Edexcel International A Level (IAL) Biology

Your notes

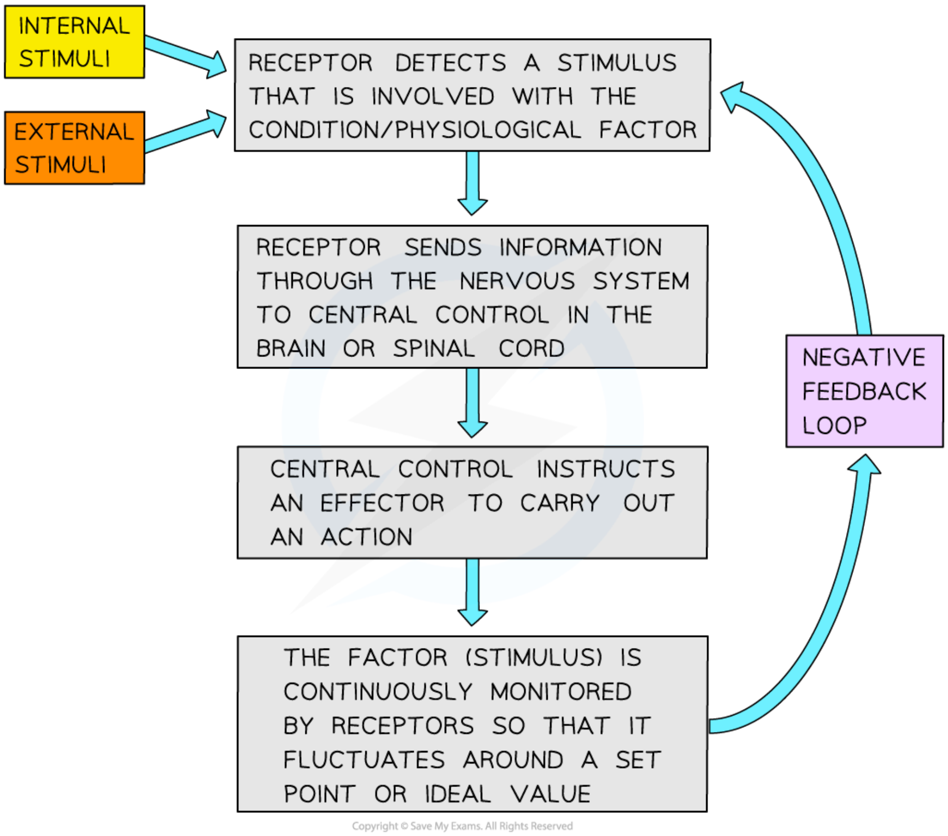
The Internal Environment

Contents

Negative & Positive Feedback

Negative feedback

- The majority of homeostatic control mechanisms in organisms use **negative feedback** to maintain **homeostatic balance,** i.e. to keep certain **physiological factors**, such as internal temperature or blood glucose concentration, **within certain limits**
- Negative feedback control loops involve
  - A **receptor** detects a **stimulus** that is involved with a **physiological factor**
    - E.g. a change in temperature or blood glucose level
  - A **coordination system** transfers information between different parts of the body
    - This could be the nervous system or the hormonal system
  - An **effector** carries out a **response**
    - Effectors are **muscles** or **glands**
- The outcome of a negative feedback loop is
  - If there is an **increase** in the factor the body responds to make the factor **decrease**
  - If there is a **decrease** in the factor the body responds to make the factor **increase**
- Negative feedback systems work by **reversing a change** in the body to bring it back within **normal limits,** e.g.
  - If body temperature rises a negative feedback system will act to lower body temperature, bringing it back to normal
  - If blood glucose levels drop a negative feedback system will act to raise blood glucose, bringing it back to normal



Negative feedback loops involve the monitoring of physiological factors and act to reverse any changes, keeping the factors within normal limits. Information can be transferred via nerve signals, as shown here, or by hormonal signals.

Positive feedback

- In **positive** feedback loops the original stimulus produces a response that causes the factor to **deviate even more** from the normal range
    - They **enhance** the effect of the original stimulus
- An example of this is the **dilation of the cervix** during labour
    - The cervix stretches as baby pushes against it
    - Stretch receptors in the cervix are stimulated and send impulses to the brain
    - The pituitary gland is stimulated to release oxytocin which increases the intensity of uterine contractions
    - This pushes the baby further down the birth canal and stretches the cervix even further
- Positive feedback loops are useful to **quickly activate** a process, e.g. blood clotting to close up a wound
    - When the body is injured, **platelets become activated**

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    - They **release chemicals** which will **activate more platelets**, which in turn, will release chemicals that will activate even more platelets etc.
    - This ensures that the **wound is quickly closed up** by a blood clot before too much blood is lost or too many pathogens enter the bloodstream
    - The body will **revert to negative feedback mechanisms** once the blood clot has formed
- Positive feedback may also kick in when **homeostatic mechanisms break down**
    - E.g. during prolonged exposure to extreme cold hypothermia can occur; body temperature drops, resulting in decreased metabolism which in turn causes body temperature to drop further
- Since these mechanisms do not maintain a constant internal environment, they are **not involved in homeostasis**

Negative Feedback in Maintaining Conditions

The control of negative feedback

- Negative feedback loops help maintain a normal range or balance within an organism
    - They **reduce** the initial effect of the stimulus
- **Receptors** detect any deviations in a factor from the normal range; this results in a **corrective mechanism** to return the factor back to its normal range
- In negative feedback loop there are usually **two corrective mechanisms**
    - One for when the factor becomes **too low**
    - One for when the factor becomes **too high**
- The corrective mechanisms may involve the **nervous system** or the **endocrine system**
- The **magnitude** of the correction required to bring a factor back within its normal range is monitored and **regulated** by negative feedback
    - As the factor gets closer to its normal value the level of correction reduces

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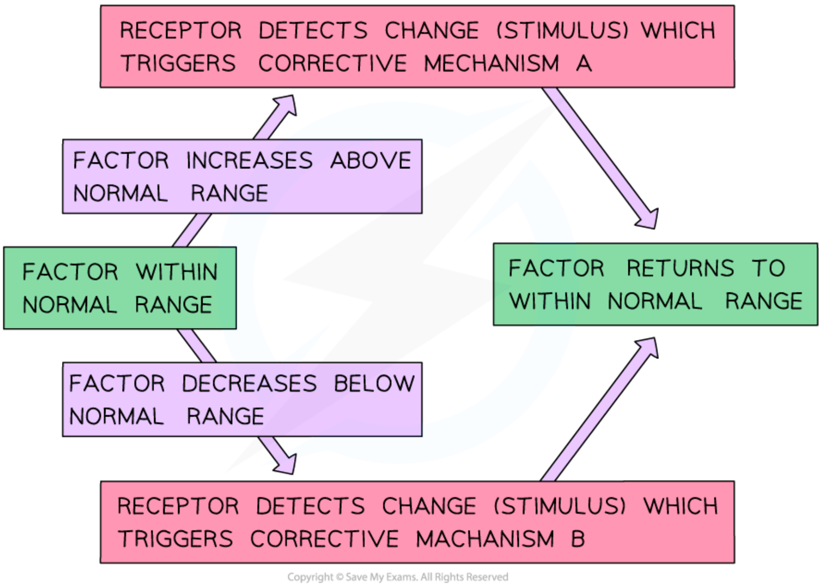

Two corrective mechanisms are involved in the negative feedback loop

Homeostasis

- In order to function properly and efficiently organisms have different control systems that ensure their **internal conditions are kept relatively constant**
- **Physiological control systems** maintain the internal environment within restricted limits through a process known as **homeostasis**
- This keeps the internal environment of the body **fluctuating around a specific normal level**
  - This is known as a **state of dynamic equilibrium**
- **Sensory cells** known as **receptors** can detect information about the conditions inside and outside the body

The importance of homeostasis

Temperature

- Homeostasis is critically important for organisms as it ensures the maintenance of **optimal conditions for enzyme action and cell function**
  - For example, an increase in body temperature above 40 °C would cause enzymes to **denature**
    - This is due to an **increase in kinetic energy** which would result in the **breakage of hydrogen bonds** holding the enzyme in a specific 3D shape
    - The **active site will change shape** and will no longer be **complementary** to the substrate molecule
    - An enzyme-substrate complex cannot form and the enzyme **cannot catalyse** that reaction anymore, leading to **less efficient** metabolic reactions

Blood glucose

- Cells also need a **constant supply of energy** in the form of ATP to work efficiently
- **Glucose** is respired to supply this ATP, meaning that the body needs to carefully monitor and control **blood glucose concentrations**
  - Cells in the **pancreas** monitor blood glucose concentrations

Water

- **Water** is another essential requirement for cells to function optimally; it makes up the cell cytoplasm and it takes part in metabolic reactions
- It is therefore crucial for the **amount of water in the blood** to remain constant
  - Water is lost during **excretion of waste products,** e.g. urine, and in **sweat**

- The **kidneys** are responsible for regulating the amount of water in the blood

Control mechanisms for maintaining body temperature

- Maintenance of a constant internal body temperature is known as **thermoregulation**
- This process involves both **cooling** and **warming mechanisms** depending on whether there is an increase or decrease in body temperature

