

Homeostasis and response

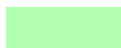
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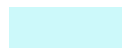
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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Define Homeostasis

- regulation of the internal conditions of a cell or organism to maintain optimum conditions for function, in response to internal and external changes.

Define Effector

- a muscle or gland that brings about a response to restore optimum levels.

Define Accommodation BIOLOGY ONLY

- changing the shape of the lens to focus on near or distant objects.

Define Insulin

- pancreatic hormone that causes glucose to move from the blood into the cells.

HIGHER TIER

Define Negative feedback

- **HT ONLY** control in which a change from the normal level triggers a response that reverses it.

Define Auxin BIOLOGY ONLY

- a plant hormone whose unequal distribution causes unequal growth rates in roots and shoots.

Define Receptor

- a cell that detects a stimulus (a change in the environment).

Define Coordination centre

- the brain, spinal cord or pancreas: receives and processes information from receptors.

Define Reflex action

- an automatic, rapid response not involving the conscious part of the brain.

Define Hormone

- a chemical secreted by a gland into the blood and carried to a target organ, where it has an effect.

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Define Glucagon

- **HT ONLY** pancreatic hormone that causes glycogen to be converted into glucose and released into the blood.

Define Phototropism / gravitropism (geotropism) BIOLOGY ONLY

- plant growth responses to light / to gravity.

5.1 Homeostasis

Homeostasis maintains optimum conditions for enzyme action and all cell functions. In the human body it includes control of **blood glucose concentration**, **body temperature** and **water levels**, by **nervous** or **chemical (hormonal)** responses.

All control systems include **receptors** (cells that detect stimuli — changes in the environment), **coordination centres** such as the brain, spinal cord and pancreas (which receive and process information from receptors) and **effectors** — muscles or glands, which bring about responses that restore optimum levels.

ANALOGY

Homeostasis works like a **central-heating thermostat**: it detects the room getting cold, switches on the boiler (the effector), then switches it off once the room is warm. The temperature is never perfectly constant — it wobbles just above and below the set point, exactly as body conditions do.

5.2 The human nervous system

5.2.1 Structure and function

The nervous system enables humans to **react to their surroundings** and to **coordinate their behaviour**.

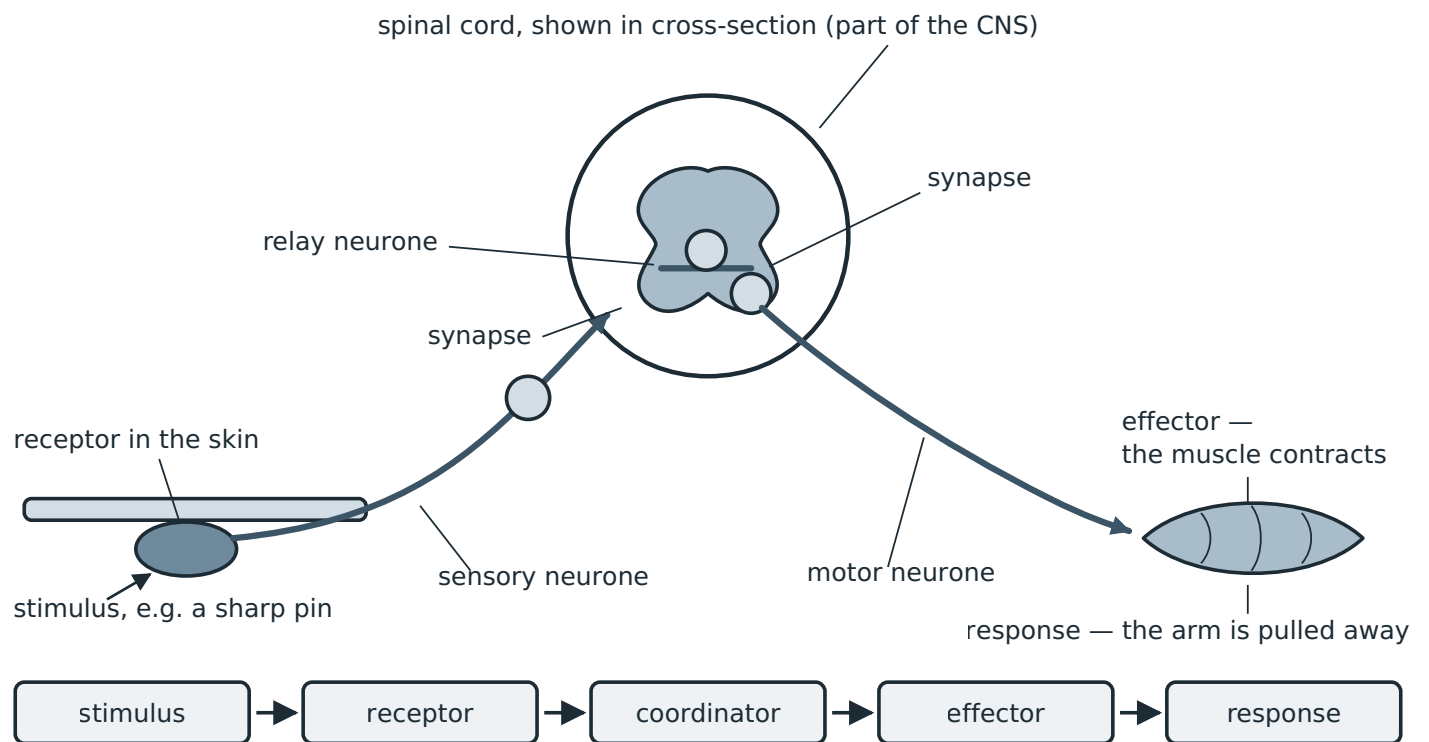
- Information from receptors passes along **neurones** as **electrical impulses** to the **central nervous system (CNS)** — the **brain and spinal cord**.
- The CNS coordinates the response of **effectors: muscles contracting or glands secreting hormones**.
- General pathway: stimulus → receptor → coordinator → effector → response.

