AQA
Realising potential

# Teaching notes

## Control of blood water potential

**These teaching notes relate to section 3.6.4.3 of our A-level Biology specification. This resource describes key teaching points in the accompanying PowerPoint presentation.**

## Key points

There are two aspects to this topic:

- the role of the hypothalamus, posterior pituitary and ADH in osmoregulation
- the structure and function of the nephron.

Depending on the interests of your students, you could choose to treat these as two separate topics, linking osmoregulation to the overall topic of homeostasis and dealing with the nephron at another time.

# PowerPoint presentation

## What might happen if… (slide 2)

Use this slide to:

- remind students of the correct way to refer to water potential. Examiners accept descriptions such as ‘the water potential becomes more/less negative’ and many students find this easier to understand than ‘high’ having a value of zero and ‘low’ having a negative value
- think about the damage that might occur as a result of osmosis (eg lysis of cells if the blood water potential is higher than that of cells and cell shrinkage/slowing of hydrolysis reactions if the blood water potential is lower than that of cells).

## Gains and losses of water in mammals (slide 3)

You could ask students:

- to name **two** ways in which we lose water by evaporation (eg, evaporation of sweat from the skin and evaporation of water from the alveoli)
- which of these gains or losses we can control by changing our behaviour (eg, drink more when thirsty, move from a hot environment when we are sweating).

## Diuresis – terminology (slide 4)

By introducing the term ‘diuresis’, students are encouraged to understand why ADH is so called and this could help them to recall its function. Some students might know someone who is taking a prescribed antidiuretic.

This slide introduces the role of the hypothalamus in producing ADH and the role of the posterior pituitary gland in storing and releasing ADH. The specification clearly states posterior pituitary, so examiners could expect students to use this level of specificity in their answers.

It is worth stressing here that a decrease in the blood’s water potential (water potential becomes more negative) results in stimulation of the posterior pituitary to release ADH, which reduces water loss (diuresis).

## Formation of urine: an overview (slide 5)

This slide encourages students to gain an overview of basic principles.

Students learnt about the formation of tissue fluid in Year 1 of this course (specification section 3.3.4.1). Once ultrafiltration in the glomerulus has been covered, a comparison of the two processes could form the basis of a good class discussion.

More detail of the structure and function of kidney tubules comes later in this presentation.

## Control of water loss in the urine (slide 6)

We will look at the structure of the kidney in later slides.

The important points being consolidated here are the roles of the hypothalamus, posterior pituitary and ADH.

## Overview of osmoregulation (slide 7)

This diagram summarises the information in the previous slide and might be more helpful to visual learners.

This type of negative feedback loop will recur in specification sections 3.6.4.1 and 3.6.4.2.

So far, students have learnt about the roles of the hypothalamus, posterior pituitary and ADH. The following slides look at the structure and function of nephrons. You could choose to leave this to a later session.

## The role of the kidney (slide 8)

This slide introduces the components of nephrons named in the four bullet points in specification section 3.6.4.3.

In this slide, the capsule is referred to as the Bowman's capsule. Terms such as 'renal capsule' or 'capsule of the nephron' would be acceptable in an examination answer.

## A single nephron (slide 9)

It is worth pointing out here the importance of the capillaries. Students usually refer to the glomerulus but fail to show understanding of the importance of the capillary networks around the rest of the tubule in the reabsorption of 'useful' ions, molecules and water.

## VS kidney showing a single nephron (slide 10)

This slide simply shows the position of an individual nephron within a kidney.

The capsules, glomeruli, proximal tubules and distal tubules are mainly in the outer cortex; the loops of Henle and collecting ducts are in the inner cortex.

The position of the collecting duct and its pathway to the pelvis is also shown.

The results of filtered blood (ie urine) pass from each nephron into the pelvis and from there via the ureter to the bladder.

## And the location of the kidneys (slide 11)

Like the previous slide, this slide puts the whole system into context.

If you choose to use this slide, you could point out that the renal arteries (name required in specification section 3.3.4.1) are short extensions from the aorta, reinforcing the concept of high blood pressure resulting in ultrafiltration from the glomeruli.

