IGCSE BIOLOGY 0610 · CHAPTER 11 NOTES · ~17 MIN READ

Coordination & response

How impulses travel along neurones, the reflex arc, how the eye focuses, what hormones do, how the body keeps glucose and temperature steady, and how plants respond to light and gravity.

Nervous system | Reflex arc | Eye | Hormones | Homeostasis | Tropisms

AS
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No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

- The **nervous system** sends **electrical impulses** along **neurones**: **CNS** (brain + spinal cord) and **PNS** (nerves). A **reflex** is a **fast, automatic** response that protects you.
- **Hormones** are **chemicals** made by **glands** and carried in the **blood**. They act **more slowly** than nerves but the effect **lasts longer**. **Homeostasis** keeps blood glucose and temperature **steady**.
- **Plants** respond by **growing**: towards light (**phototropism**) and with or against gravity (**gravitropism**). EXT

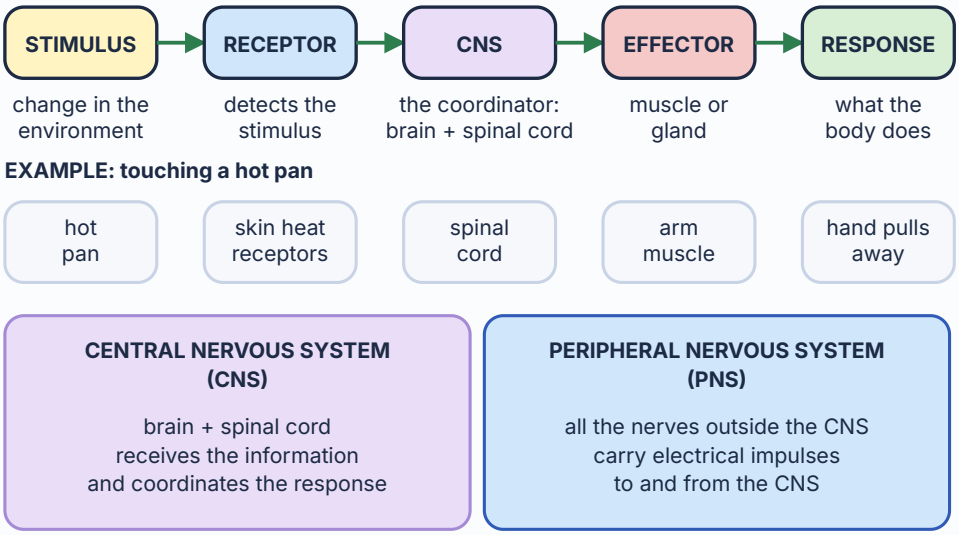
BY THE END YOU CAN

- Describe the nervous system (CNS and PNS) and identify sensory, relay and motor neurones.
- Describe a reflex arc and a reflex action, and say why reflexes are useful.
- Define synapse and name the sense organs and what they detect.
- Identify the parts of the eye and describe the pupil reflex.
- Define hormone and name the main endocrine glands; describe the effects of adrenaline.
- Compare nervous and hormonal control.
- Define homeostasis and state that insulin lowers blood glucose.
- Define gravitropism and phototropism and describe how to investigate them.
- Describe what happens at a synapse, and explain one-way transmission. EXT
- Explain accommodation, and the roles of rods, cones, fovea and the iris muscles. EXT
- Explain negative feedback, glucagon, diabetes, and temperature control by the skin. EXT
- Explain how auxin causes tropisms. EXT

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1 The nervous system

From stimulus to response



Every response follows the same chain: stimulus, receptor, coordinator, effector, response.

