Westville GIRLS' HIGH SCHOOL

LIFE SCIENCES
GRADE 11 EXCRETION IN MAN

SA 1 Learn about

- The structure and functioning of the kidneys
- The importance of the kidneys for homeostasis.
- Suitability of the nephrons for their functions
- The regulation of kidney activity

SA 2 Learn how to

- Dissect a sheep's kidney
- Read tables and graphs related to kidney functioning

SA 3 Think about

- Detecting performance-enhancing drugs in athletes & discuss
- The ethics of using such drugs
- The composition of urine in diabetics
- Renal failure and renal dialysis
- Kidney stones and the treatment thereof
- The effect of alcohol on urine composition
- Different views on organ donation

NOTES:

1. TERMS:

- EXCRETION is the removal of metabolic wastes, i.e. the waste products produced by the cells due to chemical reactions, such as urine, CO_2 and sweat.

[Don't confuse this with SECRETION (passing out useful substance like saliva and mucus) or with EGESTION, the removal of undigested waste through the anus].

- OSMOREGULATION is the control of water content.

- HOMEOSTASIS is the maintenance of a constant, optimal internal environment independent of changes in the external environment. Homeostatic mechanisms maintain this steady state, which is vital for survival. Excretion and osmoregulation are both homeostatic mechanisms.

2. THE NECESSITY FOR EXCRETION:

Metabolism causes the formation of wastes like CO_2 & nitrogenous wastes like urea, which are harmful if they accumulate. Cells only function normally if **tissue fluid remains constant** with respect to water, temperature, pH, waste content, ions etc. The excretory organs help to maintain this optimal internal state by the **removal of metabolic wastes** and by **osmoregulation.** The best possible internal environment is created for the survival of cells, so the excretory organs are important for **homeostasis**.

3. THE MAIN EXCRETORY ORGANS:

3.1 KIDNEYS: They eliminate urine (excess water, salts and nitrogenous wastes), thereby removing metabolic wastes and regulating the water and salt concentration of the body.

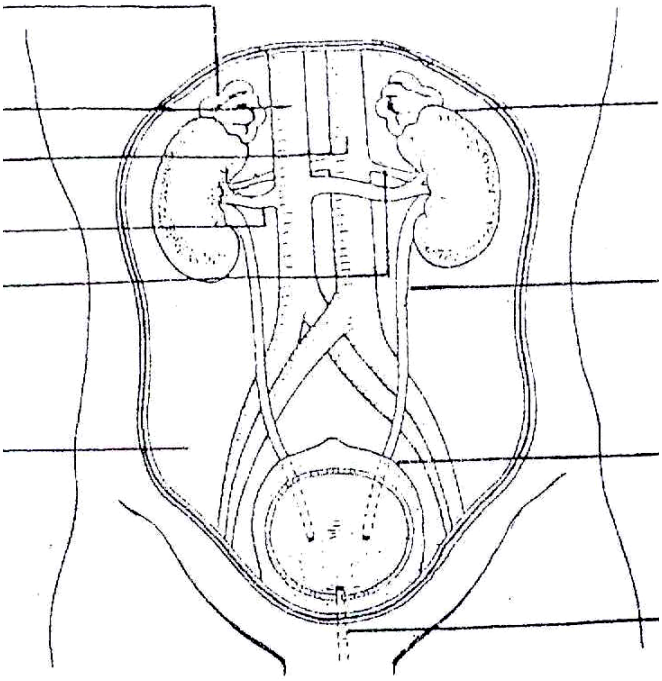
3.2 LUNGS: Remove CO_2 by diffusion from the blood at the alveoli.

3.3 SKIN: Sweat glands eliminate sweat (also water, salts and nitrogenous wastes, but less concentrated than urine). The main salt eliminated is sodium chloride.

3.4 LIVERRemoves many cellular wastes, e.g. the remains of hemoglobin from broken down red blood cells, which are excreted via bile. Proteins are deaminated and urea is formed; many ingested poisons are detoxified.

4.5 ALIMENTARY CANAL Metabolic wastes and excess inorganic substances like salts and calcium are excreted into the large intestine and eliminated with the faeces.

