OCR (B) Biology A-level

5.3 Homeostasis

Notes

5.3.1 Homeostasis

Homeostasis serves to ensure that **a constant internal environment** consisting of factors such as **temperature, water potential, pH and blood glucose level** is maintained, despite changes in the external environment of the organism.

This is achieved with the help of **negative feedback which counteracts any change in internal conditions**. This means that all changes are **reversed to restore the optimum conditions**. In order for the negative feedback pathway to work, the following elements need to be present: **sensory receptors such as temperature receptors to detect changes in internal conditions**, in a case where a change is detected, the r**eceptors** pass the message either via the **nervous or hormonal system to the effectors** such as liver or muscles which bring about a response to restore the optimum conditions.

Another example of a control pathway is **positive feedback** which doesn't occur as often as negative and has an opposing effect, that is it increases the original change in the conditions. An example of positive feedback is **dilation of the cervix during childbirth.**

Thermoregulation

An **ectotherm** is an organism which regulates its body temperature with the help of external source. Ectotherms are **unable to increase their respiration rate to increase the internal production of heat therefore they cannot rely on internal energy sources**. Therefore, they control their body temperature by **exchanging heat with their surroundings**, for instance by exposing their body to sun, orientating it to either minimise or maximise sun exposure, hiding away from sun or increasing breathing for heat loss via evaporation of water.

Endotherms are able to maintain a **constant body temperature**, independent of the external temperature. They contain **thermoreceptors which monitor core body temperature changes** and communicate them to the **hypothalamus which in turn coordinates appropriate responses** to restore the optimum temperature through either physiological or behavioural responses. Actions taken by endotherms to control body temperature through heat gain or heat loss include:

- **Shivering** – contractions of **skeletal muscles** stimulated by nerve impulses sent out by the hypothalamus, lead to increase in temperature as heat is released
- **Sweat glands** – sweat production to **decrease body temperature via evaporation**
- **Hairs on skin** – lie flat to minimise insulation and increase heat loss, raised to **provide insulation** and reduce heat loss
- **Arterioles** – **dilate** to increase heat loss as blood flows clo**s**er to skin, **constrict** to reduce blood flow and therefore minimise heat loss

Thyroid hormones:

1. increase basal metabolic rate and the rate of oxygen uptake.
2. Increase heart rate, blood pressure, nervousness and sweating via sympathetic stimulation.
3. help regulate body temperature.
4. increase synthesis of proteins and break down of lipids - therefore playing a role in growth and development.
5. Increases both bone turnover and formation of red blood cells.

5.3.2 The hormonal control of blood glucose and management of diabetes

Overview

There are two hormones that are used to regulate blood-sugar levels: **glucagon [secreted by alpha cells] and insulin [secreted by beta cells]**. Both of these are synthesised in cells in the **pancreas** and are released into the blood from here when the levels of blood-glucose are too high or too low:

- **Insulin** is released when blood-glucose concentration is **too high**. This is detected in the pancreas. Insulin causes **glucose to be converted to glycogen** in the **liver**. This **lowers the concentration of glucose in cells**; thus **glucose diffuses into cells** from the blood, lowering the amount of glucose in the blood.

- **Glucagon** is released when blood-glucose concentration is **too low**. Glucagon inhibits glucose being converted to glycogen in the liver and activates an enzyme that **converts glycogen to glucose**, making more glucose available to cells. It also **decreases the respiratory rate** in cells so that less glucose is used in respiration.

People with diabetes cannot produce insulin. Type 1 diabetes is caused by an **autoimmune response** in which antibodies attack cells in the pancreas which usually make insulin. This means that **no insulin can be produced**. In type 2 diabetes, either not enough insulin is produced by the pancreas, or the cells do not respond correctly to the insulin. Type 1 diabetes is usually treated by patients **injecting insulin** themselves. There are several new treatments being developed, including the use of stem cells and artificial pancreases, although these treatments will be very expensive.

