

## Communication, Homeostasis & Energy

### Communication & Homeostasis

*Outline the need for communication systems within multicellular organisms, with reference to the need to respond to changes in the internal and external environment and to co-ordinate the activities of different organs.*

**Organisms need to respond to external stimuli, e.g. temperature, oxygen concentration and levels of sunlight. These may be over time, e.g. winter fur to summer fur, or quickly, e.g. changing size of pupils. Internal environments change too- the build up of carbon dioxide as a result of respiration changes the pH of the tissue fluid, and therefore inhibits enzyme activity. Multicellular organisms need to coordinate different organs, so this requires a good communication system which will:**

- Cover the whole body
- Enable cells to communicate with each other
- Enable specific communication
- Enable rapid communication
- Enable both short and long-term responses.

*State that **cells need to communicate with each other by a process called cell signalling.***

*State that **neuronal and hormonal systems are examples of cell signalling.***

*Define the terms **negative feedback, positive feedback and homeostasis.***

**Negative feedback- A process in which any change in a parameter brings about the reversal of that change so that the parameter is kept fairly constant.**

**Positive feedback- A process in which any change in a parameter brings about an increase in that change**

**Homeostasis- The maintenance of a constant internal environment despite external changes**

*Explain the principles of homeostasis in terms of receptors, effectors and negative feedback.*

**Any change is detected by receptors, the communication system transmits a message from the receptor to the effector and, through negative feedback, the effectors reverse the change.**

*Describe the physiological and behavioural responses that maintain a constant core body temperature in ectotherms and endotherms, with reference to peripheral temperature receptors, the hypothalamus and effectors in skin and muscles.*

**To maintain a constant core body temperature, ectotherms have physiological and behavioural responses;**

#### Physiological

The horned lizard expands its ribcage and the frilled lizard uses its frill to expand its surface area to absorb more heat from the sun

Locusts increase their abdominal breathing movements to increase water loss when hot

#### Behavioural

Snakes expose their body to the sun so more heat is absorbed

Locusts orientate their body towards the sun to expose a larger surface area & so more heat is absorbed. By orientating their body away from the sun, more heat is lost.

Lizards hide in burrows to prevent heat absorption by staying out of the sun.

**To maintain a constant core body temperature, endotherms have physiological and behavioural responses;**

#### Physiological

##### Sweat glands

When hot they secrete sweat onto the skin. Water evaporates using heat from the blood to supply latent heat of vaporisation.

When cold, less sweat is secreted, less water evaporates and so less loss of latent heat

##### Lungs, nose and mouth

When hot, panting increases water evaporation from lungs, tongue and moist surfaces. Loss of latent heat as above.

When cold, no panting, less water evaporates, no loss of latent heat.

##### Hairs on skin

When hot, the hairs lie flat, providing little insulation, meaning heat can be lost through convection and radiation.

When cold, hairs raise to trap a layer of air, insulating the skin and reducing heat loss.

##### Arterioles leading to capillaries in skin

Hot- vasodilatation allows more blood to capillaries near skin surface, so heat can be radiated from skin

Cold- vasoconstriction reduced the flow of blood through the capillaries near skin, so less heat is radiated

##### Liver cells

Hot- reduce rate of metabolism so less heat is generated from exergonic reactions e.g. respiration.

Cold- increased rate of metabolism so more heat is generated. Respiration generates more heat which is transferred to the blood.

**Skeletal muscles**

Hot- not spontaneous contractions

Cold- spontaneous contractions generates heat as muscle cells respire more

**Behavioural**

**Hot**

Move into shade or hide in burrow

Orientate body to decrease surface area exposed to sun

Remain inactive and spread out limbs to increase surface area

**Cold**

Move into sunlight

Orientate body to increase surface area exposed to sun

Move about to generate heat in muscles

In extreme heat, roll into ball and keep still to decrease surface area

Endotherms monitor blood temperature in the hypothalamus. If the core temperature drops or rises it sends signals to the effectors to reverse the changes.

Peripheral temperature receptors monitor the extremities. The information is fed to the thermoregulatory centre. If it signals a temperature change to the brain, it can initiate behavioural mechanisms for maintaining body temperature.

*Outline the roles of sensory receptors in mammals in converting different forms of energy into nerve impulses.*

Light sensitive cells in the retina detect light intensity and range of wavelengths (colour).

Olfactory cells in the nasal cavity detect the presence of volatile chemicals.

Tastebuds detect the presence of soluble chemicals.

Pressure receptors in the skin detect pressure on the skin.

Sound receptors in the cochlea detect vibrations in the air.

Muscle spindles detect the length of muscle fibres.

These are all transducers and convert the stimulus to a nerve impulse.

*Describe, with the aid of diagrams, the structure and functions of sensory and motor neurones.*

The motor neurone has:

A cell body at the end with a large nucleus and lots of rough ER and golgi bodies

Many short dendrites that carry impulses to the cell body

A long axon which carries an impulse from the cell body to the effector

The sensory neurone has:

Long processes on either side of the cell body

A dendron carrying nerve impulses from a receptor to the cell body

An axon carrying an impulse from the cell body to the central nervous system.

*Describe and explain how the resting potential is established and maintained.*

When not conducting an impulse, the potential difference across the membrane is -60mV.

Sodium-Potassium pumps actively transport 3Na<sup>+</sup> ions out for every 2 K<sup>+</sup> ions in.

The axon contains organic anions, which the membrane is impermeable to.

Slight loss of K<sup>+</sup> ions through the permeable membrane.

Membrane impermeable to Na<sup>+</sup> ions.