The reflex arc. Reflex actions are **automatic and rapid**; they do not involve the conscious part of the brain (though the impulse does still pass through the CNS). This makes them protective — pulling a hand off a hot object, or the pupil narrowing in bright light — reducing the chance of injury.

stimulus → receptor → sensory neurone → synapse → relay neurone → motor neurone → effector → response

- **Receptor** — detects the stimulus, starting an electrical impulse.
- **Sensory neurone** — carries the impulse to the CNS.
- **Synapse** — a chemical is released, diffuses across the gap and starts a new impulse in the next neurone.
- **Relay neurone** — passes the impulse across the spinal cord, bypassing the conscious brain.
- **Motor neurone** — carries the impulse to the effector.
- **Effector** — a muscle contracts or a gland secretes: the response.

The reflex arc



Reflex actions are automatic and rapid. They do not involve the conscious part of the brain, so the body is protected before you have time to think about it.

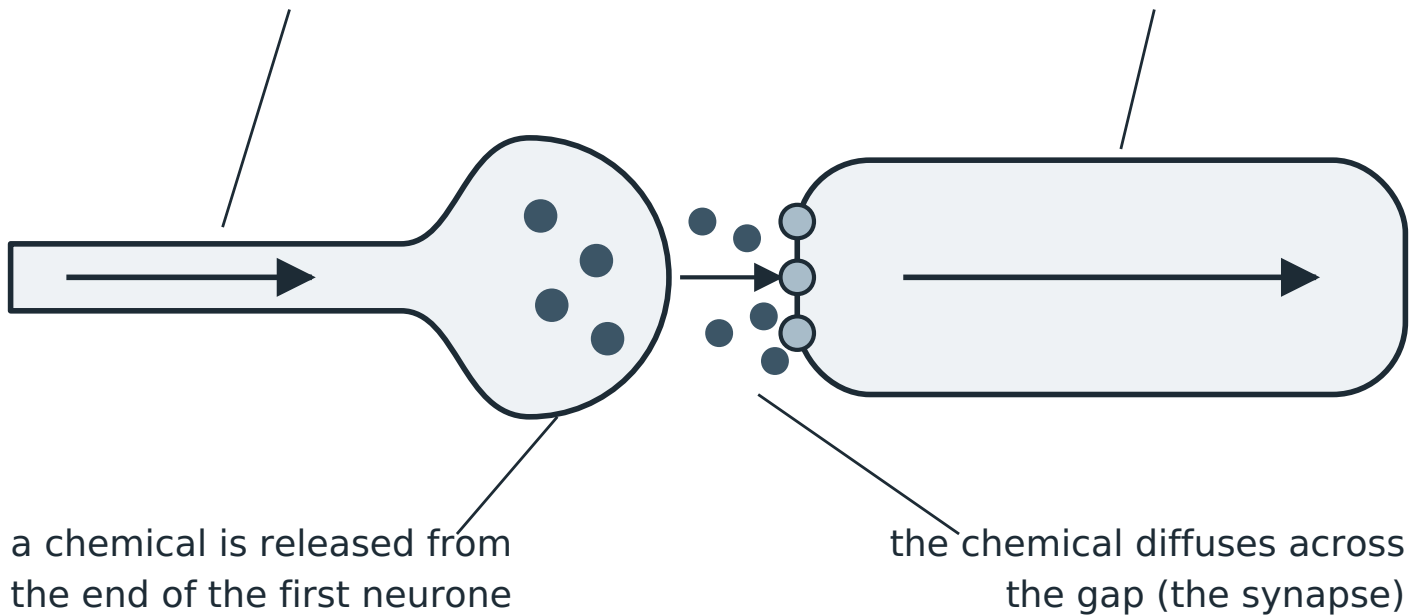
ANALOGY

A reflex arc is a fire alarm wired straight to the sprinklers: the smoke detector (receptor) sets off the sprinklers (effector) via the panel in the corridor (spinal cord), without phoning the manager upstairs (the conscious brain) for permission.

