### Objectives

At the end of this sub section students should be able to:

**3.4.5 Plant Excretion**

1. Say why plant leaves are flattened
2. Give the role of leaves as excretory organs of plants.
3. Give the role of lenticels as excretory organs of plants

**3.4.6 The Excretory System in the Human**

1. Explain the role of the excretory system in Homeostasis
2. Give the function of the lungs, skin and urinary system
3. Give the location of the lungs, skin and urinary system
4. Give the excretory products of the lungs, skin and urinary system
5. Explain the need to drink water before, during and after exercising
6. Draw the structure of the urinary excretory system in humans
7. Label these parts -- kidney, ureter, urinary bladder, and urethra
8. Give the basic function of the urinary excretory system in humans
9. Explain the role of the kidney in regulating body fluids
10. Explain the role of the kidney extracting wastes and toxins from the blood and recycling valuable substances
11. Explain the terms filtration, reabsorption and secretion -- thus regulating the body fluids and chemistry of the body
12. Identification of the site of filtration and reabsorption in the cortex, medulla and renal pelvis
13. Identify the position of secretion in the kidney
14. Describe the pathway of urine from the kidney to the urethra

**3.4.8.H The Nephron**

16. Draw the Nephron and its associated blood supply
17. Explain how urine is formed
18. Why the blood is under pressure in the glomerulus
19. Why the plasma is force-filtered
20. Say what components of the plasma are not filtered and why
21. Explain the terms "Glomerular filtrate", convoluted tubule, "proximal convoluted tubule "
22. Explain what substances are reabsorbed into the blood
23. Explain how substances are reabsorbed into the blood
24. Give the roles of the Loop of Henle and the distal convoluted tubule
25. Give some of the components found in urine
26. Give the pathway for urine from the nephron to the kidney
27. Explain how reabsorption of water in the collecting duct is under hormonal influence
28. Give the full name for ADH
Excretion is getting rid of the waste products of metabolism from the body. Excretion is an important part of homeostasis. Without excretion wastes would quickly build up and interfere with the internal chemical and fluid balances of the organism.

Plants produce very little waste. Plant excretion consists mainly of carbon dioxide by night, and oxygen during the day. Store some wastes in vacuoles and lose more when dead structures fall off.

<table>
<thead>
<tr>
<th>Organs of excretion</th>
<th>Excretory products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lungs</td>
<td>carbon dioxide and water</td>
</tr>
<tr>
<td>2. Liver</td>
<td>bile and excess amino acids, water and cholesterol</td>
</tr>
<tr>
<td>3. Skin</td>
<td>salt, water and some urea</td>
</tr>
<tr>
<td>4. Kidneys</td>
<td>salts, urea, water, uric acid*</td>
</tr>
</tbody>
</table>

*Uric acid is a nitrogenous waste produced during the breakdown of adenine and guanine. pH of urine is 6.0 and yellow due to urochrome - a pigment produced during protein metabolism

Urinary system

Blood, high in waste products, enters kidneys through renal arteries. Kidneys filter out waste and reabsorb useful substances. Purified blood leaves kidneys through renal veins and the urine flows from kidneys via ureters to bladder (storage) and out through the urethra.

Kidney
Location: Back of abdominal cavity, in the “small of the back”, left kidney slightly higher than the right and both covered by a protective layer of fat.
Structure
Cortex - outer fibrous part, dark red in colour.
Medulla - inner region, bright red in colour.
Pyramids - cone-shaped areas projecting into pelvis of kidney.
Pelvis - hollow chamber, expanded head of ureter.

Functions - both homeostatic:
(1) Excretion - to remove waste products i.e. urea which results from deamination of excess amino acids in the liver and excess water and salts.
(2) Osmoregulation - the kidneys balance the water and salts composition of blood.

Nephron
Nephrons are tiny tubules in the kidney, which filter the blood (≈ 1 x 10⁶/kidney).
Nephron structure:

Urine production
3 major stages:
1. Filtration:
   (a) Blood in the glomerulus capillaries is under high pressure because (i) the renal arteries branch directly from the aorta and (ii) the efferent arteriole (outgoing) is narrower than the afferent arteriole (incoming).
   (b) High pressure and large surface area of capillaries causes ultrafiltration of blood plasma through the pores in the glomerulus wall into the lumen of the Bowman’s capsule, forming a liquid called the glomerular filtrate. Both walls are one cell thick. The filtrate does not contain proteins and blood cells as they are too large for the pores.

2. Selective reabsorption:
   Reabsorption of useful substances e.g. water, amino acids, glucose, vitamins and salts from glomerular filtrate back into capillaries.
   Different substances are reabsorbed by different methods e.g. water by osmosis and solutes by diffusion and active transport.

