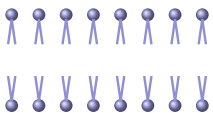
Cell Structure and Function

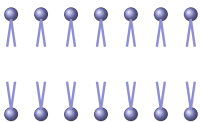
AP Biology ▪ Unit 2

AP Biology



What we will cover

1. Organelles and the endomembrane system
2. Surface area-to-volume ratio
3. The fluid mosaic membrane
4. What crosses the membrane
5. Passive and active transport
6. Tonicity and endosymbiosis



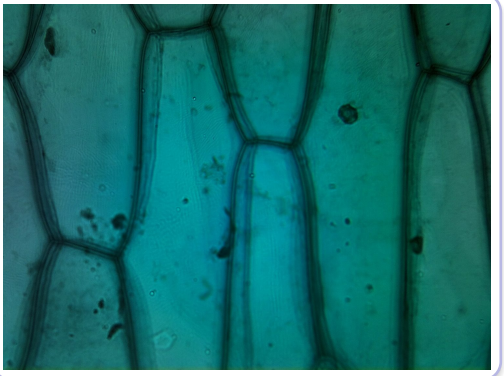
1 Organelles

Organelles and the endomembrane system

A **eukaryotic** 真核的 cell divides work among **organelles** 细胞器:

- **nucleus** 细胞核 – stores DNA
- **mitochondria** 线粒体 – make ATP
- **ribosomes** 核糖体 – build proteins
- **ER** 内质网 + **Golgi** 高尔基体 – pack and ship

> The endomembrane team traces a protein: nucleus → rough ER → Golgi → vesicle → membrane.



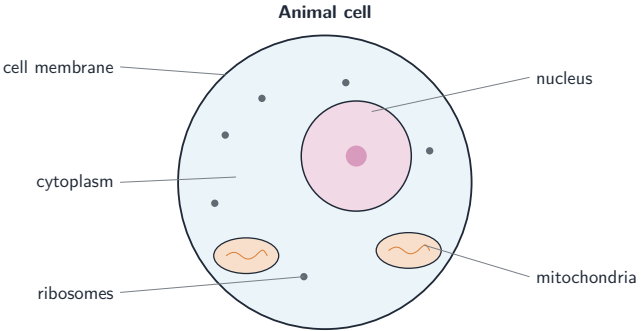
Organelles divide labour inside the cell

Three organelles, and one job of the membrane

Endoplasmic reticulum	The **endoplasmic reticulum**: rough (with ribosomes) makes and transports proteins; smooth makes lipids and detoxifies.
Lysosomes	**Lysosomes** hold hydrolytic enzymes at low pH and digest worn organelles and engulfed material.
Golgi	The Golgi modifies, sorts and packages what the ER sends, then ships it out in vesicles.
Osmoregulation	**Osmoregulation** is the cell's control of its own water balance – a contractile vacuole in a paramecium, turgor in a plant.

Follow one protein from ribosome to ER to Golgi to vesicle. That single path organises most of this unit.

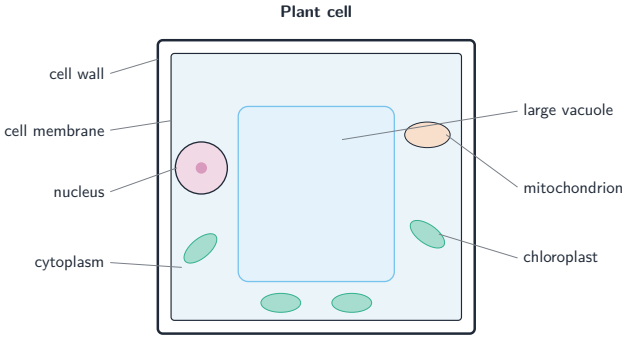
A generalised animal cell and its organelles – one



