Excretion in Humans
Waste products excreted by:

- **skin**
  - urea
  - excess water
  - excess salts
  - **in sweat**

- **lungs**
  - carbon dioxide
  - **in expired air**

- **liver**
  - bile pigments
  - **in faeces through the intestines**

- **kidneys**
  - urea
  - excess water
  - excess salts
  - **in urine**
Excretion: is the removal of waste products formed by metabolism, out of the body

- Accumulation of wastes in the cells would affect the normal functioning of the cells
- By getting rid or the removal of waste products formed by metabolism, excretion ensures that these waste products do not build up to toxic levels
TERMINOLOGY

1. Metabolism
2. Excretion
3. Egestion
4. Secretion
5. Urea
6. Renal capsule
7. Cortex
8. Renal papilla
9. Renal pelvis
10. Nephrons
11. Dialysis
12. Bilharzia

1. Renal failure
2. Malpighian body
3. Afferent arteriole
4. Efferent arteriole
5. Podocytes
6. Loop of Henle
7. Glomerular filtration
8. Tubular reabsorption
9. Buffer
10. Aldosterone
11. ADH
The excretory organs

- Lungs
- Skin
- Liver
- Kidneys
- Bladder
Lungs

• During cellular respiration, energy is released from the food we eat. Carbon dioxide is also released during cellular respiration.

• Gaseous exchange in the lungs removes carbon dioxide from the blood and into the alveoli of the lungs.

• The carbon dioxide leaves the lungs, together with water vapour, during exhalation.
The Skin

- The skin contains numerous sweat glands which secrete sweat onto the surface of the skin.

- Sweat serves to keep the body cool as well as for the excretion of urea and salts.
The liver

- Proteins are digested into amino acids
- When these amino acids are carried to the liver by blood vessels, excess amino acids are broken down to form ammonia which is then converted to urea.
- This process is called deamination
- Urea is transported by the blood to the kidneys.
- In the kidneys, urea, together with other substances, forms urine
The urinary system

- It consists of two kidneys, two ureters, the urinary bladder and the urethra.
- The renal artery carries oxygenated blood laden with nitrogenous wastes to the kidneys.
- The renal vein which carries deoxygenated blood with very little nitrogenous waste away from the kidneys.
• Kidneys filter the blood and produce urine.

• Urine contains urea, as well as other toxic waste products and salts

• The bladder stores urine (up to 500 cm³) until it can be excreted during urination

• Sphincter muscles contract to close the urethra and relax to open it for urination
• Kidneys are surrounded by a thick layer of adipose tissue.
• Each kidney is enclosed in a renal capsule for protection.
• Near the centre of the concave side of the kidney is the hilum – where the ureter leaves the kidney.
• Within the kidney there are two regions: the outer cortex and inner medulla.
• The medulla is made up of a number of conical pyramids
• These pyramids have a number of tubes called ducts of Bellini/renal papilla
• Urine drains from these renal papilla into minor calyces and the into major calyces
• Finally collecting in the pelvis – a large cavity leading into the ureter
Functions of the kidneys

- Excretion: filter the blood to remove waste substances such as urea from the body

- Homeostasis: help to regulate the amount of water and salts in the body, and to maintain the acid-base balance.
1 – Filtration by the Kidney

- Supplied with blood from **renal artery**
- Inside it splits into many fine **capillaries**
- Each capillary supplies blood to hundreds of thousands of tiny filtration units called **nephrons**

![Diagram of a kidney with labeled parts: Renal artery, Renal vein, Ureter. A highlighted box says, “Let’s have a look at a nephron!!!”]
Nephron Structure

Glomerulus:
- High-pressure capillary bed
- The site of blood filtration

Bowman’s Capsule:
- Funnel-like structure
- ‘Beginning’ of the nephron

Each nephron has its own independent blood supply (renal arterioles and veins)
THE NEPHRON - WITHIN EACH KIDNEY THERE ARE ABOUT 1 MILLION

Each nephron consists of:

