Grade 11 excretion notes

Physical Science (Fourways High School)

SESSION 7: EXCRETION

Key Concepts

In this session we will focus on summarising what you need to know about:

- The different organs responsible for excretion in the human body
- The macroscopic structure of the urinary system
- The macroscopic and nicroscopic structure and functioning of the kidney
- Disorders of the kidney

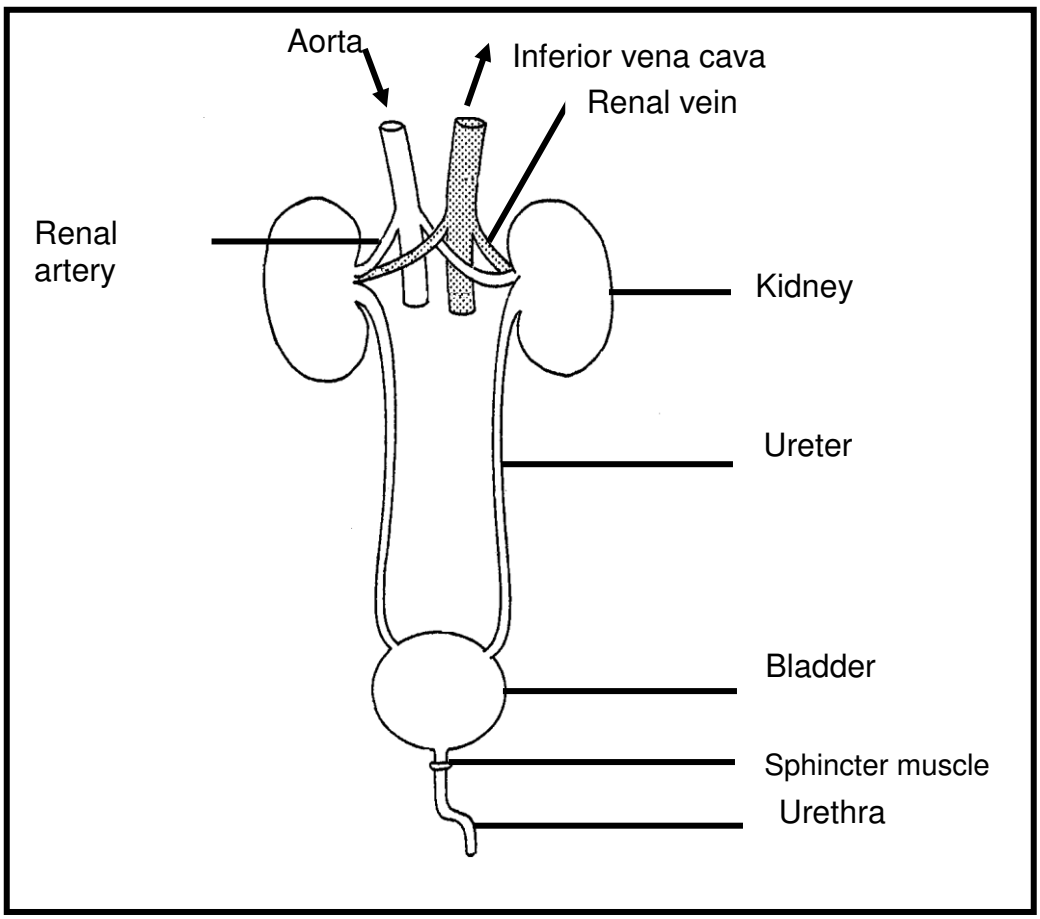
Terminology & definitions

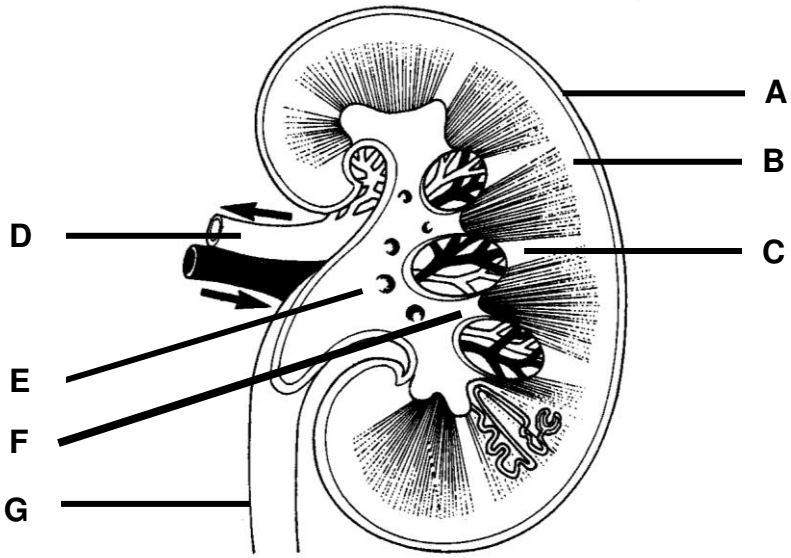
Active absorption: absorption of substances against the concentration gradient using energy
Ascending limb: a part of the loop of Henlé of the renal tubule of the nephron which carries wastes from the hairpin bend towards the distal convoluted tubule
Bowman's capsule: cup-shaped structure surrounding the glomerulus of the nephron in the human kidney
Calyx: wide funnel-like structure found in the kidney into which the collecting tubules open
Descending limb: a part of the loop of Henlé of the renal tubule of the nephron which carries wastes from the proximal convoluted tubule towards the hairpin bend
Dialysis: a method of artificially removing waste products from the bloodstream if the kidneys are unable to do so on their own
Distal convoluted tubule: the twisted portion of the renal tubule that is furthest away from the Malpighian body
Duct of Bellini: tubes formed by the union (joining) of the collecting ducts in the kidney
Excretion: removal of waste products of metabolism from cells
Filtration: the process by which water and small solutes, including metabolic wastes, are extracted from the body fluid and passed into the excretory system
