

Homeostasis

A-Level Biology

What homeostasis is

Homeostasis 稳态 means keeping the conditions inside the body steady, even when the outside changes. Keeping things like temperature, water and blood glucose steady lets enzymes and cells work properly all the time.



A blood glucose meter: homeostasis keeps blood glucose within narrow limits

Image: Roy Zuo, CC BY-SA 4.0 (commons.wikimedia.org)

The principles of homeostasis

Most homeostasis follows the same plan:

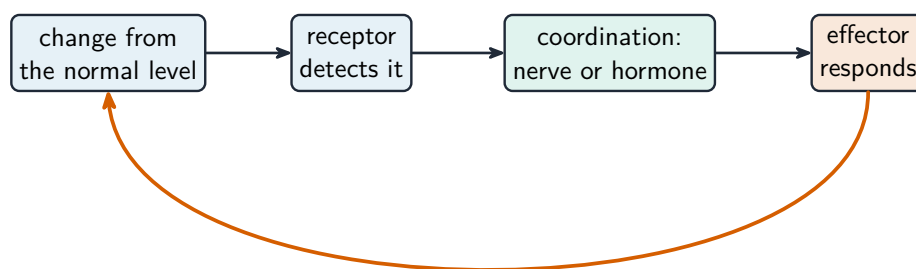
- a change (an internal or external **stimulus** 刺激) is detected by a **receptor** 受体.
- a coordination system carries the message —either the **nervous system** 神经系统 (using nerve signals) or the **endocrine system** 内分泌系统 (using **hormones** 激素).
- an **effector** 效应器 (a muscle or a **gland** 腺体) makes a response that corrects the change.



Sweating cools the body —part of temperature homeostasis, with the skin as the effector

Image: Spc. Tyler Meister, Public domain (commons.wikimedia.org)

This works by **negative feedback** 负反馈: a change away from the normal level triggers a response that pushes it back towards normal.



the response pushes the level back to normal (negative feedback)

Negative feedback: a receptor detects a change and an effector corrects it, returning to normal

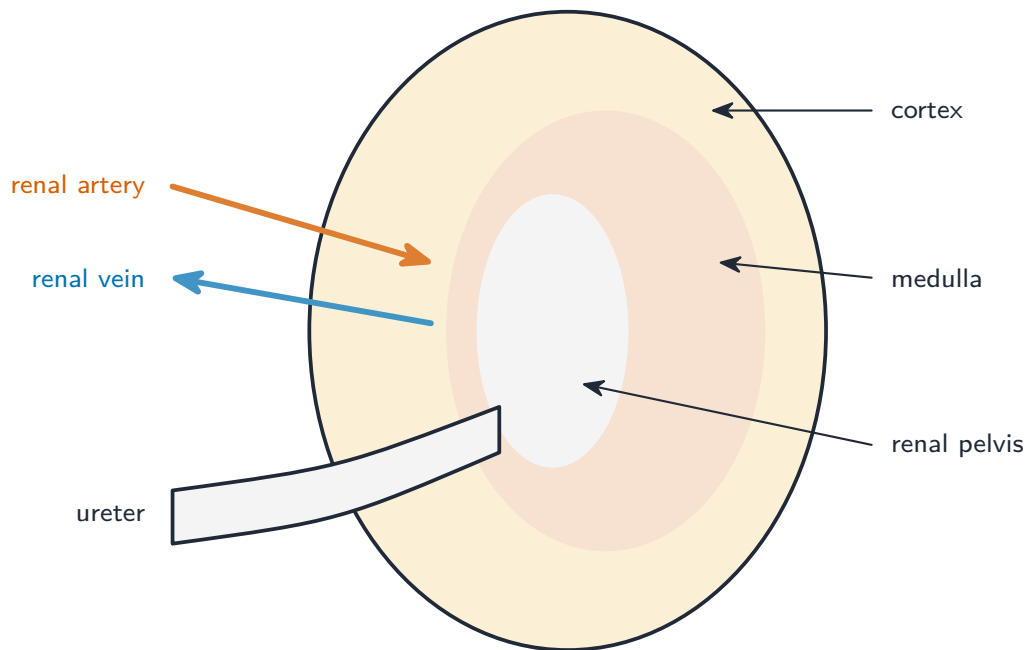
The liver and urea

The body cannot store extra amino acids. In the **liver** 肝脏, the process of **deamination** 脱氨基作用 removes the amino group from excess **amino acids** 氨基酸, and this is turned into **urea** 尿素. The urea is carried in the blood to the kidneys to be removed.

