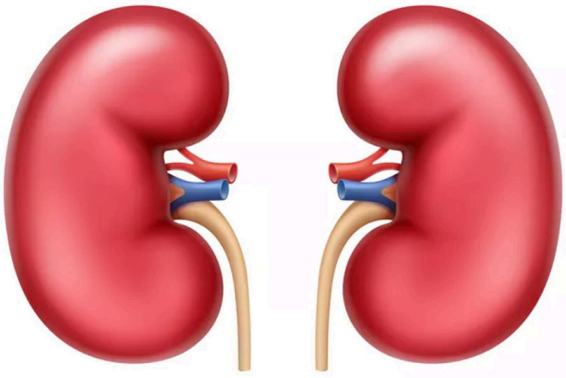
Year 13 AHL

IB BIOLOGY

11.3 The Kidney and Osmoregulation



Name:

Teacher: Mr Trent

11.3 The Kidney & Osmoregulation

Essential idea:
All animals excrete nitrogenous waste products and some animals also balance water and solute concentrations.
Nature of science:
Curiosity about particular phenomena—investigations were carried out to determine how desert animals prevent water loss in their wastes.

Understandings:
11.3.U1 Animals are either osmoregulators or osmoconformers.
11.3.U 2 The Malpighian tubule system in insects and the kidney carry out osmoregulation and removal of nitrogenous wastes.
11.3.U3 The composition of blood in the renal artery is different from that in the renal vein.
11.3.U4 The ultrastructure of the glomerulus and Bowman's capsule facilitate ultrafiltration.
11.3.U.5 The proximal convoluted tubule selectively reabsorbs useful substances by active transport.
11.3.U6 The loop of Henle maintains hypertonic conditions in the medulla.
11.3.U7 ADH controls reabsorption of water in the collecting duct.
11.3.U8 The length of the loop of Henle is positively correlated with the need for water conservation in animals.
11.3.U9 The type of nitrogenous waste in animals is correlated with evolutionary history and habitat.

Applications and skills:
11.3.A1 Application: Consequences of dehydration and overhydration.
11.3.A2 Application: Treatment of kidney failure by hemodialysis or kidney transplant.
11.3.A3 Application: Blood cells, glucose, proteins and drugs are detected in urinary tests.
11.3.S1 Skill: Drawing and labelling a diagram of the human kidney.
11.3.S2 Skill: Annotation of diagrams of the nephron.
11.3.S3 The diagram of the nephron should include glomerulus, Bowman's capsule, proximal convoluted tubule, loop of Henle, distal convoluted tubule; the relationship between the nephron and the collecting duct should be included.
Utilization:

- The removal of kidney stones by ultrasound treatment

The Kidney

Define *excretion*.

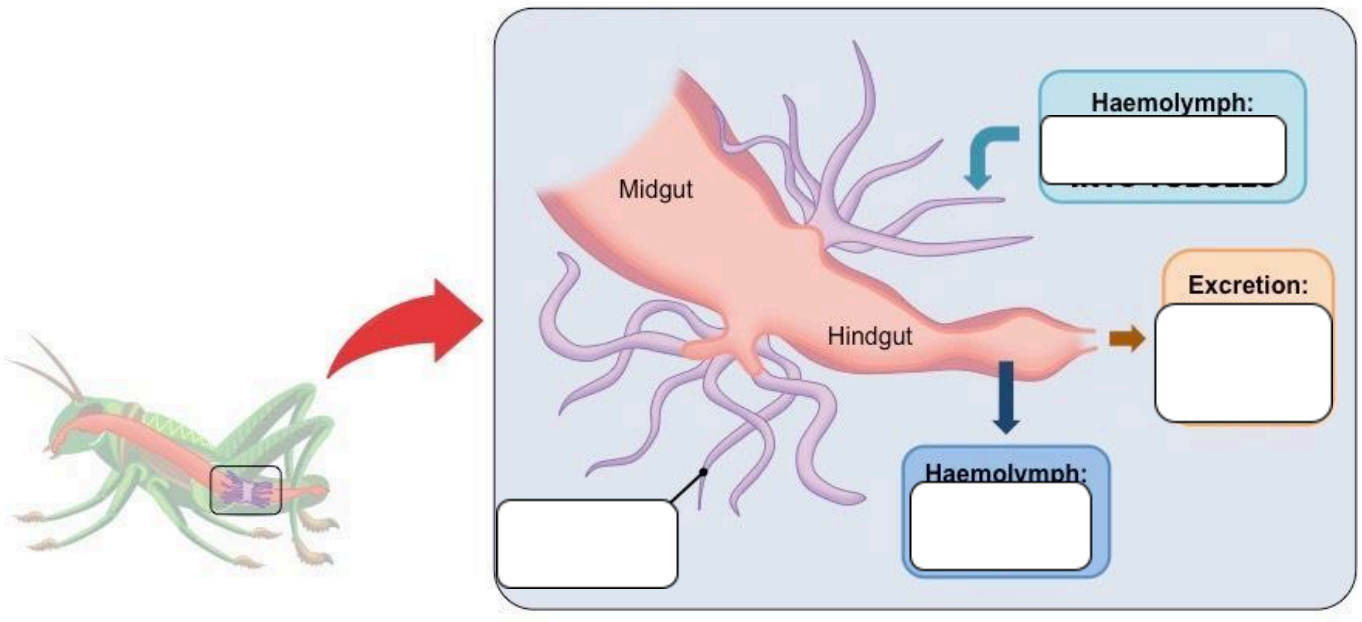
11.3.U1 Animals are either osmoregulators or osmoconformers.
11.3.U 2 The Malpighian tubule system in insects and the kidney carry out osmoregulation and removal of nitrogenous wastes.