A generalised animal cell and its organelles

A generalised animal cell and its organelles

A generalised animal cell and its organelles – two



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

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

2

SA:V

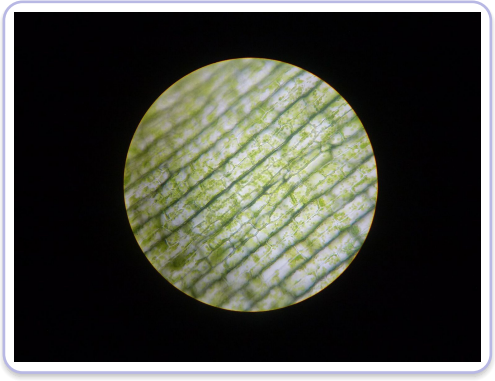
Surface area-to-volume ratio

Materials cross the **surface** 表面积; the **volume** 体积 must be served. As a cell grows, volume outpaces surface:

A cube of side s

$$\frac{\text{area}}{\text{volume}} = \frac{6s^2}{s^3} = \frac{6}{s}$$

The ratio shrinks as s grows – so cells stay small (or add **folds** 褶皱).



Leaf cells micrograph

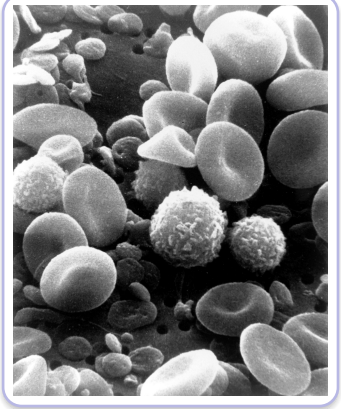
3 Membrane

The fluid mosaic membrane

The **fluid mosaic model** 流动镶嵌模型: a **phospholipid bilayer** 磷脂双分子层 (hydrophilic heads out, hydrophobic tails in) with drifting proteins.

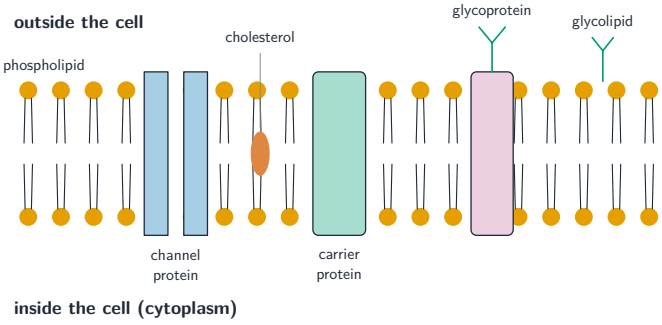
- **membrane proteins** 膜蛋白 – channels, pumps, receptors
- **cholesterol** 胆固醇 – steadies the fluidity

Selectively permeable 选择性通透的 – it maintains **homeostasis** 稳态.



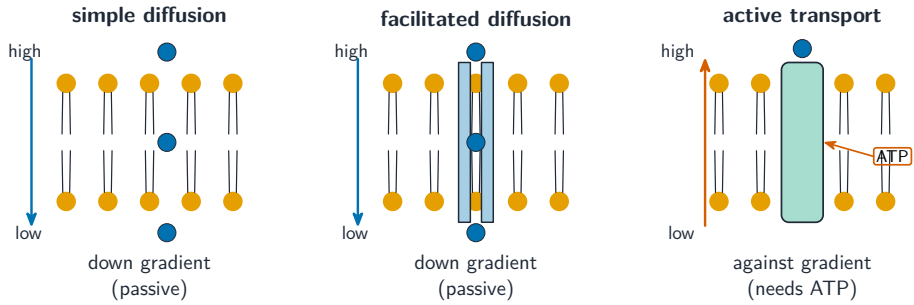
Rbc SEM

The fluid mosaic model of the cell membrane



The fluid mosaic model of the cell membrane

Three ways substances cross the membrane



Three ways substances cross the membrane

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.

