IB · DP · Biology

3 hours 15 questions

Structured Questions: Paper 2

11.3 The Kidney & Osmoregulation

11.3.1 Osmoregulation in Organisms / 11.3.2 Kidney: Structure & Function / 11.3.3 Conserving Water / 11.3.4 The Role of ADH / 11.3.5 Types of Nitrogenous Waste / 11.3.6 Kidney Failure & Urinalysis / 11.3.7 Skills: Drawing & Annotating the Kidney

Easy (5 questions)	/47
Medium (5 questions)	/47
Hard (5 questions)	/56
Total Marks	**/150**

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Easy Questions

1 (a) Much of the behaviour of water in living organisms is determined by the osmolarity of fluids within those organisms.

Define osmolarity

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(2 marks)

(b) State the name of the structures which insects use to concentrate and excrete nitrogenous waste.

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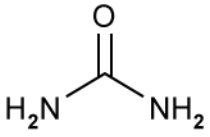
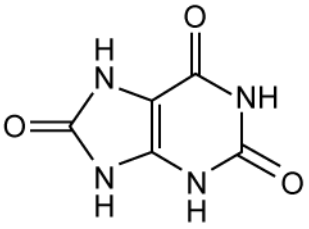
(1 mark)

(c) The image below shows two compounds, **A** and **B** involved in the excretion of nitrogenous waste from animals.



Molecule **A**
Highly soluble excretion product in mammals



Molecule **B**
Insoluble excretion product in insects

Identify **A** and **B**.

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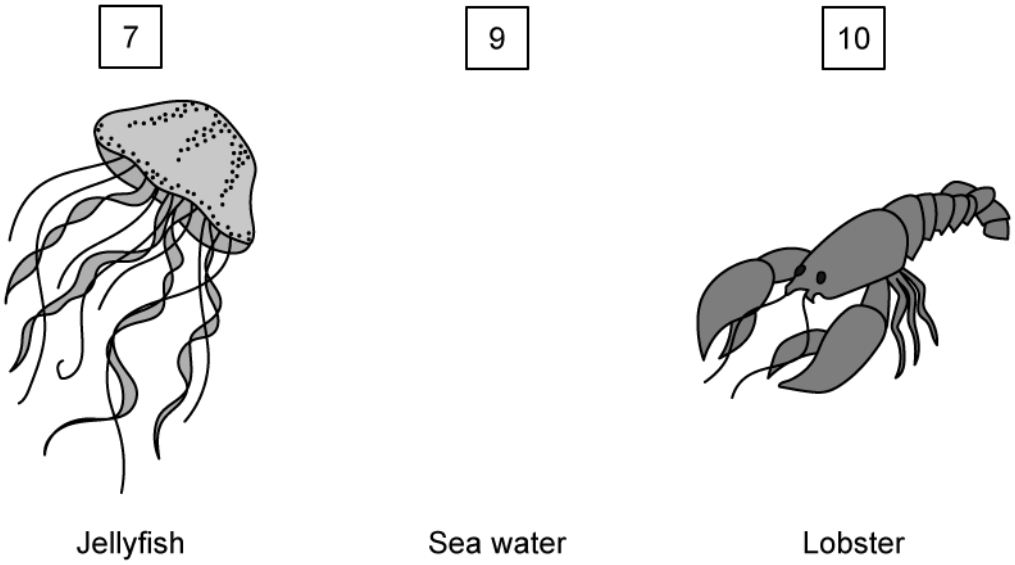
(2 marks)

(d) The image below represents part of a marine ecosystem and two of its inhabitants, a jellyfish and a lobster. Both animals have recently entered this part of the ecosystem from another area of the ocean.



The numbers represent the osmolarity of the cell contents of the organisms and that of the surrounding sea water, in arbitrary units.

Predict and explain the level of osmolarity of the **jellyfish's** cell contents after a period of time in this part of the ecosystem.

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(2 marks)

2 (a) The names of six blood vessel types that carry blood in and around the kidney are shown below as **A - F**.

A. Efferent arteriole	**B.** Renal vein
D. Renal artery	**C.** Afferent arteriole
E. Capillaries alongside nephron	**F.** Glomerulus

Place these blood vessels into the correct order through which blood passes during normal circulation.

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(3 marks)

(b) State the relationship between the length of an organism's Loop of Henlé and the conditions that the organism lives in.

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(2 marks)

(c) Certain species of animal that survive in very arid habitats can drink very little water. Instead, they derive much of their water intake from respiratory water.

Explain what respiratory water is.

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(2 marks)

(d) State the name of the hormone that controls the level of water that is excreted via the kidney.

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(1 mark)

3 (a) Blood undergoes ultrafiltration in the kidney.

Define ultrafiltration.

(2 marks)

(b) Outline the composition and role of the basement membrane in ultrafiltration.

(2 marks)

(c) Explain the ways in which the following adaptations of the proximal convoluted tubule (PCT) help the PCT to carry out its function.

1.	Microvilli on the inner surface	
2.	Many mitochondria in epithelial cells	
3.	Tightly-packed cells in the epithelium	

(3 marks)

(d) Distinguish between the afferent and efferent arterioles in the kidney.

(2 marks)

4 (a) Maintaining water levels in cells and tissues is an example of a negative feedback system.

Define the term 'negative feedback'.

(2 marks)

(b) The negative feedback mechanism of osmoregulation relies on the hormone ADH, antidiuretic hormone.

Certain compounds, when in the blood, act as diuretics. Ethanol is one example.

Use your knowledge of the action of ADH to suggest the effect of a diuretic drug such as ethanol.

(2 marks)

(c) During haemodialysis treatment of kidney failure, the patient's blood and the dialysis fluid flow in opposite directions within the dialysis machine.