The kidney

The **kidney** 肾脏 cleans the blood and controls its water content. Its parts are:

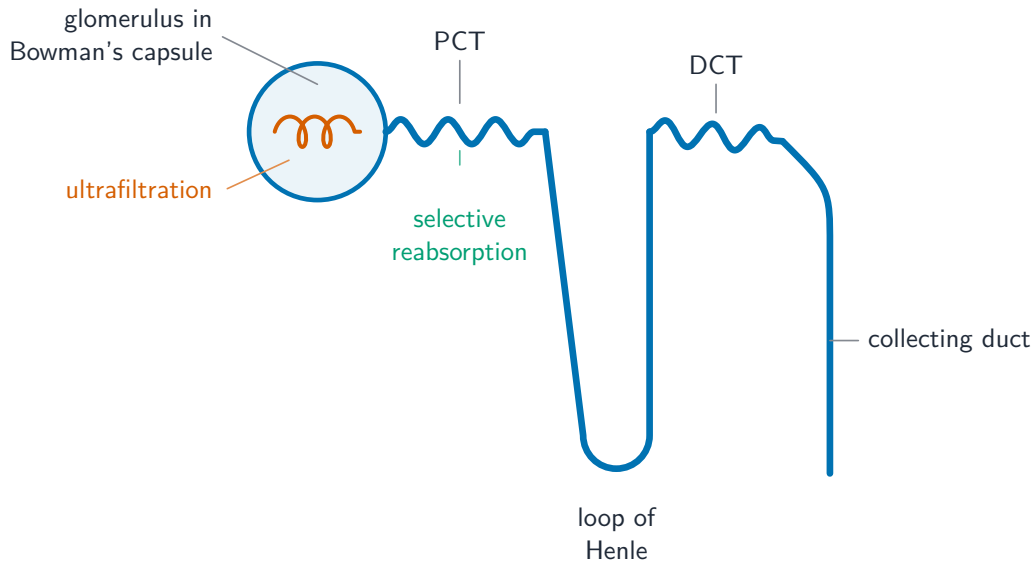
- an outer **fibrous capsule**,
- an outer region, the **cortex** 皮质,
- an inner region, the **medulla** 髓质,
- a central space, the **renal pelvis** 肾盂, which collects urine,
- the **ureter** 输尿管, which carries urine to the bladder,
- branches of the renal artery (bringing blood in) and renal vein (taking blood out).



A section through the kidney: blood is cleaned in the cortex and medulla, and urine collects in the renal pelvis before leaving down the ureter

The nephron

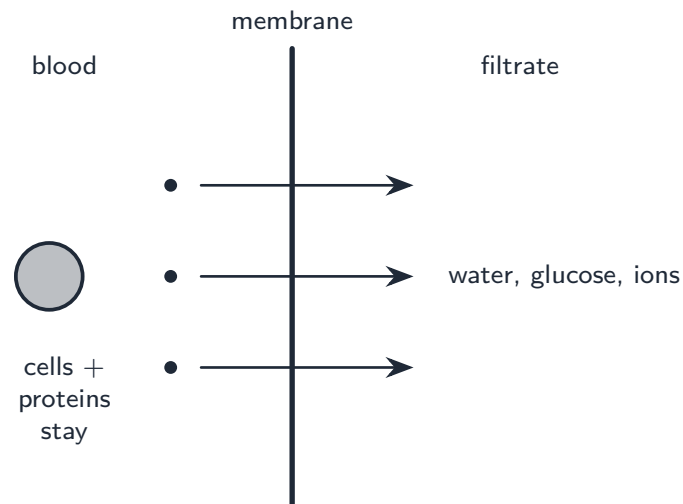
Each kidney holds about a million tiny tubes called **nephrons** 肾单位. Along a nephron are: the **glomerulus** 肾小球 (a knot of capillaries), the **Bowman's capsule** 鲍曼囊 around it, the **proximal convoluted tubule** 近曲小管, the **loop of Henle** 亨利环, the **distal convoluted tubule** 远曲小管, and the **collecting duct** 集合管.



Ultrafiltration happens in the Bowman's capsule; selective reabsorption happens in the proximal convoluted tubule

Making urine

1. **Ultrafiltration** 超滤 happens in the Bowman's capsule. The blood in the glomerulus is under high pressure, so water and small molecules (**glucose** 葡萄糖, **ions** 离子, urea) are pushed out into the capsule, forming the **filtrate** 滤液. Blood cells and large proteins are too big to pass, so they stay in the blood.
2. **Selective reabsorption** 选择性重吸收 happens in the proximal convoluted tubule. Useful substances are taken back into the blood. All the glucose and much of the water and ions are reabsorbed here. The tubule wall is well suited to this: its cells have **microvilli** 微绒毛 to give a large surface area, and many **mitochondria** 线粒体 to power **active transport** 主动运输.