*Describe and explain how an action potential is generated.*

1. The membrane is at resting state; -60mV inside compared to outside. **Polarised**.
2. Na<sup>+</sup> ion channels open and some Na<sup>+</sup> ions diffuse out.
3. The membrane **depolarises**- it become less negative with respect to the outside and reaches the **threshold potential** of -50mV.
4. Voltage-gated sodium ion channels open and many Na<sup>+</sup> ions enter. As more Na<sup>+</sup> ions enter, the more positively charged the cell becomes, compared to outside.
5. The potential difference across the membrane reaches +40mV. The inside is now positive compared to the outside.
6. The Na<sup>+</sup> ion channels shut and the K<sup>+</sup> ion channels open.
7. K<sup>+</sup> ions diffuse out of the cell, bringing the potential difference back to negative compared with the outside- **repolarisation**.
8. The potential difference overshoots slightly, making the cell **hyperpolarised**.
9. The original potential difference is restored, so the cell returns to its resting state.

Describe and explain how an action potential is transmitted in a myelinated neurone, with reference to the roles of voltage-gated sodium ion and potassium ion channels.

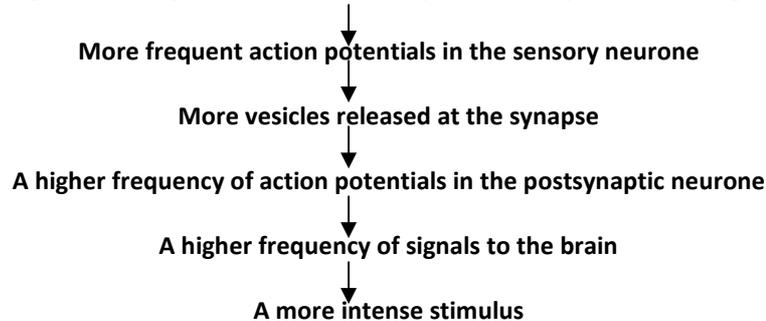
The myelin sheath is an insulating layer of fatty material which Na and K ions cannot pass through. Between the Schwann cells are gaps- called the Nodes of Ranvier, which contain Voltage-gated Sodium and Potassium ion channels, allowing ionic exchange to occur. The action potential 'jumps' from one node to the next- **Saltatory conduction.**

Interpret graphs of the voltage changes taking place during the generation and transmission of an action potential.

1. The membrane is at its resting state- polarised with the inside being -60mV compared to the outside.
2. Sodium ion channels open and some sodium ions diffuse in.
3. The membrane depolarises- it becomes less negative with respect to the outside and the threshold value of -50mV is reached.
4. Voltage gated sodium ion channels open, and sodium ions flood in. As more sodium ions enter, the membrane becomes positively charged on the inside compared to the outside.
5. The potential difference across the membrane reaches +40mV. The inside is positive compared to the outside.
6. The sodium ion channels close and the potassium ion channels open.
7. Potassium ions diffuse out of the cell, bring the potential difference back to negative inside compare to out- this is called repolarisation.
8. The potential difference overshoots slightly making the cell hyperpolarised.
9. The original potential difference is restored so the cell returns to its resting state.

Outline the significance of the frequency of impulse transmission.

A stimulus at the higher intensity will cause the sensory neurons to produce more generator potentials.



Compare and contrast the structure and function of myelinated and non-myelinated neurones.

**Myelinated neurones**

100-120ms<sup>-1</sup>

Up to 1m transmission distance

Fast response time

Used in movement

1/3 of all neurones

One neurones is surrounded by one Schwann cell, wrapped round many times

**Non-myelinated neurones**

2-20ms<sup>-1</sup>

mm or cm transmission distance

Slow response time

Used in breathing and digestion

2/3 of all neurones

Many neurones are surrounded by one Schwann cell

Describe, with the aid of diagrams, the structure of a cholinergic synapse.

The synaptic knob contains:

- Many mitochondria
- A large amount of smooth ER
- Vesicles containing acetylcholine
- There are also voltage gated sodium ion channels in the membrane

The postsynaptic membrane contains:

- Specialised sodium ion channels that will only open when acetylcholine binds to them

*Outline the role of neurotransmitters in the transmission of action potentials.*

A neurotransmitter is a chemical that diffuses across the cleft of the synapse to transmit a signal to the postsynaptic neurone. They cause the generation of a new action potential in the postsynaptic neurone. In cholinergic synapses the neurotransmitter is acetylcholine. It is stored in vesicles in the synaptic knob, and when the action potential arrives, the voltage gated sodium ion channels open, so calcium ions diffuse out. This causes the vesicles to fuse with the synaptic membrane, so acetylcholine is released by exocytosis. It diffuses across the cleft and binds to receptor sites on the sodium ion channels on the postsynaptic membrane. Sodium ions diffuse across the synaptic membrane into the postsynaptic neurone, creating a generator potential. If the generator potential is sufficient, the potential across the membrane reaches the threshold potential, and a new action potential is created.

*Outline the roles of synapses in the nervous system.*

Primarily, the role of synapses is to connect two neurones together to pass a signal from one to the other, but they do have other functions:

- Several presynaptic neurones may converge together to allow signals from different parts of the nervous system to create the same response.
- One presynaptic neurone may diverge to several post synaptic neurones to allow one signal to be transmitted to several parts of the nervous system- one may elicit a response, and one may inform the brain.
- They ensure that signals are transferred in only one direction- only the presynaptic knob contains acetylcholine in vesicles.
- They can filter out unwanted low-level signal, possibly created by a low level stimulus. Several vesicles of acetylcholine must be released for an action potential to be created in the post synaptic neurone.
- Low level signals can be amplified by summation (when several small potential charges combine to produce one larger charge in the potential membrane). If a low-level stimulus is persistent, it can generate several successive action potentials in the presynaptic neurone. The release of many vesicles of acetylcholine in a short space of time will enable the postsynaptic generator potentials to combine together to produce an action potential.
- Acclimatisation- after repeated stimulation, a synapse may run out of vesicles containing the transmitter substance. The synapse is said to be fatigued. This helps avoid overstimulation of an effector, which could damage it.
- The creation of specific pathways in the nervous system is thought to be the basis of conscious thought and memory.

*Define the terms endocrine gland, exocrine gland, hormone and target tissue.*

**Endocrine gland:** a gland that secretes hormones directly into the blood. Endocrine glands have no ducts.

**Exocrine gland:** a gland that secretes molecules directly into a duct that carries the molecules to where they are used.