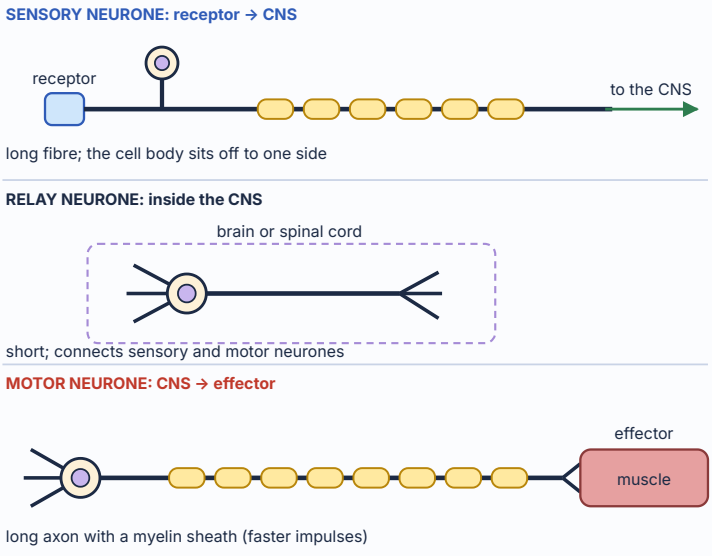
Stimulus — a **change in the environment** (light, heat, pressure, chemicals) that is **detected** by a receptor.

- **Receptors** detect the stimulus. The **CNS (central nervous system)** = **brain + spinal cord** and acts as the **coordinator**. **Effectors** are **muscles or glands** that produce the response.
- The **PNS (peripheral nervous system)** = **all the nerves** outside the CNS. They carry **electrical impulses** between the CNS and the rest of the body.
- **Impulses** are **electrical signals** that travel along **neurones** (nerve cells).

MEMORY TRICK

Stimulus → **R**eceptor → **C**oordinator → **E**ffector → **R**esponse. **"Some Really Clever Elephants Run"**.

Three types of neurone



A reflex uses all three types, in this order: sensory, relay, motor.

- **Sensory neurone:** carries impulses **from a receptor to the CNS**.
- **Relay neurone: inside the CNS**, links the sensory neurone to the motor neurone.
- **Motor neurone:** carries impulses **from the CNS to an effector** (muscle or gland).
- Long neurones have a **myelin sheath**, a fatty covering that **speeds up** the impulse.

MEMORY TRICK

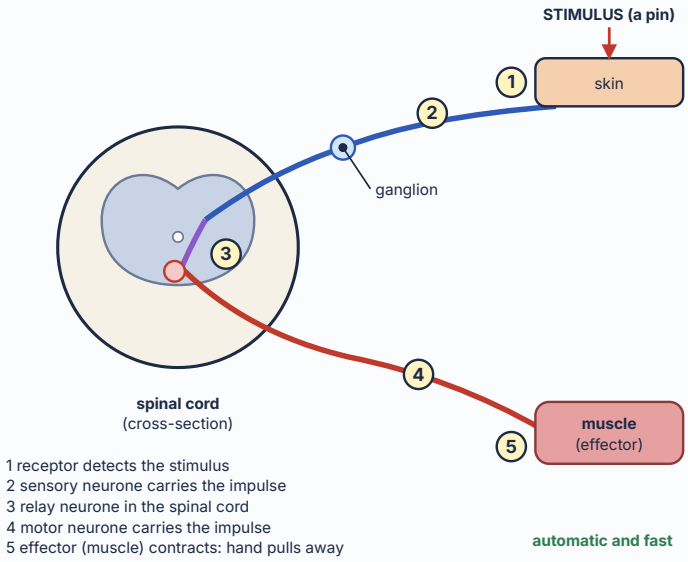
S-R-M: **S**ensory → **R**elay → **M**otor. **S**enses go **in**, **M**uscles get the order **out**.

WORKED EXAMPLE

An impulse travels along a motor neurone at 100 m/s. The neurone from the spinal cord to a foot muscle is 0.9 m long. Find the time taken.

1. time = distance ÷ speed
2. time = 0.9 ÷ 100 = **0.009 s**
3. 0.009 s = **9 ms** (milliseconds)
4. **impulses are very fast, so a reflex can happen in a fraction of a second**

The reflex arc



The reflex arc: receptor, sensory neurone, relay neurone, motor neurone, effector.

Reflex action — a means of **automatically and rapidly integrating and coordinating stimuli** with the **responses of effectors** (muscles and glands).