4 Crossing

What crosses, and how

The hydrophobic core decides what crosses directly:

- cross easily – small nonpolar (O_2, CO_2), and water
- blocked – large or charged (**glucose** 葡萄糖, Na^+)

Facilitated diffusion 易化扩散:
channel 通道蛋白/**carrier** 载体蛋白 proteins – passive, but saturates.

Passive: down the gradient, *no* ATP

Active: against the gradient, uses *ATP*

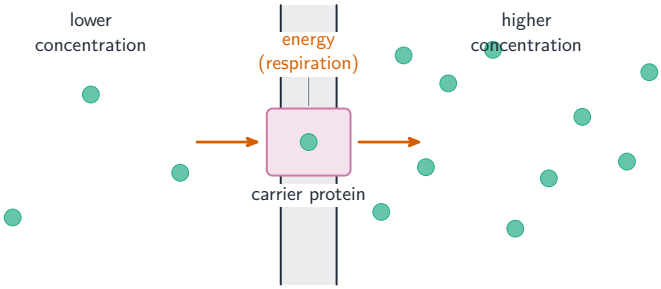
Osmosis 渗透 = diffusion of water.

Endo/exocytosis move bulk cargo.

Passive and active transport

- **Passive transport** 被动运输 moves substances down the gradient, high → low, with no energy – **diffusion** 扩散.
- **Active transport** 主动运输 moves them against it, low → high, and so needs ATP and a protein pump – the sodium–potassium pump.

Passive and active transport, in detail



particles moved against the gradient, using energy

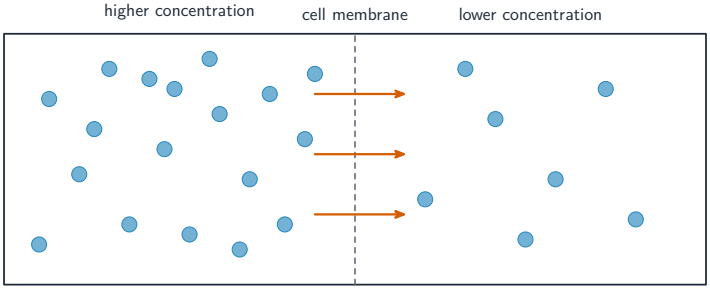
Against the gradient, using ATP and a carrier protein

Facilitated diffusion

Facilitated diffusion 易化扩散 is passive transport *through* a membrane protein – a channel or a **carrier** 载体 – for particles that cannot cross the lipid alone.

> Still down the gradient, still no energy – but the rate saturates once every protein is busy. That plateau is what distinguishes it from simple diffusion in a graph question.

Facilitated diffusion, in detail



Particles spread from higher to lower concentration

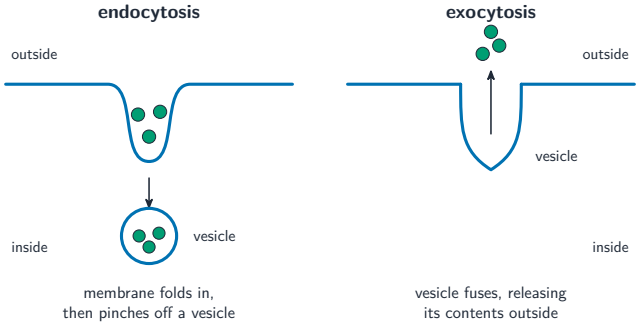
Bulk transport by vesicle

Large materials cross in bulk, wrapped in **vesicles**:

- **endocytosis** 内吞 brings material in – the membrane engulfs it;
- **exocytosis** 外排 sends material out – a vesicle fuses with the membrane.

> Both cost energy. This is how a cell imports and secretes molecules too big for any protein channel.

Bulk transport by vesicle, in detail



The membrane itself does the carrying: it folds inwards to make a vesicle, or a vesicle fuses with it to release the contents.

