- Triple Science Content only in purple
- Triple Science and Higher Content Only in blue

GCSE AQA Biology- Topic 5

5. Homeostasis and Response

Homeostasis

- **Homeostasis** = maintaining stable and constant internal conditions (e.g. temperature, water, blood glucose) so that cells and enzymes function well.

- **Control systems** consist of:
  • **Receptors** — cells detect stimuli (changes in internal or external environment)
  • **Coordination centers** (e.g. brain, spinal cord, pancreas) — interpret signals and process information
  • **Effectors** (muscles or glands) — act to restore balance by bringing the response.

Important variables regulated:

- Body temperature
- Blood glucose concentration
- Water levels

The Human Nervous System

Structure and Function

- The **nervous system** allows humans to react to their environment and coordinate their actions.

How it Works:

1. **Receptors** detect a stimulus (e.g., temperature change).
2. They send **electrical impulses** to the Sensory Neurons, which then send an electrical impulse to the central **nervous system (CNS)** through.
3. The **CNS** processes the information to co-ordinate the appropriate response, and sends signals to **effectors (muscles or glands) via the motor neurons** which respond.

Structure & Signalling (summary)

- Stimulus → receptor → sensory neuron → coordination centre (CNS) → motor neuron → effector → response

- Signals travel as **electrical impulses** along neurons.

Reflex Actions:

- **Reflexes** are automatic, fast responses that don't involve the conscious brain.
    - Example: Pulling your hand away from a hot surface.
    - **Pathway**: Stimulus → receptor → sensory neurone → relay neurone in the CNS → motor neuron → effector → response.
    - Signals are again travelled as electrical impulses.

Synapse

- A synapse is the junction (a gap) between two neurons
- Where an electrical impulse is transmitted
- Using neurotransmitters.

Mechanism:

1. Electrical impulse reaches the end of the presynaptic neuron.

2. Neurotransmitters (held in vesicles) are released into the synaptic cleft.

3. Neurotransmitters bind to receptors on the postsynaptic neuron.

4. A new electrical impulse is initiated in the postsynaptic neuron.

Key Points:

- **Ensure one-way** transmission of impulses.

- Important for **reflexes, voluntary responses, and brain processing.**

The Brain

- The **brain** controls complex behaviour and has different areas for different functions.

Part of the Brain	Function
Cerebral Cortex	Responsible for consciousness, intelligence, memory, and language.
Cerebellum	Controls muscle coordination and balance.
Medulla	Controls unconscious activities, like breathing and heart rate.

Studying the Brain:

Studying the Brain:

- **MRI scans:** Imaging of brain structure to show which part of the brain is affected

- **Electrical stimulation:** Identify regions responsible for specific functions by inserting an electrode onto the brain.

- **Case studies:** Observing effects of brain damage on a person to infer the damaged area's role or function.

However, treating/investigating on the brain may be difficult/dangerous:

- The brain is a complex structure that can be damaged easily
- We do not fully understand everything about the brain.

The Eye

- The **eye** is an organ that focuses light onto the **retina** to create an image.

Part of the Eye	Function
Retina	Contains **light-sensitive cells** that send signals to the brain when light hits them.
Optic Nerve	Carries impulses from the retina to the brain for an image to be made.
Cornea	Bends light into the retina
Iris	Controls the size of the **pupil** by contracting or relaxing. - Bright light → circular muscles contract, radial muscles relax to make pupil smaller - Less Light —> Circular muscles relax and radial muscles contract to make pupils bigger to allow more light in.
Lens	Focuses light onto the retina.
Sclera	White outer layer which prevents damage to the eye.
Ciliary muscles and suspensory ligaments	Control shape of the lens

Accommodation of the Eye

Definition:
Accommodation is the process by which:

- The lens changes shape
- To focus light from objects at different distances
- Onto the retina

1. Focusing on a Distant Object

- **Ciliary muscles: Relax**
- **Suspensory ligaments: Tighten**
- **Lens: Becomes thin and flatter**
- **Effect: Bends light less, allowing it to focus on the retina**

2. Focusing on a Near Object

- **Ciliary muscles: Contract**
- **Suspensory ligaments: Loosen**
- **Lens: Becomes thicker and more curved**
- **Effect: Bends light more sharply, focusing it on the retina**

Common Eye Problems:

- **Myopia (short-sightedness)**: The lens is too curved, so distant objects appear blurry and are focused in front of the retina
  - Treatments:
  - **Concave (diverging) lenses** in glasses or contact lenses → spread light rays so they focus on the retina.
  - **Laser surgery:** Reshapes the cornea to correct focus.
  - **Lens replacement:** Artificial lens implanted in severe cases.

- **Hyperopia (long-sightedness)**: The lens is too flat, so close objects appear blurry and are focused behind the retina.
  - Treatments:
  - **Convex (converging) lenses** in glasses or contact lenses → bend light more to focus on the retina.

