Rewarding Learning

eGUIDE//Biology

Physiology, Co-ordination and Control, and Ecosystems

Unit A2 1 4.1 Homeostasis

This e-book is designed to complement other support materials and enhance the understanding of this unit for students at GCE level. The topics covered are in accordance with those topics present in the current specification.

Contents

Homeostasis

4.1

4.1.1 Key Concepts

Students should be able to:

- demonstrate knowledge and understanding of the concept of homeostasis and the components of homeostatic mechanisms

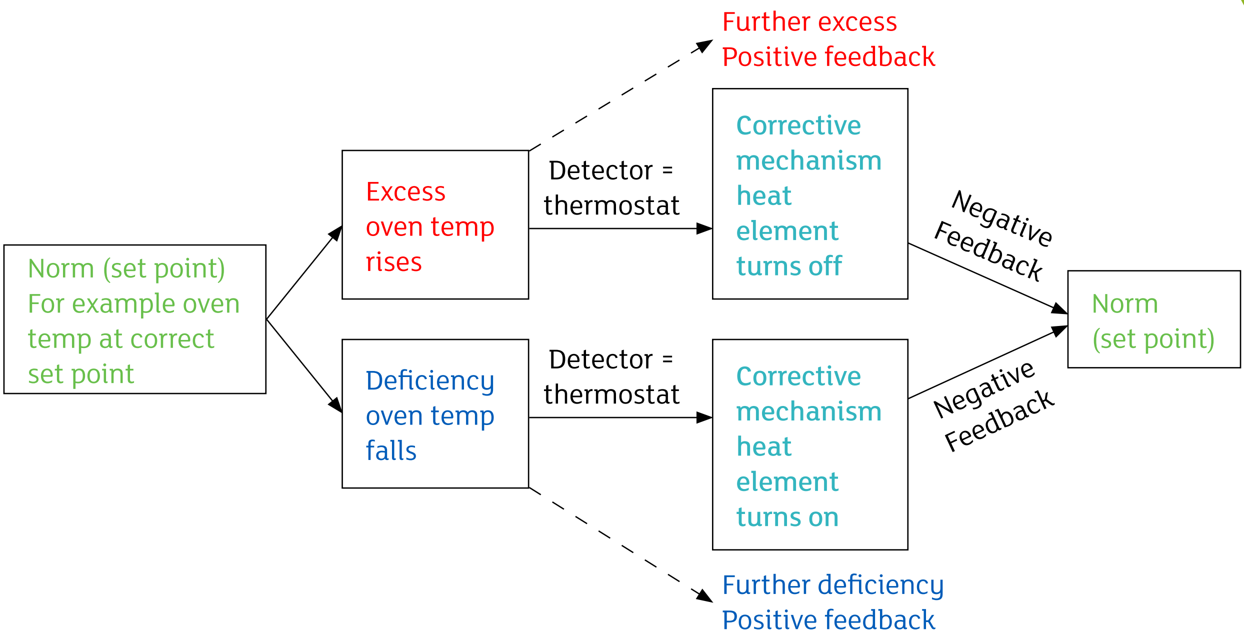
Principles of Homeostasis

Organisms need to control their internal conditions. The optimum conditions in which cells can function are narrow; small fluctuations in temperature, osmotic pressure and concentration of certain chemical substances (for example carbon dioxide) can disrupt biochemical activities. As most organisms live in changeable environments their cells are at the mercy of environmental change. The principle of homeostasis is to keep conditions inside the cell constant in spite of what may be going outside. In mammalian tissues cells are surrounded by spaces filled with fluid. This fluid is called intercellular, interstitial or tissue fluid. This is an organism's internal environment and must be kept constant through these fluids respiratory gases diffuse cells, extract metabolites and shed unwanted waste substances. As this fluid is formed from the blood it is the blood that has to be kept constant. Much of an animal's physiology is concerned with the homeostasis of the blood. Many animals will also control their body temperature as well as keeping key molecules at constant levels within cells and bodies.

Many control systems both in nature and in engineering will keep a variable at or near a fixed value called a set point. The variable is monitored by a sensor or receptor. The value to be controlled could, for example be temperature or blood cholesterol level. If the level increases, a chain of events are set in motion which will decrease the level again. If the level falls too low, changes will occur to bring the level up to the set point again. This is called *negativ*e feedback.

- *Feedback* because the chain of events feeds back to the variable
- *Negative* because an increase causes a decrease and vice versa.

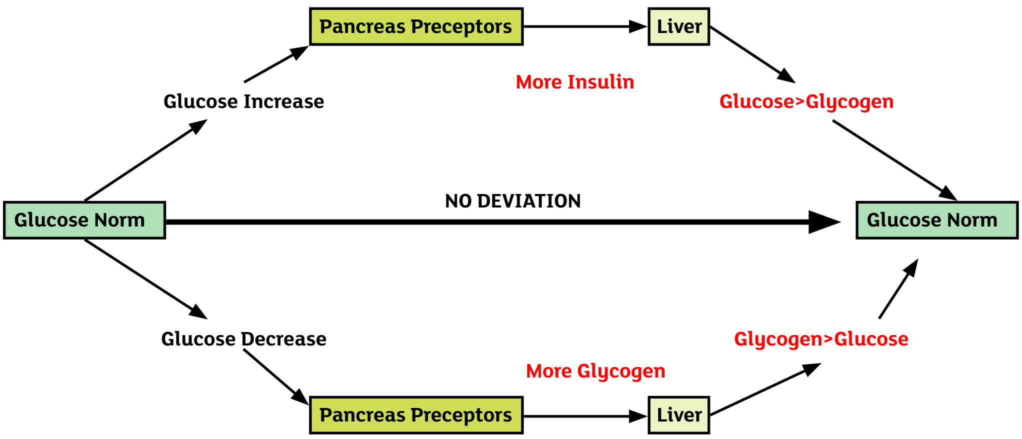
Below is a simple scheme summarising homeostatic control. Deviations from the normal values (set point) set into motion the corrective chain of events to restore the norm (negative feedback). This is in contrast to positive feedback where a deviation from the norm or set point will lead to further deviation.



The video below presents the principle of homeostasis and negative feedback.
https://youtu.be/hNoOhezHdmU

An example of homeostasis in mammals is the control of blood glucose concentration. Blood glucose concentration rises after a meal but returns to its set point after a couple of hours. Glucose concentration must not fall too low as some organs like the brain rely on glucose for their major energy supply. It must not get too high as cells could become dehydrated by osmosis and glucose could be lost in the urine. Two organs are involved; it is detected by the pancreas and then removed or added by the liver.
The pancreas communicates with the liver by hormones. Two cell types in the pancreas detect glucose concentration and communicate with the rest of the body by releasing two different hormones depending on whether concentration are high or low. When glucose concentration is too high β-cells release insulin. This will stimulate the liver to take up glucose, convert it to glycogen and store it until it is required. If the concentration of glucose falls too low this is detected by α-cells which release glucagon, which in turn stimulates the conversion of the stored glycogen to glucose.