Identify the name of this kind of flow and give **one** reason why it is set up in this way.

(2 marks)

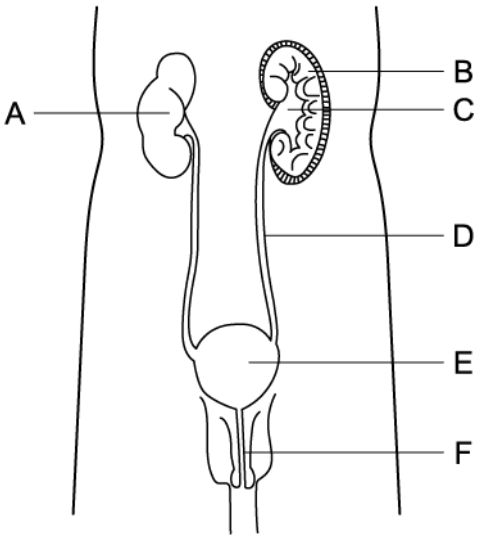
(d) Urinalysis can detect the presence of many compounds in the urine and can give information about the state of a person's renal health.

List **two** possible illnesses that could cause protein to be detected in urine.

(2 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

The drawing represents the human male urinary system.



Identify structures **A** - **F**.

(6 marks)

(b) Several substances are filtered out of blood in the mammalian kidney.

List those that are later selectively reabsorbed into the blood and those that are not.

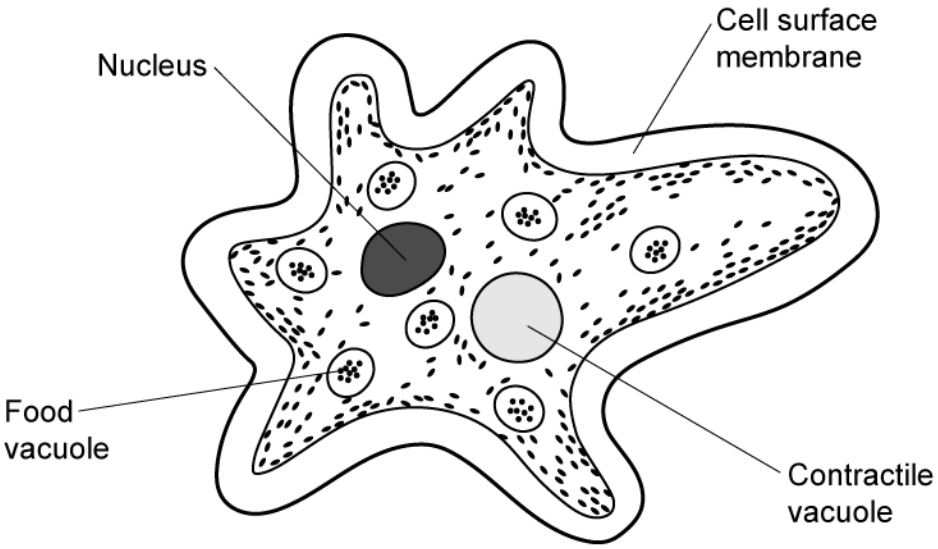
(6 marks)

(c) Outline the main effects of dehydration on a human.

(3 marks)

Medium Questions

1 (a) Amoebas (singular amoeba) are free-living, single-celled eukaryotes that live in freshwater ponds and lakes. They carry out osmoregulation using an organelle called a contractile vacuole, shown in the image below.



Explain why amoebas need to carry out osmoregulation.

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(3 marks)

(b) A contractile vacuole can expand to take on water, and is able to fuse with the cell-surface membrane.

Suggest how a contractile vacuole aids osmoregulation in amoebas.

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(2 marks)

(c) Describe what would happen to an amoeba cell placed into saltwater.

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(2 marks)

(d) Amoebas are an example of an osmoregulator. An alternative strategy for dealing with the problem of osmosis is to be an osmoconformer.

Outline what it means to be an osmoconformer.