**Hormone:** a molecule released into the blood which acts as a chemical messenger

**Target tissue:** a group of cells that have receptors embedded in the plasma membrane that are complementary in shape to specific hormone molecules. Only these cells will respond to the specific hormone.

*Explain the meaning of the terms first messenger and second messenger, with reference to adrenaline and cyclic AMP (cAMP).*

The first messenger is the hormone that transmits a message around the body, e.g. adrenaline. The second messenger, e.g. cAMP transmits a signal inside the cell.

*Describe the functions of the adrenal glands.*

The adrenal glands have two distinct regions- the cortex region and the medulla region. The adrenal medulla releases adrenaline, which:

- Relaxes smooth muscle in the bronchioles
- Increases the stroke volume of the heart
- Increases heart rate
- Causes general vasoconstriction- raising blood pressure
- Stimulates conversion of glycogen to glucose
- Dilates the pupils
- Increases mental awareness
- Inhibits the action of the gut
- Causes body hair to erect

The adrenal cortex releases cholesterol. Cholesterol is used to make steroid hormones in the body;

- Mineralocorticoids help control the concentrations of Na and K in the blood
- Glucocorticoids help control the metabolism of carbohydrates and proteins in the liver

Describe, with the aid of diagrams and photographs, the histology of the pancreas, and outline its role as an endocrine and exocrine gland.

The cells surrounding exocrine gland of the pancreas secretes digestive enzymes into the pancreatic duct, which then goes onto the small intestine. This is the majority of the pancreas.

The exocrine cells- the Islets of Langerhans- consist of  $\alpha$  and  $\beta$  cells. The  $\alpha$  cells manufacture and secrete glucagon, whereas the  $\beta$  cells manufacture and secrete insulin. They are involved in the regulation of blood glucose levels.

Explain how blood glucose concentration is regulated, with reference to insulin, glucagon and the liver.

If blood glucose concentration drops too low:

- Detected by  $\alpha$  cells
- The fall inhibits insulin production
- They secrete glucagon into the blood
- Bind to receptors on hepatocytes
  - Glycogenolysis- conversion of glycogen to glucose
  - More fatty acids are used in respiration
  - Gluconesgenesis- conversion of amino acids and fats to glucose
- More glucose in the bloodstream

If blood glucose concentration rises too high:

- Detected by  $\beta$  cells
- The rise inhibits glucagon production
- Secrete insulin into the blood
- Bind to receptors on hepatocytes, in the liver
- This activates adenyl cyclase in the cell
- Converts ATP to cAMP
- The cAMP activates a series of enzyme catalysed reactions within the cell;
  - More glucose channels are places in the cell surface membrane
  - More glucose enters the cell
  - Glycogenesis- glucose in the cell is converted to glycogen
  - More glucose is converted to fats
  - More glucose is used in respiration

Outline how insulin secretion is controlled, with reference to potassium channels and calcium channels in beta cells.

1. The cell membranes of the  $\beta$  cells contain  $\text{Ca}^{2+}$  and  $\text{K}^+$  ion channels.
2. The K ion channels are normally open, and the Ca ion channels are normally shut. K ions diffuse out of the cell, making the inside more negative.
3. When glucose concentrations outside of the cells are high, glucose molecules diffuse into the cell.
4. The glucose is quickly metabolised to ATP.
5. The extra ATP causes the K ion channels to close.
6. The K ions can no longer diffuse out, so the cells become less negative inside.
7. This change in potential difference opens the Ca ion channels.
8.  $\text{Ca}^{2+}$  ions enter the cell and cause the secretion of insulin by making the vesicles containing insulin move to the cell surface membrane and fuse with it, releasing insulin by exocytosis.

Compare and contrast the causes of Type 1 (insulin-dependent) and Type 2 (non-insulin-dependent) diabetes mellitus.

Type I Diabetes	Type II Diabetes
Auto-immune response in which body's $\beta$ cells are attacked and so insulin is not produced	Body can produce insulin but insulin receptors lose ability to detect and respond to insulin
Treatment-injections and blood glucose concentrations are closely monitored	Treatment-monitoring and controlling diet and may be supplemented by injections

## Communication, Homeostasis & Energy

*Discuss the use of insulin produced by genetically modified bacteria, and the potential use of stem cells, to treat diabetes mellitus.*

### **GM bacteria:**

- **Exact copy of human insulin.**
  - **Faster acting.**
  - **More effective.**
- **Less chance of developing tolerance.**
- **Less chance of rejection.**
- **Cheaper.**
- **More adaptable to demand.**
- **Less likely to have moral objections.**

### **Stem cells**

- **Could be used to produce new  $\beta$  cells.**
- **Scientists have found stem cells in the pancreas of adult mice.**
- **Undifferentiated.**

*Outline the hormonal and nervous mechanisms involved in the control of heart rate in humans.*

**Action potentials sent down the Accelerator Nerve to the heart; from the Cardiovascular centre of the medulla oblongata cause the heart to speed up. This may be because of:**

- **Movement of limbs detected by stretch receptors in muscles**
  - **Extra oxygen may be needed**
- **Drop in pH detected by chemoreceptors in the carotid arteries, the aorta and the brain (when we exercise we produce  $\text{CO}_2$ , this may react w/  $\text{H}_2\text{O}$  in the blood and reduce the pH).**
  - $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$
  - $\text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^-$

**Action potentials sent down the Vagus Nerve decreases the heart rate. This may be because of:**

- **Blood pressure rising**

**When the concentration of  $\text{CO}_2$  in the blood falls, it reduces the activity of the Accelerator Nerve, slowing the heart rate.**

**The presence of Adrenaline increases the heart rate to prepare the body for activity.**

Excretion

*Define the term excretion.*

**Excretion: The removal of metabolic wastes from the body**

*Explain the importance of removing metabolic wastes, including carbon dioxide and nitrogenous waste, from the body.*

