Excretion Scope

Topic	Topic breakdown
Excretion in humans	Differentiate between excretion and secretion Brief role of the following organs in excretion organs: - Lungs - Kidneys and bladder - Liver - Alimentary canal (Gut) - Skin Substances excreted by each of the excretory organs and their origins Structure of the urinary system (kidneys, ureters, bladder and urethra) Structure and functions of the kidney - Removal of urea and excess water and salts - Re-absorption of glucose and some salts - Control of the water balance in the body - Regulation of pH Structure and functioning of the nephron - Ultra-filtration - Re-absorption - Tubular excretion - pH control - Formation of urine Homeostatic control of water and salts (Osmoregulation) Role of ADH and aldosterone

Excretion

The human body is designed to effectively remove waste.

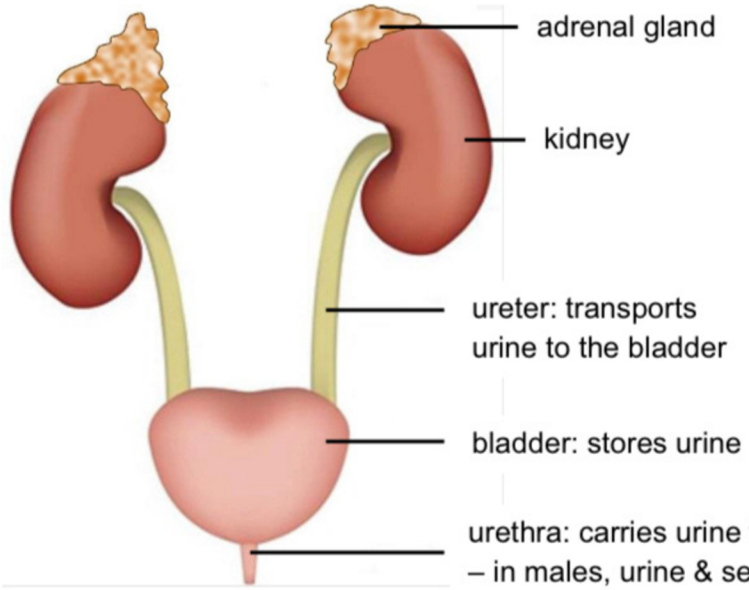
Excretion

Excretory waste products include CO_2, H_2O, bile pigments, urea and mineral salts.

Waste products	Origin	Excreted product
Lungs		
carbon dioxide and water vapour	cellular respiration	CO_2 and $H_2O(g)$ in exhaled air
Skin (sweat glands)		
mineral salts, traces of urea, water	extracted from the blood	perspiration (sweat)
Liver		
urea	deamination of excess amino acids	faeces
bile pigments	breakdown of haemoglobin	
Colon		
bile pigments, excess mineral salts	from the breakdown of haemoglobin in the liver	faeces
Kidney		
urea	deamination of excess amino acids in the liver	urine
mineral salts	excess taken in with food	
water	excess water consumed and taken in as food	