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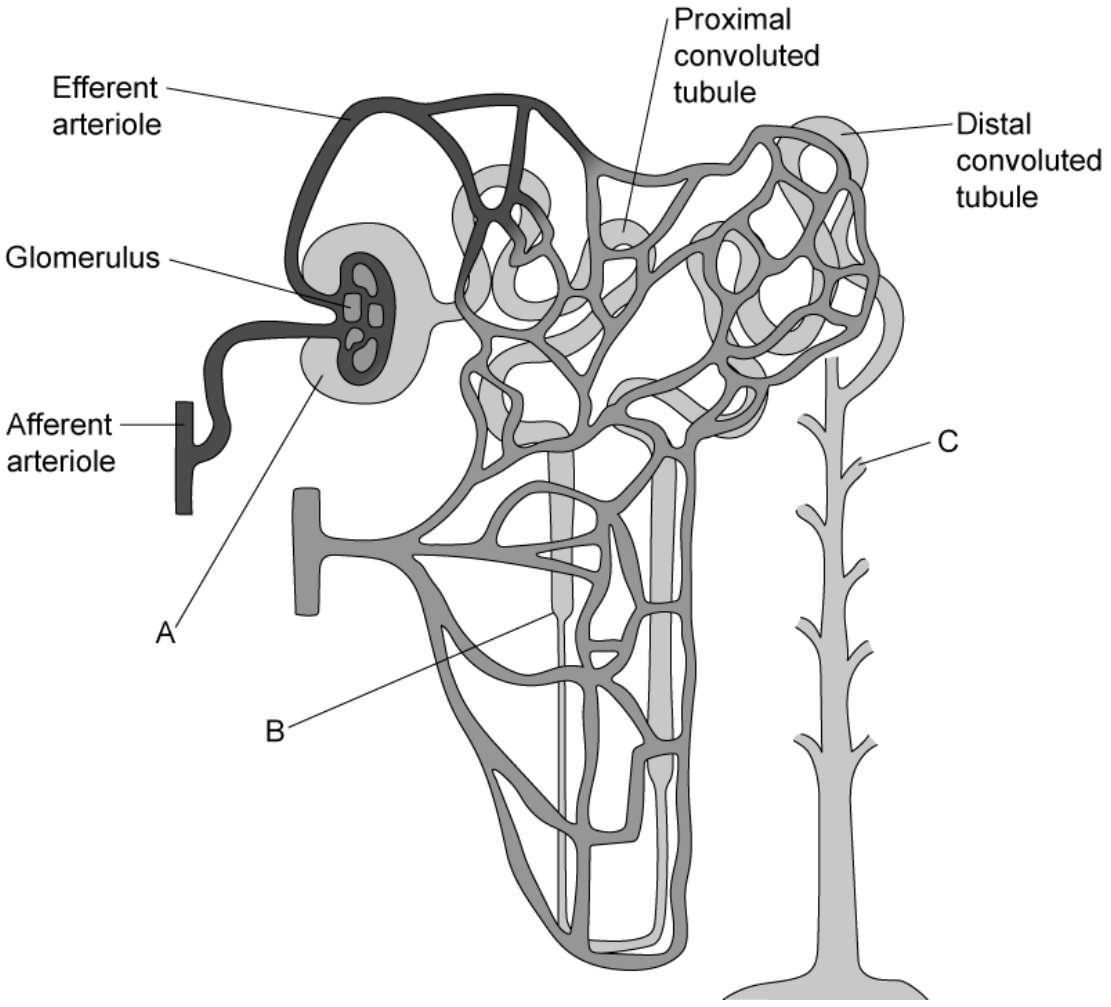
(1 mark)

2 (a) The image below shows a kidney nephron.



Identify the structures labelled **A-C** in the image.

(3 marks)

(b) State, with a reason, **one** feature of structure **A** from the image in part a) which enables ultrafiltration to take place.

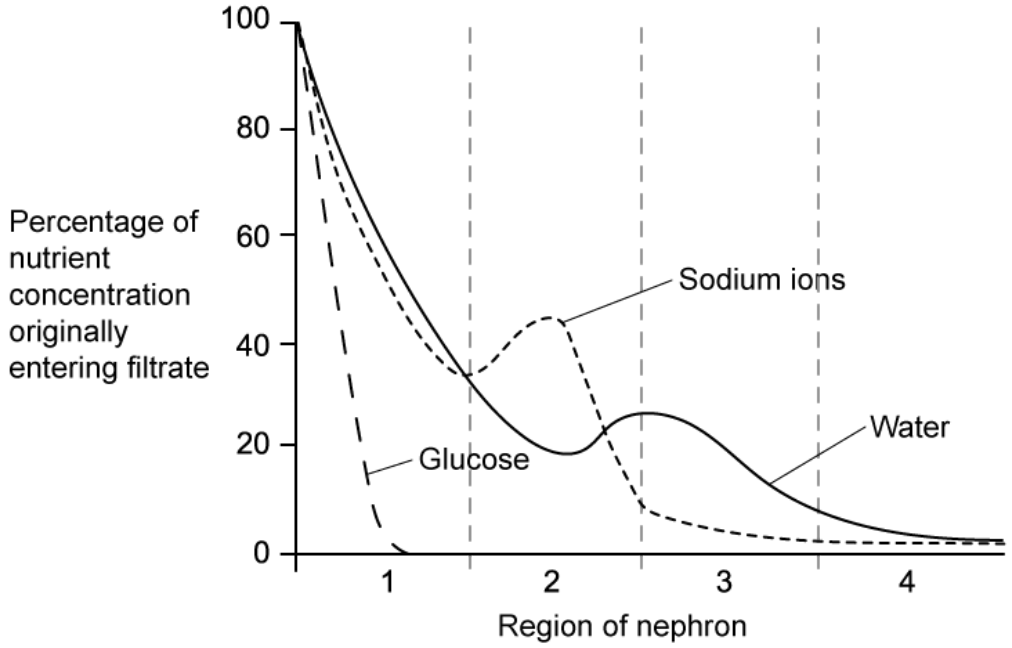
(2 marks)

(c) Selective reabsorption takes place after ultrafiltration.

Describe the events of selective reabsorption.

(3 marks)

3 (a) The graph below shows what happens to various components of the glomerular filtrate as they move through the different regions of an individual's nephron.



Describe and explain the shape of the curve for glucose concentration.

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(2 marks)

(b) Explain the shapes of the curves for sodium ions **and** water in the graph in part a) as they travel through the **first half of region 2** of the nephron. Note that region 2 in this graph is the loop of Henle.