How an impulse crosses a synapse

electrical impulse arrives along the first neurone

the chemical sets off a new electrical impulse in the second neurone



HIGHER TIER

5.2.2 The brain **BIOLOGY ONLY**

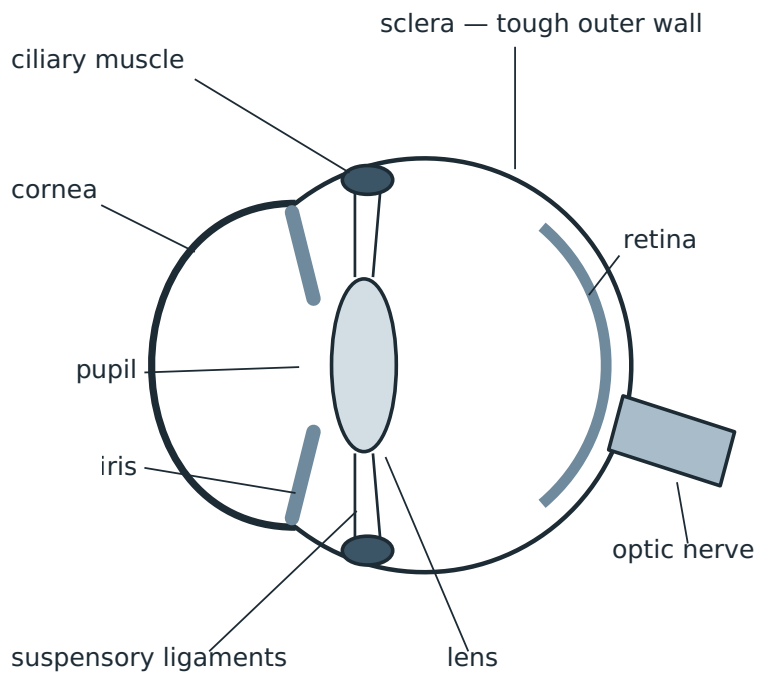
- **BIOLOGY ONLY** The brain controls **complex behaviour**. It is made of **billions of interconnected neurones**, with different regions carrying out different functions. **BIOLOGY ONLY**
Cerebral cortex — outer folded layer; consciousness, intelligence, memory and language. **BIOLOGY ONLY**
Cerebellum — lower back of the brain; coordination of movement and balance. **BIOLOGY ONLY**
Medulla — base of the brain; unconscious activities such as heart rate and breathing rate.
- **BIOLOGY ONLY HT ONLY** Neuroscientists have mapped brain regions to functions by studying patients with **brain damage**, by **electrically stimulating** parts of the brain, and by **MRI scanning**.
- **BIOLOGY ONLY HT ONLY** The **complexity and delicacy** of the brain make investigating and treating brain disorders very difficult: it is easily damaged, hard to reach surgically, drugs may not cross from the blood into the brain, and surgery risks permanent loss of function — so benefits must be weighed against risks.

5.2.3 The eye **BIOLOGY ONLY**

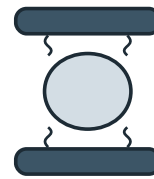
BIOLOGY ONLY The eye is a **sense organ** containing receptors sensitive to **light intensity** and **colour**.

Structure	Function
Retina	Light receptor cells, sensitive to light intensity and colour
Optic nerve	Carries impulses from the retina to the brain
Sclera	Tough white outer layer; protects the eye
Cornea	Transparent front layer; refracts light into the eye
Iris	Muscles controlling pupil size, and so light entering
Ciliary muscles	Contract and relax to change the lens shape
Suspensory ligaments	Attach the lens to the ciliary muscles; pull it thin

The structure of the eye

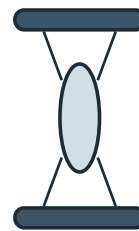


focusing on a near object



ciliary muscles contract
suspensory ligaments loosen
the lens is thicker and
refracts light strongly

focusing on a distant object



ciliary muscles relax
suspensory ligaments are
pulled tight
the lens is thinner and only
slightly refracts light

Adaptation to dim light — the iris widens the pupil so more light reaches the retina; in bright light it narrows to protect the retina.

Accommodation is the process of changing the shape of the lens to focus on near or distant objects.

	Near object	Distant object
Ciliary muscles	Contract	Relax
Suspensory ligaments	Loosen	Pulled tight
Lens	Thicker	Pulled thin
Refraction	Strong	Only slight

ANALOGY

The lens is a water-filled balloon held in a ring of elastic. Let the elastic go slack (ciliary muscles contract) and it bulges fat — strong refraction for close work. Pull the elastic tight (ciliary muscles relax) and it is squashed thin — slight refraction for distant objects.