THE URINARY SYSTEM OF MAN



adrenal gland

inferior vena cava

aorta

renal vein

renal artery

abdominal cavity

_____

- Excretion
- Osmoregulation
- pH control

_____

- Carries urine to bladder

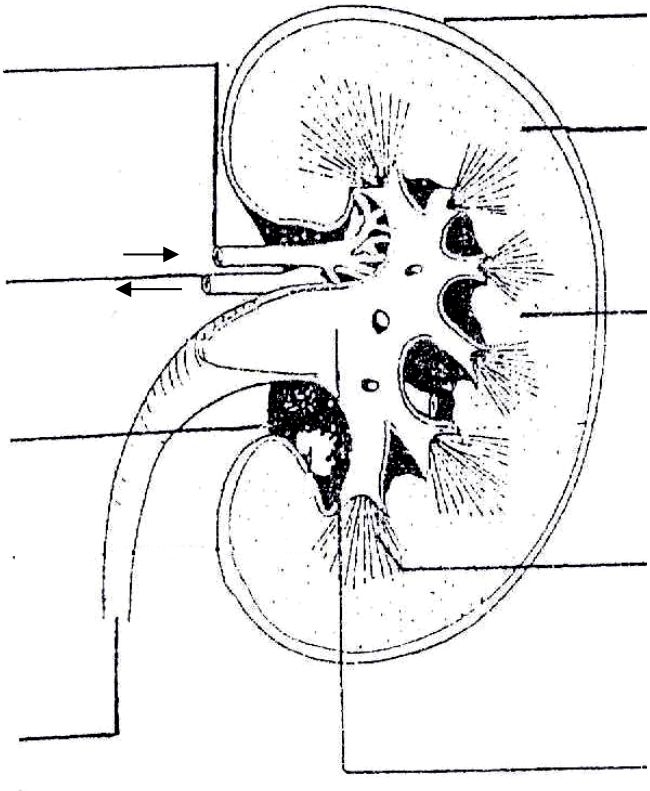
_____

- Stores urine

_____

- Carries urine to outside

L/S KIDNEY TO SHOW INTERNAL STRUCTURE



_____
Oxygenated blood & wastes into kidney

_____
Deoxygenated blood out of kidney

_____
Concave side of kidney where tubes attach

_____
Carries urine to bladder

_____
Allows accumulation of fat for protection

_____
Dark outer region mainly for filtration of blood

_____
Pale inner region mainly for reabsorption of water

_____
Consists of large collecting ducts. Carries urine of many nephrons to pelvis.

_____
Collects urine of all the pyramids & passes it to ureter

4. URINARY SYSTEM OF MAN:

- **Kidneys,** which are organs of excretion and osmoregulation.
- **Ureters,** which are tubes to carry urine from the kidneys to the _____.
- **Bladder,** which stores urine temporarily.
- **Urethra,** which carries urine from the bladder to the _____. It is controlled by a sphincter muscle.

4.1 KIDNEYS:

- On either side of the spine, with the concave side facing the spinal cord.
- In the posterior part of the abdominal cavity, just below the diaphragm.

4.1.1 Macroscopic structure of the kidneys:

- Kidneys are dark red, bean-shaped and about the size of your palm.
- The concave side or **hilum** is the place where all the tubes are attached:
    - RENAL ARTERY - enters kidney from the _____
    - RENAL VEIN - leads away from kidney into _____
    - URETER - carries urine to the _____
- The **renal capsule** is a thin layer of connective tissue around the kidney. It allows accumulation of _____ for protection and to holds the kidneys in position against the back of the abdominal cavity.

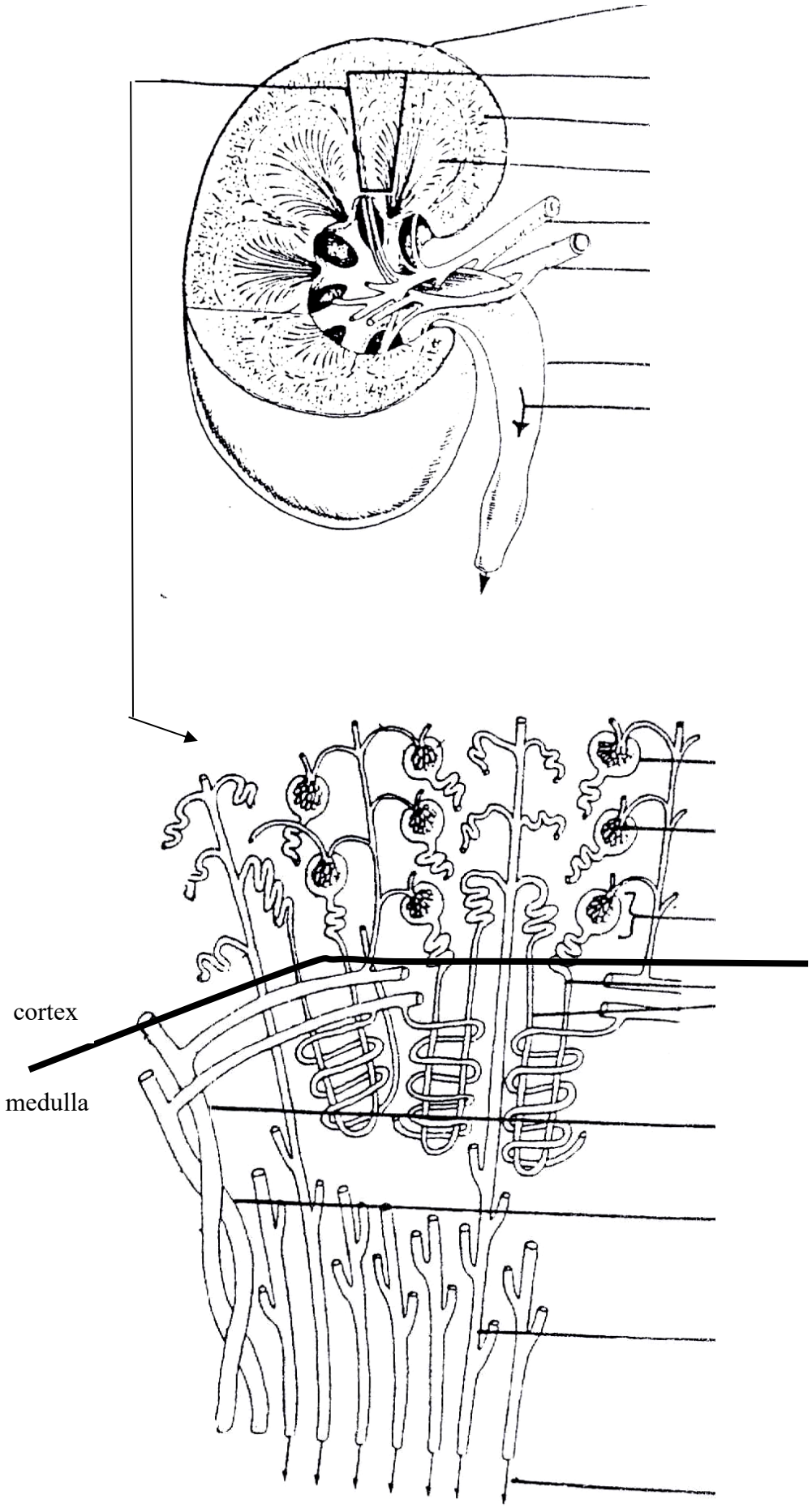
- Internally, kidneys are seen to have an outer, dark red **cortex** and a paler, middle **medulla** region. The medulla consists of triangular **pyramids.** The central funnel-shaped **pelvis** has narrower areas called **calyces / calyxes** collecting urine. It leads to the ureter.