- _____ tightly regulate their body osmolarity, which always stays constant, irrespective of their environment.
- _____ play a large role in osmoregulation by regulating the amount of water reabsorbed. A disadvantage is that osmoregulation costs the animal _____.
- Osmoregulators are much more common in the _____- kingdom

- _____maintain an internal conditions that are equal to osmolarity of their environment.

- Minimizing the osmotic gradient minimizes the water movement in and out of cells. A disadvantage is that internal conditions may be _____.
- Most osmoconformers are _____invertebrates, e.g. starfish.

Animal Excretion



11.3.U9 The type of nitrogenous waste in animals is correlated with evolutionary history and habitat.

Where do our wastes come from?

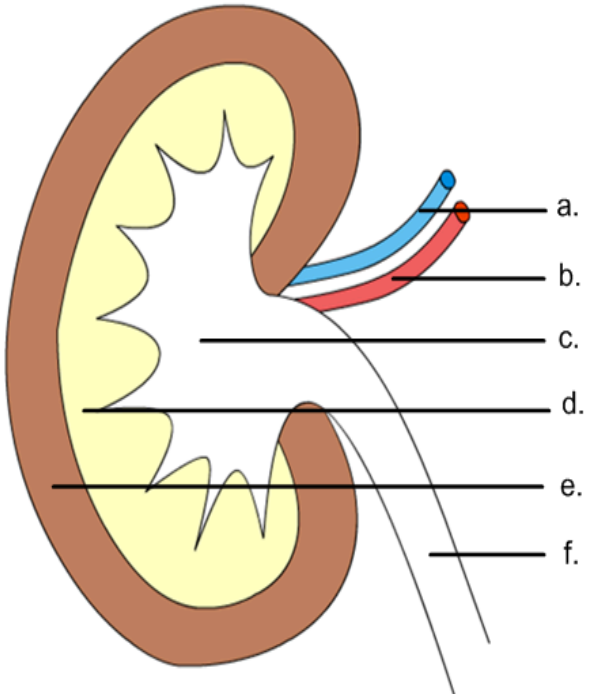
Proteins

Nucleic Acids

Compound	Chemical Formula	Toxicity	Water Solubility	Animals
Ammonia				Aquatic Animals
	$(NH_2)_2CO$			
	$C_5H_4N_4O_3$			

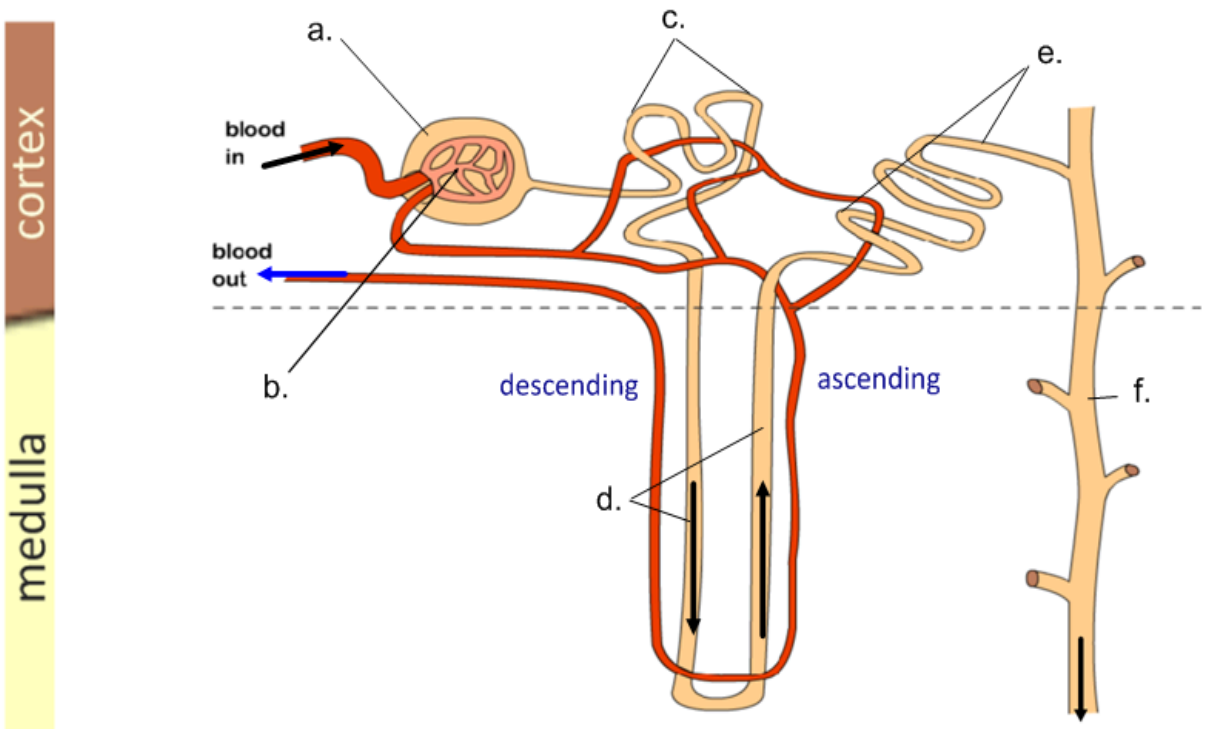
Summarise this table in 10 words or less (and as many images as possible)

11.3.U3 The composition of blood in the renal artery is different from that in the renal vein.
Label and state the functions of the structures of the kidney.