Negative Feedback



Glossary

Glucagon	a hormone produced in the pancreas that raises blood sugar level.
Glycogen	a polysaccharide that is the main carbohydrate storage material in animals.
Homeostasis	the tendency of an organism or a cell to regulate its internal conditions, usually by a system of feedback controls to stabilise its functions regardless of the outside changing environment.
Hormone	a chemical signal released into the blood.
Insulin	a hormone made by the pancreas that lowers blood sugar level.
Negative feedback	a regulatory mechanism where a system responds in an opposite direction to restore its optimum set point.
Receptor	a molecular structure that is sensitive to a particular stimulus and will bring about a change in response to a change in the concentration of the stimulus.

4.1.2 Key Concepts

Students should be able to:

- demonstrate knowledge and understanding of the role of the mammalian kidney in excretion and osmoregulation

The Kidney and Excretion

Osmoregulation is the process which regulates the concentration and osmotic pressure of blood by regulating the water contents of blood plasma. It is an important process as loss of too much water may cause dehydration whereas intake of too much water may dilute the body fluids. The kidney can excrete large amount of hypotonic (dilute) urine when water intake is very high, while it will excrete small amounts of hypertonic (concentrated) urine when water levels are low.

Excretion is the removal of metabolic waste. For example, nitrogenous wastes such as ammonia from breakdown of proteins are removed by the kidney in the form of urea. Ammonia is converted to urea as it is less toxic. Insects and birds remove their nitrogenous waste as uric acid crystals. Uric acid is of very low toxicity and can be removed at high concentration with the minimum amount of water, allowing these creatures to conserve water very effectively.

Creatinine is a by-product of muscle metabolism and is excreted unchanged by the kidneys. If kidney function is deficient then little or no removal of creatinine occurs and the levels in the blood will rise. Levels in the blood and urine can then be tested and act as an indication of kidney function.

The kidney carries out excretion and osmoregulation by the formation of urine from materials delivered in the blood. Excretion occurs by transfer of waste products from blood to urine while osmoregulation occurs by varying the volume and salt concentration of the urine.

The following video animations present (1) excretion and (2) osmoregulation by the kidney.

(1) https://youtu.be/fhU8UHpo6sg?list=PL02A353DDED7199A0
(2) https://youtu.be/VCDwWlBBq3A

Glossary

Creatinine	a nitrogenous compound formed in the muscles in relatively small amounts which passes into the blood and is excreted in the urine.
Excretion	the removal of the toxic waste products of metabolism.
Hormone	a chemical signal released into the blood.
Osmoregulation	the process which regulates the concentration and osmotic pressure of blood by regulating the water contents of blood plasma.

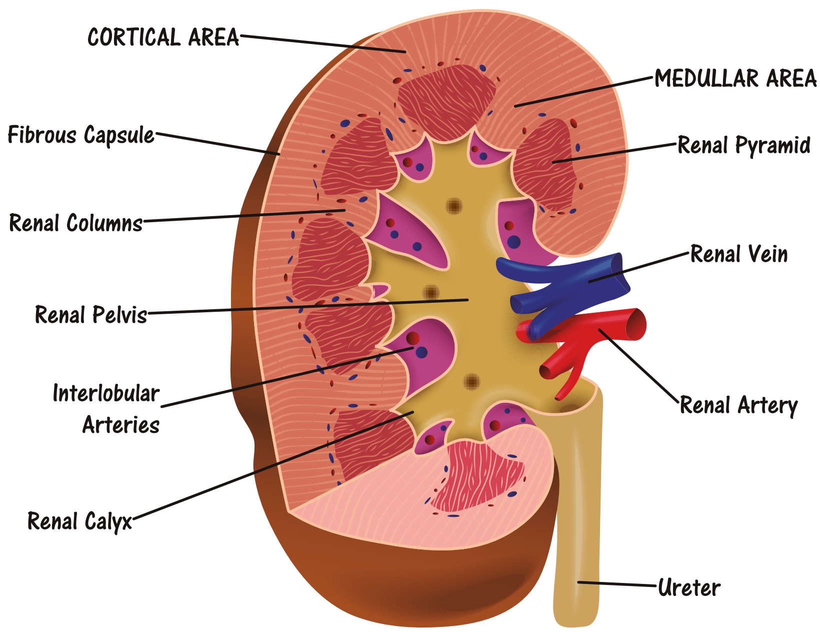
4.1.3 Key Concepts

Students should be able to:

- demonstrate knowledge and understanding of the gross structure of the mammalian kidney and excretory system

There are two kidneys, one on each side of the abdomen. The bulk of the kidney is a mass of tubes each containing a vast network of capillaries, collecting ducts and between one and two million nephrons embedded in connective tissue. The nephron is where urine is formed. Each kidney receives blood from the renal artery and is drained of blood by the renal vein. Kidney tissue has little mechanical strength and so is protected by a thick covering of adipose (fatty) tissue. The body of the kidney is composed of two distinct regions; the inner medulla and the outer cortex.

An illustration of the internal structure of the human kidney.



The following video introduces the gross structure of the kidney.
https://www.youtube.com/watch?feature=player_embedded&v=1QX0Wc_-MW0

The following web site presents the structure and function of the mammalian kidney using good clear diagrams.
http://cronodon.com/BioTech/Excretion.html

Glossary

Adipose tissue	a type of connective tissue that contains stored cellular fat.

4.1.4 Key Concepts

Students should be able to:

- demonstrate knowledge and understanding of the structure of the nephron

The nephron is the functional unit of the kidney. Each nephron begins in the cortex with a dense network of capillaries called a glomerulus surrounded by a bag called Bowman's capsule. Podocytes (also known as glomerular epithelial cells) are a type of cell located in the Bowman's capsule which helps filter out substances in the blood.

Leading from Bowman's capsule is a tubule that winds through the cortex before dipping into the medulla and then returning to the cortex again opening into a collecting duct. These regions are called the proximal convoluted tubule, loop of Henle and the distal convoluted tubule. The ducts converge at the pelvis of the kidney releasing their contents into the ureter which conveys the urine to the bladder for storage.

