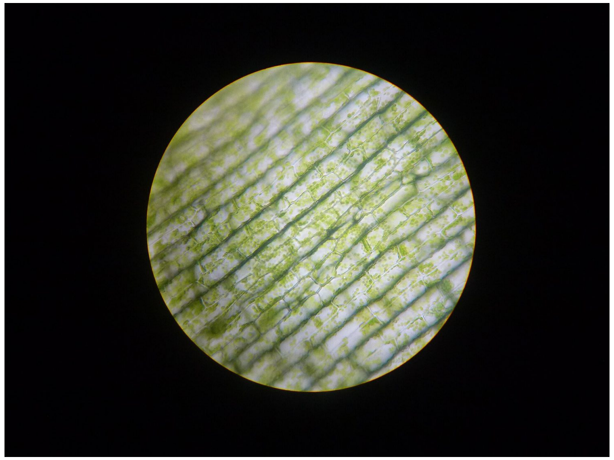
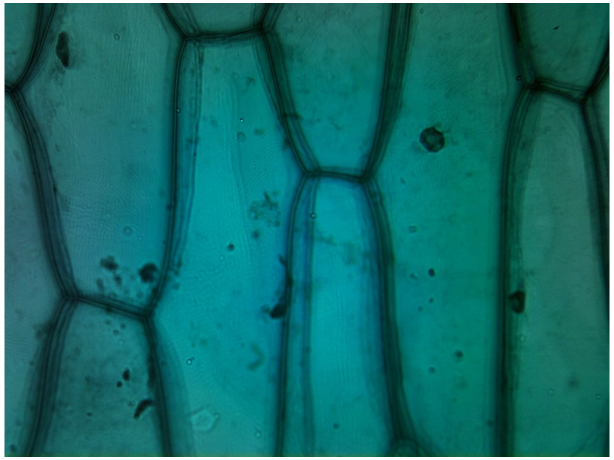
Cell Structure and Function

AP Biology

Organelles and the Endomembrane System



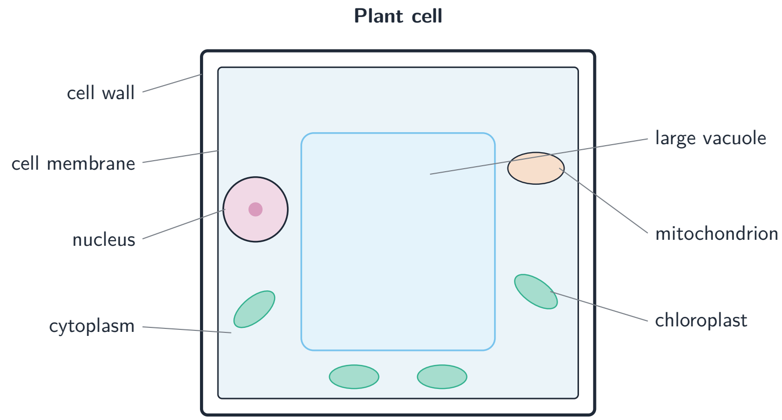
Elodea leaf cells packed with green chloroplasts (light micrograph)



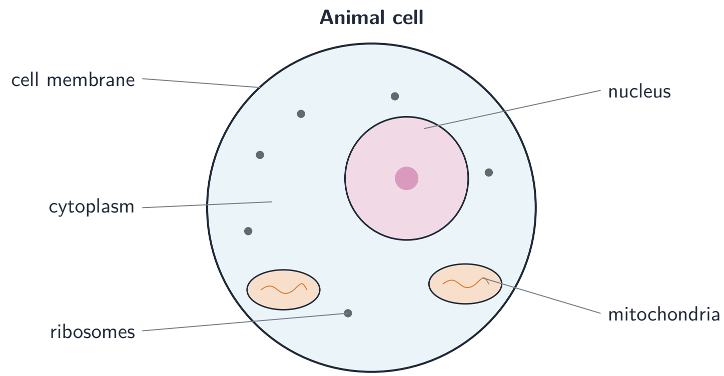
Onion epidermis cells under a light microscope — cell walls and nuclei clearly visible

A eukaryotic cell divides its work among **organelles** 细胞器. The **endomembrane system** 内膜系统 is a connected set that makes, modifies, and ships molecules: the

nucleus 细胞核 (holds DNA), rough and smooth **endoplasmic reticulum** 内质网 (protein and lipid synthesis), the **Golgi** 高尔基体 (modifies and packages), **lysosomes** 溶酶体 (digestion), and vesicles that carry material between them. **Mitochondria** 线粒体 (respiration) and **chloroplasts** 叶绿体 (photosynthesis) have their own membranes.



A plant cell also has a cell wall, a large vacuole, and chloroplasts



A generalised animal cell and its organelles

What each organelle actually does

The exam asks you to name a structure **and** say what it does, so learn them as pairs.

