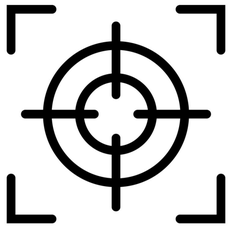
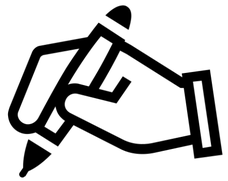
Topic 9: Excretion in Humans

Chapter Analysis



FOCUS

- straightforward chapter
- linked to homeostasis & hormones



EXAM

- commonly tested in MCQ and structured questions
- tested twice in section B in the past 5 years

WEIGHTAGE

- Constitute to around 5% in Paper 2 in the past 5 years

Key Concept

Excretion
Human Urinary System
Kidney and Nephron

Excretion

- Excretion is the process by which the body removes metabolic waste products and toxic materials.
- Important process because metabolic waste products can be harmful to the body if they are not removed and accumulate in the body
- **Metabolic processes** consist of both **anabolic process** and **catabolic process**

Anabolic: reaction that **build small molecules to complex molecules**

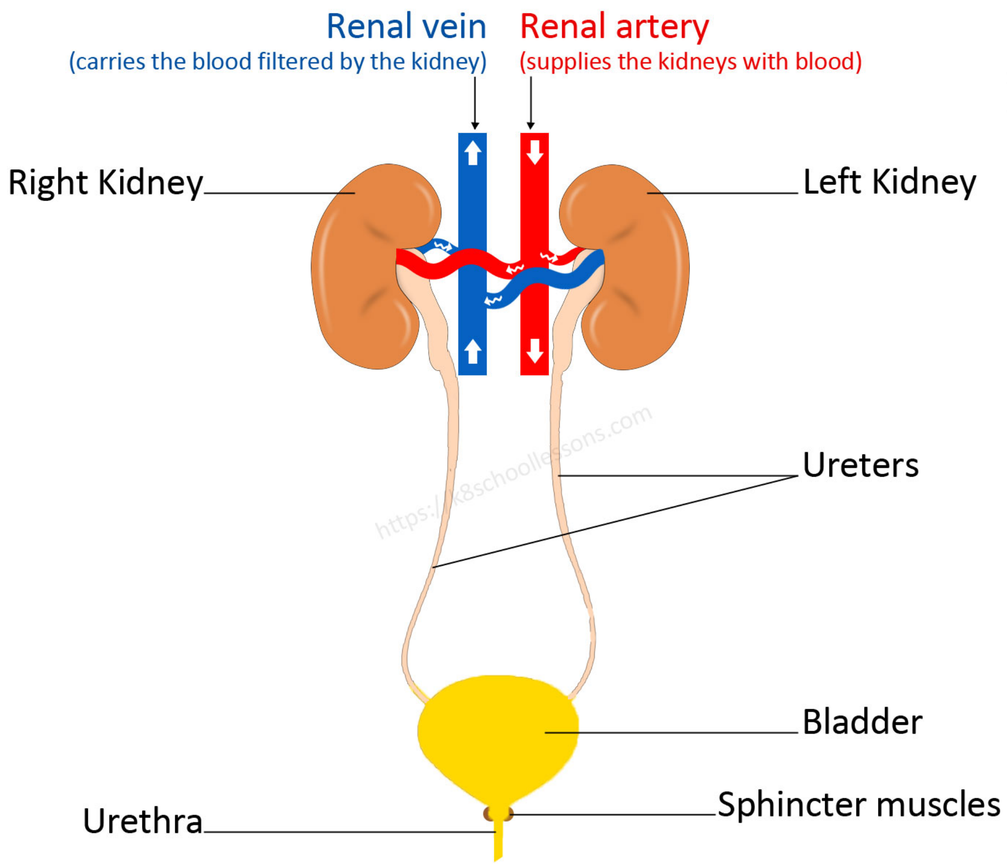
- Condensation reaction eg synthesis of proteins from amino acids, synthesis of glycogen from glucose, synthesis of lipid from fatty acids and glycerol
- Photosynthesis

Catabolic: reaction that **break down complex molecule to smaller molecules**

- Hydrolysis reaction eg digestion of food substance
- Respiration
- Deamination of amino acids