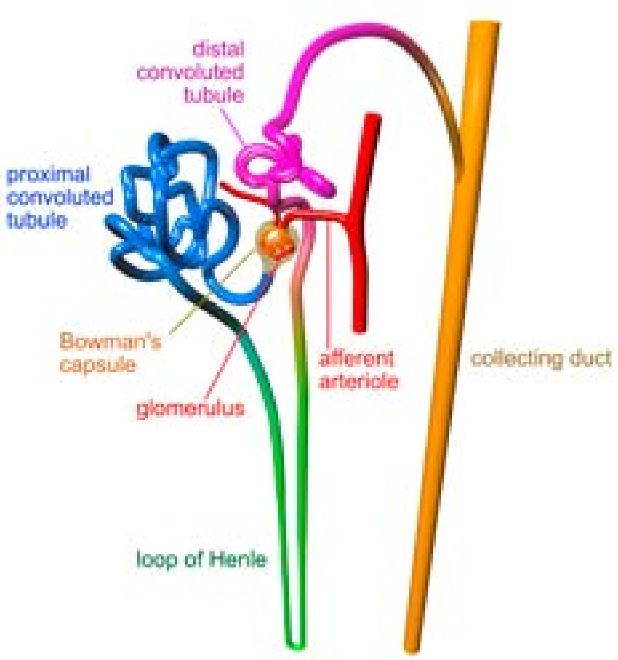
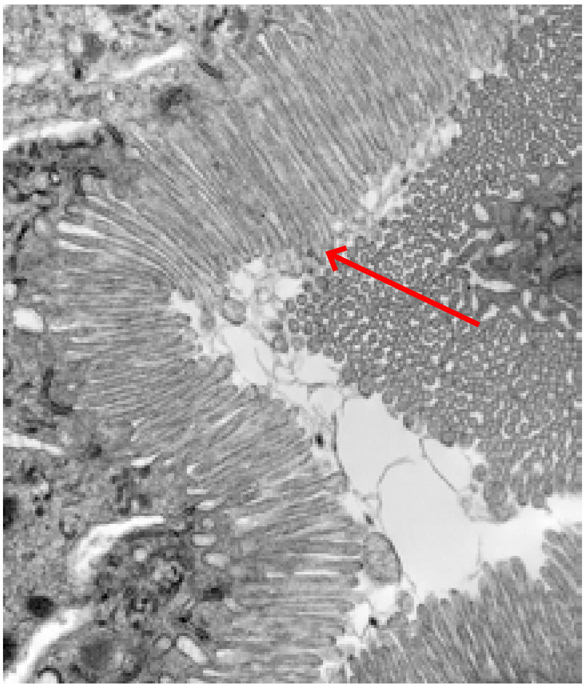


Illustration showing the structure of a nephron, the functional filtering unit of a kidney. The function of the kidney is to filter waste products such as urea from the blood. The filtration occurs in the renal corpuscle where a glomerulus (red capillary bundle) is encased in a Bowman's capsule (transparent). Waste products drain through the proximal convoluted tubule (blue), the loop of Henle (green, where water is reabsorbed), and the distal convoluted tubule (pink), into a collection duct (orange). Each human kidney contains around one million nephrons.

The proximal convoluted tubule is where over 65% of ions (salts), glucose and water are reabsorbed. Reabsorption may be active or passive. Since the transfer of substances from the filtrate back into to the blood is against a concentration gradient much of this selective reabsorption is active. The energy for this is provided by respiration in the nephron's cells in which many mitochondria are present. Reabsorption is controlled by the membranes of the cuboidal epithelium cells around the tubule. Each cell has one face in contact with the fluid in the tubule and it is this surface that is folded into microvilli to increase surface area.

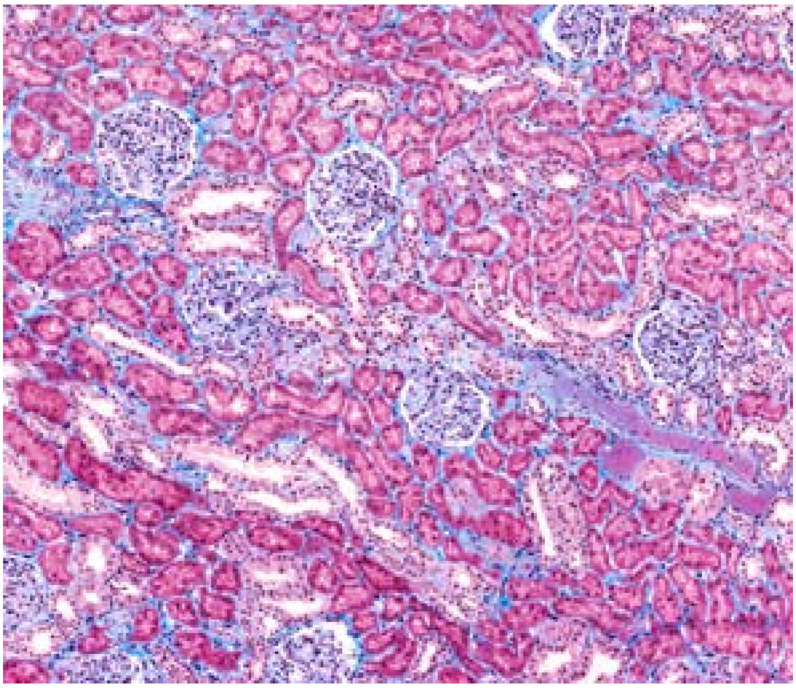


Transmission electron micrograph (TEM) of a section through the proximal convoluted tubule of a human kidney. The proximal convoluted tubules function to reabsorb water, glucose and other small molecules from the filtrate, producing concentrated urine. The tubules consist of a lumen (interior) lined with cuboidal epithelial cells (left). These cells are covered in many finger-like projections known as microvilli, which serve to increase the cells' surface area for reabsorption. The reabsorbed molecules move into the interstitial fluid of the kidney and are absorbed back into the blood. The liquid in the tubules passes to the bladder.

The loop of Henle is important in creating a water potential gradient; this allows water to be reabsorbed from the nephrons beyond the area of the proximal convoluted tubule. In all nephrons the descending limb is permeable to water but relatively impermeable to solutes. This results in the solute concentration of the filtrate in the descending limb increasing as water leaves by osmosis and so a solute concentration gradient is established. The ascending limb is thicker walled than the descending limb and is impermeable to the outward movement of water. This results in a high build-up of salts in the medullary region of the kidney. The salts are actively transferred from the ascending limb to the surrounding tissue where they diffuse back into the descending limb.

The following animation video presents a summary of the function of the loop of Henle.
https://youtu.be/_CnhwhHsWLI
The start of this animation covers terminology associated with the function of the kidney.
https://youtu.be/KINOArtDeWg

The distal convoluted tubule and collecting duct are also composed of cuboidal epithelial cells; this is where sodium chloride is actively reabsorbed. In the presence of a hormone called ADH (antidiuretic hormone) the collecting duct will become more permeable to water and urine will become more concentrated. Water is absorbed by osmosis. The regulation of water retention by ADH is an example of a homeostatic feedback process.



Light micrograph of a section of the kidney cortex. Round renal corpuscles (blue) contain a complex tuft of capillaries surrounded by Bowman's capsule. Abundant proximal convoluted tubules (red) and lesser profiles of distal convoluted tubules (pink) with wider lumens are noted.

Over 99% of fluid is reabsorbed in the kidney tubules. It is estimated that if the kidney stopped reabsorbing water complete dehydration would occur in less than 3 minutes.

The following animation is a step-by-step tutorial about the function of the nephron. Includes an overview of filtration, reabsorption, secretion and excretion in the kidneys. Detailed explanation of what happens in the loop of Henle is included.
https://youtu.be/8UVlXX-9x7Q

Glossary

Cuboidal epithelium	epithelium whose cells are of approximately the same height and width, and appear square in transverse section.
Filtrate	fluid in the tubule that has been filtered from the blood.
Lumen	the inner open space or cavity of a tubular organ such as a blood vessel or an intestine.
Reabsorption	the selective passage of certain substances–glucose, proteins, sodium–back into the blood after it has been secreted into the renal tubules.
Solute	a substance that dissolves in a liquid to form a solution for example salt.

