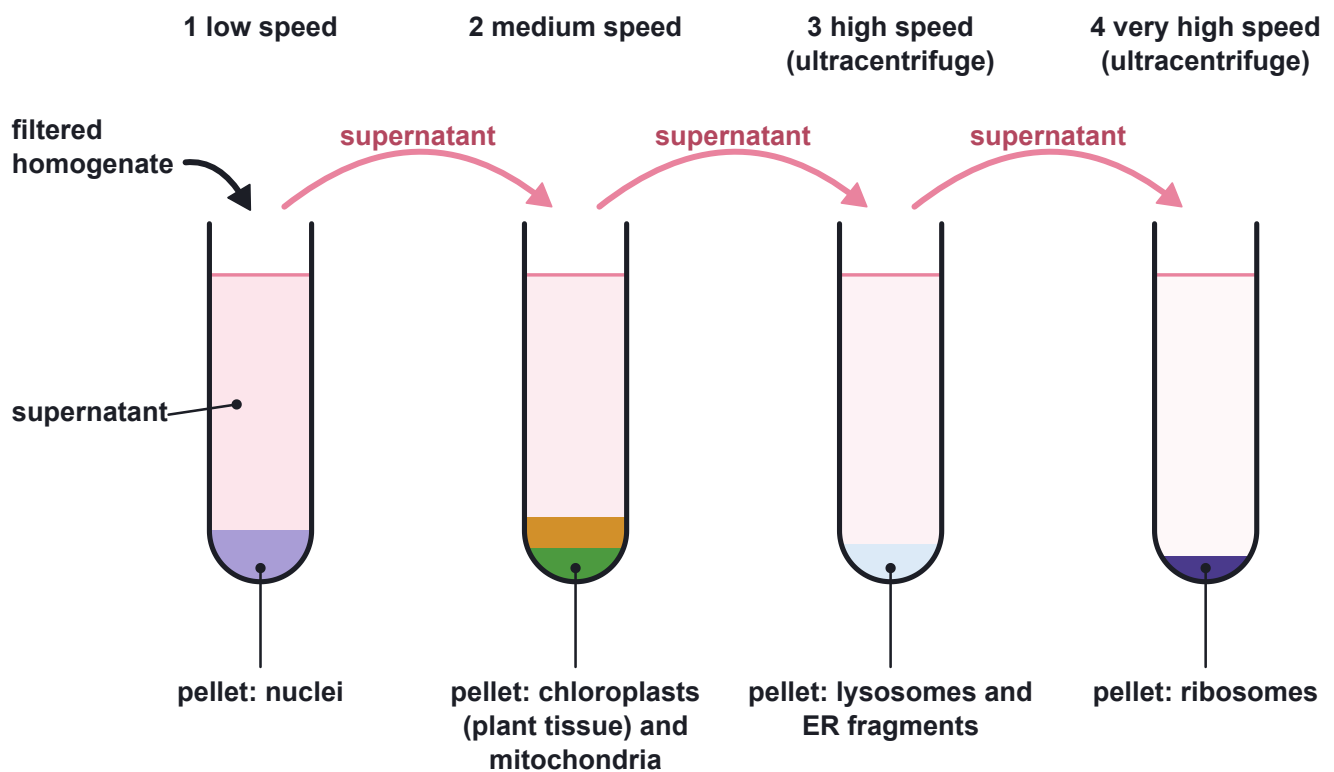
The cell wall, the cytoskeleton and the cytoplasm are **not considered organelles**. The wall lies outside the plasma membrane, the cytoskeleton is a network running through the whole cell, and the cytoplasm is the medium in which the organelles sit.

Cell fractionation

Progress in science often follows the development of new techniques. The functions of individual organelles could only be studied once **ultracentrifuges** had been invented and methods of using them for **cell fractionation** had been developed.

1. Tissue is cut up and homogenised (blended) in a cold, isotonic, buffered solution to break the cells open.
2. The homogenate is filtered to remove large debris.
3. It is spun in a centrifuge at low speed. The largest, densest organelles (nuclei) form a pellet at the bottom of the tube.
4. The liquid above the pellet (the supernatant) is spun at a higher speed to pellet chloroplasts (from plant tissue) and then mitochondria, then at even higher speeds in an ultracentrifuge for smaller parts such as fragments of ER and ribosomes.
5. Each pellet is resuspended and tested, for example by measuring the activity of enzymes, to find out what that organelle does.