Proximal convoluted tubule:
All of the glucose, vitamins, amino acids, and ≈80% salts and water are reabsorbed here.
To help reabsorption the cells of the wall of the tubule (i) contain lots of mitochondria to provide the energy for active transport (ii) have numerous microvilli to increase the surface area and (iii) the PCT is one-celled thick and long (14mm).

**Loop of Henle:**
An extra 5% of water is reabsorbed into blood by osmosis in the descending limb. Secretion of salt into the surrounding area by the ascending limb permits extra water reabsorption from the descending limb.

**Distal convoluted tubule:**
Salts (Na\(^{+}\)Cl\(^{-}\)) and water can be reabsorbed, depending on the needs of the body. Aldosterone from the adrenal cortex helps to control the amount of sodium re-absorbed.

**Collecting duct:**
Further reabsorption of water by osmosis (due to high salt conc. in the medulla created by the loop of Henle) can occur depending on state of body - controlled by ADH - anti-diuretic hormone*.

### 3. Selective secretion:

Some substances pass from blood into nephron.
- **Proximal tubule** = Hydrogen ions are secreted in response to changes in the blood plasma’s pH (normal pH = 7.4), ammonium ions, drugs and poisons.
- **Distal tubule** = potassium and hydrogen ions. High levels of potassium prevents nerve impulses from travelling correctly and reduces the strength of muscular contraction.

The urine now in the collecting duct passes through the ureters to the bladder where it can be stored. It is released via a sphincter muscle into the urethra.

The **volume and composition of the urine** produced is affected by a number of factors e.g. atmospheric temperature, exercise, diet (water/salt/protein intake) etc.

The body keeps the balance between water and dissolved solutes by balancing water gained with water lost.

#### Water gain:
- drinking, eating, respiration, reabsorption in nephron.

#### Water loss:
- breathing, sweating (increased by temp. increase e.g. hot day, exercise), bleeding, tears, faeces, urine

Kidneys regulate osmosis by keeping blood and body cells at the same concentration.

<table>
<thead>
<tr>
<th>Location</th>
<th>% water reabsorbed</th>
<th>Salts reabsorbed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal tubule</td>
<td>80</td>
<td>Most (as well as glucose, amino acids and vitamins)</td>
</tr>
<tr>
<td>Descending limb of loop of Henle</td>
<td>5</td>
<td>None</td>
</tr>
<tr>
<td>Ascending limb of loop of Henle</td>
<td>0</td>
<td>Some</td>
</tr>
<tr>
<td>Distal tubule</td>
<td>10</td>
<td>Some</td>
</tr>
<tr>
<td>Collecting duct</td>
<td>4.9</td>
<td>None</td>
</tr>
</tbody>
</table>

*Hypothalamus in brain measures concentration of blood plasma. If hypertonic (too salty) ⇒ pituitary secretes ADH. ADH increases the permeability of the distal convoluted tubule and collecting duct causing more water to be reabsorbed into the blood. Hence a small volume of concentrated urine is produced.

When plasma becomes isotonic ADH production is stopped, permeability of DCT and CD decreases, less water reabsorbed and a large volume of dilute urine is produced.

- A protein rich meal produces the same amount of urine, but a higher conc. of urea and uric acid.
- Very high levels of glucose in the blood will result in some of it being lost from the body in the urine. This indicates diabetes mellitus.
- Increase in conc. in urine of urea and salts compared to blood plasma/glomerular filtrate is due to the reabsorption of water back into the blood.
- Glomerular filtrate has more water and useful substances such as glucose and amino acids compared to urine.

### KIDNEY FAILURE

Caused by infections, poisons, tumours, kidney stones, shock and blood disease.

#### Dialysis

Haemodialysis machines can be used as artificial kidneys.

Blood is diverted from a patient’s artery through a bath of dialysing fluid and returned through a vein. Waste (urea and salt) diffuse out of the blood across a dialysing membrane made from cellophane into the fluid. This fluid contains all the...
nutrients but no toxins. Eventually most of the patient’s blood chemistry returns to normal ranges. Procedure takes about 6 hours and needs to be done about 3 times per week. Kidney machines are expensive, clumsy and inconvenient. Serious side effects can be osteoporosis (“brittle bone syndrome”) caused by bone calcium loss.

**Transplant**

In younger patients a kidney transplant is a better option if a suitable donor can be found. There is a shortage of donor kidneys but this could be solved in the future by the cultivation and genetic screening of human embryos.

**Urinary tract infections (UTIs)**

Due to presence of bacteria in urinary tract e.g. E. coli, Clamydia, Mycoplasma and Neisseria (gonorrhoea) are sexually transmitted and both partners have to be treated.