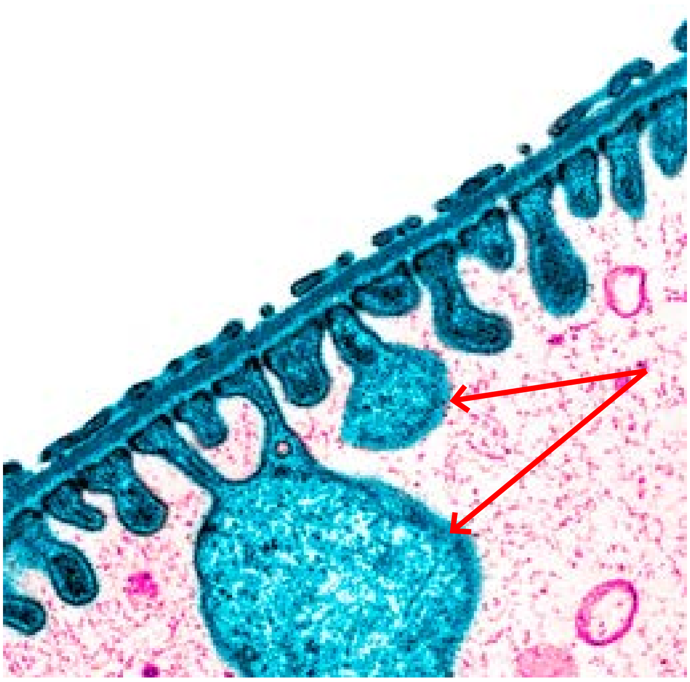
Filtration occurs in the glomerulus. Three layers lie between the blood in the glomerulus and the filtrate in the Bowman's capsule;

1. The squamous endothelium which is one cell thick, forming the wall of the capillaries.
2. The basal membrane which is not made of cells but is a gel containing peptidoglycans which acts as a molecular sieve.
3. On the other side of the basal membrane are epithelial cells known as podocytes which have long narrow extensions which spread out like an octopus over the surface of the capillaries in the glomerulus.

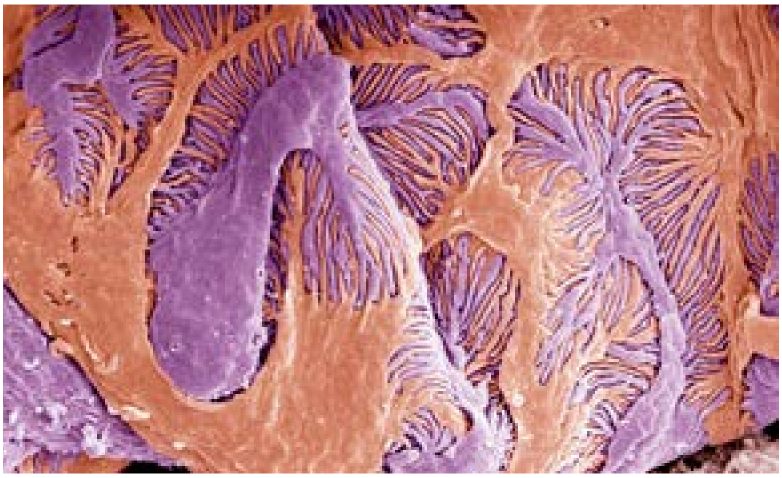
4.1.5 Key Concepts

Students should be able to:

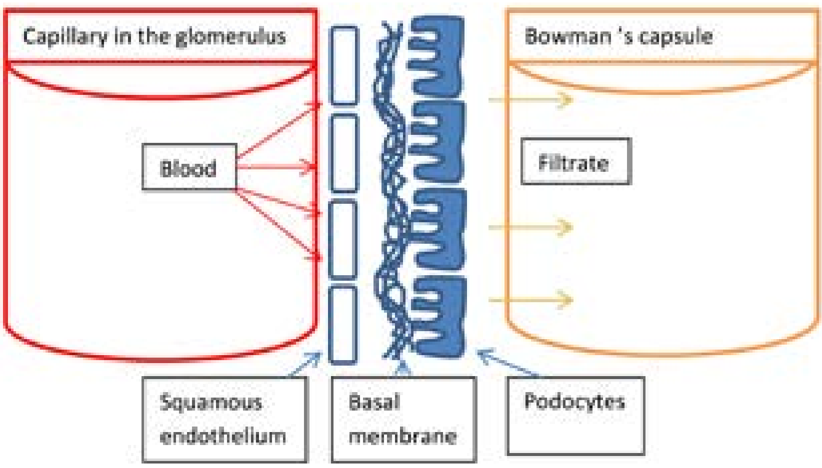
- demonstrate knowledge and understanding of the structure of the filter



Coloured transmission electron micrograph (TEM) of a section through a kidney glomerulus showing its basement membrane (blue line running from top right to bottom left). The smaller projections from the membrane are podocyte foot processes, which attach the podocytes (larger projections) to the membrane. The podocytes function as a barrier through which waste products are filtered from the blood. Waste from the kidneys is excreted as urine.



Coloured scanning electron micrograph (SEM) of tissue from a healthy kidney, showing the glomerular structure. The surface of a glomerulus is encased in podocyte cells (purple and pink).



(left) A simple diagram showing the 3 layers that lie between the blood in the glomerulus and the filtrate in the Bowman's capsule.

The following animation presents the structure and the mechanism of filtration.
https://youtu.be/wWsdcfGta4k

Glossary

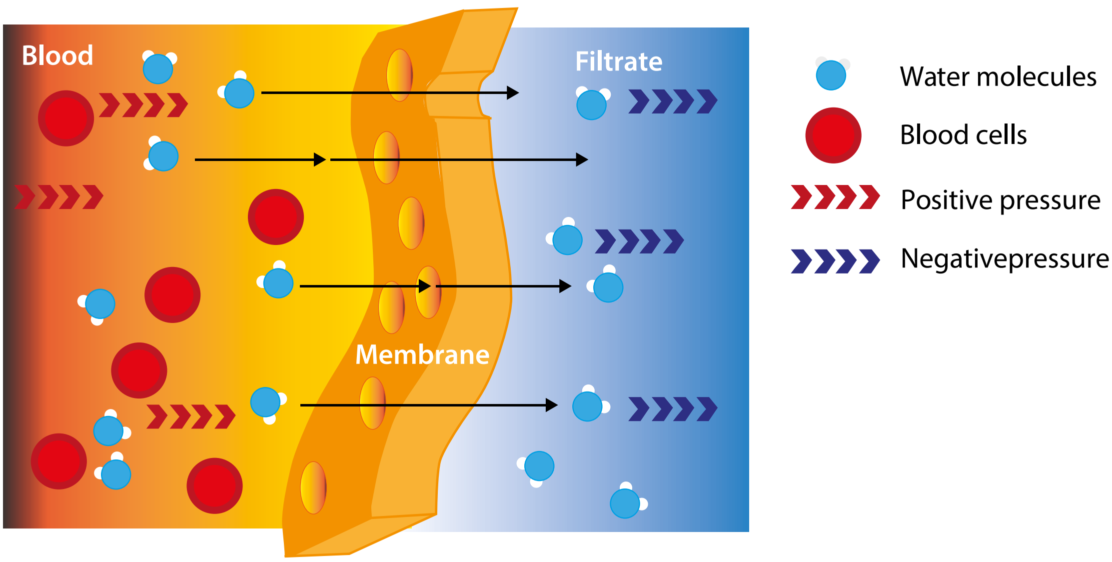
Basement membrane	a thin flat layer of tissue that covers a surface, lines a cavity, or divides a space or organ.
Peptidoglycan	a complex molecule that is composed of polysaccharide and peptide chains.
Squamous epithelium	a single layer of thin flat cells exposed to a basement membrane on one side.