Practical skill: Cold slows enzymes that would digest the organelles, an isotonic solution stops organelles gaining or losing water by osmosis, and a buffer keeps the pH constant so proteins are not denatured.



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Differential centrifugation: each faster spin pellets **smaller, less dense** organelles from the supernatant.

Separating the nucleus from the cytoplasm

In eukaryotes, **transcription** happens in the nucleus and **translation** happens at ribosomes in the cytoplasm. Because they are in separate compartments, **post-transcriptional modification** of mRNA (such as removing introns) can happen before the mRNA meets ribosomes. Prokaryotes have no nucleus, so mRNA may meet ribosomes immediately and translation can begin before transcription has finished.

Compartments in the cytoplasm

- Enzymes and their substrates (metabolites) can be concentrated in a small volume, so reactions are faster.
- Incompatible biochemical processes are kept apart, for example digestion of molecules and their synthesis.
- Conditions such as pH can be kept different in each compartment.

Lysosomes are vesicles containing hydrolytic enzymes that work best at acid pH. If these enzymes were free in the cytoplasm they would digest the cell's own molecules. **Phagocytic vacuoles** form when a cell such as a white blood cell engulfs a bacterium by endocytosis. Lysosomes then fuse with the vacuole, so the bacterium is digested inside a closed compartment.

Exam tip: Linking question: what separation techniques are used by biologists? Centrifugation separates cell parts by size and density; compare chromatography and gel electrophoresis, which separate molecules.

Adaptations of mitochondria and chloroplasts

Spec B2.2.4, B2.2.5

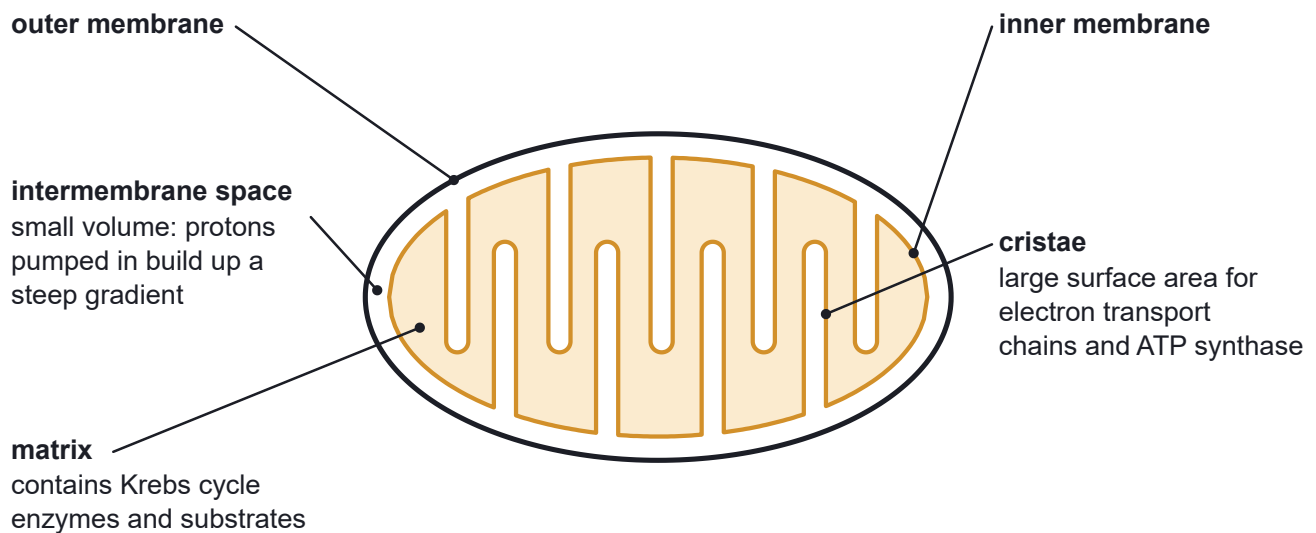
HL only

Adaptations of the mitochondrion for production of ATP by aerobic cell respiration

Feature	Adaptation
Double membrane	The outer membrane separates the mitochondrion from the cytoplasm; the inner membrane holds the electron transport chain and ATP synthase.
Small volume of intermembrane space	Protons pumped into it by the electron transport chain quickly build up to a high concentration, giving a steep gradient for making ATP by chemiosmosis.
Cristae	Folds of the inner membrane give a large surface area for many electron transport chains and ATP synthase molecules.
Matrix	Compartmentalizes the enzymes and substrates of the Krebs cycle, keeping them together at high concentration.