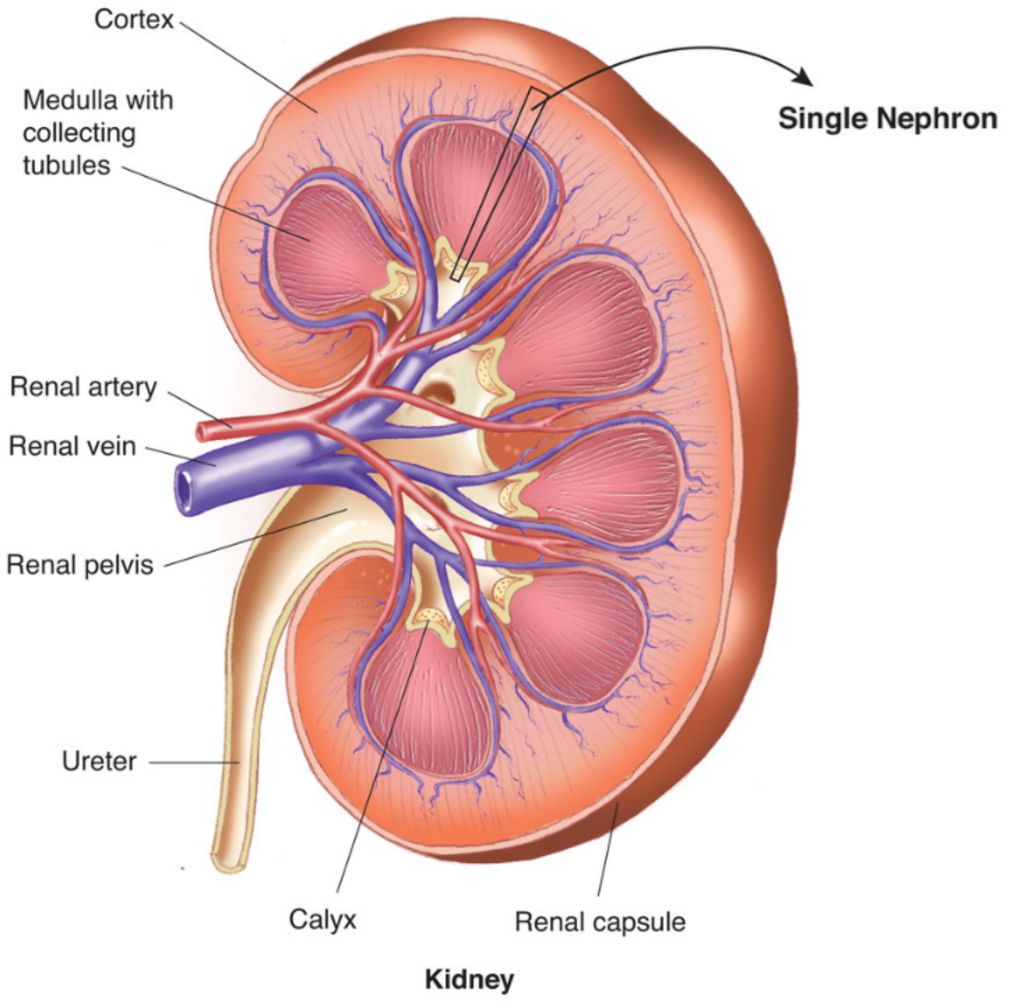
Excretory organs	**Metabolic waste products**	**Excretion**
Lungs	Carbon Dioxide	Exhaled air
Kidneys	Excess mineral salts, urea and excess water	Urine
Skin	Excess mineral salts, small amount of urea and excess water	Sweat
Liver	Bile pigments	Secreted as bile, excreted as part of faeces
Leaves	Oxygen	Diffuse out of leaf