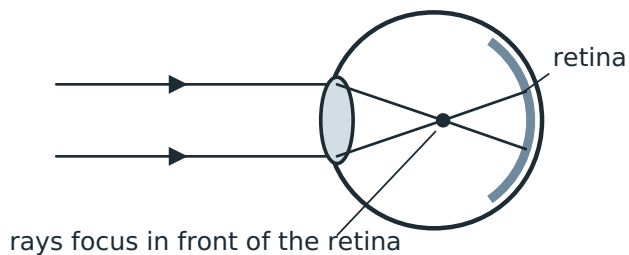
Defects of the eye. In **myopia (short sightedness)** and **hyperopia (long sightedness)**, light rays **do not focus on the retina**.

- **Myopia** — light focuses **in front of** the retina, blurring distant objects; corrected by a **concave** spectacle lens that spreads the rays.
- **Hyperopia** — light focuses **behind** the retina, blurring near objects; corrected by a **convex** spectacle lens that brings the rays together.
- Generally these defects are treated with **spectacle lenses** which refract light so it does focus on the retina. New technologies: **hard and soft contact lenses**, **laser surgery** to change the shape of the cornea, and a **replacement lens** in the eye.

Myopia and hyperopia, and the lenses that correct them

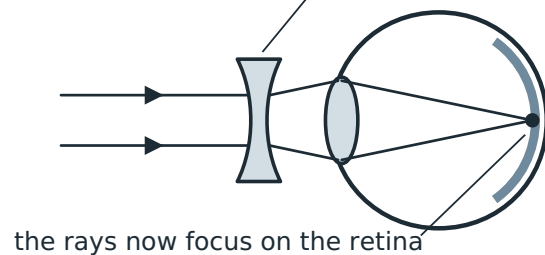
myopia — short sightedness

light rays from a distant object



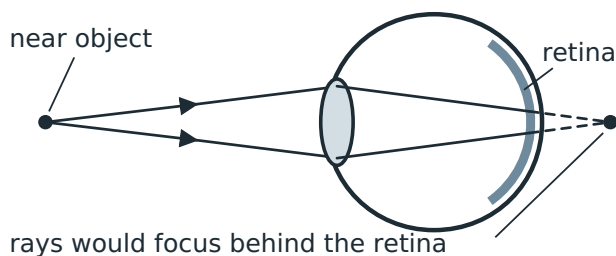
correcting myopia

a concave (diverging) spectacle lens



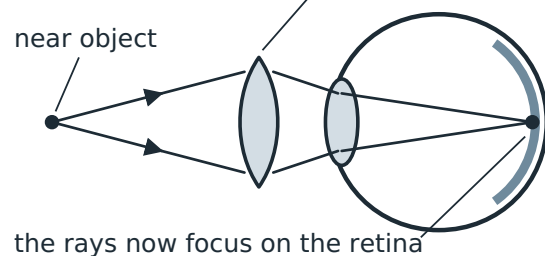
hyperopia — long sightedness

light rays from a near object



correcting hyperopia

a convex (converging) spectacle lens



HIGHER TIER

5.2.4 Control of body temperature **BIOLOGY ONLY**

- **BIOLOGY ONLY** Body temperature is monitored and controlled by the **thermoregulatory centre** in the brain, which contains receptors sensitive to the temperature of the blood. The **skin** also contains temperature receptors and sends nervous impulses to it. **BIOLOGY ONLY Too hot:** blood vessels **dilate (vasodilation)** and sweat is produced from the sweat glands; both cause a transfer of energy from the skin to the environment. **BIOLOGY ONLY Too cold:** blood vessels **constrict (vasoconstriction)**, **sweating stops** and **skeletal muscles contract (shiver)**.
- **BIOLOGY ONLY HT ONLY** In context: vasodilation brings more blood near the skin surface so more energy is transferred to the surroundings, and evaporating sweat takes the energy it needs from the body, cooling it. Vasoconstriction reduces blood flow near the surface so less energy is lost, and shivering is muscle contraction requiring respiration, which releases energy and warms the body.