4.1.6 Key Concepts

Students should be able to:

- demonstrate knowledge and understanding of the mechanism of ultrafiltration

Filtration under pressure is called ultrafiltration. The pressure of the blood in the glomerular capillaries is high and this is mainly due to the fact that the diameter of the afferent (*towards*) arterioles is larger than that of the efferent (*away*) arterioles. Because the blood in the glomerulus is under high pressure, fluid is forced out through the basement membrane and into the Bowman's capsule. This hydrostatic pressure is opposed by the osmotic pressure of the plasma proteins which tends to hold the plasma back in the capillaries. Under normal circumstances the osmotic pressure is only half as great as the hydrostatic pressure resulting in a gradient which ensures the formation of glomerular filtrate. Blood cells and larger molecules such as plasma proteins are too large to pass through the pores, podocyte spaces and the basement membrane. The blood components of water, salts, glucose and urea are all filtered out of the blood based on their particle size. The glomerular filtrate has almost the same composition as blood plasma minus its proteins. This means there are some substances such as water, salts, glucose and amino acids present in the filtrate which should not be lost in the urine and these need to be reabsorbed in the tubules. The volume of urine excreted is far less than the volume of filtrate produced with approximately 99% of the glomerular filtrate being reabsorbed through the renal tubules and ducts.



The following video presents ultrafiltration.
https://youtu.be/VtCAUly4cdk

The following video is a step-by-step tutorial about glomerular filtration. It uses a simple analogy to explain ultrafiltration. It also covers GFR and NFP which may be ignored at this stage.
https://youtu.be/9A2dAyWyK6o

Glossary

Afferent	conducting inwards or toward something.
Efferent	conducting outwards or away from something.
GFR	glomerular filtration rate.
Hydrostatic pressure	pressure exerted on the walls of a vessel by the liquid contained within.
NFP	net filtration pressure.
Osmotic pressure	pressure exerted by plasma proteins on the walls of the vessel they are contained within, having the effect of drawing fluid into the vessel.
Plasma	the liquid part of the blood and lymphatic fluid, which makes up about half of the volume of blood. Plasma is devoid of cells and contains antibodies and other proteins.

4.1.7–4.1.8 Key Concepts

Students should be able to:

- demonstrate knowledge and understanding of the mechanism of selective reabsorption and the role of the loop of Henle

Changes in the composition of the filtrate begin in the proximal convoluted tubule. The epithelial cells of the nephron wall reabsorb a large proportion of the filtrate, with glucose being reabsorbed in the proximal tubule and chloride ions in the distal tubule.

The following video presents selective reabsorption in the proximal convoluted tubule.
https://youtu.be/MMDDJqx2QOU

Filtrate flows down through the medulla in the descending limb round the loop of Henle and back up towards the cortex in the ascending limb. The descending and ascending limbs behave quite differently and this is how the osmotic gradient is established. The wall of the descending limb is permeable to salts and as the filtrate moves deeper into the medulla the salt concentration increases outside the tubule. Salts will then enter the tubule by diffusion and get carried in the flow to the loop of Henle where they become most concentrated. As the filtrate moves up the ascending limb the epithelium is impermeable to salts so passive diffusion will not occur, salts are actively transported out of the tubule and deposited in the surrounding tissue fluid. From there the salts will move across and diffuse into the filtrate in the descending limb. The overall result is the concentration of salts in the descending limb is higher than that in the ascending limb with highest concentration in the loop of Henle. The creation of the solute concentration gradient occurs due to the flow of fluid in opposite directions in the two adjacent ascending and descending limbs of the loop of Henle. This is called *counter-current multiplication*.

- *Counter-current*; the flow goes in two different directions – down the ascending limb and up the ascending limb.
- *Multiplication*; the concentration of the salts in turn drives water to be absorbed back from the filtrate by osmosis.

The following video is part of a series of presentations on the structure and mechanisms of the kidney. This particular video focuses on the nephron and counter-current multiplication.
https://youtu.be/Vqce2dtg45U?list=PLbKSbFnKYVY2NV3CWR7UR9VLRYkVJVpfG

In the distal convoluted tubule (collecting ducts) the epithelial cells lining the tubule are sensitive to the levels of a hormone called anti-diuretic hormone (ADH). ADH is a hormone produced in the hypothalamus in the brain. ADH increases permeability of the collecting ducts to water allowing it to move freely out by osmosis making urine more concentrated.

The following is a simple but excellent overview of kidney structure and function which should help condense the knowledge gained in each of the previous individual sections on the kidney.
https://youtu.be/hiNEShg6JTI

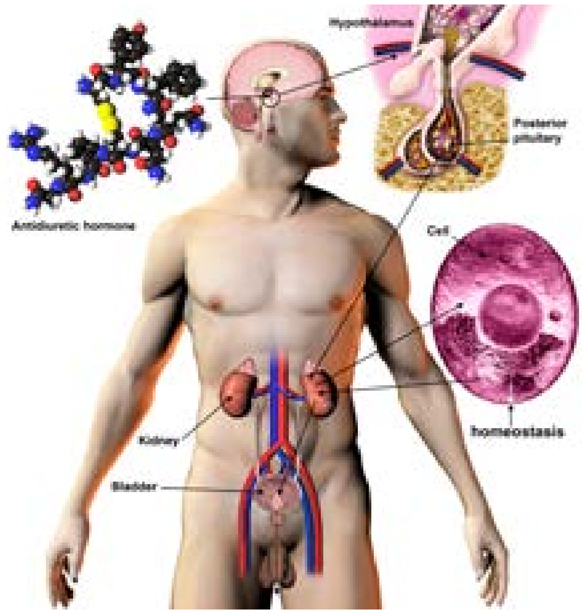
Glossary

Hormone	a chemical messenger produced by cells of the body and transported in the blood to cells and organs where it has a specific effect.
Hypothalamus	a region of the brain, between the thalamus and the midbrain, that functions as the main control centre for the autonomic nervous system and also acts as an endocrine gland by producing hormones.

We can now appreciate the two main functions of the kidney; excretion and regulation.

Excretion – lowers the urea content of the blood and removes toxic nitrogenous waste.
Regulation – controls the amount of water and salts reabsorbed.

It is the composition of the blood that will determine the re-absorptive activities of the kidney. The osmotic pressure of the blood does not have a direct influence on the kidney tubules but does so indirectly via hormones. In the brain there are osmoreceptor cells sensitive to the concentration of ions/molecules in the blood. These include sodium, potassium, chloride and carbon dioxide. Osmoreceptors are located in the hypothalamus at the base of the pituitary gland. The hypothalamus will respond to a high blood concentration sending signals that trigger the release of ADH into the blood. The target cells for ADH are the epithelial cells that line the collecting ducts. Receptor molecules will bind the ADH triggering proteins in the cell membranes to form pores that allow water to move freely out of the collecting duct by osmosis. This increased water reabsorption will then decrease blood concentration. This is an example of a negative feedback system. This ADH feedback system is very fast occurring within seconds.