Glomerulus: capillary network within Bowman's capsule of the nephron of the human kidney; also referred to as the first capillary network
Loop of Henlé: region of the nephron of the human kidney which lies between the proximal and distal convoluted tubules
Malpighian body: part of the nephron of the human kidney; made up of the Bowman's capsule and the glomerulus
Nephron: the functional unit responsible for excretion and osmoregulation in the kidney
Passive absorption: absorption of substances down a concentration gradient i.e. from high concentration to low concentration
Podocytes: specialised squamous cells in the inner layer of the Bowman's capsule in the nephron; assist in the filtration process
Proximal convoluted: the twisted portion of the renal tubule that is closest to the Malpighian body
Renal artery: blood vessel carrying oxygenated blood with nitrogenous wastes to the kidney
Renal capsule: the thin, fibrous, protective outer covering of the kidney
Renal vein: blood vessel carrying de-oxygenated blood with very little nitrogenous wastes away from the kidney
Selective absorption: the absorption of only certain solutes from blood filtrate; takes place in the excretory organs of animals

Slit pores: tiny pores between the podocytes which form the lining of the Bowman's capsule; the pores enable the podocytes to act as selective filters
Tubular secretion: movement of waste substances, from the second capillary network, into the renal tubule of the nephron in the human body
Ureter: the duct which conveys urine from the kidney to the bladder
Urethra: tube transporting urine from the bladder to the exterior