11.3.S1 Skill: Drawing and labelling a diagram of the human kidney.
Try drawing and labelling a kidney in the space below:

11.3.S2 Skill: Annotation of diagrams of the nephron.
11.3.S3 The diagram of the nephron should include glomerulus, Bowman's capsule, proximal convoluted tubule, loop of Henle, distal convoluted tubule; the relationship between the nephron and the collecting duct should be included.
The nephron is the functional unit of the kidney.

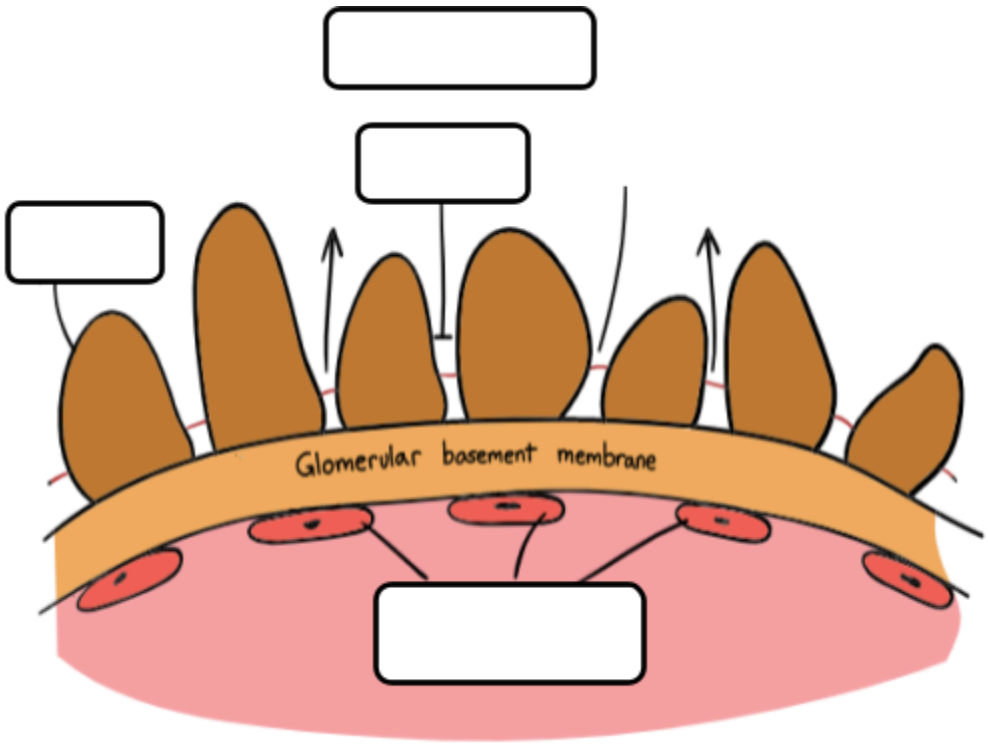


Renal (Bowman's) Capsule
Glomerulus
Loop of Henle
Collecting duct
Proximal Convoluted Tubule
Distal Convoluted Tubule

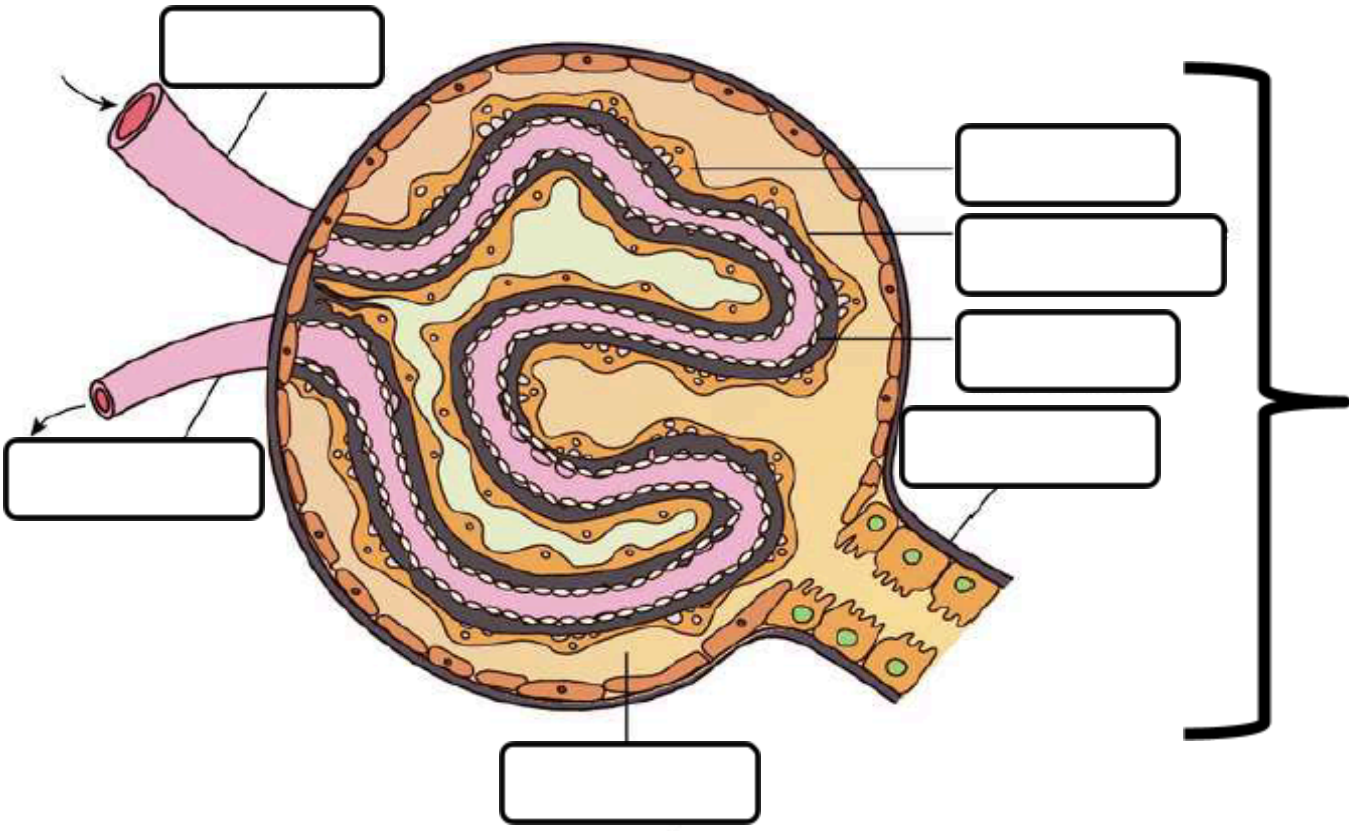
Label and state the structures of the functions of the nephron.