**Symptoms include:**

- A frequent urge to urinate;
- A painful, burning feeling in the area of the bladder or urethra during urination;
- feeling tired or shaky;
- women feel an uncomfortable pressure above the pubic bone;
- a small amount of urine is passed;
- urine itself may be cloudy

A fever may mean that the infection has reached the kidneys. Other symptoms include pain in back or side below ribs, nausea or vomiting. Treatment using antibiotics and lots of fluids. Acidic drinks such as cranberry juice can be of some help.

**Kidney stones**

Most common type is excess calcium combining with excretory products. Yellow/brown, 2 cm in diameter.

A stone may stay in the kidney or travel down the urinary tract. It may pass out of the body unnoticed or get stuck and block the flow of urine and cause great pain.

**Treatment:**

Surgery or shockwave lithotripsy - stone crushing using ultrasound. If prone to kidney stones drink lots of water and eat less meat.

### 3.4.6 The Excretory System in the Human

**Examination Questions**

SEC Sample Paper OL

15. (a) The diagram shows a vertical section through a human kidney.

(i) Name the parts A, B, C, D.
(ii) To what structure does D link the kidney?
(iii) Where does filtration occur in the kidney?
(iv) Filtration ensures that cells and valuable substances are not lost from the body when urine is being formed. Name two of these substances or cells.
(v) Suggest a treatment that may be used for a person whose kidneys are not carrying out their normal functions.
(vi) Name an organ in the human body, other than the kidney, in which excretion takes place.
Excretory system

2005 OL

14. (a) The diagram shows a section through a human kidney.

(i) Name A, B, C, D.

(ii) To what structure does D connect the kidney?

(iii) Filtration is an essential process in the formation of urine. In what part of the kidney does it take place?

(iv) Reabsorption of useful substances takes place in the kidney. In what part does this occur?

(v) Name an excretory substance present in urine.

(vi) Name an excretory organ in the human body other than the kidney. Name a substance, other than the one you have named in (v), excreted by this organ. (30)

2007 OL

14. (b) (i) What is meant by excretion?

(ii) Name two products excreted by the human.

(iii) Name one organ of excretion, other than the kidney, in the human body.

(iv) What is meant by osmoregulation?

(v) Study the diagram of a section through the kidney and answer the following questions.
   1. Where does filtration of blood take place?
   2. Where does reabsorption of salt take place?
   3. To what organ does the ureter link the kidney?
   4. To which main blood vessel does the renal artery link the kidney?

(vi) Name the fluid present in the ureter.

2009 OL

7. (a) (ii) Give one way in which water is lost from the body.

2009 OL

14. (b) The diagram shows a vertical section through a human kidney.

(i) Name the parts labelled A, B and C.

(ii) Which organ is attached to the kidney by part C?

(iii) In which of the three labelled parts does filtration of the blood occur?

(iv) Name two substances excreted by the kidneys.

2004 HL

12. State the role of the kidneys in homeostasis. (9)
Excretory system

2006 HL
6. Distinguish between the members of each of the following pairs by making a brief comment on each.
   (b) Ureter and urethra

2006 HL
13. (b) Use your knowledge of the human vascular and excretory systems to answer the following.
   (i) Explain the terms, plasma, glomerular filtrate.
   (ii) Explain why red blood cells are normally absent from glomerular filtrate.
   (iii) The concentration of glucose is the same in plasma and glomerular filtrate. Why is this?
   (iv) Why is glucose normally absent from urine?
   (v) Following a period of heavy exercise an athlete may produce only a small volume of concentrated urine. Explain this observation and give an account of the process that concentrates the urine.

2008 HL
13. (a) (i) What is meant by excretion?
   (ii) Urea and carbon dioxide are excretory products of the human body. In the case of each product name a substance from which it is derived.

2010 HL
H 3.4.8 The Nephron as a Unit of Kidney Function
2004 HL
12. (b) (i) Draw a labelled diagram of a nephron. Include blood vessels in your diagram.
   (ii) Filtration and reabsorption are vital processes that take place in the nephron. Describe how each of these processes occurs.

2006 HL
13. (b) Use your knowledge of the human vascular and excretory systems to answer the following.
   (i) Explain the terms, plasma, glomerular filtrate.
   (ii) Explain why red blood cells are normally absent from glomerular filtrate.
   (iii) The concentration of glucose is the same in plasma and glomerular filtrate. Why is this?
   (iv) Why is glucose normally absent from urine?
   (v) Following a period of heavy exercise an athlete may produce only a small volume of concentrated urine. Explain this observation and give an account of the process that concentrates the urine.