• A cup-shaped Bowman’s capsule – which contains a network of capillaries called the glomerulus (together they are called the Malpighian body)
• A coiled proximal convoluted tubule
• A loop of Henle
• A coiled distal convoluted tubule – which leads to a collecting duct
How the kidney works

Clean blood

Renal vein

Blood with waste products

Renal artery

Ureter

Waste products (urine) to the bladder

Nephron

Tubule
1. ULTRAFILTRATION

- Glomerulus brings a **large surface area** of blood capillaries in close contact with Bowman’s capsule

- Blood flows from the arteriole into the glomerulus

- Some of the blood plasma from the capillaries passes through walls of the glomerulus and collects in the Bowman’s capsule
1. Ultrafiltration Cont.

- The liquid that collects is called filtrate and contains
  - water
  - glucose
  - amino acids
  - vitamins
  - minerals
  - urea
  - ammonia

- The blood cells and plasma proteins are too large to pass through the walls and hence remain in the blood.
Blood from renal artery enters wide capillary (afferent)

Blood travels through narrow capillary (efferent) towards renal vein

Glomerular filtrate

Ultrafiltration
1. The afferent arteriole is wider than the efferent arteriole and so the blood in the glomerulus is at a high pressure – this pressure forces the blood plasma out of the glomerulus and into the Bowman’s capsule.

2. Large filtration surface due to the numerous capillaries of the glomerulus. This increases the rate at which ultrafiltration occurs.
Adaptations of the Malpighian Body Cont.

3. The capillary walls are thin with tiny pores – allowing blood plasma to pass through easily but not larger proteins and blood cells.

4. The inner wall of the Bowman’s capsule is made up of cells called podocytes that wrap around the glomerulus – these cells have foot processes that fit together tightly forming filtration slits that allow plasma to pass into the Bowman’s capsule.
Key Words!!

Nephron: structure in the kidney that acts as a microscopic filtration unit

Glomerulus: dense mass of very fine blood capillaries at the nephron that act as a filter

Bowman’s capsule: cup-shaped part of the nephron that holds a glomerulus and collects the products of filtration from it

Glomerular filtrate: liquid removed from the blood by filtration in the kidney
2 – Tubular reabsorption

• The blood forms about 180L of filtrate everyday but only 1 - 1.5L of urine a day.

• As the filtrate passes along the nephron all useful substances are reabsorbed back into the blood.

• This occurs at the proximal convoluted tubule.

• Substances such as glucose, amino acids, vitamins and minerals are reabsorbed using active transport.

• Most of the water is reabsorbed in this stage as well (through osmosis).
Adaptations of the proximal convoluted tubule

1. The wall of the tubule is thin – only one cell thick.
2. The cells forming the wall of the tubule have many microvilli – which increase the surface area for reabsorption of substances into the blood.
3. The cells forming the wall of the tubule contain many mitochondria – which provide the cells with energy (ATP) for active transport.
3 - Tubular excretion

- As the filtrate passes along the nephron, additional waste is added to it from the blood.

- This waste – e.g. ammonia, hydrogen ions, bicarbonate ions passes from the capillaries surrounding the nephron into the nephron.

- Mostly into the distal convoluted tubule.
4 - Formation of Urine

• As the filtrate passes along the nephron the wastes become concentrated.

• The liquid then flows out of the nephron into collecting ducts – this is now called urine.

• These ducts join up to form larger ducts called ducts of Bellini/Renal papilla – which open into the minor calyces and the major calyces.

• The urine then leaves the kidney and passes into the renal pelvis, then into the ureter and finally to the bladder to be stored until it is excreted through urination.
Glucose reabsorbed

Variable amounts of water and salts reabsorbed and filtrate gradually turning into urine

More water reabsorbed

Final urine containing:
- excess water
- unneeded salts
- waste urea
Regulating the pH of the blood

• Normal pH of blood 7.4
• The pH is kept constant by maintaining the balance of hydrogen ions (H\(^+\)) and hydrogen carbonate ions (HCO\(_3^-\)) in the blood

• More hydrogen ions compared to hydrogen carbonate ions blood will be acidic (less than 7.4)
• More hydrogen ions will then pass from the blood into the distal convoluted tubule during tubular excretion restoring the pH balance

