

Co-ordination in Plants and Animals

Unit 3 Topic Note · Biology · Secondary 4

This unit covers how plants and animals detect and respond to changes around them — plant growth responses driven by hormones, and the nervous and endocrine systems that coordinate animal behaviour.

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3.1 Co-ordination in Plants

Before this: You should know that living things can sense and respond to their environment.

Why this matters: A plant cannot run from danger or walk toward water, but it isn't helpless — it can grow in the direction that best helps it survive, using its own internal signals to steer that growth.

Key Vocabulary

- **Co-ordination:** giving the correct response, at the correct time, to a stimulus
- **Tropism:** a growth response of a plant toward or away from a directional stimulus
- **Positive/negative response:** growth toward the stimulus is positive; growth away from it is negative

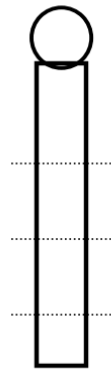
Types of Tropism

Tropism	Stimulus	Typical response
Phototropism	Light	Shoots grow toward light (positive); roots often grow away (negative)
Geotropism (gravitropism)	Gravity	Roots grow toward gravity (positive); shoots grow away (negative)
Hydrotropism	Water	Roots grow toward water (positive); shoots grow away (negative)
Thigmotropism	Touch/contact	Climbing stems/tendrils wind around a support (positive)
Chemotropism	Chemicals	Pollen tubes grow toward chemicals released by the ovule (positive)

Experiment — Testing for Phototropism and Geotropism

1. Take two healthy potted seedlings of the same age and species (e.g. bean or maize seedlings).
2. Place Seedling A in a box with a single small hole cut in one side, so light only enters from that direction. Leave Seedling B in open, evenly-lit conditions as a comparison.
3. Lay Seedling A's pot on its side to test geotropism separately, marking the original 'up' direction on the pot.
4. Check both seedlings after 2–3 days without disturbing them.
5. Record the direction of stem growth relative to the light hole (phototropism) and relative to the original 'up' mark (geotropism).

grows straight up



even light
(all sides)

bends toward light

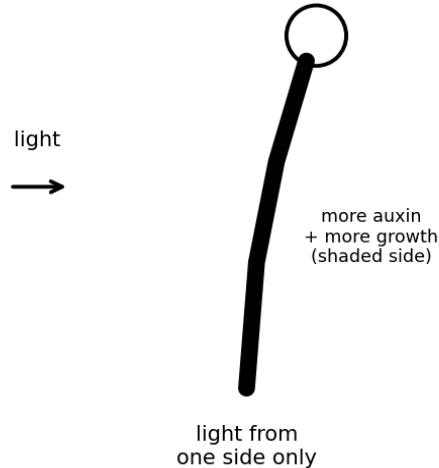


Diagram: original schematic showing a seedling growing straight under even light, versus bending toward a one-sided light source.

Local Example — Passion Fruit Vines on a Fence

Passion fruit and other climbing crops common in South Sudanese home gardens wind their tendrils tightly around a fence wire or stick as soon as they touch it — a clear example of positive thigmotropism. A farmer training young vines onto a trellis is deliberately using this response to guide the plant's growth.

Key Takeaways & Common Pitfalls

- **Must-remember:** "positive" and "negative" describe direction relative to the stimulus, not whether the response is good or bad for the plant.
- **Common mistake:** students often assume all plant parts respond the same way to a stimulus — roots and shoots frequently show opposite responses to the same stimulus (e.g. gravity).

Practice Questions

Easy

Q: What stimulus does phototropism respond to?

A: **Light.** Shoots typically grow toward it (positive phototropism).

Medium

Q: A bean seedling is placed on its side. After two days, the root has curved to grow downward and the shoot has curved to grow upward. Name the tropism responsible and explain the difference in direction.

A: **Geotropism (gravitropism).** The root shows positive geotropism (grows toward gravity, anchoring the plant and reaching water/minerals), while the shoot shows negative geotropism (grows away from gravity, reaching light for photosynthesis) — the same stimulus produces opposite responses in the two organs.

Hard

Q: A climbing bean plant grown in complete darkness, but given a stick to touch, still winds around the stick. A separate bean plant grown in light but with nothing to touch grows straight upward. Using both results together, explain what this tells you about thigmotropism versus phototropism as separate response systems.

A: **The two responses operate independently of each other.** The plant in darkness winding around the stick shows that thigmotropism does not require light to occur — touch alone is a sufficient stimulus. The plant

with nothing to touch growing straight upward under light shows normal phototropism/growth without a contact stimulus. Together, this indicates the plant has separate, independently-triggered response pathways for different stimuli, rather than one single generic 'response system' triggered by any stimulus.