Ribosomes 核糖体 are made of **ribosomal RNA** 核糖体核糖核酸 (rRNA) and protein. They have no membrane, and they are found in **every** form of life — bacteria, archaea and eukaryotes alike. That shared presence is evidence of common ancestry: a structure this central was already present in the last common ancestor of all living things. A ribosome reads **messenger RNA** 信使核糖核酸 (mRNA) and builds the protein it codes for. Free ribosomes make proteins for use inside the cell; ribosomes bound to the rough endoplasmic reticulum make proteins for export or for the membrane.

The Golgi complex 高尔基复合体 is a series of flattened, membrane-bound sacs. A protein arriving from the endoplasmic reticulum is passed through them, and three things happen to it:

- it is folded correctly and chemically modified — most often by **glycosylation** 糖基化, the attachment of short sugar chains;
- it is **sorted and targeted**, so the modified sugar or phosphate tag decides which compartment the protein is sent to;
- it is packaged into a vesicle for transport.

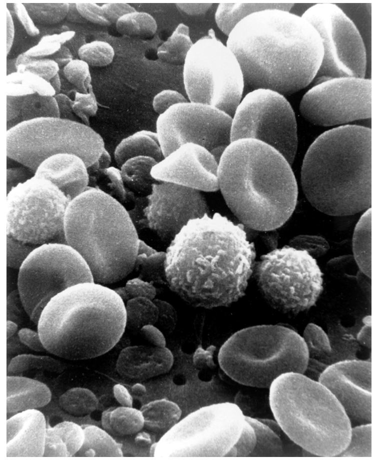
So the Golgi is not storage: it is the cell's finishing and dispatch department, and its modifications *determine* what a protein does and where it ends up.

Lysosomes are membrane-enclosed sacs of **hydrolytic enzymes** 水解酶 that digest material — worn-out organelles, engulfed bacteria, and food particles taken in by the cell. Their enzymes work best at a low pH, which the lysosome maintains inside itself; keeping them enclosed protects the rest of the cell. Lysosomes also take part in **apoptosis** 细胞凋亡, programmed cell death, in which a cell is dismantled deliberately, for example to sculpt fingers from a webbed embryonic hand.

Vacuoles 液泡 are membrane-bound sacs with many different roles: storing water, ions, nutrients or waste, and in a plant cell the large central vacuole also presses outwards on the cell wall to keep the cell firm.

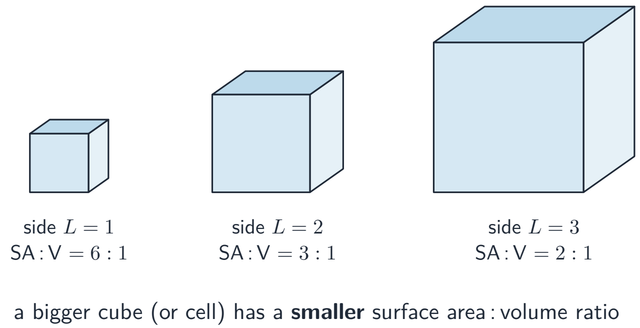
Mitochondria and **chloroplasts** each have a **double membrane** and their own circular DNA and ribosomes — the evidence behind endosymbiotic theory below.

Why Cells Stay Small



Scanning electron micrograph of red blood cells — no nucleus, high surface area for gas exchange

Cells stay small because of the **surface-area-to-volume ratio** 表面积与体积比. As a cell grows, its volume rises faster than its surface area, so its membrane cannot exchange materials fast enough for the interior. Staying small (or being flat or folded) keeps enough surface to serve the volume.

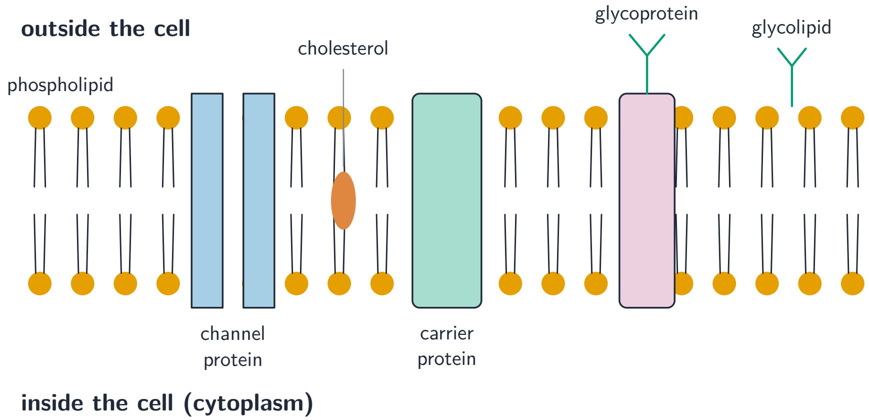


The surface-area-to-volume ratio falls as a cell gets bigger

Worked example. A cube-shaped cell 2 μm on a side has surface area $6\times2^2 = 24\ \mu\text{m}^2$ and volume $2^3 = 8\ \mu\text{m}^3$, so its surface-area-to-volume ratio is $\frac{24}{8} = 3$. Double the side to 4 μm: surface area $= 6 \times 4^2 = 96$, volume $= 4^3 = 64$, ratio $= \frac{96}{64} = 1.5$. Doubling the size **halved** the ratio – the larger cell has far less membrane per unit of interior, which is why cells stay small.

