HL IB Biology

Your notes

Homeostasis

Contents

Homeostasis: Maintaining the Internal Environment

Your notes

Maintaining the Internal Environment

- The process of **maintaining a constant internal environment** is known as **homeostasis**
- Homeostasis ensures that conditions inside the body are kept within **preset limits**
- Homeostasis is **critically important** for organisms as it ensures the maintenance of **optimal conditions** for **enzyme action** and **cell function**
- **Sensory cells** can **detect** information about the **conditions** inside and outside the body; if conditions have changed then the body can respond to keep conditions constant
- Examples of physiological factors that are **controlled** by **homeostasis** in **mammals** include
  - Core body temperature
  - Blood pH
  - Concentration of glucose in the blood
  - Osmotic concentration of the blood

Negative Feedback Loops

Your notes

- The majority of homeostatic control mechanisms in organisms use **negative feedback loops** to achieve homeostasis
- Negative feedback mechanisms work to **return values to a set point**; they **reverse the effects of any change** within a system
  - Negative feedback loops are essential for **maintaining conditions** within set limits; this is not the case in positive feedback mechanisms which instead **amplify any change**
- Negative feedback control loops involve:
  - A **receptor** – receptor cells **detect change** in a physiological factor
  - A **coordination system** – the brain and nervous system **transfer information** between different parts of the body
  - An **effector** – the muscles and glands bring about a **response**
- Outcome of a negative feedback loop:
  - The factor / stimulus is **continuously monitored**
  - 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

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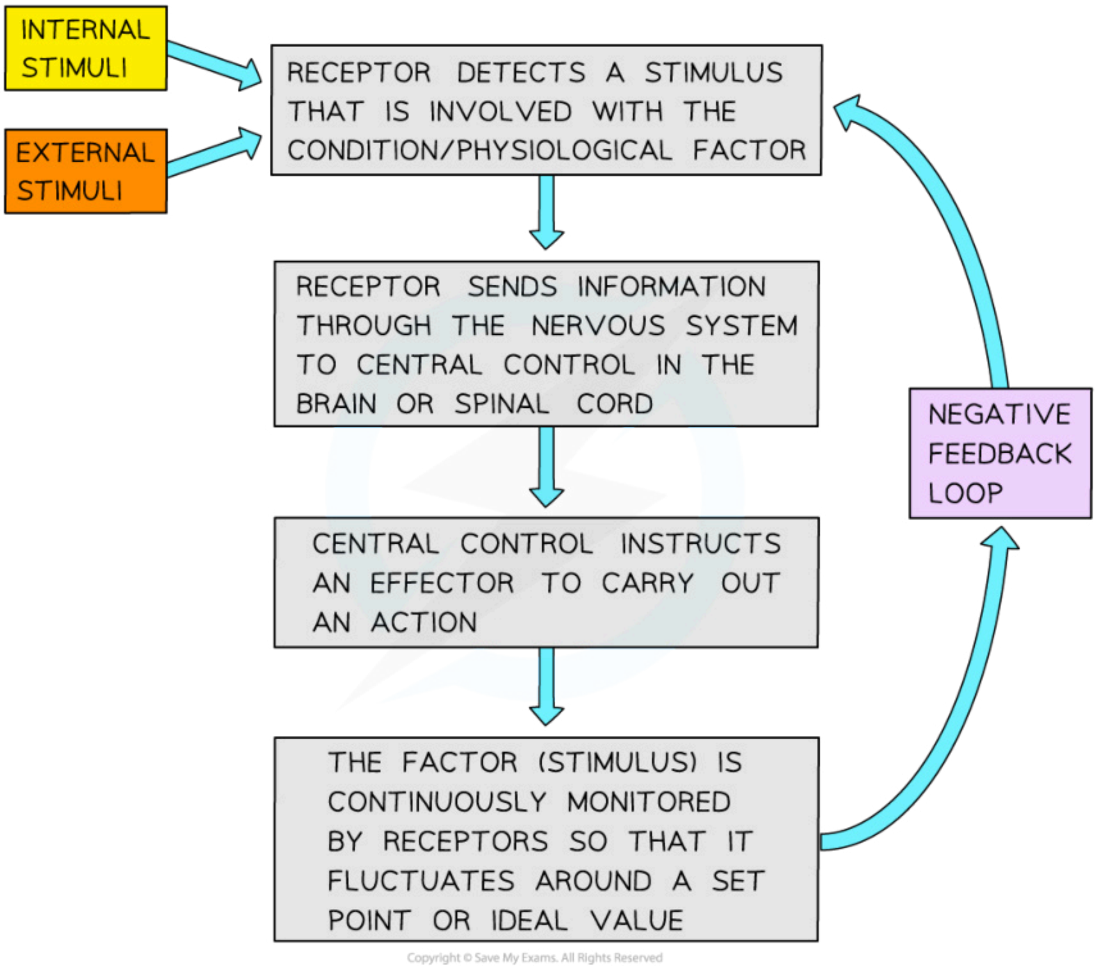


Negative feedback loops maintain conditions to a set point

Your notes

Regulation of Blood Glucose

Diabetes: Type 1 and Type 2

- Diabetes is a condition in which the **homeostatic control of blood glucose has failed** or deteriorated
- The insulin function of diabetic individuals is disrupted which allows the **glucose concentration in the blood to rise**
  - The kidneys are unable to filter out this excess glucose in the blood and so it often appears in the **urine**
  - The increased glucose concentration also causes the kidneys to produce large volumes of urine, making the individual feel thirsty due to **dehydration**
  - Glucose remains in the blood rather than entering the cells, so cellular respiration is reduced, resulting in **fatigue**
  - If the blood glucose concentration reaches a dangerously high level after a meal then **organ damage** can occur
- There are two different types of diabetes: type 1 and type 2

Type 1 diabetes

- Type 1 diabetes is a condition in which the **pancreas fails to produce sufficient insulin** to control blood glucose levels
- It normally begins in childhood due to an **autoimmune response** whereby the body's immune system **attacks the β cells** of the islets of Langerhans in the pancreas
- The damage to the β cells means that **insulin production can no longer take place**, and blood glucose concentration can therefore not be regulated
- Type 1 diabetes is normally treated with regular blood tests, **insulin injections** and a modified **diet**
  - Such a diet may involve a reduction in carbohydrate intake

Type 2 diabetes

- Type 2 diabetes is **more common** than type 1, and usually develops in **older adults**
- In type 2 diabetes the pancreas still produces insulin but the **cell membrane receptors** to which insulin binds have **reduced in number** or **no longer respond**
  - The inability of cells to respond to insulin can be described as **insulin resistance**
- The pancreas will attempt to compensate for this by **secreting more and more insulin**; eventually insulin production will no longer be able to compensate for the reduced cellular response
- There is a **reduced glucose uptake** which leads to uncontrolled **high blood glucose concentration**
- Type 2 diabetes is managed by
  - **Medication** to lower blood glucose
  - A **low carbohydrate diet**
    - Any food that is rapidly digested into sugar will cause a sudden, dangerous spike in blood sugar
  - An **exercise regime** that lowers blood glucose
- **Obesity** is a major risk factor for type 2 diabetes; the over-production of insulin in response to a high-carbohydrate diet triggers the development of insulin resistance

Your notes

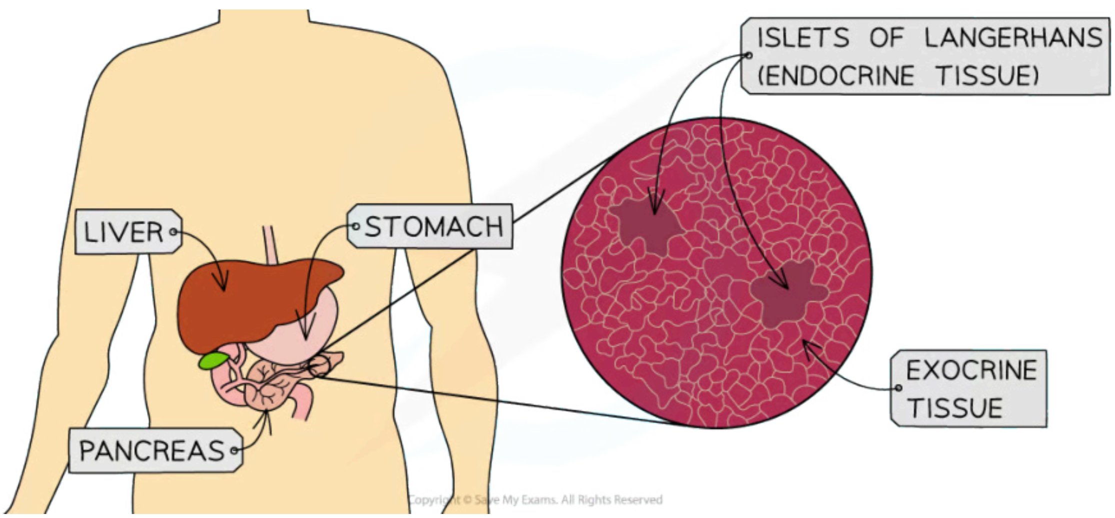
Type 1 and type 2 diabetes table

	Type 1	Type 2
Cause	Inability of pancreas to produce insulin	Cells of the body become resistant to insulin
Treatment	Monitoring blood glucose levels and injecting human insulin throughout the day (particularly after meals consumed)	Maintain a low-carbohydrate diet and regular exercise to reduce need for insulin

Your notes

Regulation of Blood Glucose

- It is essential that **blood glucose concentration** is kept **within narrow limits**
  - Glucose is essential for **respiration**, so it is important that blood glucose levels do not drop too low
  - Glucose is soluble, so blood glucose concentration **affects the osmotic balance** between the cells and the blood
- The control of blood glucose concentration is a key part of **homeostasis**
- Blood glucose concentration is controlled by two hormones which are secreted into the blood by specialised tissue in the **pancreas**
- This tissue is made up of groups of cells known as the **islets of Langerhans**
  - The islets of Langerhans contain two cell types:
    - **α cells** that secrete the hormone **glucagon**
    - **β cells** that secrete the hormone **insulin**
  - These α and β cells are involved with **monitoring** and **responding to** blood glucose levels



The islets of Langerhans form the endocrine tissue of the pancreas, while the exocrine tissue is involved with the production of digestive enzymes

The effects of insulin

- Blood glucose concentration **increases** after a meal that contains **carbohydrate**
- This increase in blood glucose is detected by the **β cells** in the pancreas, which synthesise and **secrete insulin**
- Insulin is **transported in the blood** to **target cells** all over the body
  - Insulin's main target cells are in the **liver and muscles**
- The effects of insulin include:
  - **Glucose channels in cell surface membranes open**, and glucose moves **out of the blood** and into the body cells by facilitated diffusion
  - Liver and muscle cells **convert excess glucose into glycogen** to be stored; this is **glycogenesis**
  - An **increase in the rate of respiration**, using up glucose

- Conversion of **glucose to fatty acids**, resulting in fat storage
- Insulin **lowers blood glucose** concentration