human urinary system



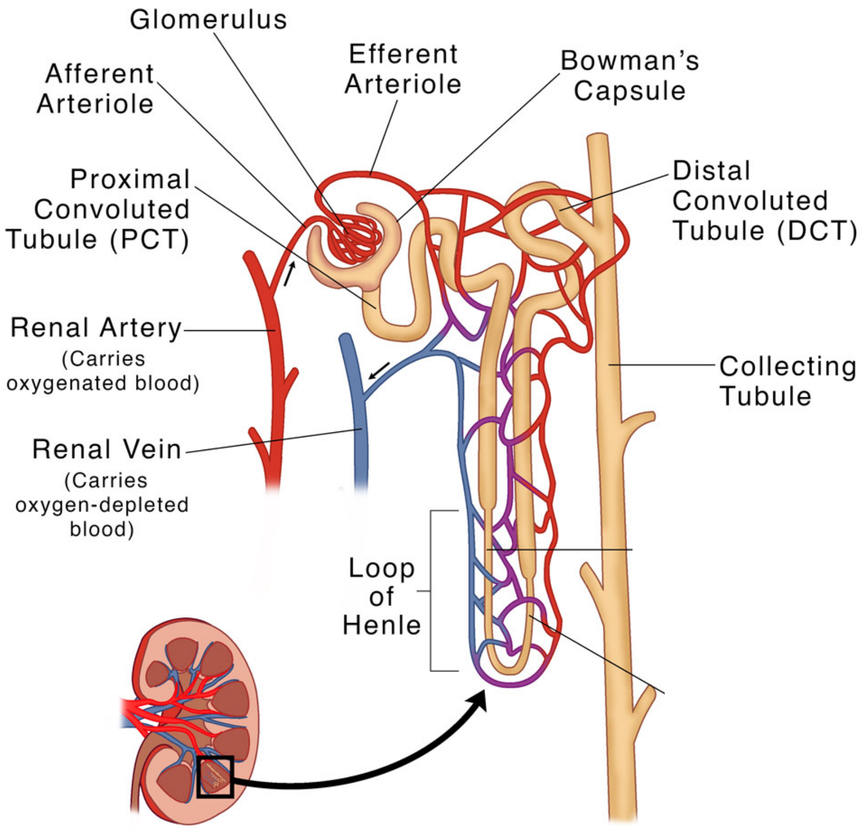
kidney	• two bean-shaped organs • unit of kidney is **nephron**
ureters	Tube that connects the kidney to the urinary bladder
bladder	• an elastic organ that collects and stores urine excreted by the kidneys. • sphincter muscle at the base of the bladder controls the flow of urine into the urethra, which is controlled by nervous impulses from the brain.
urethra	Tube that connects bladder to outside of body

structure of kidney



cortex	The outer region of kidney, covered by protective fibrous renal capsule
medulla	The inner region of kidney consisting of a number of renal pyramids/conical pyramids
renal pyramid	• conical structures consisting of nephrons, which are the urine-producing units of the kidney. • empty urine into the renal pelvis, which will collect urine from all the pyramids to deliver to the ureter
renal pelvis	Enlarged portion of ureter
renal artery and renal vein	Blood enters each kidney from the renal artery and leaves via the renal vein

structure of nephron



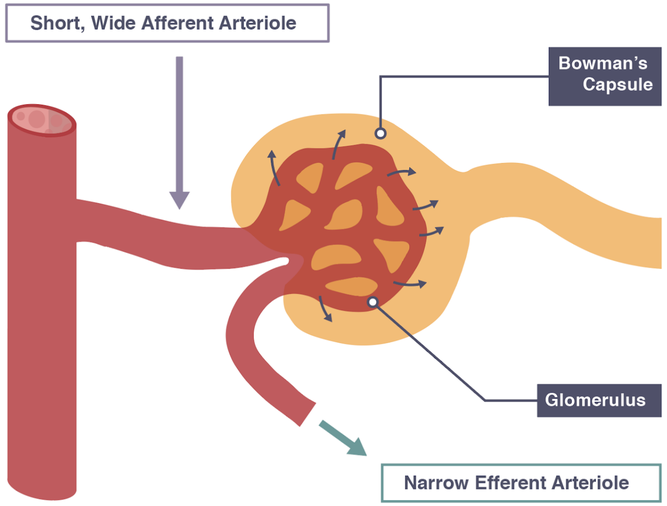
Nephron	functional unit of kidney, responsible of urine formation
renal corpuscle (malpighian corpuscle)	consists of both bowman capsule and glomerulus
glomerulus	A ball of capillaries start from wider afferent arteriole and drains into a narrower efferent arteriole.
bowman's capsule	Surrounds the glomerulus in a cup-like structure
path of blood	renal artery —> afferent arterioles —> efferent arterioles —> capillaries —> venues —> renal vein
proximal convoluted tubule	• responsible for **selective reabsorption** of water, mineral salts, glucose and amino acid • contain many mitochondria
loop of henlé	
distal convoluted tubule	