Excretion
Urinary system

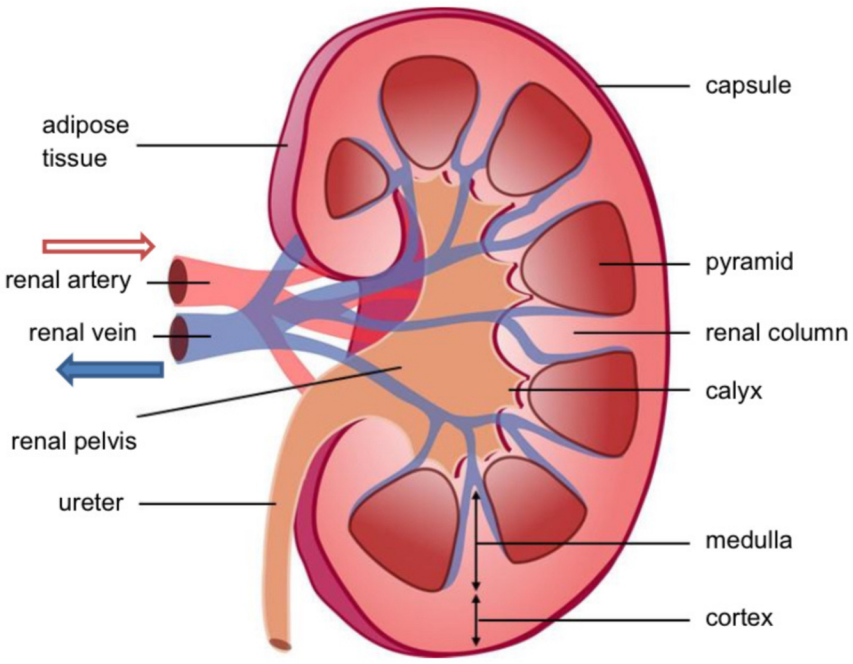
The two **kidneys**, two **ureters**, **bladder** and **urethra** form the **urinary system**. The renal blood supply, including an extensive network of blood **capillaries**, ensures that a steady flow of blood reaches and leaves the kidneys.



four **main functions** of the urinary system

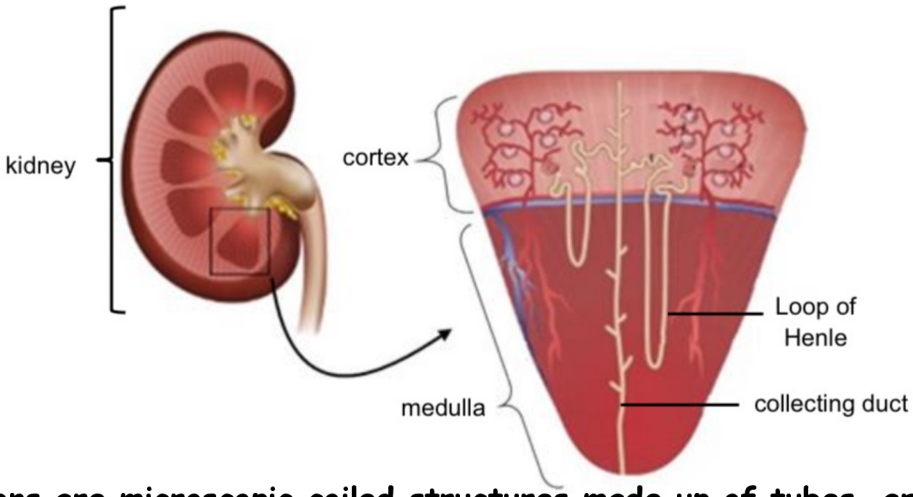
- **Osmoregulation** – regulation of levels of H_2O in body fluids
- **Excretion** – removal of nitrogenous waste e.g. urea
- **Regulation of pH** of body fluids
- **Regulation of salt** concentration of body fluids

- The kidneys are protected by **adipose** (fat) tissue and each kidney is covered by a **renal capsule** which protects the kidney and its internal structures from infections.
- Blood carrying waste products but rich in oxygen, is taken to the kidneys by the **renal artery** which branches off the aorta.
- The blood is filtered by the kidney.
- Deoxygenated blood with the waste products removed, leaves the kidney through the **renal vein**.