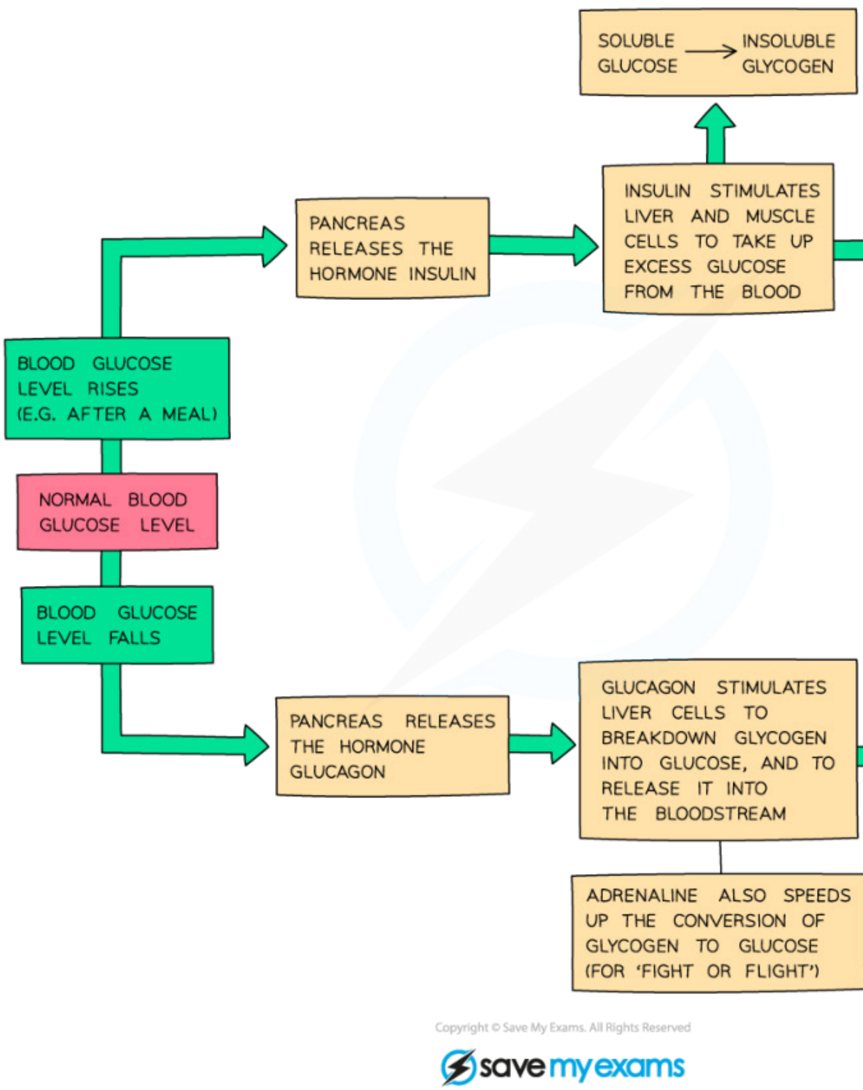
The effects of glucagon

- **Glucagon** is synthesised and secreted by **α cells** when **blood glucose falls**
  - Blood glucose could fall after a period of fasting, or after exercise
- Glucagon is transported in the blood to target cells
- The effects of glucagon include:
  - The **activation of enzymes** that enable the hydrolysis of glycogen in liver and muscle cells, **releasing glucose** that enters the blood; this is **glycogenolysis**
  - A **decrease in the rate of respiration**
  - Amino acids are **converted to glucose**; this is **gluconeogenesis**
- Glucagon **increases blood glucose** concentration

Regulation of blood glucose diagram

Your notes

Your notes



Blood glucose is regulated by insulin and glucagon

Examiner Tip

The terms glucagon and glycogen are very often mixed up by students as they sound similar. Remember:

- Glucagon is the **hormone**
- Glycogen is the **storage polysaccharide** of animal cells

Learn the differences between the spellings and what each one does so you do not get confused in the exam!

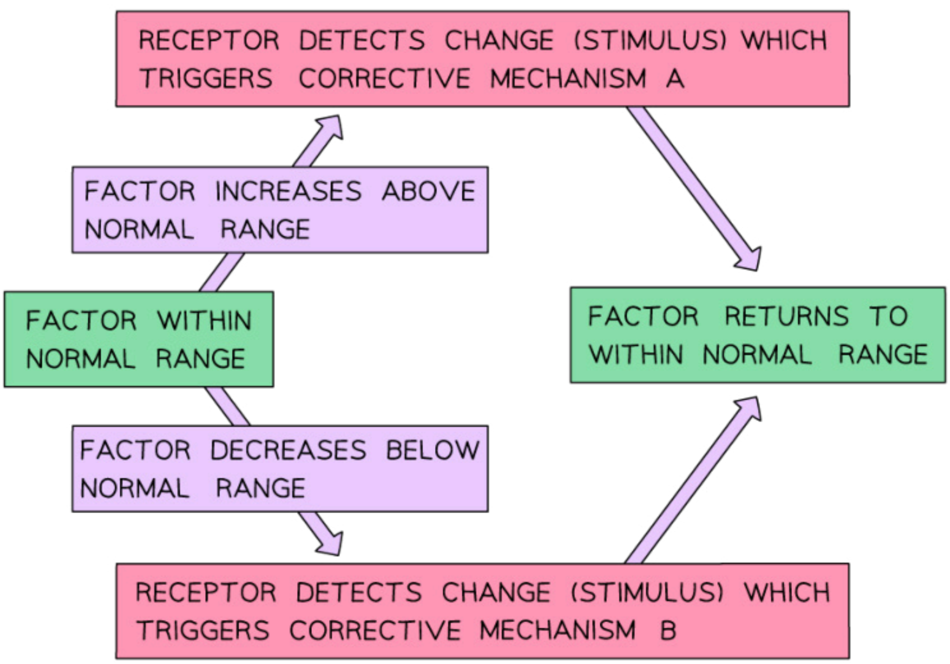
Your notes

Thermoregulation

Thermoregulation as Negative Feedback Control

- **Thermoregulation** is the **control of internal body temperature**
- Thermoregulation is an example of a **negative feedback mechanism**; when body temperature **deviates from pre-set limits**, the responses of the body act to **reverse the change** and bring temperature back to normal
- Negative feedback is brought about by:
  - Using **receptors** to **detect** any deviation from normal levels
    - External body temperature is monitored using **peripheral thermoreceptors** in the skin
    - Internal body temperature is monitored using receptors located inside the **hypothalamus** of the brain
  - Effectors **respond** to any deviation from normal levels
    - **Controlling heat loss** at the skin to the external environment
    - Modifying the generation of heat inside the cells by metabolism

Negative feedback mechanism diagram



Thermoregulation is an example of negative feedback; the 'factor' here is temperature, the 'stimulus' is a change in internal body temperature, and the 'corrective mechanisms' are the action of effectors that control heat generation and loss

- Examples of effectors involved with temperature change include:

- The **hypothalamus**
  - Regulates secretion of a hormone called thyrotropin-releasing hormone
  - Thyrotropin-releasing hormone stimulates the **pituitary gland** to release thyroid-stimulating hormone
  - Thyroid-stimulation hormone stimulates the **thyroid gland** to release **thyroxin**
  - Thyroxin **increases metabolic rate**
    - Altering the level of thyroxin alters **heat generation by cell metabolism**, aiding regulation of body temperature
- **Muscle tissue**
  - **Shivering** in the muscles raises the metabolic rate of muscle cells, releasing heat energy
- **Adipose tissue**
  - White adipose tissue stores lipids in a layer beneath the skin and around the internal organs, providing **insulation** that aids temperature regulation
  - Brown adipose tissue can **generate heat energy** before shivering begins in the muscles; this is known as non-shivering thermogenesis

Your notes

Mechanisms of Thermoregulation

Your notes

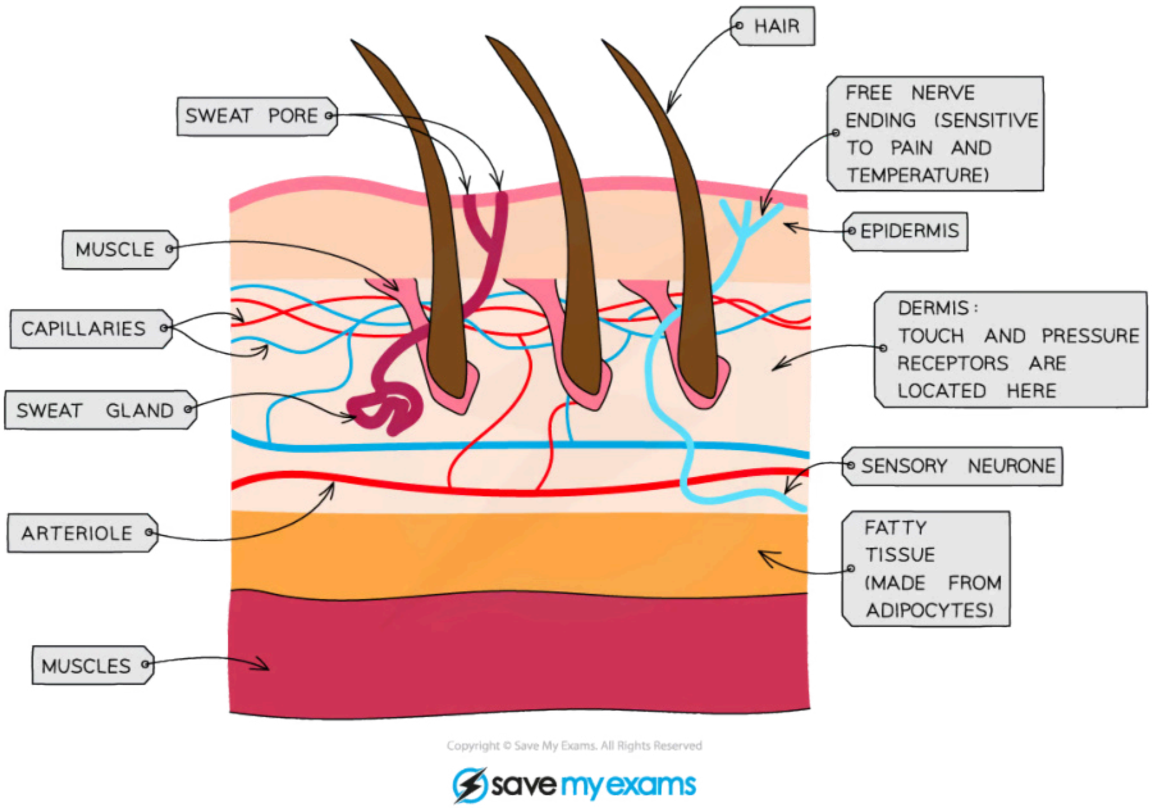
- **Internal body temperature** is a key factor that needs to be controlled in homeostasis
  - A stable core temperature is vital for **enzyme activity**, e.g. human enzymes have evolved to function optimally at a core body temperature of about 37 °C
    - **Lower temperatures** either **prevent** reactions from proceeding or **slow them down**:
      - At lower temperatures molecules have little kinetic energy, so collisions are infrequent and few enzyme-substrate complexes form
    - Temperatures that are **too high** can cause enzymes to **denature**, meaning that they lose their tertiary structure and **enzyme-substrate complexes can no longer form**
- Endotherms are animals that **maintain a constant internal body temperature**, e.g. **mammals** and **birds**
- Mammals and birds can regulate their body temperature using:
  - **Physiological mechanisms**, such as shivering and altered metabolism
  - **Behavioural mechanisms**, such as seeking the shade of an underground burrow, or sunbathing