- **Laser surgery:** Adjusts cornea curvature to improve focus.
- **Lens replacement:** Artificial lens for severe cases.

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5.2.4 Control of Body Temperature

- Body temperature is controlled by the **thermoregulatory centre** in the brain, which has **receptors** that detect changes in blood temperature.

Vasodilation and Vasoconstriction

Purpose: Both processes help regulate **body temperature (best at 37.5 degrees celsius)** by controlling blood flow near the skin surface.

1. Vasodilation

- **Definition:** Widening of blood vessels near the skin.
- **Effect:** More blood flows close to the surface → heat is lost to the environment.
- **When it happens:** When body temperature is **too high**.
- **Example:** Skin appears red and warm when it's hot because blood is closer to the surface.

2. Vasoconstriction

- **Definition:** Narrowing of blood vessels near the skin.
- **Effect:** Less blood flows near the surface → heat is retained.
- **When it happens:** When body temperature is **too low**.
- **Example:** Skin may appear pale or cold as the body conserves heat.
- Body temperature is controlled by the **thermoregulatory centre** in the brain, which has **receptors** that detect changes in blood temperature.

When Body Temperature is Too High:

- **Sweat glands** produce sweat, which cools the body as it evaporates.
- **Vasodilation**: Blood vessels near the skin widen, increasing heat loss.

When Body Temperature is Too Low:

- **Shivering** generates heat as muscles contract.
- **Vasoconstriction**: Blood vessels near the skin narrow, reducing heat loss.
- No sweating

5.3 Hormonal Coordination in Humans

5.3.1 The Human Endocrine System

- The **endocrine system** is made up of **glands** that release **hormones** directly into the blood.
    - Hormones are **chemical messengers** that travel through the bloodstream to target organs.

Gland	Hormone	Function
Pituitary Gland	Master gland, controls other glands.	Releases hormones that regulate other glands.
Pancreas	**Insulin**	Controls blood glucose levels.
Thyroid	**Thyroxine**	Regulates metabolic rate, heart rate, and temperature.
Adrenal Glands	**Adrenaline**	Prepares the body for "fight or flight".
Ovaries	**Oestrogen**	Involved in the menstrual cycle and female development.
Testes	**Testosterone**	Controls sperm production and male development.

Blood Glucose Concentration

Definition:
Blood glucose concentration refers to the amount of glucose in the blood

1. Regulation by the Pancreas

- High blood glucose (e.g., after eating something with carbohydrates):
    - Pancreas detects rise of glucose → insulin released
    - Insulin causes:
        - Glucose uptake by cells for energy
        - Storage of glucose as glycogen in liver and muscles
- Low blood glucose (e.g., fasting or exercise):
    - Pancreas detects drop → glucagon released
    - Glucagon stimulates:
        - Conversion of glycogen to glucose in the liver → released into blood, increasing blood glucose levels.

2. Effects of Rigorous Activity

- Exercise increases glucose consumption by muscles for energy.
- Blood glucose drops → glucagon released to restore levels.
- Insulin levels fall to prevent further uptake by cells.

3. Negative Feedback Loop

Blood Glucose Example:

1. Blood glucose rises → insulin secreted → glucose decreases
2. Blood glucose falls → insulin decreases, glucagon secreted → glucose increases

- **Ensures stable energy supply and prevents extreme highs/lows.**

Type 1 Diabetes

- Cause: Pancreas fails to produce enough insulin.
- Effect: Blood glucose rises → can damage organs if untreated.
- Treatment: Daily insulin injections, monitoring diet and activity.

Type 2 Diabetes

- Cause: Body cells become resistant to insulin or pancreas produces insufficient insulin.
- Effect: Blood glucose remains high → long-term complications.
- Treatment:
    - Lifestyle: healthy diet, regular exercise
    - Medication to improve insulin sensitivity or reduce glucose levels

Maintaining Water and Nitrogen Balance in the Body

- If water concentration in the blood increases → cells take up more water due to osmosis
- If water concentration in the blood decreases → cells lose more water
- If body cells gain too much or lose too much water, it ceases to function properly

Role of the Kidneys

- **Filter blood** to remove waste (urea, excess ions, water)
- **Reabsorb** useful substances (glucose, ions, water) into blood - selective reabsorption
- Maintain **homeostasis** for water, ions, and nitrogen-containing compounds

Waste Products Removed:

- **Urea**: Formed from the deamination of amino acids in the liver to ammonia gas, which is toxic so is converted to urea. Lost in sweat.
- **Water and ions**: Lost in sweat and urine.