5

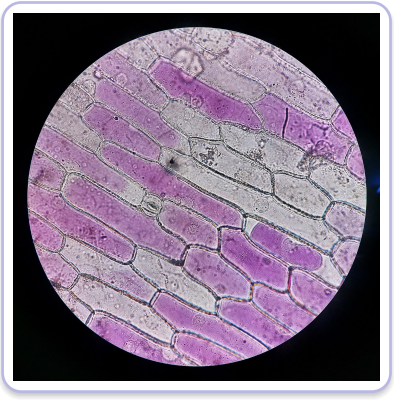
Tonicity

Tonicity and endosymbiosis

Water moves toward the saltier side. **Water potential** 水势 $\Psi = \Psi_S + \Psi_P$.

- **hypertonic**: cell shrinks
- **hypotonic**: cell swells
- **isotonic**: steady volume

Endosymbiotic theory 内共生学说: mitochondria & chloroplasts were once bacteria – own circular DNA, double membranes, own ribosomes.



Water leaves cells in a hypertonic solution

Water potential, and which way water moves

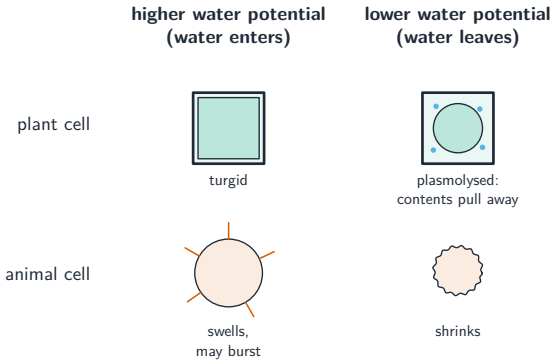
Water potential 水势 predicts the direction: water moves to the lower Ψ.

$$\Psi = \Psi_p + \Psi_s, \qquad \Psi_s = -iCRT$$

0.1 M sucrose, open beaker, $25\,^\circ$C

$\Psi_s = -(1)(0.1)(0.0831)(298) \approx -2.48$ bar, and $\Psi_p = 0$, so $\Psi \approx -2.48$ bar. A cell at $\Psi = -1.0$ bar sits in it: the solution is more negative, so water leaves the cell and it loses turgor.

Water potential, and which way water moves, in detail



Plant and animal cells in solutions of different water potential

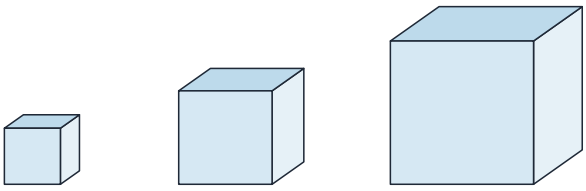
Compartments, and where they came from

Membranes create separate **compartments** 区室 so incompatible reactions run at once and pH and ion levels are tuned locally. The internal membranes also add surface area for those reactions.

The **endosymbiotic theory** 内共生学说 explains mitochondria and chloroplasts: a larger cell engulfed free-living prokaryotes that went on living inside it.

> The evidence is three-fold – their own circular DNA, their own ribosomes, and double membranes.

Why Cells Stay Small



side $L = 1$
SA : V $= 6 : 1$

side $L = 2$
SA : V $= 3 : 1$

side $L = 3$
SA : V $= 2 : 1$

a bigger cube (or cell) has a **smaller** surface area : volume ratio

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

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.

6 Recap

Unit 2 – key takeaways

1 Organelles

compartments for parallel reactions; endomembrane ships proteins

2 SA:V

ratio $6/s$ shrinks with size – cells stay small

3 Membrane

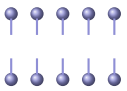
fluid mosaic bilayer; selectively permeable

4 Transport

passive down / active up the gradient; osmosis

Check yourself

1. As a cell grows, does its surface-to-volume ratio rise or fall?
2. Why can O_2 cross the membrane but Na^+ cannot?
3. Does active transport use ATP?
4. Name one piece of evidence for endosymbiosis.



Answers **1.** it falls **2.** Na^+ is charged; O_2 is nonpolar **3.** yes **4.** own circular DNA (or double membrane)