	Structure	Function
	Renal capsule	Ultrafiltration of blood.

11.3.U4 The ultrastructure of the glomerulus and Bowman's capsule facilitate ultrafiltration.



This shows the relationship between the Glomerulus and the Bowman's Capsule



11.3.U.5 The proximal convoluted tubule selectively reabsorbs useful substances by active transport.
In (overly) simple terms, the kidney works by forcing everything out of the blood and then selectively reabsorbing the components which are desirable. Waste products therefore continue to the pelvis and become part of the urine.

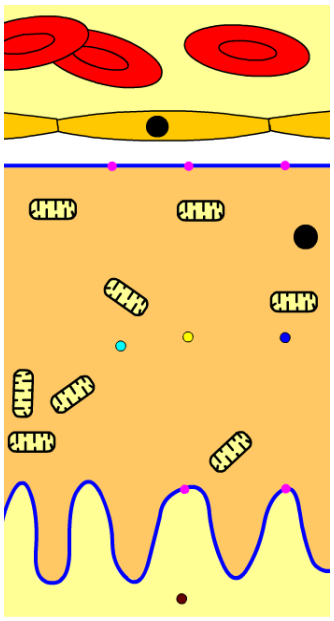
1. Ultrafiltration is the first step, and takes place in the renal capsule. Explain the process of ultrafiltration.

2. List three components of the blood which are not pushed into the glomerular filtrate and state the reason why.

3. Selective reabsorption returns valuable molecules to the blood.

   a. State the location of selective reabsorption in the kidney.

   b. List three molecules that are recovered back into the blood by selective reabsorption.



Explain the significance of the following elements of selective reabsorption.

Convolutions of the tubule	

Microvilli	
Mitochondria	
Protein pumps and channels	
Osmosis	

Exam Style Question: Explain the process of ultrafiltration (8 marks)

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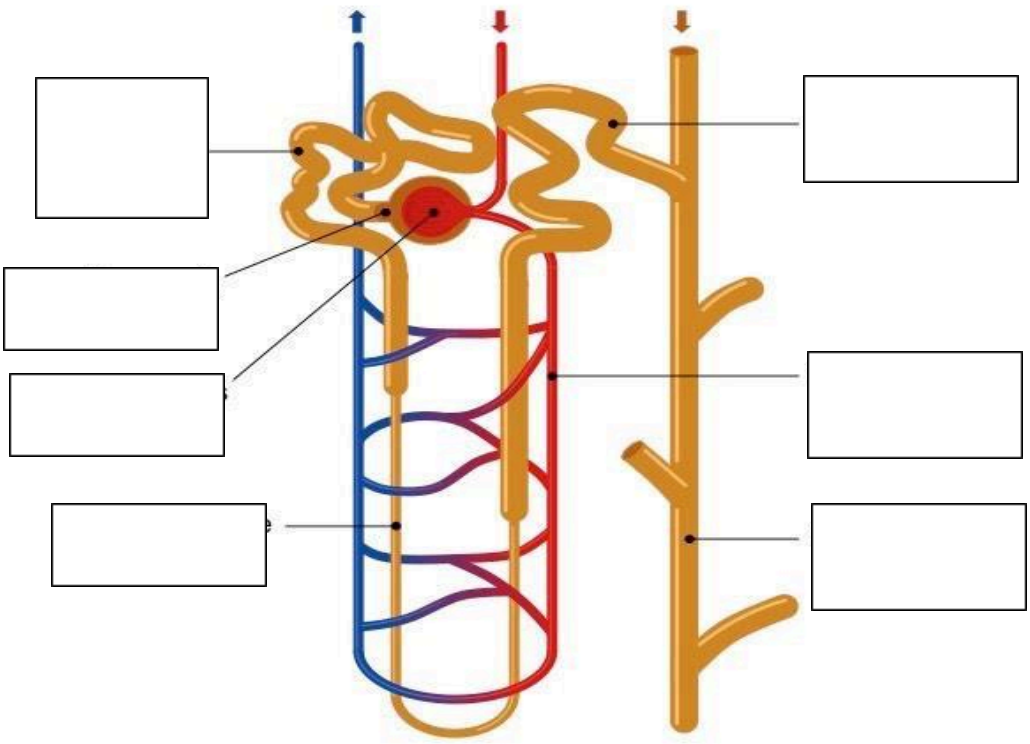
Occurs in the Bowman's/renal capsule;
In the kidney cortex;
The (entering) afferent arteriole has a larger diameter than the (leaving) efferent arteriole;
This creates high pressure in the capsule;
Some smaller molecules are forced out of the glomerulus/blood into the capsule;
Through basement membrane and the fenestrations/pores in the capillary wall;
filtration slits between foot projections of podocyte cells also act as a filter;
Molecules in the filtrate include water, urea, glucose, amino acids, salts;
Plasma proteins, platelets, and cells are too large so remain in the blood;
Glomerular filtrate is then transported through the nephron;

11.3.U6 The loop of Henle maintains hypertonic conditions in the medulla.
11.3.U7 ADH controls reabsorption of water in the collecting duct.