Thermoregulation in humans

- Endothermic animals detect external temperatures via **peripheral receptors**, e.g. thermoreceptors found in the skin
  - There are receptors for both heat and cold
  - These communicate with the **hypothalamus** to bring about a **physiological response** to changing external temperatures
- Human skin contains a variety of **structures** that are involved in processes that can **increase** or **reduce heat loss** to the environment

Skin structure diagram

Your notes



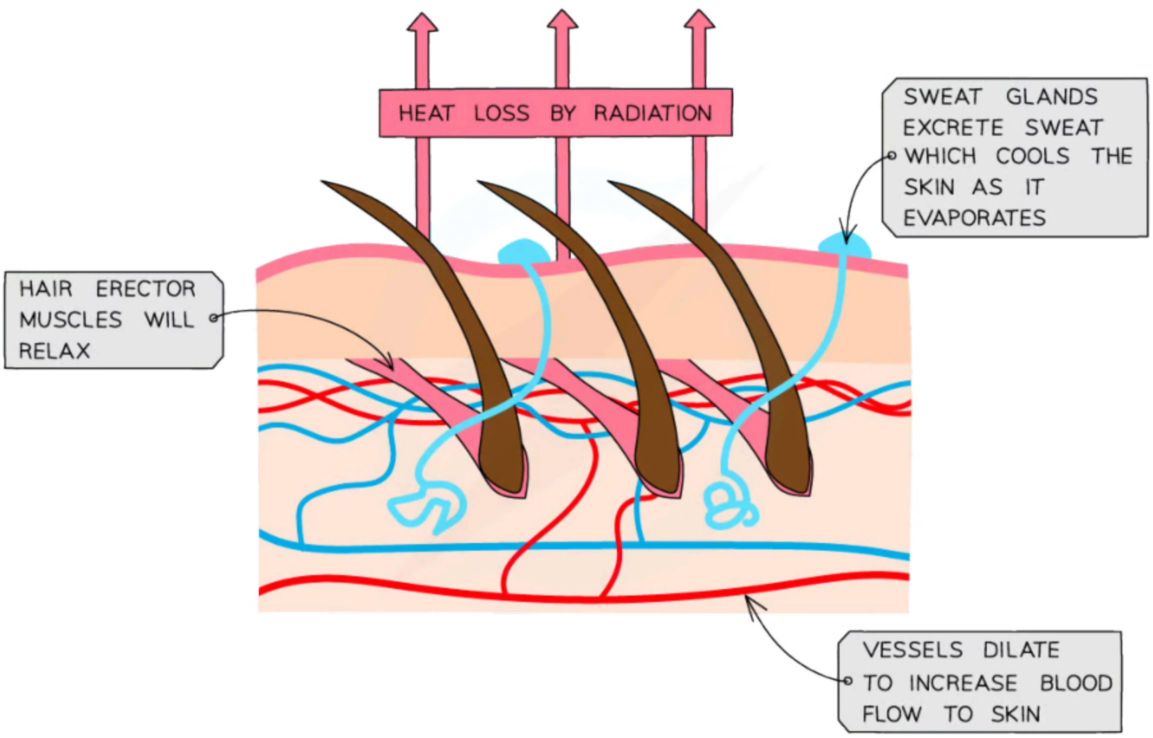
Human skin contains structures that are involved with monitoring and responding to temperature change

Human responses to an increase in temperature

- **Vasodilation**
  - **Arterioles** (small vessels that connect arteries to the skin capillaries) 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
  - The increased blood flow to the skin means that **more heat is lost** to the environment by **radiation** from the skin surface
- **Sweating**
  - Sweat is secreted by sweat glands
  - This cools the skin by **evaporation** which uses **heat energy** from the body to **convert liquid water into water vapour**
- **Flattening of hairs**
  - The **hair erector muscles** in the skin **relax**, causing **hairs to lie flat**
  - This **stops the hairs from forming an insulating layer** of air and **allows air to circulate** over skin, meaning that heat energy lost by radiation can be moved away from the skin surface

Your notes

Increasing heat loss via the skin diagram

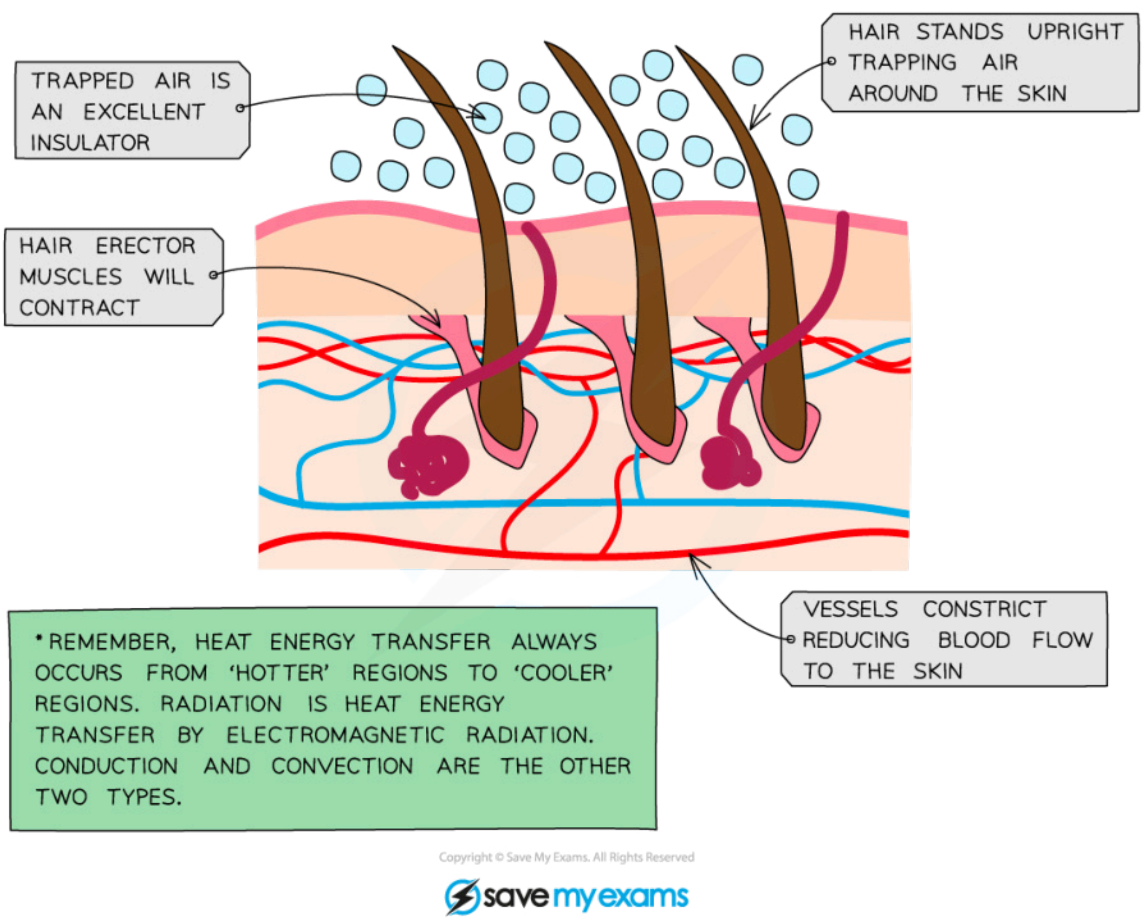


The skin responds to high temperatures with vasodilation, sweating, and relaxation of hair erector muscles

Human responses to a decrease in temperature

- **Vasoconstriction**
  - During vasoconstriction the **muscles in the arteriole walls contract**, causing the arterioles near the skin to **constrict** and allowing **less blood to flow through capillaries**
    - Instead, the blood is diverted through **shunt vessels**, which are deeper in the skin and therefore do not lose heat to the environment
  - The reduction in blood flow to the skin surface means that **less heat energy is lost** by **radiation**
- **Erection of hairs**
  - The hair erector 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
    - Humans have very little hair on their skin, so this response is less effective than it would have been in their evolutionary ancestors

Reducing heat loss via the skin diagram

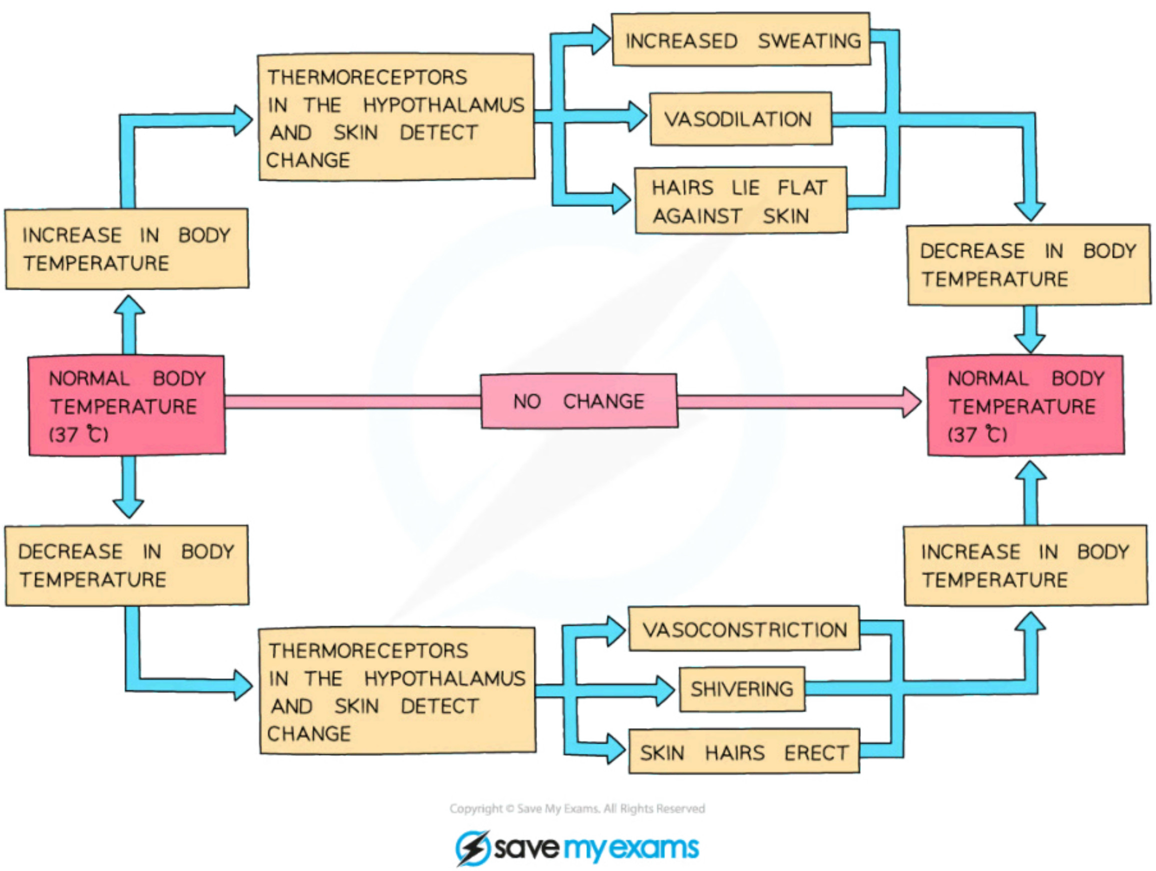


The skin responds to low temperatures by vasoconstriction and the contraction of hair erector muscles