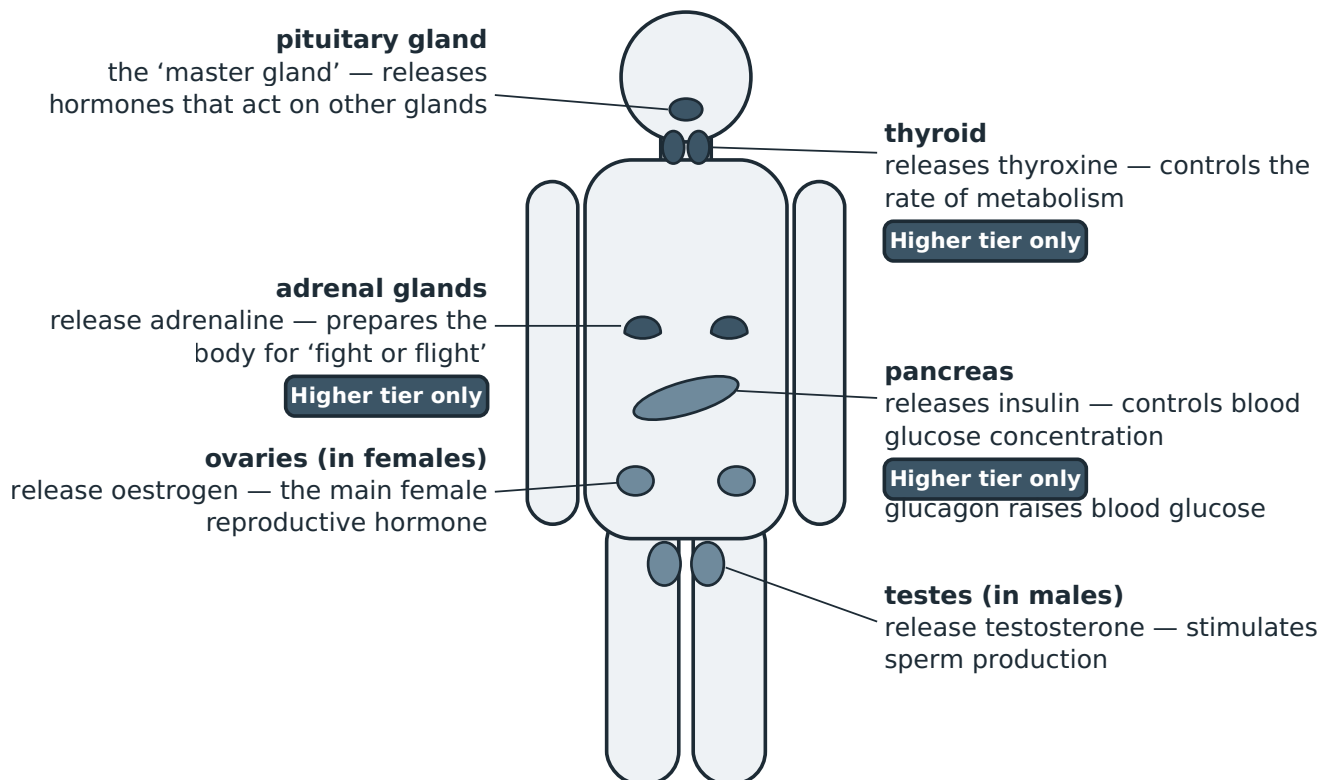
5.3 Hormonal coordination in humans

5.3.1 Human endocrine system

- The endocrine system is composed of **glands** which secrete **hormones** directly into the **bloodstream**; the blood carries the hormone to a **target organ**, where it produces an effect. Compared with the nervous system the effects are **slower but act for longer**.
- The **pituitary gland** in the brain is a '**master gland**': it secretes several hormones in response to body conditions, and these act on other glands to stimulate the release of other hormones.

Identify on a body diagram: **pituitary gland** (brain), **thyroid** (neck), **adrenal glands** (one on each kidney), **pancreas** (below the stomach), **ovaries** (lower abdomen) and **testes**.

The glands of the human endocrine system



Glands secrete hormones directly into the blood, which carries them to their target organs. The badges mark the hormone actions that are Higher Tier only; all students must know where the glands are.

	Nervous system	Endocrine system
Information carried by	Electrical impulses along neurones	Hormones dissolved in the blood
Speed	Very fast	Slower
Duration of effect	Short-lived	Longer lasting
Target	Precise — a specific muscle or gland	General — any organ with target cells

