CELL STRUCTURES

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B2.2.5 Adaptations of the chloroplast for photosynthesis

B2.2.6 Functional benefits of the double membrane of the nucleus

B2.2.7 Structure and function of free ribosomes and of the rough endoplasmic reticulum

B2.2.8 Structure and function of the Golgi apparatus

B2.2.9 Structure and function of vesicles in cells

B2.3.7 Adaptations to increase surface area-to-volume ratios of cells

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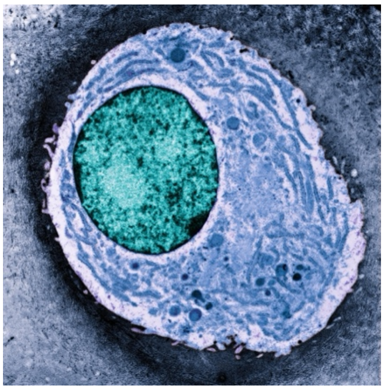
B2.3.9 Adaptations of cardiac muscle cells and striated muscle fibres

B2.3.10 Adaptations of sperm and egg cells

ORGANELLES

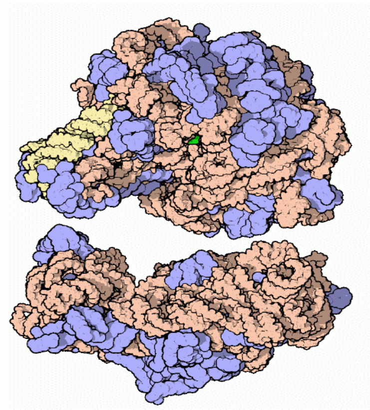
Organelles are sub-cellular structures that are adapted to carry out specific functions. Organelles that are membrane-bound are able to maintain an internal chemistry that is different to the cytosol, enabling them to perform specialised reactions. Examples include nuclei, rough ER, mitochondria, chloroplast and Golgi.

NUCLEUS



The nucleus stores the genetic material of the cell (as **chromatin**) and acts as a control centre by coordinating the expression of genes. The nucleus is surrounded by a double membrane called the **nuclear envelope**, which is embedded with pores. The envelope functions as a barrier to separate the processes of transcription and translation, while the presence of the pores allows the cell to control the rate at which these interlinked processes can occur. A double membrane is also beneficial to the process of mitosis and meiosis, as it enables the envelope to be disassembled and broken down into vesicles (to be later reconstituted at the end of the division process).

RIBOSOMES

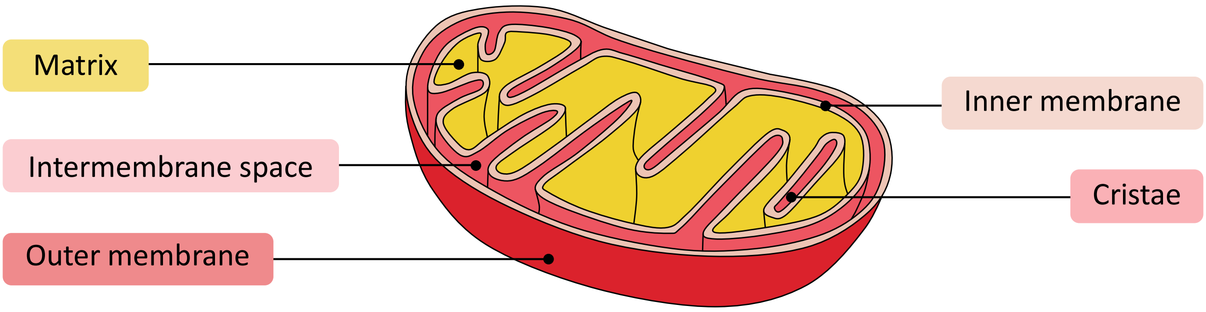


The ribosome is the site of **protein synthesis** in the cell. Ribosomes consist of protein (providing stability) and rRNA (responsible for catalytic activity). Each ribosome is composed of two subunits. The small subunit will bind to mRNA, while the large subunit will bind to tRNA. When both subunits form a complex, translation can occur. Within eukaryotes, ribosomes can either be located freely within the cytosol or embedded within the endoplasmic reticulum (rough ER). **Free ribosomes** will synthesise proteins that are used within the cytosol (intracellular), while ribosomes embedded on **rough ER** produce proteins to be packaged into vesicles for transport and secretion.