**Carbon dioxide must be removed as, when it dissolves in water it produces hydrogen carbonate ions. These ions compete with oxygen for space on the haemoglobin. This causes a reduction in oxygen transport. Carbon dioxide can also combine directly with haemoglobin to form carbaminohaemoglobin, which has a low affinity for oxygen.**

**Can cause respiratory acidosis; breathing difficulties, headaches, drowsiness, restlessness etc caused by Carbon Dioxide dissolving in the blood plasma and combining with water to produce carbonic acid, which dissociates to release hydrogen ions. This lowers the pH.**

**Nitrogenous wastes must be removed because the amino group is highly toxic, but proteins and amino acids are very high in energy, so it would be wasteful to excrete them. In the ornithine cycle, the amine group is removed to form ammonia, which forms urea, water and a keto acid when added to oxygen and carbon dioxide. The keto acid can be used in respiration and the urea is transported to the kidneys for excretion.**

*Describe, with the aid of diagrams and photographs, the histology and gross structure of the liver.*

**The hepatic arteries supply the liver with oxygenated blood from the heart, so the liver has a good supply of oxygen for respiration, providing plenty of energy.**

**The hepatic vein takes deoxygenated blood away from the liver - which rejoins the vena cava and normal circulation will proceed.**

**Bile duct is where the substance bile is secreted, which is carried to the gall bladder where it is stored until it is required in the small intestines.**

**The hepatic portal vein brings blood from the small intestine, the blood is rich in the products of digestion, and this means that any harmful substances ingested will be broken down quickly by the liver cells (hepatocytes).**

**The liver is made up of lobules, which consists of cells called hepatocytes that are arranged in rows.**

**Each Lobule has a Central vein in the middle that connects to the hepatic vein.**

**Every single lobule has branches of the hepatic artery, hepatic portal vein and bile duct.**

**Hepatic artery and hepatic vein are connected to the central vein via capillaries called sinusoid.**

**The blood flows past every hepatocytes via the sinusoid, this ensures that the harmful stuff are broken down quickly. Also the blood provides the liver cells with oxygen.**

**The central veins from all the lobules join up to form the hepatic vein.**

*Describe the formation of urea in the liver, including an outline of the ornithine cycle.*

**Amino acid + Oxygen → Keto acid + Ammonia**

**Ammonia + Carbon dioxide → Urea + Water**



*Describe the roles of the liver in detoxification.*

**Catalase can convert 5 million molecules of  $\text{H}_2\text{O}_2$  into harmless substances in a minute.**

**Alcohol contains a lot of chemical potential energy which can be used in respiration. Ethanol**

**Dehydrogenase catalyses the detoxification of alcohol in hepatocytes.**

**Ethanol → Ethanal → Ethanoic Acid → Acetyl CoA**

**Ethanal and Ethanoic acid are dehydrogenated, and the hydrogen reduces NAD. If too many NADs are busy detoxifying alcohol, there will be too few NAD to break down fatty acids for use in respiration, so the fatty acids are converted back to lipids, which are stored in hepatocytes, making the liver enlarged- Fatty liver.**

*Describe, with the aid of diagrams and photographs, the histology and gross structure of the kidney.*

**Supplied with blood from the renal artery and is drained by the renal vein. The Kidney is surrounded by a tough capsule, the outer region is the cortex and the inner is the medulla. The central region is the pelvis, which leads into the ureter.**

*Describe, with the aid of diagrams and photographs, the detailed structure of a nephron and its associated blood vessels.*

**The nephron starts in the cortex, where the capillaries form a knot called the glomerulus, surrounded by the Bowman's capsule. Fluid from the blood is pushed into the capsule by ultrafiltration. The fluid leaves the capsule and flows through the nephron, starting with the proximal convoluted tubule, and then into the medulla for the loop of Henle, which is a hairpin counter current multiplier. Here the composition of the fluid is altered by Selective reabsorption. Substances are reabsorbed back into the tissue fluid and capillaries surrounding the nephron tubule. The fluid then passes into the Distal convoluted tubule, and then into the collecting duct as urine.**

*Describe and explain the production of urine, with reference to the processes of ultrafiltration and selective reabsorption.*

**Kidney**

**Ultrafiltration:-**

- **Blood flows into the glomerulus via the afferent arteriole which is at a higher pressure than the blood that leaves through the efferent arteriole due to the difference in size of the diameters of the lumen**
- **Blood enters the glomerulus and must pass through 3 distinct layers in order to enter the Bowman's capsule**
- **Endothelium of capillaries- contains gaps from which blood passes through as well as the substances dissolved in it**
- **Basement membrane- fine mesh of collagen fibres and glycoproteins that do not allow molecules with an RMM larger than 69000 to pass through (usually proteins)**
- **Epithelium of Bowman's capsule- contain finger like projections (podocytes) that fluid from the glomerulus can pass through into the Bowman's capsule**

**Selective Reabsorption: - (Proximal Convoluted Tubule)**

- **Na ions are actively transported out of the wall of the convoluted tubule and enter the surrounding tissue fluid**
- **Sodium is transported into the cell with Amino Acids or Glucose by facilitated diffusion.**
- **As the concentrations of Amino Acids or glucose rise, they diffuse into the tissue fluid; they may also be actively removed.**
- **They then diffuse into the blood and are carried away.**
- **The reabsorption of salts, glucose or amino acids reduces the water potential of the cell and increases the water potential in the tubule fluid, so water will enter the cells and be reabsorbed into the blood by osmosis.**
- **Larger molecules, such as proteins, will be reabsorbed by osmosis.**

**Structure of the cells of the proximal convoluted tubule**

**Microvilli - increase the surface area for re-absorption.**

**Co-transporter proteins - contained in the cell surface membrane that is in contact with the tubule fluid. Transports glucose or amino acids.**

**Na/K pumps - contained in the cell surface membrane opposite to the fluid tubule. Actively transports Na<sup>+</sup> and K<sup>+</sup> against their concentration gradient.**

**Many Mitochondria - provides the energy needed to drive the selective re-absorption process. Many mitochondria= a lot of ATP.**