The hormone _____ balances the water concentration of the blood by changing the _____of the collecting duct by opening _____.

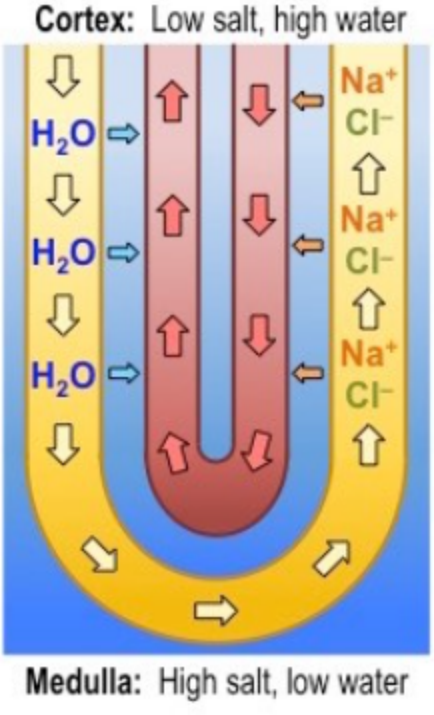
A major function of the kidney is to maintain the balance of water in the blood.

a. Define *osmoregulation*.

b. State the location of osmoregulation in the kidney.

c. Distinguish between the descending and ascending parts of the loop of Henle.

d. Explain the role of the loop of Henle in osmoregulation.



Explain the role of the collecting duct in osmoregulation.

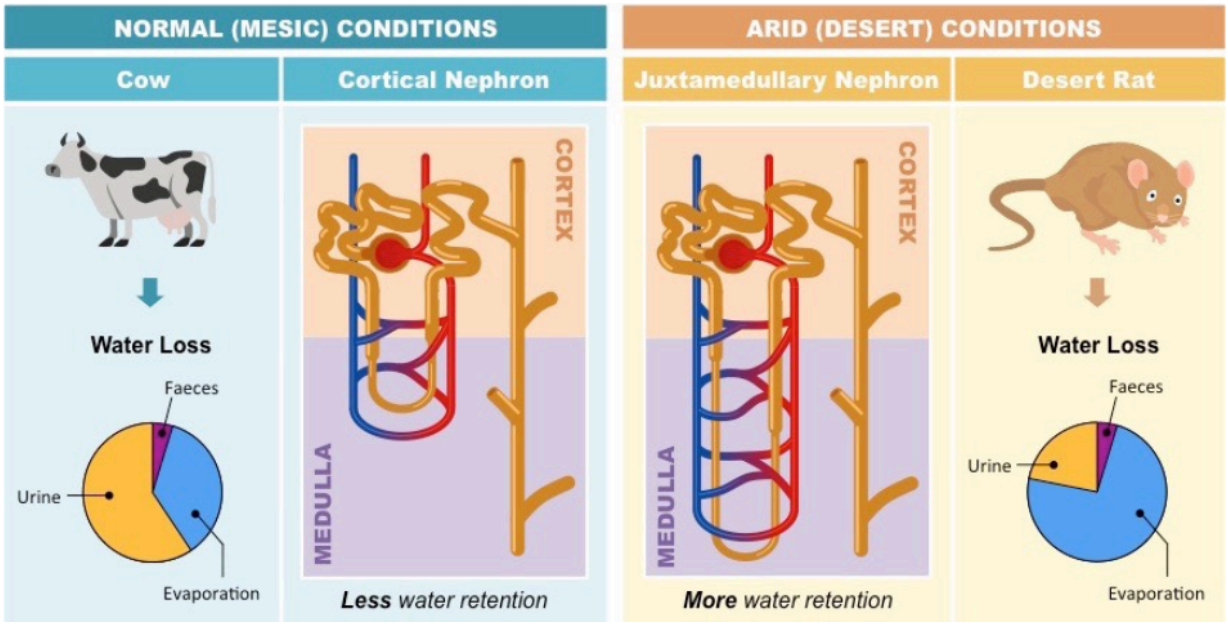
ADH is a hormone used in negative feedback control of blood water balance.

i. State the two parts of the brain involved in osmoregulation and their functions.
   - o
   - o

ii. Describe the effects of ADH on:

The walls of the collecting duct	
Water uptake into the blood	
Concentration of the urine	

11.3.U8 The length of the loop of Henle is positively correlated with the need for water conservation in animals.