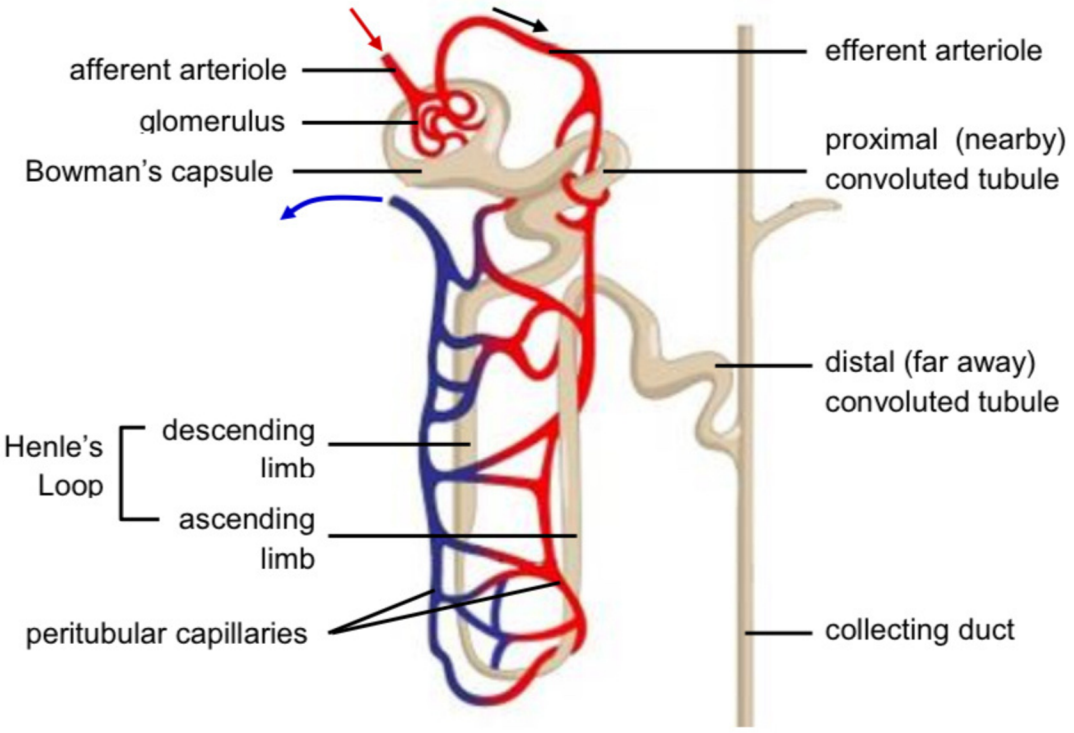


Excretion
Urinary system
The kidney

The kidneys are highly complex filtration organs. Once in the kidney the renal artery branches into narrower blood vessels until they are in contact with the core functional unit of the kidney, the **nephron**



Nephrons are microscopic coiled structures made up of tubes, arterioles, capillaries and ducts. Each human kidney has about 1 million nephrons.
Their main function is to filter the blood, regulate the waste, water and other important substances the body needs.



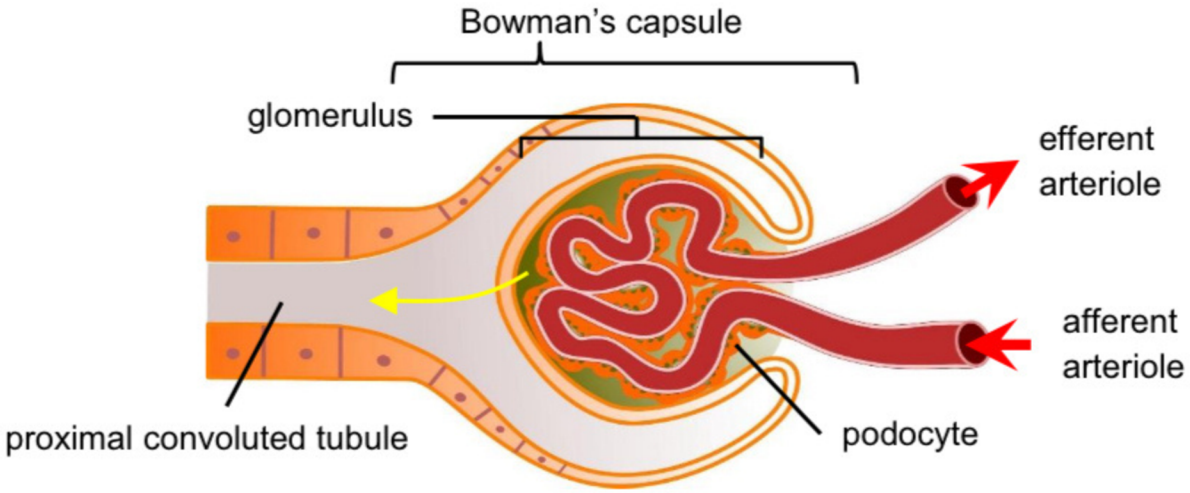
The nephron can be divided into 2 separate sections – the Malpighian body and the renal tubule.