*Explain, using water potential terminology, the control of the water content of the blood, with reference to the roles of the kidney, osmoreceptors in the hypothalamus and the posterior pituitary gland.*

**In the loop of Henle, salts are transferred from the ascending limb to the descending limb. This means that the tissue fluid in the medulla has a very negative water potential, as so water is lost by osmosis, particularly in the collection duct.**

1. **The water potential of the blood is monitored by osmoreceptors in the hypothalamus of the brain**
2. **When the water potential is very low, they shrink, and stimulate neurosecretory cells in the hypothalamus.**
3. **These produce and release anti diuretic hormone which flows down the axon to the posterior pituitary gland where it is stored until needed.**
4. **When the neurosecretory glands are stimulated they send action potentials down their axons and cause the release of ADH**
5. **It enters the capillaries running through the posterior pituitary gland. It is transported around the body and acts on the cells of the collecting ducts.**
6. **When it binds to the receptors, it causes a chain of enzyme catalysed reactions, the end result of which is the insertion of vesicles containing water-permeable channels (aquaporins) in the walls of the cells, so they are more permeable to water.**
7. **More water is reabsorbed, by osmosis, into the blood**
8. **Less urine, with a lower water potential is released.**
9. **Less ADH is released when the water potential rises again.**
10. **The ADH is slowly broken down and the collecting ducts receive less stimulus.**

## Communication, Homeostasis & Energy

*Outline the problems that arise from kidney failure and discuss the use of renal dialysis and transplants for the treatment of kidney failure.*

### Problems:

- **Unable to remove excess water & waste products from the body**
  - E.g. urea & excess salts
- **Inability to regulate urea and salt levels**
- **Death**

### Dialysis

Waste, excess fluids and salts are removed from the body by passing the blood over a dialysis membrane. This allows the exchange of substances between the blood and the dialysis fluid, which has the same concentration of substances as blood plasma. Substances diffuse from both sides to create the correct concentration of substances.

### Haemodialysis:

- **Blood is passed through a machine that contains an artificial dialysis membrane. Heparin is used to avoid clotting. Thrice weekly trips to hospital lasting several hours.**

### Peritoneal dialysis

- **The body's own abdominal membrane is used as a filter.**

### Transplant

#### Advantages

- **No dialysis**
- **Less limited diet**
- **Better physical feeling**
- **Better quality of life**
- **No longer 'chronically ill'**

#### Disadvantages

- **Need immunosuppressants for life of kidney**
- **Major surgery**
- **Risk of infection**
- **Need frequent checks in case of rejection**
- **Side effects of medication**

*Describe how urine samples can be used to test for pregnancy and detect misuse of anabolic steroids.*

### Pregnancy

- **A human embryo secretes human chorionic gonadotrophin (hCG) as soon as it is implanted on the uterine lining. The hormone can be detected in the mother's urine after as few as 6 days.**
- **Pregnancy tests contain monoclonal antibodies which are tagged with a blue bead and bind only to hCG.**
- **The hCG-antibody complex moves along the strip until it sticks to a band of immobilised antibodies, so forms a blue line**
- **One blue line is a control, so two means pregnancy**

### Anabolic Steroids

- **Urine samples are tested using gas chromatography**
  1. **The sample is vaporised in the presence of a gaseous solvent**
  2. **It is passed down a long tube lined with an absorbing agent.**
  3. **Each substance dissolves differently in the gas and stays there for a unique, specific time- the retention time**
  4. **Eventually, the substance leaves the gas and is absorbed by the lining**
  5. **It is then analysed to make a chromatogram**
  6. **Standard samples of drugs and urine samples are run so drugs can be identified and quantified in the chromatogram.**

## Communication, Homeostasis & Energy

### Photosynthesis

*Define the terms autotroph and heterotroph.*

**Autotroph-organisms that use light or chemical energy and inorganic molecules to synthesise complex organic molecules.**

**Heterotroph- organisms that ingest and digest complex organic molecules releasing the chemical potential energy stored in them.**

*State that **light energy is used during photosynthesis to produce complex organic molecules.***

*Explain how respiration in plants and animals depends upon the products of photosynthesis.*

**Photoautotrophs and heterotrophs can release the chemical potential energy in complex organic molecules which were made during photosynthesis- respiration. They use oxygen, which was first released into the atmosphere as a product of photosynthesis, for aerobic respiration.**

*State that **in plants photosynthesis is a two-stage process taking place in chloroplasts.***

*Explain, with the aid of diagrams and electron micrographs, how the structure of chloroplasts enables them to carry out their functions.*

**The inner membrane contains transport proteins which control the entry and exit of substances between the cytoplasm and then stroma.**

**The grana provide a surface area for photosynthetic pigments, electron carriers, and ATP synthase, all involved in the Light-dependent reaction.**

**The photosynthetic pigments are arranged into photosystems to allow for maximum absorption of light energy.**

**Proteins embedded in the grana hold the photosystems in place**

**The stroma contains enzymes needed to catalyse the reactions in the light-independent stage.**

**The stroma surround the grana, so the products of the light-dependent reaction, needed in the light-independent reaction, can readily pass into the stroma.**

**Chloroplasts can make some of the proteins they need for photosynthesis using the genetic instructions on their chloroplast DNA, and the chloroplast ribosomes to assemble the proteins.**

*Define the term photosynthetic pigment.*

**Molecules that absorb light energy. Each pigment absorbs a range of wavelengths in the visible region and has its own distinct peak of absorption. Other wavelengths are reflected.**

*Explain the importance of photosynthetic pigments in photosynthesis.*

**They are substances that absorb certain wavelengths of light and reflect others. They appear to us the colour of the wavelength they reflect. There are many different pigments that act together, to capture as much light energy as possible. They are in thylakoid membranes, arranged in funnel shaped structures called photosystems, held in place by proteins**

*State that **the light-dependent stage takes place in thylakoid membranes and that the light-independent stage takes place in the stroma.***

*Outline how light energy is converted to chemical energy (ATP and reduced NADP) in the light-dependent stage (reference should be made to cyclic and non-cyclic photophosphorylation)*

When a photon hits a chlorophyll molecule the energy of the photon is transferred to two electrons and they become excited. These electrons are captured by electron acceptors and passed down a series of electron carriers embedded in the thylakoid membranes. Energy is released as electrons pass down the chain of electron carriers. This pumps protons across the thylakoid membrane into the thylakoid space where they accumulate. A proton gradient is formed across the thylakoid membrane and the protons flow down their gradient, through proteins associated with ATP synthase enzymes. This flow of protons is chemiosmosis, and it produces a force which joins ADP to  $P_i$  to produce ATP. The kinetic energy from the proton flow is converted to chemical energy in the ATP molecules, which is used in the light-independent stage of photosynthesis. The making of ATP using light energy is called photophosphorylation, of which there are two types- cyclic and non cyclic.

