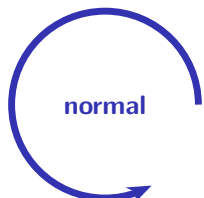
Homeostasis

A-Level Biology ▪ Topic 14

A-Level Biology



What we will cover

1. Negative feedback
2. The kidney
3. The nephron
4. Osmoregulation & ADH
5. Blood glucose
6. Stomata

glucose kept in narrow limits

1 Principles

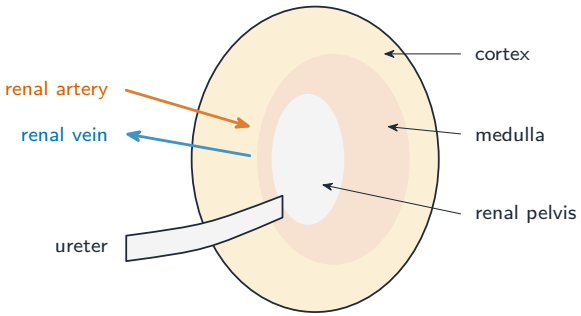
Negative feedback

A change is detected, and the response reverses it – keeping the factor near a set point. That is **homeostasis** 稳态.

> Positive feedback increases the change (oxytocin in labour). It is rare, and it does not give a stable internal environment.

2 The kidney

The kidney

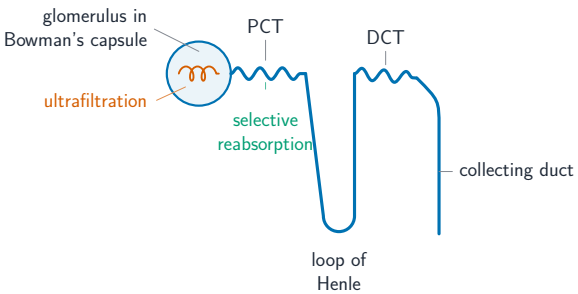


The **kidney** 肾脏 cleans the blood and controls its water.

- **cortex** 皮质 & **medulla** 髓质 clean the blood
- urine collects in the **renal pelvis** 肾盂

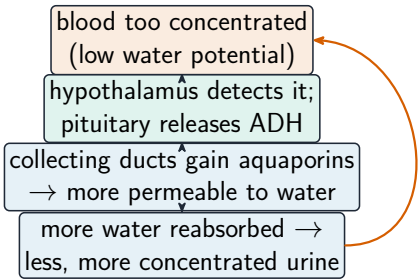
The liver makes **urea** 尿素 from excess amino acids (**deamination** 脱氨基作用).

The nephron and making urine



- **ultrafiltration** 超滤 (**Bowman's capsule** 鲍曼囊) – pressure pushes out small molecules; cells & proteins stay
- **selective reabsorption** 选择性重吸收 (**proximal tubule** 近曲小管) – glucose & water taken back

Osmoregulation and ADH



The **hypothalamus** 下丘脑 detects the blood's **water potential** 水势.

If too concentrated, the pituitary releases **ADH** 抗利尿激素 – the **collecting ducts** 集合管 reabsorb more water, so less, concentrated urine is made.

ADH, and what it changes

The detector	Osmoreceptors in the hypothalamus sense the water potential of the blood.
The hormone	When the blood is too concentrated, the **pituitary gland** 垂体 releases **antidiuretic hormone** 抗利尿激素 (ADH).
The effect	ADH makes the collecting duct wall more permeable to water – aquaporins are inserted – so more water returns to the blood and the urine is small and concentrated.
The feedback	Blood water potential rises, the osmoreceptors quieten, ADH release falls. Negative feedback, in one loop.

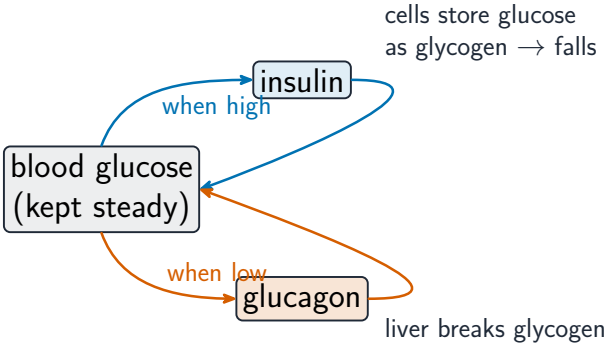
ADH changes a *permeability*, not a pump. The water still moves down its own gradient.