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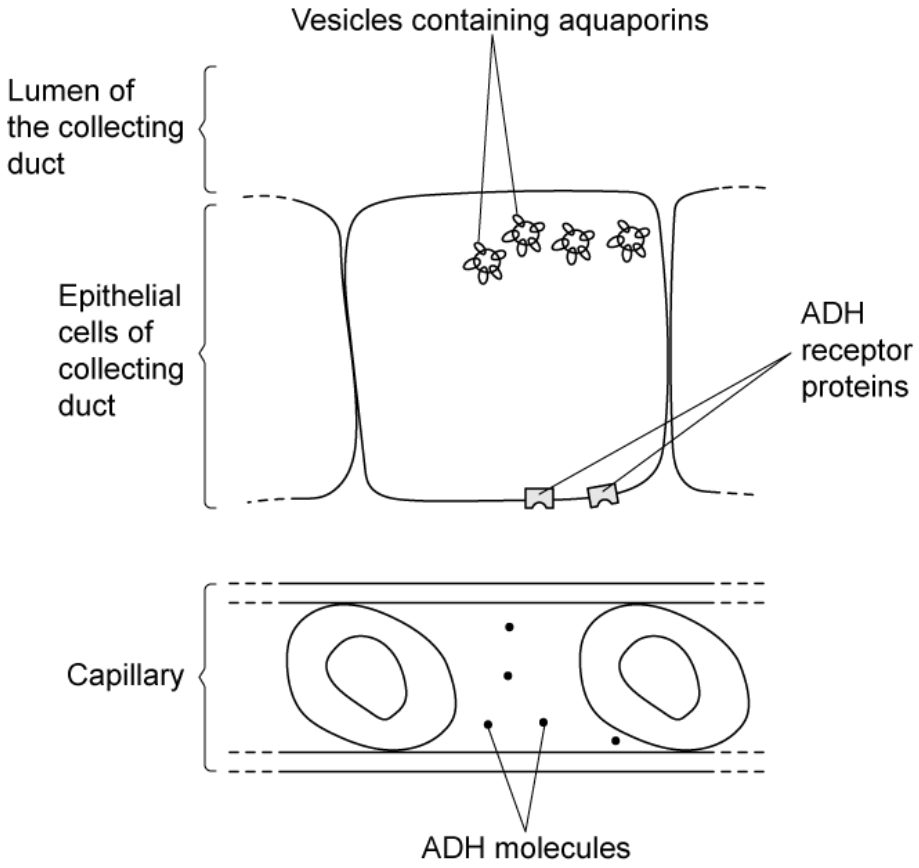
(2 marks)

(c) The image below shows cells lining the collecting duct. ADH released from the pituitary gland binds to the receptor proteins on the collecting duct cell surface membranes. This triggers vesicles containing aquaporins to bind with the plasma membrane next to the lumen. Note that aquaporins are channel proteins that enable the movement of water molecules.



Explain how ADH increases the movement of water from the lumen of the collecting duct into the blood.

(3 marks)

(d) Suggest why ADH only affects the cells lining the kidney nephron.

(1 mark)

4 (a) Outline the link between excretion of nitrogenous waste and water loss in mammals.

(2 marks)

(b) The table below shows the maximum urine solute concentrations that can be achieved in different species of mammal. Seawater has been included for comparison.

	Solute concentration / mEq L^{-1}	**Urine:blood plasma osmolarity ratio**
Human urine	460	
Brown rat urine	600	8:1
Kangaroo rat urine	1200	14:1
Seawater	600	N/A

Humans have a blood plasma concentration of roughly 120 mEq L^{-1}.

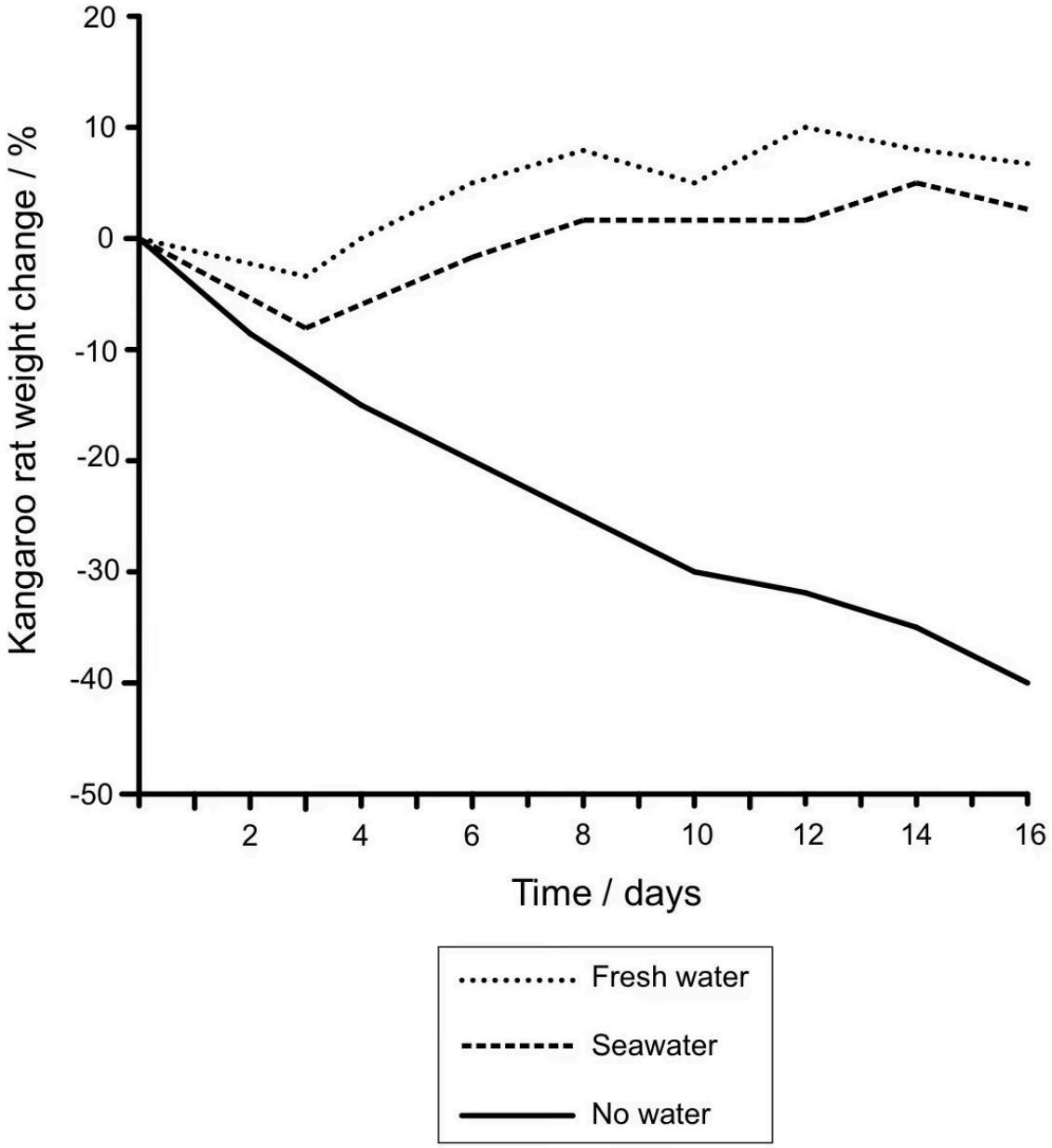
Calculate the urine:blood plasma osmolarity ratio in humans.