MITOCHONDRIA

Mitochondria are the site of **aerobic respiration** in eukaryotic cells (some prokaryotes may use their cell membrane to respire aerobically). The structure of a mitochondrion is adapted to the function it performs:

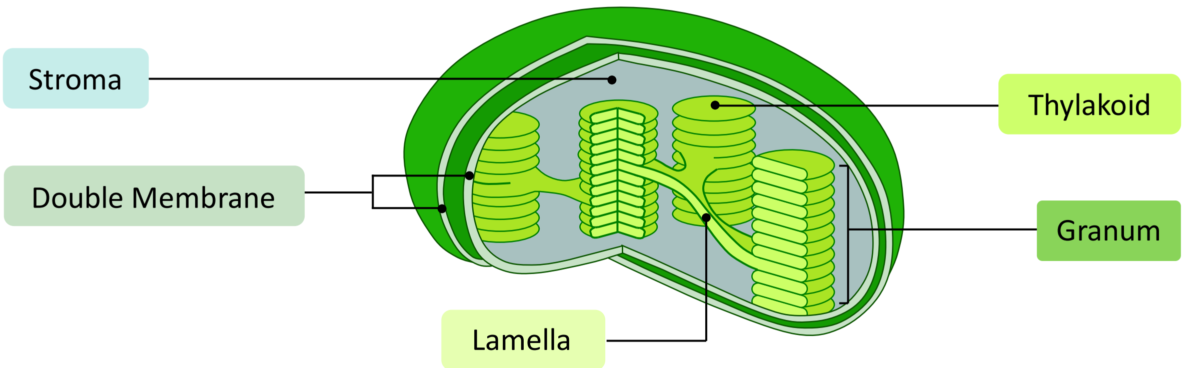
- **Outer membrane** – Contains transport proteins that enable the shuttling of pyruvate from the cytosol
- **Inner membrane** – Contains the electron transport chain and ATP synthase (oxidative phosphorylation)
- **Cristae** – The inner membrane is arranged into folds called cristae to increase the available surface area
- **Intermembrane space** – A small space exists between the membranes to maximise the proton gradient
- **Matrix** – The central cavity contains appropriate enzymes and a suitable pH for the Krebs cycle to occur



CHLOROPLAST

Chloroplasts are the site of **photosynthesis** (photosynthetic pigments are used to convert light energy from the Sun into chemical energy). The structure of a chloroplast is largely adapted to the function it performs:

- **Thylakoid** – Flat disc with a small internal volume to maximise the gradient upon proton accumulation
- **Grana** – The thylakoids are arranged into stacks to increase SA:Vol ratio of the thylakoid membrane
- **Photosystems** – Pigments are organised into clusters within the thylakoids to optimise light absorption
- **Stroma** – The central cavity contains appropriate enzymes and suitable pH for the Calvin cycle to occur
- **Lamellae** – Connects and separates the thylakoid stacks (grana), maximising photosynthetic efficiency

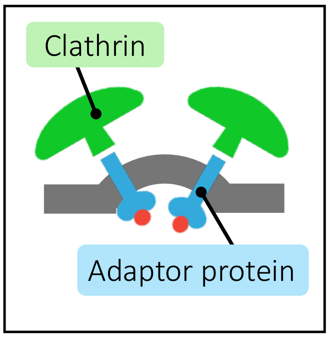


GOLGI COMPLEX

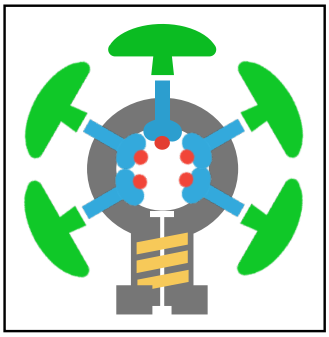
The Golgi apparatus is responsible for sorting, storing, modifying and exporting cellular material. It is composed of a series of flat sacs (called **cisternae**) that are located between the ER (*cis* facing) and the cell membrane (*trans* facing). When proteins (from rough ER) and lipids (from smooth ER) arrive at the Golgi body in vesicles, they are modified into functional molecules – with different sacs being responsible for specific modifications (e.g. glycosylation). Materials destined for secretion are then packaged into **vesicles** for extracellular release (**exocytosis**) – either immediate (constitutive) or in response to a signal (regulatory secretion).

