Cell structure and microscopy

Cells, tissues and organs, the ultrastructure of eukaryotic and prokaryotic cells, protein transport in the cell, and light and electron microscopy.

Cells, tissues and organs

All living organisms are made of cells with common features: a **cell surface membrane**, **cytoplasm**, genetic material (DNA) and **ribosomes**.

In multicellular organisms, cells are organised into **tissues** (groups of similar cells with a common function, e.g. epithelium), **organs** (tissues working together, e.g. the stomach) and **organ systems** (e.g. the digestive system).

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Eukaryotic cells

Organelle	Structure	Function
Nucleus	Double membrane (nuclear envelope) with **pores**, containing **chromatin** and a **nucleolus**	Holds DNA; controls the cell; transcription
Nucleolus	Dense region in the nucleus	Makes **ribosomal RNA** and assembles ribosomes
Ribosomes	Small (80S in eukaryotes), made of rRNA and protein; free or on rough ER	**Translation**: protein synthesis
Rough endoplasmic reticulum (rER)	Flattened sacs (cisternae) with ribosomes	Makes and folds proteins, which pass into the lumen
Smooth endoplasmic reticulum (sER)	Tubules, no ribosomes	Makes **lipids** (including steroids) and detoxifies
Golgi apparatus	Stack of flattened sacs	Modifies and packs proteins (adding carbohydrate to make glycoproteins), makes **lysosomes** and **vesicles** for secretion
Mitochondria	Double membrane, inner membrane folded into **cristae**, matrix	**Aerobic respiration**, making ATP
Lysosomes	Membrane-bound sacs of **hydrolytic enzymes**	Digest worn-out organelles and engulfed material
Centrioles	Two hollow cylinders of microtubules	Organise the **spindle** in cell division

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Protein transport in the cell

For a protein that is secreted, for example an extracellular enzyme:

1. The protein is made by ribosomes on the **rough ER** and enters its lumen.
2. It is folded and carried in a **transport vesicle** that buds off the rER.
3. The vesicle fuses with the **Golgi apparatus**, where the protein is modified.
4. A **secretory vesicle** buds from the Golgi, moves to the cell surface membrane, and releases the protein by **exocytosis**.

Energy is supplied by mitochondria, and the vesicles move along the cytoskeleton.

Prokaryotic cells

Prokaryotes (bacteria) are **smaller** and have **no nucleus**.

Structure	Function
Cell wall (peptidoglycan)	Protects and maintains shape
Capsule	Protects against drying and the host's immune system
Plasmid	Small **circular DNA** carrying extra genes (e.g. antibiotic resistance)
Circular DNA	The main genetic material, not in a nucleus
Flagellum	Movement
Pili	Attachment, and transfer of DNA in conjugation
Ribosomes (70S, smaller)	Protein synthesis

Microscopy

Magnification is the number of times larger an image is than the object:

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

Resolution is the ability to distinguish two points as separate. It is limited by the wavelength of the radiation used.

	Light microscope	Transmission electron microscope (TEM)	Scanning electron microscope (SEM)
Radiation	Light (long wavelength)	Electrons (short wavelength)	Electrons
Resolution	About 200 nm	About 0.1 nm	About 10 nm
Magnification	Up to about ×1500	Up to about ×1 000 000	Up to about ×100 000
Specimen	Living or dead, thin	**Dead**, in a vacuum, very thin sections	Dead, in a vacuum, surfaces
Image	2D, colour (with stains)	2D, black and white, shows **internal structure**	3D surface view

Staining makes structures visible (increasing contrast). Different stains bind to different structures, such as **methylene blue** and **iodine**. For the electron microscope, heavy-metal salts are used. Artefacts can be introduced by preparation.

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Core Practical 5: light microscope and graticule

1. Mount the specimen and view at low power first, then increase the magnification.
2. Make **labelled drawings** using sharp pencil lines, with no shading, and a title and magnification.
3. To measure cells, use an **eyepiece graticule** that is **calibrated** against a **stage micrometer** at each magnification:

$$1 \text{ eyepiece division} = \frac{\text{length on stage micrometer}}{\text{number of eyepiece divisions}}$$

The actual size is the number of divisions times this value.

> **TRY IT**
>
> An image of a cell is 45 mm wide and the actual cell is 15 µm. Find the magnification.

$45\ \text{mm} = 45\,000$ µm, so magnification $= 45\,000/15 = \times 3000$. (Always convert to the same units.)

Recognising organelles in electron micrographs

- **Nucleus**: a large round body with a double envelope and pores.
- **Mitochondria**: oval, double membrane, folded inner membrane.
- **Rough ER**: flattened sacs dotted with ribosomes; **Golgi**: stack of curved sacs with vesicles.
- **Lysosomes**: small, dark, round.

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