(1 mark)

(c) Use information from part b) and your own knowledge to explain how kangaroo rats are adapted for survival in a **dry** environment.

(3 marks)

(d) A researcher wanted to investigate kangaroo rat kidneys. They fed the kangaroo rats on soybeans for several days to increase their thirst (kangaroo rats normally get all their water from their food), and then either gave the rats access to fresh water, seawater, or no water for the following 16 days, using weight over the experimental period as a measure of rat health. The results are shown in the graph below.



Suggest, with a reason, one possible conclusion about the capabilities of kangaroo rat kidneys that can be drawn from the graph above. Note that humans cannot drink seawater without becoming severely dehydrated.

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(2 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

Draw a labelled diagram of the human kidney.

(3 marks)

(b) Outline the process of haemodialysis.

(4 marks)

(c) Describe how nitrogenous waste is excreted in land insects.

(8 marks)

Hard Questions

1 (a) Contrast the renal cortex and the renal medulla.

(3 marks)

(b) Nephrotic syndrome is a condition that causes the kidneys to leak large amounts of protein into the urine. This can lead to a variety of problems, including swelling of body tissues and an increased risk of catching infections.

Suggest why research into cures for nephrotic syndrome are focused more on the components of the basement membrane than on those of the endothelial layer within a glomerular complex.

(2 marks)

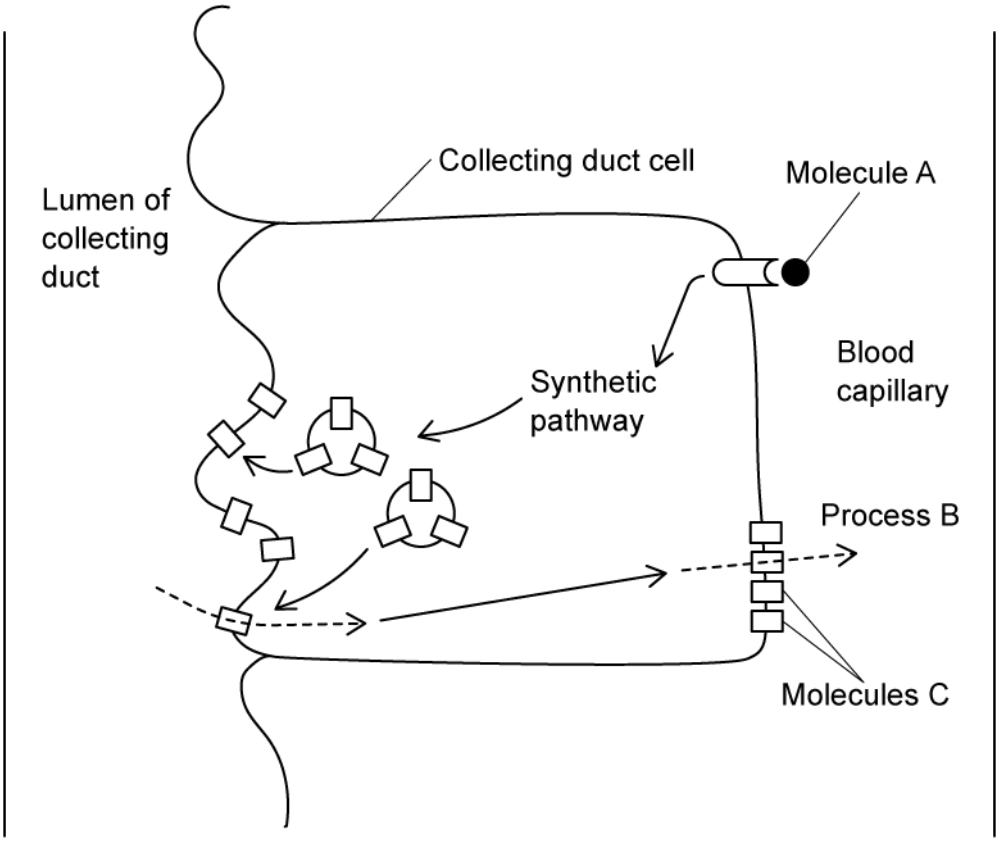
(c) A well-documented effect of antidiuretic hormone (ADH) is the increase in permeability of the distal convoluted tubules and collecting ducts to water, thereby allowing more water to be reabsorbed at times of low blood water content.

There is also a secondary osmoregulatory effect of ADH; this takes place on arterioles.

Suggest what this effect is and give a reason for your suggestion.

(2 marks)

(d) The diagram shows a sequence of events involved in osmoregulation.



Identify Molecule **A**, Process **B** and Molecules **C**.

(3 marks)

2 (a) One effect of an ageing population is the increase in deaths and health complications from dehydration in the elderly, many of whom lack a thirst response when partially dehydrated.