Key Concept

urine formation
osmoregulation
kidney dialysis

urine formation

ultra filtration



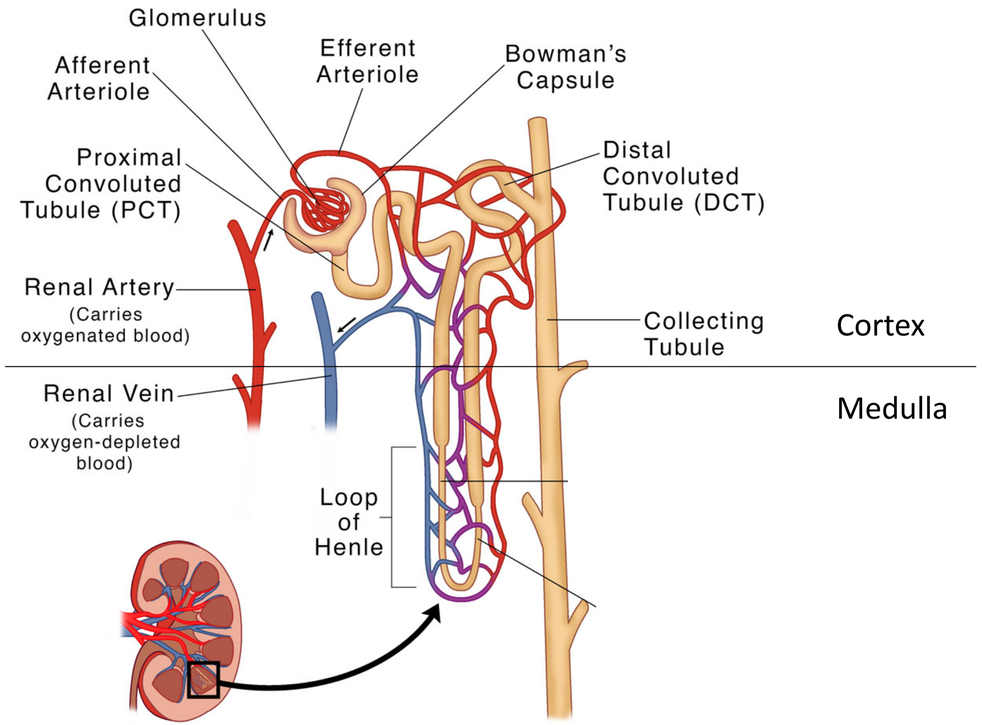
Ultra filtration

1. Blood flows from renal artery and enters the glomerulus through afferent arteriole.
2. **Afferent arterioles** have a **larger diameter** than the **efferent arteriole**, where blood leaves glomerulus, creating high blood pressure or **high hydrostatic pressure**
3. This forces **water, urea, salts** and other small solutes such as **glucose, amino acids** into the **Bowman's capsule**, while **blood cells** and large molecules such as **protein remain in the capillaries**.
4. The **glomerular filtrate** passes from the Bowman's capsule into the proximal convoluted tubule.

- The endothelium of the glomerular capillaries and the basement membrane of the Bowman's capsule that wraps around the glomerular capillaries are **partially permeable** —> only small soluble substances are able to pass through.

urine formation

selective reabsorption



Selective reabsorption

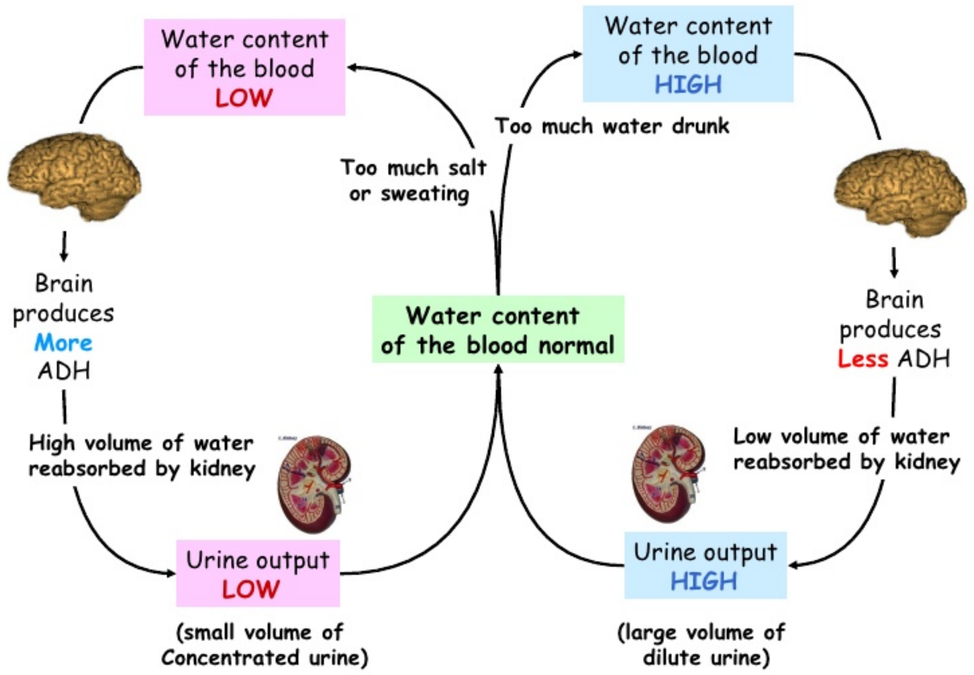
1. At **proximal convoluted tube**, most of the mineral salts and all of the glucose and amino acids are **absorbed through active transport or diffusion**. Water is reabsorbed by **osmosis**.
2. **Reabsorption of water** continues in the **loop of Henlé**.
3. **Water and salts** are reabsorbed in the **distal convoluted tubule**.
4. Water is reabsorbed from the **collecting duct** (not part of nephron)**.**
5. Excess salts, nitrogenous waste products, excess water enter the renal pelvis as urine and are excreted out of the body