3 Blood glucose

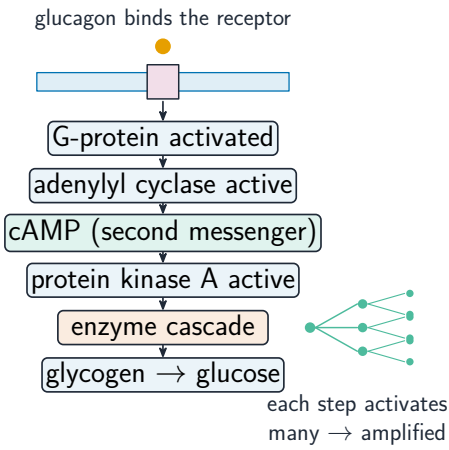
Controlling blood glucose

Two hormones work against each other:

- high glucose → **insulin** 胰岛素 stores it as **glycogen** 糖原
- low glucose → **glucagon** 胰高血糖素 breaks glycogen back to glucose



Cell signalling: the glucagon cascade



Glucagon binds a receptor → **G-protein** G 蛋白 → **cAMP** 环腺苷酸 (a **second messenger** 第二信使) → an **enzyme cascade** 酶级联反应.

> Each step switches on many of the next, so the signal is greatly **amplified** 放大.

One hormone, an amplified answer

1. Binding	Glucagon binds a receptor on the liver cell surface, causing a **conformational change** 构象变化 – a change in the receptor's shape.
2. G-protein	That activates a **G-protein** G 蛋白, which switches on the enzyme **adenylyl cyclase** 腺苷酸环化酶.
3. Second messenger	Adenylyl cyclase makes a **second messenger** 第二信使 inside the cell: **cyclic AMP** 环腺苷酸 (cAMP).
4. Enzyme cascade	cAMP activates **protein kinase A** 蛋白激酶 A, which starts an **enzyme cascade** 酶级联 – each enzyme switching on the next by **phosphorylation** 磷酸化.

The point of the cascade is amplification: a few hormone molecules outside end in millions of glucose molecules released.

4 Plants

Stomata and guard cells

open
ions pumped in $\longrightarrow$
water enters $\longrightarrow$ turgid

closed
ions leave $\longrightarrow$
water leaves $\longrightarrow$ floppy

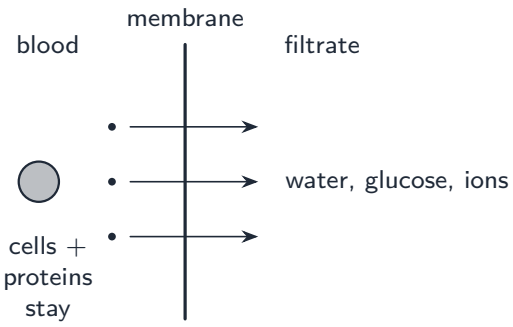
Guard cells 保卫细胞 open a **stoma** 气孔 by taking in water (turgid) and close it by losing water. Under water stress, **abscisic acid** 脱落酸 closes the stomata to save water.

Stomata: balancing two needs

stomata 气孔	pores in a leaf, opened and closed by guard cells
the conflict	letting in **carbon dioxide** 二氧化碳 for photosynthesis, against losing water by transpiration
opening	**active transport** 主动运输 pumps K^+ into the guard cells, water follows by osmosis, and the turgid cells bow apart
aquaporins 水通道蛋白	channel proteins that let that water move quickly
closing	**ADH** 抗利尿激素's plant counterpart abscisic acid is released in drought and triggers closure
calcium ions 钙离子	act as the second messenger inside the guard cell during that response

Guard cells work by changing their own water potential deliberately – the only cells in the plant that do.