Exam-Style Question: Explain osmoregulation in the kidney (8 marks)

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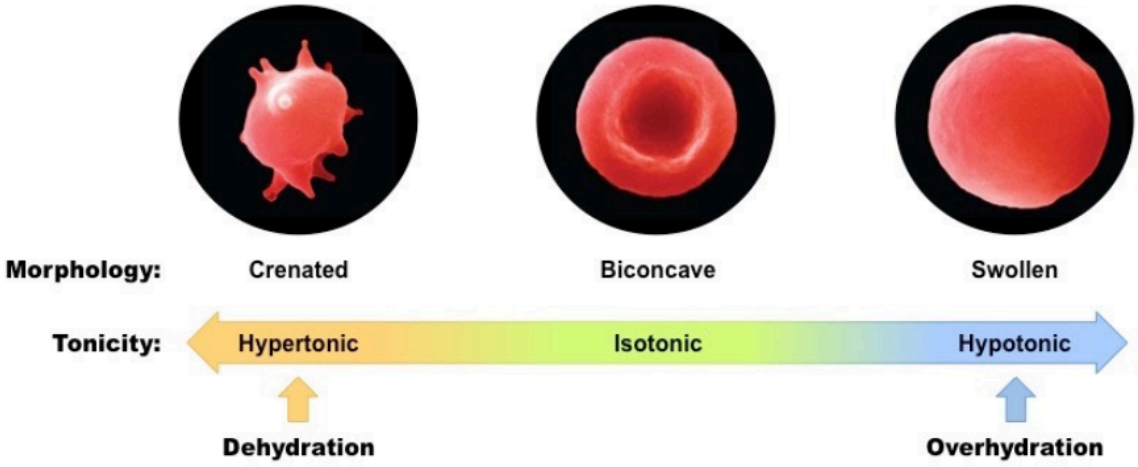
Osmoregulation takes place in the Loop of Henle and collecting duct;
In the medulla;

Loop of Henle
Descending limb is permeable to water but not to Na^+;
Descending limb is permeable to Na^+ but not to water;
Na^+ is pumped out of the ascending limb into the medulla;
Generating osmotic potential between nephron and medulla;
Some water leaves descending loop by osmosis;
Output is reduced volume, reduced salt concentration;

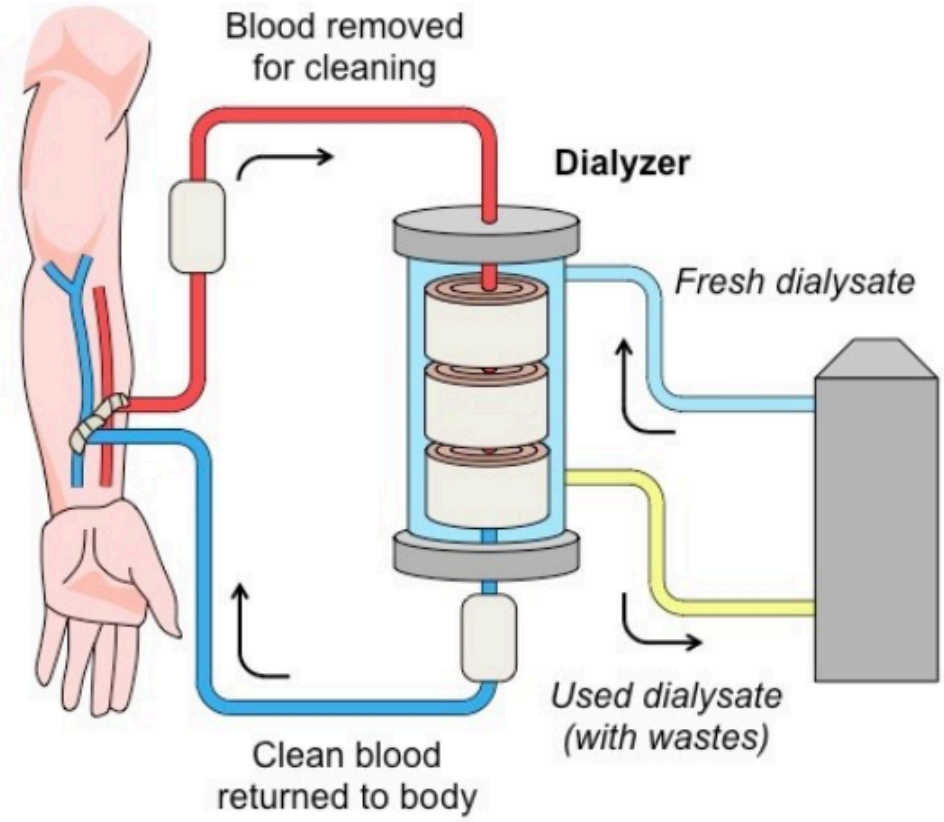
Collecting duct
Filtrate enters collecting duct from distal convoluted tubule;
Countercurrent flow of blood in capillaries and filtrate in duct
maintains concentration gradient- osmosis of water into blood;
Dehydration (detected by hypothalamus) leads to release of ADH (by pituitary);
ADH opens aquaporins (water channels) in walls of duct;
Increased transfer of water into blood, therefore hypertonic urine;
Excess water in blood leads to break down of aquaporins and hypotonic urine.

Other learning points

- Application: Consequences of dehydration and overhydration.



- Application: Treatment of kidney failure by hemodialysis or kidney transplant.



Explain how this kidney dialysis machine works,

- Application: Blood cells, glucose, proteins and drugs are detected in urinary tests.