- **Shivering**
  - **Muscles contract and relax** rapidly
  - The metabolic reactions required to power shivering **generate sufficient heat** to warm the blood and raise the core body temperature
- **Uncoupled respiration in brown adipose tissue**
  - The reactions of respiration are usually said to be 'coupled' with ATP production, meaning that most of the energy released from carbon compounds is used to generate ATP
  - The 'uncoupling' of respiration from ATP production means that **all of the energy released from metabolism is released as heat**, and ATP is not produced
  - This can occur in **brown adipose tissue** where **lipids are metabolised** to release heat energy
    - This process occurs mainly in newborn infants, who cannot shiver so rely on this non-shivering thermogenesis
- **Boosting metabolic rate**
  - Most of the metabolic reactions in the body release heat

- The hormone thyroxine is released from the thyroid gland, and acts to increase the basal metabolic rate (BMR), increasing heat production in the body

Thermoregulation negative feedback diagram



Thermoregulation is an example of negative feedback

Examiner Tip

Remember that vasodilation and vasoconstriction are caused by the relaxing and contracting of muscles in the arterioles, **not** the capillaries; capillaries do not have muscles in their walls

Your notes

Osmoregulation & Excretion (HL)

Your notes

Osmoregulation & Excretion

- The **kidney** has two roles in the body of mammals
  - Excretion
  - Osmoregulation

Excretion

- Excretion is the process by which toxic **waste products of metabolism** are removed from the body
- The kidneys are involved with the excretion of **nitrogenous waste**
  - Nitrogenous waste comes from the breakdown of **excess dietary amino acids** and **nucleic acids**
- The waste is first converted into ammonia
- Ammonia is highly toxic; it cannot be stored in the body and must therefore be removed quickly from the body
- Some organisms convert highly toxic ammonia into less toxic **urea**; urea can remain in the body at low concentrations, but needs to be excreted before it builds up to a harmful level
- Organisms that excrete urea need to **dilute it with water to form urine** before it is excreted
- Urine is produced in the **kidneys**

Osmoregulation

- Living organisms need to maintain a **safe balance of water and solutes** in their cells; this is the **osmotic concentration** of the cells
- Failure to maintain this balance will mean that an organism's cells could either take on water and burst, or lose water and shrink due to the effects of osmosis
  - Cells with a **lower water potential** than their surrounding environment will **gain water by osmosis** and the resulting internal pressure increase could cause the cell to **burst**
    - Note that plant cells are protected from bursting by their strong cell walls
  - Cells with a **higher water potential** than their surrounding environment will **lose water by osmosis** and the resulting drop in internal pressure will cause the cell to **shrink**
- The units for osmotic concentration are **osmoles per litre** (osmol L^{-1})

Your notes

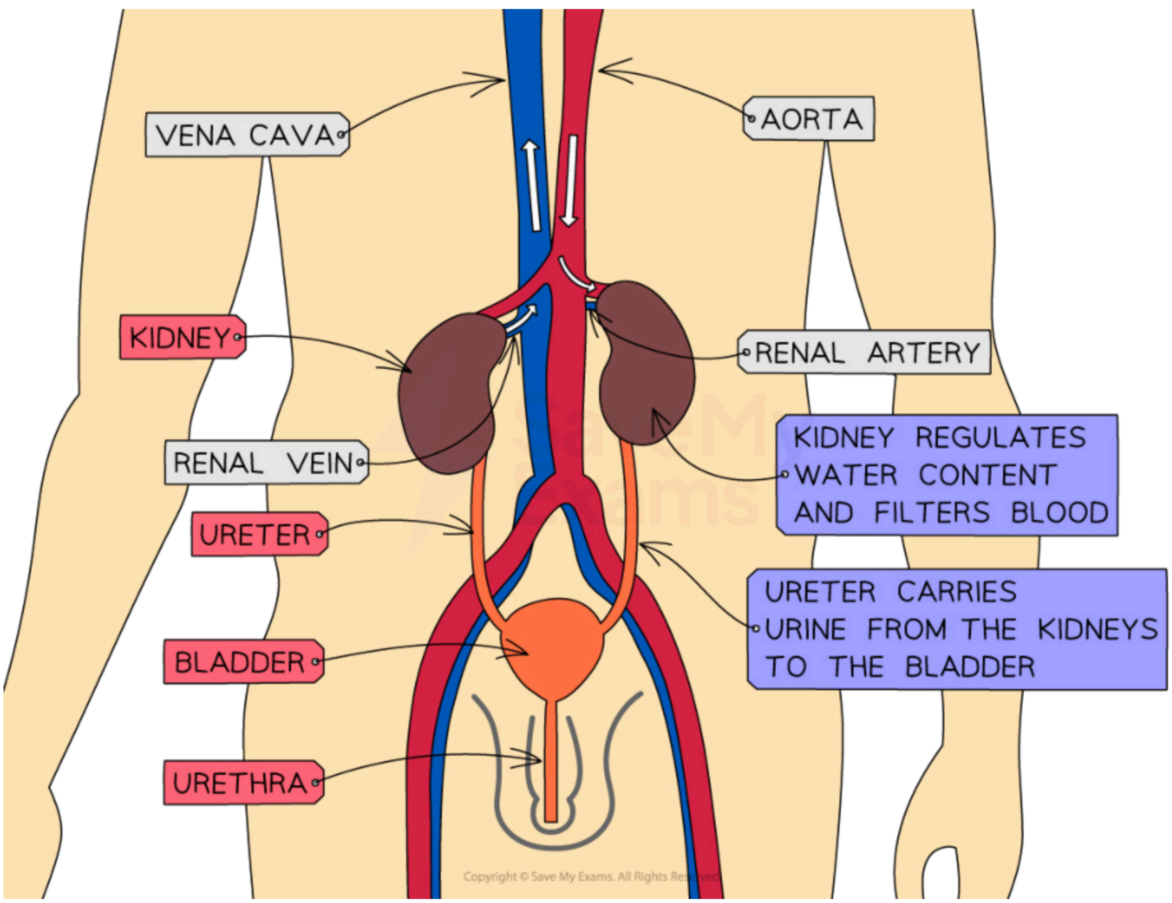
Production of Urine (HL)

Ultrafiltration & Selective Reabsorption

Introduction to kidney structure

- Humans have **two kidneys**, which remove waste products from the blood and maintain the blood's balance of water and solutes
- The **renal artery** supplies blood to the kidneys, while the **renal vein** carries blood away
- The filtrate produced by the kidneys forms **urine** which is **transferred to the bladder via a tube called the ureter**

The urinary system diagram



The kidneys are supplied with blood by the renal artery, while the renal vein carries blood away. A ureter carries urine from each kidney to the bladder.