Cooling mechanisms

- **Vasodilation of the blood vessels that supply skin capillaries**
    - Heat exchange during both warming and cooling occurs at the body's surface as this is where the blood comes into close proximity to the environment
        - The warmer the environment, the less heat is lost from the blood at the body's surface
    - One way to **increase heat loss** is to **supply the capillaries in the skin with a greater volume of blood**, which then **loses heat to the environment via radiation**
        - Arterioles have muscles in their walls that can relax or contract to allow more or less blood to flow through them
        - During **vasodilation** these **muscles relax**, causing the **arterioles near the skin to dilate** and allowing **more blood to flow through skin capillaries**
        - This is why pale-skinned people go red when they are hot
- **Sweating**
    - Sweat is secreted by **sweat glands**
    - This cools the skin by **evaporation;** heat energy from the body converts liquid water into water vapour
    - Sweating is less effective as a cooling mechanism in humid environments; sweat evaporates more slowly due to a reduced concentration gradient between the sweat and the surrounding air
- **Flattening of hairs**
    - The hair **erector pili muscles** in the skin **relax**, causing hairs to lie flat
        - These muscles can be described as **effectors**, as they respond to a change in body temperature
    - This **stops them from forming an insulating layer** of trapped air and allows air to circulate over skin; heat can therefore leave by radiation

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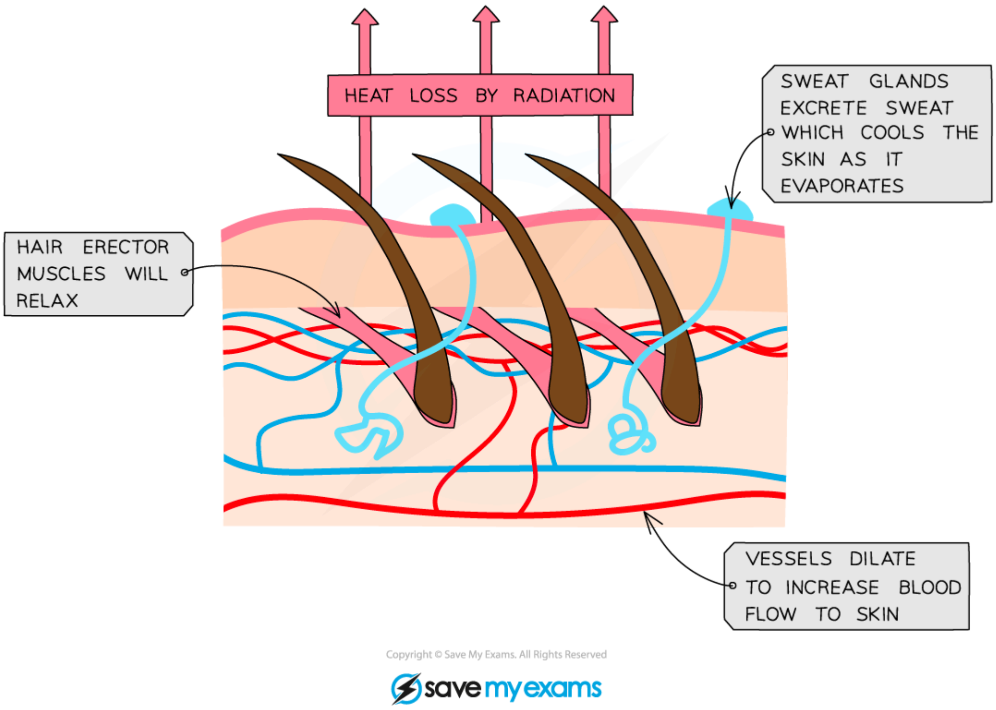

Changes in the skin help to increase heat loss when body temperature rises

Warming mechanisms

- **Vasoconstriction of blood vessels that supply skin capillaries**
  - One way to decrease heat loss is to **supply the capillaries in the skin with a smaller volume of blood**, minimising the loss of heat to the environment by **radiation**
  - During **vasoconstriction** the muscles in the arteriole walls contract, causing the **arterioles** near the skin to **constrict** and allowing **less blood to flow through skin capillaries**
  - Instead, the blood is diverted through **shunt vessels**, which are deeper in the skin and therefore do not lose heat to the environment
  - Vasoconstriction is not, strictly speaking, a 'warming' mechanism as it does not raise the temperature of the blood but instead **reduces heat loss from the blood** as it flows through the skin
- **Boosting metabolic rate**
  - Most of the metabolic reactions in the body are exothermic and this provides warmth to the body
  - In cold environments the **hormone thyroxine,** released from the thyroid gland, increases the basal metabolic rate (BMR), increasing heat production in the body
  - **Adrenaline** may also be released to speed up the metabolic rate and release more heat

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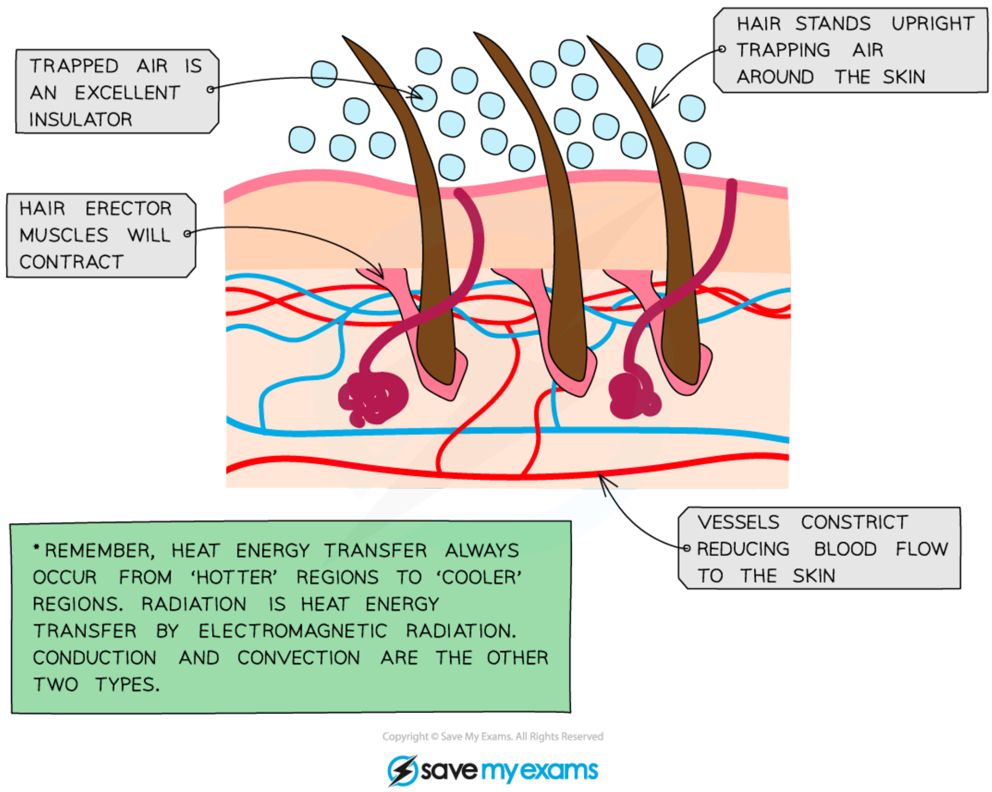
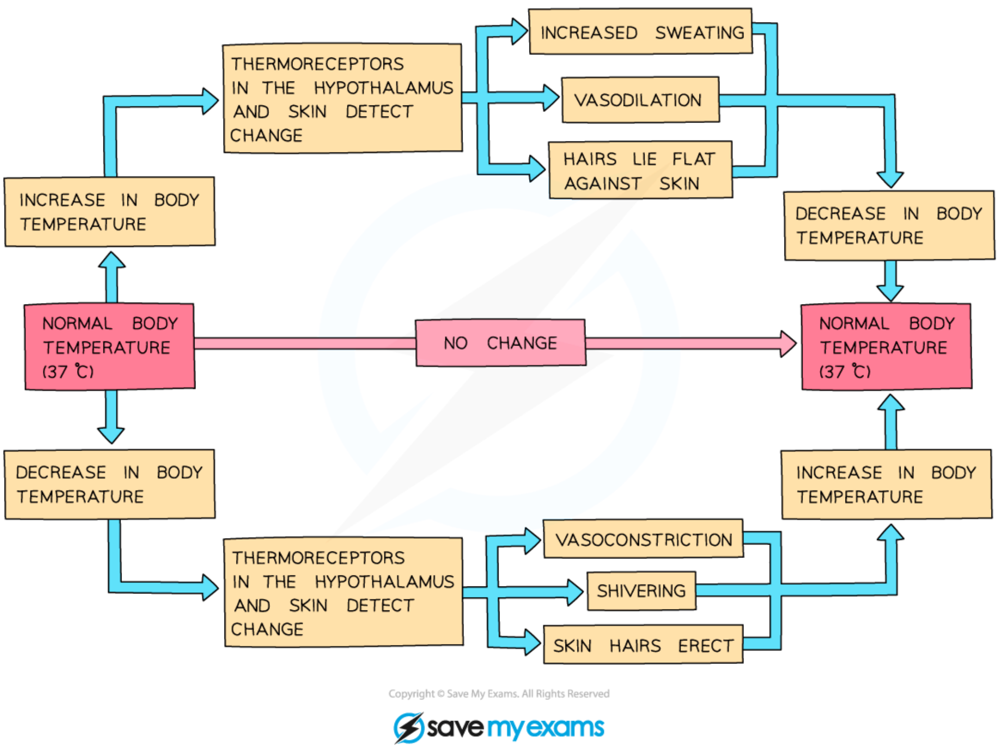
- **Shivering**
  - This is a **reflex action** in response to a **decrease in core body temperature**
    - This means it is a nervous mechanism, not a hormonal one
  - In this case muscles are the effectors and they **contract in a rapid and regular manner**
  - The metabolic reactions required to power this shivering **generate sufficient heat** to warm the blood and raise the core body temperature
- **Erection of hairs**
  - The hair **erector pili muscles** in the skin **contract**, causing hairs to stand on end
  - This **forms an insulating layer** over the skin's surface by trapping air between the hairs and stops heat from being lost by radiation
  - Note that, like vasoconstriction, this is a heat retention mechanism rather than a warming mechanism
- **Less sweating**
  - The **sweat glands** will **secrete less sweat** when it is cold
  - This will **reduce** the amount of heat lost through the **evaporation** of sweat
  - This is a heat retention mechanism rather than a warming mechanism