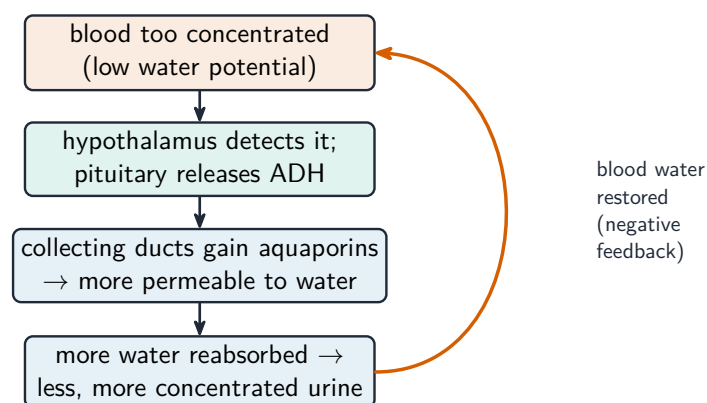


Ultrafiltration keeps blood cells and proteins in the blood

Osmoregulation

Osmoregulation 渗透调节 controls the water content of the blood. It is run by the brain:

- the **hypothalamus** 下丘脑 detects the **water potential** 水势 of the blood.
- when the blood is too concentrated, the **pituitary gland** 垂体 releases **antidiuretic hormone** 抗利尿激素 (ADH).
- ADH makes the collecting ducts more permeable to water by adding water channels called **aquaporins** 水通道蛋白.
- more water is then reabsorbed back into the blood, so less, more concentrated urine is made. This is negative feedback.

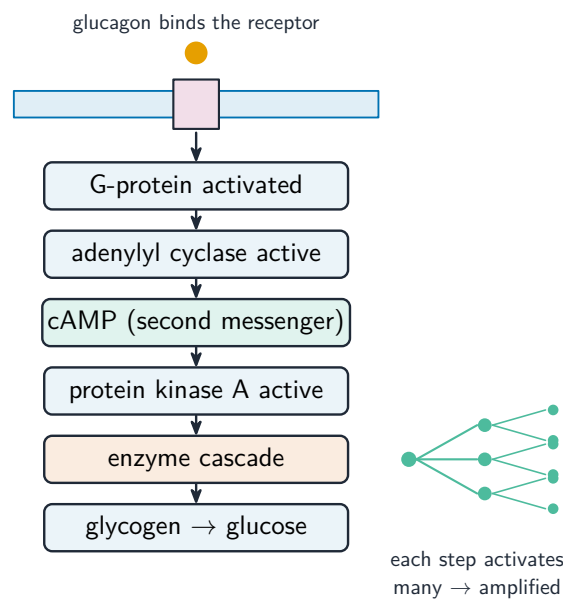


ADH makes the collecting ducts reabsorb more water, restoring the blood's water content by negative feedback

Controlling blood glucose by cell signalling

When blood glucose falls, the hormone **glucagon** 胰高血糖素 is released. It shows how a hormone passes its message into a cell — **cell signalling** 细胞信号传递:

1. glucagon binds to a receptor on the liver cell surface, causing a **conformational change** 构象变化 (a change in the receptor's shape).
2. this activates a **G-protein** G 蛋白, which switches on the enzyme **adenylyl cyclase** 腺苷酸环化酶.
3. adenylyl cyclase makes a **second messenger** 第二信使 inside the cell, called **cyclic AMP** 环腺苷酸 (cAMP).
4. cAMP activates **protein kinase A** 蛋白激酶 A, which starts an **enzyme cascade** 酶级联反应—one **enzyme** 酶 switches on the next, by **phosphorylation** 磷酸化.
5. because each enzyme switches on many of the next, the signal is greatly **amplified** 放大.
6. the final enzyme breaks down **glycogen** 糖原 into glucose, which raises the blood glucose level.