Making urine



Ultrafiltration keeps blood cells and proteins in the blood

The kidney's structure, and measuring glucose

the fibrous capsule 纤维囊	the tough outer covering
the cortex 皮质	the outer region, holding the glomeruli and convoluted tubules
the medulla	the inner region, holding the loops of Henle and collecting ducts
the pelvis	where urine collects before the ureter
test strips 试纸 and biosensors 生物传感器	measure glucose in blood or urine using glucose oxidase and peroxidase
why enzymes	they are specific to glucose, so no other sugar in the sample gives a reading

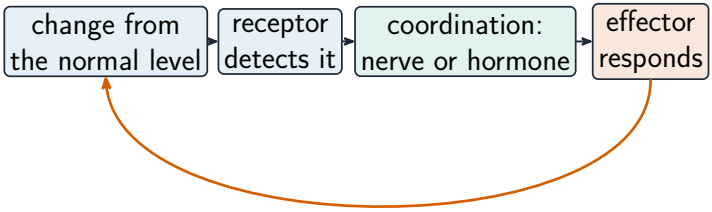
Specificity is the whole reason a biosensor works. A chemical test that reacted with any reducing sugar could not diagnose diabetes.

Along one nephron, in order

Glomerulus and capsule	Each kidney holds about a million **nephrons** 肾单位. Blood in the **glomerulus** 肾小球 is under high pressure, so water and small molecules – glucose, ions, urea – are pushed into the **Bowman's capsule** 鲍氏囊 as the **filtrate** 滤液.
Proximal tubule	The **proximal convoluted tubule** 近曲小管 reabsorbs all the glucose and most of the ions and water.
Loop of Henle	The **loop of Henle** 亨利氏袢 builds a salt gradient in the medulla – the pump that makes concentrated urine possible.
Distal tubule and duct	The **distal convoluted tubule** 远曲小管 fine-tunes ions and pH; the **collecting duct** 集合管 sets the final water content.

The tubule wall is built for the job: **microvilli** 微绒毛 for surface area, and many **mitochondria** 线粒体 to power the **active transport** 主动运输.

The principles of homeostasis



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

What homeostasis is, and the parts it needs

homeostasis 稳态	keeping conditions inside the body steady even when the outside changes
what is held steady	temperature, blood glucose, water potential, pH and ion **concentration 浓度**
a receptor	detects the change from the set point
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 in the blood
an effector	brings about the correction – a muscle or a gland
negative feedback	the correction *reverses* the change, so the value returns toward the set point

Positive feedback amplifies instead, which is why it is rare in the body and used only for events that must run to completion – childbirth, the action potential.

The principles of homeostasis, continued

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

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).

5 Recap

Worked example – controlling blood glucose

Explain how blood glucose returns to normal after a meal.

- Glucose rises above the set point. β cells in the islets of Langerhans detect it.
- They secrete insulin, which binds receptors on liver and muscle cells.
- More GLUT4 transporters move into the membrane, and glucose $\rightarrow$ glycogen (glycogenesis).
- Blood glucose falls $\Rightarrow$ less insulin secreted: negative feedback.

Name the detector (β cell), the signal (insulin) and the effector (liver). Insulin lowers, glucagon raises – both from the pancreas.

Topic 14 – key takeaways

1 Negative feedback

receptor detects, effector corrects

2 Nephron

ultrafiltration then selective reabsorption

3 Osmoregulation

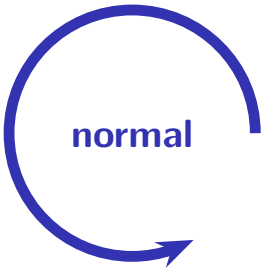
ADH makes ducts reabsorb more water

4 Blood glucose

insulin vs glucagon; cascade amplifies

Check yourself

1. Where in the nephron does ultrafiltration happen?
2. Which hormone makes collecting ducts reabsorb water?
3. Which hormone lowers blood glucose?
4. What is cAMP called in cell signalling?



Answers **1.** the Bowman's capsule **2.** ADH **3.** insulin **4.** a second messenger