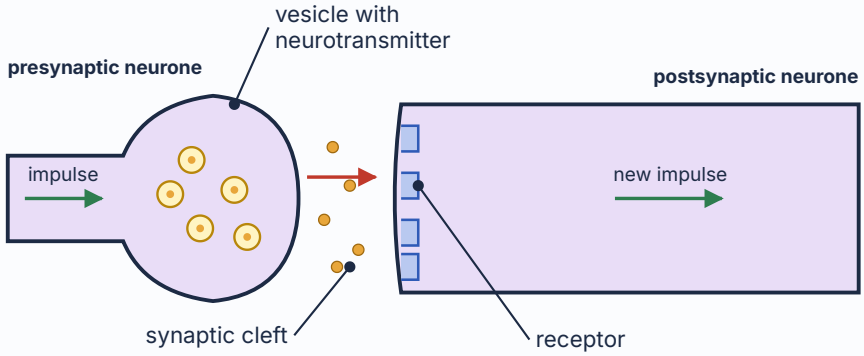
- **Reflex arc** = the pathway: **stimulus → receptor → sensory neurone → relay neurone (in the spinal cord) → motor neurone → effector → response**.
- **Examples:** pulling your hand from a hot object, blinking, the pupil narrowing in bright light, coughing, the knee jerk.
- **Why are reflexes useful?** They are **fast** (few neurones, no thinking), **automatic** (you cannot stop them) and **protect the body from harm**.

Feature	Reflex action	Voluntary action
brain decides?	**no** (the spinal cord coordinates)	**yes**
speed	**very fast**	slower
example	pulling away from a hot pan	picking up a pen

COMMON MISTAKE

"The brain is the control centre of a reflex." In many reflexes **the spinal cord** coordinates the response. The brain is told **afterwards** (that is why you feel pain after you have moved).

The synapse



EXT A chemical, not an electrical spark, crosses the gap.

Synapse — a **junction between two neurones**, with a tiny gap between them.

- EXT **What happens:** (1) the **impulse arrives** at the end of the first neurone, (2) **vesicles release neurotransmitter**, (3) the neurotransmitter **diffuses across the gap** (diffusion), (4) it **binds to receptors** on the next neurone and a **new impulse** starts.
- EXT **One way only: only the first neurone has vesicles** of neurotransmitter and **only the second has receptors**, so impulses can only travel **forwards**.

COMMON MISTAKE

"The impulse jumps across the synapse." **No.** The electrical impulse stops. A **chemical** crosses the gap and starts a **new** impulse.

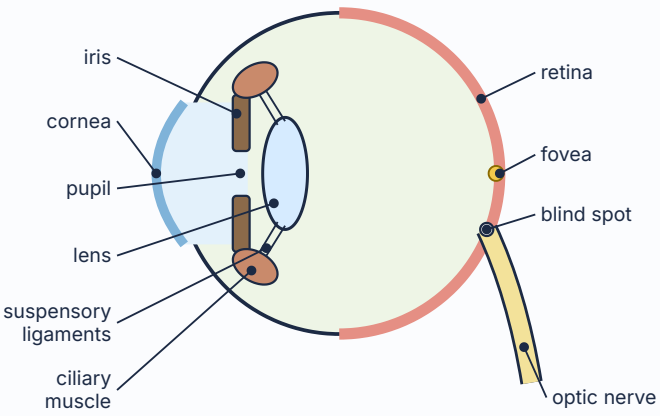
2 Sense organs and the eye

Sense organs and receptors

Sense organ	Receptors detect	Example
eye	**light**	colour and brightness
ear	**sound**	pitch and loudness
skin	**touch, pressure, pain, temperature**	a hot pan
nose	**chemicals** in the air	smell
tongue	**chemicals** in food	taste

- A **sense organ** is a group of **receptor cells** that respond to a **specific stimulus** and send impulses to the brain along **sensory neurones**.

Structure of the eye



Light passes through the cornea, pupil and lens, and is focused on the retina.

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Part	Function
cornea	clear front layer; **refracts (bends)** light into the eye
iris	coloured ring of muscle; **controls how much light** enters the pupil
pupil	the **hole** in the iris through which light enters
lens	**focuses** light onto the retina
retina	layer of **light receptors** (rods and cones)
optic nerve	carries **impulses to the brain**
EXT **ciliary muscle**	changes the **shape of the lens**
EXT **suspensory ligaments**	hold the lens; **pulled tight or slack** by the ciliary muscle
EXT **fovea**	part of the retina with **most cones**: sharpest vision
EXT **blind spot**	where the optic nerve leaves: **no receptors**, so no vision

The pupil reflex



circular muscles CONTRACT
radial muscles RELAX
pupil gets SMALLER
less light enters the eye:
protects the retina

radial muscles CONTRACT
circular muscles RELAX
pupil gets LARGER
more light enters the eye:
you can see in the dark

A reflex: automatic and fast. The two sets of iris muscles work in opposite ways.