Diagrams

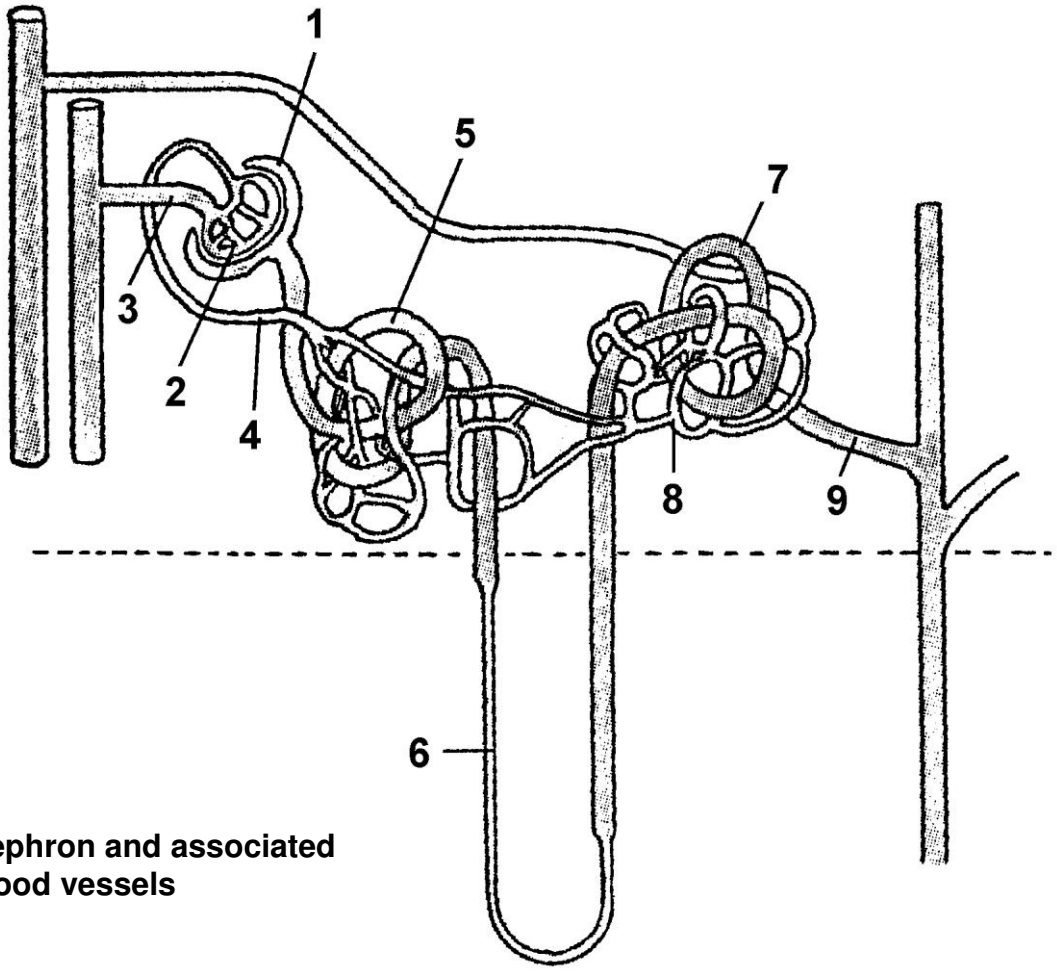
The urinary system





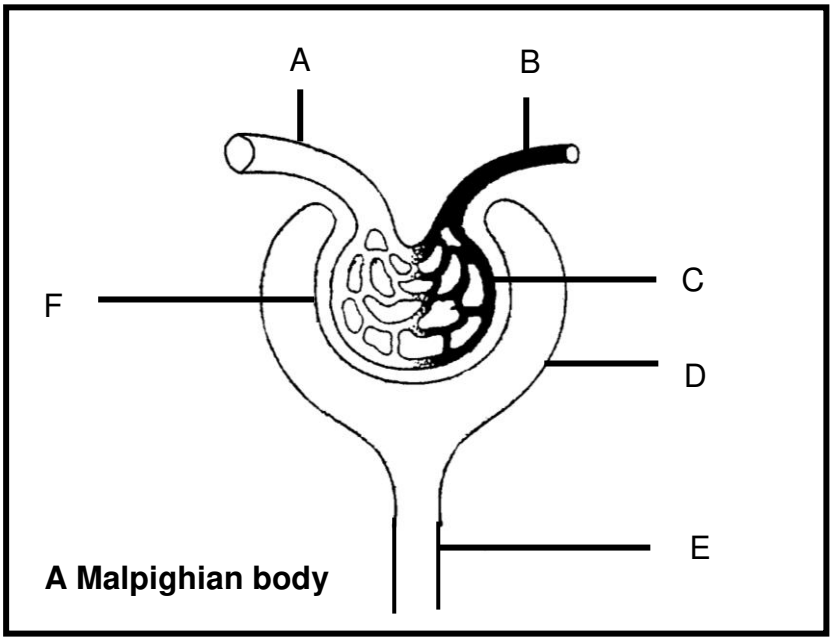
Longitudinal section of a human kidney

A – Renal capsule
B- Cortex
C- Medulla
D- Renal vein
E - Pelvis
F - Calyx
G - Ureter



Nephron and associated blood vessels

1 – Bowman's capsule
2 – Glomerulus
3 – Afferent arteriole
4 – Efferent arteriole
5 – Proximal convoluted tubule
6 – Descending limb of Henle
7 – Distal convoluted tubule
8 – Secondary capillary network
9 – Collecting tubule



A – Afferent arteriole
B – efferent arteriole
C – Glomerulus
D – Bowman's capsule
E – Proximal convoluted tubule

X-planation

What is excretion?
Excretion, which is the removal of waste products formed by metabolism, ensures that these waste products (like CO_2 and nitrogenous wastes) do not build up to toxic levels.

The different organs responsible for excretion in the human body

Excretion organ	Substance excreted	Origin of substance excreted
Lungs	CO_2 + Water vapour	Cellular respiration
Kidneys	Urine (Urea, Uric acid, Water, Salts, Ammonia)	Metabolic waste
Liver	Bile pigments into the alimentary canal	Dead red blood cells
Bladder	Urine	Metabolic waste
Skin	Sweat (H_2O, Salts, Urea)	Metabolic waste

The macroscopic structure of the urinary system
The urinary system consists of two kidneys, two ureters, the urinary bladder and the urethra.
The renal artery carries blood to the kidney and the renal vein carries blood away from the kidney.
The renal artery, renal vein and ureter are attached to the kidney at its hilum.