2. Anti-Diuretic Hormone (ADH)

- Released by **pituitary gland** when blood water levels are low
- Makes **kidney tubules more permeable**, so more water is reabsorbed into blood
- Less ADH → less water reabsorbed → more urine produced

3. Kidney Failure

- **Definition:** Kidneys cannot filter blood effectively
- **Causes:** Disease, injury, or long-term conditions like diabetes
- **Consequences:** Waste accumulates → water/ion balance disrupted → dialysis or kidney transplant needed

Treatment:

1. Dialysis

Purpose: To artificially remove waste products (like urea), excess ions, and water from the blood.

Process:

- Blood is passed through a **dialysis machine** containing a semi-permeable membrane.
- The **dialysis fluid** contains the correct concentrations of water, ions, and glucose.
- Waste products (urea, excess ions) **diffuse out of the blood** into the fluid by **diffusion** and **osmosis**, while useful substances remain in the blood.

Frequency: Usually several times per week; treatment is ongoing unless a kidney transplant is performed.

Advantages:

- Keeps patients alive while waiting for a transplant or if transplant is not possible.

Disadvantages:

- Time-consuming, inconvenient, and can restrict lifestyle.
- Cannot fully replace all kidney functions (e.g., hormone production).

2. Kidney Transplant

Purpose: To replace a failed kidney with a healthy donor kidney.

Process:

- A healthy kidney from a **living or recently deceased donor** is surgically implanted.
- The new kidney restores normal filtration of blood and balance of water, ions, and urea.

Advantages:

- Can fully restore kidney function, reducing or eliminating the need for dialysis.
- Significantly improves quality of life compared to long-term dialysis.

Disadvantages / Risks:

- Requires **immunosuppressant drugs** to prevent rejection of the transplanted kidney.
- Risk of infection due to suppressed immune system.
- Shortage of donor kidneys can mean long waiting times.

Hormones in Human Reproduction

- During **puberty**, **reproductive hormones** cause **secondary sexual characteristics** to develop:
    - In males: **Testosterone** (from the testes) controls sperm production.
    - In females: **Oestrogen** (from the ovaries) controls the menstrual cycle.

The Menstrual Cycle:

- The cycle prepares the body for pregnancy and involves four main hormones:
    1. **FSH** (from the pituitary gland) matures an egg in the ovary, causes ovaries to produce oestrogen
    2. **Oestrogen** thickens the uterus lining and stimulates the release of **LH**, and inhibits FSH
    3. **LH** (from the pituitary gland) triggers **ovulation** (release of an egg).
    4. **Progesterone** maintains the uterus lining, preparing for potential pregnancy, LH and FSH is inhibited by progesterone.

Contraception

Hormonal Methods:

1- Combined Contraceptive Pill

- Contains oestrogen and progesterone.
- Prevents ovulation by **inhibiting FSH release** (no egg matures).
- Thickens cervical mucus → sperm struggle to reach egg.
- **Pros:** Highly effective if taken correctly.
- **Cons:** Must be taken daily; possible side effects (mood changes, weight gain, headaches).

2- Progesterone-only Pill

- Thickens cervical mucus and sometimes inhibits ovulation.
- **Pros:** Safer for women who cannot take oestrogen.

- **Cons:** Slightly less effective than combined pill if not taken at the same time daily.

3- Contraceptive Patch

- Worn on skin, releases oestrogen and progesterone.
- Changed weekly.
- **Pros:** Low effort, effective.
- **Cons:** May cause skin irritation.

4- Contraceptive Implant

- A small tube inserted under the skin; releases progesterone continuously.
- Works for up to 3 years.
- **Pros:** Very effective, long-lasting.
- **Cons:** Minor surgical procedure required to insert/remove.

5- Contraceptive Injection

- Progesterone injection every 8–12 weeks.
- **Pros:** Convenient, long-term protection.
- **Cons:** Side effects (irregular periods, weight gain).

6- Hormonal Intrauterine Device (IUD, "coil")

- Inserted into uterus, releases progesterone.
- Prevents implantation of fertilised egg.

- **Pros:** Works for 3–5 years.
- **Cons:** Must be fitted by doctor, small risk of infection.

Non-hormonal Methods:

1- Barrier Methods

- Condoms (male/female), diaphragms (with spermicide).
- Prevent sperm reaching the egg.
- **Pros:** Protect against STIs (condoms).
- **Cons:** Can break, less effective if not used properly.

2- Copper Intrauterine Device (non-hormonal coil)

- Copper is toxic to sperm and prevents implantation.
- Works for up to 10 years.
- **Pros:** Highly effective, long-term.
- **Cons:** Periods may become heavier and more painful.

3- Surgical Methods

- Male sterilisation (vasectomy): sperm ducts cut.
- Female sterilisation: fallopian tubes tied/cut.
- **Pros:** Permanent solution.
- **Cons:** Very difficult to reverse.