Control of blood glucose

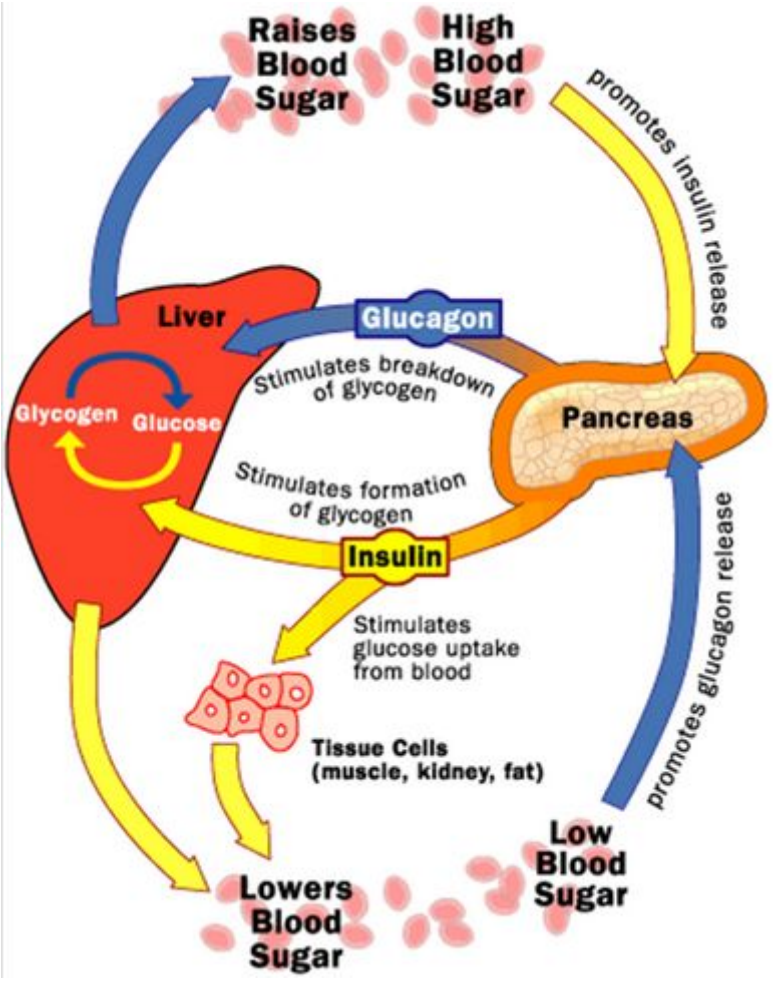

Image source: thealevelbiologist.co.uk

Types of diabetes

- **Type 1 diabetes**
- **Type 2 diabetes**
- **Gestational diabetes –** diabetes occurring as a result of pregnancy, resolves when baby is delivered
- **Medication induced diabetes – steroids, anti-psychotics [medication for mental health]** – inherited forms
- **Monogenic diabetes – maturity onset diabetes of the young [MODY]**