Excretion

The nephron

The Malpighian body (renal corpuscle) occurs in the cortex region of the kidney:
it includes the cup-shaped Bowman's capsule
a dense capillary network in the hollowed out region of the capsule called the glomerulus.
The inner lining of the Bowman's capsule has special cells called podocytes (with finger-like extensions that wrap around the capillaries of the glomerulus)
There are slits between these extensions to allow substances to pass through.

The renal tubule:
This includes the proximal convoluted tubule in the cortex,
the loop of Henle which runs into the medulla and the distal convoluted tubule back in the cortex. The distal tubule feeds into the collecting ducts that lead to the pelvic region of the kidney.
The renal tubule is surrounded by a secondary capillary network known as the peritubular capillary network.
Cuboidal epithelial cells line the renal tubule and have microvilli extensions on their surface. Each of these cells has a rich supply of mitochondria.
Energy supplied by cellular respiration can be used to move substances against a gradient.



As a structural unit

Many nephrons make up the kidney

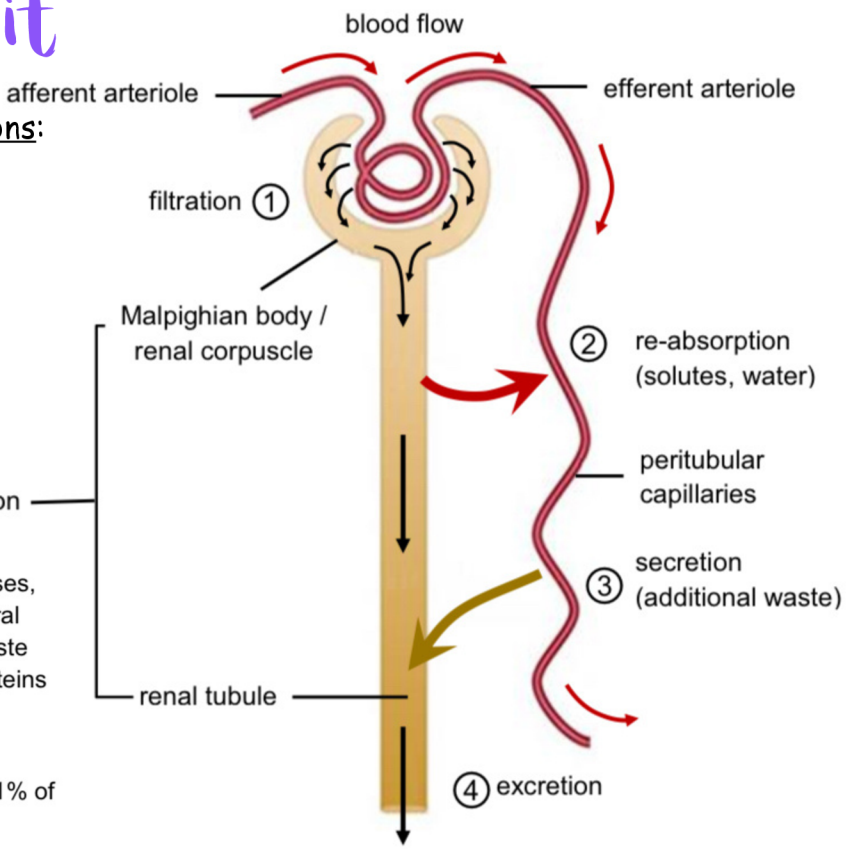
Excretion

The nephron

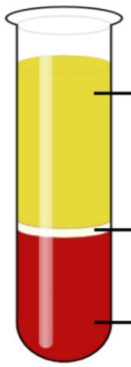
As a functional unit

It performs the following kidney functions:

- glomerular filtration or ultrafiltration
- tubular re-absorption
- tubular secretion
- excretion



Blood Composition



liquid plasma: made up of water, dissolved gases, useful dissolved substances e.g. glucose, mineral salts, amino acids and fatty acids, dissolved waste e.g. urea, uric acid and creatinine and large proteins 55% of total blood

leukocytes (white blood cells) and platelets (< 1% of total blood)

erythrocytes (red blood cells) (45% of total blood)

Glomerular filtration

Glomerular filtration takes place in the Malpighian body of the nephron. Blood enters the glomerulus from the renal artery in the afferent arteriole and leaves the glomerulus in the efferent arteriole.

The afferent arteriole is wider than the efferent arteriole. This results in the blood being put under high pressure forcing the plasma with dissolved substances into the Bowman's capsule

The walls of the glomerulus capillaries are thin and consist of a single layer of squamous epithelial cells. This together with the podocytes found on the inner wall of the Bowman's capsule make ultra-filtration possible.

Only the smaller dissolved substances travel through the filtration slits between the podocytes. Larger proteins remain in the blood.

Bowman's capsule is cup-shaped to enlarge the contact area with the glomerulus.

The formation of the **glomerhular filtrate** is a non-selective process, i.e. both useful (e.g. glucose, amino acids, vitamins, minerals and water) and waste substances (e.g. urea and uric acid) are filtered through into the capsule.

Excretion
The nephron

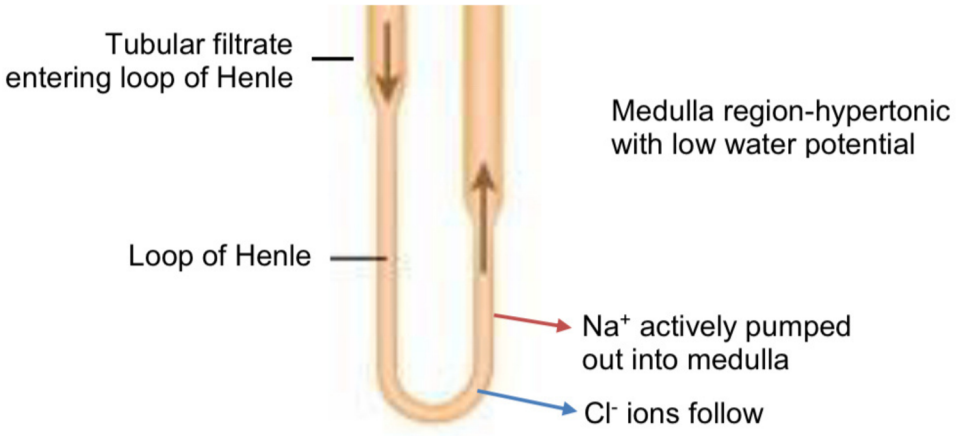
Tubular reabsoption

takes place in the **proximal convoluted tubule** (involves active re-absorption of the glucose, amino acids, vitamins and other important substances that ended up in the **glomerular filtrate.**
About 65% of the water also moves back into the blood of the peritubular capillaries by **osmosis** (to prevent dehydration and any unnecessary loss of important substances).

Cuboidal epithelial cells lining the tubules have many mitochondria (site for cellular respiration). Microvilli on these same cells increase surface area for maximum re-absorption. The movement of water is by the passive process of osmosis. The fluid in the renal tubule is now called **tubular filtrate.**

The Loop of Henle ensures that water is conserved and recovered from the filtrate and returned to the blood. The cells lining the ascending loop of Henle are impermeable (block movement) to water. Salt is actively pumped out of the loop and into the medulla tissue of the kidney. The **medulla** becomes **hypertonic** (very salty) which means it has a low water potential (water does not want to leave). A steep gradient develops between the tubular filtrate and the medulla tissue.