The Use of Hormones to Treat Infertility

1. Fertility Drugs

- Contain **FSH** and **LH** to stimulate the maturation and release of eggs in women who do not ovulate.
- **Pros:** Helps many women conceive naturally.
- **Cons:**
    - Can lead to multiple pregnancies (twins/triplets).
    - Emotionally and physically demanding.

2. IVF (In Vitro Fertilisation)

- FSH and LH used to stimulate egg release.
- Eggs collected, fertilised with sperm in a lab.
- Embryos grown for a few days then implanted in the uterus.

Advantages:

- Enables conception when other methods fail.
- Can use donor eggs or sperm.

Disadvantages:

- Low success rate (often <30%).
- Expensive and time-consuming.
- Stressful for patients.
- Risk of multiple births → premature/underweight babies.

- Ethical concerns (unused embryos may be destroyed).

Negative Feedback

Thyroxine

Thyroxine (from thyroid gland)

- Regulates **basal metabolic rate** (how fast chemical reactions happen in the body), heart rate, and temperature.
- **Control mechanism:**
    - Low thyroxine → pituitary gland releases **TSH** → thyroid produces more thyroxine.
    - High thyroxine → TSH suppressed → thyroxine levels fall back to normal.
- **Example of negative feedback.**

Adrenaline (from adrenal glands)

- Released in **fight-or-flight situations** (when in fear/stressful situations)
- Increases heart rate, blood flow to muscles, and blood glucose availability by converting glycogen to glucose.
- **Not controlled by negative feedback** — released rapidly in response to stress, not to maintain steady levels.

- **Negative feedback** is a process that keeps body conditions within set limits.
    - Example: **Thyroxine** regulates metabolism. If levels are too high, **TSH** from the pituitary gland is suppressed, reducing thyroxine production until levels return to normal.

Plant Hormones

Control and Coordination

- Plants use **hormones** to control growth and responses to the environment.

1. Tropisms

Plants respond to stimuli by growth in certain directions:

- **Phototropism (light):**
    - Shoots grow **towards light** (positive phototropism).
    - Increases light capture for photosynthesis.
- **Geotropism/Gravitropism (gravity):**
    - Roots grow **towards gravity** (positive geotropism).
    - Ensures roots grow downwards into soil for water and nutrients.
    - Shoots grow upwards against gravity (negative geotropism).

2. Auxins

- Plant hormones produced at shoot and root tips.
- Control growth by **cell elongation**.
- **Shoots:** Auxin accumulates on shaded side → cells elongate → shoot bends towards light (positive phototropism)
- **Roots:** Auxin accumulates on lower side → inhibits cell growth → root bends downwards (positive gravitropism)

3. Gibberellins

- Stimulate **seed germination, stem growth, and flowering**.
- Commercial use: trigger seed germination in brewing and increase fruit size.

4. Ethene

- Gas hormone controlling **fruit ripening**.
- Commercial use:
    - Unripe fruit transported → sprayed with ethene at destination to ripen on demand.

Uses of Plant Hormones:

1. Auxins

- **Weed Killers (Selective Herbicides)**
    - Synthetic auxins are sprayed on broad-leaved weeds (e.g., dandelions).
    - They cause uncontrolled growth → weeds use up resources and die.
    - Grasses and cereals (narrow-leaved crops) are unaffected.
    - ✅ Useful in farming and lawn maintenance.
- **Rooting Powders**
    - Cuttings dipped in auxin powder → stimulate root growth.
    - Allows rapid cloning of plants from cuttings.
    - ✅ Common in gardening and commercial plant production.
- **Tissue Culture (Cloning)**
    - Tiny pieces of plant tissue grown in sterile conditions.

- Auxins added to growth medium → stimulate **cell division and differentiation** into roots/shoots.
- ✅ Used to mass-produce disease-free, genetically identical plants.

2. Gibberellins

- **Ending Seed Dormancy**
  - Some seeds won't germinate unless exposed to particular conditions (light, temperature).
  - Gibberellins trigger germination regardless of conditions.
  - ✅ Used in brewing to make barley seeds germinate quickly.
- **Promoting Flowering**
  - Some plants only flower in certain conditions (e.g., long days).
  - Gibberellins can override this and cause plants to flower earlier or out of season.
- **Increasing Fruit Size**
  - Seedless fruits (e.g., grapes) can be small.
  - Gibberellins applied → increase fruit growth to match seeded varieties.

3. Ethene

- **Ripening of Fruit (Food Industry)**
  - Ethene stimulates enzymes that convert starches into sugars, softening the fruit and developing flavour.
  - Commercial uses:

- Transport fruit (like bananas, tomatoes) unripe (harder, less likely to spoil).
- Expose them to ethene at destination → ripen on demand.

- ✅ Reduces waste and ensures fruit is ready for sale at the right time.