**Cyclic photophosphorylation:**

- Uses only photosystem I ( $P_{700}$ )
- The excited electrons pass to an electron acceptor and back to the chlorophyll molecule from which they were lost
- No photolysis of water
- No generation of reduced NADP
- Small amounts of ATP formed
  - May be used in light-independent stage
  - May be used in guard cells, which contain only PS1, to bring in  $K^+$  ions, so water will follow by osmosis, causing the guard cells to swell and open the stomata.

**Non-cyclic photophosphorylation**

- Uses PS1 ( $P_{700}$ ), and PSII ( $P_{670}$ ).
1. Light strikes PSII, exciting a pair of electrons that leave the chlorophyll molecule from the primary pigment reaction centre
  2. The electrons pass along a chain of electron carriers and the energy released is used to synthesise ATP
  3. Light has also struck PSI, and a pair of electrons have also been lost
  4. These electrons, along with protons (from the photolysis of water as PSII), join with NADP, which becomes reduced NADP
  5. The electrons from PSI replace those lost at PSII
  6. Electrons from photolysed water replace those lost by oxidised chlorophyll at PSI
  7. Protons from photolysed water take part in chemiosmosis to make ATP and are then captured by NADP in the stroma. They will be used in the light-independent stage.

*Explain the role of water in the light-dependent stage.*

**Water is a source of:**

- Hydrogen ions to be used in chemiosmosis to produce ATP.
- Electrons to replace those lost by oxidised chlorophyll.
- The oxygen produced comes from water.

*Outline how the products of the light-dependent stage are used in the light-independent stage (Calvin cycle) to produce triose phosphate (TP) (reference should be made to ribulose biphosphate (RuBP), ribulose biphosphate carboxylase (rubisco) and glycerate 3-phosphate (GP)).*

1.  $CO_2$  diffuses into the leaf through the open stomata
2.  $CO_2$  combines with 5c Ribulose biphosphate, catalysed by Rubisco
3. This forms two molecules of glycerate 3-phosphate
4. GP is reduced (using Reduced NADP from the light-dependent stage) and phosphorylated (using ATP from the light dependent stage) to form Triose Phosphate
5. 5/6 molecules of TP are recycled by phosphorylation (using ATP from the light dependent stage) to three molecules of RuBP.

*Explain the role of carbon dioxide in the light-independent stage (Calvin cycle).*

**Carbon dioxide is the source of carbon and oxygen for the production of all large organic molecules.**

*State that TP can be used to make carbohydrates, lipids and amino acids.*

*State that most TP is recycled to RuBP.*

## Communication, Homeostasis & Energy

*Describe the effect on the rate of photosynthesis, and on levels of GP, RuBP and TP, of changing carbon dioxide concentration, light intensity and temperature.*

### **Light intensity-Affects Light-dependent directly.**

- **Lots of light**
  - **More excitation of electrons**
  - **So, more photophosphorylation**
  - **More ATP and reduced NADP produced**
  - **More GP reduced and phosphorylated to TP**
  - **More TP phosphorylated to RuBP**
- **Little light**
  - **GP cannot be changed to TP**
  - **Levels of TP will fall**
  - **GP will accumulate**
  - **Less RuBP**
  - **Less CO<sub>2</sub> fixed**
  - **Less GP formed**

### **Carbon Dioxide Concentration**

- **Lots of CO<sub>2</sub>**
  - **More CO<sub>2</sub> fixation**
  - **More GP**
  - **More TP**
  - **More regeneration of RUBP**
  - **However, open stomata may lead to increased transpiration, so the plant may wilt if the water loss exceeds water uptake. This leads to a stress response, and following the release of abscisic acid, the stomata close, reducing the CO<sub>2</sub> uptake, and therefore the rate of photosynthesis.**
- **Little CO<sub>2</sub>- affects light-independent, not dependent.**
  - **RuBP will accumulate**
  - **Less GP**
  - **Less TP**

### **Temperature**

- **High temperature**
  - **Little effect on light dependent- not dependent on enzymes except for photolysis of water.**
  - **Light-independent is a series of biochemical steps, each catalysed by a specific enzyme.**
  - **Above 25°C, photorespiration exceed photosynthesis, as the oxygenase activity of Rubisco increases more than the carboxylase activity.**
  - **ATP and reduced NADP from the light-dependent reaction are dissipated and wasted**
  - **Reduces the overall rate of photosynthesis**
  - **High temps may also denature proteins**
  - **High temp= high water loss**
    - **This may lead to stomata closure, and the reduction of photosynthesis due to less CO<sub>2</sub>**

*Discuss limiting factors in photosynthesis with reference to carbon dioxide concentration, light intensity and temperature.*

**Carbon dioxide concentrations**

- Growers can increase the amounts of CO<sub>2</sub> in their greenhouses by burning methane or oil-fired heaters.
- This will increase the rate of photosynthesis, providing that nothing else is limiting the process

**Light intensity**

- Light causes
  - Stomata to open
    - CO<sub>2</sub> can diffuse in
  - Trapped by Chlorophyll
    - Excites electrons
  - Splits water molecules to produce protons
- The electrons and protons are used in photophosphorylation, which produced ATP to fix CO<sub>2</sub>