The **distal convoluted tubule** and the **collecting ducts** are very permeable to water so when the filtrate enters these areas water flows passively by osmosis into the medulla tissue and back into the blood of the peritubular capillaries. The amount of water that moves out of the filtrate is determined by the level of hydration of the body fluids and is regulated by the **antidiuretic hormone (ADH).**



Excretion
The nephron

Tubular secretion

Tubular secretion is the removal of unnecessary substances from the blood in the peritubular capillaries into the tubular filtrate in the distal convoluted tubule.

The substances removed include:
- creatinine
- hydrogen ions (H+)
- ammonia
- sodium ions (Na+)
- potassium ions (K+)
- bicarbonate ions
- drugs e.g. penicillin

Exretion of urine

Removal of the waste products of metabolism (Urine) from the body,

The filtrate that enters the collecting duct is now called urine.
Urine consists of:
- urea
- excess water
- and salts.

Useful substances should not be excreted in the urine.
Urine collects from all the collecting ducts and empties into **renal pelvis**.
Urine passes down the **ureter** and into the **bladder**.
The bladder has muscles that control the release of urine into the urethra and **urination** occurs.

Excretion
Homeostasis

Homeostasis is the human body has the ability to maintain a stable internal environment.

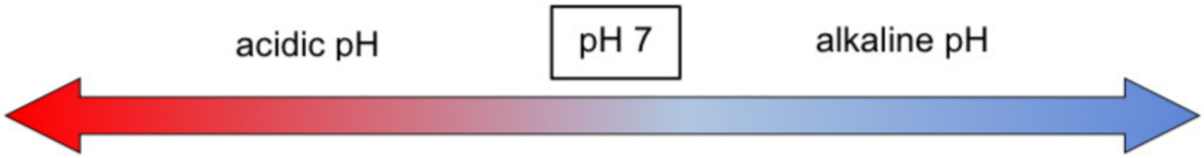
It is important that the body's temperature is kept within a narrow range of around 37°C. The pH of the body fluids needs to be regulated and the composition of these fluids need to be kept within certain limits for effective metabolism.

The kidney is involved in 3 homeostatic mechanisms:

- the **regulation of pH** of the blood (considered above)
- the **regulation of water** levels (osmoregulation)
- the **regulation of salt** levels in the blood

Control of pH

The ability of the distal convoluted tubule to take up hydrogen and bicarbonate ions is important in the regulation of the pH of the blood. Homeostasis is maintained.



Low pH in the blood due to **high hydrogen ion** (H^+) **concentration** Hydrogen ions move from blood in peritubular capillaries and into distal convoluted tubule Less hydrogen ions in the blood pH returns to normal (pH 7,4)	**High pH** due to **high bicarbonate** (HCO_3^-) **ion concentration** Bicarbonate ions move from the blood in the peritubular capillaries and into the distal convoluted tubules Less bicarbonate ions in the blood pH returns to normal (pH 7,4)

Excretion

Homeostasis

Osmoregulation

The **homeostatic** control of water and salt levels in blood and tissue fluid is known as osmoregulation.

ADH is produced by the hypothalamus and secreted from the pituitary gland and helps to limit water loss in the urine and prevent dehydration

Too little water in the blood	Too much water in the blood
Dehydration is when the blood and tissue fluid are short of water	**Overhydration** occurs when the blood and tissue fluids are very dilute.
This can be brought about by excessive exercise, hot temperatures, increased sweating or decreased water intake.	This can be because of cooler temperatures, little exercise with no sweating and an excessive intake of water.
This low level of H_2O is detected by the hypothalamus of the brain.	Water levels are elevated, and this is detected by the hypothalamus.
The pituitary gland releases antidiuretic hormone (ADH)	The pituitary gland releases less ADH.
The hormone is transported in the blood to the kidney. The permeability of the collecting duct and the distal convoluted tubule is increased.	Collecting ducts and distal convoluted tubules in the kidney become less permeable.
More H_2O is absorbed and passed into the blood.	Less H_2O is absorbed into the blood.
The blood becomes more dilute and less, concentrated urine is excreted.	Less water leaves the collecting duct and more, dilute urine is excreted.