Changes in the skin reduce heat loss when the body cools

The role of the hypothalamus in thermoregulation

- The hypothalamus is an area of the brain that is responsible for controlling many functions in the body, including
  - Hormones
  - Sleep
  - Growth
  - Body temperature
  - Blood pressure
- Mammals detect external temperatures via **thermoreceptors** found in the skin and mucous membranes
  - There are receptors for both heat and cold
  - These communicate with the **hypothalamus** along **sensory neurons**
  - The hypothalamus will send impulses along **motor neurons to effectors** to bring about a **physiological response** to changing external temperatures
- The hypothalamus also helps to regulate body temperature by **monitoring the temperature of the blood flowing through it** and **initiating homeostatic responses** when it gets too high or too low



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The regulation of body temperature involves communication between thermoreceptors, the hypothalamus and effectors to respond to change

Your notes

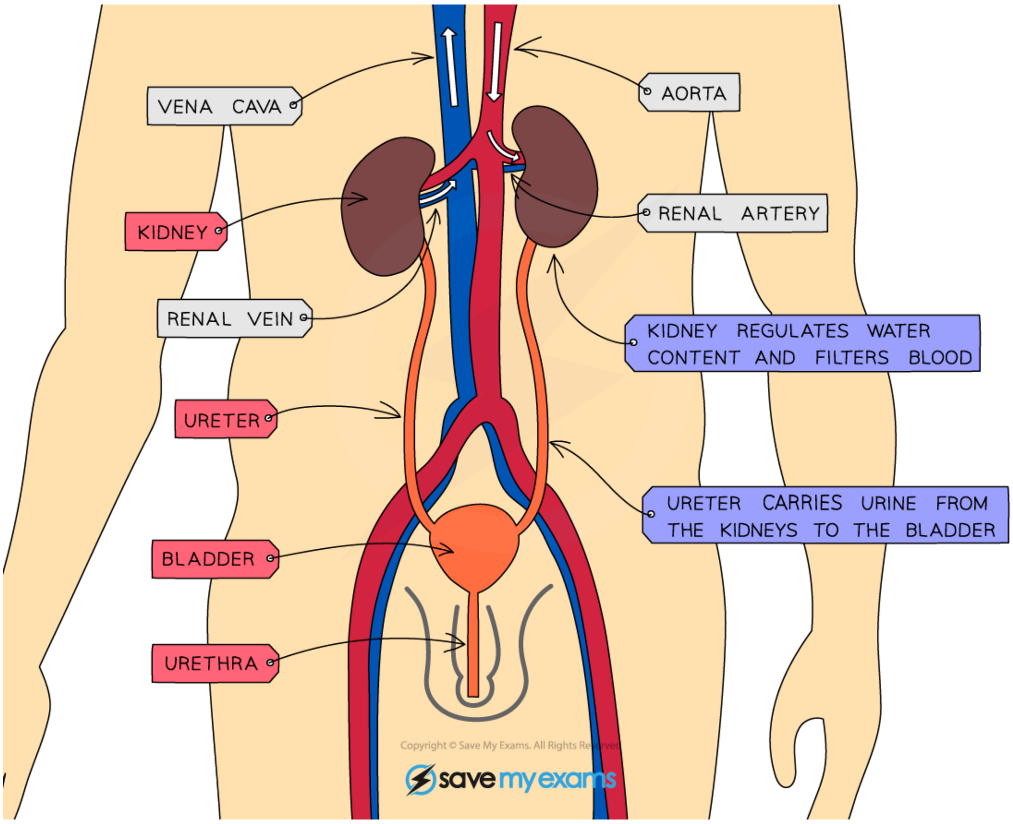
Examiner Tips and Tricks

Note that vasoconstriction and vasodilation occur in the **arterioles that supply the skin capillaries**, not the skin capillaries themselves; capillary walls are only one cell thick and do not contain any muscle fibres capable of contracting or relaxing.

Be careful with your use of language; muscles **contract**, arterioles **constrict**.

The Kidney: Structure

- Humans have **two** kidneys
- The kidneys are responsible for carrying out two very important functions
  - As an **osmoregulatory organ** they **regulate the water content of the blood**
    - This is essential for maintaining blood pressure and to prevent cell damage occurring due to osmosis
  - As an **excretory organ** they enable the **excretion of the toxic waste products of metabolism,** such as **urea,** and substances in excess of requirements, such as **salts**



The kidneys are located above the bladder. They are supplied with blood by the renal artery and connect to the bladder via the ureter.

The Function of the Kidneys & their Associated Structures Table

Structure	Function
Renal artery	Carries oxygenated blood (containing urea and salts) to kidneys
Renal vein	Carries deoxygenated blood (that has had urea and excess salts removed) away from kidneys
Kidney	Regulates water content of blood and filters blood
Ureter	Carries urine from kidneys to bladder
Bladder	Stores urine (temporarily)
Urethra	Releases urine outside of the body

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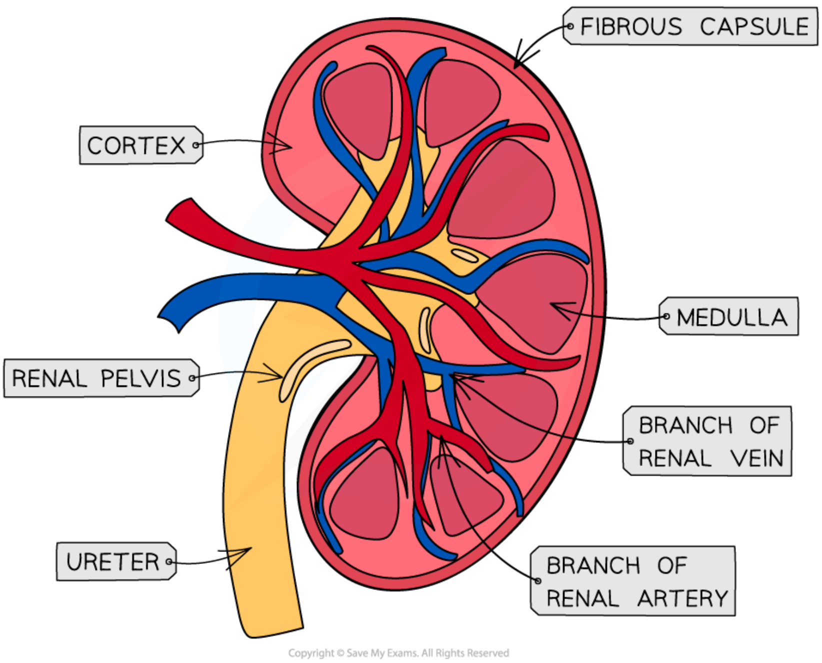
The gross structure of the kidney

- The kidney itself is surrounded by an outer layer known as the **fibrous capsule**
- Beneath the fibrous capsule, the kidney has **three main regions**
  - The **cortex**
  - The **medulla**
  - The **renal pelvis**



The kidney has three main regions; the cortex, the medulla, and the renal pelvis.

The microscopic structure of the kidney

- Each kidney contains **thousands** of **tiny tubes**, or **tubules**, known as **nephrons**
- Nephrons are the **functional unit** of the kidney and are responsible for the **formation of urine**
- Different parts of the nephron are found in different regions of the kidney
    - The **cortex**
        - Location of the glomerulus, Bowman's capsule, proximal convoluted tubule, and distal convoluted tubule
    - The **medulla**
        - Location of the loop of Henle and collecting duct
    - The **renal pelvis**
        - All kidney nephrons drain into this structure, which connects to the ureter
- There are two types of nephrons in the kidney
    - **Cortical** nephrons
        - These occur **mainly** in the **renal cortex** and have a **short loop of Henle** that barely enters the medulla
        - They make up about 85% of the nephrons in a human kidney
    - **Juxtamedullary** nephrons