Summary: Type 1 vs. Type 2 diabetes

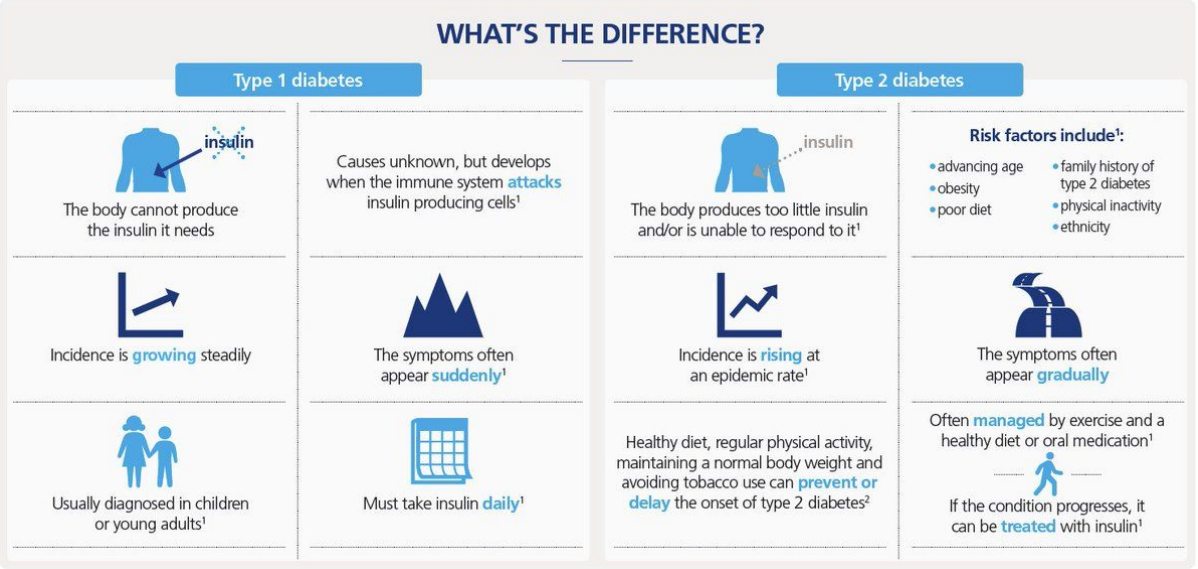

Image source: teamnovonordisk.com

Symptoms:

- **Tiredness**
- **Weight loss [TYPE 1 DIABETES]**
- **Blurry vision**
- **Increased thirst (polydipsia)**
- **Increased urination (polyuria)**

Methods of measuring blood glucose:

- **Random blood glucose –** finger-prick and measurement of glucose using a meter.
- **Fasting blood glucose –** finger-prick and measurement of glucose whilst individual is fasting (usually overnight fasting with test in the morning).
- **Oral glucose tolerance test –** blood glucose measurement in the morning [fasted], individual asked to drink 75g glucose drink [i.e. glucose], measurement of glucose again after 2 hours.
- **HbA1C –** blood test. Measures the level of blood glucose over a 3-month period. Amount of glucose bound to red blood cells which have a lifespan of around 3 months.

Diagnosis:

- **One** random blood glucose value of >11.1mmol/l + symptoms
- **Two** random blood glucose values of >11.1 mmol/l + no symptoms
- **HbA1C value >**48 mmol/l or 6.5%

Management overview:

TYPE 1 DIABETES

- Insulin remains the mainstay of treatment
  - Different preparations are available.
  - Short acting insulin – Lispro, Aspart
  - Long acting insulin – Determir
- **New technologies are being developed** – insulin pumps which can be adjusted to the amount of food eaten.
- Patient education
- Courses for improving diet/ carbohydrate counting
- Monitoring for complications – very important for preventing long-term morbidity and mortality
- **Multi-disciplinary team – i.e. diabetic nurses, dieticians, doctors**

TYPE 2 DIABETES

- Medications to reduce blood glucose
  - i.e. Metformin – inhibits hepatic gluconeogenesis [inhibits the liver producing glucose]
- Statin – control cholesterol
- Control blood pressure
- Patient education
- Monitoring for complications
- **Multi-disciplinary team – i.e. diabetic nurses, dieticians, doctors**

Complications

Split into two groups – microvascular [affecting the small vessels] and macrovascular [affecting the larger vessels]

- Cardiovascular disease – heart attack
- Stroke
- Peripheral arterial disease/intermittent claudication
- Eye disease
- Neuropathy – pins and needles / numbness peripherally; 'glove and stocking' distribution
- Nephropathy – damage to the kidney
- Foot disease – ulcers > infection > amputation

5.3.3 Kidney functions and malfunction

Homeostasis serves to ensure that a **constant internal environment** consisting of factors such as temperature, water potential, pH and blood glucose level is maintained, despite changes in the external environment of the organism.