Research & Discussion

- Find a climbing plant near your home (e.g. passion fruit, yam, or a climbing bean). Observe which direction its tendrils wind and whether all tendrils on the plant wind the same way.
- Place a potted plant on a windowsill and mark which way it's facing. Check it again after 3–4 days without moving it. What changed?
- Ask a farmer in your community how they train climbing crops like passion fruit onto a trellis or fence, and what happens if the young vine isn't given anything to grip.

3.2 Role of Auxin in Controlling Shoot Growth

Before this: You should know what phototropism and geotropism are.

Why this matters: Tropisms aren't magic — they happen because a single hormone, auxin, is unevenly distributed across the plant, causing one side to grow faster than the other.

Key Vocabulary

- **Auxin (Indole Acetic Acid, IAA):** a plant hormone produced at shoot and root tips that controls cell elongation
- **Differential growth:** unequal growth rates on two sides of the same organ, causing it to bend

How Auxin Causes Bending

Auxin is produced at the tip and diffuses down the shoot, controlling how much the cells below elongate. When light comes from only one direction, auxin shifts to the shaded side. The shaded side then has more auxin and elongates more than the lit side — causing the shoot to bend toward the light.

Organ	Effect of higher auxin concentration	Effect of lower auxin concentration
Shoot	More growth (elongation)	Less growth
Root	Less growth (opposite response to shoot)	More growth

This opposite sensitivity is exactly why roots and shoots bend in opposite directions under gravity: the same higher auxin concentration that speeds up shoot growth actually slows down root growth.

Experiment — Testing Whether the Tip Controls Bending

1. Take three identical young seedlings of the same age.
2. Leave Seedling 1 with its tip intact (control).
3. Cut off the tip of Seedling 2 completely.
4. Cut off the tip of Seedling 3, then place a small block of agar jelly that has been in contact with a separate cut tip on top of the cut stem.
5. Expose all three to light from one direction for 2 days.
6. Compare: Seedling 1 should bend toward the light; Seedling 2 should show little or no growth/bending; Seedling 3 should resume bending, showing the agar block carried the growth-controlling substance from the tip.

Local Example — Auxin-Based Weed Killers in Sorghum Fields

Some herbicides used by farmers to control broadleaf weeds in sorghum or maize fields work by mimicking auxin. At the low concentrations naturally found in a plant, auxin promotes healthy growth — but at the artificially high concentrations found in these herbicides, the same hormone pathway is overloaded and disrupts the weed's growth until it dies, while leaving grass-family crops like sorghum and maize largely unaffected.

Key Takeaways & Common Pitfalls

- **Must-remember:** auxin doesn't just turn growth on or off — its concentration determines how much a cell elongates, and roots and shoots respond oppositely to the same concentration.
- **Common mistake:** students often think auxin is only involved in light responses — it also drives geotropism and thigmotropism through the same concentration-difference mechanism.

Practice Questions

Easy

Q: Where in a plant is auxin produced?

A: At the shoot and root tips. It then diffuses down to influence growth in the cells below.

Medium

Q: Explain why a shoot bends toward light while a root grown under the same one-sided light condition bends away from it.

A: Both organs accumulate more auxin on the shaded side, but they respond to that higher concentration oppositely. In the shoot, more auxin means more elongation, so the shaded side grows faster and the shoot bends toward the light. In the root, more auxin means less elongation, so the shaded side grows slower and the root bends away from the light.

Hard

Q: A farmer sprays a broadleaf herbicide based on synthetic auxin over a field of sorghum mixed with a broadleaf weed. A week later, the weeds have died back but the sorghum is largely unaffected. Using what you know about auxin concentration and plant response, suggest why the two plant types were affected so differently.

A: Broadleaf plants (dicots) are generally far more sensitive to auxin-based herbicides than grasses (monocots) like sorghum, so the same applied concentration that overwhelms the weed's normal growth-regulation system (causing uncontrolled, disorganised growth that kills the plant) remains within a range the sorghum's different growth physiology can tolerate. This selective sensitivity is exactly why auxin-mimicking herbicides are useful in cereal fields — they exploit a real difference in how the two plant groups process the same hormone signal.

Research & Discussion

- Find a plant near your home growing on a slope or leaning surface. Has its stem curved to grow upright despite the tilt? Discuss what hormone might be responsible.
- Ask a farmer or gardener in your community whether they've used any weed killer, and if so, whether it affects some plants more than others.

3.3 Other Forms of Plant Responses

Before this: You should know what a tropism is and that it involves directional growth.

Why this matters: Not every plant response is a slow-growing tropism — some plants can move parts of themselves within seconds, using a completely different mechanism with nothing to do with growth direction.