osmoregulation

1. Osmoregulation is the maintenance of constant water potential in the body.
2. This is essential for proper functioning of the body.
   - Excess water can cause water to move into cells from tissue fluid by osmosis. This causes the cells to swell and burst.
   - Excess water could also lead to an increase in blood pressure due to an increase in volume. This could lead to stroke.
   - Too little water would cause water to move out of the cells into tissue fluid causing dehydration.
3. Osmoregulation is a homeostatic process, controlled by a hormone called antidiuretic hormone (ADH). ADH is produced by the hypothalamus and released by the pituitary gland

When the blood water potential decreases beyond normal eg eating too much salt or sweating

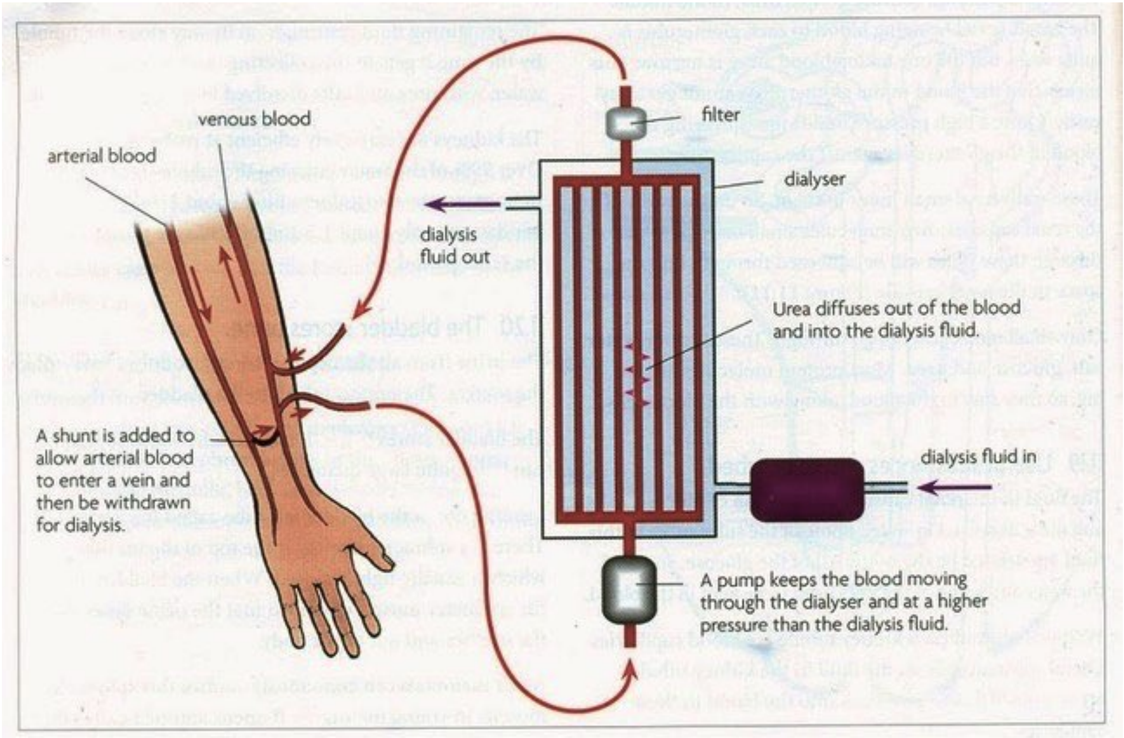
1. **Osmoreceptors in hypothalamus detects** the decrease in water potential
2. **Hypothalamus sends signal to the pituitary gland**, which is stimulated to **secrete more ADH** into the blood.
3. ADH makes the kidney tubules and the collecting ducts **more permeable to water.**
4. This causes more water to be reabsorbed, producing **a smaller volume of more concentrated urine.**
5. Water potential of blood increases and returns to regular levels.