ANALOGY

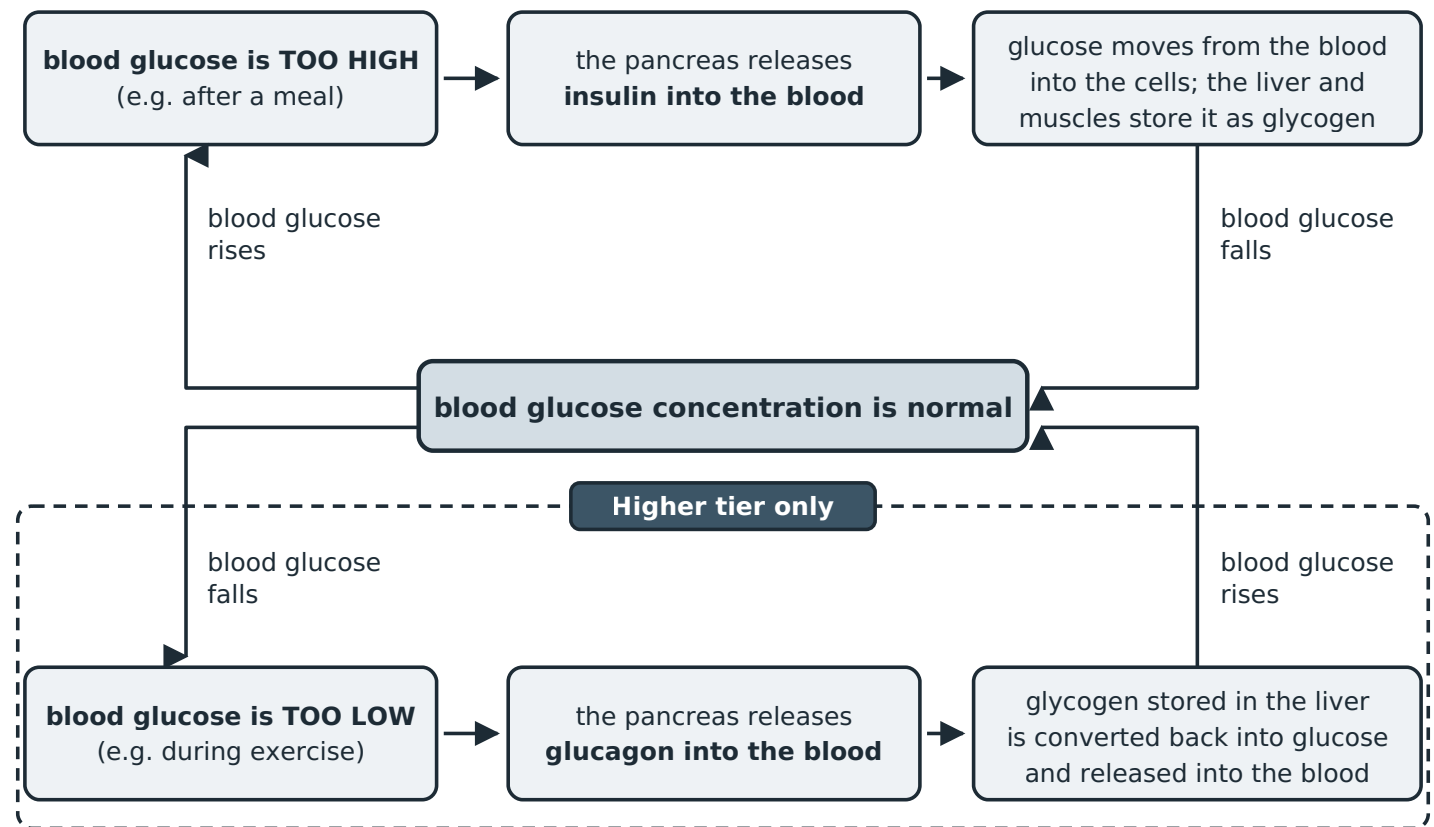
Nerves are a **phone call** — instant, aimed at one person, over in seconds. Hormones are the **post** — slower, delivered to every address on the round, and the letter sits on the table having an effect for days.

HIGHER TIER

5.3.2 Control of blood glucose concentration

- Blood glucose concentration is monitored and controlled by the pancreas.
- Too high:** the pancreas produces **insulin**, which causes glucose to move from the blood into the cells. In **liver and muscle cells** excess glucose is converted to **glycogen** for storage.
- HT ONLY Too low:** the pancreas produces **glucagon**, which causes glycogen to be converted into glucose and released into the blood.
- HT ONLY** Insulin and glucagon act in a **negative feedback cycle**: a rise in blood glucose triggers insulin, which lowers it; the fall triggers glucagon, which raises it. Each hormone reverses the change that caused its release, holding blood glucose near normal.

Control of blood glucose concentration by insulin and glucagon



	Type 1 diabetes	Type 2 diabetes
Cause	The pancreas fails to produce sufficient insulin	The body cells no longer respond to insulin produced by the pancreas
Effect	Uncontrolled high blood glucose levels	Uncontrolled high blood glucose levels
Treatment	Insulin injections	Carbohydrate controlled diet and an exercise regime
Risk factor	—	Obesity

HIGHER TIER

5.3.3 Maintaining water and nitrogen balance in the body **BIOLOGY ONLY**

- **BIOLOGY ONLY** Water leaves via the **lungs during exhalation**, and **water, ions and urea** are lost from the **skin in sweat**. There is no control over water, ion or urea loss by the lungs or skin; excess water, ions and urea are removed via the **kidneys in the urine**.
- **BIOLOGY ONLY** If body cells lose or gain too much water by osmosis they do not function efficiently — they shrink or swell and burst, disrupting enzyme-controlled reactions.
- **BIOLOGY ONLY** The kidneys produce urine by **filtration of the blood** and **selective reabsorption** of useful substances such as **glucose, some ions and water**.
- **BIOLOGY ONLY HT ONLY** Digestion of dietary proteins gives **excess amino acids** that must be excreted safely. In the **liver** these are **deaminated to form ammonia**; **ammonia is toxic**, so it is **immediately converted to urea** for safe excretion.
- **BIOLOGY ONLY HT ONLY** Water level is controlled by **ADH**, which acts on the **kidney tubules**. ADH is released by the pituitary gland when the **blood is too concentrated**; it increases the **permeability** of the tubules so more water is reabsorbed back into the blood. This is controlled by **negative feedback** — as the blood becomes more dilute, less ADH is released, so less water is reabsorbed and more dilute urine is produced.

Treating kidney failure — by **organ transplant** or **kidney dialysis**. In dialysis, blood flows between **partially permeable membranes** surrounded by **dialysis fluid** containing the same concentration of glucose and ions as healthy blood (so these are not lost) but **no urea**, so urea diffuses out down a concentration gradient, along with excess water and ions.