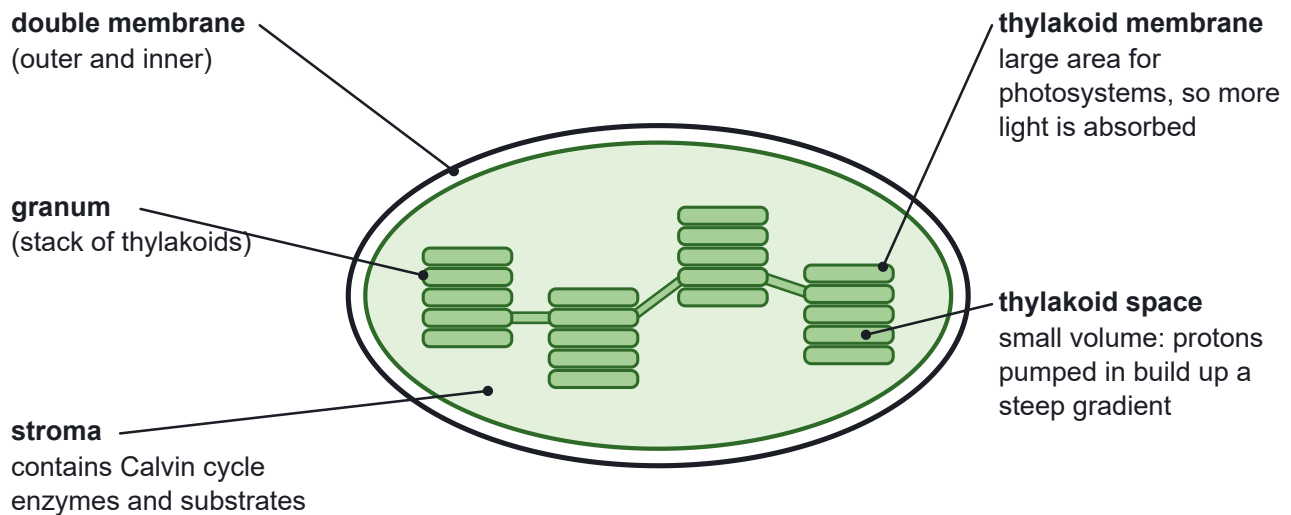
Adaptations of the chloroplast for photosynthesis

Feature	Adaptation
Thylakoid membranes	Stacked into grana, giving a large surface area for photosystems, so more light can be absorbed.
Small volume of fluid inside thylakoids	Protons pumped into the thylakoid space quickly reach a high concentration, giving a steep gradient for making ATP.
Stroma	Compartmentalizes the enzymes and substrates of the Calvin cycle , close to the ATP and NADPH made by the thylakoids.



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Mitochondrion: **cristae** give a large area for electron transport chains and ATP synthase.



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Chloroplast: stacked **thylakoids** give a large area for photosystems; the **stroma** holds the Calvin cycle enzymes.

Exam tip: For an 'explain the adaptation' question, give the feature and then its effect: for example, a small intermembrane space, so a high proton concentration builds up quickly.

The nucleus, free ribosomes and rough ER Spec B2.2.6, B2.2.7 HL only

The double nuclear membrane

The nucleus is enclosed by two membranes, together called the **nuclear envelope**. The outer membrane is continuous with the rough endoplasmic reticulum.

