# excretion

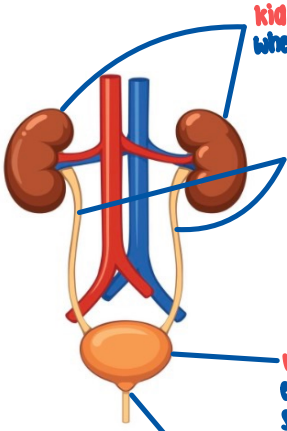
## EXCRETION

- process by which metabolic waste products and toxic substances are removed from the body of an organism
- these metabolic waste products and toxic substances are also known as excretory products
- different ways metabolic waste products are removed from our bodies:

| excretory products | excretory organs | | |
|---|---|---|---|
| | lungs | skin | kidney |
| carbon dioxide | ✓ | | |
| excess mineral salts | | ✓ | ✓ |
| nitrogenous waste products<br>- urea<br>- uric acid<br>- creatinine | | ✓ | ✓ |
| excess water | | | |

# HUMAN URINARY SYSTEM

## PARTS OF THE URINARY SYSTEM



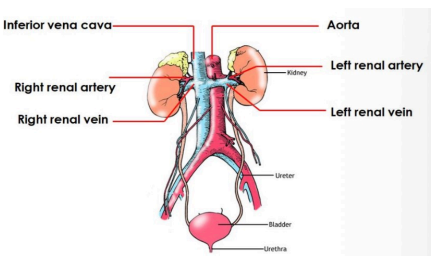
**kidneys**
where urine is formed

**ureters**
tubes that connect the kidneys to the urinary bladder; urine from each kidney passes through the urether to the urinary bladder

**urinary bladder**
elastic, muscular bag that stores urine temporarily

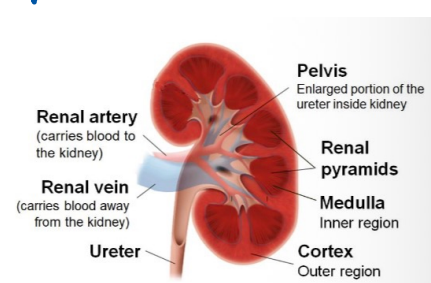
**urethra**
duct through which urine passes from the urinary bladder to outside the body

## BLOOD VESSELS RELATED TO KIDNEYS



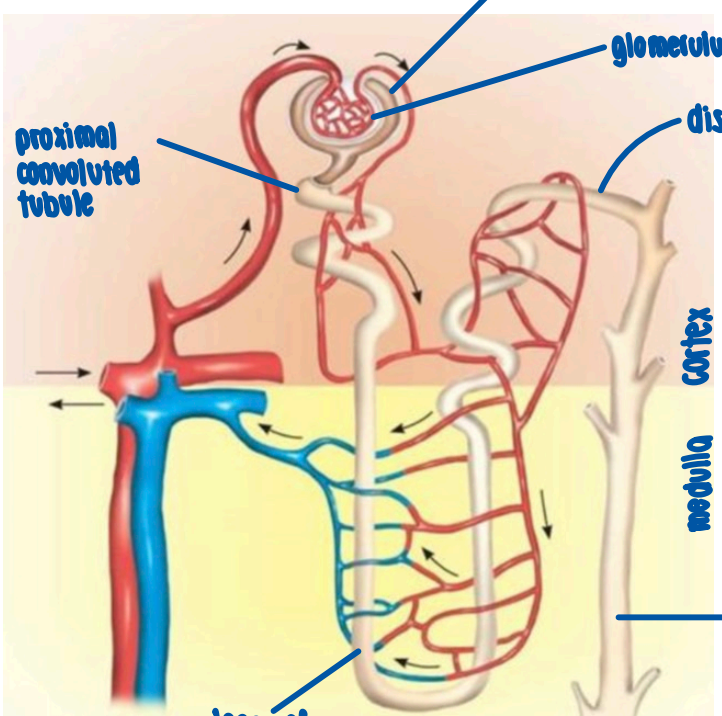

## STRUCTURE OF A KIDNEY

- consists of an **outer cortex** and an **inner medula**
- the renal pyramids are found in the medula. the renal pyramids contain the **nephrons**, aka **kidney tubules**
- nephrons are narrow tubules surrounded by blood vessels. each kidney contains about 1 million nephrons