The iris adjusts the size of the pupil automatically.

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- **Bright light:** the **pupil gets smaller** so **less light** enters. This **protects the retina** from damage.
- **Dim light:** the **pupil gets larger** so **more light** enters and you can see better.
- EXT **How:** the iris has **two sets of muscles that work against each other** (**antagonistic**). **Circular muscles contract** and **radial muscles relax** to make the pupil smaller. **Radial muscles contract** and **circular muscles relax** to make it larger.

MEMORY TRICK

Circular **C**ontracts → pupil **C**loses down (smaller). **R**adial **R**eaches out → pupil opens (larger).

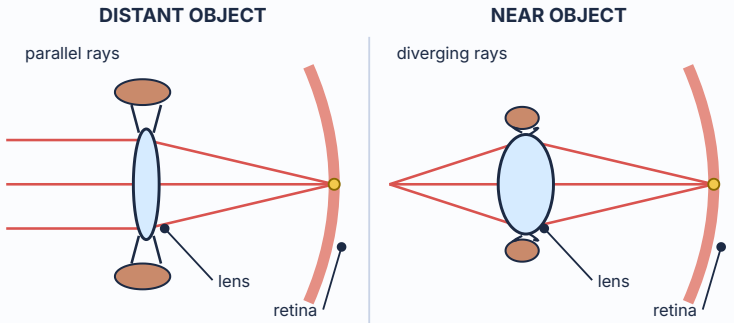
WORKED EXAMPLE

In bright light the pupil has a diameter of 2 mm. In dim light it is 8 mm. Find the area of the pupil each time (area = π × radius²) and how many times larger the dim-light area is.

1. bright: radius = 1 mm, area = 3.14 × 1^2 = **3.14 mm²**
2. dim: radius = 4 mm, area = 3.14 × 4^2 = **50.2 mm²**
3. ratio = 50.2 ÷ 3.14 = **16 times**
4. **doubling the diameter four times (2 → 8) means the area is 4^2 = 16 times larger**

Focusing on near and distant objects

EXTENDED



ciliary muscle RELAXES
suspensory ligaments PULL TIGHT
lens is pulled THIN
light is refracted LESS

ciliary muscle CONTRACTS
suspensory ligaments GO SLACK
lens becomes FAT (rounder)
light is refracted MORE

Accommodation = changing the shape of the lens so that light from near or far objects is focused on the retina

EXT The lens changes shape to focus light from near or far objects on the retina.

Accommodation — EXT the **change in shape of the lens** so that light from objects at **different distances** is focused on the retina.

- EXT **Distant object:** the **ciliary muscle relaxes**, the **suspensory ligaments pull tight**, the **lens is pulled thin** and refracts light **less**.
- EXT **Near object:** the **ciliary muscle contracts**, the **suspensory ligaments go slack**, the **lens becomes fat** (more curved) and refracts light **more**.

MEMORY TRICK

Near = ciliary **N**arrows (contracts), lens **fat**. **D**istant = ciliary muscle **D**ilates (relaxes), lens thin.

COMMON MISTAKE

"The muscle contracts to make the lens thin." **No.** When the ciliary muscle **contracts**, the ligaments **slacken** and the lens goes **fat**.

Rods and cones

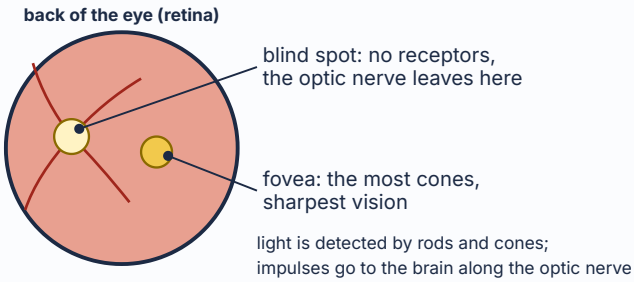
EXTENDED

RODS
sensitive to DIM light
black and white vision
most are round the edge
NONE in the fovea



CONES
sensitive to BRIGHT light
colour vision (3 types)
packed into the fovea
give sharp detail





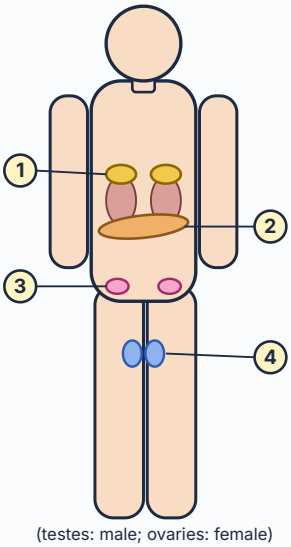
EXT The retina has two kinds of light receptor.