The two main functions of Antidiuretic hormone (ADH) are to retain water in the body and to constrict blood vessels. ADH plays an important role in homeostasis, by the regulation of water, glucose, and salts in the blood. ADH is synthesized in the hypothalamus and stored in vesicles at the posterior pituitary.

Glossary

Osmoreceptor	a structure in the hypothalamus which respond to changes in osmotic pressure of the blood by regulating the secretion of ADH.
Osmoregulation	controlling the water content of the body.
Osmotic pressure of the blood	pressure exerted by the flow of blood in the blood vessels.

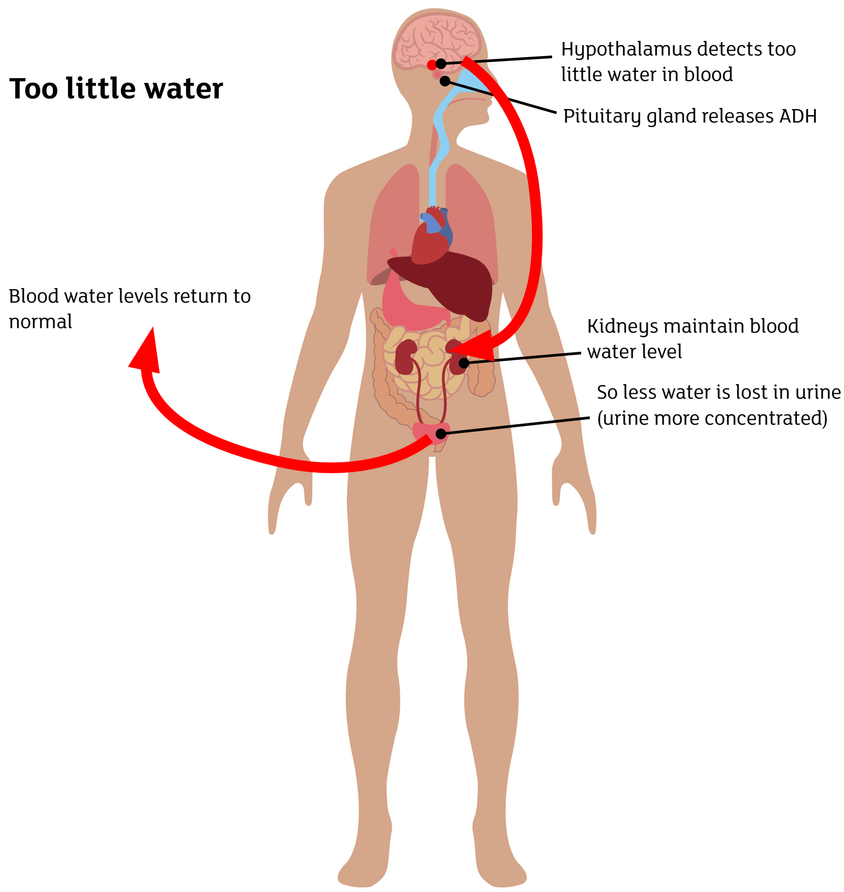
4.1.9 Key Concepts

Students should be able to:

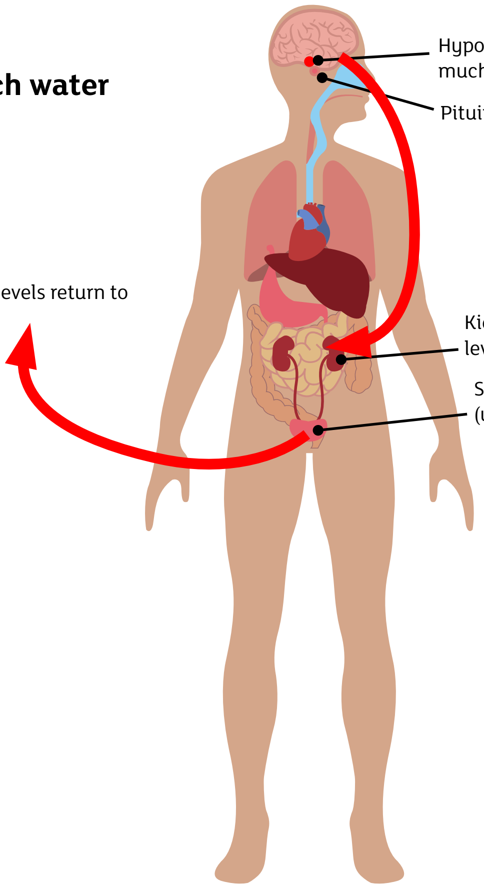
- demonstrate knowledge and understanding of the mechanism of osmoregulation

High-intensity aerobic exercise results in the loss of water through perspiration with the net resulting in the lowering of the solute potential of the blood. When the body becomes dehydrated there is a rise in osmotic pressure. This will stimulate the osmoreceptors in the hypothalamus which will in turn trigger release of ADH by the pituitary. The ADH will travel in the bloodstream to the collecting ducts in the kidney causing increased water reabsorption by osmosis in the collecting ducts. Water will enter the bloodstream lowering the osmotic potential and a more concentrated urine is formed. If the osmotic potential falls the solute potential will rise. When the blood concentrations are normal this will then result in decreased ADH secretion and inactivate the corrective mechanism.

Osmoregulation and the role of ADH as an example of negative feedback in a mammal.



Too much water



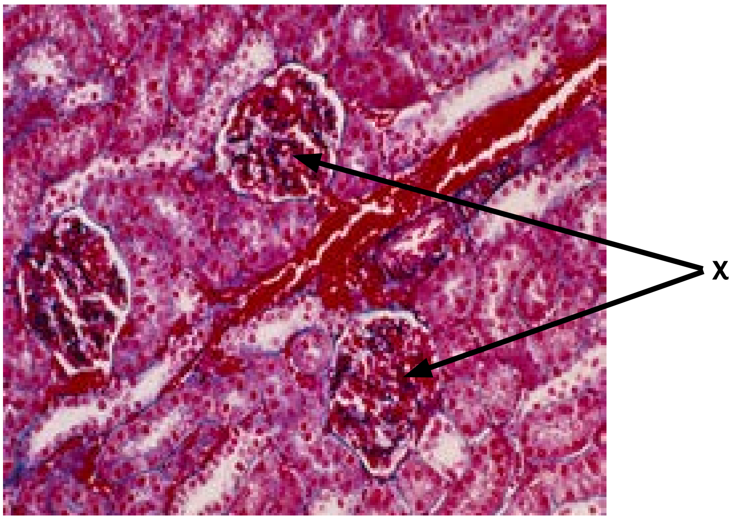
This is a slightly more advanced tutorial video that covers the negative feedback loop associated with ADH production and briefly discusses Diabetes Insipidus, the effects of alcohol on water retention, and water retention from elevated ADH production.
https://youtu.be/qqrUEjQXRak

Activities/Revision Exercises

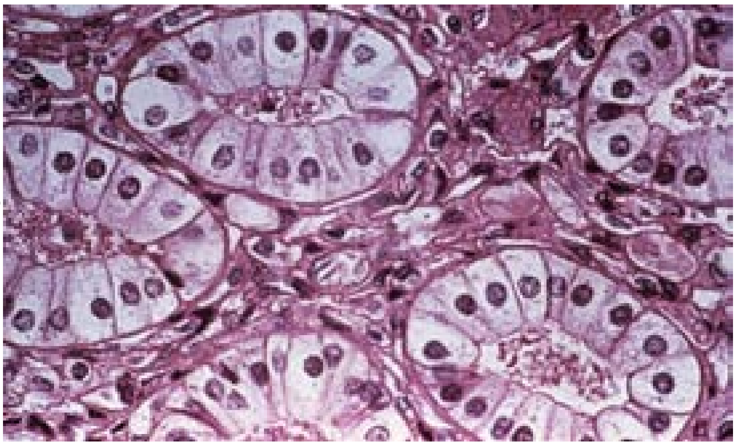
Answers are provided at the end.