It is worth stressing to students that the structure of the urinary system is not specification content, so examiners cannot expect students to recall this knowledge.

## Formation of glomerular filtrate (slide 12)

Here, you could ask all students to use their recall with understanding of topics from their Year 1 studies to:

- suggest the names of small molecules that are likely to be in the ultrafiltrate
- explain why plasma proteins and polypeptides are unlikely to be in the ultrafiltrate (a simple answer is that these molecules are too large to leave capillaries: as extension material for ‘stretch and challenge’ students, you could introduce the properties of the basement membrane as the important barrier)
- compare ultrafiltration in the nephron with tissue fluid formation (specification section 3.3.4.1), which would develop synoptic skills tested especially in Papers 2 and 3.

You could delete the terms ‘afferent’ and ‘efferent’ from this slide if you do not want to introduce these terms to your students.

You could decide to introduce the term ‘podocyte’ and the way in which podocytes are adapted for their function as **extension material** for ‘stretch and challenge’ students.

## Selective reabsorption in the proximal convoluted tubule (slide 13)

It would be a good opportunity here to avoid teleology that would occur by suggesting that ions or molecules that ‘are needed’ are reabsorbed.

You could ask students to explain:

- why water would pass into the capillaries by osmosis
- the likely process by which glucose is reabsorbed.

You could decide to introduce the term ‘podocyte’ and the way in which podocytes are adapted for their function as **extension material** for ‘stretch and challenge’ students.

## Explain the advantage of the following (slide 14)

These questions relate back to Year 1 topics such as 3.2.1.1 (Structure of eukaryotic cells - adaptations of eukaryotic cells) and 3.2.3 (Transport across cell membranes), encouraging students to develop synoptic skills.

## The role of the loop of Henle (slide 15)

Many students find the role of the loop of Henle, including the counter-current mechanism, hard to understand/explain.

This slide provides an overview that students often fail to grasp.

## The loop of Henle uses a counter-current mechanism (slide 16)

Can students recall where they learnt about the counter-current principle before? [Specification section 3.3.2, Gas exchange - gas exchange across the gills of fish]

Can students relate it to the counter-current here?

## The counter-current mechanism (slide 17)

A diagrammatic representation for students who are visual learners.

## The role of the collecting ducts (slide 18)

A model for visual learners representing the effect of ADH on the permeability of the walls of collecting ducts to water.

## Reabsorption of water (slide 19)

It is worth stressing that the water potential gradient into the medulla is always there; it is the permeability of their walls that determines whether or not water is lost from the collecting ducts into the medulla.

Further reading:
Michael Randles (2016), *The kidney filtration barrier*, Biological Sciences Review, 28 (3), pp 38-43.

## Questions for students

**1.** Mammals control the water potential of their blood.

**1.1.** Where in the body is a decrease in blood water potential detected?

**[1 mark]**

**1.2.** Explain how the body responds to a decrease in blood water potential.

**[2 marks]**

**2.** In the kidney, ultrafiltration and selective reabsorption are two processes involved in the formation of urine.

**2.1.** Where does ultrafiltration occur?

**[1 mark]**

**2.2.** Name **one** component of the blood which is **not** normally present in the filtrate and explain its absence.

**[2 marks]**

**2.3.** Name **two** components of the filtrate that are selectively reabsorbed in the proximal convoluted tubule and name the process by which each is absorbed.

**[2 marks]**

**2.4.** The kidneys of a human remove a substance called creatinine from the blood. The rate of removal of creatinine is a measure of the rate of filtration of the blood.

In 1 hour, a healthy man excreted 75 mg of creatinine in his urine. The concentration of creatinine in the blood entering his kidneys remained constant at 0.01 mg $cm^{-3}$.