Key Vocabulary

- **Nastic response:** a non-directional movement of part of a plant, triggered by a stimulus but not growing toward or away from it

Tropism vs Nastic Response

Feature	Tropism	Nastic response
Direction of movement	Determined by the direction of the stimulus	Determined by the plant's own anatomy, not the stimulus direction
Mechanism	Differential growth (permanent)	Change in water pressure inside cells (temporary)
Reversible?	No — growth is permanent	Yes — the plant part can return to its original position
Speed	Slow (hours to days)	Can be very fast (seconds)

Experiment — Observing Nastic Movement in a Sensitive Plant

1. Locate a *Mimosa pudica* (sensitive plant) growing wild — common along paths and disturbed ground in many parts of South Sudan.
2. Gently touch one leaflet on a single leaf with a finger or twig, without shaking the whole plant.
3. Observe how quickly the touched leaflets fold, and whether the folding spreads to neighbouring leaflets on the same leaf.
4. Wait 10–15 minutes without touching the plant again, and observe whether the leaflets reopen.
5. Compare the speed of this response to how long it took the seedling in Section 3.1 to visibly bend toward light.

Local Example — Groundnut Leaves Folding at Night

Groundnut (peanut) plants, widely grown in South Sudan, fold their leaflets together at night and reopen them during the day — a nastic response to changing light levels, not a growth response. Unlike a tropism, this folding and reopening repeats every single day throughout the plant's life, since it involves no permanent growth change.

Key Takeaways & Common Pitfalls

- **Must-remember:** a nastic response's direction depends on the plant's own structure, not on which direction the stimulus came from — touching a *Mimosa* leaflet from any side produces the same folding movement.
- **Common mistake:** students sometimes call the *Mimosa*'s folding response a tropism because it looks similar to a plant "moving" — but it involves no growth at all, and is fully reversible, which no tropism is.

Practice Questions

Easy

Q: Is the folding of a *Mimosa pudica* leaflet after touch reversible?

A: **Yes.** The leaflets reopen after some time, since the response is caused by a temporary change in water pressure inside cells, not permanent growth.

Medium

Q: Explain one key difference between a nastic response and a tropism, using speed as your basis.

A: **A nastic response can happen within seconds, while a tropism takes hours to days.** This is because a nastic response only requires water to move rapidly in or out of specific cells, while a tropism requires actual cell elongation (growth), which is a much slower process.

Hard

Q: A student claims that because both tropisms and nastic responses are triggered by an external stimulus, they must work by the same internal mechanism. Explain why this claim is incorrect.

A: **Being triggered by a stimulus is the only thing the two response types share — the internal mechanism is fundamentally different.** A tropism results from differential growth (unequal cell elongation caused by auxin distribution), which is slow and permanent. A nastic response results from a change in turgor pressure (water moving in or out of specific motor cells), which is fast and reversible. Two processes can respond to similar triggers while operating through entirely different biological mechanisms — the claim confuses a shared trigger with a shared mechanism.

Research & Discussion

- If groundnuts or another legume crop grows near you, observe their leaves in the morning versus late evening. Do they look different? Discuss with a family member why this might happen.
- Look for a *Mimosa pudica* plant in your area (often found along paths). Carefully touch one leaflet and time how long it takes to reopen. Compare your timing with a classmate's.

3.4 Co-ordination in Animals

Before this: You should understand what co-ordination means and have seen how plants achieve it without a nervous system.

Why this matters: Animals face the same basic problem as plants — sensing change and responding appropriately — but because animals move quickly and react to danger in an instant, they need a much faster coordination system than a plant's slow hormone-driven growth.

Key Vocabulary

- **Receptor:** a cell or organ that detects a stimulus
- **Effector:** a muscle or gland that carries out the response
- **Reception:** the process of detecting a stimulus

Animals coordinate their responses using two systems working together: the **nervous system** (fast, electrical signals via nerve cells) and the **endocrine system** (slower, chemical signals via hormones in the blood) — both covered in detail later in this unit.

Demonstration — Measuring Simple Reaction Time

1. Work in pairs. One person holds a ruler vertically, with the 0 cm mark level with the top of the other person's open thumb and finger, without touching it.
2. Without warning, the first person releases the ruler.
3. The second person closes their fingers to catch it as fast as possible.
4. Read off the distance (in cm) the ruler fell before being caught — a shorter distance means a faster reaction.
5. Repeat 5 times per person and calculate an average distance.
6. Discuss: which receptor detected the ruler falling, and which effector(s) carried out the catching response?

Local Example — Spotting a Snake While Farming

A farmer weeding a field suddenly notices a snake moving nearby. The eyes act as the receptor, detecting the movement; the brain and nervous system process the danger; and the leg muscles act as effectors, carrying out the response of stepping back quickly. Every part of this coordination happens in a fraction of a second, without the farmer consciously working out each step.

Key Takeaways & Common Pitfalls

- **Must-remember:** a receptor detects a stimulus; an effector carries out the response — they are not the same thing and are usually in different parts of the body.
- **Common mistake:** students sometimes think only sense organs like eyes and ears are receptors — internal receptors (e.g. for blood sugar level or body temperature) exist too and trigger responses without any conscious awareness.