# Structure of a nephron (kidney tubule)

| structure | function |
|---|---|
| Bowman's capsule | a cup-like structure at the beginning of the kidney tubule |
| glomerulus | mass of blood vessels within Bowman's capsule |
| proximal convoluted tubule | a short, coiled tubule that straightens out as it enters the medulla |
| loop of Henlé | the U-shaped portion of the tubule |
| distal convoluted tubule | kidney tubules coil again after loop of Henlé to form distal convoluted tubule |
| collecting duct | part of the tubule leading from the distal convoluted tubule into the renal pelvis |



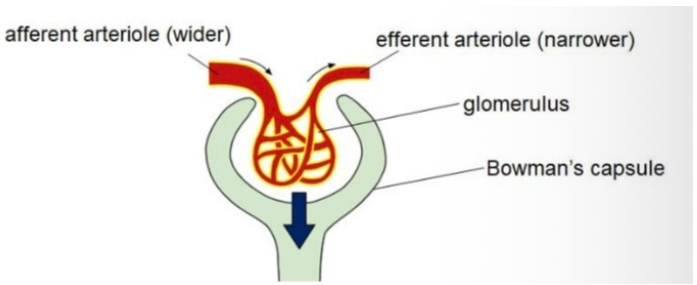
# MAIN FUNCTIONS OF THE KIDNEY

- **excretion**: removal of waste products from the body through excretion
- **osmoregulation**: regulation of the water and solute concentration in the blood, to maintain

↳ these involve urine formation

↳ in the formation of urine, 2 main processes occur in the nephron — ultrafiltration and selective reabsorption

## ULTRAFILTRATION




- the afferent arteriole splits into numerous capillaries which form a knot called a **glomerulus**. the glomerulus is surrounded by the **Bowman's capsule**
- the **afferent** arteriole leading into the glomerulus is **wider** than the one leading out (**efferent** arteriole)
  1) the difference in width leads to **high hydrostatic pressure** in the glomerulus
  2) the high hydrostatic pressure **forces** water and other small **molecules** out of the glomerulus into the Bowman's capsule, forming the **glomerular filtrate**
- the **partially permeable membrane** of the **capillary walls** in the glomerulus works like a filter, only allowing water and small molecules to pass through
- the **basement membrane** surrounding the blood capillaries in the glomerulus is also a **partially permeable membrane**
- large molecules like **blood cells**, **proteins** and **fats**, are retained in the arterioles

| after ultrafiltration | |
|---|---|
| glomerular filtrate in the Bowman's capsule contains | retained in the blood capillaries |
| small molecules such as:<br>nitrogenous waste products (e.g. urea, uric acid, creatinine)<br>• mineral salts<br>• glucose<br>• amino acids<br>• water | large molecules such as:<br>blood cells<br>• platelets<br>• proteins<br>• fats |

## COMPOSITION OF BLOOD IN THE AFFERENT & EFFERENT ARTERIOLES

| substance | afferent | efferent |
|---|---|---|
| oxygen | high | high (similar to afferent) |
| carbon dioxide | low | low (similar to afferent) |
| proteins | higher | high (same as afferent) |
| glucose | higher | lower |
| nitrogenous waste products | higher | lower |
| diameter | wider | narrower |
| blood pressure | higher | lower than afferent |

↓ where it enters ↓ where it exits

## BLOOD VESSEL THAT HAS THE LOWEST CONC. OF UREA

renal vein

- urea is transported in the blood from the liver to the kidneys
- this blood travels into the kidneys via the renal arteries during ultrafiltration, a large amount of urea is filtered out of the blood
- thus, the blood that exits the kidneys via the renal veins only have a small concentration of urea remaining