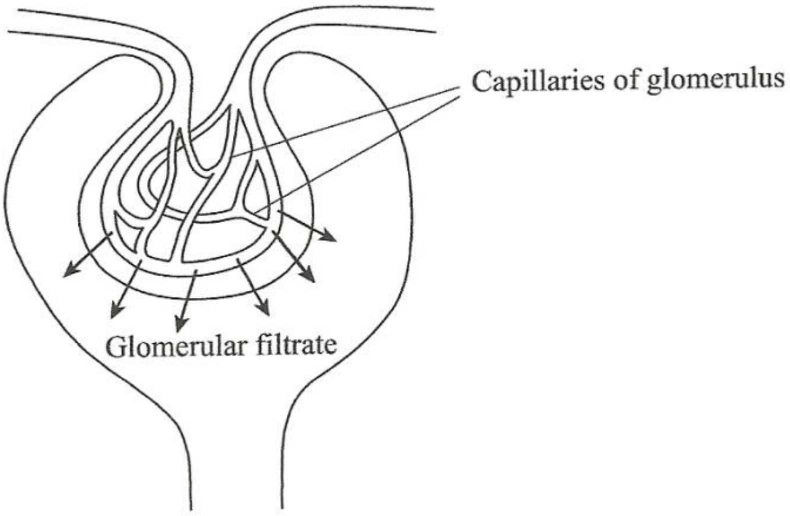
Calculate the rate at which his blood was filtered.

Show your working.

**[2 marks]**

**3.** **Figure 1** shows a renal capsule and the glomerulus within it.

**Figure 1**




**3.1.** Explain how the glomerular filtrate is formed.

**[2 marks]**

**3.2.** Name **two** substances that will be present in the glomerular filtrate.

**[1 mark]**

**3.3.** The composition of urine is different from the composition of glomerular filtrate. Give **two** reasons why.

**[2 marks]**

**4.** A whale is a large mammal that lives in the sea.

Whales take in sea water with their food. They have adaptations that prevent them from dehydrating when they take in sea water. Humans do not have such adaptations. If humans take in sea water, they become dehydrated.

Scientists investigated the effect of drinking sea water on whales and on humans. For the individual of each species, they measured:

- the volume of urine they produced
- the chloride ion concentration of their urine.

The scientists' results are shown in **Table 1**.

**Table 1**

| **Species** | **Mean volume of urine produced per $dm^3$ of sea water taken in / $cm^3$** | **Mean chloride ion concentration of urine / mmol $dm^{-3}$** |
|---|---|---|
| Human | 1350 | 400 |
| Whale | 650 | 820 |

Sea water has a chloride ion concentration of 535 mmol $dm^{-3}$.