Receptor	Rods	Cones
works best in	**dim light**	**bright light**
gives	black and white vision	**colour** vision
found	mostly round the edge of the retina	**packed in the fovea**

- EXT The **fovea** has the **most cones**, so it gives the **sharpest, colour** vision. The **blind spot** has **no rods or cones**.

3 Hormones

What are hormones?



(testes: male; ovaries: female)

1. **ADRENAL GLANDS**
hormone: adrenaline
prepares the body for "fight or flight"

2. **PANCREAS**
hormone: insulin and glucagon
control blood glucose

3. **OVARIES (female)**
hormone: oestrogen, progesterone
female characteristics,
the menstrual cycle

4. **TESTES (male)**
hormone: testosterone
male characteristics
(sperm production too)

The main endocrine glands release hormones straight into the blood.

Hormone — a **chemical substance**, produced by a **gland** and carried by the **blood**, which **alters the activity of one or more specific target organs**.

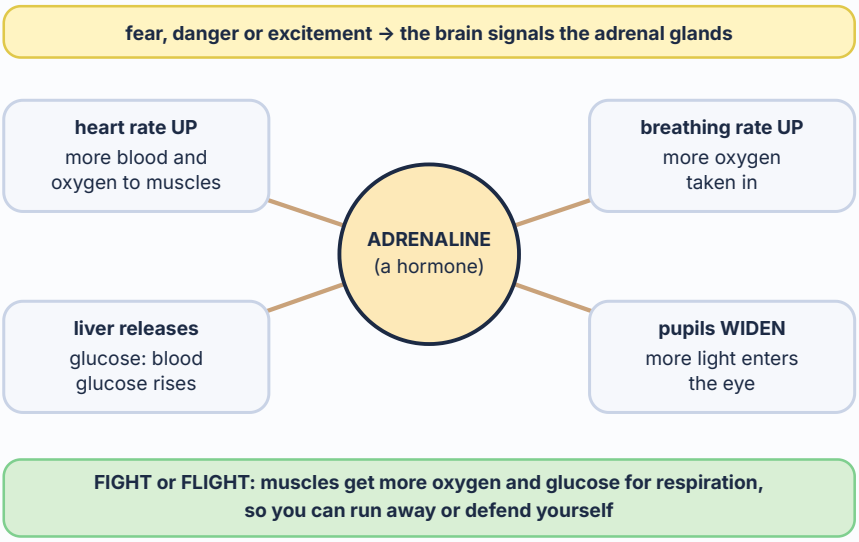
- **Endocrine glands** release hormones directly into the **blood** (not through a duct).

Feature	Nervous control	Hormonal control
message is	**electrical impulse**	**chemical (hormone)**
travels by	**neurones**	**blood**
speed	**very fast**	**slower**
effect lasts	**short time**	**longer time**
acts on	a **precise** target (a muscle, a gland)	**target organs** (can be several)
example	pulling away from a hot pan	adrenaline, insulin

MEMORY TRICK

Nerves = **N**ippy and **N**arrow. **H**ormones = **H**eavier, **H**anging around longer.

Adrenaline: the fight or flight hormone



Adrenaline prepares the body for action.

- **Adrenaline** is released by the **adrenal glands** when you are **frightened, in danger or excited**.
- **Effects: heart rate increases**, **breathing rate increases**, **pupils widen** and the **liver releases glucose** (blood glucose rises).
- **Why?** Muscles get **more oxygen and glucose** for **aerobic respiration** (respiration), releasing more energy to **run away or fight**.

