Homeostasis and Endocrine System

Homeostasis = Maintenance of a dynamically constant internal environment by an organism irrespective of changes in external environment by **self-regulating** and **negative feedback** mechanisms

Internal Environment

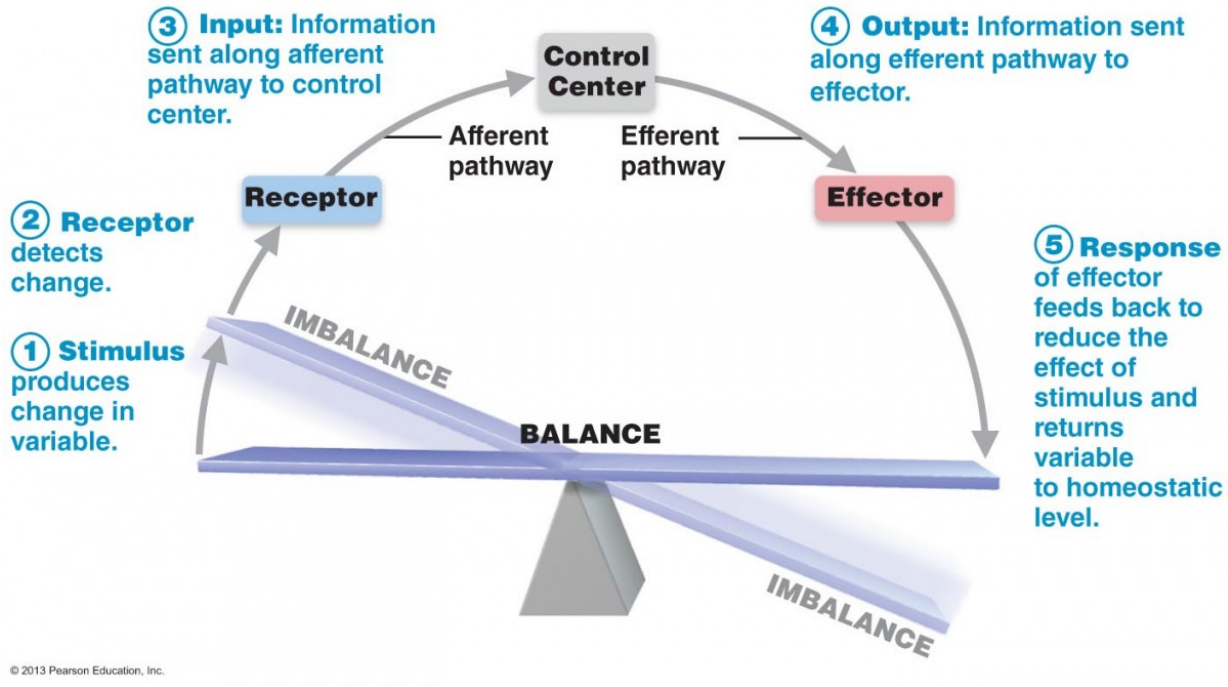
- Blood exchanges substances with interstitial fluid which then exchanges substances with tissues/capillaries

Need for communication systems within organisms

- Coordination between organs → Organs should facilitate the function of each other so that the organism can function as a whole in response to changes
- Ensures composition of internal environment is maintained at a narrow optimum range to support the functioning of body cells
- Ensures organs are not under/over-worked to minimise energy wastage

Principles of Homeostasis

1. Self-Regulation
    - Control mechanism is triggered by the parameter it serves to regulate (i.e. Changes in the parameter triggers a response which would affect the parameter)
2. Negative Feedback
    - Deviation from set point triggers a response to counteract the change
    - Components:
        - **Receptor** sends signal to **Control Centre** sends signal to **Effector**
    - Response by effector serves as negative feedback to the receptor for monitoring of any displacement from the set/reference point
    - Dynamic equilibrium



Hormones = Extracellular chemical messengers that bring about specific cell responses through cell signalling

- Secreted directly into blood by ductless endocrine gland
- Transported by blood to a specific target site
- Effective in small quantities
    - Complementary in shape to receptor molecules on specific target cells ⇒ High binding affinity to receptors
    - Signal amplification
    - Does not need to waste resources by synthesising a large amount of hormones
- Capable of eliciting different responses from
    - Different target cells/tissues
    - Same tissue at different stages of development
- Types:
    - Peptide chains
    - Amines (single type of amino acid)
    - Steroids

Endocrine Glands

- Ductless
- Secrete hormones directly into the blood circulation to be brought to the target site
- Supported by a rich supply of blood capillaries