Glucose: The presence of glucose in urine is a common indicator of diabetes (high blood glucose = incomplete reabsorption)

Proteins: High quantities of protein in urine may indicate disease (e.g. PKU) or hormonal conditions (e.g. hCG = pregnancy)

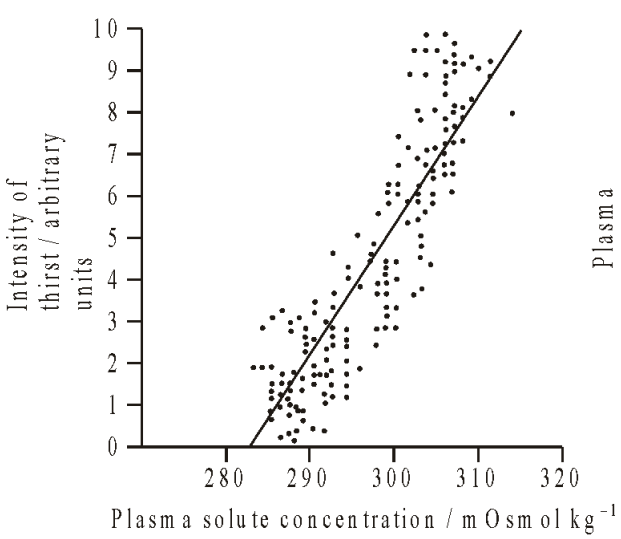
Blood cells: The presence of blood in urine can indicate a variety of diseases, including certain infections and cancer

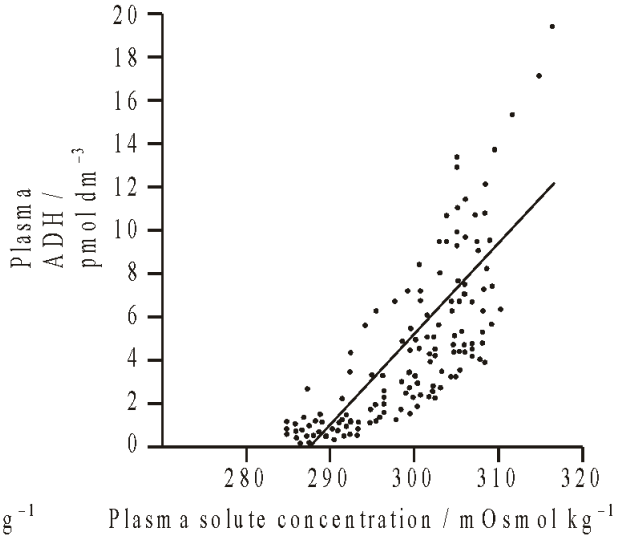
Drugs / toxins: Many drugs pass through the body into urine and can be detected (e.g. performance enhancing drugs)

Using Urinary Analysis to Detect Disease

- The removal of kidney stones by ultrasound treatment

1. The plasma solute concentration, plasma antidiuretic hormone (ADH) concentration and feelings of thirst were tested in a group of volunteers. These graphs show the relationship between intensity of thirst, plasma ADH concentration and plasma solute concentration.





(a) Identify the plasma ADH concentration at a plasma solute concentration of 300 mOsmol kg^{-1} using the line of best fit.

(1)

(b) Compare intensity of thirst and plasma ADH concentration.

(1)

(c) Outline what would happen to plasma solute concentration and ADH concentration if a person were to drink water to satisfy his/her thirst.

(2)

(d) State **two** reasons why a person's plasma solute concentration may increase.

(2)

10. The proximal convoluted tubule is a part of the nephron (kidney tubule). Its function is selective reabsorption of substances useful to the body.

(a) Outline how the liquid that flows through the proximal convoluted tubule is produced.

(2)

(b) (i) Water and salts are selectively reabsorbed by the proximal convoluted tubule. State the name of **one** other substance that is selectively reabsorbed.

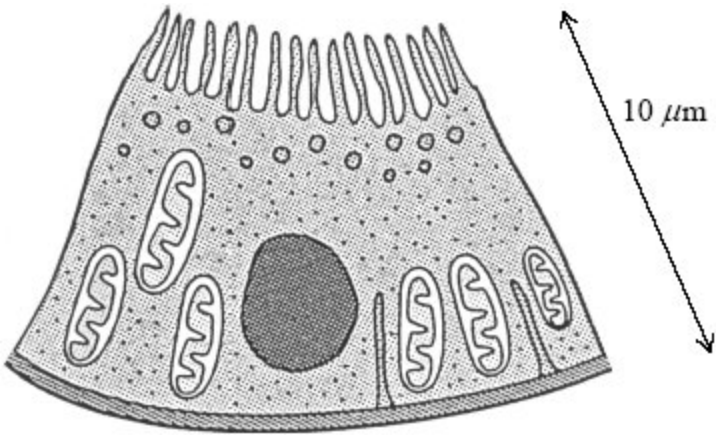
(1)

(ii) State the names of the processes used to reabsorb water and salts.

Water: salts:

(2)

The drawing below shows the structure of a cell from the wall of the proximal convoluted tubule.



(c) The actual size of the cell is shown on the diagram. Calculate the linear magnification of the drawing. Show your working.

(2)

(d) Explain how the structure of the proximal convoluted tubule cell, as shown in the diagram, is adapted to carry out selective re-absorption.

(2)

1. During urine production, what happens if the water content of the blood is too low?

A. Membrane channels are produced in the cells of the collecting duct.

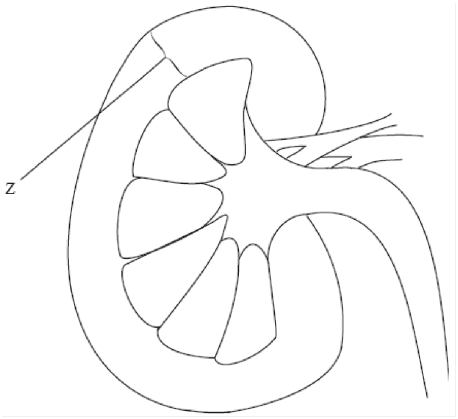
B. The pituitary gland stops secreting ADH.