**4.1.** Use data from **Table 1** to explain:

**4.1.1.** Why a human who drinks sea water becomes dehydrated

**[1 mark]**

**4.1.2.** How a whale is adapted to be able to drink sea water.

**[1 mark]**

**4.2.** The nephrons of these whales have very long loops of Henle.

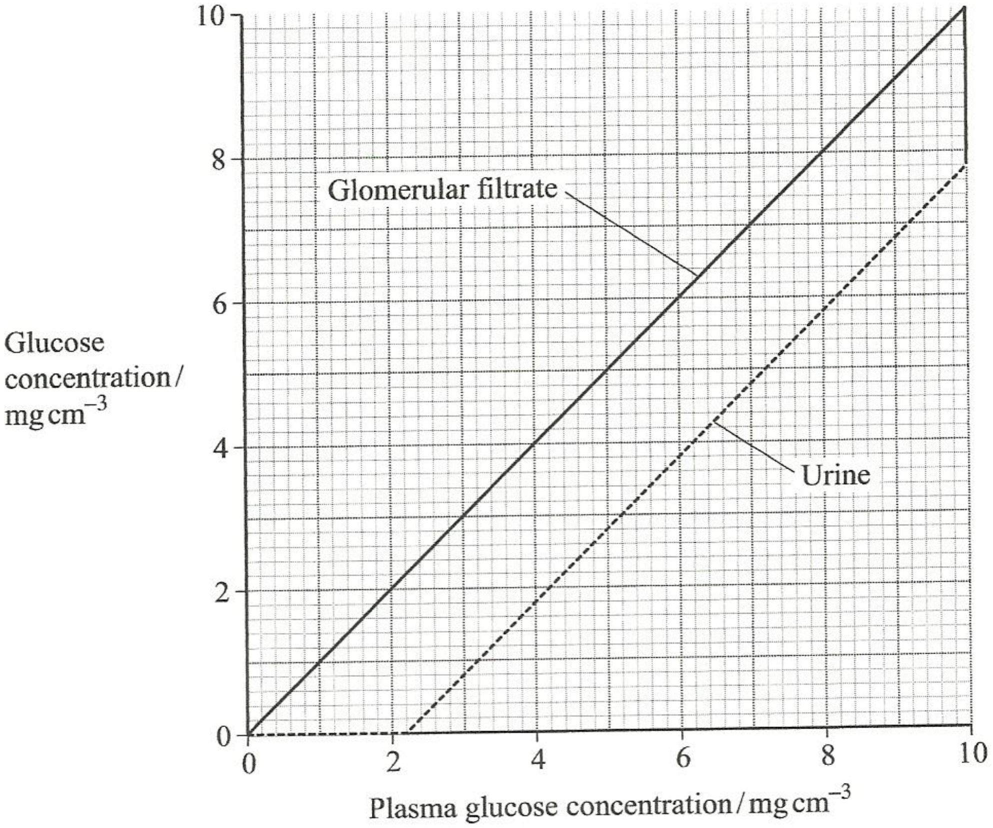
Explain how this causes the difference between the mean chloride ion concentration of the two groups.

**[3 marks]**

**5.** The threshold value for glucose reabsorption is the maximum plasma glucose concentration at which all the glucose can be reabsorbed from the glomerular filtrate.

A scientist determined the threshold value for glucose reabsorption in the kidneys of a mammal. **Figure 2** shows her results.

**Figure 2**




**5.1.** Describe precisely how glucose is reabsorbed from the glomerular filtrate into the blood.

**[3 marks]**

**5.2.** Describe and explain the change in the glucose concentration of the urine as the glucose concentration of the plasma increased from 0 to 4 mg $cm^{-3}$**.**

**[2 marks]**

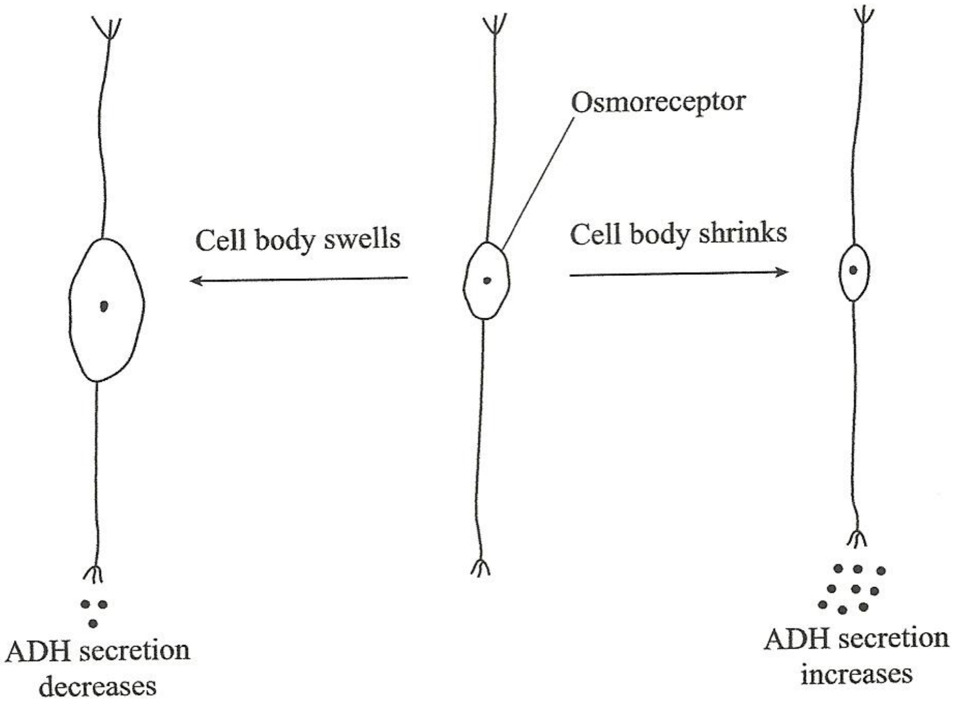
**5.3.** A person with diabetes might have a plasma glucose concentration that is greater than the threshold value for glucose reabsorption. Explain why.