INVESTIGATION 1: DISSECTION OF A KIDNEY: (Groups)

Work in groups of about 5 and follow the instructions from your teacher about how to proceed with the kidney dissection. It will be necessary to remove some of the kidney material above the calyces after the initial longitudinal cut, since sheep kidneys have a slightly different structure from the human kidney. The calyces and pyramids will be more visible then.

Make a neat, labeled drawing of the kidney L/S in the space below:

ARRANGEMENT OF NEPHRONS WITHIN THE KIDNEYS



4.1.2 Microscopic structure of the kidneys:

- Kidneys consist of about 1 million tiny **nephrons,** which are very narrow, folded tubules that are not visible to the naked eye. Each nephron has a tubule and a capillary network.

- **Bowman's capsule** is the closed, expanded end of the nephron. It is indented to form a cup-shape enclosing a capillary network called the _____**.** Both Bowman's capsule and the glomerulus consist of a single layer of squamous epithelium. Together, Bowman's capsule & the glomerulus form the **Malpighian body** in the renal cortex**.**

- The **proximal convoluted tubule** of _____ epithelium is just below Bowman's capsule in the cortex.

- The **loop of Henle** extends into the medulla. The ascending limb consists of cuboidal epithelium, while the descending limb has _____ epithelium.

- The **distal convoluted tubule** of _____ epithelium is again in the cortex.

- Several nephrons open into **collecting ducts** that lead to the **calyxes** and then into the **pelvis.**

4.2 BLOOD SUPPLY:

- Branches of the **renal artery** form renal arterioles in the kidney.

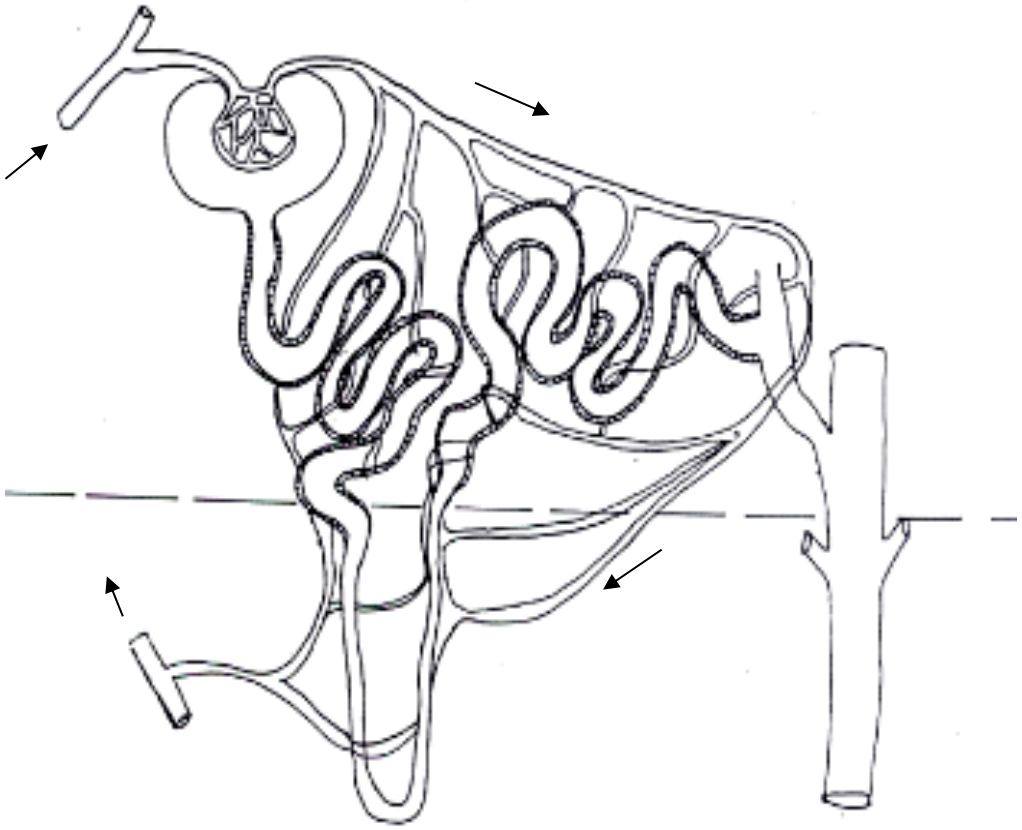
- They divide to form the _____ **arteriole going** to the glomerulus at each nephron.

- Capillaries re-unite after the glomerulus to form the _____ **arteriole** leading away from the glomerulus. It is NARROWER than the afferent arteriole, causing pressure in the glomerulus.