VESICLES

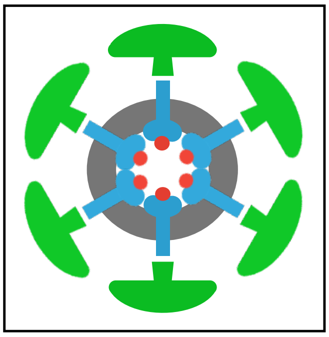
Vesicles are membrane-wrapped containers involved in shuttling materials between cellular compartments. Examples of vesicular structures include the *lysosome* (breaks down cellular waste and debris), *peroxisome* (digests toxic metabolites) and *vacuoles* (stores excess fluid and regulates pH). Some vesicles form with the help of a coat protein called **clathrin**. Clathrin is a triskelion-shaped molecule recruited to a membrane by **adaptor proteins**. Clathrin molecules then link together to form a rounded lattice that pulls the membrane into a bud, which is then cleaved by another protein (**dynamin**) to form a vesicle. After vesicle formation, the clathrin architecture disassociates. The use of clathrin can allow the cell to control when vesicles form. In receptor-mediated endocytosis, a specific ligand binds to a receptor which then recruits clathrin. This ensures that only the ligand is internalised, allowing greater regulatory control over what enters the cell.



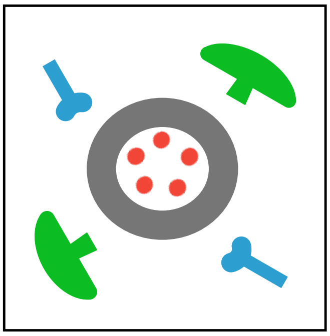
1. Recruitment



2. Budding



3. Vesicle



4. Uncoating

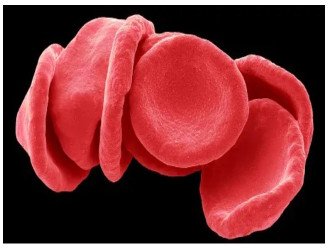
CELL ADAPTATIONS

Cells with specialised functions may have different organelle compositions to suit their intended purpose. For example, phagocytic leukocytes will have large amounts of lysosomes. Endocrine cells will have many secretory vesicles, while nerve cells will possess an increased quantity of mitochondria to meet the high energy demands of the cell. Furthermore, certain cells may have an altered morphology according to their functional needs. Cells may increase their surface area, alter size and shape or form specific connections.

SURFACE AREA

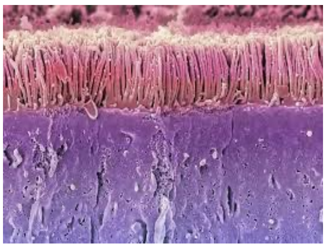
Cells that are specialised for material exchange will possess adaptations to increase their surface area. Cells that are flat and long (**squamous**) will have a higher SA:Vol ratio than cells that are cuboidal in shape. The tissues lining absorption surfaces may have ruffled projections (**villi**), while the cells themselves will possess membrane extensions (**microvilli**). Examples of cells that are specialised for material transport may include:

- **Erythrocytes:** Thin and flat (biconcave) and have had the nucleus removed to store more haemoglobin
- **Tubule cells:** The kidney tubules are folded into villi and the individual tubule cells possess microvilli
- **Neurons:** The axon is extremely narrow (allows rapid depolarisation) and dendrites are highly branching
- **Plant Roots:** Plant roots may contain cellular projections (root hairs) to increase the overall surface area