Kidney Structure & Function Table

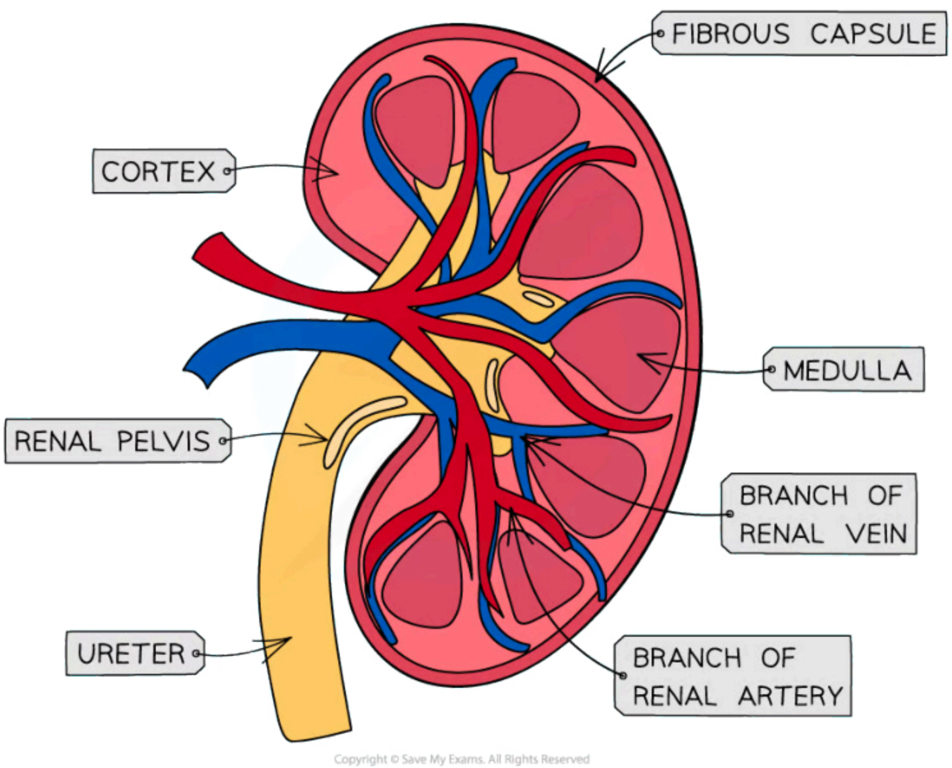
Your notes

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

- 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**

Kidney structure diagram

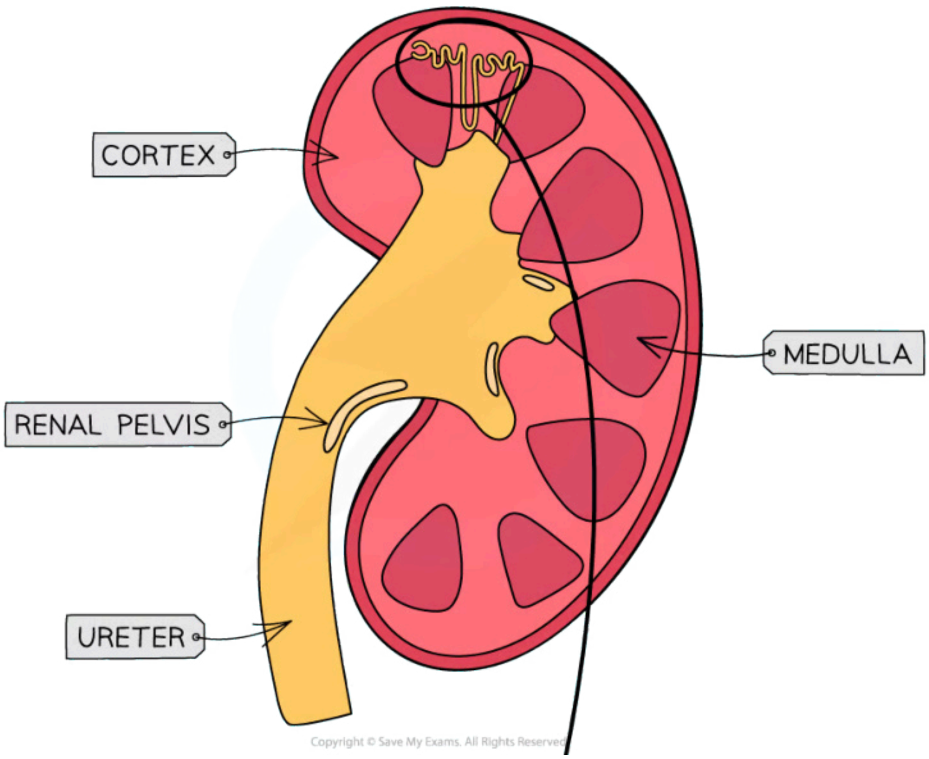
Your notes



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

- 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

The nephron diagram


CORTEX
MEDULLA
RENAL PELVIS
URETER
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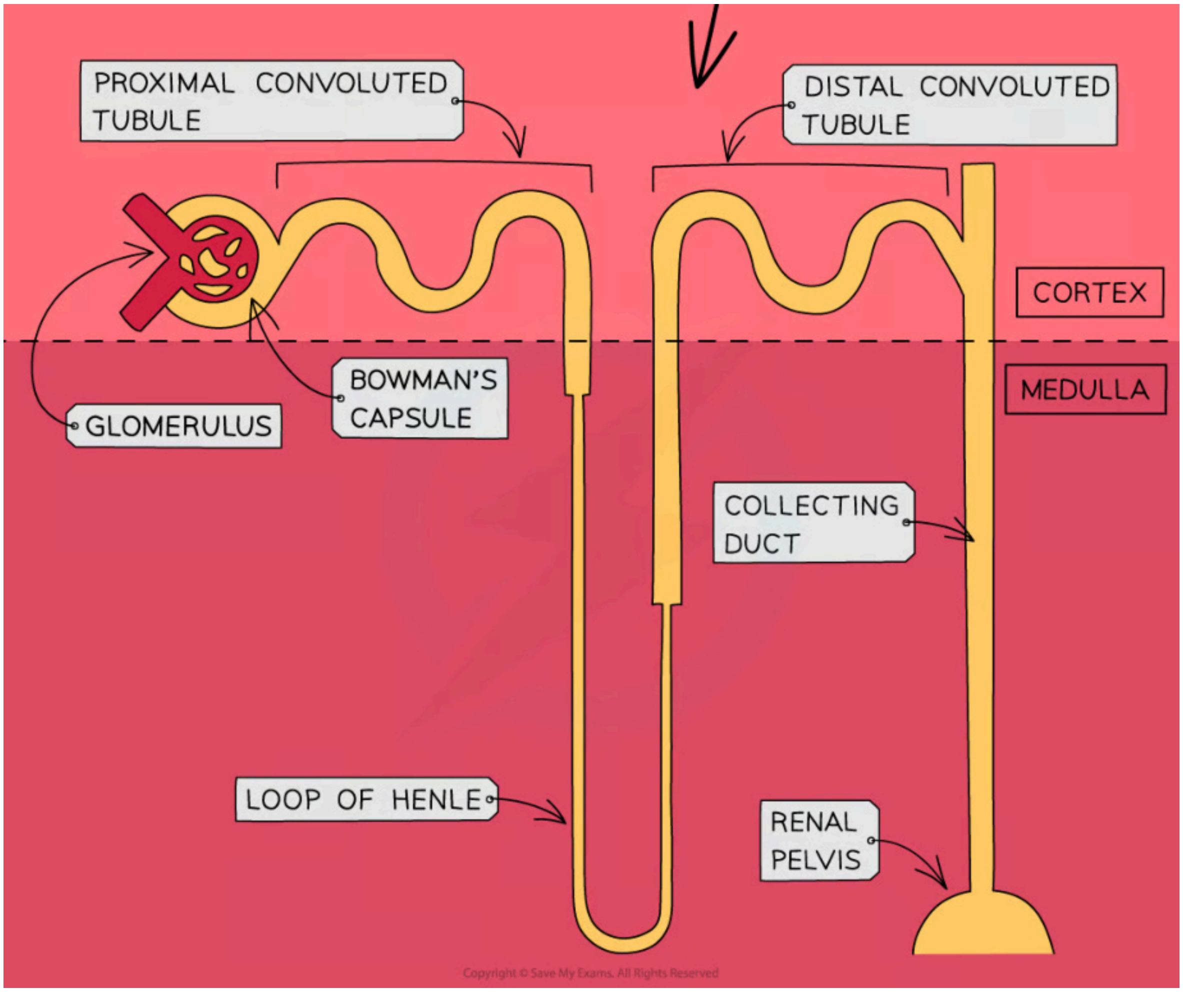


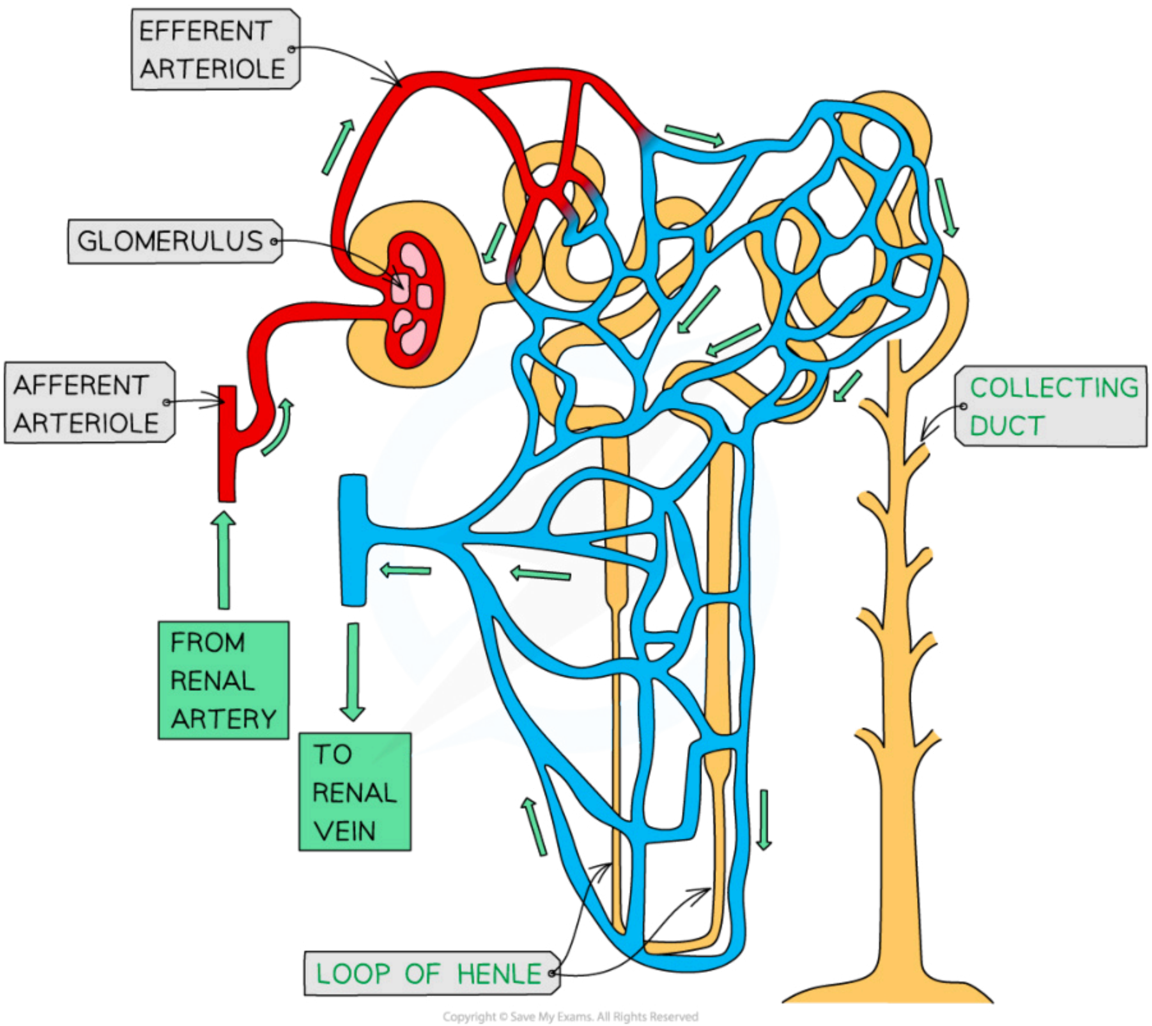
The nephron spans the three regions of the kidney.

The glomerulus and Bowman's capsule

- 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**

Glomerulus and Bowman's capsule diagram

Your notes



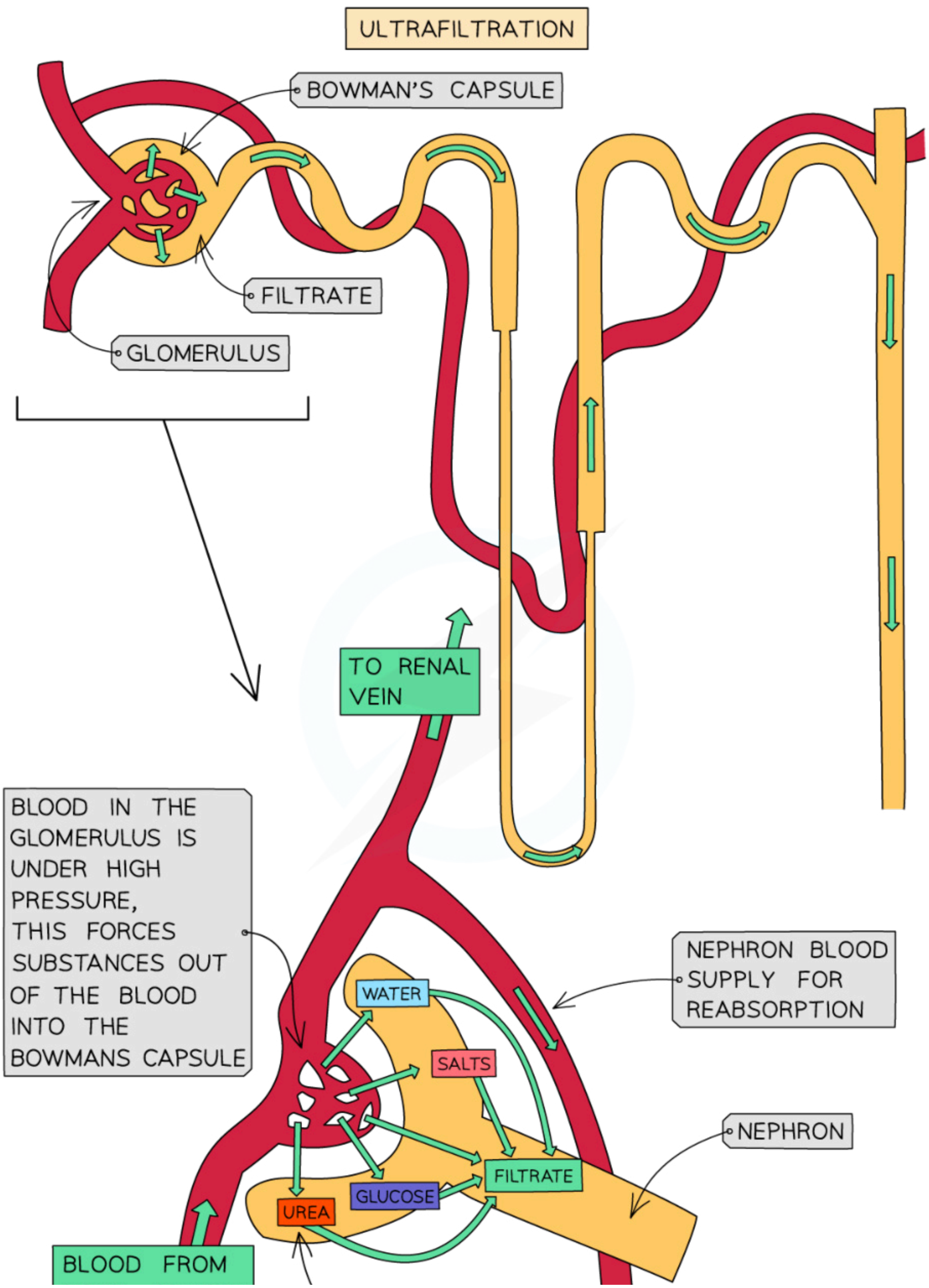
The afferent arteriole supplies the capillaries of the glomerulus, which rejoin to form the efferent arteriole