C. The collecting duct becomes less permeable to water.

D. Large volumes of dilute urine are formed.

(Total 1 mark)

2. The diagram below shows a longitudinal section through a kidney. What is the structure labelled Z and what is its function?



	Structure Z	Function
A.	cortex	osmoregulation
B.	medulla	ultrafiltration
C.	cortex	ultrafiltration
D.	pelvis	osmoregulation

(Total 1 mark)

3. The Bowman's capsule is a cup-shaped structure that is part of the nephron. What is the source of glucose in the fluid in the Bowman's capsule?

A. Blood in the glomerulus

B. Urine in the renal pelvis

C. Filtrate in the distal convoluted tubule

D. Interstitial fluid in the medulla

(Total 1 mark)

4. What does the reabsorption of glucose in the proximal tubules of the kidney require?

A. Movement of water by osmosis out of the tubule cells

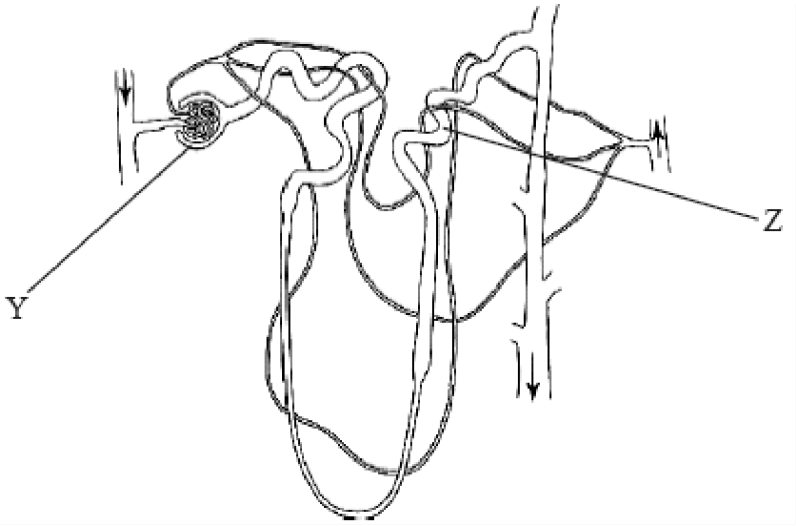
B. Facilitated diffusion of Na^+ out of the tubule cells

C. Active transport of K^+ into the tubule cells

D. Active transport of Na^+ out of the tubule cells

(Total 1 mark)

5. In the diagram of the nephron below, what structures are indicated by the letters Y and Z?



[Source: adapted from http://ex.susd.org/sjones/SGHL12007 files/image005.jpg]

	Y	Z
A.	glomerulus	collecting duct
B.	Bowman's capsule	collecting duct
C.	Bowman's capsule	distal convoluted tubule
D.	glomerulus	distal convoluted tubule

(Total 1 mark)

6. (a) Define the term *excretion*.

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(1)

(b) Explain the process of ultrafiltration.

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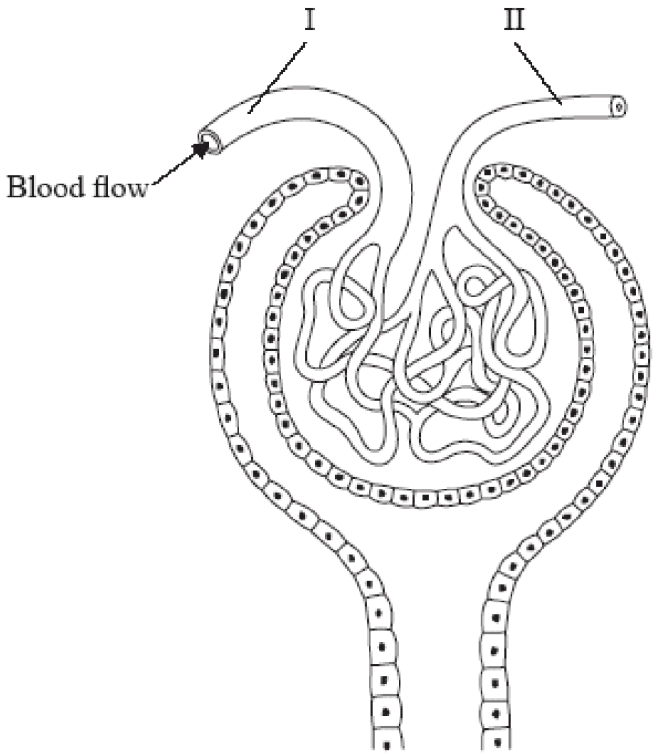
(2)

(c) The diagram below shows part of the human kidney. The arrow shows the direction of blood flow.



Compare the composition of the fluids found in the regions labelled I and II by giving **one** difference and **one** similarity.

Difference: .....

.....

Similarity: .....

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(2)

1. A

[1]

2. C

[1]

3. A

[1]

4. D

[1]

5. C

[1]

6. (a) removal of waste products of cell reactions/metabolic activities/pathways 1

(b) blood (in the glomerulus) under high pressure caused by differencein diameter of (afferent and efferent) arterioles;
fluid plasma and small molecules forced into kidney tubule/Bowman's capsule/through fenestrations/basal membrane;
which prevent larger molecules/blood cells from passing through; 2 max

(c) *difference*: fluid at II has <u>less</u> urea/glucose/oxygen/salts/ions/water;
similarity: fluid at II has <u>same</u> (amount of) proteins/blood cells as fluid at I;
2*Accept converse for both marking points.*

[5]