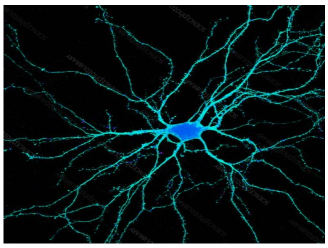


Red Blood Cells

Intestinal Villi



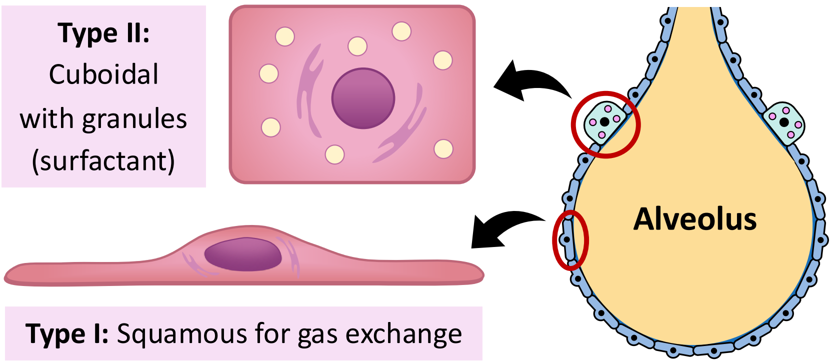
Microvilli



Neuron

PNEUMOCYTES

Pneumocytes are cells that line the alveoli and comprise of the majority of the inner surface of the lungs. There are two types of pneumocytes (type I vs type II) that differ according to their function in the alveoli.

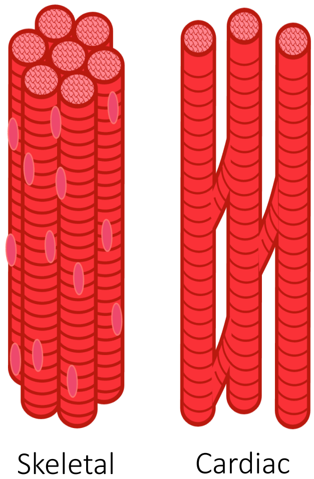


Type I pneumocytes are squamous (flattened) and extremely thin to minimise gas diffusion distances.

Type II pneumocytes are cuboidal and have granules (lamellar bodies) that store and secrete surfactant

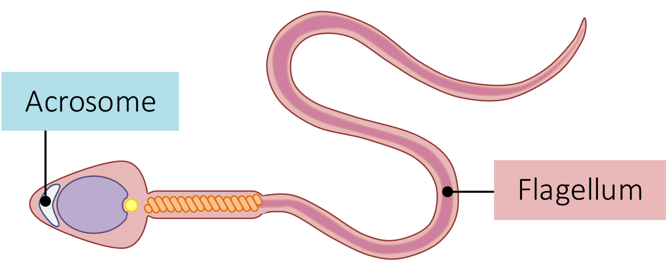
MUSCLE TISSUE

All muscles contain long protein filaments (myofibrils) which are responsible for muscular contraction. **Skeletal muscles** are composed of long, cylindrical fibres that are formed from the fusion of individual cells. The fibres will have a single, continuous plasma membrane (sarcolemma) and are multinucleate. The fibres are packed together in unbranching strands that collectively form a muscle bundle. **Cardiac muscle** cells are short and narrow. Unlike in skeletal muscle, the cardiac muscle cells are not fused together and consequently are mononucleated. The individual muscle cells are connected by gap junctions at intercalated discs, which allow for electrical conduction between the cells. Cardiac muscle cells are branched, allowing for faster signal propagation and contraction in three dimensions. The cells will also have more mitochondria.

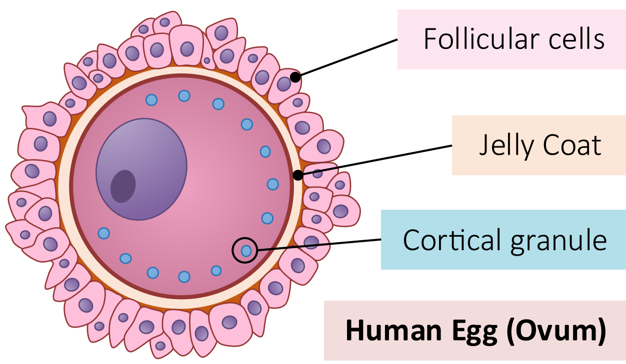


GAMETES

The male and female gametes (i.e. sperm and egg) have specialised structures which reflect their functions. The male gamete (**sperm**) is small and motile and only contributes the male's haploid nucleus to the zygote. The head region includes an **acrosome cap** (with hydrolytic enzymes which help sperm to penetrate an egg) and the tail (**flagellum**) is composed of a microtubule structure called an *axoneme* which bends to facilitate movement. The female gamete (**egg**) is large and non-motile and contributes all the organelles and cytosol to the zygote. It is surrounded by the *zone pellucida* (**jelly coat**) which acts as a barrier to sperm entry, and is supported by a layer of **follicular cells** *(corona radiata)* that provide the egg with nourishment. Within the cytosol are numerous cortical granules, which release chemicals on fertilisation to prevent polyspermy.



Human Sperm (not drawn to scale)



Human Egg (Ovum)