Ultrafiltration

- The **glomerulus sits within** the **Bowman's capsule**; these two structures together carry out the process of **ultrafiltration**
- The blood in the glomerulus is at **high pressure**
  - The **afferent arteriole is wider than the efferent arteriole**, increasing the blood pressure as the blood flows through the glomerulus
  - Note that while all capillaries exert outward pressure, forcing tissue fluid out towards the surrounding cells, the **outward pressure in the glomerulus is much higher than in other capillaries**
- This high pressure forces small molecules in the blood **out of the capillaries of the glomerulus and into the Bowman's capsule**
  - These small molecules include

Your notes

  - Chloride ions
  - Sodium ions
  - Glucose
  - Urea
  - Amino acids
- 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


ULTRAFILTRATION
BOWMAN'S CAPSULE
FILTRATE
GLOMERULUS
TO RENAL VEIN
BLOOD IN THE GLOMERULUS IS UNDER HIGH PRESSURE, THIS FORCES SUBSTANCES OUT OF THE BLOOD INTO THE BOWMANS CAPSULE
WATER
NEPHRON BLOOD SUPPLY FOR REABSORPTION
SALTS
NEPHRON
FILTRATE
GLUCOSE
UREA
BLOOD FROM

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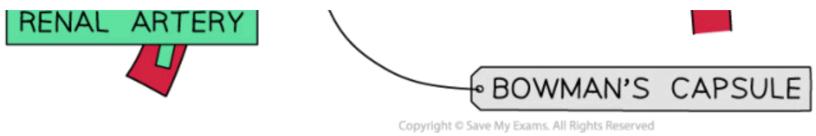


High blood pressure in the glomerulus forces small molecules into the Bowman's capsule, forming glomerular filtrate; this is ultrafiltration

Composition of the blood plasma compared to glomerular filtrate table

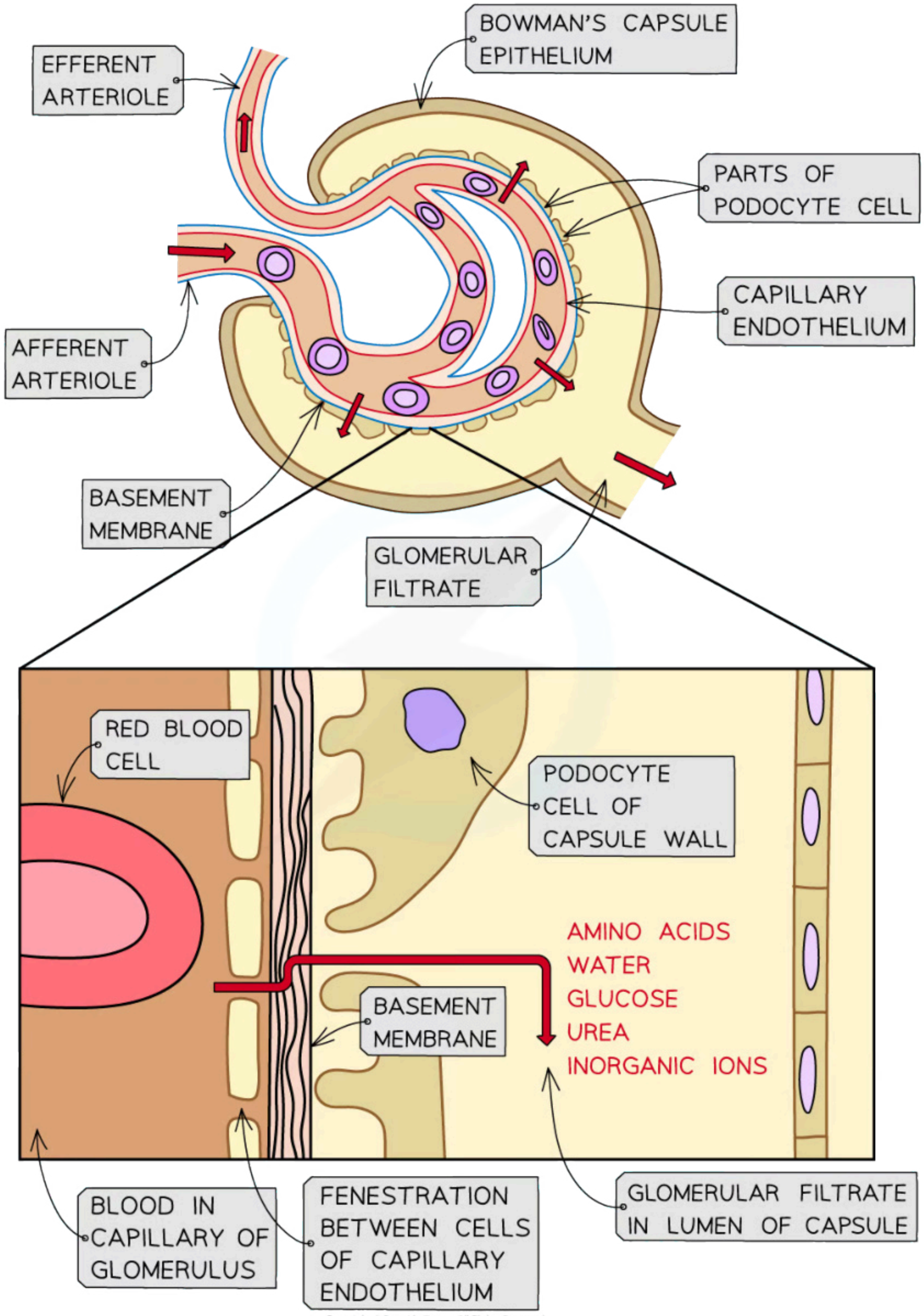
	Concentration / mol dm^{-3} OR *mg dm^{-3}	
	Blood plasma	Glomerular filtrate
Urea	5	5
Na^+ ions	150	145
Cl^- ions	110	115
Glucose	5	5
Protein*	740	5

- 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**
    - There are gaps between the cells of the capillary endothelium known as **fenestrations**; fluid can pass through these gaps but not blood cells
  - The next layer is the **basement membrane**
    - The basement membrane is made up of a **network of collagen protein** and **glycoproteins**
    - This **mesh-like structure** acts as a sieve, allowing small molecules through but **preventing passage of large proteins** from the blood plasma
  - The second cell layer is the epithelium **of the Bowman's capsule**
    - The epithelial cells have many **foot-like projections** which wrap around the capillary; these cells are known as **podocytes** and the **gaps between the projections** allow the passage of small molecules
- As blood passes through the glomerular capillaries the **fenestrations between the capillary endothelial cells**, the **mesh-like basement membrane**, and the **gaps between the podocyte**

projections 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 and salts** (Na^+ and Cl^- ions)
- **Red and white blood cells** and **platelets** remain in the blood as they are **too large** to pass through the fenestrations between the capillary endothelial cells
- The **basement membrane stops large protein molecules** from getting through

Your notes

Your notes


EFFERENT ARTERIOLE
BOWMAN'S CAPSULE EPITHELIUM
PARTS OF PODOCYTE CELL
CAPILLARY ENDOTHELIUM
AFFERENT ARTERIOLE
BASEMENT MEMBRANE
GLOMERULAR FILTRATE
RED BLOOD CELL
PODOCYTE CELL OF CAPSULE WALL
AMINO ACIDS
WATER
GLUCOSE
UREA
INORGANIC IONS
BASEMENT MEMBRANE
BLOOD IN CAPILLARY OF GLOMERULUS
FENESTRATION BETWEEN CELLS OF CAPILLARY ENDOTHELIUM
GLOMERULAR FILTRATE IN LUMEN OF CAPSULE
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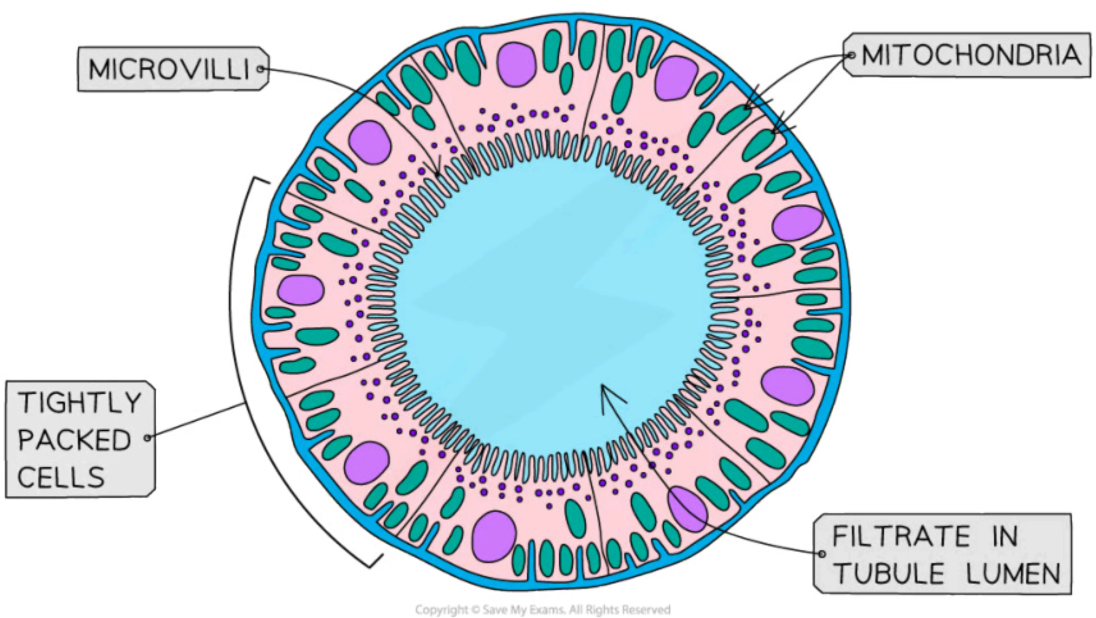
The glomerular filtrate must pass through three layers during ultrafiltration; the capillary endothelium, the basement membrane, and the Bowman's capsule epithelium

Your notes

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 **most 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
- 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
- Once useful substances are reabsorbed, the other unwanted solutes and toxins that remain in the filtrate will be excreted in urine

Proximal convoluted tubule cross-section diagram



The proximal convoluted tubule, seen here in cross section, has several adaptive features to aid selective reabsorption

