These notes explain the **why** behind every concept, not just the what. They include **analogies**, **real-life examples**, and explanations of **common mistakes**. Use these alongside your revision notes for full understanding.

4.1.1 Cell Structure — Why Cells Look the Way They Do

Every living thing is made of cells, but not all cells are the same. Understanding the structure of a cell is not just about memorising a list of parts — each organelle exists because it has a specific job that the cell needs to do to survive.

Eukaryotic vs Prokaryotic — What is the Real Difference?

The most fundamental division in biology is between eukaryotic cells (which have a proper nucleus surrounded by a membrane) and prokaryotic cells (bacteria, which do not). This matters because having a nucleus means genetic material is protected and better regulated.

■ ***Think of it like this:*** *A nucleus is like a locked filing cabinet in an office. The DNA (filing cabinet contents) is protected and only accessed when needed. Bacteria are like an open-plan office where the "files" (DNA) are just floating around on a circular desk.*

- Animal cells: nucleus, cell membrane, cytoplasm, mitochondria, ribosomes.
- Plant cells: all of the above PLUS cell wall (cellulose), chloroplasts, and a large permanent vacuole.
- Bacterial cells: cell wall, cell membrane, cytoplasm, ribosomes, circular chromosome (no nucleus), sometimes plasmids and a flagellum.

Understanding Each Organelle

The nucleus acts as the control centre. It contains DNA in the form of chromosomes, and this DNA carries the instructions for making every protein in the body. The nuclear membrane has tiny pores that let RNA leave (to go make proteins) but keep the DNA safely inside.

Mitochondria are where aerobic respiration happens — this is where glucose and oxygen are converted into ATP, the energy currency of the cell. Cells with high energy demands (like muscle cells and sperm cells) have many mitochondria.

Ribosomes are tiny but critical — they read the instructions from RNA and assemble amino acids into proteins. Every protein in your body was made on a ribosome.

The cell membrane is selectively permeable — it controls what enters and leaves the cell using phospholipid molecules and protein channels. It is NOT a rigid wall; it is flexible.

The cell wall (plant cells only) is made of cellulose fibres. It does not control what passes through — it just gives structural support, stopping the cell from bursting when it fills with water.

Chloroplasts contain chlorophyll, the green pigment that absorbs light energy for photosynthesis. They have their own DNA, which supports the theory that they were once free-living bacteria absorbed by larger cells millions of years ago.

■ **Why does this happen?** Plant cells have a permanent vacuole filled with cell sap. When the vacuole is full of water, it pushes the cytoplasm against the cell wall, making the cell rigid (turgid). This is how plants support themselves without bones — water pressure!

Microscopy — Why Resolution Matters

When we use a microscope, we care about two things: magnification (how big does the image appear?) and resolution (how much detail can we distinguish?). A light microscope can magnify up to about ×1500, but its resolution is limited to about 200 nanometres — anything smaller looks blurry.

Electron microscopes fire a beam of electrons instead of light. Since electrons have a much shorter wavelength than visible light, they can resolve details down to 0.1 nm — revealing the internal structure of organelles like mitochondria in extraordinary detail.

"A more powerful microscope just makes things bigger."

✓ **Actually:** distinguish … view of orga…

Magnification formula: Image size = Actual size × Magnification. Rearranged: Actual size = Image size ÷ Magnification.

■ **Exam tip:** In calculations, always check units. If image size is in mm and actual size should be in µm, convert first: 1 mm = 1000 µm.

4.1.2 Cell Division — Growth, Repair and Reproduction

Why Do Cells Divide?

Your body begins as a single fertilised egg cell. You now contain roughly 37 trillion cells. All of those came from that one cell dividing, again and again, through mitosis. Cell division is also how the body repairs itself — when you cut your skin, nearby cells divide to replace the damaged ones.

The Cell Cycle and Mitosis in Detail

Step 1	**Interphase (G1)**	Cell grows larger. New organelles are made. The cell prepares for division.
Step 2	**S phase (DNA replication)**	Every chromosome is copied exactly. The cell now has double the DNA it needs. If any error occurs here, it may cause a mutation.
Step 3	**Interphase (G2)**	Cell checks the copied DNA for errors and prepares division machinery (spindle fibres).
Step 4	**Mitosis**	Chromosomes condense and become visible. Spindle fibres pull identical copies to opposite ends of the cell.
Step 5	**Cytokinesis**	The cytoplasm divides. Two genetically identical daughter cells are produced, each with the full set of 46 chromosomes.

"Mitosis and cell division are the same thing."