Alcoholic and caffeine containing drinks act as diuretics (they cause you to lose water by urinating frequently). ADH acts in an opposite way as it helps the body retain water.

Excretion
Homeostasis

Control of salt

The blood and tissue fluids are affected by the presence of **solutes** (dissolved substances). **Sodium** and **potassium** are salts that are found in the body fluids. Sodium is important in the body for good nerve and muscle functioning.

Low salt levels in blood and tissue fluids make these fluids **hypotonic**	Elevated **salt levels** in the blood / tissue fluids make these fluids **hypertonic**.
Receptor cells in the afferent and efferent arterioles of the glomeruli of the kidney will detect decreased Na^+ levels.	Receptor cells in the afferent and efferent arterioles will detect an increased presence of Na^+.
The adrenal gland in the kidney secretes the hormone aldosterone.	The adrenal gland will stop releasing aldosterone.
Aldosterone stimulates the reabsorption of Na^+ from the filtrate and back into the blood.	Na^+ will not be reabsorbed.
Less sodium is excreted in the urine.	More sodium is excreted in the urine.

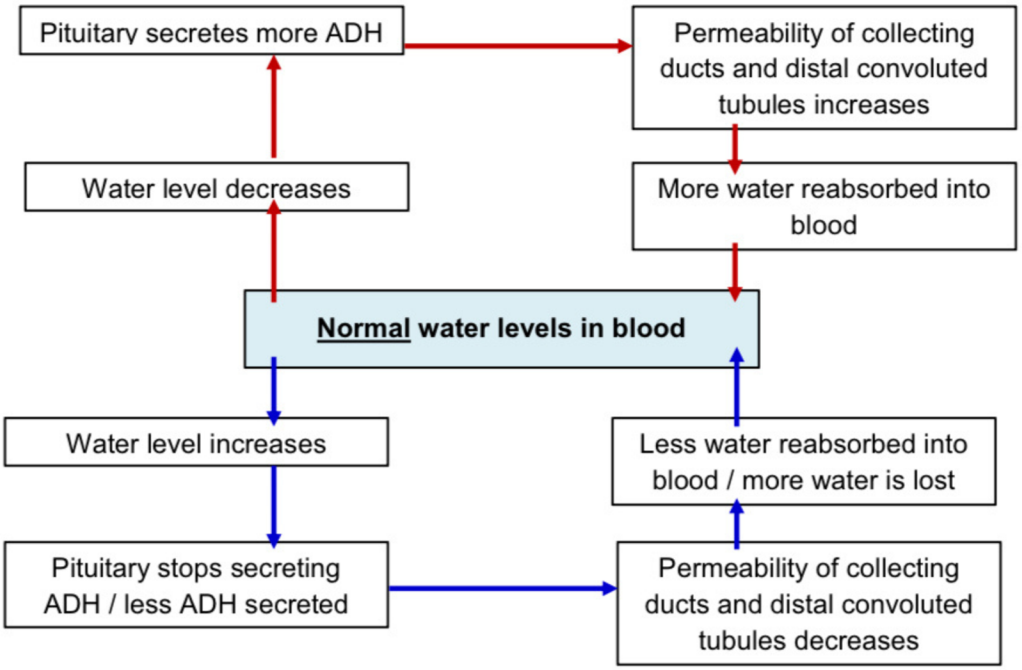
Excretion Homeostasis

Role of ADH and aldosterone

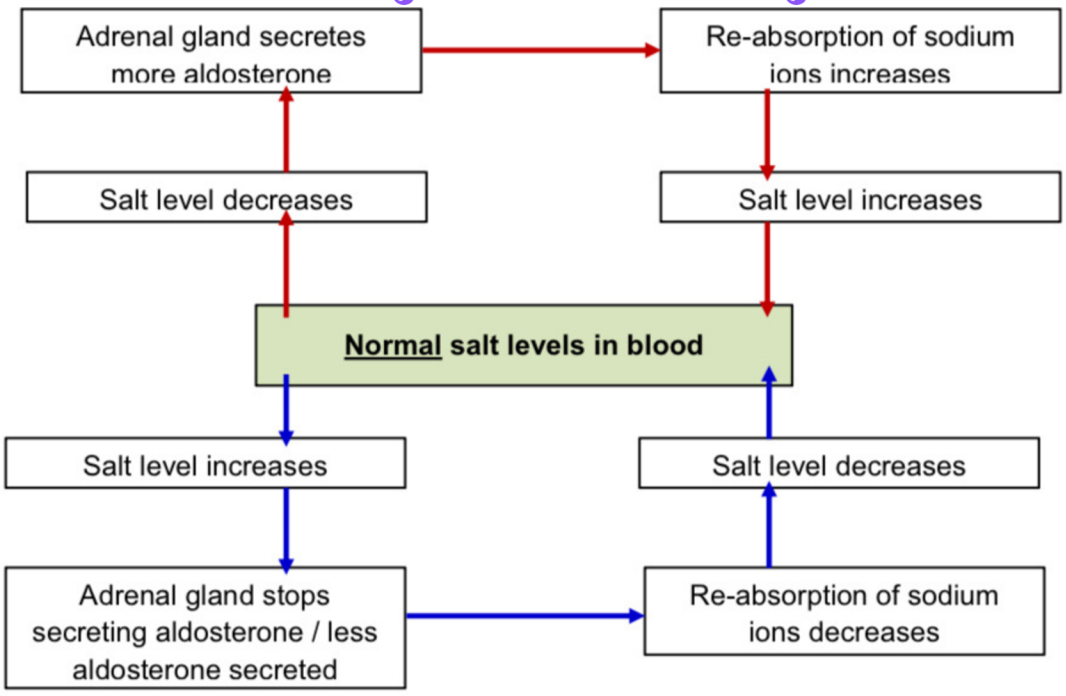
ADH and aldosterone are hormones that regulate water and salt levels in the blood.

The control centre for osmoregulation is the hypothalamus while the control centre for salt regulation is the adrenal gland. Both osmoregulation and salt regulation target organ is the kidney.

Osmoregulation diagram



Salt regulation diagram



Excretion Terminology

Key terminology

excretion	the removal or elimination of metabolic waste from an organism
secretion	the release of a useful substance (enzymes, saliva) from cells or glands