4 Homeostasis

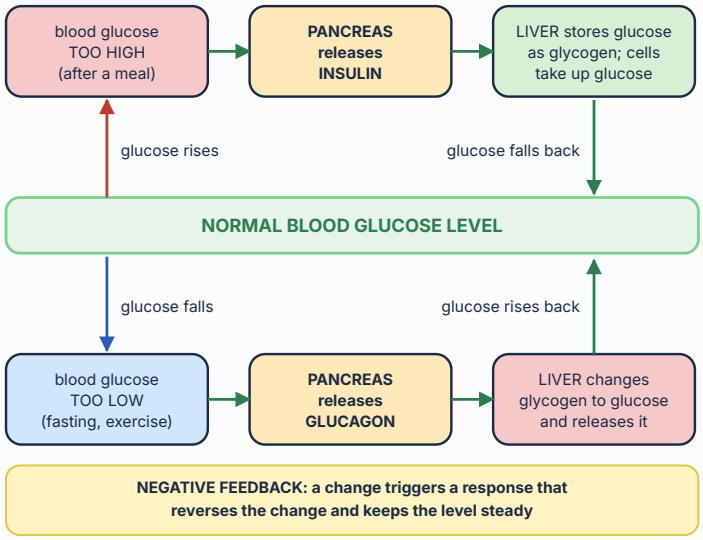
Keeping conditions steady

Homeostasis — the **maintenance of a constant internal environment**.

- The internal environment includes **blood glucose concentration**, **body temperature** and **water content**. Cells work best when these stay **steady**.
- **Insulin** is a hormone made by the **pancreas** that **lowers blood glucose**.

Controlling blood glucose

EXTENDED



EXT Two hormones from the pancreas keep blood glucose steady by negative feedback.

- EXT **Blood glucose too high** (after a meal): the **pancreas secretes insulin**. The **liver converts glucose into glycogen** for storage and cells take up glucose, so blood glucose **falls**.
- EXT **Blood glucose too low:** the **pancreas secretes glucagon**. The **liver converts glycogen back to glucose** and releases it, so blood glucose **rises**.

Negative feedback — EXT a change in conditions causes a response that **reverses the change** and returns conditions to normal.

MEMORY TRICK

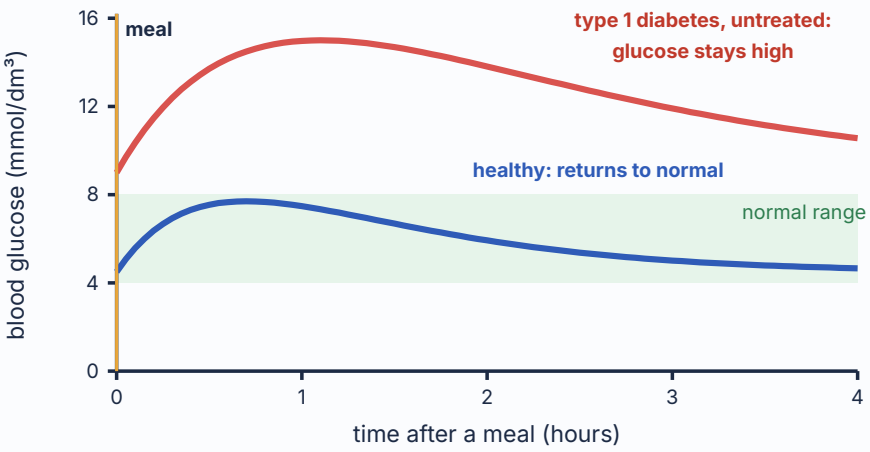
Insulin puts glucose **in** storage (glycogen). **Glucagon** gets glucose **going** (out of storage).

COMMON MISTAKE

"Insulin and glucagon do the same job." They have **opposite effects**: insulin **lowers** blood glucose, glucagon **raises** it.

Diabetes

EXTENDED



EXT After a meal, glucose rises a little and returns to normal. With untreated type 1 diabetes it stays high.

- EXT **Type 1 diabetes:** the **pancreas does not make enough insulin**, so **blood glucose stays too high**. It is treated by **insulin injections** (and managing diet) before meals.
- EXT Reading the graph: the healthy person's glucose **peaks lower** and **returns to normal within 2 to 3 hours**. In untreated diabetes it **peaks much higher** and **stays high**.