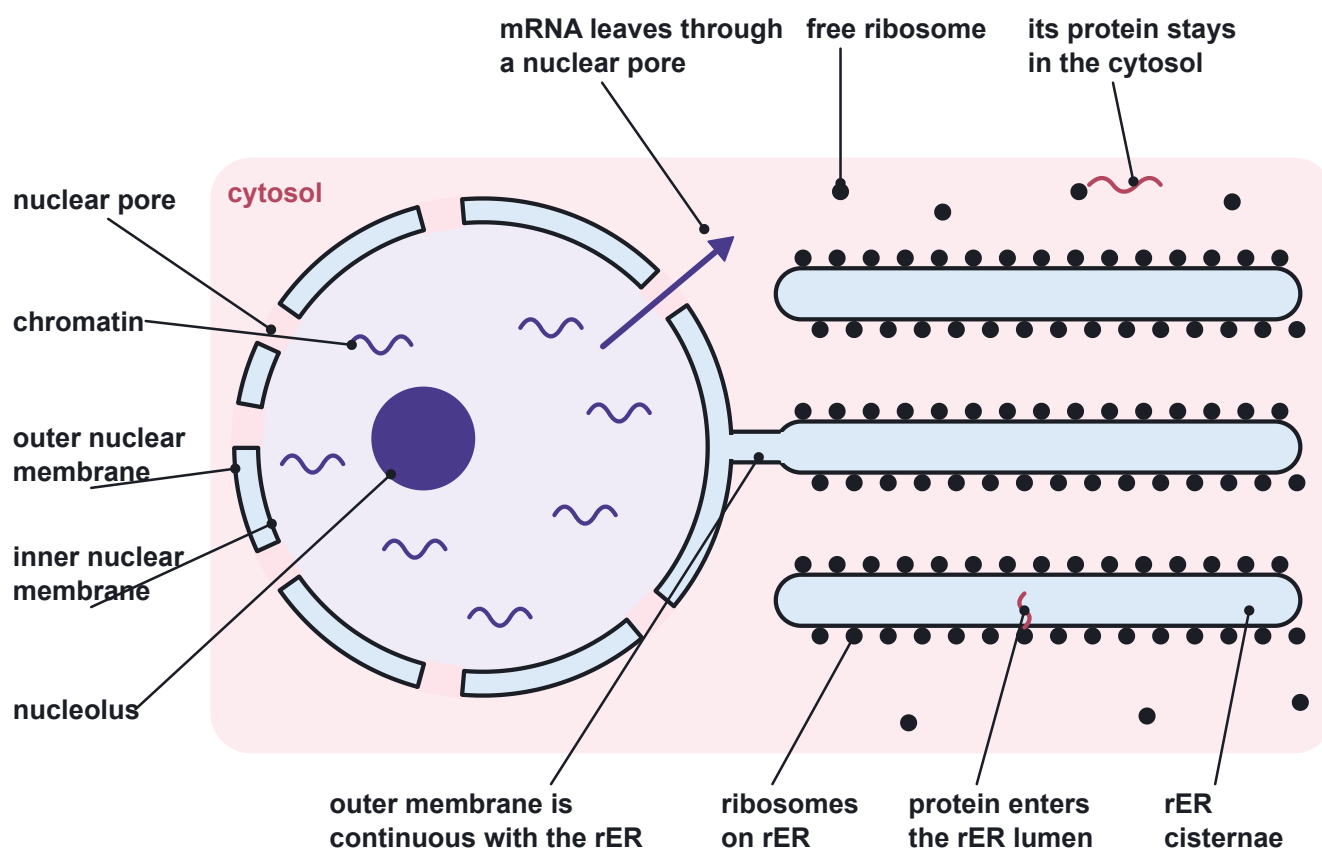
- Separation: DNA and transcription are kept apart from translation and other reactions in the cytoplasm.
- Nuclear pores: mRNA made by transcription must leave the nucleus, and proteins made in the cytoplasm (such as enzymes for DNA replication and histones) must enter. **Pores**, where the two membranes join, allow and control this traffic.
- Breakdown into vesicles: during mitosis and meiosis the nuclear membrane **breaks into vesicles** so that spindle microtubules can reach and move the chromosomes. Afterwards the vesicles fuse to form new nuclear envelopes around each set of chromosomes.

Free ribosomes and rough ER

Ribosomes are made of rRNA and protein and have no membrane. In eukaryotic cells they are found free in the cytosol or bound to the **rough endoplasmic reticulum** (rER), a network of flattened membrane sacs called cisternae.