The ureters begin within each kidney (the pelvis) and carry urine from the kidneys to the bladder.
The bladder stores urine temporarily.
The urethra carries urine from the bladder to the exterior. In the male, the urethra, carriers urine as well as semen. In the female, the urethra and vagina open separately.

The structure and functioning of the kidney
Internal structure of the kidney:
The kidney is covered and protected by the thin renal capsule. Within the renal capsule is the outer cortex and inner medulla. The medulla is made up of a number of cone-shaped pyramids. The pyramids have a number of tubes called the ducts of Bellini. The ureter extends into each kidney as a widened pelvis. The pelvis branches into a number of calyces each of which encloses the apex of a pyramid. Embedded within each kidney there are about 1 million nephrons.

The nephron:
Consists of two parts:

a) The Malpighian body
   - Made up of cup-shaped Bowman's capsule and the glomerulus
   - The inner wall of the capsule is made up of specialised cells, the podocytes.
   - They form slit pores between them.
   - The space between the inner and outer wall of the Bowman's capsule is called the capsular space.

b) The renal tubule
   - Consists of: proximal convoluted tubule, loop of Henlé (descending limb, ascending limb, hairpin bend) and distal convoluted tubule.
   - The collecting tubules unite to form a duct of Bellini which runs through the pyramids and open into the calyces of the pyramids.