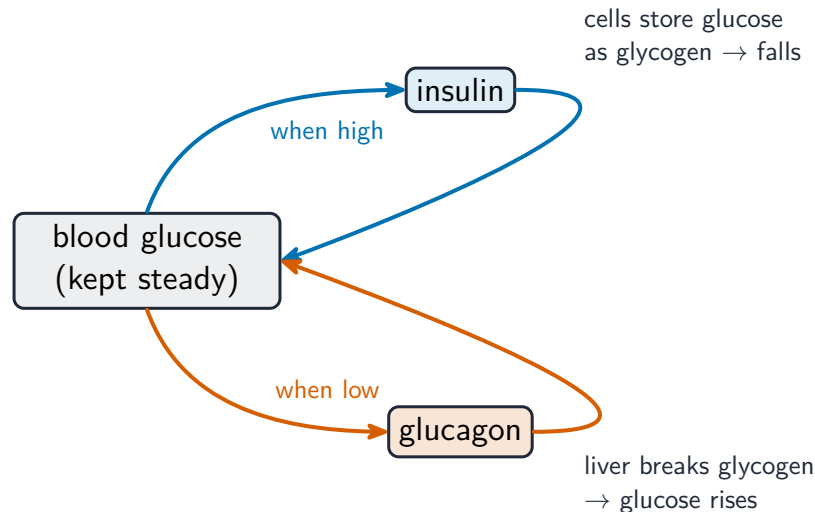


The signal passes through a second messenger (cAMP) and an enzyme cascade —each step activates many, so the signal is amplified

Negative feedback and blood glucose

Blood glucose is held steady by two hormones working against each other:

- when glucose is **high**, **insulin** 胰岛素 makes muscle and liver cells take in glucose and store it as glycogen, lowering the level.
- when glucose is **low**, glucagon makes liver cells break glycogen back into glucose, raising the level.



Insulin and glucagon work against each other to keep blood glucose steady

Measuring glucose

Test strips 试纸 and **biosensors** 生物传感器 measure glucose in blood or urine. They use the enzymes **glucose oxidase** 葡萄糖氧化酶 and **peroxidase** 过氧化物酶, which react with glucose to give a colour change (or an electric signal in a biosensor) that shows how much glucose is present.

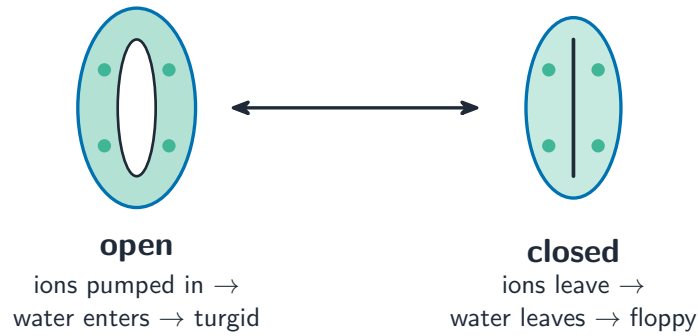
Worked example. A person drinks a large volume of water. Trace the homeostatic response. The blood's water potential **rises** (becomes less negative). **Osmoreceptors** in the hypothalamus detect this, so the posterior pituitary releases **less ADH**. With less ADH, fewer **aquaporins** are inserted into the collecting duct's membranes, so the duct becomes **less permeable** to water. Less water is reabsorbed, so a **large volume of dilute urine** is produced and the blood's water potential falls back towards normal. That return to the set point is what makes it **negative feedback** - the response reverses the original change. Name the **receptor**, the **hormone**, the **effector** and the **correction**: an answer that jumps from "drinks water" straight to "more urine" skips every marking point in between.

Homeostasis in plants: the stomata

Stomata 气孔 are pores in a leaf. The plant opens and closes them to balance two needs: letting in **carbon dioxide** 二氧化碳 for **photosynthesis** 光合作用, and limiting water loss by **transpiration** 蒸腾作用. Stomata usually open by day and close at night, following a daily rhythm.

Each stoma is opened and closed by two **guard cells** 保卫细胞 around it:

- to **open**: the guard cells pump in ions, so their water potential falls and water enters by **osmosis** 渗透. They swell and bend apart, opening the pore.
- to **close**: ions leave, water follows out, the guard cells go floppy, and the pore closes.



Guard cells open the stoma by taking in water and turgid; they close it by losing water and going floppy

When the plant is short of water (**water stress** 水分胁迫), the hormone **abscisic acid** 脱落酸 is released. It makes the guard cells lose ions and water so the stomata close, saving water. In this signalling, **calcium ions** 钙离子 act as a second messenger inside the guard cells.

Exam tips

- Frame every answer as **negative feedback**: receptor → coordinator → effector → correction; name each part.
- **Blood glucose**: insulin lowers it (uptake, glycogenesis), glucagon raises it (glycogenolysis) —explain through cell signalling.
- **Kidney**: know ultrafiltration (Bowman's capsule), selective reabsorption (proximal tubule) and the role of **ADH** in osmoregulation.
- **Stomata** open when guard cells become turgid (K⁺ enters, water follows).