The Fluid Mosaic Model of the Membrane

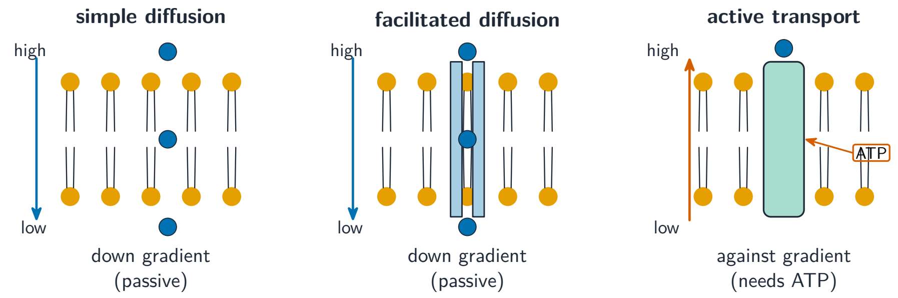
The cell membrane is a **phospholipid bilayer** 磷脂双分子层 – polar heads facing the water, nonpolar tails inside – studded with proteins. The **fluid mosaic model** 流动镶嵌模型 pictures it as a fluid sheet in which lipids and proteins drift. **Cholesterol** and the degree of unsaturation tune its fluidity.



The fluid mosaic model of the cell membrane

What Can Cross the Membrane

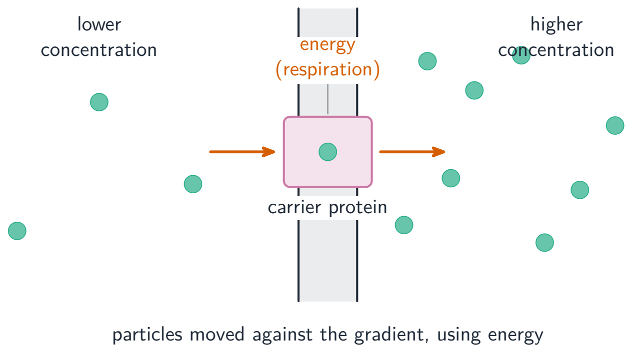
The membrane is **selectively permeable** 选择透过性. Small nonpolar molecules (O_2, CO_2) and water cross easily; large or charged/polar particles (ions, glucose) cannot pass the nonpolar core without help. This selectivity lets the cell control its internal environment.



Three ways substances cross the membrane

Passive and Active Transport

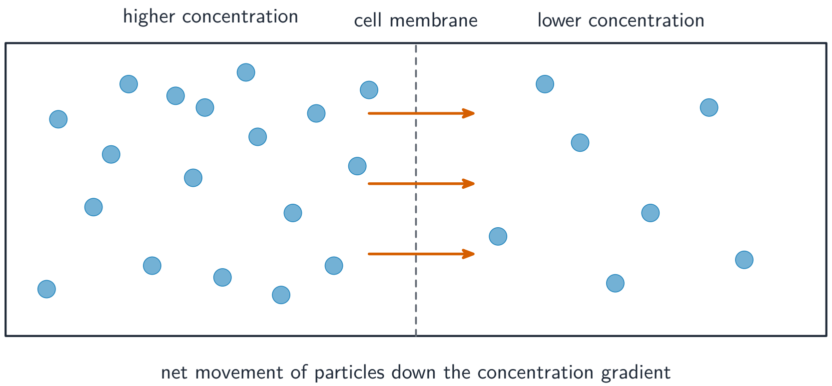
- **Passive transport** 被动运输 moves substances **down** their concentration gradient (high → low) with **no energy** – **diffusion** 扩散.
- **Active transport** 主动运输 moves substances **against** the gradient (low → high), requiring energy (ATP), via protein pumps like the sodium–potassium pump.



Active transport moves particles against the gradient, using ATP and a carrier protein

Facilitated Diffusion

Facilitated diffusion 易化扩散 is passive transport through a membrane protein – a **channel** or **carrier** 载体 – for particles that cannot cross the lipid alone. It still goes down the gradient and needs no energy, but its rate can saturate when all the proteins are busy.