WORKED EXAMPLE

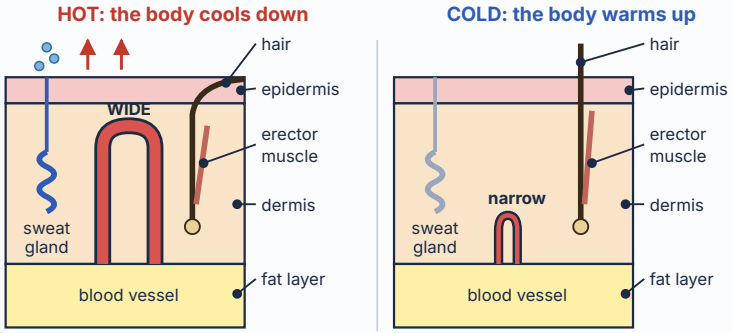
EXT **After a meal, a healthy person's blood glucose peaks at 7.7 mmol/dm³. A person with untreated type 1 diabetes peaks at 15.0 mmol/dm³. Find the difference and how many times higher the diabetic peak is.**

1. difference = 15.0 − 7.7 = **7.3 mmol/dm³**
2. ratio = 15.0 ÷ 7.7 = **1.9 times** (1.95)
3. percentage higher = 7.3 ÷ 7.7 × 100 = **95%**
4. **without insulin the glucose cannot be taken up and stored, so it stays high**

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Controlling body temperature

EXTENDED



sweating: evaporation cools the skin
VASODILATION: vessels near the surface widen: more blood flows near the surface, more heat lost
hairs lie flat

VASOCONSTRICTION: vessels near the surface narrow: less blood flows near the surface, less heat lost
SHIVERING: muscles contract, releasing heat

Body temperature stays near 37 °C by negative feedback.

EXT The skin responds to heat and cold. Body temperature stays near 37 °C.

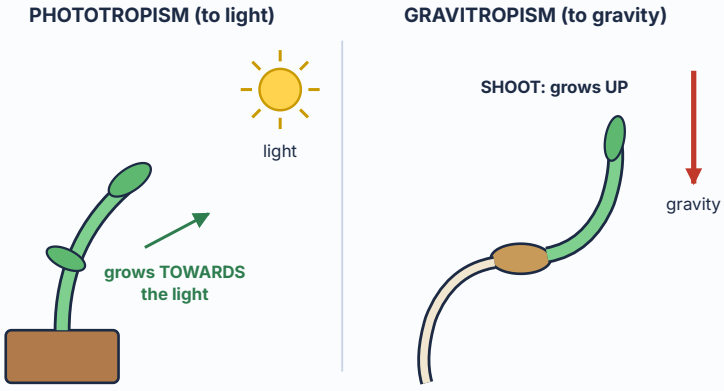
- EXT **Too hot: sweat glands** release **sweat**; the **evaporation of sweat cools** the skin. **Blood vessels near the surface widen** (**vasodilation**) so more blood flows near the surface and **more heat is lost**.
- EXT **Too cold: less sweat**; the **vessels near the surface narrow** (**vasoconstriction**), so **less heat is lost**. **Shivering** (rapid muscle contractions) **releases heat**.
- EXT The **temperature is detected** by receptors in the skin and brain, which is **negative feedback** again.

COMMON MISTAKE

"The capillaries move closer to the skin." **No.** The blood vessels **do not move**. They **widen or narrow**, which changes **how much blood flows** near the surface.

5 Plant responses

Tropisms



A shoot grows towards a one-sided light source.
Roots tend to grow away from light.

ROOT: grows DOWN

(a seedling laid on its side)
Roots grow in the direction of gravity; shoots grow against it.

Tropism = a growth response to a stimulus from one direction.

Shoots grow towards light and away from gravity. Roots grow towards gravity.

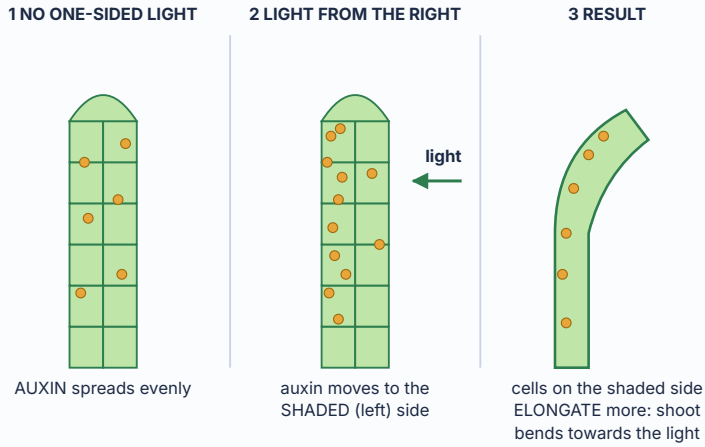
Gravitropism — a response in which parts of a plant **grow in a particular direction in response to gravity**.