When the blood water potential increase beyond normal eg drinking too much water

1. **Osmoreceptors in hypothalamus detects** the increase in water potential
2. **Hypothalamus sends signal to the pituitary gland**, which is stimulated to **secrete less ADH** into the blood.
3. The kidney tubules and collecting ducts are **less permeable to water.**
4. Less water is reabsorbed resulting in a **larger volume of diluted urine.**
5. The water potential of blood returns to normal levels.

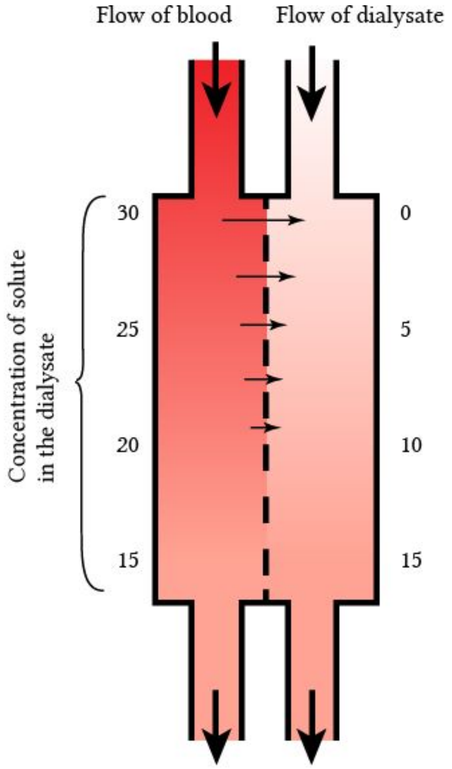
kidney dialysis



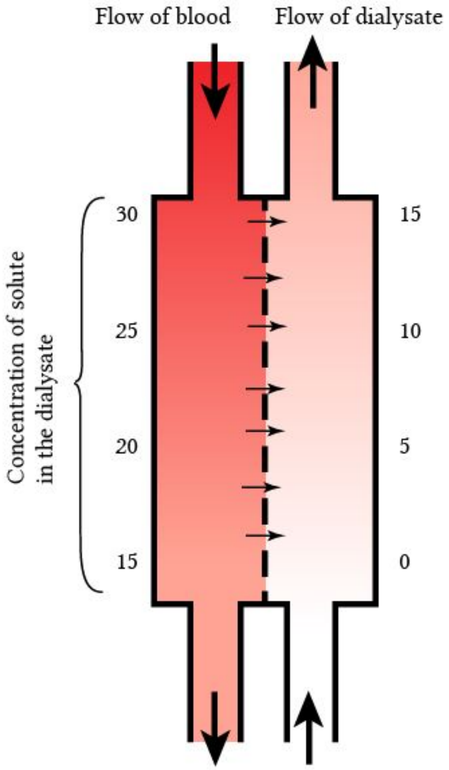
- The kidneys function to r**emove waste products, excess water and excess mineral salts.**
- When kidneys fail to fulfil the function, a **dialysis machine** is needed to perform the functions of a kidney.

1. Blood is **drawn from the vein** in patient's arm and is passed through in dialysis machine.
2. The tubing is bathed in **dialysis fluid** which contains the **same concentration of essential substances as the blood** plasma and with **no waste products.**
3. The tubing is **partially permeable** thus small molecules such as **urea and other metabolic waste products diffuse out** of the tubing into the dialysis fluid. **Blood cells, platelets and other large molecules remain** in the tubing.
4. Blood is then returned to the vein in the patient's arm.

adaptation of dialysis machine



concurrent flow



countercurrent flow

1. Tubing is **narrow, long and coiled**. This **increases surface area to volume ratio** for the **diffusion** of waste material into the dialysis fluid
2. There is **countercurrent flow** which is the **direction of blood flow is opposite to the flow of dialysis machine**. This **maintains the same concentration gradient** along the entire exchange.
3. Dialysis fluid contains the **same concentration of essential substances as blood**. This ensures no essential substances will diffuse out of the blood to the dialysis fluid.
4. Dialysis fluid **does not contain metabolic waste products**. This maintains the steep concentration gradient for waste products to diffuse out of the tubing into the dialysis fluid.

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