__________________________ or
Regulating the pH of the blood Cont.

• More hydrogen carbonate ions compared to hydrogen ions blood will be alkaline (more than 7.4)

• More hydrogen carbonate ions will then pass from the blood into the distal convoluted tubule during tubular excretion restoring the pH balance
Control of the water balance of the body

• Osmoregulation – the regulation of the water balance of the body of an organism.
• This is achieved by ensuring the amount of water gained is the same as the amount of water lost by the body.
• If a lot of water is taken in then the body needs to get rid of the excess water.
• If, on the other hand, a lot of water is lost by the body then it will need to retain a large amount.
• The nephrons of the kidney help to regulate the water balance of the blood.
Control of the water balance of the body Cont.

• The hypothalamus controls the release of a hormone called antidiuretic hormone (ADH) or vasopressin.
• This hormone affects the water permeability of the walls of the distal convoluted tubule and collecting duct of the nephron.
• If the walls are more permeable more water passes out of the tubule and into the blood – retaining water.
• If the walls are less permeable then less water passes into the blood – therefore less is retained.
Maintaining a lower water concentration in the tissue fluid of the medulla Fig 8.13

• Before water can be reabsorbed there needs to be a lower water concentration outside the nephron in the medulla

• This is achieved by increasing the number of sodium ions in the medulla

• When the filtrate passes through the loop of Henle sodium ions pass out into the medulla via active transport by means of a sodium pump

• These sodium ions diffuse back into the blood vessels of the kidney and hence maintain the concentration gradient across the medulla
The role of the hypothalamus and ADH in regulating water balance

1. Normal water concentration of blood
2. Decrease in water concentration of blood
3. Detected by Hypothalamus
4. Causes pituitary gland to secrete more ADH
5. Acts on the kidney and causes the distal convoluted tubule and the collecting duct to become more permeable to water
6. More water is therefore reabsorbed into the blood and the water concentration of the blood increases and returns to normal

Or
The role of the hypothalamus and ADH in regulating water balance Cont.

1. Normal water concentration of blood
2. Increase in water concentration of blood
3. Detected by Hypothalamus
4. Causes pituitary gland to secrete less ADH
5. Acts on the kidney and causes the distal convoluted tubule and the collecting duct to become less permeable to water
6. Less water is therefore reabsorbed into the blood and the water concentration of the blood decreases and returns to normal
How does it work?

too little water in blood
  detected by hypothalamus
    more ADH secreted into blood by pituitary gland
      kidneys absorb less water from blood
        less urine produced
          blood water level back to normal

too much water in blood
  detected by hypothalamus
    less ADH secreted into blood by pituitary gland
      kidneys absorb more water from blood
        lots of dilute urine produced
          blood water level back to normal
Control of the salt balance of the body

1. Normal sodium ion \((\text{Na}^+)\) concentration of blood
2. Decrease in sodium ion concentration of blood
3. Adrenal gland on top of kidney
4. Releases Aldosterone
5. Acts on the kidney and causes the distal convoluted tubule and the collecting duct to reabsorb more sodium ions into the blood, restoring the balance.
Control of the salt balance of the body Cont.

1. Normal sodium ion (Na⁺) concentration of blood
2. Increase in sodium ion concentration of blood
3. Adrenal gland on top of kidney
4. Releases less Aldosterone
5. Acts on the kidney and causes the distal convoluted tubule and the collecting duct reabsorb less sodium ions into the blood restoring the balance
Kidney Failure

• We can live a relatively normal life with one kidney
• Sometimes both kidneys stop working – this could be due to infection that causes damage to the cells.
• If this happens then
  ▪ wastes are not removed from the blood – urea builds up which will inevitably be fatal if not treated
  ▪ Excess water and salts are not removed from the blood – they accumulate in the tissues – leads to strain on the heart
Dialysis

• Blood is taken from a vein pressurised and transported to the dialysis machine
• Once in the machine the blood flows through small channels of the dialysis tubing
• On the other side of the tubing there is a liquid called dialysis fluid.
• This fluid has a similar composition to blood plasma – water, glucose, amino acids and minerals salts at the same concentration
• Fresh fluid flows in through one end of the machine and out the other in the opposite direction to the blood.
Dialysis Fig 8.17 Cont.