## SELECTIVE REABSORPTION

- as the glomerular filtrate passes through the kidney tubule, useful substances are reabsorbed into the bloodstream by selective reabsorption
- useful substances we reabsorb
  1) water
  2) mineral salts
  3) glucose
  4) amino acids
- reabsorption is carried out by diffusion, osmosis and active transport

at the proximal convoluted tubule

- 80% of water is reabsorbed by osmosis
- all glucose, amino acids and most mineral salts are reabsorbed via diffusion and active transport
- cells of the walls of the proximal convoluted tubule cells contain a large number of mitochondria to provide energy for active transport
- the cells also have microvilli to increase SA:V ratio for more efficient absorption
- these ensure that all useful materials are returned to the bloodstream

at the loop of Henlé and distal convoluted tubule some water and mineral salts are reabsorbed

at the collecting duct

- only water is reabsorbed
- the collecting duct is important in regulating final concentration of urine by controlling amount of water reabsorbed

| substance | process by which substance is selectively reabsorbed |
|---|---|
| water | osmosis |
| mineral salts | diffusion & active transport |
| glucose | diffusion & active transport |
| amino acids | diffusion & active transport |

some substances from the filtrate are absorbed back into the surrounding blood capillaries.
the rest are passed out as urine:

- urea, creatinine, uric acid
- excess water
- excess mineral salts

passes along:

nephron → collecting duct → renal pelvis → ureter → urinary bladder → urethra

# URINE COMPOSITION

the average composition of normal human urine in grams per $100cm^3$ is:

| constituent | mass /g |
|---|---|
| water | 96.0 |
| mineral salts | 1.8 |
| urea | 2.0 |
| other nitrogenous substances | 0.2 |
| total | 100.0 |

# KIDNEYS AS OSMOREGULATORS

- osmoregulation is the control of water and solute levels in the blood to maintain constant water potential of blood
- if blood plasma is:

1) too dilute:
   - water moves into blood cells and tissue cells by osmosis
   - cells swell and burst/lyse

2) too concentrated:
   - water moves out of blood cells and tissue cells by osmosis
   - cells become dehydrated, crenated and shrink; unable to carry out metabolic functions

# ANTIDURETIC HORMONE

↳ water potential of blood is controlled by antidiuretic hormone, aka vasopressin

- ADH is produced by the hypothalamus and released by the pituitary gland in the brain into the bloodstream
- ADH increases the permeability of the cells in the walls of the distal convoluted tubule and collecting duct to water
  this increases selective reabsorption of water at the collecting ducts of the nephrons
- as a result, an increase in ADH secretion causes the urine produced to lower in volume and be more concentrated

## POSSIBLE CAUSES OF KIDNEY FAILURE

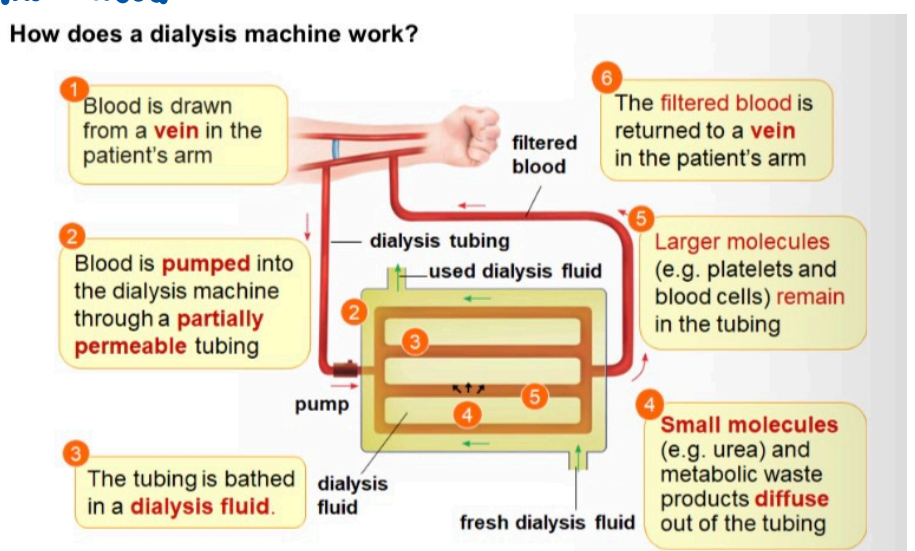
- diabetes
- high blood pressure
- kidney infection
- physical injury to kidney
- damage to kidneys from toxins
- blockage of kidney tubules due to kidney stones or tumor