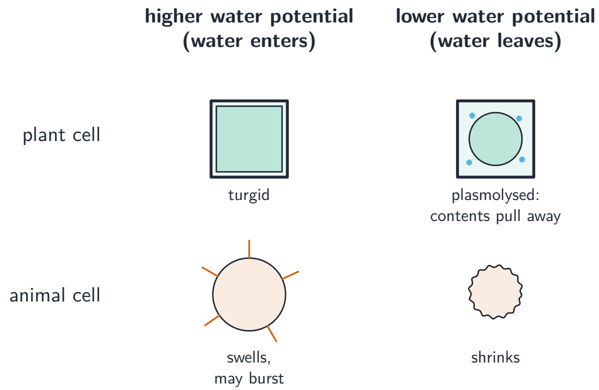
Diffusion: particles spread from higher to lower concentration, down the gradient

Tonicity, Water Potential, and Osmoregulation

Red onion cells in hypertonic solution: the membrane pulls away from the wall (plasmolysis)

Osmosis 渗透 is the diffusion of water across a membrane. **Tonicity** 张力 compares solute concentrations: in a **hypotonic** 低渗 solution a cell gains water (may burst);

in a **hypertonic** 高渗 one it loses water (shrinks); in an **isotonic** 等渗 one there is no net change. **Water potential** 水势 predicts the direction of water movement (water moves to lower water potential), and is the sum of a pressure term and a solute term: $\Psi = \Psi_p + \Psi_s$, where the solute potential $\Psi_s = -iCRT$. **Osmoregulation** 渗透调节 is how organisms control this balance.

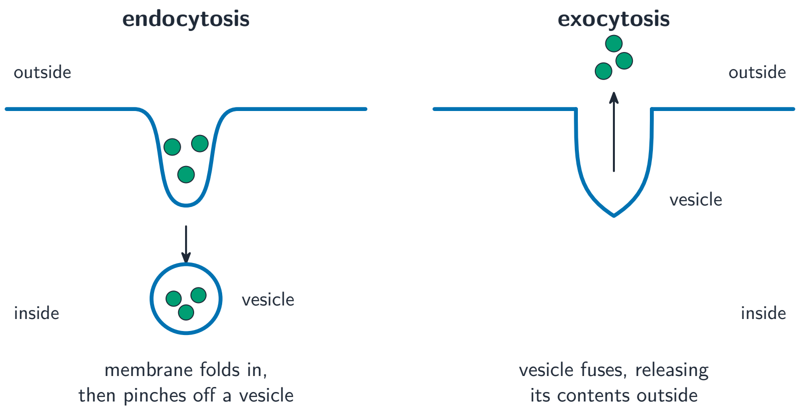


How plant and animal cells respond to solutions of different water potential

Worked example. For a 0.1 M sucrose solution ($i = 1$) in an open beaker (so pressure potential $\Psi_p = 0$) at 25 °C ($T = 298\,\mathrm{K}$, $R = 0.0831\ \mathrm{L \cdot bar/mol \cdot K}$): $\Psi_s = -iCRT = -(1)(0.1)(0.0831)(298) \approx -2.48$ bar, so $\Psi \approx -2.48$ bar. A plant cell whose interior is $\Psi = -1.0$ bar sits in this solution: since the solution is **more negative**, water moves *out* of the cell into the solution, and the cell loses turgor.

Mechanisms of Membrane Transport

Large materials move in bulk by **vesicles**: **endocytosis** 内吞 brings material **in** (the membrane engulfs it), and **exocytosis** 外排 sends material **out** (a vesicle fuses with the membrane). Both require energy and let cells import and secrete large molecules.



Endocytosis brings material in; exocytosis releases it out

Compartmentalization Inside the Cell

Membranes create separate **compartments** 区室 so incompatible reactions can run at once and conditions (pH, ion levels) can be tuned locally. This organization boosts efficiency – the internal membranes also add surface area for reactions.

The Origins of Cell Compartmentalization

The **endosymbiotic theory** 内共生学说 explains mitochondria and chloroplasts: they arose when a larger cell engulfed free-living prokaryotes that then lived inside it. The evidence – their own circular DNA, their own ribosomes, and double membranes – supports this shared evolutionary origin.

Exam tips

- Use the two AP-formula skills: **surface-area-to-volume ratio** (why cells stay small) and **water potential** $\Psi = \Psi_p + \Psi_s$ ($\Psi_s = -iCRT$).
- Water moves toward the **lower (more negative) water potential**; predict swelling or shrinking from tonicity (hypo/hyper/isotonic).
- **Passive transport and osmosis need no energy** (down the gradient); **active transport** needs ATP (against the gradient).
- Distinguish diffusion, facilitated diffusion (a channel/carrier protein), and active transport.

- Explain membrane selectivity from the **phospholipid bilayer** — small non-polar molecules cross, large/charged ones need help.