Q1 (a) The photographs 1.6A and 1.6B are from different regions of the kidney. Photograph 1.6B is at a higher magnification than photograph 1.6A.
- (i) Identify the structures labelled X in Photograph 1.6A.
- (ii) Identify the kidney regions that the photographs are taken from.

Photograph 1.6A

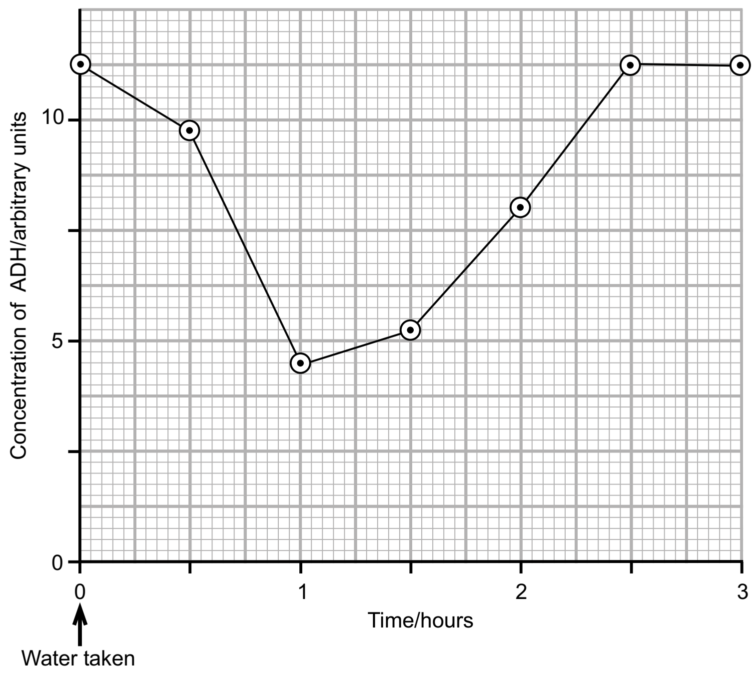


Photograph 1.6B



(b) The hormone ADH is involved in water reabsorption in the kidney. However, most of the water reabsorption in the kidney takes place independently of ADH being present.
- (i) State precisely where ADH is produced in the body.
- (ii) State where most water reabsorption takes place in the kidney and also state the process by which this water is reabsorbed.

Q2 The graph below shows the level of ADH in a student's blood over a three hour period after drinking 0.5 litres of water.

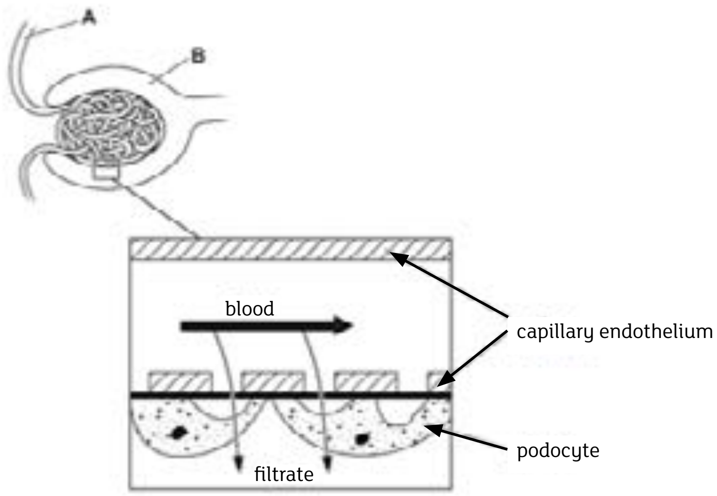


With reference to the process of osmoregulation, explain fully the changes in ADH concentration.

Q3 One symptom of diabetes is the higher than normal level of glucose in the blood which results in the appearance of glucose in the urine. Glucose is actively reabsorbed in the proximal tubule. Using the information provided and your understanding of reabsorption, suggest an explanation for the presence of glucose in the urine of people with diabetes.

Q4 (a) The diagram below shows the site of ultrafiltration in a kidney. Identify structures **A** and **B** shown on the diagram and name the structure which is the effective filter in ultrafiltration.

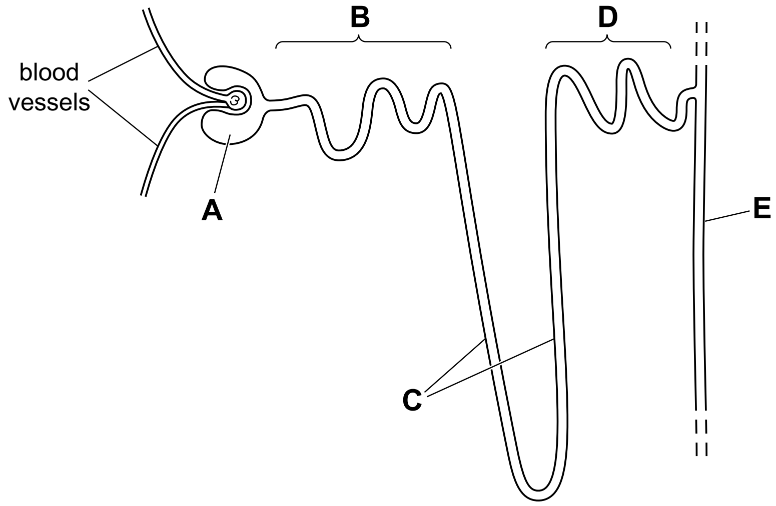
(b) In healthy individuals, protein does not normally appear in the urine. One indicator of high blood pressure is the presence of protein in the urine. Explain the presence of protein in the urine in someone with high blood pressure



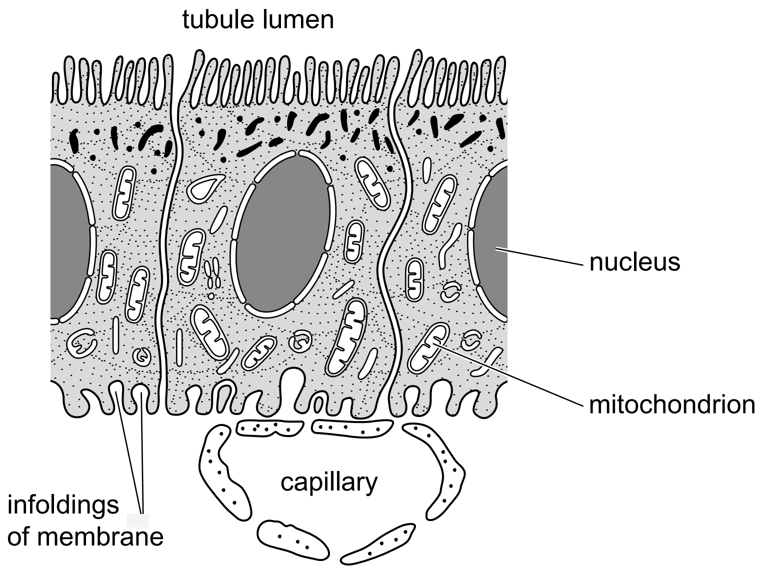
Q5 The kidney is a homeostatic organ important in excretion and osmoregulation.