This is achieved with the help of **negative feedback** which counteracts any change in internal conditions. This means that all changes are reversed to restore the optimum conditions.

In order for the negative feedback pathway to work, the following elements need to be present: **sensory receptors** such as temperature receptors to detect changes in internal conditions. The receptors pass the message either via the **nervous or hormonal system** to the **effectors** such as liver or muscles which bring about a response to restore the optimum conditions.

Another example of a control pathway is **positive feedback** which doesn't occur as often as negative and has an opposing effect - it increases the original change in the conditions. An example of positive feedback is **dilation of the cervix during childbirth.**

Kidneys

The main role of the kidneys is **excretion of waste products**, such as urea in the form of urine.
Summary of kidney function:

- Blood enters the kidney through the **renal artery** and subsequently passes through the **capillaries in the cortex** of the kidneys.
- The waste products are **filtered out of the blood** as it passes through the capillaries and into the **long tubules called nephrons** which surround the capillaries in a process known as **ultrafiltration**.
- **Selective reabsorption** is the name of a process where useful substances such as **amino acids, glucose, vitamins** are reabsorbed back through the tubules in the medulla.
- The substances to be excreted pass along the **tubules and ureter** and finally reach the bladder where they're excreted as urine.
- The filtered blood then passes out of the kidneys through the **renal vein**.

Control of water potential of the blood

In the case of **dehydration**, where the water content of blood is too low, not as much water is **reabsorbed into the blood by osmosis from the loop of Henle, the distal convoluted tubule and collecting duct.** This leads to production of more concentrated urine and vice versa in the case of water content of blood being too high.

Hormones also play an important role in controlling the reabsorption of water.

Osmoreceptors in the **hypothalamus** control the water potential and content. In the case where the osmoreceptors detect the occurrence of low water content in the blood, the hypothalamus sends nerve impulses **to the posterior pituitary gland** to release **antidiuretic hormone (ADH)** into the blood which makes walls of **DCT and collecting duct** more permeable to water therefore increasing the reabsorption of water from the tubules into the blood. At the same time, some **concentrated urine** is also produced to ensure that no water is lost from the body. The opposite occurs in the case where the body is well hydrated.

Kidney failure

Kidney failure can be triggered by various **kidney infections** which cause **inflammation**. The resulting damage causes the kidneys to perform processes such as **filtration and**

reabsorption less efficiently. High blood pressure can also cause damage to the kidney by damaging the **capillaries of glomeruli** thus meaning that larger molecules can find their way into urine.

Causes of kidney failure:

- Uncontrolled diabetes
- High blood pressure
- Inflammation [glomerulonephritis]
- Genetic disorders: i.e. autosomal dominant polycystic kidney disease

The consequences of kidney failure include the **build-up of toxic waste** products such as urea which causes symptoms such as vomiting. In cases where excess water cannot be removed from the blood by the kidneys, **fluid accumulation** occurs which leads to oedema. Apart from this, kidney failure can **disrupt the balance of electrolytes**, in result making the bones **more brittle** or causing water to be retained. May also result in anaemia due to the reduction in production of erythropoietin.

If not treated, kidney failure may cause death.

Kidney failure can be treated with a **renal dialysis** which filters the blood with the help of a machine containing **dialysis fluid** which serves as a means of removing the waste products as well as excess water and ions. Dialysis is only a temporary solution while the patient awaits a transplant. Dialysis needs to be performed several times a week and may cause the patient to feel unwell between sessions as the toxic waste builds up.

Kidney transplant is required to replace the damaged kidney and to reverse kidney failure symptoms, it is believed to be the better solution as it is a more convenient and long-term solution. Sometimes patients need to wait a long time for a **suitable donor** which needs to be of the **same blood type and tissue type** to minimise the risk of rejection. However, **immunosuppressants** still need to be taken by the patient to prevent rejection. In most cases a donor is a family member due to the degree of similarity, this is possible as only one kidney is required for survival.