Practice Questions

Easy

Q: What is the role of an effector?

A: To carry out the response to a stimulus. Effectors are usually muscles (which contract) or glands (which secrete).

Medium

Q: In the reaction-time experiment, identify the receptor and effector involved, and explain the role of each.

A: The receptor is the eye, which detects the ruler beginning to fall (the stimulus). The effector is the hand/finger muscles, which contract to close and catch the ruler (the response). Between the two, the nervous system carries the signal from receptor to effector.

Hard

Q: Two people take the reaction-time test. Person A is told in advance exactly when the ruler will be dropped (e.g. "I will drop it after counting to three"), while Person B is not warned at all. Predict and explain which person is likely to catch the ruler after a shorter fall distance, and why this does not necessarily mean their receptors or effectors work faster.

A: Person A is likely to catch the ruler after a shorter fall distance. This is not because their receptor or effector speed is actually faster — it's because knowing the approximate timing allows the brain to prepare the response in advance, reducing the decision-making time between detecting the stimulus and triggering the effector. This shows that measured "reaction time" in an experiment like this reflects more than pure receptor/effector speed — it also reflects how much the nervous system already anticipated the stimulus.

Research & Discussion

- Think of a moment when you reacted very quickly to something without thinking (e.g. pulling your hand from something hot, catching something falling). Identify the receptor, the effector, and the stimulus involved.
- Ask a family member who does physical work (farming, herding, fishing) about a time a fast reaction helped them avoid an accident or danger. What triggered it?

3.5 Structure of the Nervous System in Vertebrates

Before this: You should know the difference between a receptor and an effector, and that the nervous system carries fast electrical signals.

Why this matters: The nervous system isn't one single structure — it's built from clearly divided parts, each with its own specific job, working together so that a signal detected in your finger can reach your brain and come back as a movement in a fraction of a second.

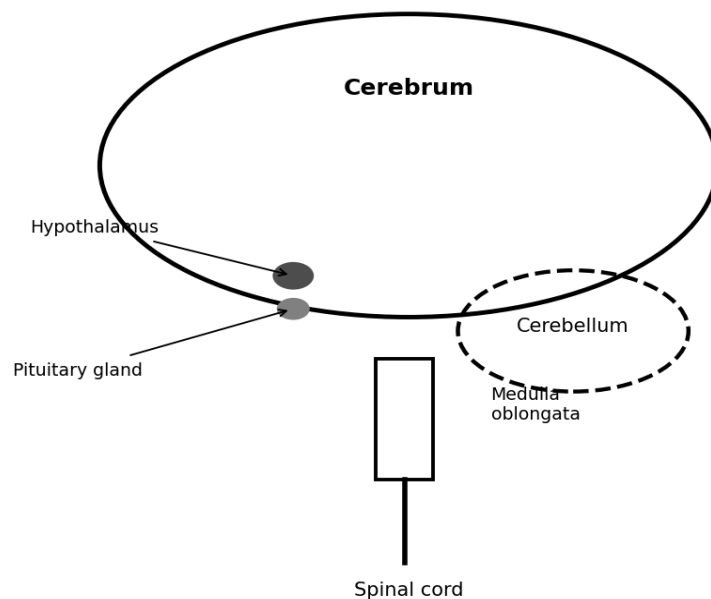
Key Vocabulary

- **Central nervous system (CNS):** the brain and spinal cord
- **Peripheral nervous system (PNS):** the nerves connecting the CNS to the rest of the body
- **Meninges:** three protective membranes surrounding the brain and spinal cord
- **Cerebral-spinal fluid:** fluid that cushions the brain and spinal cord and supplies nourishment

Main Parts of the Brain and Their Functions

Brain region	Function
Cerebrum	Thinking, memory, intelligence, personality, voluntary movement, and interpreting signals from the sense organs
Cerebellum	Coordinating body movements, balance, posture, and fine motor skill (e.g. writing, playing an instrument)
Medulla oblongata	Controlling vital involuntary functions: breathing, heartbeat, blood circulation, swallowing
Hypothalamus	Controls hormone secretion by the pituitary gland; regulates hunger, thirst, and sleep
Pituitary gland	The "master gland" — produces hormones that control other endocrine glands (covered fully in 3.8)

Human brain — original schematic (side view)



Demonstration — Modelling the CNS and PNS

1. Using clay, string, or rolled paper, build a simple model: a central mass representing the brain, a long cord representing the spinal cord, and thin strands branching outward representing peripheral nerves reaching to a hand and a foot.
2. Label which part represents the CNS and which represents the PNS.
3. Trace a path with your finger along the model from the 'hand' to the 'brain' and back to the 'foot', explaining aloud which structure a signal would pass through at each point.

