Coordination and Homeostasis

The nervous system, neurones, reflex arcs and synapses, the eye, hormones and adrenaline, homeostasis and negative feedback, temperature control in the skin, and blood glucose control and diabetes.

14.1 Coordination and the nervous system

The **nervous system** (the brain, spinal cord and nerves) **coordinates and regulates** body functions.

- The **central nervous system (CNS)** is the **brain and spinal cord**.
- The **peripheral nervous system (PNS)** is the **nerves outside** the brain and spinal cord.

Electrical **impulses** travel along **neurones** (nerve cells).

Types of neurone

Neurone	Function
sensory neurone	carries impulses from a **receptor** to the CNS
relay neurone	in the CNS; carries impulses from sensory to motor neurones
motor neurone	carries impulses from the CNS to an **effector** (a muscle or gland)

The reflex arc

> **A reflex action is a rapid and automatic response to a stimulus. It does not involve conscious thought.**

The path is called a **reflex arc**:

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

Example: touching a hot object. The **receptors** in the skin detect the heat; the impulse passes along a sensory neurone to the spinal cord, then through a relay neurone to a motor neurone, which carries the impulse to a **muscle** (the effector) that contracts to pull the hand away. Because few neurones are involved and the brain is not involved first, the reaction is very fast, and it protects the body from harm.

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Synapses

> **A synapse is a junction between two neurones.**

There is a tiny gap (the **synaptic gap**) between the neurones. The first neurone's end contains **vesicles** that hold **neurotransmitter** molecules, and the next neurone has **receptor proteins** on its membrane.

Events at a synapse.

1. An **impulse arrives** and stimulates the **release of neurotransmitter molecules** from the vesicles into the synaptic gap.
2. The neurotransmitter molecules **diffuse across the gap** and **bind to receptor proteins** on the next neurone.
3. This **stimulates an impulse** in the next neurone.

Synapses ensure that impulses travel in **one direction only**, because only the first neurone releases neurotransmitter, and only the second has receptors.

14.2 Sense organs

Sense organs are groups of **receptor cells** that respond to **specific stimuli**: light (eye), sound (ear), touch, temperature (skin) and chemicals (nose and tongue).

The eye

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Part	Function
cornea	**refracts** (bends) light as it enters the eye
iris	controls **how much light enters the pupil**
pupil	the hole through which light enters
lens	**focuses** light onto the retina
ciliary muscles and **suspensory ligaments**	control the **shape of the lens**
retina	contains **light receptors** (some are sensitive to light of different colours)
fovea	the part of the retina with the **greatest density of receptors**, for the sharpest vision
optic nerve	carries impulses from the retina to the brain
blind spot	where the optic nerve leaves the retina; no receptors, so no vision

The pupil reflex

The **iris** has two sets of muscles that act **antagonistically** (in opposite ways): **circular muscles** and **radial muscles**.

	Bright light	Dim light
circular muscles	**contract**	relax
radial muscles	relax	**contract**
pupil	**gets smaller**	**gets larger**
effect	less light enters, protecting the retina	more light enters so that the person can see

Accommodation

Accommodation is changing the shape of the lens to focus on objects at different distances.

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	Near object	Distant object
ciliary muscles	**contract**	**relax**
suspensory ligaments	**slacken** (less tension)	**tighten** (more tension)
lens	becomes **thicker and more curved**	becomes **thinner and flatter**
refraction	light is refracted **more**	light is refracted **less**

14.3 Hormones

A hormone is a chemical substance, produced by a gland and carried by the blood, which alters the activity of one or more specific target organs.

Gland	Hormones
adrenal glands	adrenaline
pancreas	insulin and glucagon
pituitary gland	FSH (follicle-stimulating hormone) and LH (luteinising hormone)
testes	testosterone
ovaries	oestrogen and progesterone

Adrenaline

Adrenaline is made by the **adrenal glands** in situations of fear, stress or excitement (for example before a race, or when frightened). It **increases the heart rate** (so more blood carries oxygen and glucose to the muscles) and it **increases the blood glucose concentration** (the liver changes glycogen into glucose), so that more energy is available for muscles in a "fight or flight" response.

Nervous and hormonal control compared

	Nervous	Hormonal
speed of action	very fast (milliseconds)	slower (carried in the blood)
duration of effect	short	longer lasting
pathway	along neurones	in the blood

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14.4 Homeostasis

> **Homeostasis is the maintenance of a constant internal environment.**

Examples: body temperature, blood glucose concentration, water content.

> **Negative feedback is control in which a change from a set point is detected, and the body responds to reverse it, bringing the level back to the set point.**

If the level goes **above** the set point, a response makes it **fall**. If it goes **below**, a response makes it **rise**. This keeps the level close to the set point.

14.4 Temperature control

Mammals keep their body temperature constant at about $37\,^{\circ}\mathrm{C}$, so that their enzymes work at the optimum.

The skin

- **Hairs** and **fatty tissue** insulate the body (the fat under the skin reduces heat loss).
- **Hair erector muscles** raise the hairs.
- **Sweat glands** produce sweat.
- **Temperature receptors** in the skin detect the temperature of the surroundings, and receptors in the brain detect the temperature of the blood.
- **Blood vessels** (arterioles supplying capillaries) can change in diameter.

The **hypothalamus** in the brain is the **control centre**. It monitors the temperature of the blood and receives impulses from the temperature receptors in the skin, and it sends impulses to the effectors.

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Responses

	When too hot	When too cold
sweating	sweat glands make **sweat**; evaporation of the sweat **removes heat** from the skin	little or no sweat
vasodilation / vasoconstriction	**vasodilation**: the arterioles widen so **more blood flows through the capillaries near the surface**, and more heat is lost by radiation	**vasoconstriction**: the arterioles narrow, so **less blood flows near the surface** and less heat is lost
hair erector muscles	relax; hairs **lie flat**	contract; hairs **stand up**, trapping a layer of insulating air
shivering	none	muscles contract rapidly, and **respiration releases heat** that warms the body

NOTE

Blood vessels do **not** move towards or away from the skin. The **arterioles** get wider (vasodilation) or narrower (vasoconstriction), which changes the amount of blood flowing in the surface capillaries.

14.4 Blood glucose control

The blood glucose concentration must be kept near its set point, because cells need glucose for respiration, and if it is too high or too low, cells can be damaged (for example by osmotic effects).

- After a meal, blood glucose **rises**. The **pancreas** secretes **insulin**, which makes the **liver** convert **glucose into glycogen** for storage (and cells take up more glucose), so the blood glucose **falls**.
- If blood glucose **falls** (for example between meals or in exercise), the pancreas secretes **glucagon**, which makes the liver convert **glycogen into glucose** and release it into the blood, so the blood glucose **rises**.

Diabetes (Type 1)

In **Type 1 diabetes** the pancreas does **not make enough insulin**. The blood glucose concentration **rises** (increased blood glucose) and **glucose appears in the urine**. It is treated by **injecting insulin** (usually with meals), together with attention to diet.

TRY IT

Explain what happens when the blood glucose concentration rises above the set point.

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The **pancreas** secretes **insulin**. Insulin makes the **liver** change glucose into **glycogen** (and cells take up glucose), so the blood glucose concentration **falls** back to the set point. This is **negative feedback**.

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