A study was performed to examine the effect of ethanol ('alcohol') consumption on the urine output of a group of elderly men.

Ethanol is a known diuretic.

Define the term diuretic and outline its mode of action.

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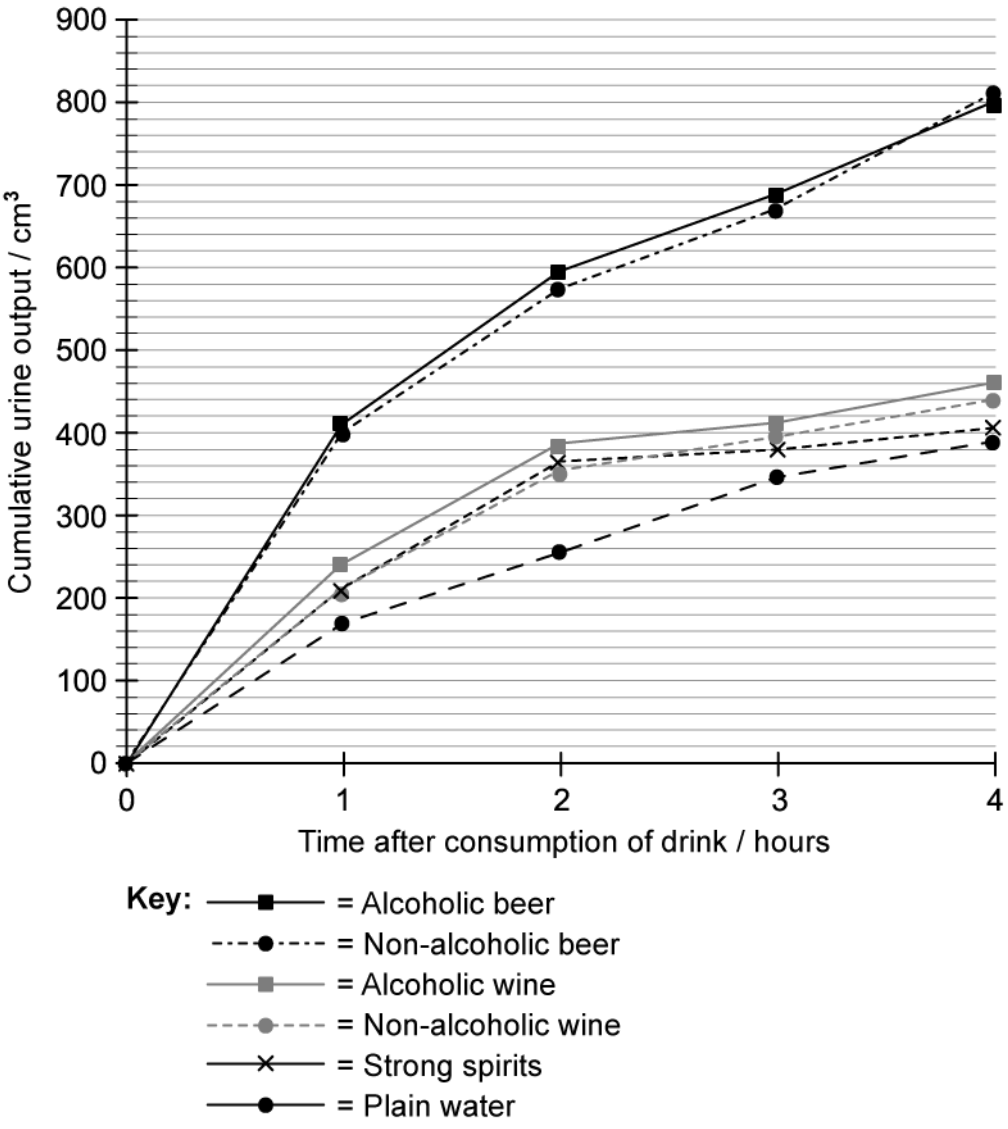
(2 marks)

(b) In the study referred to in part a), a group of 20 elderly men (age range 65-75) were given the same diet and were optimally hydrated before the study. All the men consumed no alcohol for 48 hours prior to the experiment. At the beginning of the study,

- one subgroup was given alcoholic beer, another non-alcoholic beer
- one subgroup was given alcoholic wine, another non-alcoholic wine
- one subgroup was given strong spirits, another plain water
- for the men given alcoholic drinks, an equivalent volume of ethanol was consumed in each case
- for the men given non-alcoholic drinks, the same volume was consumed as for their alcohol-containing counterparts

In each case, the men's average cumulative urine output was measured over the 4 hours following consumption of the drinks. The results are shown below.



Calculate the percentage difference between the urine produced in the first hour by men drinking alcoholic beer versus those drinking alcoholic wine.

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(2 marks)

(c) The researchers conducting the study concluded that drinking beer of any variety contributed more to dehydration than any other choice of drink.

Evaluate this conclusion.

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(6 marks)

3 (a) Organisms that live in a saltwater environment face extreme osmoregulatory challenges.

Suggest why it is so difficult for marine mammals to maintain the correct osmotic balance in their blood.

(2 marks)

(b) The table below contains information about several marine mammals and their osmoregulatory mechanisms. Humans have been added for comparison purposes, and seawater sodium concentration has also been included.

Organism	**Habitat**	**Primary water source**	**Urine osmolarity / mol dm^{-3}**	**Na^+ concentration / mmol dm^{-3}**
Human	Terrestrial	Drinking fresh water	1 400	20
West Indian Manatee	River (but can survive in marine)	Diet/metabolism	1 158	31
Sea otter	Marine	Drinking sea water	2 130	505
Elephant seal	Marine	Diet/metabolism	1 850	297
Seawater	*N/a*	*N/a*	*N/a*	*470*

Suggest how sea otters are able to drink seawater and still maintain osmotic balance.