✓ **Actually:** (DNA replic…

Cancer — When the Cell Cycle Goes Wrong

Cancer occurs when cells lose control of the cell cycle and divide continuously. This happens because of mutations in genes that normally regulate division (tumour suppressor genes and proto-oncogenes). The result is a tumour — a mass of cells that serve no useful purpose.

- Benign tumours: stay in one place, do not invade other tissues, usually not life-threatening.
- Malignant tumours: invade surrounding tissue and can break off to travel to other parts of the body (metastasis) — this is what makes cancer deadly.
- Risk factors for cancer: UV radiation, smoking, certain viruses (e.g. HPV), asbestos, obesity.

■ **Real-life example:** Skin cancer (melanoma) is caused by UV radiation from sunlight damaging the DNA of skin cells. This is why sunscreen is important — it reduces the amount of UV radiation reaching skin cell DNA.

Stem Cells — The Body's Blank Slate

Stem cells are undifferentiated cells — they have not yet committed to being a specific cell type. They can divide indefinitely and differentiate into specialised cells.

Embryonic stem cells are totipotent — they can become ANY cell type in the body. Adult stem cells (e.g. in bone marrow) are more limited, producing only certain blood cell types. Plant meristem cells at the tips of roots and shoots are also stem cells.

■ ***Think of it like this:*** *Stem cells are like a blank template on a computer. You can use that template to create any type of document. Once you have saved it as a specific file type (e.g. a spreadsheet), it can only do spreadsheet things. Differentiation is like saving as a specific file type.*

■ **Why does this happen?** Adult stem cells exist because our bodies constantly need to replace worn-out cells. Red blood cells only live for about 120 days — bone marrow stem cells produce millions of new ones every second to replace them.

4.1.3 Transport in Cells — How Substances Move

Diffusion — The Natural Tendency to Spread Out

Particles in a liquid or gas are constantly moving randomly in all directions. Diffusion is simply the net result of this random movement — more particles move from a crowded region to a less crowded region than move the other way, so the overall effect is movement from high to low concentration.

■ ***Think of it like this:*** *Imagine opening a bottle of perfume in one corner of a room. At first all the perfume molecules are clustered near the bottle. Over time they spread out randomly until they are evenly distributed throughout the room. That is diffusion.*

The steeper the concentration gradient, the faster diffusion happens. Temperature also speeds it up because particles have more kinetic energy and move faster.

Osmosis — Water is Special

Osmosis is a type of diffusion — but it only applies to water, and it only happens across a partially permeable membrane (one that lets water through but not large solutes). Water moves from a region of high water concentration (dilute solution) to a region of low water concentration (concentrated solution).

■ **Why does this happen?** Why can't we just say "water moves from low to high solute concentration"? We can — it means the same thing. A dilute solution has MORE water and LESS solute. A concentrated solution has LESS water and MORE solute. Water always moves towards where there is more solute.

- Turgid plant cell: full of water; the vacuole pushes outward against the cell wall, making the plant firm. This is how plants stand upright.
- Plasmolysed cell: cell has lost water into a concentrated external solution; the membrane pulls away from the cell wall. Plant wilts.
- Crenated animal cell: shrunk due to water loss in concentrated solution (no cell wall to maintain shape).
- Lysed animal cell: burst due to excessive water intake in a very dilute solution.

"Osmosis is about salt or sugar moving into the cell."

✓ **Actually:** through the

Active Transport — Going Uphill

Sometimes cells need to move substances against the concentration gradient — from a region of low concentration to a region of high concentration. This cannot happen passively — it requires energy in the form of ATP produced by respiration. Special carrier proteins in the membrane grab the substance and move it through, using ATP to power the process.

■ **Real-life example:** Root hair cells use active transport to absorb mineral ions (like nitrates) from the soil. The concentration of nitrates in the soil water is often lower than inside the root cell, so the cell has to use energy to "pump" them in against the gradient.

Diffusion	Net movement of particles from HIGH to LOW concentration — passive, no energy needed
Osmosis	Net movement of WATER from HIGH water potential (dilute) to LOW water potential (concentrated) through a partially permeable membrane
Active transport	Movement of substances AGAINST the concentration gradient using energy (ATP) and carrier proteins
Concentration gradient	The difference in concentration between two regions — steeper gradient = faster diffusion
Partially permeable membrane	A membrane that allows water and small molecules through but not large molecules
Turgid	A plant cell that is firm because it is full of water (vacuole pressing against cell wall)
Plasmolysed	A plant cell that has lost water — the membrane has pulled away from the cell wall