Local Example — Cerebral Malaria

Malaria remains a serious health concern across South Sudan. In severe cases, the Plasmodium parasite can affect the brain directly, specifically the cerebrum — a condition called cerebral malaria, which can cause confusion, seizures, or coma if not treated urgently. This is a direct, real-world illustration of why understanding which brain region controls which function matters: damage to the cerebrum specifically disrupts thinking and consciousness, not, for example, heartbeat (controlled by the medulla oblongata instead).

Key Takeaways & Common Pitfalls

- **Must-remember:** the CNS (brain + spinal cord) processes and makes decisions; the PNS (nerves) only carries signals to and from the CNS — the PNS itself does not "think" or decide anything.
- **Common mistake:** students often confuse the cerebellum (movement coordination and balance) with the cerebrum (thinking, memory, and voluntary decisions) because the names sound alike — they control very different functions.

Practice Questions

Easy

Q: What two structures make up the central nervous system?

A: The brain and the spinal cord. Together they process incoming signals and issue responses.

Medium

Q: Explain why damage to the medulla oblongata is far more immediately life-threatening than damage to the cerebrum.

A: The medulla oblongata controls vital involuntary functions — breathing, heartbeat, and blood circulation — that the body needs continuously to stay alive. Damage there can stop these functions immediately. The cerebrum controls thinking, memory, and voluntary movement — critically important, but its damage does not directly stop the automatic processes that keep the body alive from moment to moment.

Hard

Q: A person suffers a head injury and afterward has difficulty with balance and struggles to perform precise hand movements (like buttoning a shirt), but their memory, personality, and ability to think clearly are unaffected. Which brain region was most likely damaged, and explain your reasoning using the functions of at least two different brain regions.

A: The cerebellum was most likely damaged. The cerebellum specifically controls coordination of movement, balance, and fine motor skill — exactly the functions affected here. If the cerebrum had been damaged instead, we would expect to see problems with memory, thinking, or personality, since those are the cerebrum's functions — but the case states these remain unaffected. This selective pattern of symptoms (motor coordination affected, cognition intact) points specifically to the cerebellum rather than the cerebrum, illustrating how different brain regions can be damaged independently of one another.

Research & Discussion

- Ask a family member or community health worker what they know about malaria's effects on the brain. Relate what they say to what you've learned about the cerebrum.
- Using items around your home, build a simple physical model of the CNS and PNS as described in the demonstration, and explain it to a sibling or friend.

3.6 Structure and Functions of Neurones

Before this: You should know the difference between the CNS and PNS, and that nerves carry signals through the body.

Why this matters: Nerves are made of individual cells, and the exact shape of those cells — with long thin extensions instead of a normal round cell shape — is what makes it possible to send a signal over a long distance almost instantly.

Key Vocabulary

- **Neurone:** a nerve cell, specialised to carry electrical signals (nerve impulses)
- **Dendrite/dendron:** extensions that carry impulses toward the cell body
- **Axon:** a long extension that carries impulses away from the cell body
- **Myelin sheath:** a fatty covering (made by Schwann cells) that insulates the axon and speeds up impulse transmission
- **Node of Ranvier:** a gap in the myelin sheath that further increases transmission speed
- **Synapse:** the small gap between two neurones, crossed using a chemical transmitter substance (e.g. acetylcholine)

Three Types of Neurones

Type	Carries impulses...	Cell body location
Sensory neurone	From a receptor to the CNS	Outside the CNS
Motor neurone	From the CNS to an effector (muscle/gland)	Inside the CNS
Intermediate (relay) neurone	Between sensory and motor neurones	Inside the grey matter of the CNS

Sensory neurone — original schematic

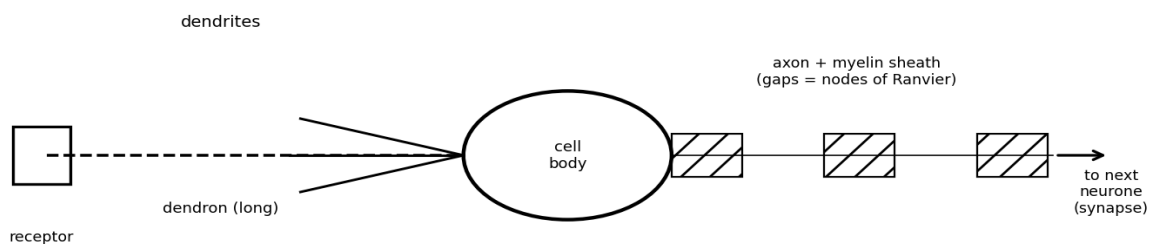


Diagram: original schematic of a sensory neurone, showing the receptor, dendron, cell body, and myelinated axon leading to a synapse.