(3 marks)

(c) Manatees are unusual marine mammals in that they are able to spend time in both saltwater and freshwater environments.

Research into osmoregulation in manatees shows that levels of a hormone called aldosterone change when the manatee's environment changes. Aldosterone is known to activate a sodium transporter protein in the cells lining the nephron.

Suggest how the saltwater and freshwater environments might affect aldosterone levels and explain how this could help the manatee regulate its ion balance.

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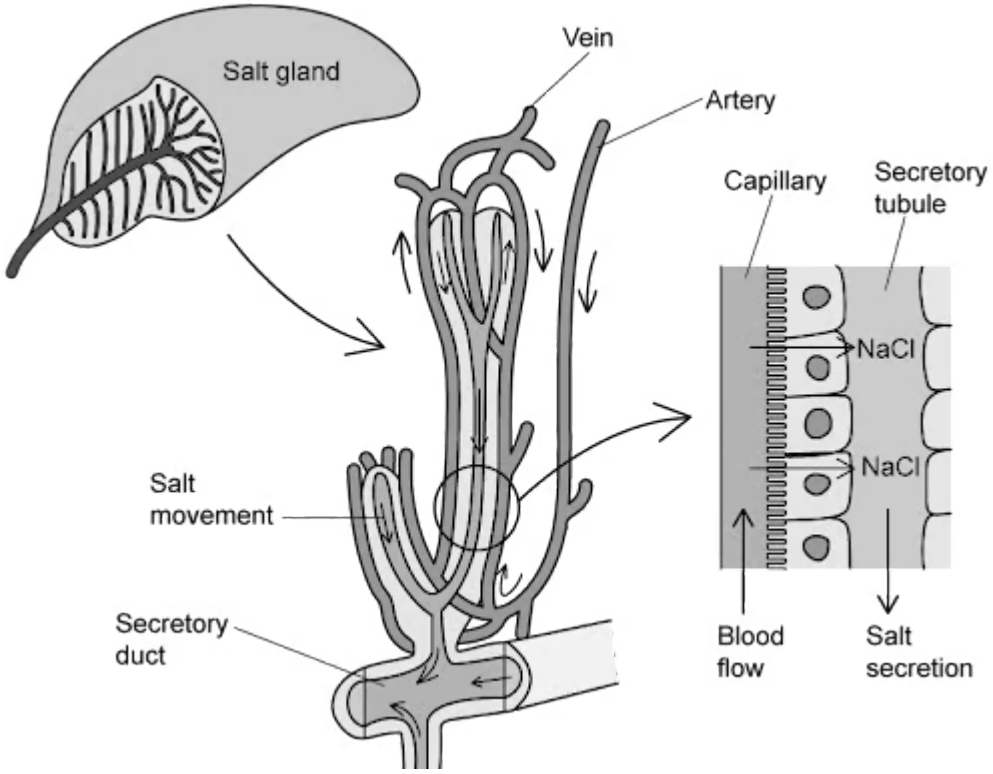
(3 marks)

(d) Sea birds do not osmoregulate in the same way as marine mammals. They excrete nitrogenous waste via highly concentrated uric acid, and excrete excess salt separately via salt glands.

The diagram below shows the structures within the salt glands, where a countercurrent mechanism involving capillaries and salt secretory tubules removes excess salt to an external secretory duct.



Explain how the countercurrent system ensures maximum salt excretion from the blood of sea birds.

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(2 marks)

4 (a) The glomerulus is a structure in the kidneys responsible for the process of ultrafiltration. Explain how ultrafiltration would be affected by severe dehydration.

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(2 marks)

(b) An important role of the kidneys is the removal of urea from the blood. The amount of urea removed from the blood can be used as a measure of the rate of ultrafiltration, also known as the glomerular filtration rate (GFR).

An individual excreted 540 mg of urea from the blood over the course of 1 hour, and has a blood urea concentration of 0.01 mg cm^{-3} entering the kidneys. Use this information to calculate this person's GFR.

State your answer in cm^3 min^{-1}.

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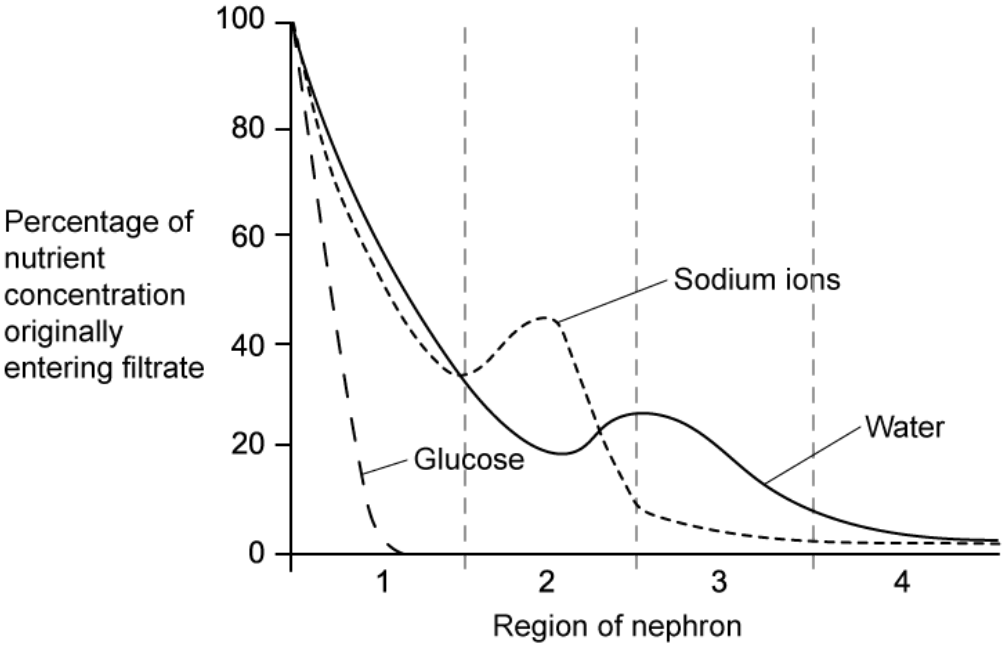
(2 marks)

(c) After ultrafiltration, the filtrate travels through the kidney nephron. The graph below shows what happens to various components of the glomerular filtrate as they move through the different regions of an individual's nephron.