Contrasting free ribosomes and ribosomes on the rER		
Feature	Free ribosomes	Ribosomes on the rER
Location	In the cytosol, not attached to membranes	Attached to the cytoplasmic surface of the rER
Proteins made	Proteins for retention in the cell , used in the cytoplasm or in organelles such as mitochondria and the nucleus	Proteins for transport within the cell (for example to lysosomes) or for secretion
Where the polypeptide goes	Released into the cytosol	Into the lumen of the rER, then in vesicles to the Golgi apparatus

Free and rER-bound ribosomes have the same structure, and translation always begins on a free ribosome in the cytosol. If the polypeptide being made begins with a signal sequence (a short stretch of mainly hydrophobic amino acids), the ribosome is guided to the rER and attaches to it. The growing polypeptide is fed through a pore in the rER membrane into the lumen, and the signal sequence is usually cut off. The details of this targeting are not required.



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The **outer nuclear membrane** is continuous with the rER; free ribosomes make proteins for the cytosol, rER ribosomes feed proteins into the **lumen**.

The Golgi apparatus and vesicles Spec B2.2.8, B2.2.9 HL only

The Golgi apparatus

The **Golgi apparatus** is a stack of flattened, curved membrane sacs (cisternae) that are not joined to each other. Vesicles from the rER fuse with the cis face, nearest the rER. Proteins are **processed** as they

pass through the cisternae, for example by adding or changing carbohydrate chains to make glycoproteins. At the trans face, processed proteins are packed into vesicles that bud off.

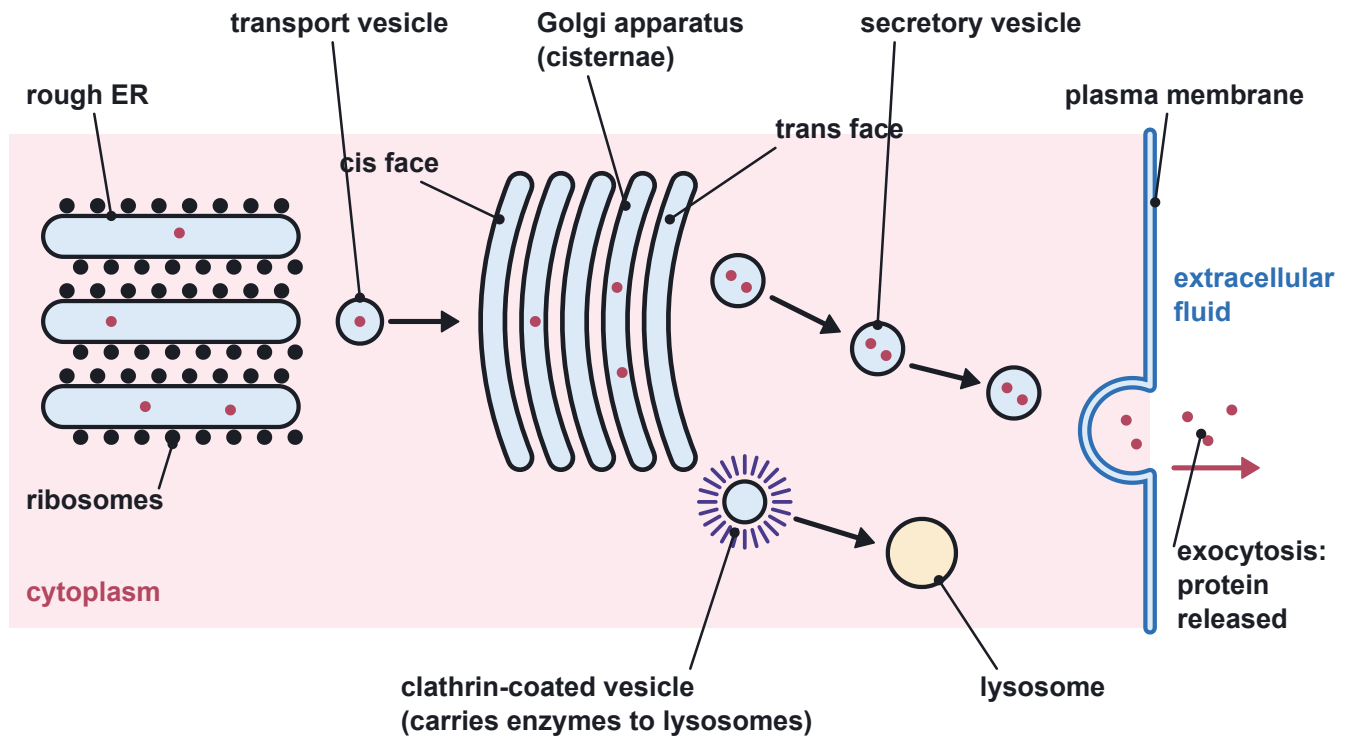
- 1 . A protein is made by ribosomes on the rER and enters the rER lumen.
- 2 . Vesicles bud off the rER and carry the protein to the cis face of the Golgi apparatus.
- 3 . The protein is processed as it moves through the Golgi cisternae.
- 4 . Secretory vesicles bud from the trans face and move to the plasma membrane.
- 5 . The vesicle membrane fuses with the plasma membrane and the protein is released by **exocytosis**.