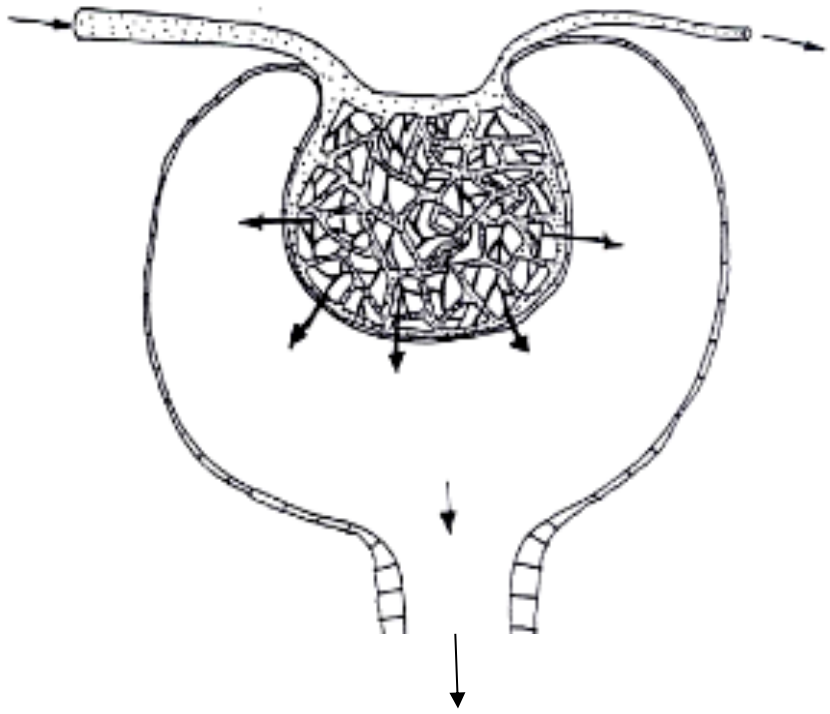
- The efferent arteriole re-divides to form a **capillary network** around the proximal and distal tubules and the loop of Henle.

- The capillary network re-unites to form renal venules that ultimately form the **renal vein**, which leaves the kidney at the hilum.

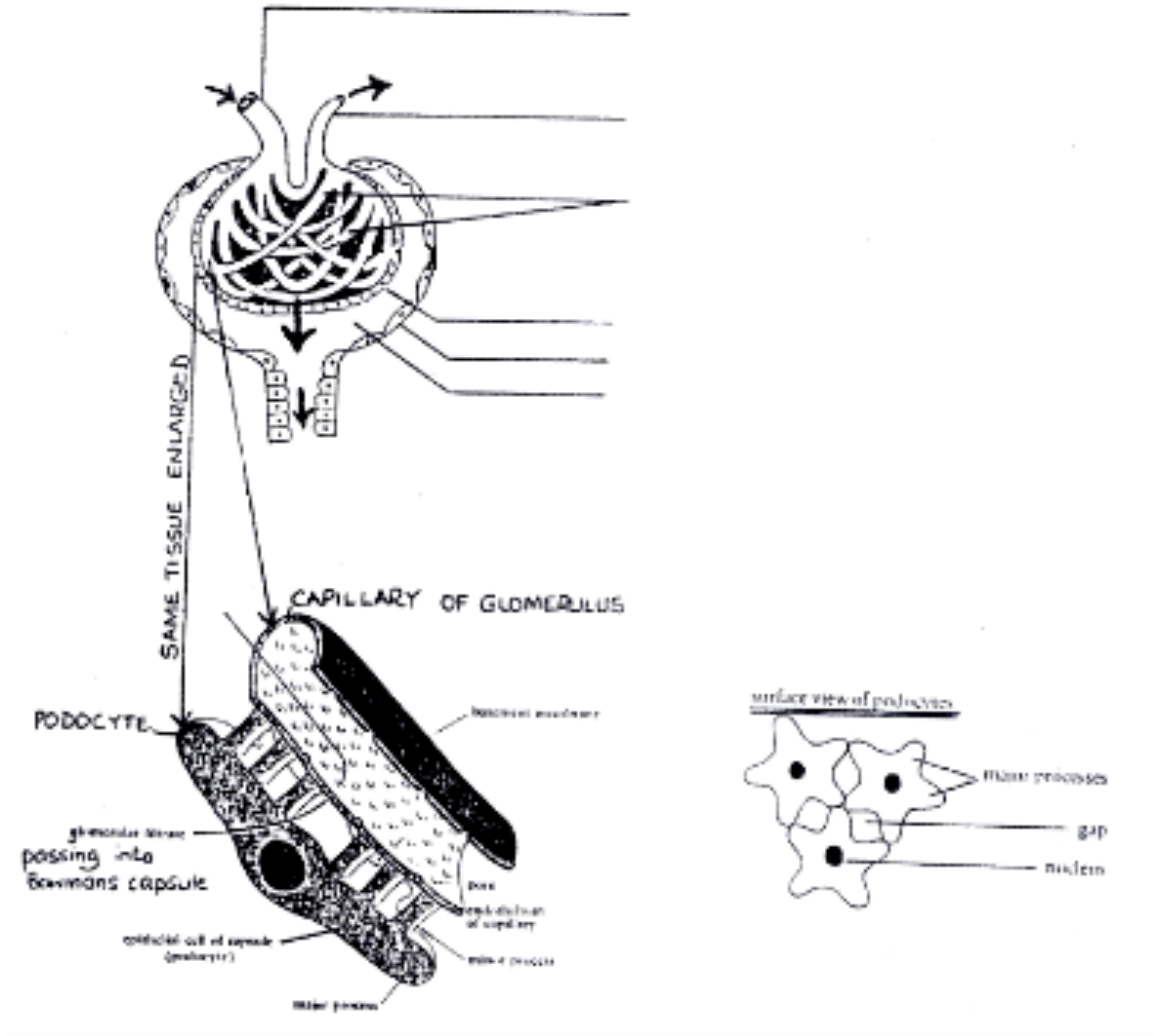
STRUCTURE OF ONE NEPHRON:



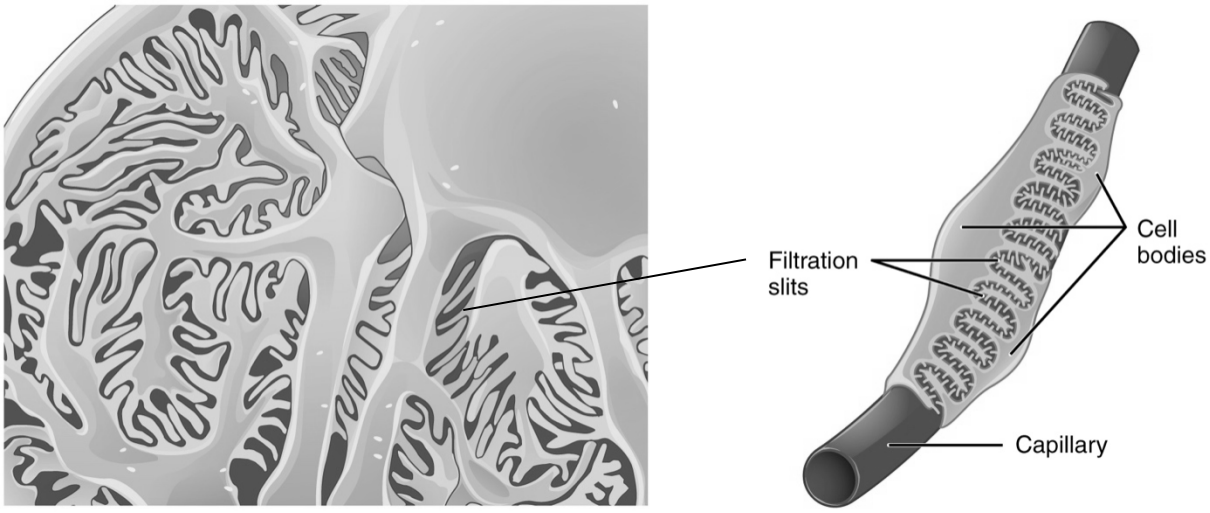
ENLARGEMENT OF THE MALPIGHIAN BODY (renal corpuscle)



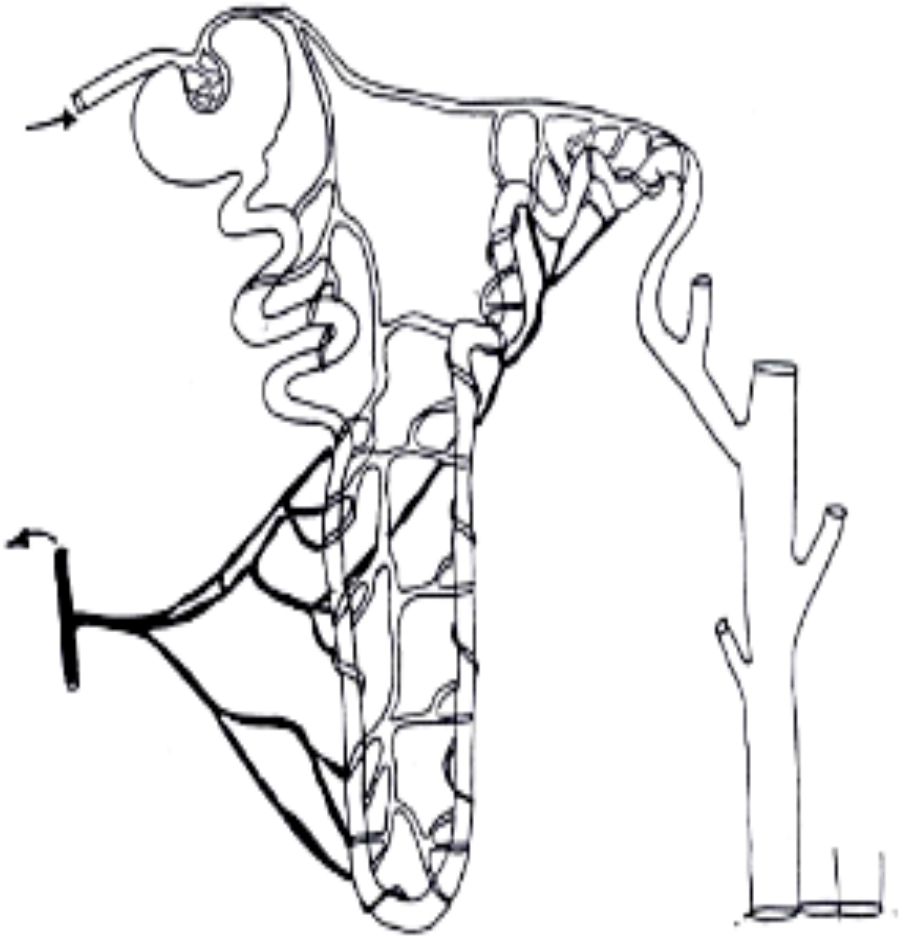
PODOCYTES ON THE INNER WALL OF BOWMAN'S CAPSULE:



DETAIL OF PODOCYTES FORMING THE INNER WALL OF THE CAPSULE:



THE FORMATION OF URINE (General functioning of the kidneys)



4.3 THE FUNCTIONING OF THE NEPHRON: URINE FORMATION:

The nephrons are the functional units of the kidneys. They remove wastes, regulate the pH, salt and water content of the blood by 3 processes, namely

- Glomerular filtration / Ultra-filtration
- Selective reabsorption
- Tubular excretion

4.3.1 Glomerular filtration / Ultra-filtration

- This is made faster by _____the glomerulus, as the afferent arteriole is wider than the efferent arteriole. Pressure is also increased by the pumping of the heart (blood pressure). Ultra-filtration is caused by hydrostatic pressure and *cannot be called diffusion.*

- Small molecules like water, salts, glucose, vitamins and urea filter out of the glomerulus into the capsular space. They pass through narrow pores between specialized star-shaped cells in the inner wall of the capsule, called _____**.** They have major processes and minor processes, the latter to keep the cells attached to the capillary network.