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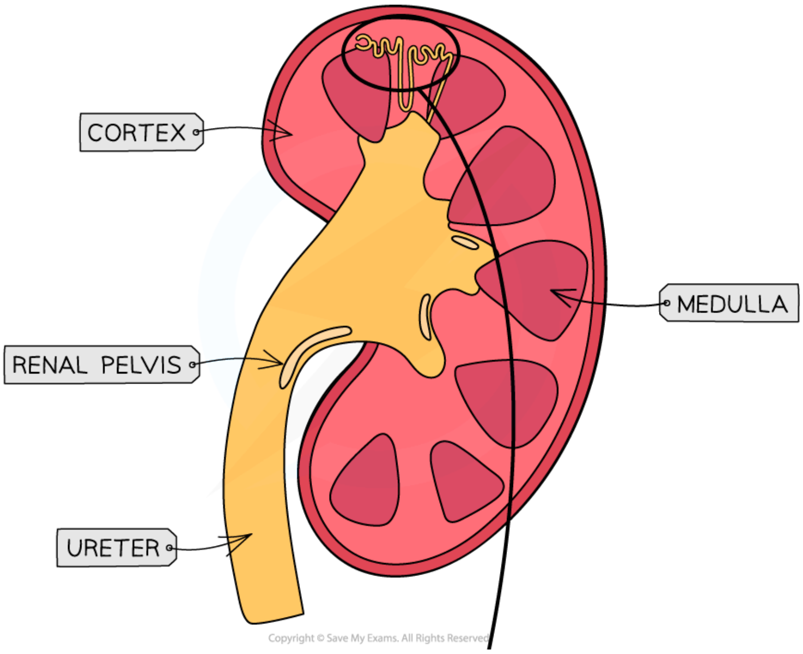
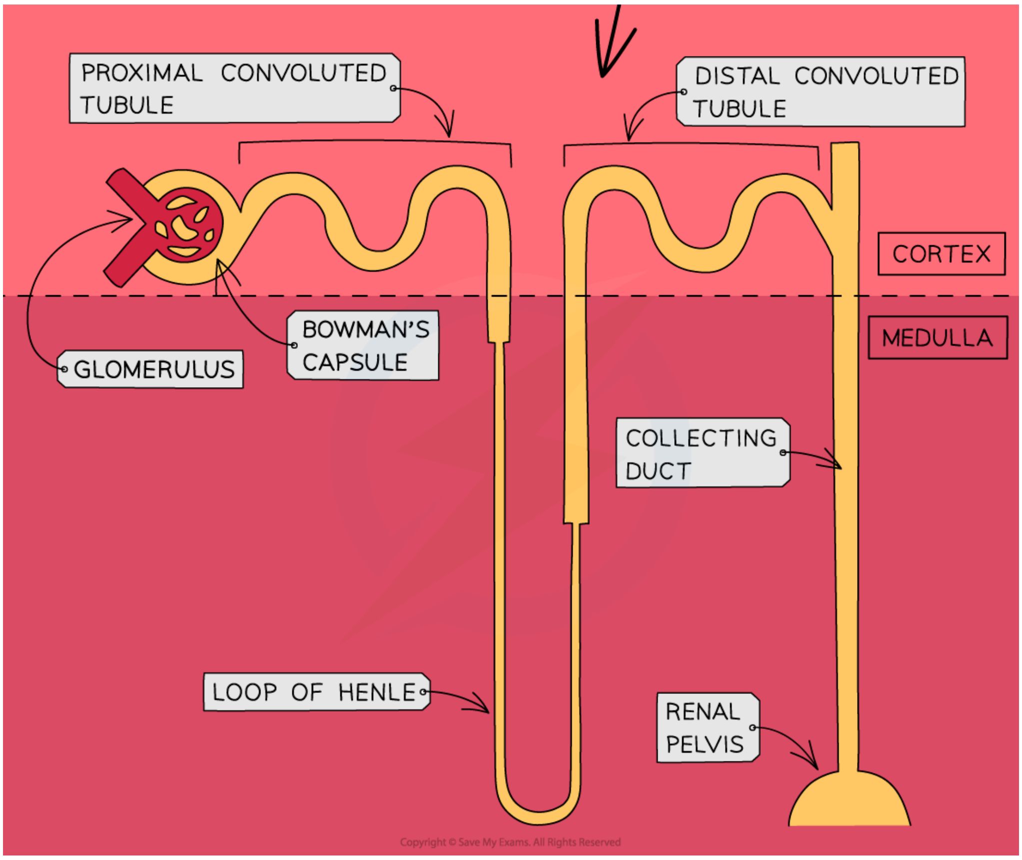
- They have **long loops of Henle** that span across the entire medulla
- Very efficient at **conserving water** in the body

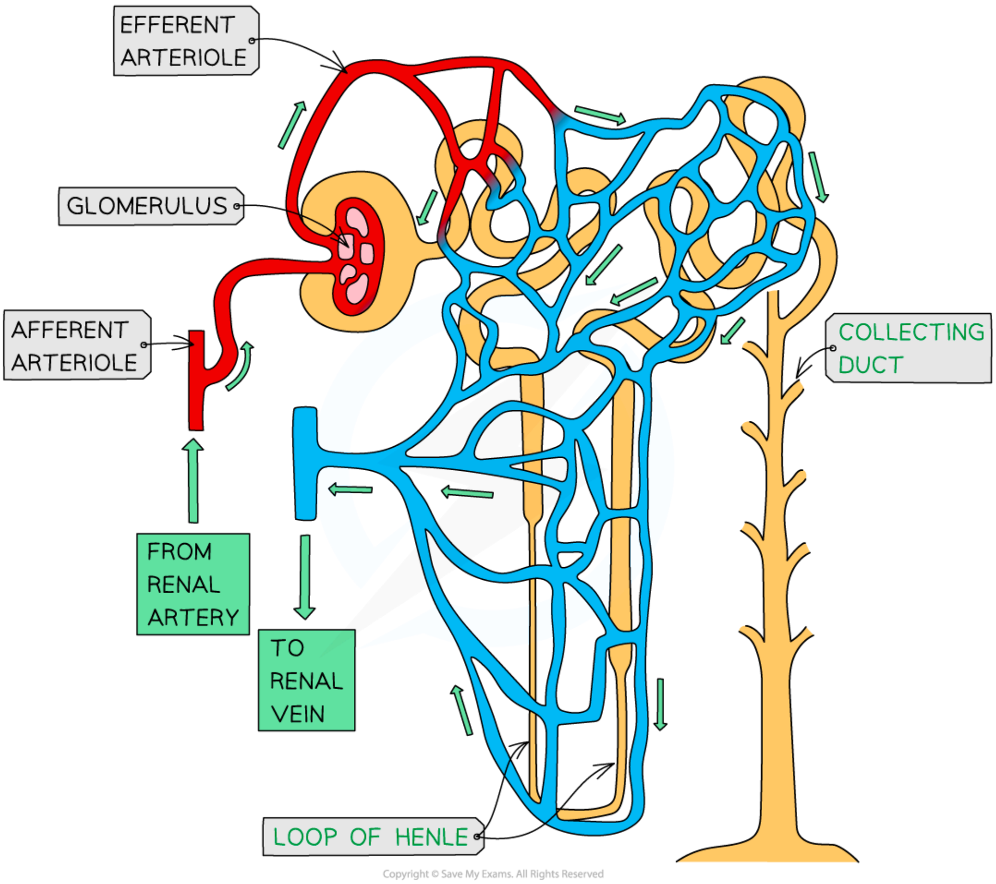




The nephron spans the three regions of the kidney.

Your notes

- There is also a network of **blood vessels** associated with each nephron
- Within the **Bowman's capsule** of each nephron is a structure known as the **glomerulus**
  - Each glomerulus is supplied with blood by an **afferent arteriole** which carries blood from the **renal artery**
  - The afferent arteriole splits into a **ball of capillaries** that forms the **glomerulus** itself
  - The capillaries of the glomerulus rejoin to form the **efferent arteriole**
- Blood flows from the glomerulus into a network of capillaries that run closely **alongside the rest of the nephron** and eventually into the **renal vein**



The afferent arteriole supplies the capillaries of the glomerulus, which rejoin to form the efferent arteriole.

Your notes

Urea as a Waste Product

Formation of urea

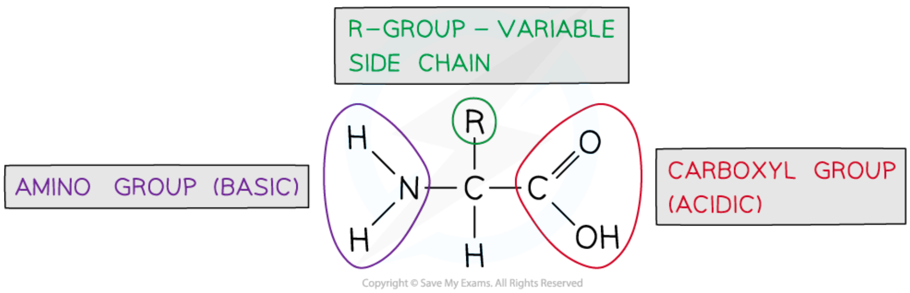
- The body **cannot store** excess protein or amino acids
- Liver cells, or hepatocytes, are responsible for **removing the amino group** from excess amino acids in a process called **deamination**
- During deamination the amino group (**-NH_2**) of an amino acid is removed, together with an extra hydrogen atom
- These combine to form **ammonia** (NH_3)

amino acids → ammonia + keto acid

- The remaining keto acid may enter the Krebs cycle to be **respired**, be converted to **glucose**, or converted to **glycogen / fat for storage**
  - This means that the amino acids within the protein will not be wasted but can function as a useful source of **energy**
- Due to its toxicity ammonia is quickly converted into **less toxic urea**
  - This happens in a series of steps known as the **ornithine cycle**, which can be summarised as

ammonia + carbon dioxide → urea + water

- Urea forms part of urine and can be **excreted** by the kidneys
- Urea is filtered out of the bloodstream into the Bowman's capsule of the nephron by the process of **ultrafiltration**