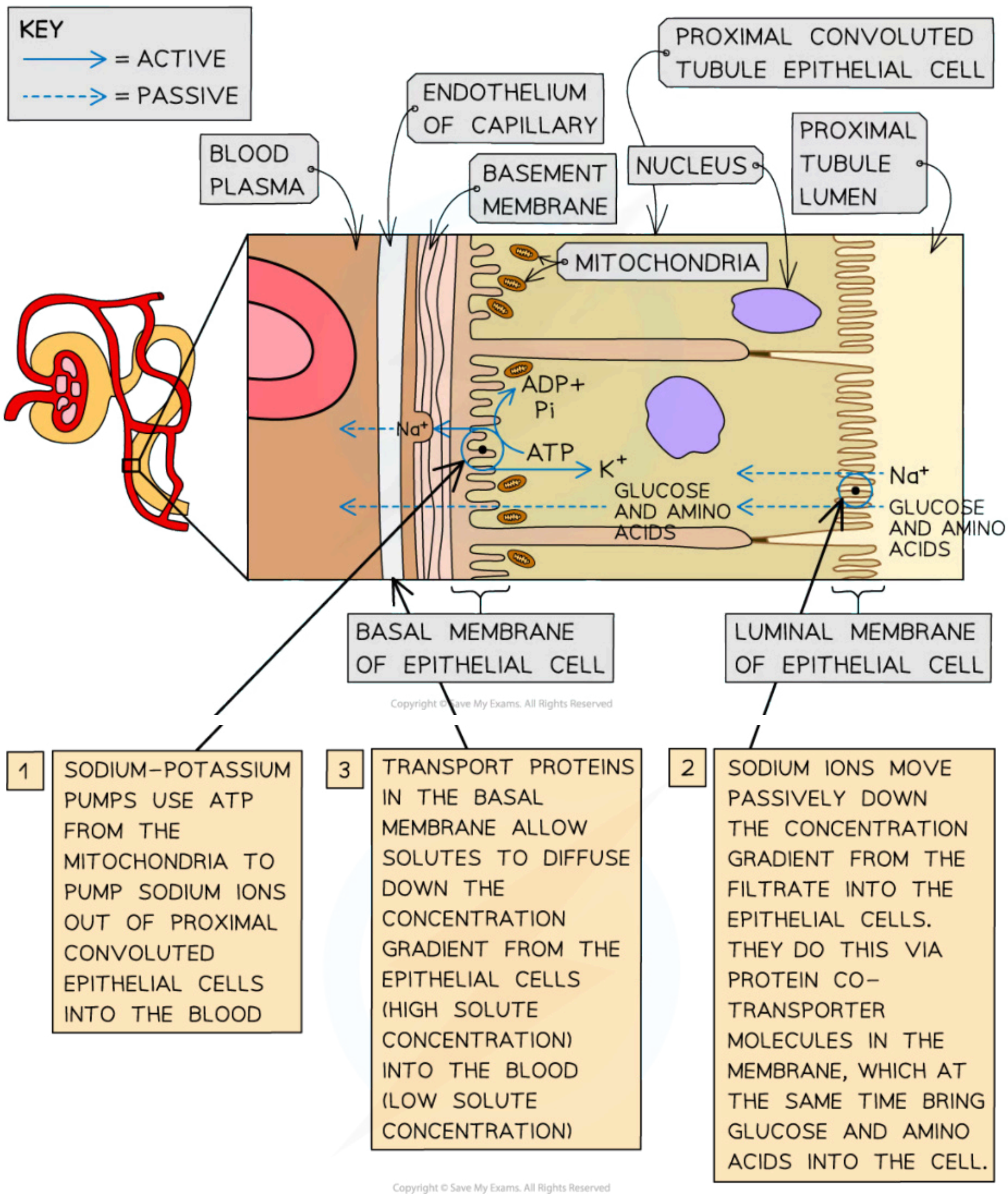
Adaptations for selective reabsorption table

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 (e.g. 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)

The process of selective reabsorption

- **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 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

Cotransport in the proximal convoluted tubule diagram



Sodium ions, as well as sugars and amino acids, are reabsorbed by the action of cotransporter proteins

Note that while diffusion occurs during this process, cotransport is considered to be an active process

Your notes

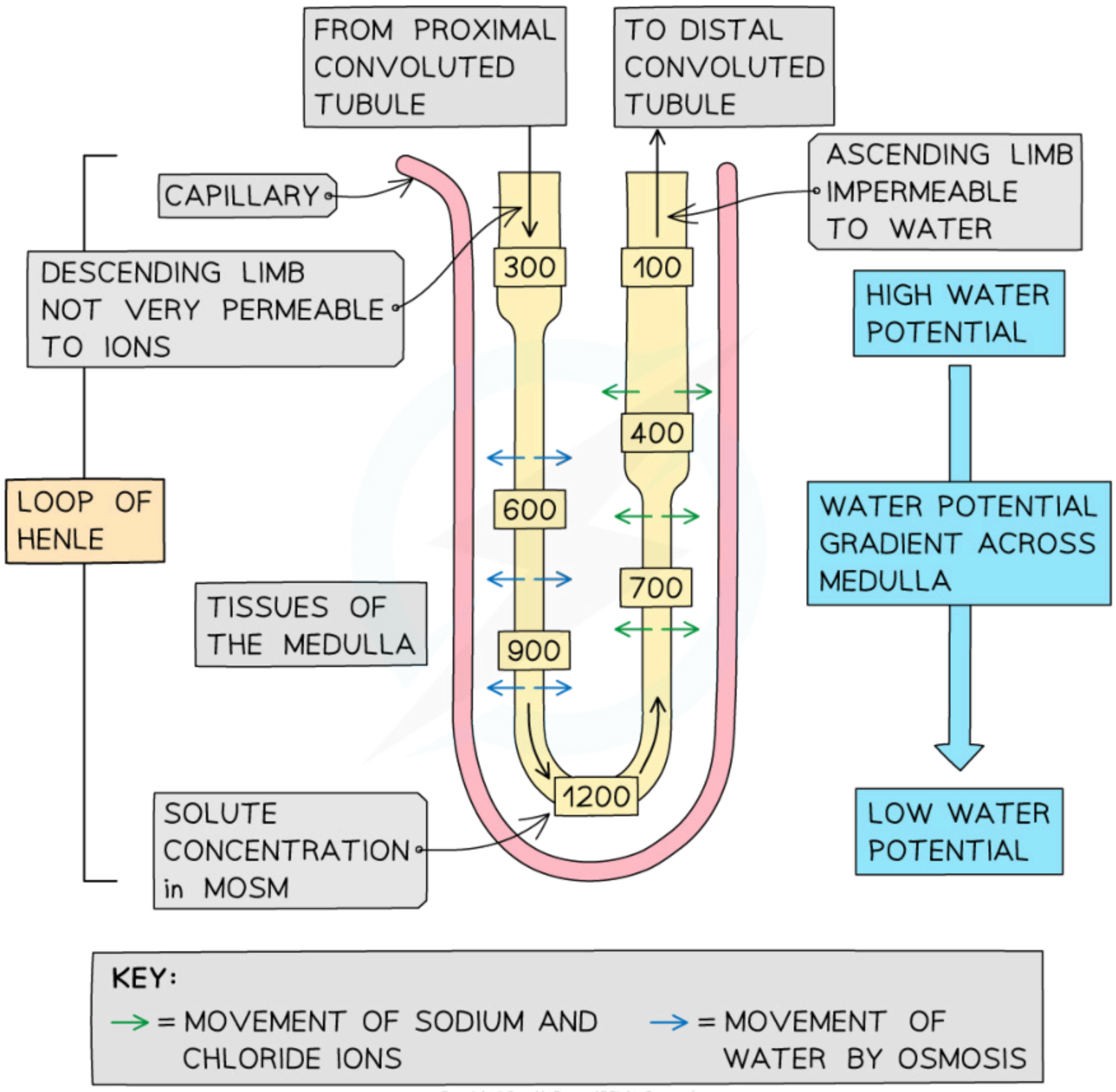
Water Reabsorption in the Loop of Henlé

- 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**
  - 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

The process in the loop of Henle

- **Sodium** and **chloride** ions are pumped **out of the filtrate in the ascending limb** of the loop of Henle into the **surrounding medulla** region, lowering its water potential
  - 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 of 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 of 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 low water potential in the medulla created by the ascending limb also enables the reabsorption of water from the **collecting duct** by osmosis
- The water and ions that leave the loop of Henle for the medulla make their way **into nearby capillaries**
  - The capillary that flows directly alongside the loop of Henle is known as the **vasa recta**
  - The vasa recta also supplies oxygen to and removes carbon dioxide from the **respiring cells of the loop of Henle**

Water reabsorption in the loop of Henle diagram



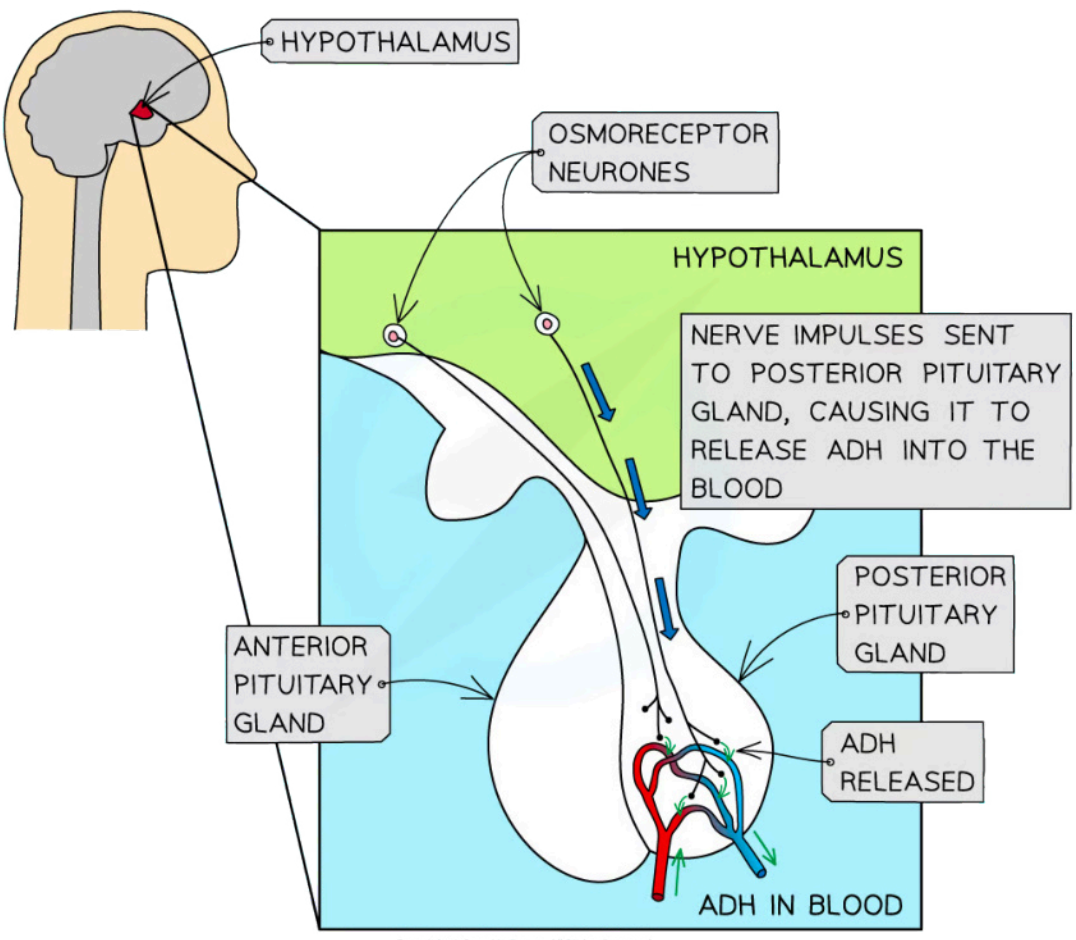
The loop of Henle generates a steep water potential gradient across the medulla, maximising the reabsorption of water