Demonstration — Modelling a Neurone and a Synapse Chain

1. Using string or wool for axons/dendrons and a bead or knot for each cell body, build three connected neurone models representing a sensory, relay, and motor neurone in sequence.
2. Leave a small visible gap between each model where they connect — this represents the synapse.
3. Pass a small object (representing the nerve impulse) hand to hand along your string models, pausing briefly at each 'synapse' gap before continuing — this mimics the slight delay caused by the chemical transmitter crossing the gap.

4. Discuss: why might having many synapses along a pathway make a response slightly slower than if the whole pathway were a single unbroken cell?

Local Example — Stepping on a Thorn

Walking barefoot is common in many rural parts of South Sudan, and stepping on a thorn is a familiar experience. The moment the thorn pricks the skin, a sensory neurone carries the impulse from the foot's receptors toward the spinal cord; a relay neurone passes it to a motor neurone, which then signals the leg muscles (the effector) to lift the foot away — all before the pain is even consciously registered.

Key Takeaways & Common Pitfalls

- **Must-remember:** neurones never actually touch end-to-end — every connection between two neurones has a synapse gap crossed chemically, not electrically.
- **Common mistake:** students often mix up dendrites (carry impulses toward the cell body) and axons (carry impulses away from the cell body) — the direction relative to the cell body is the key distinguishing feature, not just their appearance.

Practice Questions

Easy

Q: What is the function of the myelin sheath?

A: It insulates the axon and speeds up the transmission of nerve impulses. It is produced by Schwann cells.

Medium

Q: Explain what happens at a synapse when a nerve impulse needs to pass from one neurone to the next.

A: The impulse triggers the release of a chemical transmitter substance (such as acetylcholine) into the synaptic gap. This chemical crosses the gap and stimulates the next neurone, generating a new impulse there — ensuring the signal continues in only one direction.

Hard

Q: A nerve pathway from a person's toe to their brain passes through several neurones connected by synapses, rather than being one single, very long cell. Suggest one advantage this multi-neurone, multi-synapse design might offer over a single continuous cell, despite synapses slightly slowing signal transmission.

A: A multi-neurone pathway allows signals from many different receptors to be combined, filtered, or redirected at each synapse — for example, a relay neurone in the spinal cord can route a signal toward a reflex response immediately, without waiting for the brain, while also passing a copy onward to the brain for conscious awareness. A single unbroken cell from toe to brain could only ever send its signal to one fixed destination, with no opportunity for the nervous system to combine information from multiple sources or make quick local decisions (as happens in reflexes, covered next in 3.7).

Research & Discussion

- Recall a time you stepped on something sharp or touched something rough while barefoot. Try to describe, in order, what you think happened inside your nervous system in that moment.
- Using the string-and-bead model from the demonstration, explain to a family member how a signal from a pricked finger reaches the brain.

3.7 Reflex Arcs and Reflex Actions

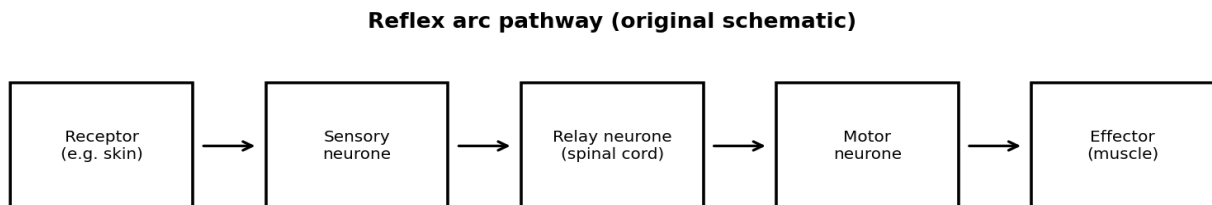
Before this: You should know the three types of neurones and what a synapse is.

Why this matters: Some responses are so urgent — like pulling your hand from fire — that waiting for the brain to consciously decide would be dangerously slow. The body has a shortcut pathway that skips conscious thought entirely.

Key Vocabulary

- **Reflex action:** a rapid, automatic, involuntary response to a stimulus
- **Reflex arc:** the pathway a nerve impulse follows during a reflex action
- **Simple reflex:** an inborn, unlearned reflex present from birth (e.g. blinking)
- **Conditioned reflex:** a learned reflex, produced when a new stimulus is repeatedly paired with a natural one

The Reflex Arc Pathway



Signal always travels one direction: receptor to effector

Diagram: original schematic of the reflex arc — receptor, sensory neurone, relay neurone (spinal cord), motor neurone, effector.

A reflex arc bypasses the brain almost entirely for speed: a receptor detects the stimulus, a sensory neurone carries the impulse to the spinal cord, a relay neurone passes it directly to a motor neurone in the same spinal segment, and the motor neurone triggers the effector — all without waiting for the impulse to travel up to the brain and back.