Phototropism — a response in which parts of a plant **grow in a particular direction in response to the direction of light**.

- **Shoots** are positively **phototropic** (grow **towards** light) and negatively **gravitropic** (grow **up**). **Roots** are positively **gravitropic** (grow **down**).
- **Investigating phototropism:** grow seedlings in a box with a **slit of light from one side**. Shoots bend **towards** the light. Keep a **control** with light from all sides (or a rotating clinostat).
- **Investigating gravitropism:** lay seedlings **on their side** in **darkness** (so light cannot affect them). Roots turn **down** and shoots turn **up**.

Auxin

EXTENDED



AUXIN is made in the shoot tip and diffuses down. More auxin on one side makes the cells there elongate more, so the shoot bends

EXT Auxin made in the tip moves to the shaded side and makes those cells elongate more.

Auxin — EXT a **plant growth hormone made in the shoot tip** that **diffuses down** the shoot and makes **cells elongate**.

- EXT In **one-sided light**, auxin collects on the **shaded side**. Cells there **elongate more** than on the lit side, so the shoot **bends towards the light**.
- EXT **Gravity** has a similar effect on a shoot lying sideways: auxin collects on the **lower side**, the shoot **bends upwards**.

COMMON MISTAKE

"Auxin makes plants bend towards light." Auxin makes **cells elongate**. The **uneven** distribution causes the bending.

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6 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. What does CNS stand for and what does it contain?
2. Name the three types of neurone in a reflex arc, in order.
3. What is a reflex action?
4. Give one example of a reflex.
5. What is a synapse?
6. What detects light in the eye?
7. What happens to the pupil in bright light?
8. What is a hormone?
9. Name two effects of adrenaline.
10. What does insulin do?
11. Define homeostasis.
12. Define phototropism.
13. EXT What crosses a synapse?
14. EXT Which hormone raises blood glucose?
15. EXT Where is auxin made?

EXAM-STYLE

16. Explain why a reflex is faster than a voluntary action. [3]
17. Describe the path of a reflex arc when you touch a hot object. [4]
18. EXT Describe what happens at a synapse. [4]
19. EXT Explain how the eye focuses on a near object. [4]
20. EXT Explain how the body responds when blood glucose is too high. [4]
21. EXT Explain how auxin causes a shoot to bend towards light. [4]

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Show answers

1. central nervous system; brain and spinal cord
2. sensory, relay, motor
3. an automatic and rapid response to a stimulus, using effectors
4. pulling away from a hot object, blinking, pupil reflex
5. a junction between two neurones
6. the retina (rods and cones)
7. it gets smaller
8. a chemical made by a gland and carried in the blood that affects target organs
9. heart rate increases, breathing rate increases, pupils widen, glucose released
10. lowers blood glucose
11. maintaining a constant internal environment
12. growth of a plant part in response to the direction of light
13. neurotransmitter (a chemical)
14. glucagon
15. in the shoot tip
16. few neurones and no thinking by the brain
    impulse goes through the relay neurone in the spinal cord
    so the response is automatic and rapid
17. receptor in the skin detects the heat
    sensory neurone carries the impulse to the spinal cord
    relay neurone then motor neurone
    effector (muscle) contracts to pull the hand away
18. impulse arrives at the end of the neurone
    vesicles release neurotransmitter
    it diffuses across the gap
    it binds to receptors and starts a new impulse
19. ciliary muscle contracts
    suspensory ligaments slacken
    lens becomes fatter (more curved)
    light is refracted more and focused on the retina
20. pancreas secretes insulin
    liver converts glucose to glycogen
    cells take up glucose
    blood glucose falls (negative feedback)
21. auxin is made in the shoot tip
    it moves to the shaded side
    cells on the shaded side elongate more
    so the shoot bends towards the light

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