- Large molecules like _____ and blood cells do not pass into the capsule.

- The liquid that enters the capsule is an **ultra-filtrate of blood plasma**. It is mainly water and has useful substances like amino acids, glucose, salts and vitamins, but also wastes like urea, uric acid and excess minerals. The liquid is called 'the filtrate'.

- The filtrate is *not yet urine.* Much selective reabsorption and excretion needs to be done before it can pass out of the body.

Structural suitability of the Malpighian body for ultra-filtration:

PART	STRUCTURE	SUITABILITY
Glomerulus	Network of _____	increase _____ for ultra-filtration.
	Capillaries are_____	to _____ pressure & slow down the movement of blood.
	Walls have _____	to allow _____ to pass through.
Arterioles	_____ arteriole has a wider lumen than the efferent arteriole	to create _____ in the glomerulus for rapid ultra-filtration.
Bowman's capsule	Is _____ shaped	to increase _____ for ultra-filtration.
	Walls consist of a single layer of _____ epithelium	to allow _____ passage of substances.
	Special cells called _____ have pores between cells	to _____ _____

4.3.2 Selective reabsorption:

- **Useful** substances are selectively reabsorbed from the **proximal** convoluted tubules into the surrounding _____ network. This process is partly active and partly passive.

- **Active reabsorption** involves carrier molecules and often occurs against the concentration gradient, to ensure that *all* useful substances can re reabsorbed into blood. The cuboidal cells thus have many _____ to supply energy.

- The cells also have a **brush border / microvilli** to increase the surface area for reabsorption.

- **Passive reabsorption** occurs by diffusion and/or _____ and needs no energy, as it always occurs with the concentration gradient. Much water is reabsorbed here by osmosis.

- Capillaries reabsorb all _____ and amino acids here, also any vitamins & minerals the body needs. Excess vitamins / minerals won't be reabsorbed, e.g. if the person has more vitamin C in the blood than needed (we can't store water-soluble vitamins).

- The **loop of Henle** is specifically concerned with **water reabsorption**. _____ are pumped into the medulla on the ascending side, so that water is easily reabsorbed into the capillaries around the descending side. This always occurs by osmosis. In desert animals like camels and kangaroo rats, the loop of Henle is very long, so water is conserved easily. Their renal medulla is thus wider than that of other animals.

4.3.3 Tubular excretion:

- At the **distal** convoluted tubule, large wastes like **creatinine** are actively excreted from the _____ into the tubules, as such molecules are too big to filter into the capsule. Smaller wastes like **urea & uric acid** are also passed out of the blood, as many of them may not have come close to the podocytes during ultra-filtration. Drugs like **penicillin and aspirin** are excreted into the distal convoluted tubule after they have circulated through the body and done their work.

- The walls of the distal tubule do not have microvilli.

- The distal tubule also regulates the _____ **of blood** by regulating the excretion of H+ ions and bicarbonate ions. More H+ ions are excreted if the blood is too acidic and more bicarbonate ions are excreted if the blood is too alkaline.

- **Much water** passes from the distal tubule and collecting duct into the blood stream. This is regulated by the hormone _____ from the pituitary gland and is the chief mechanism responsible for osmoregulation.

The distal convoluted tubule:

Consider the functioning of the distal convoluted tubule. Why is it that athletes at most high-level events are asked to submit urine samples? What are organizers looking for and why are they confident of finding "the cheats"? _____

_____

_____

_____

_____

4.3.4 The composition of urine:

Urine composition varies depending on diet, activity, fluid intake and environmental temperature.

Factors affecting urine composition:

How will each of the factors mentioned above influence the composition of urine and why?

Diet _____

_____

Activity _____

_____

Fluid intake _____

_____

Environmental temperature _____

_____

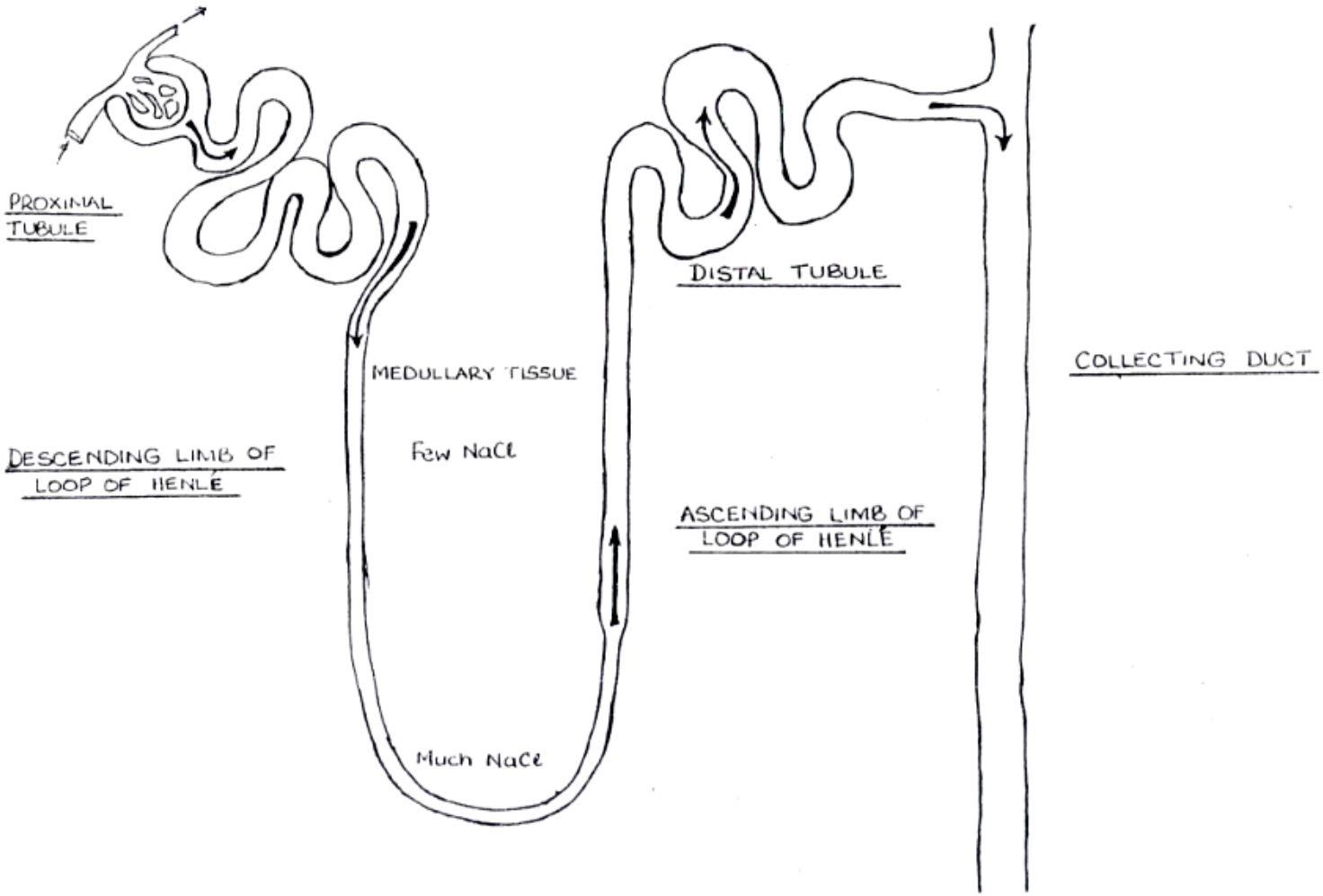
The average person's urine may contain the following:

Water	96 %
Urea	2 %
Inorganic salts (mainly NaCl)	1,5 %
Other substances*	0,5 %

* These include **bile pigments** (which give urine the typically yellow colour), as well as **bile salts** (which gives urine a bitter taste) [No, the staff have not tasted urine to find out… ☺] The smell of urine is due to urea.

The pH of urine is usually **slightly acidic** (pH 6,5), but it may be neutral or slightly alkaline, depending on diet.

OSMOREGULATION IN THE KIDNEYS



4.4 THE REGULATION OF KIDNEY ACTIVITY:

- The hormone _____is released by the pituitary gland & reaches the kidneys via the blood.
- It controls the permeability of the walls of the _____ convoluted tubules and _____ ducts of the nephrons.
- The amount of water in the blood is detected by **osmorecepetors** in the brain
- If there is too little water in the blood, e.g. due to _____:

  MORE ADH is released, making the walls of the distal tubule & collecting ducts more permeable to water. More water is reabsorbed into the blood by **osmosis**, so water is conserved. A _____ volume of concentrated urine is excreted.
- If there is too much water in the blood, e.g. due to _____:

  LESS ADH is released, making the walls of the distal tubule and collecting ducts less permeable to water. Less water is reabsorbed into the blood by **osmosis**, so more water is released via urine. A _____ volume of dilute urine is excreted.
- So the kidneys and pituitary gland together maintain the correct water content in the blood.

4.5 FUNCTIONS OF THE KIDNEYS:

- **Excretion** Eliminate nitrogenous wastes like _____ and uric acid.
- **Osmoregulation** Maintain normal _____ content of the blood by elimination of salts and excess water.
- **pH control** H+ or bicarbonate ions are excreted to maintain the blood pH at a slightly alkaline level.
- **Toxin control** Some ingested poisons may be excreted by the kidneys.

5. IMPLICATIONS FOR HOMEOSTASIS

The kidneys are the ultimate CONTROLLERS OF CHEMICAL BALANCE between the body and environment. Osmoregulation causes the retention / elimination of water to maintain the volume of blood and intercellular fluid at levels optimal for the functioning of the cells.

DISCUSSION TOPIC: Organ donation:

See Worksheet Question 6. Discuss in class. This need not be a formal debate, but *must* be done.

WORKSHEET: QUESTION 5 IS ESSENTIAL, THE REST ARE OPTIONAL ACTIVITIES

QUESTION 1: Differentiate between:

- Ureter & urethra _____

  _____
- Renal artery & renal vein _____

  _____
- Cortex & medulla _____

  _____
- Nephron & Malpighian body _____

  _____
- Afferent & efferent arteriole _____

  _____
- Active & passive reabsorption _____

  _____

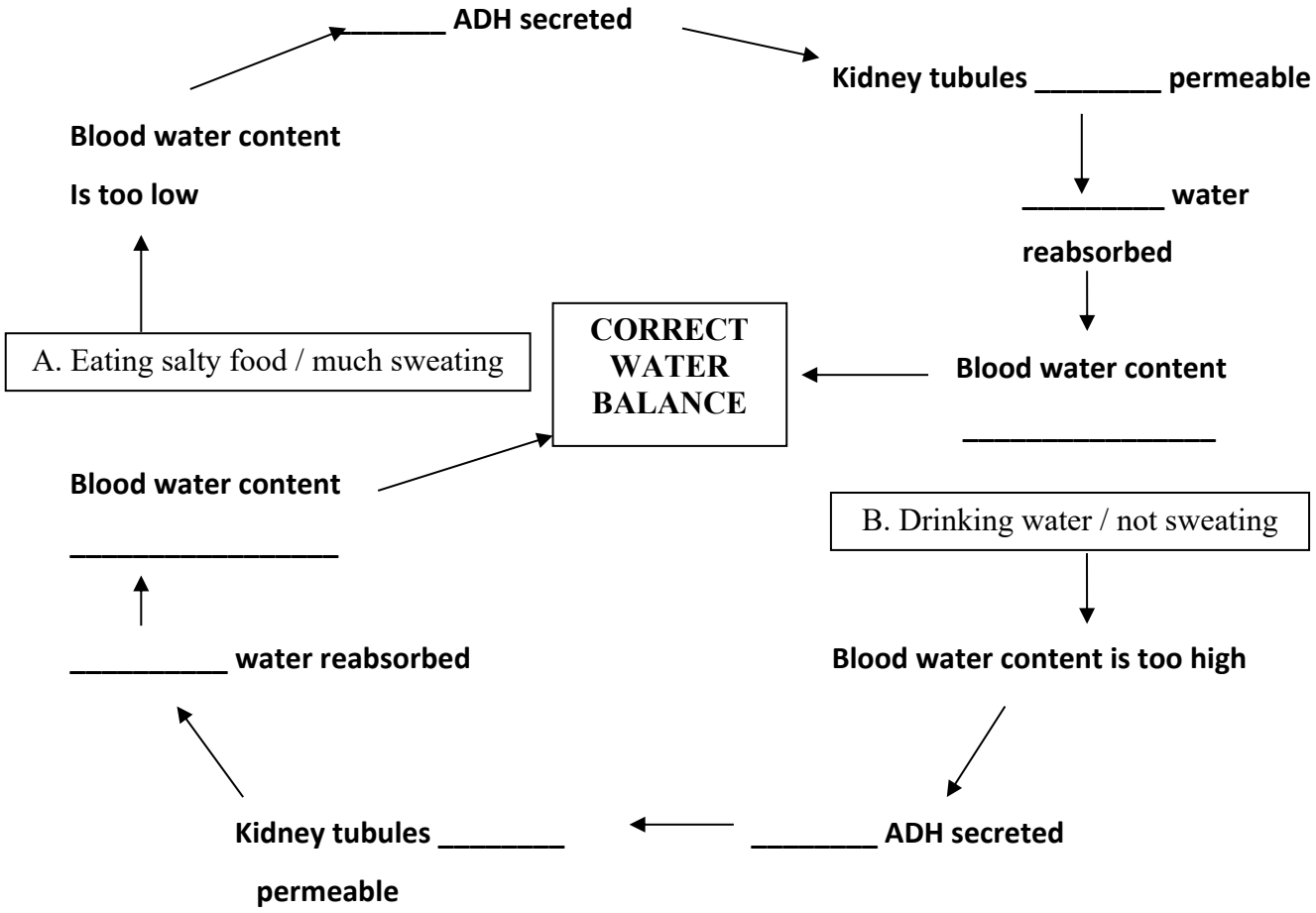
QUESTION 2:

List the following parts in their correct order and briefly give the function of each:
Collecting duct; Proximal convoluted tubule; Distal convoluted tubule; Loop of Henle; Bowman's capsule.

PART	FUNCTION

QUESTION 3:

Fill in the following flow diagram on the functioning of ADH.



QUESTION 4:

(1) What is "oedema" and why is it associated with renal failure? _____

_____

(2) Why is a "selectively permeable" membrane used in a dialysis machine?

_____

_____

_____

_____

_____

_____

QUESTION 5:

Interpreting data in a table and making deductions:

The table below compares the concentrations of selected substances in normal blood plasma, the glomerular filtrate and urine of a healthy person:

Substance	(A) Blood g/100 ml	(B) Filtrate g/100 ml	(C) Urine g/100 ml
Glucose	0,1	0,1	0
Protein	7	0	0
Urea	0,03	0,03	2
Ammonia	0	0	0,04
Water	92	98	96

5.1 Briefly explain the differences in concentrations of

(1) glucose in B and C

_____

_____

(2) protein in A and B

_____

_____

(3) urea in B and C

_____

_____

(4) ammonia in A and C

_____

_____

5.2 The intake of alcohol **inhibits the release of ADH**. Explain how the composition of urine would differ from normal if a person has had a fair amount of alcohol to drink.

_____

_____

_____

_____

5.3 The concentration of which of the substances on the table, if any, would be affected if a person ate a meal with a very high protein content? _____

_____

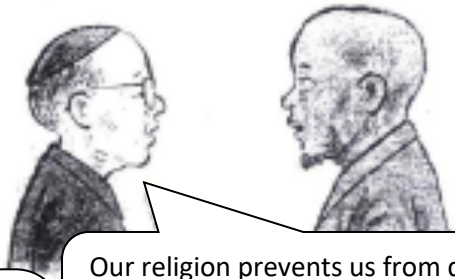
_____

QUESTION 6:

Discussion topic: **ORGAN DONATION**

Read the viewpoints of different people regarding organ donation and have a class discussion.

It was so fortunate that I was compatible with my husband. I donated one of my kidneys to him more than 2 years ago. Today, you would never know that he had ever been sick. We had a beautiful little girl two months ago. If I hadn't donated my kidney, I wouldn't have my husband or my daughter.



Our religion prevents us from donating any organs – we have to be buried with all our organs intact.

My mom is really sick. She needs a new kidney. I don't know what I'll do if she dies. She is the only person who cares about me. Is there someone who can help us?

I've heard that you can get quite a lot of money for selling one of your kidneys. I'd like to find out more about this – I'm struggling to find enough money to feed my family. I'll do anything it takes.

We have such a long waiting list of patients needing a kidney transplant. It's not so bad for private patients, but there are so many poor people who need a donor. Many will die before one becomes available.

My twin sister needs a kidney transplant, but there is no way I'm giving up one of my kidneys. It is just not done in our culture. Even if I decided to do it, what would happen if my other kidney stopped working? And what about the scar? She's been on the waiting list for a while and I'm sure she will get a donor soon.