Experiment — Testing the Knee-Jerk Reflex

1. Work in pairs. Have your partner sit on a raised surface with one leg crossed over the other so it hangs freely, muscles relaxed.
2. Locate the soft area just below the kneecap.
3. Using the side of your hand or a small rubber-tipped object, tap that spot firmly but gently once.
4. Observe and record what happens to the lower leg.
5. Repeat on the other leg and compare, then swap roles.
6. Discuss: is this response something your partner could have stopped from happening on purpose? What does that tell you about where it's controlled?

Local Example — Training Livestock to Respond to a Call

Many households in South Sudan keep goats or cattle that learn to come toward a specific whistle, call, or the sound of a feed bucket being banged, even before they can see any actual food. At first, the animals only responded to the natural stimulus (the sight or smell of food). After the call was repeatedly given at the same time as feeding, the animals learned to associate the call itself with food — a conditioned reflex, just like Pavlov's dogs, but built entirely through the herder's own daily routine.

Key Takeaways & Common Pitfalls

- **Must-remember:** a reflex arc's speed comes from the relay neurone connecting directly to a motor neurone in the spinal cord — the brain is informed afterward, but doesn't need to be consulted first for the response to happen.
- **Common mistake:** students sometimes think a conditioned reflex is not a "real" reflex because it's learned — but once established, it is just as fast, automatic, and involuntary as a simple reflex.

Practice Questions

Easy

Q: Name the five components of a typical reflex arc, in order.

A: Receptor, sensory neurone, relay neurone, motor neurone, effector. The impulse always travels in that order, from stimulus detection to response.

Medium

Q: Explain why a reflex action happens faster than a conscious, voluntary response to the same stimulus.

A: A reflex action's pathway is shorter — the impulse only needs to travel from the receptor to the spinal cord and back to the effector via a relay neurone, without needing to travel further up to the brain, be consciously processed, and travel back down. **A voluntary response requires the extra time** for the signal to reach the cerebrum, be interpreted, and for a decision to be made before a motor response is even issued.

Hard

Q: A herder's goats initially only ran toward the feeding trough when they smelled food. After several months of the herder always ringing a bell right before bringing the food, the goats now run toward the trough as soon as they hear the bell alone, even with no food smell present. Explain this change using the concept of conditioned reflex, and describe what would likely happen to the goats' response if the herder rang the bell many times in a row without ever bringing food afterward.

A: The goats have formed a conditioned reflex — repeatedly pairing the new stimulus (the bell) with the natural stimulus (the smell of food) led the goats to associate the two, so the bell alone now triggers the same response (running to the trough) that only the food smell used to trigger. **If the herder rang the bell repeatedly without ever providing food afterward, the goats' response to the bell would likely weaken and eventually stop** — the learned association depends on the two stimuli continuing to occur together, and without reinforcement, a conditioned reflex fades over time (a process known more broadly as extinction of the learned response).

Research & Discussion

- Ask a family member who keeps livestock whether their animals respond to any particular call, sound, or routine. Discuss whether this is a conditioned reflex and how it might have developed.
- Think of a skill you do automatically now (e.g. riding a bicycle, typing, a sport movement) that you had to learn slowly at first. Discuss with a classmate whether this counts as a conditioned reflex, and why or why not.

3.8 Chemical Co-ordination in Animals and the Endocrine System

Before this: You should know that the nervous system provides fast, short-lived coordination using electrical impulses.

Why this matters: Not every response needs to happen instantly — growth, metabolism, and long-term changes in the body are better controlled by a slower, longer-lasting chemical messenger system: hormones.

Key Vocabulary

- **Hormone:** a chemical messenger produced by an endocrine (ductless) gland and carried in the blood
- **Endocrine gland:** a gland that releases hormones directly into the bloodstream (no duct)
- **Target organ:** the specific organ a hormone acts upon

Major Endocrine Glands and Their Hormones

Gland	Key hormone(s)	Main effect
Pituitary gland ("master gland")	TSH, FSH, LH, Growth Hormone, ADH, Oxytocin	Controls other endocrine glands; growth; water reabsorption in kidneys; uterine contractions during birth
Thyroid gland (neck)	Thyroxine (T ₄), Triiodothyronine (T ₃)	Controls metabolic rate and growth/development
Pancreas	Insulin, Glucagon	Insulin lowers blood glucose (converts glucose to glycogen); glucagon raises it (converts glycogen back to glucose)
Adrenal gland (above kidneys)	Adrenaline	"Fight or flight" response — raises heart rate, breathing rate, and blood glucose availability
Ovary / Testis	Oestrogen, Progesterone / Testosterone	Development and maintenance of sex-specific reproductive functions and secondary characteristics