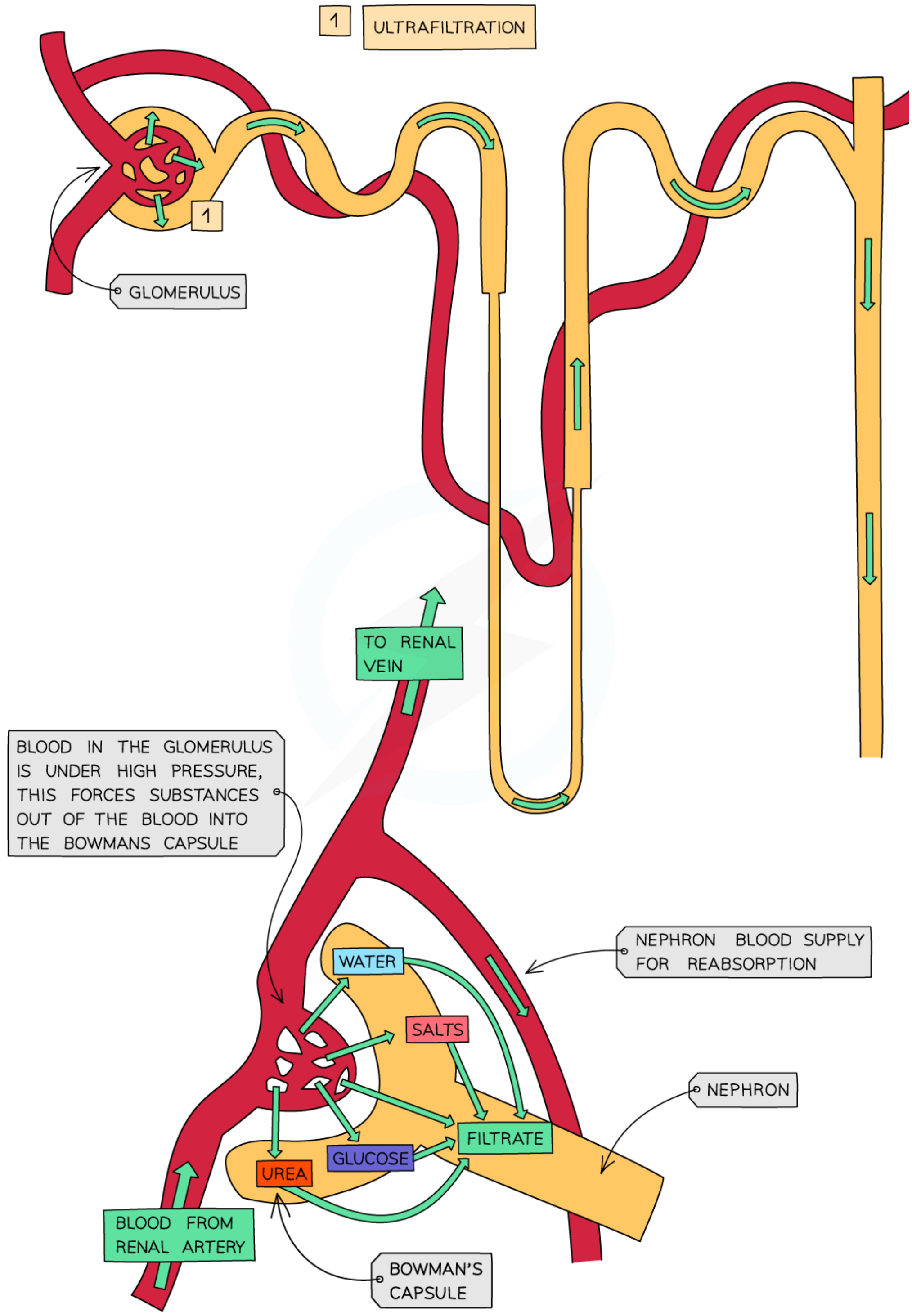


During the process of deamination the amino group (-NH_2) is removed from the amino acid and converted into ammonia (NH_3)

Ultrafiltration

- Within the **Bowman's capsule** of each kidney nephron is a structure known as the **glomerulus**; these two structures together carry out the process of **ultrafiltration**

- The blood in the glomerulus is at **high pressure**
    - The **afferent arteriole** that enters the glomerulus **is wider than the efferent arteriole** that leaves it, increasing the blood pressure as the blood flows through the glomerulus
- This high pressure forces small molecules in the blood **out of the capillaries of the glomerulus and into the Bowman's capsule**
- The resulting fluid in the Bowman's capsule is called the **glomerular filtrate**
- **Large molecules such as proteins remain in the blood** and do not pass into the filtrate



During the process of ultrafiltration small molecules are forced out of the capillaries into the Bowman's capsule

Your notes

Your notes

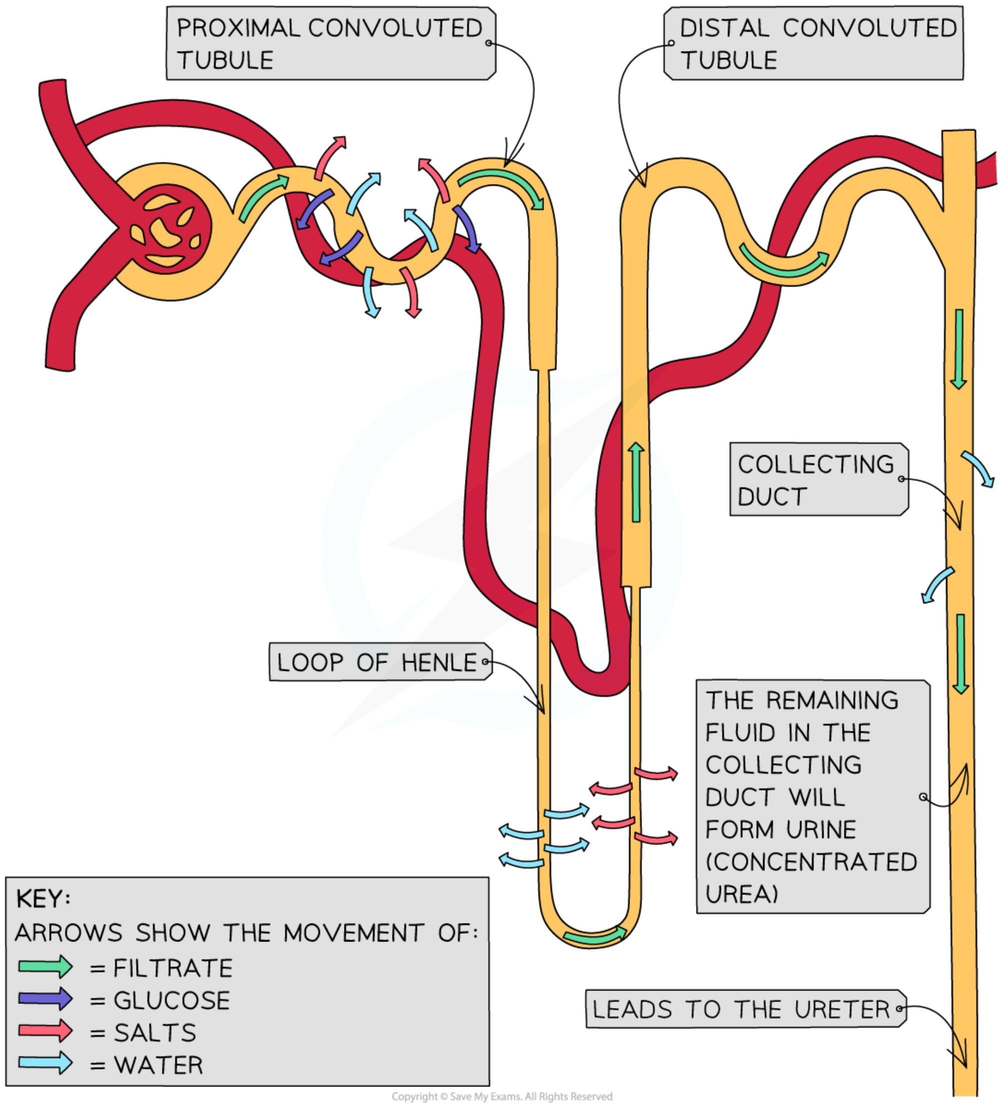
- The **structures** within the glomerulus and Bowman's capsule are especially **well adapted for ultrafiltration**
- The blood in the **glomerular capillaries** is **separated** from the **lumen** of the **Bowman's capsule** by **two cell layers** with a **basement membrane** in between them
  - The first **cell layer** is the endothelium **of the capillary;** gaps between the cells allow **fluid** to pass through
  - The next layer is the mesh-like **basement membrane**
  - The second cell layer is the epithelium **of the Bowman's capsule;** gaps between the cells allow the passage of **small molecules**
- As blood passes through the glomerular capillaries the **gaps between the cells** and the **mesh-like basement membrane** allow substances dissolved in the blood plasma to **pass into the Bowman's capsule**
  - The substances that pass into the Bowman's capsule make up the **glomerular filtrate**
  - The main substances that form the glomerular filtrate are
    - Amino acids
    - Water
    - Glucose
    - Urea
    - Salts (Na^+ and Cl^- ions)
- **Red and white blood cells** and **platelets** remain in the blood as they are **too large** to pass between the cells
- The **basement membrane stops large protein molecules** from getting through

Selective Reabsorption in the Kidney

- The nephron is the **functional unit** of the kidney and is responsible for the **formation of urine**
- The process of urine formation in the kidneys occurs in **two stages**
    - **Ultrafiltration**
    - **Selective reabsorption**
- Ultrafiltration involves filtering small molecules from the blood at high pressure
    - This occurs between the glomerulus and the bowman's capsule
- Selective reabsorption allows the kidney to reabsorb useful small molecules into the blood