# TREATMENT OF KIDNEY FAILURE

- kidneys have 2 important functions:
  1) excretion
  2) osmoregulation
- if one kidney fails to function, the person can still lead a normal life with one kidney
  kidneys that are no longer able to filter and remove waste products lead to accumulation of waste products at unsafe levels
  → can cause death if untreated
- can be treated by haemodialysis

## HAEMODIALYSIS

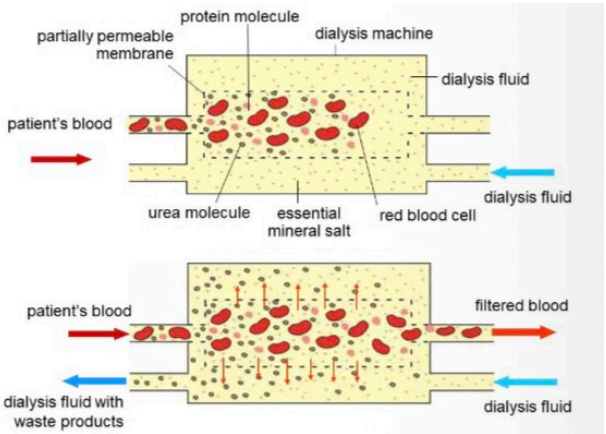
- the process of removing waste products and excess fluid from the blood using an artificial kidney machine that filters the blood



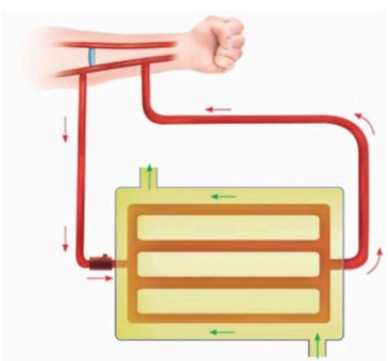
# CHARACTERISTICS OF DIALYSIS FLUID & TUBING

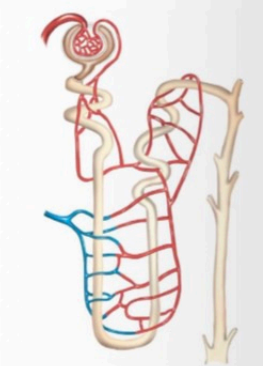
1) dialysis fluid has the same concentration of essential substances and the same water potential as healthy blood
   - ↳ ensures essential substances do not diffuse out of blood into dialysis fluid
   - ↳ provides patient with substances, if they are lacking in patient's blood
   - ↳ prevents loss of water from blood
2) there are no metabolic waste products in the dialysis fluid
   - ↳ sets up a concentration gradient to allow waste products to diffuse from the blood into the tubing into the dialysis fluid, and be removed
3) tubing in dialysis machine is long, narrow & coiled
   - ↳ ↑ SA:V ratio to increase effiency of exchange of substances between patient's blood and dialysis fluid and the removal of waste products
4) tubing in dialysis machine is made up of material that is partially permeable
   - ↳ smaller molecules e.g. water, mineral salts, urea and other metabolic waste products to diffuse out of tubing into dialysis fluid
   - ↳ larger substances e.g. blood cells, proteins, platelets and other large molecules remain in tubing

5) direction of blood flow in tubing is opposite to flow of dialysis fluid
↳ maintains a steep concentration gradient of the waste products, for their efficient removal




**What are the differences between a dialysis machine and kidney tubules?**





- selective reabsorption does not take place during dialysis
- dialysis does not depend on hydrostatic pressure of blood
- there is no active transport of solutes in or out of the blood during dialysis

↓

depends largely on diffusion