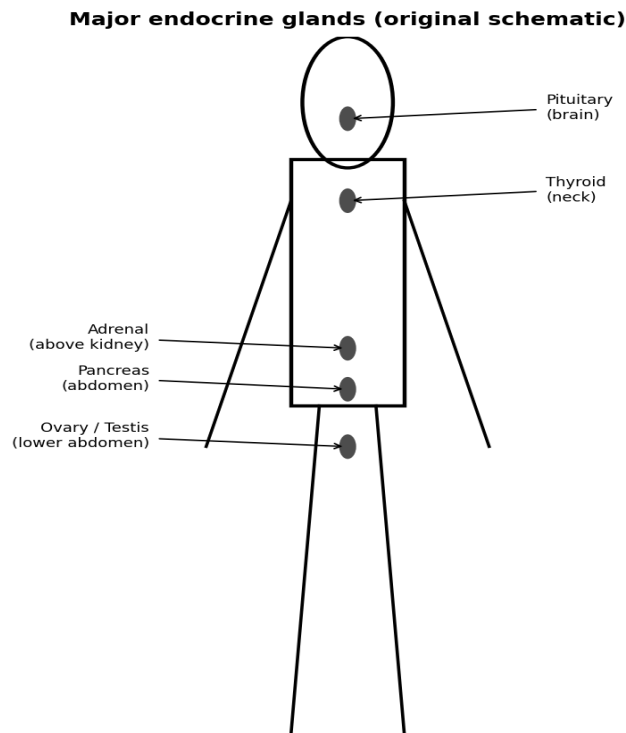


Diagram: original schematic showing the approximate location of the major endocrine glands in the human body.

Experiment — Observing the Adrenaline Response

1. Work in pairs. Have your partner sit quietly for two minutes, then measure their resting pulse rate for 30 seconds (count and multiply by 2 for beats per minute).
2. Without warning your partner exactly when, clap loudly and unexpectedly right next to them (with their consent given beforehand).
3. Immediately measure their pulse rate again for 30 seconds.
4. Compare the two pulse readings and discuss what hormone is responsible for the change, and why the body would benefit from this rapid response.

Local Example — Iodine Deficiency and Goitre

Thyroxine requires iodine to be produced correctly. In landlocked regions like much of South Sudan, far from marine sources of iodine, iodine deficiency in the diet is a real and documented concern — leading to under-secretion of thyroxine and, in some cases, visible swelling of the thyroid gland in the neck (goitre). This is exactly why iodized salt is promoted as a simple, low-cost public health measure in many inland African countries.

Key Takeaways & Common Pitfalls

- **Must-remember:** hormone effects last much longer than nerve impulses because hormones remain in the blood and act on distant target organs, while nerve impulses are brief and highly localised.
- **Common mistake:** students often think insulin and glucagon do the same job — they are direct opposites: insulin lowers blood glucose, glucagon raises it, and the body needs both to keep glucose levels balanced.

Practice Questions

Easy

Q: Which gland produces adrenaline, and under what circumstances is it released?

A: **The adrenal gland** (specifically the adrenal medulla), released during danger, excitement, or emergency — the "fight or flight" response.

Medium

Q: Explain why hormonal (endocrine) responses generally last longer than nervous responses, using insulin as your example.

A: **Hormones like insulin travel through the blood and remain in circulation for a period of time, continuing to act on target cells throughout the body until they are broken down.** A nerve impulse, by contrast, is a brief electrical signal that lasts only milliseconds and only affects the specific cells connected by that nerve pathway — which is why hormonal effects (like insulin gradually lowering blood glucose over minutes) last much longer than a nerve impulse's effect.

Hard

Q: A person's diet lacks sufficient iodine over a long period. Trace the chain of cause and effect from this dietary gap to the visible swelling of the thyroid gland (goitre), explaining the role of at least two different hormones.

A: **Without enough iodine, the thyroid gland cannot produce sufficient thyroxine** (since thyroxine requires iodine as a building block). **The pituitary gland detects the resulting low thyroxine level and responds by producing more thyroid-stimulating hormone (TSH)** in an attempt to push the thyroid into producing more thyroxine. **The thyroid gland, repeatedly over-stimulated by TSH but still lacking the iodine needed to actually make thyroxine, grows larger in a compensatory attempt to increase output** — this enlargement is what becomes visible as a goitre. The swelling is therefore not caused directly by the iodine deficiency itself, but by the pituitary's hormonal feedback response to it.

Research & Discussion

- Ask a family member whether iodized salt is used in your household, and whether they know why it's recommended.
- Think about a time you felt your heart racing before a stressful or exciting event (a test, a competition, a sudden scare). Relate this to what you've learned about adrenaline.
- Discuss with a classmate: why might it make sense for the body to have a fast (nervous) system and a slow (hormonal) system, rather than just one or the other?