Describe and explain the shape of the curve for sodium ions and water as they travel through region 2 of the nephron as shown in the graph.

(4 marks)

(d) Explain how the plotted line for water in region 4 of the graph in part (c) would look different if the ADH concentration in this individual's blood were to decrease.

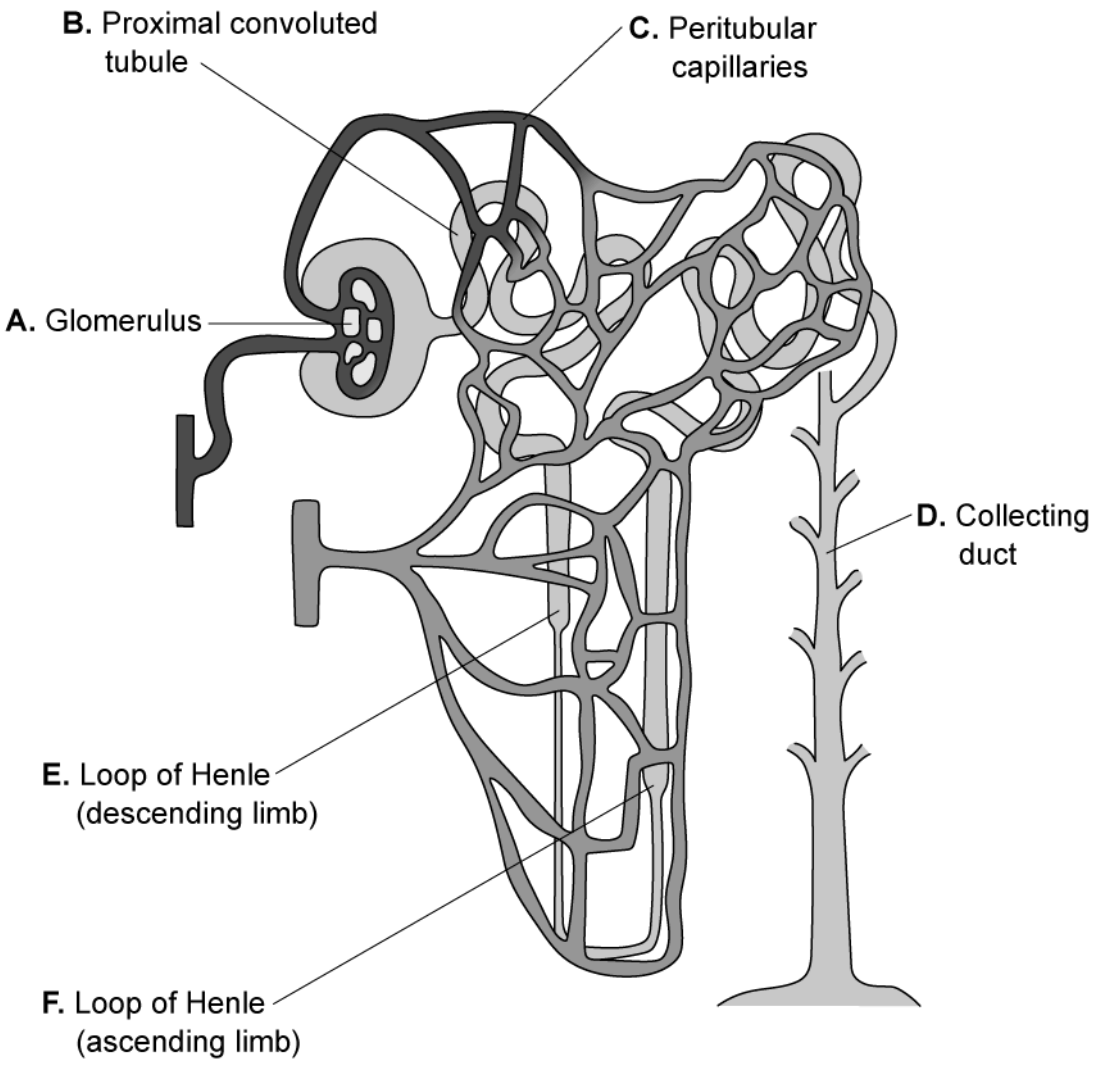
(3 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

Draw and label a diagram of a human kidney.

(6 marks)

(b) The diagram below shows a human nephron and its associated blood supply.



Annotate the labels **A - F** shown to explain briefly the functions of the various parts of the nephron.

Label	Structure	Annotation
A.	Glomerulus	
B.	Proximal convoluted tubule	
C.	Peritubular capillaries	
D.	Collecting duct	
E.	Loop of Henlé (descending limb)	
F.	Loop of Henlé (ascending limb)	

(6 marks)

(c) Kidney patients on a course of haemodialysis treatment are advised to increase their protein intake and limit the amount of ions (eg. potassium, phosphorus, sodium) and fluid in their diets.

Suggest **three** reasons for this dietary advice.

(3 marks)