**[3 marks]**

**6.** Osmoreceptors are specialised neurons that secrete antidiuretic hormone (ADH). The mass of ADH secreted is dependent on the water potential of the blood.

**Figure 3** shows how these osmoreceptors respond to changes in the water potential of the blood.

**Figure 3**




**6.1.** Where in the body are these osmoreceptors located?

**[1 mark]**

**6.2.** Where in the body is ADH released into the blood?

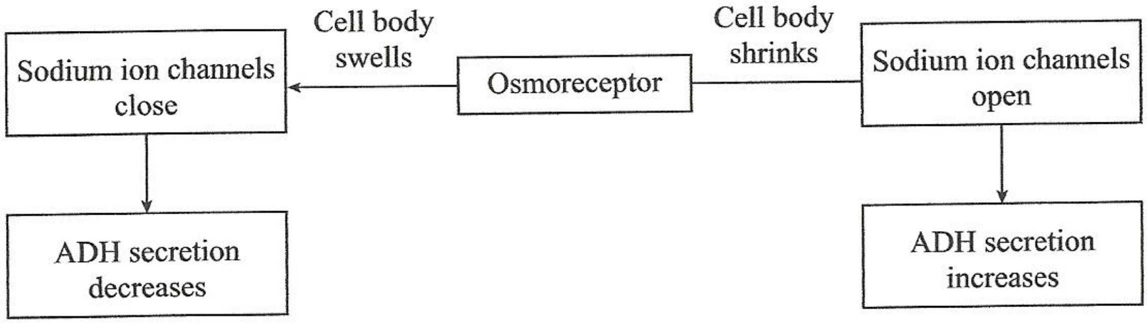
**[1 mark]**

**6.3.** Use information from **Figure 3** to explain how the osmoreceptors would respond after a person drinks a large volume of water.

**[2 marks]**

**6.4.** The membranes of the osmoreceptors contain sodium ion channels that open or close depending on the volume of the cell body. **Figure 4** shows how changes in the volume of the cell body of an osmoreceptor affect these sodium ion channels and ADH secretion.

**Figure 4**




After the water potential of the blood falls, the transmission of nerve impulses along the axon of an osmoreceptor leads to the secretion of ADH.

Use information from **Figure 4** and your own knowledge of nerve impulses to explain how action potentials would be initiated by a change in the sodium ion channels and describe how nerve impulses would be transmitted along an osmoreceptor.

**[6 marks]**

**7.** Scientists investigated urine production in humans.

**7.1.** They found that the total volume of fluid filtered in the kidneys of a human is normally 130 $cm^3$ $minute^{-1}$. When water intake is high, up to 15% of this filtrate can be excreted as urine.

Calculate the maximum volume of urine that could be excreted in 1 hour.

Show your working.

**[2 marks]**

**7.2.** People suffering from a disease called diabetes insipidus secrete less ADH than non-sufferers.

**7.2.1.** Explain how a decrease in ADH secretion affects the function of the kidneys.

**[2 marks]**

**7.2.2.** Give **two** symptoms you would expect to be associated with diabetes insipidus.

**[2 marks]**

**8.** Mammals can produce urine that is more concentrated than their blood plasma.

**8.1.** Describe the role of the loop of Henle in the absorption of water from the glomerular filtrate.

**[6 marks]**

**8.2.** Explain the role of ADH in the production of concentrated urine.

**[4 marks]**

**The guide mark scheme for these student questions is available in e-AQA through Secure Key Materials.**