Your notes

Water Reabsorption in the Collecting Ducts

- Living organisms can maintain a **safe balance of water and solutes** in their bodies by **osmoregulation**
  - **Osmoregulation** is an example of homeostasis
- The kidneys play an important role in osmoregulation by altering the **amount of water reabsorbed** from the glomerular filtrate into the blood
- The amount of water reabsorbed by the kidneys can be regulated by changing the **permeability of the walls of the distal convoluted tubule** and **collecting duct** to water
- The permeability of these parts of the nephron is regulated by a hormone called **antidiuretic hormone**, or **ADH**
- ADH is released from the posterior section of the **pituitary gland** in the brain, which is regulated by a region of the brain called the **hypothalamus**
  - The hypothalamus **monitors the composition of the blood** as it flows past osmoreceptor cells in the brain, as well as **receiving signals from receptors** elsewhere in the body

Osmoreceptors in the hypothalamus diagram



Blood water content is monitored by osmoreceptor cells in the hypothalamus, which then regulates the release of ADH from the posterior pituitary gland into the blood

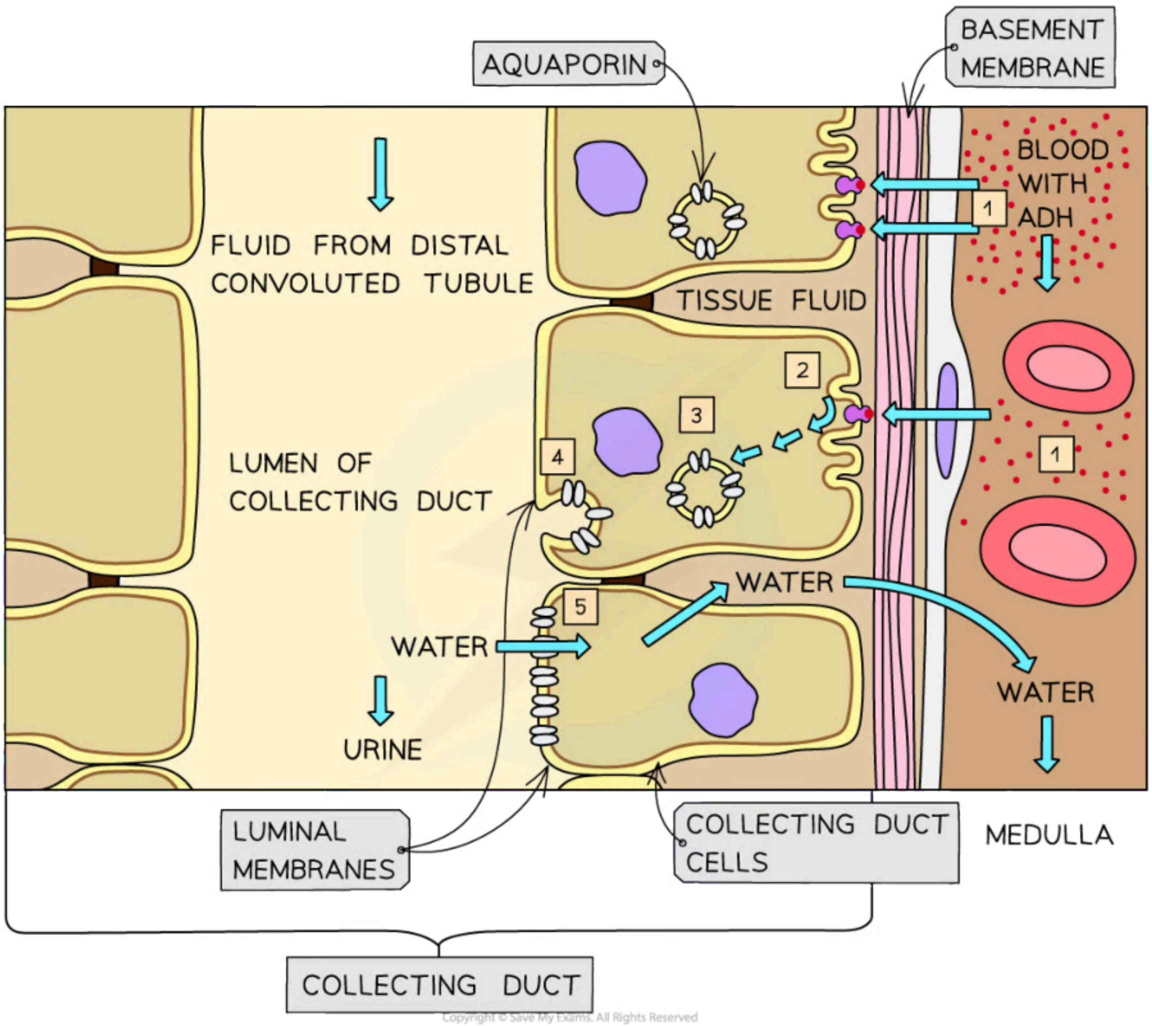
Your notes

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**
  - 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
  - Aquaporins are stored in the **membranes of vesicles** in the cells that line the collecting duct; ADH causes these vesicles to **fuse with the cell surface membranes**, incorporating the aquaporins into the cell surface membranes
- **More water is reabsorbed into the blood** via the distal convoluted tubule and collecting duct
  - The activity of the loop of Henle generates a **concentration gradient across the medulla**, meaning that as the collecting duct descends into the medulla the **osmolarity of the tissues of the medulla increases**; this means that **water is reabsorbed by osmosis** all the way down the length of the 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 volume** of **concentrated urine** is produced

Aquaporin vesicles diagram

Your notes



ADH causes vesicles containing aquaporins to fuse with the cell surface membrane of cells that line the collecting duct, increasing the permeability of the walls of the collecting duct to water

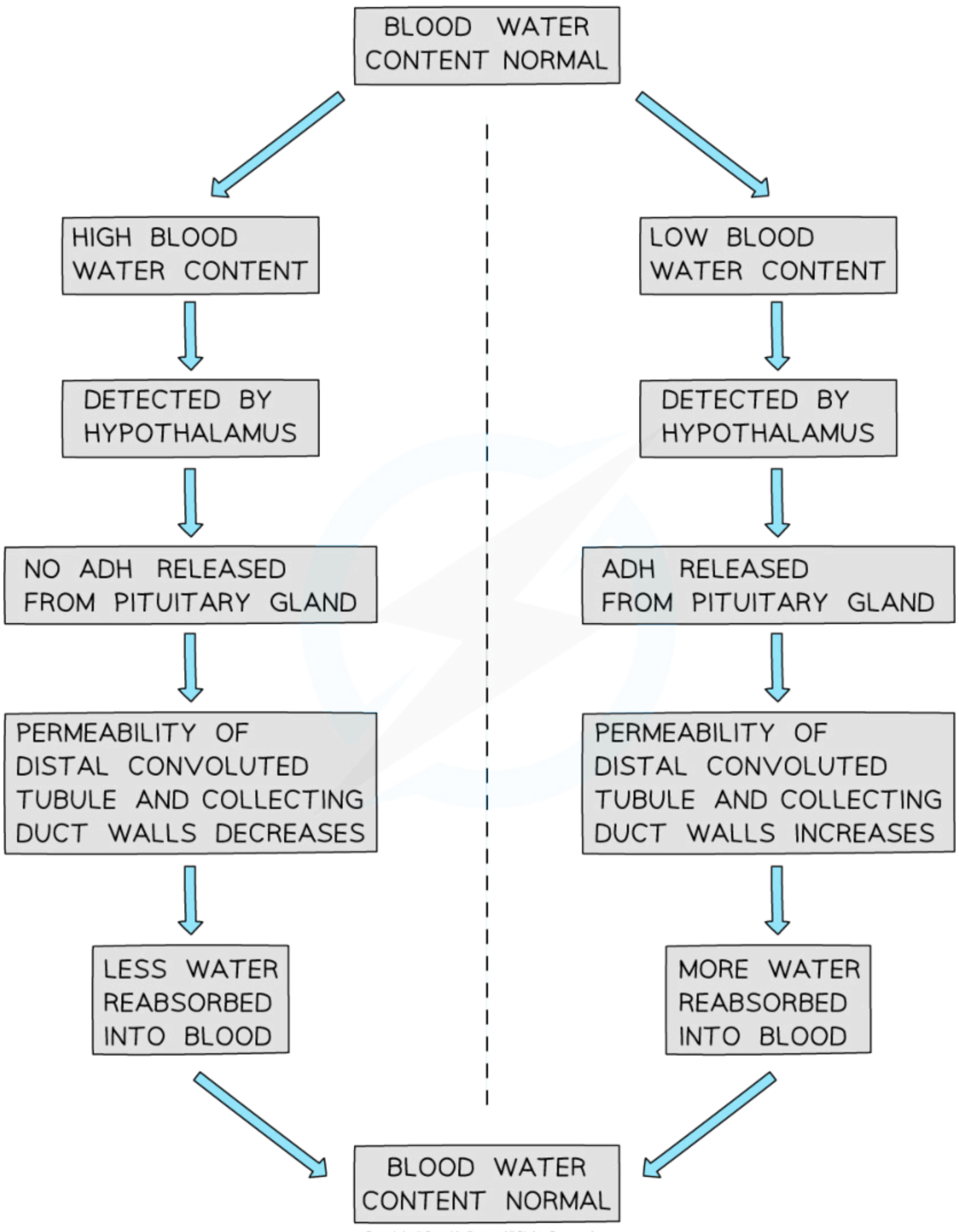
High blood water content

- 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**
  - 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
  - The cell surface membrane is pinched inwards to **reform the vesicles** in which aquaporins are stored

- **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

Osmoregulation diagram



Osmoregulation is an example of homeostasis; the volume of water reabsorbed by the kidneys into the blood is regulated

Your notes

Changes in Blood Supply to Organs (HL)

Changes in Blood Supply to Organs

- The role of the circulatory system is to **supply the cells of the body with oxygen and nutrients**, and to **remove the waste products of metabolism**
- The requirements of the cells in different parts of the body will **differ depending on the activity levels of the body**, e.g.
  - During **exercise** the **muscles** will require **more oxygen and glucose** to fuel muscle contraction, so will need an **increased blood supply**
  - After a **meal** the **digestive system** will require **more oxygen and glucose** to fuel digestion and absorption, so will need an **increased blood supply**
- The circulatory system can **divert blood** flow to increase or decrease the blood supply to different organs
  - This is achieved by vasodilation or vasoconstriction in the **arterioles** that supply the capillary beds in different parts of the body

- The blood supply to the organs may change as follows:
  - **Skeletal muscles**
    - During sleep the skeletal muscles are relaxed and blood flow to these muscles is relatively low
    - During wakefulness some muscle groups will be working to keep the body upright, and blood flow will increase
    - There will be a large increase in blood flow during physical exercise, as rapid contraction of many muscle groups will occur
  - **Gut**
    - Soon after a meal the blood flow to the gut will increase
    - Blood flow decreases during exercise so that more blood can be diverted to the skeletal muscles
  - **Brain**
    - The blood flow to the brain remains relatively constant regardless of the activity levels of the body, as it carries out processes that need to occur all the time
    - Blood flow increases slightly during a stage of sleep known as REM
  - **Kidneys**
    - Blood flow does not change significantly on the basis of activity level, but will increase slightly during sleep and rest, and decrease slightly during prolonged exercise