egestion	the removal of undigested food solid waste from the digestive tract in the form of faeces = defaecation
metabolism	chemical reactions that take place within every cell of the body. these can be building up (anabolic) or breaking down (catabolic) reactions
renal	relates to the kidney
deamination	removal of an amino group from amino acids

osmoregulation	the control of water levels in the body
adipose	fat tissue
aorta	the main artery leaving the heart, supplying body with blood
renal artery	brings oxygenated, unfiltered blood to the kidneys
renal vein	carries deoxygenated, filtered blood, from the kidneys
renal capsule	outer membrane covering the kidney

nephron	the microscopic functional unit of the kidney
podocytes	specialised cells lining the Bowman's capsule in the kidney
afferent arteriole	blood vessel bringing blood from the renal artery into the bowman's capsule of the nephron and forming the glomerulus
efferent arteriole	blood vessel taking blood from the glomerulus and into the peritubular capillary
glomerulus	a dense capillary network in the Bowman's capsule of the kidney
Bowman's capsule	a cup-shaped structure surrounding the glomerulus
Malpighian body / renal corpuscle	made up of the glomerulus plus Bowman's capsule
proximal convoluted tubule	the folded portion of the nephron that lies between Bowman's capsule and the loop of Henle

distal convoluted tubule	the folded portion of the nephron between the loop of Henle and the collecting tubule.
peritubular capillaries	tiny blood vessels, supplied by the efferent arteriole, that travel alongside nephrons allowing reabsorption and secretion between blood and the inner lumen of the nephron.

hypertonic	a relatively low water and a high salt concentration
hypotonic	a relatively high water and a low salt concentration
permeable	allows substances to flow easily
dehydration	loss of water