****Control of Blood Glucose Concentration**

- **Endocrine gland:** Islets of Langerhans of pancreas
    - Alpha cells → Glucagon
    - Beta cells → Insulin
- Ratio of concentration of insulin and glucagon is more critical than absolute levels
- Insulin and glucagon work in antagonistic fashion
- Insulin
    - Structure:
        - Peptide made of 2 polypeptide chains, A and B, linked by 2 disulphide bridges
        - Pro-insulin consists of an additional C-chain which is cleaved by proteolytic enzymes packaged together in secretory vesicles from the Golgi apparatus during post-translational modification
    - Role - Triggers the decrease blood glucose:
        - **Stimulus**: Blood glucose concentration rises above set point of about **90mg/dL**
        - **Receptor** + **Control Centre**: Detected by beta cells of islets of Langerhans in pancreas
        - **Signal**: More insulin is secreted by beta cells which binds to insulin receptors (RTK)
        - **Effector**: Liver and muscle cells
            - Translocate glucose transporters from the membrane of cytoplasmic vesicles to the cell membrane to <u>increase rate of glucose intake by liver and muscle cells</u>
            - Stimulates <u>glycolysis</u> (i.e. oxidation of glucose)
            - Activates glycogen synthase which catalyses <u>glycogenesis</u> (i.e. synthesis of glycogen from glucose)
            - Increase lipid synthesis by increasing rate of glycolysis ⇒ Glucose broken down by aerobic respiration to form intermediates used for fatty acid sythesis
            - Increase protein synthesis
        - **Effect**: Decrease in blood glucose concentration via **<u>negative feedback</u>**
        - **Negative Feedback**: Decrease in blood glucose levels towards set level diminishes stimulus to the beta cells of the islets of Langerhans of the pancreas which then decrease insulin secretion
    - Deficiency causes Type 1 Diabetes Mellitus
- Glucagon
    - Structure:
        - Peptide hormone
    - Role - Triggers the increase in blood glucose
        - **Stimulus**: Blood glucose concentration drops below set point of about **90mg/dL**
        - **Receptor** + **Control Centre**: Detected by alpha cells of islets of Langerhans in pancreas
        - **Signal**: More glucagon secreted into bloodstream by alpha cells which

binds to glucagon receptors (GPCR)
- **Effector**: Liver cells
  - Stimulates glycogen phosphorylase which catalyses glycogenolysis (i.e. breakdown of glycogen to glucose)
  - Increase gluconeogenesis (i.e. generation of glucose from non-carbohydrate carbon substrates)
  - Inhibits glycogen synthase which catalyses glycogenesis
- **Effect**: Increase in blood glucose via **negative feedback**
- **Negative Feedback**: Increase in blood glucose levels towards set level diminishes stimulus to the alpha cells of the islets of Langerhans of the pancreas which then decreases glucagon secretion

Explain the role of glucagon in regulation of blood glucose concentration in humans

1. When blood glucose level falls below set point of 90mg/dL, it is detected by **alpha cells of islets of Langerhans**
2. which secretes **glucagon** into bloodstream
3. Glucagon is transported via the bloodstream and binds to its specific receptor on the liver cells, its main target cells the liver cells
4. Glucagon stimulates enzymes involved in the break down of glycogen to glucose (glycogenolysis) in the liver,
5. Synthesis of glucose from non-carbohydrate precursors e.g. pyruvate, amino acids and glycerol (gluconeogenesis) and the
6. Break down of lipids in adipose tissues
7. Increase in blood glucose levels serve as **negative feedback** to the alpha cells of the islets of Langerhans of the pancreas to decrease glucagon secretion
8. Until blood glucose level returns to set point

Explain the role of insulin in regulation of blood glucose concentration in humans

1. When blood glucose concentration rises above set point of about 90mg/dL, it is detected by beta cells of islets of Langerhans in pancreas
2. which secretes insulin into the bloodstream
3. Insulin is transported via the bloodstream and binds to its specific receptor on the liver and muscle cells, its main target cells
4. Insulin stimulates enzymes involved in increasing glucose intake by tissues,
5. Glycolysis (i.e. oxidation of glucose),
6. Glycogenesis (i.e. synthesis of glycogen from glucose),
7. Lipid synthesis and
8. Protein synthesis
9. Decrease in blood glucose levels serve as **negative feedback** to the beta cells of the islets of Langerhans of the pancreas to decrease insulin secretion
10. Until blood glucose level returns to set point