Selective reabsorption

- Many of the substances that pass into the **glomerular filtrate** are useful to the body
- These substances are therefore **reabsorbed** into the blood as the filtrate passes along the nephron
- This process is known as **selective reabsorption** since not all substances are reabsorbed
    - Reabsorbed substances include **water, salts, glucose,** and **amino acids**
- Most of this reabsorption occurs in the **proximal convoluted tubule**
    - Note that while **water and salts** are reabsorbed in the proximal convoluted tubule, the **loop of Henle** and **collecting duct** are also involved in the reabsorption of these substances



Selective reabsorption of useful substances occurs in the proximal convoluted tubule, the loop of Henle and the collecting duct

- The lining of the proximal convoluted tubule is composed of a **single layer of epithelial cells** which are **adapted to carry out reabsorption** in several ways
  - Microvilli
    - **Microvilli** are tiny finger-like projections on the surface of epithelial cells which increase the surface area for diffusion
  - Co-transporter proteins
  - Many mitochondria
  - Tightly packed cells

Adaptations for Selective Reabsorption Table

Adaptation of proximal convoluted tubule epithelial cell	How adaptation aids reabsorption
Many microvilli present on the luminal membrane (the cell surface membrane that faces the lumen).	This increases the surface area for reabsorption.
Many co-transporter proteins in the luminal membrane.	Each type of co-transporter protein transports a specific solute (eg. glucose or a particular amino acid) across the luminal membrane.
Many mitochondria.	These provide energy for sodium-potassium (Na+-K+) pump proteins in the basal membranes of the cells.
Cells tightly packed together.	This means that no fluid can pass between the cells (all substances reabsorbed must pass through the cells).

Molecules reabsorbed from the Proximal Convoluted Tubule

- **Sodium ions** (Na^+) are transported from the proximal convoluted tubule into the surrounding tissues by **active transport**
- The positively charged sodium ions creates an electrical gradient, causing **chloride ions** (Cl^-) to follow by **diffusion**
- **Sugars** and **amino acids** are transported into the surrounding tissues by **co-transporter proteins** which also transport sodium ions
- The movement of ions, sugars, and amino acids into the surrounding tissues **lowers the water potential** of the tissues, so **water leaves the proximal convoluted tubule** by osmosis
- **Urea** moves out of the proximal convoluted tubule from a high to a low concentration by **diffusion**
- All of the substances that leave the proximal convoluted tubule for the surrounding tissues **eventually make their way into nearby capillaries** down their concentration gradients

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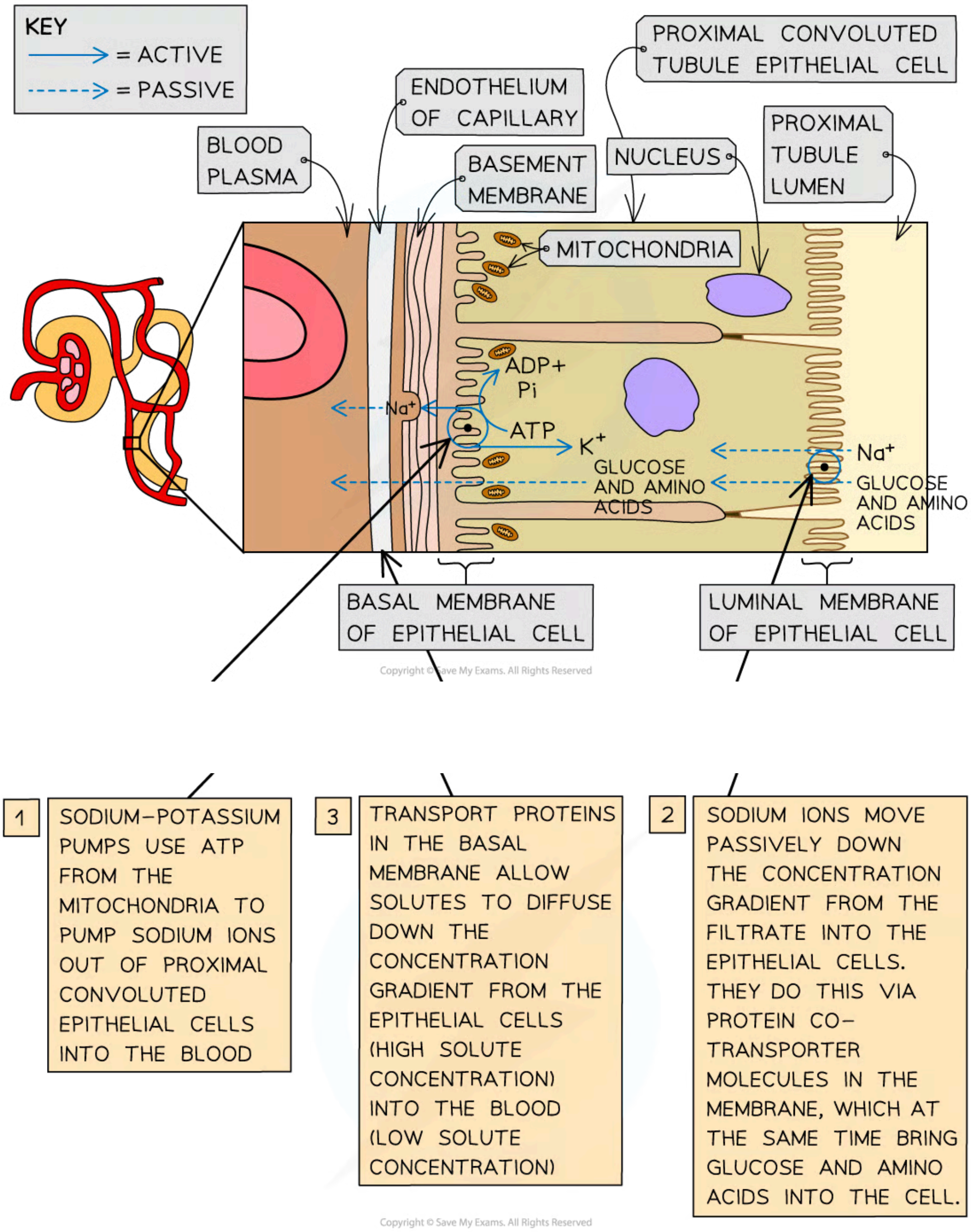

Sodium, amino acids, and glucose are reabsorbed from the proximal convoluted tubule by an active process that involves co-transporter proteins.

The role of the loop of Henle

- Many animals deal with the excretion of the toxic waste product **urea** by **dissolving it in water** and **excreting** it
- While this method of excretion works well, it brings with it the **problem of water loss**
- The role of the loop of Henle is to **enable the production of urine that is more concentrated than the blood**, and to therefore **conserve water**

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- Note that it is also possible to produce urine that is less concentrated than the blood; this is important when water intake is high to prevent blood becoming too dilute

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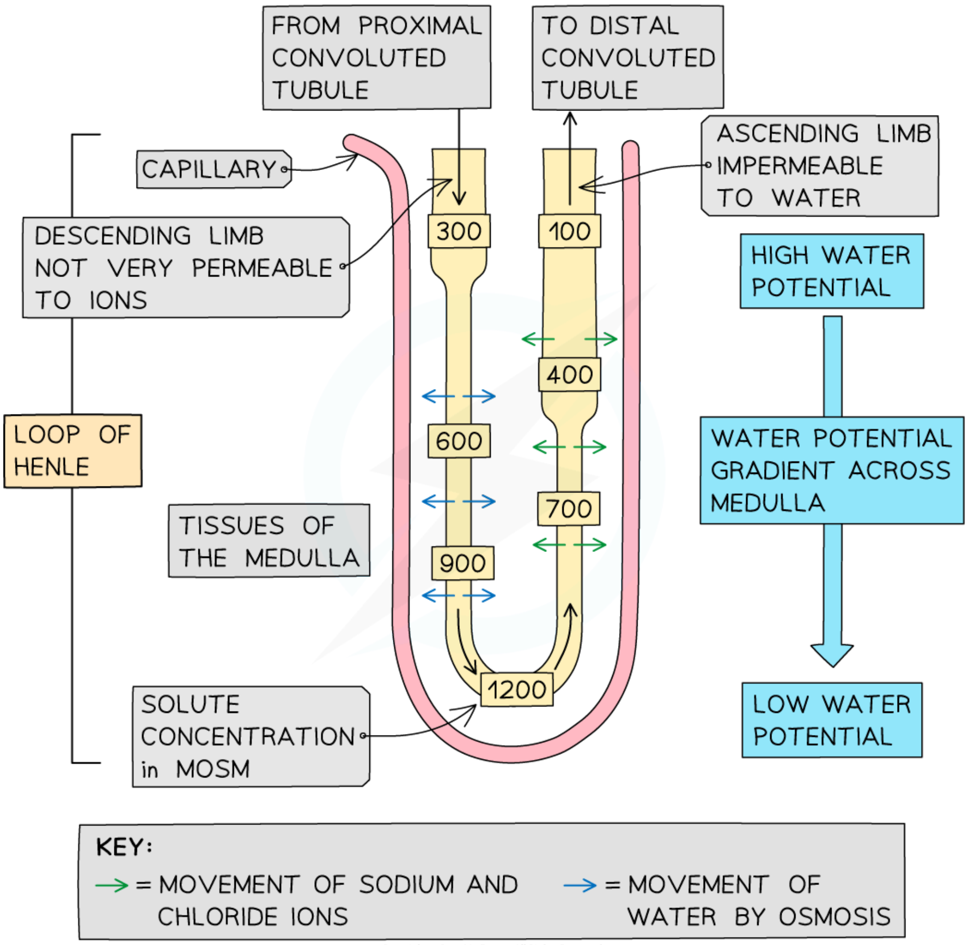
- The loop of Henle achieves this by the use of a **countercurrent multiplier system**
  - ***Countercurrent*** refers to the opposite directions of filtrate flow in the descending and ascending limbs of the loop of Henle
  - ***Multiplier*** refers to the steep concentration gradient that the loop of Henle is able to generate across the medulla