**Temperature**

- The calvin cycle is very much affected by temperature as it is enzyme-catalysed.
  - At too higher temperatures, the enzymes work less effectively, and O<sub>2</sub> successfully competes for the active site of rubisco, preventing it from accepting CO<sub>2</sub>
- Also, at too higher temperatures, more water is lost from the stomata, leading to a stress response where the stomata close, limiting the availability of CO<sub>2</sub>

*Describe how to investigate experimentally the factors that affect the rate of photosynthesis.*

**Could measure:**

- Volume of O<sub>2</sub> produced
- Rate of uptake of CO<sub>2</sub>
- Rate of increase in dry mass of plants

**Light-Intensity:**

- using a photosynthometer/audus microburette is set up, air-tight ensuring no air bubbles are present
- gas given off by the plant over time collects in the flared end of the capillary tube
- the syringe can be used to move the air bubble into the part of the capillary tube against the scale
- distance moved by the air bubble at each light intensity can be used to work out the volume and essentially the rate (by dividing the volume by the time left)
- experiment should be repeated at the same light intensity and average values used
- apparatus should be left to acclimatise for 5 minutes
- all other factors should be kept constant for e.g. a water bath to keep the temperature constant

**Disks:-**

- cut disks from leaves
- place 5/6 in a syringe and half fill the syringe with dilute sodium hydrogencarbonate solution
- hold syringe upright placing finger over the end and gently pulling on the plunger. (air is extracted from the spongy mesophyll in the leaf disks) As density of leaf disks increases, they sink to the bottom
- after all disks have sunk, transfer contents of syringe into a beaker. Illuminate using bright light and time how long it takes for one leaf disk to float to the top of the surface.
- repeat at same light intensity
- repeat at different light intensities
- record results in a table.

The leaves rise as they become less dense due to them photosynthesising and releasing O<sub>2</sub>.

## Communication, Homeostasis & Energy

### Respiration

*Outline why plants, animals and microorganisms need to respire, with reference to active transport and metabolic reactions.*

- **Active transport-** much of an organism's energy is used for this
- **Secretion-** large molecules made in some cells are released by exocytosis
- **Endocytosis-** bulk movement of larger molecules into the cell
- **Metabolic reactions-** synthesis of large molecules from smaller ones- proteins from Amino Acids, steroids from cholesterol, cellulose from  $\beta$ -glucose. These are all anabolic
- **Replication of DNA and synthesis of organelles before a cell divides**
- **Movement**
  - Bacterial flagella
  - Eukaryotic cilia and undulipodia
  - Muscle contractions
- **Activation of chemicals e.g. phosphorylation of glucose**

*Describe, with the aid of diagrams, the structure of ATP.*

**An Adenosine group attached to a Ribose sugar and three phosphate molecules**

*State that ATP provides the immediate source of energy for biological processes.*

*Explain the importance of coenzymes in respiration, with reference to NAD and coenzyme A.*

**Coenzymes aid in the oxidation and reduction of reactions.**

**NAD combines with the Hydrogen atoms and takes them to the mitochondrial membrane where they can be later split into hydrogen ions and electrons for the electron transport chain. It is used in glycolysis, the Krebs cycle and anaerobic respiration.**

**Coenzyme A carries acetate groups either from the link reaction, or that have been made from fatty acids or amino acids onto the Krebs cycle.**

*State that glycolysis takes place in the cytoplasm.*

*Outline the process of glycolysis beginning with the phosphorylation of glucose to hexose biphosphate, splitting of hexose biphosphate into two triose phosphate molecules and further oxidation to pyruvate, producing a small yield of ATP and reduced NAD.*

1. An ATP molecule is hydrolysed and the phosphate attached to the glucose molecule at C-6
2. Glucose 6 Phosphate is turned into fructose 6 phosphate
3. Another ATP is hydrolysed, and the phosphate attached to C-1
4. The hexose sugar is activated by the energy release from the hydrolysed ATP molecules. It now cannot leave the cell and is known as Hexose-1,6-biphosphate
5. It is split into two molecules of Triose phosphate
6. Two hydrogen atoms are removed from each Triose Phosphate, which involved dehydrogenase enzymes.
7. NAD combines with the Hydrogen atoms to form reduce NAD
8. Two molecules of ATP are formed- substrate level phosphorylation
9. Four enzyme-catalysed reactions convert each triose phosphate molecule into a molecule of pyruvate.
10. Two more molecules of ATP are formed, so there is a net gain of two ATP.

*State that, during aerobic respiration in animals, pyruvate is actively transported into mitochondria.*

*Explain, with the aid of diagrams and electron micrographs, how the structure of mitochondria enables them to carry out their functions.*

**The Matrix:**

1. Enzymes that catalyse the stages of aerobic respiration (highly-concentrated mixture of hundreds of enzymes).
2. Molecules of coenzyme NAD.
3. Oxaloacetate - the 4-carbon compound that accepts acetate from the link reaction.
4. Mitochondrial DNA, some of which codes for mitochondrial enzymes and other proteins.
5. Mitochondrial ribosomes where the proteins are assembled.

**The Inner Membrane:**

6. different lipid composition than the outer layer (Impermeable to most small ions, including protons (or else aerobic respiration would stop if damaged))
7. Is folded into many cristae to give a large surface area.
8. Has embedded on it many electron carriers and ATP synthase enzymes.
9. high protein-to-phospholipid ratio.

**The Outer Membrane:**

10. It contains proteins, some of which form channels or carriers that allow the passage of molecules such as pyruvate.

**Electron Transport Chain:**

11. Contain 100s of oxidoreductase enzymes - involved in oxidation and reduction reactions.
12. Some of the electrons carrier also has a co-enzyme that pumps (using energy released from the passage of electrons) protons from the matrix to the intermembrane space.