Blood supply of the nephron:
- Renal artery → afferent arterioles → glomerulus → efferent arteriole → second capillary network → venules → renal vein

Functioning of the kidney

Function	Where it takes place	What happens
1. Transport of blood to the glomerulus	From the renal artery to the glomerulus	Blood carrying useful and waste substances is carried to the glomerulus via the afferent arteriole.
2. Glomerular filtration (ultra-filtration)	In the glomerulus	All the substances in the blood, except blood corpuscles and proteins, are forced into the capsular space of Bowman's capsule.
3. Selective re-absorption (tubular re-absorption)	At the: Proximal convoluted tubule Distal convoluted tubule Parts of loop of Henlé Collecting tubules	Water, salts, glucose and amino acids are selectively re-absorbed (by osmosis and active transport) by the blood capillaries surrounding the tubules.
4. Tubular excretion	Along the entire kidney tubule	Cells in the walls of the tubule excrete waste into the blood capillaries. These substances include salts, hydrogen ions and some poisons.
5. Transport of urine to the bladder and urination	Bladder and urethra	From the tubules the urine passes into the pelvis and then down the ureters into the bladder. From time to time the bladder is emptied. The urine passes along the urethra to the outside. The process is called urination.

The structural suitability of the nephron for its functions:

a) Adaptations of the Malpighian body for its functions:

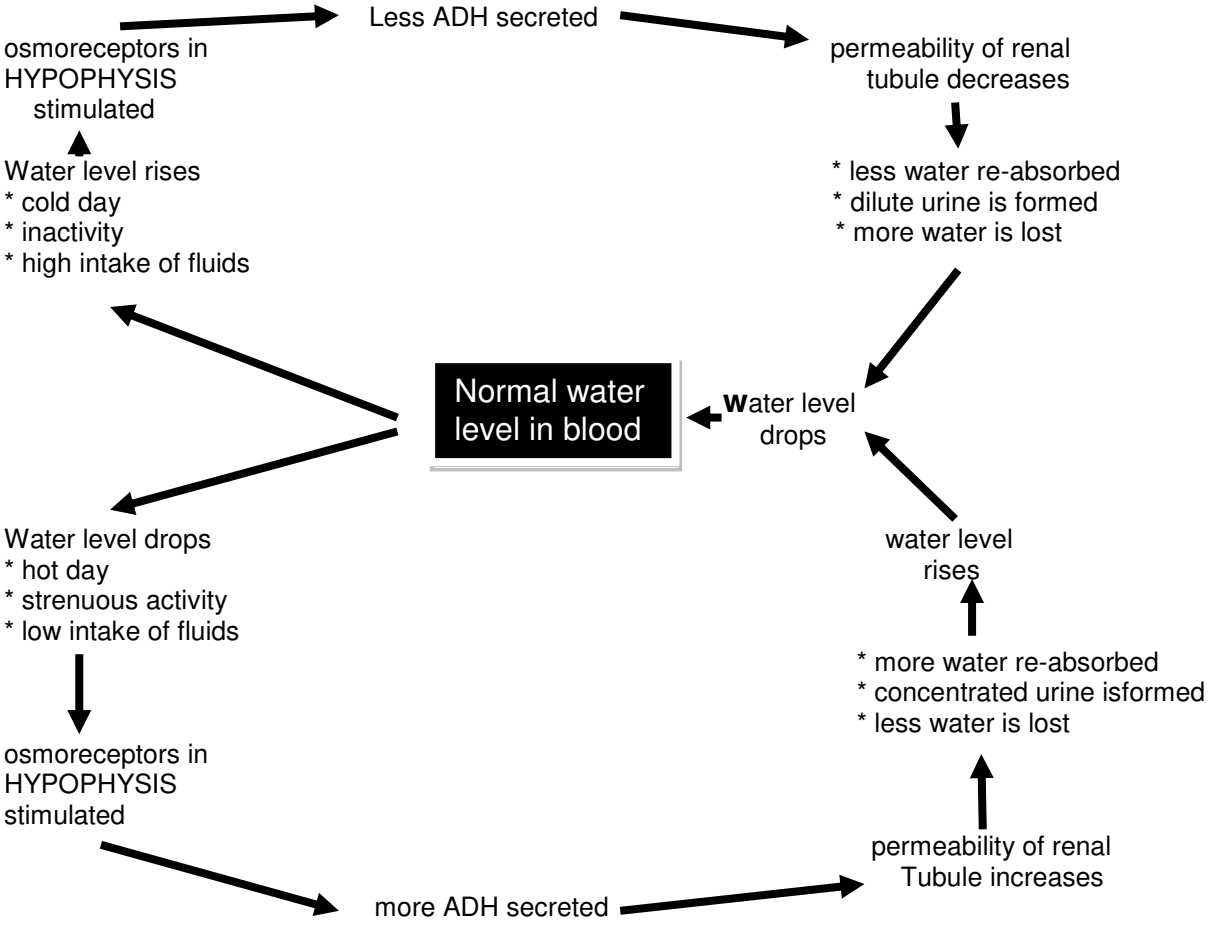
- The efferent arteriole is narrower than the afferent arteriole allowing a pressure system to develop which is essential for filtration.
- The small size of the slit pores between the podocytes ensures that the blood corpuscles and large plasma proteins do not pass through into the capsular space.(filtration)
- The Bowman's capsule is cup-shaped allowing more close contact with the blood capillaries of the glomerulus for filtration.
- A single layer of endothelial cells of the capillary wall and a single layer of podocytes of the Bowman's capsule form a thin surface for filtration.
- Large surface area of the capillary network of the glomerulus increases the efficiency of filtration. (many capillaries increase the surface area for reabsorption and excretion)