	Dialysis	Transplant
Advantages	Available to all; no surgery; no rejection risk	Patient lives a normal life; cheaper long term
Disadvantages	Several sessions a week; restricted diet; expensive long term	Shortage of donors; risk of rejection ; immunosuppressant drugs ; major surgery

NOTE

Not required by the spec. Knowledge of **other parts of the urinary system**, the **structure of the kidney** and the **structure of a nephron** is not required — learn what the kidney *does*, not its anatomy.

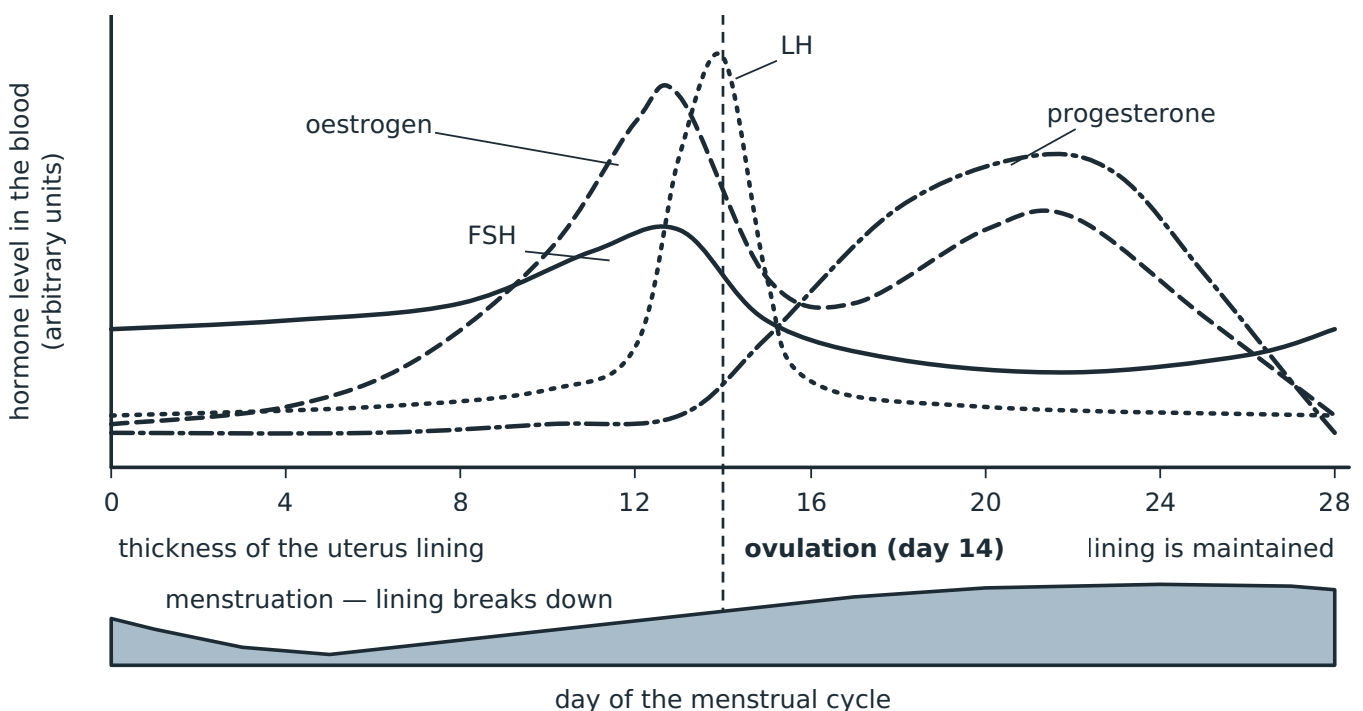
5.3.4 Hormones in human reproduction

- During **puberty**, reproductive hormones cause **secondary sex characteristics** to develop.
- **Oestrogen**, the main **female** reproductive hormone, is produced in the **ovary**. At puberty eggs begin to mature and one is released approximately **every 28 days** — **ovulation**.
- **Testosterone**, the main **male** reproductive hormone, is produced by the testes and **stimulates sperm production**.
- **Follicle stimulating hormone (FSH)** — causes **maturation of an egg** in the ovary.
- **Luteinising hormone (LH)** — **stimulates the release of the egg**.
- **Oestrogen and progesterone** — involved in **maintaining the uterus lining**.

HT ONLY Interactions in the menstrual cycle:

HT ONLY FSH from the pituitary matures an egg and **stimulates the ovaries to produce oestrogen**. **HT ONLY** Oestrogen makes the **uterus lining grow**, **inhibits FSH** and **stimulates the release of LH**. **HT ONLY** LH from the pituitary causes ovulation at about day 14. **HT ONLY** Progesterone from the ovary **maintains the uterus lining** and **inhibits FSH and LH**; when it falls, the lining breaks down and the cycle restarts.