The process in the loop of Henle

- **Sodium** and **chloride** ions move **out of the filtrate in the ascending limb** of the loop of Henle into the **surrounding medulla** region, lowering its water potential
  - The movement of ions occurs by both **diffusion** and **active transport**
    - Diffusion takes place in the first part of the ascending limb
    - Active transport occurs in the second part of the ascending limb
  - The ascending limb of the loop of Henle is **impermeable to water**, so water is **unable to leave the loop here by osmosis**
  - The **water potential in the ascending limb increases as it rises** back into the cortex due to the **removal of solutes** and **retention of water**
- The neighbouring **descending limb is permeable to water**, so water moves **out of the descending limb by osmosis** due to the low water potential in the medulla created by the ascending limb
  - The descending limb has few transport proteins in the membranes of its cells, so **has low permeability to ions**
  - The **water potential of the filtrate decreases as the descending limb moves down** into the medulla due to the **loss of water** and **retention of ions**
- The water and ions that leave the loop of Henle for the medulla make their way **into the nearby capillary network**



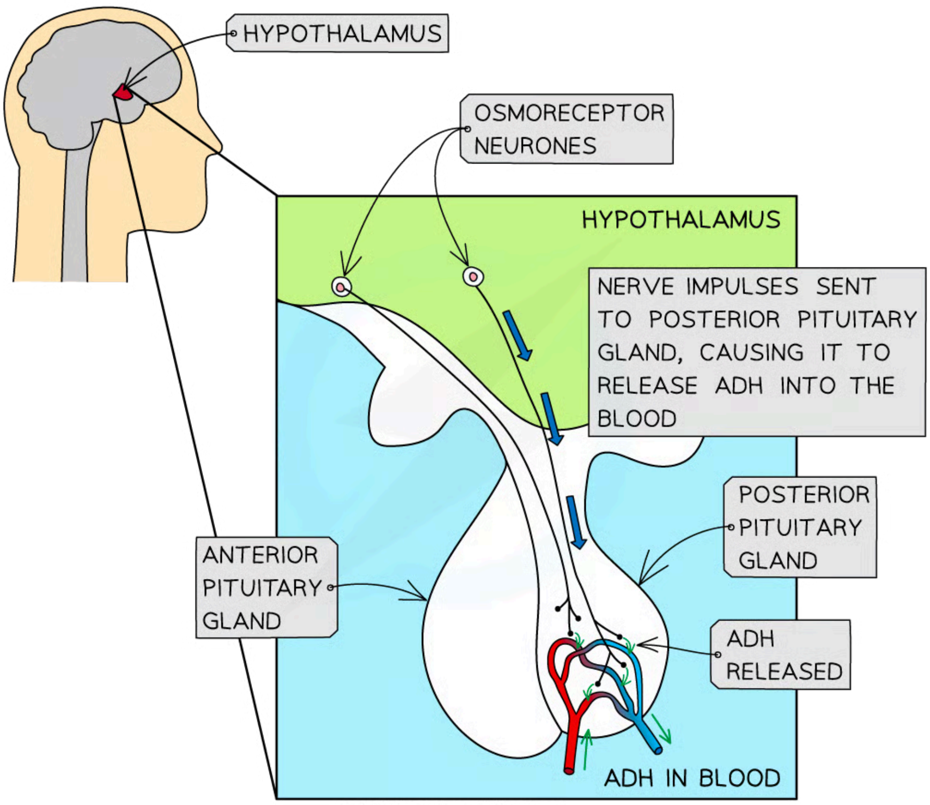
The loop of Henle acts as a countercurrent multiplier, maximising the reabsorption of water by creating a steep water potential gradient across the medulla

Your notes

Your notes

Hormones in Osmoregulation

- The control of the **water potential** of body fluids is known as **osmoregulation**
  - Osmoregulation is a key part of **homeostasis**
- Specialised **sensory receptors**, known as **osmoreceptors**, monitor the water potential of the blood
  - These osmoreceptors are found in an area of the brain known as the **hypothalamus**
- If the osmoreceptors detect a **decrease** in the water potential of the **blood**, nerve impulses are sent along sensory neurones to the **posterior pituitary gland,** located just below the hypothalamus
- These nerve impulses stimulate the posterior pituitary gland to release **antidiuretic hormone (ADH)**
- ADH molecules enter the blood and travel throughout the body
  - ADH causes the **kidneys** to **reabsorb** more water
  - This **reduces the loss of water in the urine**



When osmoreceptors detect a decrease in blood water potential, nerve impulses stimulate the release of ADH at the posterior pituitary gland. This ADH then travels in the blood to the kidneys, causing them to increase water reabsorption

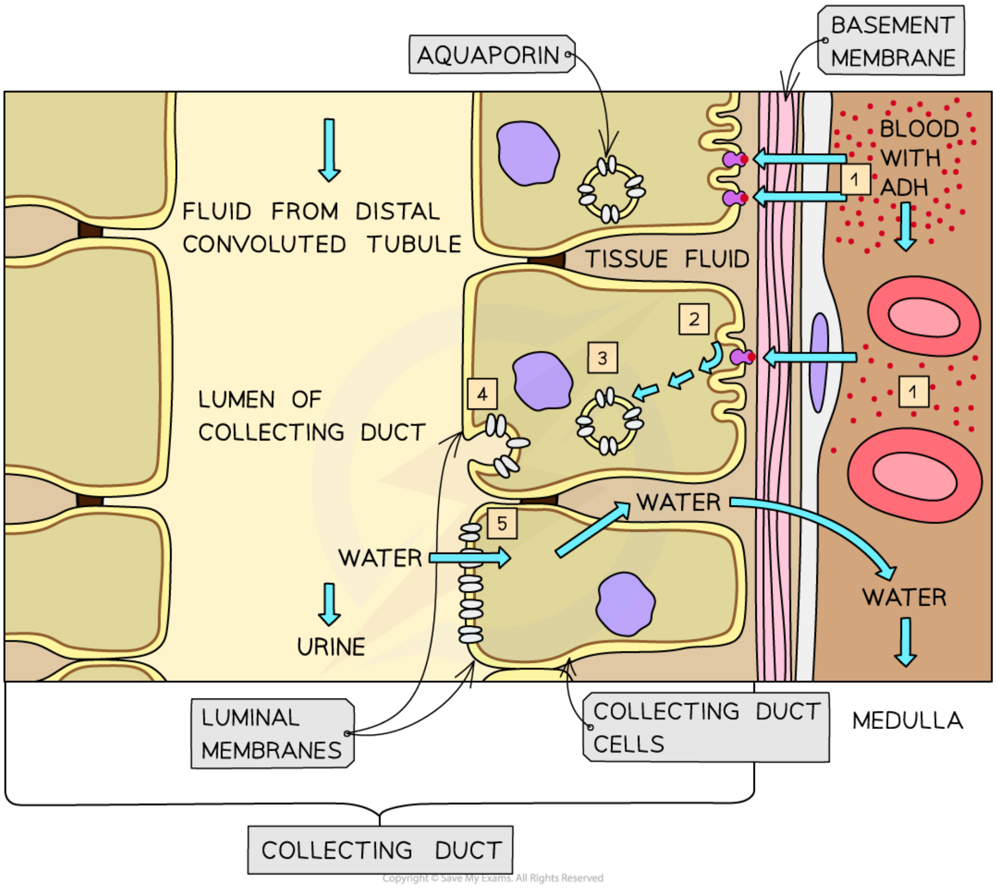
Your notes

The effect of ADH on the kidneys

Low blood water content

- Blood water content might drop as a result of **reduced water intake**, **sweating**, or **diarrhoea**
  - Low blood water content can also be referred to as **high blood solute concentration**, or **low blood water potential**
  - If blood water content gets too low it can lead to **dehydration**
- A reduction of blood water content is **detected by the hypothalamus** in the brain
- The hypothalamus **causes the pituitary gland to secrete ADH** into the blood
  - The target cells of ADH are in the distal convoluted tubule and collecting duct in the kidneys
- ADH **increases the permeability of the walls of the distal convoluted tubule** and **collecting duct** in the kidneys to water
  - The permeability of the walls of the distal convoluted tubule and collecting duct are increased by increasing the number of **channel proteins called aquaporins** in the cell surface membranes of the cells lining the nephron lumen; this occurs in the following way
    - Collecting duct cells contain **vesicles**, the membranes of which contain many **aquaporins**
    - ADH molecules bind to receptor proteins, activating a signalling cascade that causes the **vesicles** to **move to** and **fuse with** the **luminal membranes** of the collecting duct cells
    - This **increases the permeability** of the membrane to water
- **More water is reabsorbed into the blood** via the distal convoluted tubule and collecting duct
- The reabsorption of water leaves a **concentrated filtrate** that passes through the collecting duct and into the renal pelvis
  - This remaining filtrate is the **urine**; from the renal pelvis it passes along the ureter to the **bladder**
- The **blood water content increases** and a **small quantity** of **concentrated urine** is produced

Your notes



1	ADH BINDS TO RECEPTOR PROTEINS IN THE CELL SURFACE MEMBRANES OF THE COLLECTING DUCT CELLS
2	AQUAPORINS ARE PHOSPHORYLATED
3	VESICLES (WITH AQUAPORIN–CONTAINING MEMBRANES) MOVE TOWARDS LUMINAL MEMBRANES OF COLLECTING DUCT CELLS
4	VESICLES FUSE WITH LUMINAL MEMBRANES
5	WATER MOVES THROUGH AQUAPORINS DOWN THE WATER POTENTIAL GRADIENT INTO THE CONCENTRATED TISSUE FLUID AND BLOOD PLASMA IN THE MEDULLA OF THE KIDNEY

ADH increases the permeability of the walls of the collecting duct to water by increasing the number of aquaporins in the cell surface membranes of the collecting duct cells.