- Pores on endothelium of the capillaries allow for a passageway of substances during filtration.

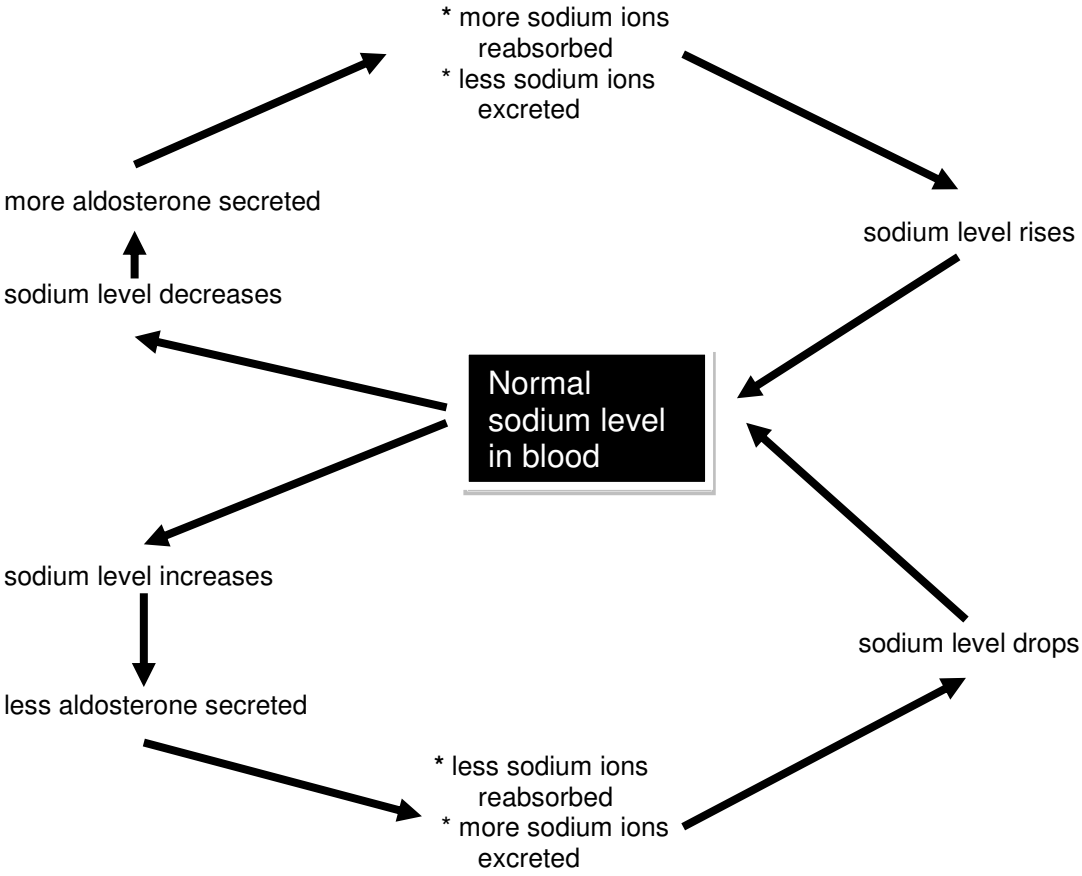
b) Adaptations of the renal tubule for its functions:

- It is long and convoluted allowing sufficient time for re-absorption of useful substances. (also increasing surface area)
- The second capillary network allows for the re-absorption of useful substances and for excretion of waste substances into the tubules.
- The cells of the tubules are richly supplied with mitochondria providing energy for active re-absorption to take place.
- The cells of the tubule have micro-villi to increase the surface area for excretion and re-absorption.
- The sodium pump ensures that the medulla always has a high concentration of salts ensuring that large amounts of water can be absorbed from the distal tubule and the collecting tubule by osmosis.(rephrase to include difference in water potential/water potential gradient)

Role of the kidney in osmoregulation:



Role of the kidney in salt regulation:



Disorders of the kidney

Disease leading to kidney failure
E.g. kidney stones, kidney infections, bilharzia

Disease	Cause	Symptoms	Treatment
Bilharzia	Bilharzia worm	Tiredness Headaches Swollen liver and spleen	Drugs, e.g. praziquantel

Protection of the kidneys:
We can keep our kidneys healthy by:

- Drinking enough water
- Avoiding overuse of painkillers, anti-inflammatory drugs,
- Avoiding physical injury

Dialysis:
People with severe renal failure can be treated using an artificial kidney. An artificial kidney is a machine that uses the process of dialysis to purify the blood.
Dialysis is the separating of small molecules such as urea from large molecules such as proteins. A dialysis tube is used, through which the small molecules can diffuse.

Two or three times a week, a patient is connected to a kidney machine for three to six hours. Blood is taken from a vein, usually in the arm, and pumped through he fine tubes in the artificial kidney and back into another vein. The fine tubes are made of selectively permeable membranes. Dialysis fluid flows into the kidney machine around these tubes and out again. The dialysis fluid contains salts, glucose and other blood plasma constituents in the same concentration as the blood, but contains no wastes. Dialysis occurs. Wastes such as urea diffuse from the blood into the dialysis fluid, which then leaves the machine.

Advantages and disadvantages of kidney transplants and dialysis treatment:

Treatment	Advantages	Disadvantages
Kidney transplant	More permanent solution to the problem.	The patient's immune system might reject the transplanted kidney. Very expensive.
Dialysis treatment	Can be used for many years.	It is expensive to travel to the hospital to have dialysis. There is a high demand for the machine. Patients need to live close to a hospital that has a dialysis machine. If the machine is not cleaned properly, patients could catch blood-borne diseases.

X-ample Questions

Question 1

(Adapted from Senior Certificate Examination, March 2004, Biology SG, Paper II, Question 4.2.2)

Study the passage below and answer the questions that follow.

Urine is formed by the nephrons. The two kidneys contain approximately two million nephrons. The basic function of the nephron is to "clean" or "clear" the blood plasma of unwanted substances as it passes through the kidney, while retaining in the blood those substances that are still needed by the body.

(i) How many nephrons will there be in ONE kidney? (1)

(ii) What is the basic function of a nephron? (1)

(iii) Give any other function of the kidney apart from the function mentioned in (ii). (1)

(iv) Give any THREE useful substances which are retained in the blood. (3)

(v) Name THREE unwanted substances which will not be reabsorbed into the blood and eventually become part of urine. (3)

Question 2

(Adapted from Senior Certificate Examination, March 2004, Biology HG, Paper II, Question 5.1)

The following graph indicates the concentrations of certain substances as they move through the various regions of the nephron. Study the graph and answer the questions that follow.