Hormone levels through the menstrual cycle



- FSH — causes an egg to mature in one of the ovaries
- - - oestrogen — causes the lining of the uterus to grow and thicken
- LH — stimulates the release of the egg (ovulation)
- . - . - progesterone — maintains the lining of the uterus

5.3.5 Contraception

Fertility can be controlled by **hormonal** and **non-hormonal** methods; you must be able to **evaluate** them.

Method	How it works	Hormonal?
Oral contraceptives	Contain hormones to inhibit FSH production so no eggs mature	Yes
Injection, implant or skin patch	Slow-release progesterone inhibits the maturation and release of eggs for months or years	Yes
Barrier methods (condoms, diaphragms)	Prevent the sperm reaching an egg	No
Intrauterine devices	Prevent implantation of an embryo. or release a hormone	Either
Spermicidal agents	Kill or disable sperm	No
Abstaining from intercourse	Avoiding intercourse when an egg may be in the oviduct	No
Surgical sterilisation	Male or female sterilisation; permanent	No

Evaluating them: hormonal methods are very effective and long lasting, but can have side effects and give no protection against sexually transmitted infections; barrier methods are cheap and do protect against STIs but are less reliable; sterilisation is most reliable but permanent. Because personal, religious and ethical views are involved, issues around contraception cannot be answered by science alone.

HIGHER TIER

5.3.7 Negative feedback HT ONLY

HT ONLY Adrenaline is produced by the adrenal glands in times of **fear or stress**. It **increases the heart rate** and boosts delivery of oxygen and glucose to the brain and muscles, preparing the body for '**flight or fight**'. **HT ONLY** Thyroxine from the **thyroid gland stimulates the basal metabolic rate** and is important in **growth and development**. **HT ONLY** Thyroxine is **controlled by negative feedback**: if blood thyroxine falls below normal, the pituitary releases **TSH**, stimulating the thyroid to release more; if thyroxine rises above normal, TSH release is **inhibited**, so less is made and the level returns to normal.

- **HT ONLY** Adrenaline is not controlled this way — it responds to a stimulus (fear or stress), not to a deviation from a set level.

HIGHER TIER

5.3.6 The use of hormones to treat infertility HT ONLY

- **HT ONLY** A '**fertility drug**' of **FSH and LH** can be given to a woman; she may then become pregnant in the normal way. **HT ONLY In Vitro Fertilisation (IVF)**: the mother is given FSH and LH to stimulate the **maturation of several eggs**; the eggs are collected and fertilised by the father's sperm in the laboratory; they develop into **embryos**; at the stage when they are **tiny balls of cells**, one or two are inserted into the mother's uterus (womb). **HT ONLY Evaluation**. IVF gives a woman the chance of a baby of her own, but it is **very emotionally and physically stressful, success rates are not high**, and it **can lead to multiple births**, a risk to babies and mother. Developments in **microscopy** enabled IVF; there are also social and ethical issues around unused embryos.

5.4 Plant hormones BIOLOGY ONLY

5.4.1 Control and coordination **BIOLOGY ONLY**

- **BIOLOGY ONLY** Plants produce **hormones** to coordinate and control **growth** and responses to **light (phototropism)** and **gravity (gravitropism or geotropism)**. Unequal distributions of auxin cause unequal growth rates in plant roots and shoots.

BIOLOGY ONLY Phototropism — auxin gathers on the **shaded side** of a shoot and **promotes** cell elongation there, so that side grows faster and the shoot **bends towards the light**, giving leaves more light for photosynthesis. **BIOLOGY ONLY**

Gravitropism — auxin gathers on the **lower side** of a root but **inhibits** elongation in roots, so the lower side grows more slowly and the root **bends downwards**, anchoring the plant and reaching water and mineral ions. Shoots grow upwards, away from gravity. **BIOLOGY ONLY HT ONLY Gibberellins** are important in **initiating seed germination**. **BIOLOGY ONLY HT ONLY Ethene** controls **cell division** and the **ripening of fruits**.

NOTE

Not required by the spec.

HT ONLY The mechanisms of how gibberellins and ethene work are not required — learn what they do and how they are used, not how they act at cell level.

5.4.2 Use of plant hormones **BIOLOGY ONLY**

HT ONLY

BIOLOGY ONLY HT ONLY Plant growth hormones are used in **agriculture and horticulture**.

BIOLOGY ONLY HT ONLY Auxins are used as **weed killers** (selective — broad-leaved weeds grow uncontrollably and die, leaving narrow-leaved crops), as **rooting powders**, and for **promoting growth in tissue culture**. **BIOLOGY ONLY HT ONLY Ethene** is used in the **food industry** to control the ripening of fruit during storage and transport — fruit is picked firm and unripe, then ripened with ethene on arrival.

BIOLOGY ONLY HT ONLY Gibberellins are used to **end seed dormancy**, **promote flowering** and **increase fruit size**.

- **BIOLOGY ONLY HT ONLY** Everyday use of weed killers reduces the variety of plant species in an area, lowering **biodiversity** and removing food and habitats for insects and other animals.