- The tubing is semi-permeable therefore blood cells and plasma proteins are too large to pass through.
- Urea has a higher concentration in the blood than in the dialysis fluid and hence diffuses across the tubing and into the fluid.
- By the time the blood leaves the machine it is free of urea and clean blood enters a vein.
- Those with kidney failure need to have access to a machine for 12-18 hours a week.
- Portable machines are now available but at a high cost.
Kidney Transplant

• The donated kidney can come from a living person or from a donor who recently died.

• Advantage of receiving from relative – transferred quickly so less chance of it getting damaged, less likely to be rejected

• Rejection is rare today with the development of an anti-rejection agent

• Donors need to be tested first to determine if their blood and tissues are compatible with those of the patient.
<table>
<thead>
<tr>
<th>Method of Treatment</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialysis</td>
<td>Available immediately</td>
<td>Very time consuming</td>
</tr>
<tr>
<td></td>
<td>Can be continued for a long time</td>
<td>Patients attached to a machine throughout</td>
</tr>
<tr>
<td></td>
<td>Few complications</td>
<td>It may be too expensive for some</td>
</tr>
<tr>
<td></td>
<td>Not as expensive</td>
<td>May be too far to travel for some</td>
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<tr>
<td></td>
<td></td>
<td>Side effects – nausea and feeling cold</td>
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<tr>
<td></td>
<td></td>
<td>There are dietary restrictions</td>
</tr>
<tr>
<td>Kidney Transplant</td>
<td>Not attached to a machine</td>
<td>Surgery is required</td>
</tr>
<tr>
<td></td>
<td>Good quality of life</td>
<td>Very expensive</td>
</tr>
<tr>
<td></td>
<td>Few dietary restrictions</td>
<td>Tissue match needed</td>
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<tr>
<td></td>
<td>Better for overall health</td>
<td>Not many donors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>May be rejection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lifelong medication</td>
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</tbody>
</table>
Diseases and disorders affecting kidney function

• The kidneys are quite close to the surface so they are easily damaged by a hard punch or kick to the back or side.

• Sportsmen and woman can protect their kidneys by wearing a kidney belt.

• Overuse of painkillers such as aspirin and paracetamol may also lead to kidney failure.

• Diabetes and high blood pressure can cause kidney damage and so can a few diseases.
Bilharzia

- Disease caused by parasitic worms.
- They live in the blood vessels around the bladder and lay their eggs in the blood.
- The eggs pass into the bladder and then into the water in dams etc. when urination occurs.
- Can become infected when swimming in, washing in or touching contaminated water.
- Symptoms – fever, fatigue and blood in the urine.
- Can be treated with oral pharmaceutical drugs.
- Long term infection can lead to kidney damage.
- Reduced chances by avoiding contact with stagnant water.
Worms bore through skin, grow to maturity then mate in the human body.

Eggs pass into water in urine and faeces.

Larvae mature and multiply inside the snail.

Worms emerge into water after 3–7 weeks.

Rapidly hatched larvae must find a snail within 26 hours to survive.
Kidney Stones

- One of the most common disorders of the kidney
- Formed from crystals that appear in the urine
- They stick together to form large masses that can block the tubes of the urinary system
- Most pass out on their own but others may need to be removed by surgery
- Symptoms – sharp pain in the side or blood in the urine
- Reduce the chances by drinking lots of water
Calcium Stone

Uric Acid Stone

Struvite Stones

Cystine Stone
Kidney Infections

• Fairly common – particularly in women
• Usually caused by bacterial infections of the bladder that spread through the urinary system
• Symptoms – pain in the back or side, frequent urination, painful urination and blood or pus in the urine
• Can be treated with antibiotics (bacterial infection)
• If untreated could lead to kidney damage
• Reduce chances of getting an infection by treating a bladder infection quickly, eating less sugar, drinking lots of water and maintaining good genital hygiene