(a) Describe and explain the processes of ultrafiltration and reabsorption in excretion in the kidney.
(b) Using osmoregulation in the kidney as an example, explain the term homeostasis and outline the essential components of homeostatic mechanisms.

Q6 The diagram below is of a mammalian nephron and associated structures. Identify the parts labelled **D** and **E**.
(i) Reabsorption of substances takes place along the regions labelled **B**, **C**, **D** and **E**. Which **two** letters correspond to the regions in which most water is absorbed?



The proximal tubule is the main site of reabsorption of solutes. The diagram below represents the cells lining the proximal convoluted tubule.



Adapted from: © CCEA A2 Biology: Unit 1: Physiology and Ecosystems by John Campton, page 15, published by Philip Allan, 2010. ISBN 1444112546. "Reproduced by permission of Philip Allan (for Hodder Education)"

(ii) Describe and explain the distinct ways in which the cells of the proximal tubule are adapted for the function of selective reabsorption.

Q7 The table below summarises differences in the concentration of some substances in the blood plasma and the renal filtrate at the end of the proximal convoluted tubule. Explain these results.

Substance	Concentration in blood plasma/ arbitrary units	Concentration in renal filtrate at end of proximal tubule/ arbitrary units
Large proteins	12	0
Glucose	0.15	0
Urea	0.04	0.09

Q8 In mammals, there is a strong positive correlation between the length of the loop of Henlé and the degree of aridity (dryness) of the environment that a mammal, such as the desert rat, inhabits. Explain this relationship.

Q9 The relative concentrations of a range of substances found in the glomerular (renal) filtrate and the plasma can be compared. The relative concentration is expressed as the filtrate/plasma (**F/P**) ratio which is calculated by dividing the concentration of the substance in the filtrate by its concentration in the plasma. Some **F/P** ratios are shown in the table below. Explain the ratios shown in the table.

Substance	F/P ratio
Glucose	1
Amino Acids	1
Small proteins	0.002
Medium-sized proteins	0.0003
Urea	1

Answers

A1 (a) (i) Glomerulus;
(ii) Cortex;
Medulla.
(b) (i) Hypothalamus;
(ii) Reabsorbed in proximal tubule; by osmosis

A2 Drinking water causes the blood to become more dilute and so the water potential of the blood to increase. Osmoreceptors in the hypothalamus detects the water potential of the blood causing less ADH to be produced. This in turn causes the walls of collecting ducts to become less permeable and therefore less water is reabsorbed from the collecting ducts. This results in the production of urine that is more dilute. A decreased water potential of the blood will cause ADH levels to increase.

A3 A higher level of glucose is filtered into the kidney tubules. Active reabsorption of glucose involves carriers and carriers may become saturated.

A4 (a) A=Afferent arteriole (capillary); B=Bowman's capsule/renal capsule. The effective filter in ultrafiltration is the basement membrane.
(b) In individual with high blood pressure protein is filtered into the nephron and not reabsorbed . High blood pressure can result in kidney basement membrane damage.

A5 (a) The blood entering the glomerulus is at high (hydrostatic) pressure due to the short distance from the heart and the afferent arteriole being thicker than the efferent arteriole. Smaller components of the blood (e.g. glucose, amino acids, salts, water, urea) are filtered out of glomerulus into the Bowman's capsule while larger components (e.g. blood cells and plasma proteins) are retained. Ultrafiltration is aided by pores in capillary walls with the basement membrane as the effective filter located between the podocytes in wall of Bowman's capsule. Filtration is opposed by the more negative solute potential of the plasma protein. In reabsorption useful products (e.g. glucose, amino acids) are selectively reabsorbed in the proximal tubule by facilitated diffusion/active transport. In the proximal tubule cells are adapted by the presence of microvilli to increase their surface area and also possess abundant mitochondria to provide ATP/release energy for active transport. Urea is not reabsorbed (but some diffuses back into the blood) while water is reabsorbed by osmosis allowing the concentration of urea to increase down the proximal convoluted tubule. Small proteins are reabsorbed by pinocytosis with additional water reabsorbed from the collecting ducts (descending limb of loop of Henlé/distal convoluted tubule).
(b) Homeostasis is the maintenance of constant (steady state) conditions in the body and maintains the blood water potential at a constant level. Osmoreceptors (sensors) in the hypothalamus allow the blood water/solute potential to be monitored. If a deviation from the set point or normal water (solute) potential occurs a corrective mechanism takes place to return the water/solute potential to its normal value. If the water/solute potential decreases more ADH is released (if the water/solute potential increases less ADH is released). Increased ADH will lead to more water being reabsorbed in the collecting ducts (decreased ADH will lead to less water being reabsorbed in

the collecting ducts). This is an example of a homeostatic mechanism having a negative feedback system; as the water/solute potential returns to normal/set point the effect of the corrective measure is reduced – explained in a water/solute potential context (as water/solute potential rises towards normal the level of ADH released decreases or converse).

A6 (i) D = distal convoluted tubule;
E = collecting duct;
B and E are where most water is absorbed.

(ii) The cells of the proximal tubule are adapted for the function of selective reabsorption in the following ways;

- The microvilli/infoldings increase surface area for reabsorption
- There are many mitochondria present to provide ATP/energy for active transport
- The capillaries are in close contact with cells providing short diffusion distances
- The membrane possesses carrier molecules for glucose/amino acids/active transport/facilitated diffusion.

A7 Proteins are too large to pass through the basement membrane; all the glucose is actively/selectively reabsorbed (in the proximal tubule); urea more concentrated as water is reabsorbed.

A8 The loop of Henlé creates a negative water potential, osmotic gradient and this leads to a high salt concentration in medulla.
The longer the loop of Henlé the better the species is at concentrating urine because more water is reabsorbed from the collecting duct.
In the desert it is necessary to conserve water as this prevents dehydration in the mammal.

A9 The ratios in the table can be explained as follows;
Glucose, amino acids and urea are filtered in proportion (into the Bowman's capsule) as these are small molecules only a very small amount of protein is filtered as they are normally too big to filter through the basement membrane. Many more small proteins are filtered than medium-sized proteins due to their smaller size.