High blood water content

- Blood water content might increase due to increased water intake or loss of salts during sweating
    - High blood water content can also be referred to as **low blood solute concentration**, or **high blood water potential**
    - If blood water content gets too high it can lead to **overhydration**
- High blood water content is detected by the hypothalamus
- The hypothalamus **no longer stimulates the pituitary gland to release ADH** and ADH levels in the blood drop
- The **distal convoluted tubule and collecting duct walls become less permeable to water**
    - Fewer aquaporins are present
- **Less water is reabsorbed** from these regions of the nephron into the blood, and the water instead passes down the collecting duct into the renal pelvis along with the rest of the filtrate
- **Blood water content decreases** and a **large quantity** of **dilute urine** is produced

Your notes

Control of Gene Expression

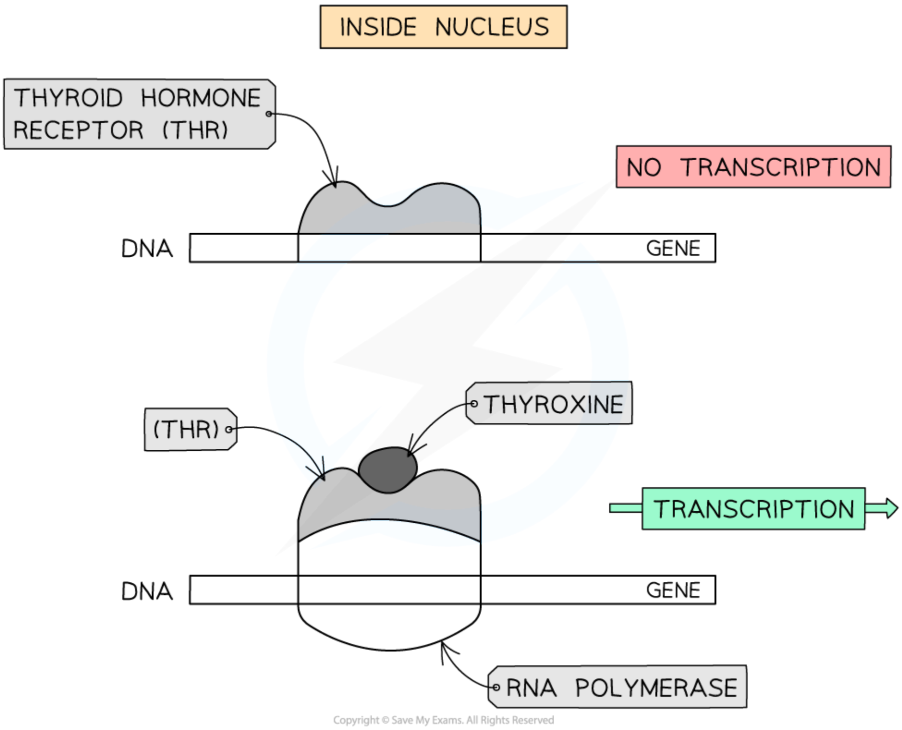
- Hormones can alter the events inside a cell by **influencing** gene expression
- Eukaryotes use **transcription factors** to control gene expression
  - A transcription factor is a protein that **controls the** transcription **of genes** by binding to a specific region of DNA
  - It is estimated that ~10 % of human genes code for transcription factors
    - There are **several types of transcription factors** that have varying effects on gene expression
      - E.g. transcription factors that **increase** the rate at which a gene is expressed are known as **activators**, while those that **decrease** gene expression are known as **repressors**
    - Transcription factors ensure that genes are being expressed in the correct cells, at the correct time and to the right level
    - Transcription factors allow organisms to **respond to their environment**
- Some **hormones** achieve their effect by acting upon transcription factors

Effect of hormones inside cells

- Hormones that can **cross the cell surface membrane,** e.g. steroid hormones and thyroid hormones, are able to **enter the nucleus** and **bind to transcription factors** that are present there
  - Steroid hormones are **lipid soluble**, allowing them to pass between the phospholipids of the cell surface membrane
- An example of this is the **hormonal regulation of body temperature**
  - At normal body temperature a transcription factor known as the **thyroid hormone receptor** binds to a section of DNA at the start of a gene
    - This gene codes for a **protein that increases** the metabolic rate, generating more heat and therefore increasing body temperature
  - As long as the thyroid hormone receptor is bound to the region of DNA at the start of the gene, the gene will not be expressed; it can be said to be **switched off**
    - In reality it is more likely that expression of the gene will be **reduced** rather than switched off entirely
  - However, **in cold temperatures** the body will release the **hormone thyroxine** which **binds** to the thyroid hormone receptor
  - Once the hormone and the receptor are bound together the thyroid hormone receptor allows RNA polymerase to bind to the start of the gene; the gene is said to

be **switched on** and its rate of expression will **increase**

- The protein which **increases the metabolic rate** is produced in larger quantities, leading to an increase in body temperature



The hormone thyroxine acts as a transcription factor by binding to the thyroid hormone receptor; this switches on the gene, allowing it to be transcribed by RNA polymerase

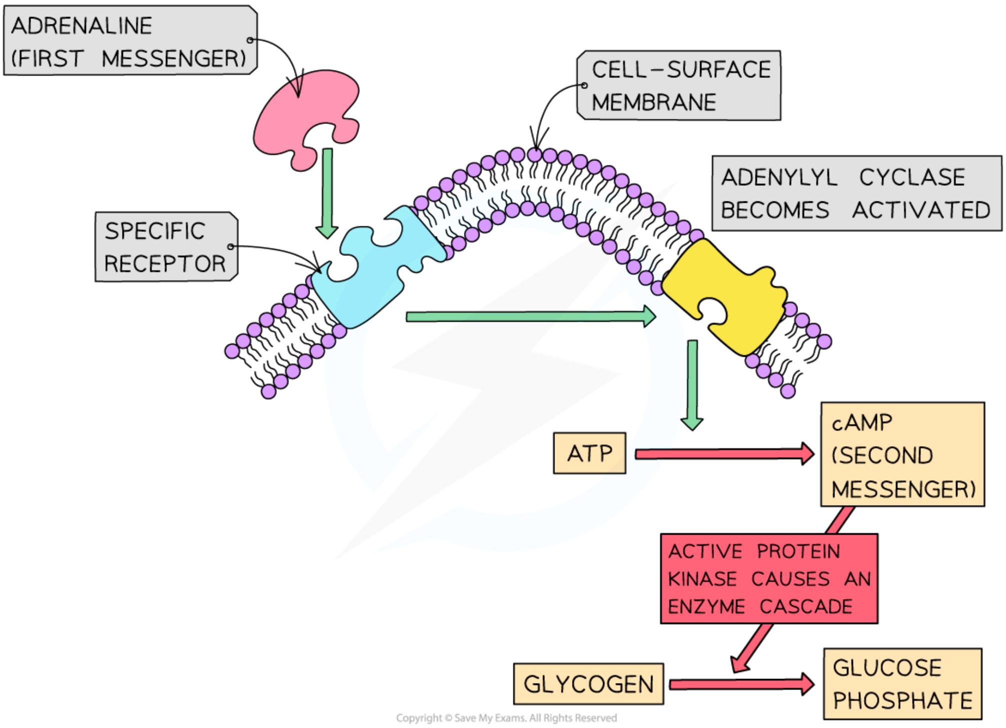
Effect of hormones from outside cells

- Hormones that **cannot cross** the cell membrane, e.g. protein and peptide hormones, bind to **receptors in the cell surface membrane**
  - Examples of such hormones include
    - Adrenaline
    - Insulin
    - Glucagon
    - ADH
- The binding of these hormones to cell surface membrane receptors initiates a process that **activates messenger molecules** in the cytoplasm of the cell known as **second messengers**
  - A common second messenger molecule is cyclic AMP (cAMP), formed from ATP
- The activated second messenger molecules **activate enzymes** called **protein kinases**

Your notes

- Active protein kinase enzymes **trigger a chain of reactions,** known as a **cascade,** inside the cell
- The cascade may result in **changes to the activity of transcription factors** which may then affect gene expression in the cell

Your notes



Adrenaline acts by binding to a receptor on cell surface membranes; this activates the second messenger cAMP, leading to a cascade of reactions that affects the activity of the cell, e.g. by influencing transcription factors