*State that the link reaction takes place in the mitochondrial matrix.*

*Outline the link reaction, with reference to decarboxylation of pyruvate to acetate and the reduction of NAD.*

**Pyruvate dehydrogenase removes hydrogen atoms from pyruvate**

**Pyruvate decarboxylase removes a carboxyl group, which eventually becomes CO<sub>2</sub>, from pyruvate**

**NAD accepts the hydrogen atoms**

**CoA accepts the acetate to become Acetyl CoA, which then travels to the Krebs Cycle**

*Explain that acetate is combined with coenzyme A to be carried to the next stage.*

*State that the Krebs cycle takes place in the mitochondrial matrix.*

*Outline the Krebs cycle; with reference to the formation of citrate from acetate and oxaloacetate and the reconversion of citrate to oxaloacetate (names of intermediate compounds are not required).*

1. Acetate is offloaded from CoA and joins with Oxaloacetate to form citrate.
2. Citrate is decarboxylated and dehydrogenated to form a 5C compound.
  - a. The hydrogen atoms are accepted by NAD, which take them to the Electron Transport Chain
  - b. The Carboxyl group becomes CO<sub>2</sub>.
3. The 5C compound is decarboxylated and dehydrogenated to form a 4C compound.
4. The 4C compound is changed into another 4C compound, and a molecule of ATP is phosphorylated.
5. The second 4C compound is changed into a third 4C compound and a pair of hydrogen atoms are removed, reducing FAD.
6. The third 4C compound is further dehydrogenated to regenerate oxaloacetate.

*Explain that during the Krebs cycle, decarboxylation and dehydrogenation occur, NAD and FAD are reduced and substrate level phosphorylation occurs.*

*Outline the process of oxidative phosphorylation, with reference to the roles of electron carriers, oxygen and the mitochondrial cristae.*

- The final stage of respiration involved electron carriers embedded in the mitochondrial membrane
- The membranes are folded into cristae, which increases the surface area for electron carriers and ATP synthase enzymes.
- Oxidative phosphorylation is the formation of ATP by the addition of an inorganic phosphate to ADP in the presence of oxygen.
- As protons flow through ATPsynthase, they drive the rotation part of the enzyme and join ADP to P<sub>i</sub> to make ATP
- The electrons are passed from the final electron carrier to molecular oxygen, which is the final electron acceptor.
- Hydrogen ions also join, so oxygen is reduced to water

*Outline the process of chemiosmosis, with reference to the electron transport chain, proton gradients and ATPsynthase.*

1. Reduced NAD and FAD donate hydrogens, which are split into protons and electrons, to the electron carriers.
2. The protons are pumped across the inner mitochondrial membrane using energy released from the passing of electrons down the electron transport chain.
3. This builds up a proton gradient, which is also a pH gradient, and an electrochemical gradient
4. Thus, potential energy builds up
5. The hydrogen ions cannot diffuse through the lipid part of the inner membrane, but can diffuse through ATP synthase- an ion channel in the membrane. The flow of hydrogen ions is chemiosmosis.

*State that oxygen is the final electron acceptor in aerobic respiration.*

*Evaluate the experimental evidence for the theory of chemiosmosis.*

- **Researchers isolated mitochondria and treated them by placing them in a solution with a very low water potential.**
- **This meant that the outer membrane ruptured, releasing the contents of the intermembrane space.**
- **If they further treated these mitoblasts with a strong detergent, they could release the contents of the matrix.**
- **This allowed them to identify the enzymes in the mitochondria, and to work out that the link reaction and Krebs cycle occurred in the matrix, whilst the enzymes for the electron transfer chain were embedded in the mitochondrial membrane.**
- **Electron transfer in mitoblasts did not produce ATP, so they concluded that the intermembrane space was also involved**
- **ATP was also not made if the mushroom-shaped parts of the stalked particles were removed from the inner membrane of the intact mitochondria.**
- **ATP was also not made in the presence of oligomycin, an antibiotic which is now known to block the flow of protons through the ion channel part of ATP synthase.**
- **In the intact mitochondria**
  - **The potential difference across the membrane was -200mV, being more negative on the matrix side than on the intermembrane space side.**
  - **The pH of the intermembrane space was lower than that of the matrix.**

*Explain why the theoretical maximum yield of ATP per molecule of glucose is rarely, if ever, achieved in aerobic respiration.*

**The maximum yield for ATP is rarely reached as:**

- **Some hydrogens leak across the mitochondrial membrane**
  - **Less protons to generate the proton motive force**
- **Some ATP is used to actively transport pyruvate into the mitochondria**
- **Some ATP is used to bring Hydrogen from reduced NAD made during glycolysis, into the cytoplasm, into the mitochondria.**

*Explain why anaerobic respiration produces a much lower yield of ATP than aerobic respiration.*

**Because only glycolysis occurs. The electron transport chain cannot occur, as there is no oxygen to act as the final electron acceptor. This means that the Krebs cycle stops, as there are no NAD- they are all reduced. This prevents the link reaction from occurring. Anaerobic respiration takes the pyruvate, and by reducing it, frees up the NAD, so glycolysis can continue, producing two molecules of ATP per glucose molecule respired.**

*Compare and contrast anaerobic respiration in mammals and in yeast.*

#### **Mammals**

- 1. Pyruvate combines with a hydrogen which is provided by reduced NAD, this forms lactate and oxidised NAD**
- 2. it involves the enzyme lactate dehydrogenase and is referred to as the lactate pathway**
- 3. Oxidised NAD can go back to accepting hydrogen from glucose, and so Glycolysis can continue**

#### **Yeast**

- 1. Pyruvate is converted to ethanal which involves decarboxylation as CO<sub>2</sub> is released.**
- 2. Ethanal combines with hydrogen from reduced NAD to form ethanol, catalysed by alcohol dehydrogenase**
- 3. oxidised NAD can continue to go back and accept hydrogen from glucose, so glycolysis can continue**

*Define the term respiratory substrate.*

**An organic substance that can be used for respiration**

*Explain the difference in relative energy values of carbohydrate, lipid and protein respiratory substrates.*

**The higher the number of hydrogen atoms per mole, the higher the relative energy value, as more NAD molecules can be reduced & used in the Electron Transport Chain. Lipids have the most, followed by proteins, and then carbohydrates.**