Cells that secrete a lot of protein, such as pancreatic cells that make digestive enzymes and plasma cells that make antibodies, have extensive rER and a large Golgi apparatus.

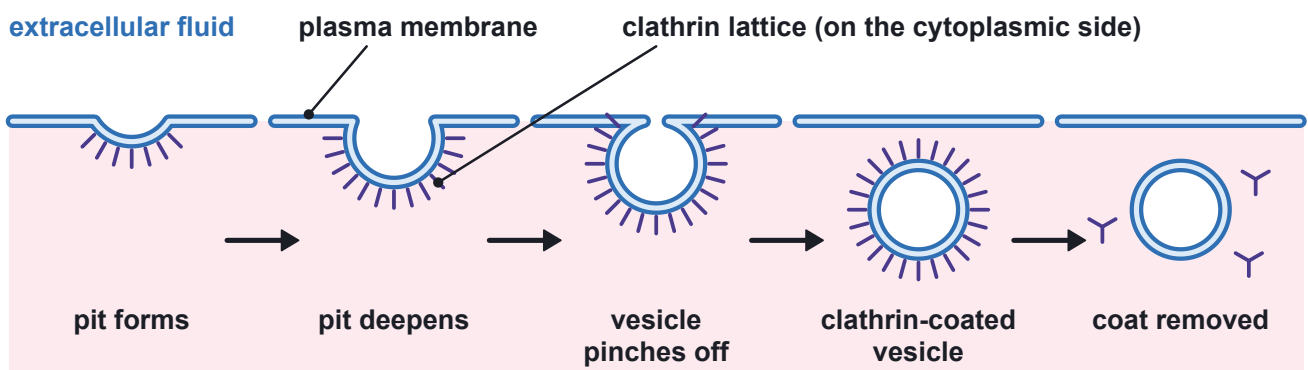
Vesicles and clathrin

Vesicles are small spheres of membrane enclosing fluid. They carry materials within the cell (for example from the rER to the Golgi apparatus), carry proteins for secretion, deliver hydrolytic enzymes as lysosomes and bring material in by endocytosis. Because membranes are fluid, vesicles can bud off one membrane and fuse with another.

Clathrin is a protein that helps vesicles form. Clathrin molecules assemble into a basket-shaped lattice on the cytoplasmic side of a membrane: at the plasma membrane during endocytosis, and at the trans face of the Golgi apparatus for vesicles carrying enzymes towards lysosomes. The lattice pulls the membrane into a curved pit that deepens and pinches off as a clathrin-coated vesicle. The coat is then removed so the vesicle can fuse with its target membrane. Vesicles travelling from the rER to the Golgi apparatus use different coat proteins, whose names are not required.



Clathrin-coated vesicle forming at the plasma membrane (endocytosis)



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rER → Golgi → secretory vesicle → exocytosis. **Clathrin** coats vesicles at the **plasma membrane** and the **trans face** of the Golgi apparatus.

Common mistake: The Golgi apparatus does not make proteins. Ribosomes on the rER make them; the Golgi apparatus processes them and packages them into vesicles.

Quick check

1. Name two structures that are not considered organelles.
2. In cell fractionation, which organelles form a pellet first, at the lowest speed?
3. Why must the hydrolytic enzymes of lysosomes be kept in a compartment?
4. **HL only** Which part of the mitochondrion contains the enzymes of the Krebs cycle?
5. **HL only** What is the role of clathrin?

Quick check answers

Organelles and compartmentalization

1. Any two of: the cell wall, the cytoskeleton, the cytoplasm.
2. Nuclei.
3. So they do not digest the cell's own molecules, and so they can be concentrated at their acid optimum pH.
4. The matrix.
5. It forms a coat that curves a membrane into a bud, forming a vesicle.