TOPIC: HOMEOSTASIS

Key Knowledge:

- Regulation of body temperature, blood glucose and water balance in animals by homeostatic mechanisms, including stimulus-response models, feedback loops and associated organ structures
- Malfunctions in homeostatic mechanisms: type 1 diabetes, hypoglycaemia, hyperthyroidism

HOMEOSTASIS

Cells must preserve certain intracellular conditions in order to maintain the enzyme-catalysed metabolic reactions needed for cellular survival. Examples of conditions that must maintain an internal equilibrium include temperature, pH levels, water balance and nutrient supply. Homeostasis is the tendency for a cell or organism to maintain a **constant internal environment** within physiological tolerance limits. A failure to maintain homeostasis results in the development of a disease. Homeostatic regulation involves the use of communication systems (cell signalling) to respond to changing internal conditions via **feedback loops**.

STIMULUS-RESPONSE MODEL

A stimulus is a change in the environment (either external or internal) that is detected by a receptor. Receptors then transform the environment signal into a cellular message which will trigger an appropriate response. Hence, the stimulus-response model can be summarised according to three key steps:

- **Reception:** Stimulus (either external condition or signalling molecule) is detected by a specific receptor
- **Transduction:** The conversion of an external (extracellular) signal into an internal (intracellular) signal
- **Response:** A change in the activity of the cell as a result of the stimulus (e.g. change in gene expression)

TYPES OF SIGNALLING

Cells communicate by releasing chemicals that travel to specific target sites. Only the cells that possess a specific receptor to the signalling molecule can be activated to initiate a response. Types of cell signalling may include either autocrine ('self'), paracrine ('adjacent') and endocrine ('distant') signalling mechanisms.

Autocrine Signalling

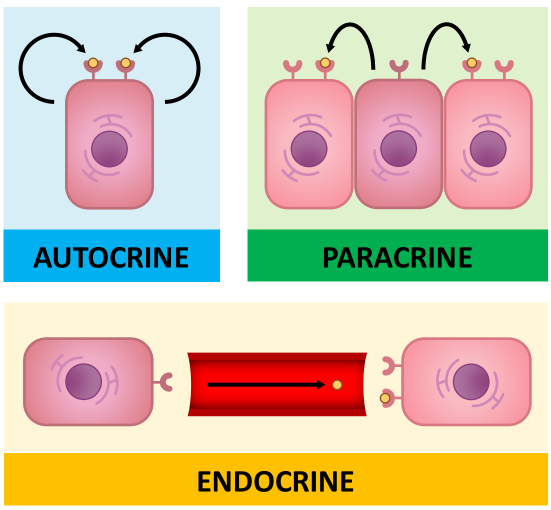
- Chemicals stimulate the cell responsible for their release
- E.g. Clonal proliferation of a T_H cell after cytokine release

Paracrine Signalling

- Chemicals stimulate an adjacent / neighbouring cell
- E.g. Neurotransmitters stimulate post-synaptic neurons

Endocrine Signalling

- Chemicals stimulate distant target cells (e.g. via blood)
- E.g. Animal hormones are released from endocrine glands



NEGATIVE FEEDBACK

Negative feedback involves a response that is the **reverse** of a change detected (it functions to reduce the initial change). The effector will induce an opposite effect to the change detected by a receptor in order to promote equilibrium (i.e. homeostasis). Examples of body processes that utilise negative feedback include:

- **Thermoregulation** (if body temperature changes, mechanisms are induced to restore normal levels)
- **Blood sugar concentration** (insulin lowers blood sugar levels, while glucagon raises blood sugar levels)
- **Osmoregulation** (ADH retains body water when dehydrated and its release is inhibited when hydrated)

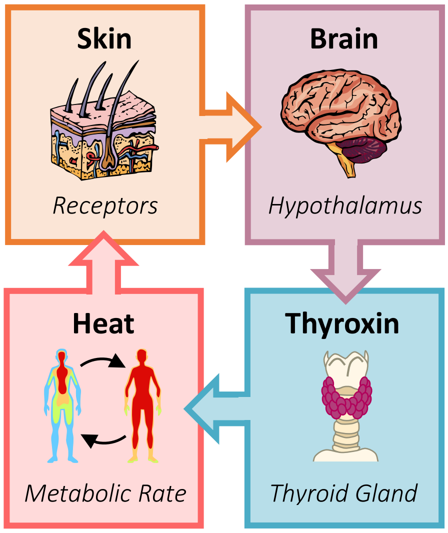
Positive feedback involves a response that **reinforces** the stimulus (it amplifies the change). This positive feedback loop will continue until the initial stimulus is removed and hence does **not** promote homeostasis.

THERMOREGULATION

Changes to core body temperature are detected by thermoreceptors in the skin and hypothalamus. These trigger a variety of mechanisms (either heating or cooling) to restore equilibrium. Responses include:

- **Heating mechanisms:** Shivering, vasoconstriction or piloerection
- **Cooling responses:** Sweating (evaporative cooling), vasodilation

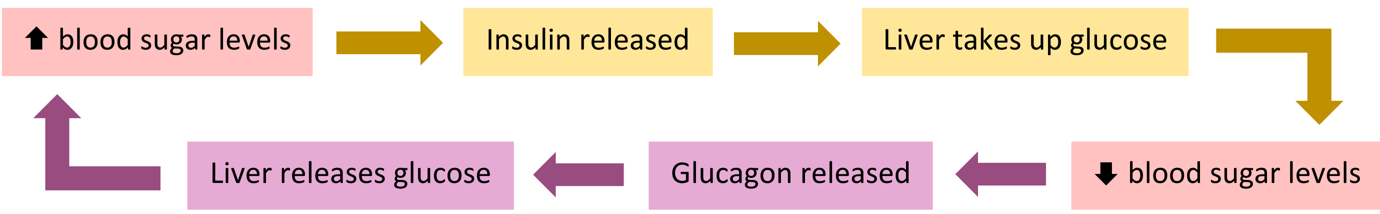
Additionally, **thyroxin** is a hormone produced by the thyroid gland to regulate body temperature. Thyroxin increases metabolic rate, which produces heat as a by-product of cell respiration. Excess production of thyroxin leads to **hyperthyroidism**, which can lead to weight loss, irregular heartbeats and heat intolerance. Hyperthyroidism can be caused by excess iodine intake or development of thyroid tumours.



BLOOD SUGAR REGULATION

Blood glucose concentrations are controlled by a set of antagonistic hormones secreted by the pancreas. **Insulin** (secreted by β cells) lowers blood sugar levels by increasing the uptake of glucose by the liver and adipose tissue (stored as glycogen). **Glucagon** (secreted by α cells) raises blood sugar levels by increasing the release of glucose by the liver and adipose tissue. Blood sugar levels may be increased following a meal and will decrease as a response to vigorous exercise (glucose is used in aerobic and anaerobic respiration).

Type I diabetes mellitus is a metabolic disorder that occurs when the body does not produce insulin and is unable to regulate blood sugar levels (leading to hyperglycaemia). It can be treated with insulin injections.



OSMOREGULATION

Antidiuretic hormone (**ADH**) is released from the pituitary gland in response to dehydration (detected by osmoreceptors). ADH acts to increase the permeability of the kidney to water, by upregulating expression of water channels (**aquaporins**). This will mean that more water is thus returned to the bloodstream and that the urine is more concentrated. When an individual is suitably hydrated, ADH levels are decreased.