2008 HL
13. (b) The diagram shows the structure of a nephron and its associated blood supply.
   (i) Name the parts A, B, C, D, E and F.
   (ii) From which blood vessel is A derived?
   (iii) Where in the kidney is B located?
   (iv) Give the part of the nephron in which each of these following takes place:
       1. filtration, 2. reabsorption of amino acids.
   (v) Give two features of the nephron that aid filtration.
(vi) Name a group of biomolecules in the blood which are too large to pass through the filtration system of the nephron. (27)

c) (i) Suggest two situations which may result in a drop in the water content of the blood.

(ii) When the water content of the blood drops a hormone is released.

Name this hormone and the endocrine gland from which it is secreted.

(iii) Give a precise target area for this hormone. How does the hormone reach the target area?

(iv) Explain the role of the hormone at its target area, when the water content of the blood is low. (24)

2010 HL

15. (c) Suggest a biological explanation for each of the following observations:

(iv) After a long session of heavy exercise, an athlete’s urine is likely to be concentrated and low in volume.

SEC Marking Scheme

2005 OL

14. (a) (i) A = cortex B = medulla/pyramid C = pelvis D = ureter 4(3)

(ii) bladder 3

(iii) cortex (A) / nephron /glomerulus / Bowman’s capsule 3

(iv) cortex (A) /medulla (B) /nephron/convoluted tubule / loop 3

(v) urea /water /salt 3

(vi) skin/lungs / liver 3

water/carbon dioxide/urea / salt / bile /sweat (not mentioned in (v)) 3

2004 HL

12. (a) Maintaining (a constant) internal environment or described 3

Role of kidneys: Maintaining salt balance or explained / 3
Maintaining water balance or explained / 3

[Note: Osmoregulation = 2 points]

(b) (i) Diagram of nephron 3, 0

Diagram of blood supply 3, 0

labels 3(1)

(ii) Filtration:

Blood in arteriole / under pressure/ plasma (accept blood) or small molecules or

named from (or in) glomerulus /in or into (Bowman’s) capsule /large molecules or

named or cells or named cells cannot pass

any three 3(3)

Reabsorption:

Substance (or named) from (or in) tubule (or named part or from filtrate) /

/ into blood / active transport / diffusion / osmosis / mention of hormonal control

any three 3(3)

2006 HL

13. (b) (i) plasma: liquid part of blood 3

glomerular filtrate: (plasma) that has entered Bowman’s capsule

or has left the glomerulus or plasma less proteins 3

(ii) too big (to pass into Bowman’s capsule) 3

(iii) (glucose) small or passes through 3

(iv) reabsorbed or explained 3

(v) sweating or water loss or dehydration / blood volume drops or

concentration increases /detected by receptors / brain alerted /

ADH secreted / from pituitary / (stimulates) reabsorption of water/

in distal tubule or collecting duct any four 4(3)

H 3.4.8 The Nephron as a Unit of Kidney Function
Excretory system

2004 HL

12. (a) Maintaining (a constant) internal environment or described 3

Role of kidneys: Maintaining salt balance or explained / 3
Maintaining water balance or explained / 3
[Note: Osmoregulation = 2 points]

(b) (i) Diagram of nephron 3, 0
Diagram of blood supply 3, 0
labels 3(1)

(ii) Filtration:
Blood in arteriole / under pressure/ plasma (accept blood) or small molecules or
named from (or in) glomerulus /in or into (Bowman’s) capsule /large molecules or
named or cells or named cells cannot pass any three 3(3)

Reabsorption: Substance (or named) from (or in) tubule (or named part or from filtrate) /
/ into blood / active transport / diffusion / osmosis / mention of hormonal control
any three 3(3)

(c) (i) Source: respiration or named site e.g. muscle, liver, kidney,
brain or named food e.g. carbohydrate or named 3

(ii) Two methods of insulation: fat (adipose tissue) / (trapped) air or hair2(3)

(iii) When temp high: vasodilation (or explained) / (secretion of) sweat /
hairs lie flat or less air trapped any two 2(3)

(iv) Response when temp drops: receptor (or detection) / receptor in skin /
receptor in medulla or brain / shiver / generates heat / hairs stand up
or goose bumps / air trapped / vasoconstriction (or explained) / increased
metabolic rate or increased respiration / any relevant comment on named
hormone e.g. thyroxine increases metabolic rate or increases respiration
any three 3(3)

2006 HL

13. (b) (i) plasma: liquid part of blood 3
glomerular filtrate: (plasma) that has entered Bowman’s capsule
or has left the glomerulus or plasma less proteins 3

(ii) too big (to pass into Bowman’s capsule) 3

(iii) (glucose) small or passes through 3

(iv) reabsorbed or explained 3

(v) sweating or water loss or dehydration / blood volume drops or
concentration increases /detected by receptors / brain alerted /
ADH secreted / from pituitary / (stimulates) reabsorption of water/
in distal tubule or collecting duct any four 4(3)