Maintaining water and nitrogen balance

4.5.3.3 · Homeostasis and response · revision notes

How the body loses water, how excess amino acids are turned into urea, how the kidneys make urine and control water balance, and how kidney failure is treated. Expect data questions comparing blood, filtrate and urine, and questions on dialysis and transplants. This subtopic is in GCSE Biology only.

Key facts

- Water lost: lungs (breathing out), skin (sweat), kidneys (urine); only kidney losses are controlled
- Kidney: filtration, then selective reabsorption
- Urine: urea, excess ions, excess water (no glucose or protein when healthy)
- Dialysis fluid: normal glucose and ion concentrations, no urea
- Grade 7+ only Liver: excess amino acids → deamination → ammonia (toxic) → urea
- Reabsorbed: all the glucose, some ions, some water
- Grade 7+ only Blood too concentrated → pituitary releases more ADH → tubules reabsorb more water
- Transplant: shortage of donors; drugs needed to prevent rejection

Notes

Water and ion balance

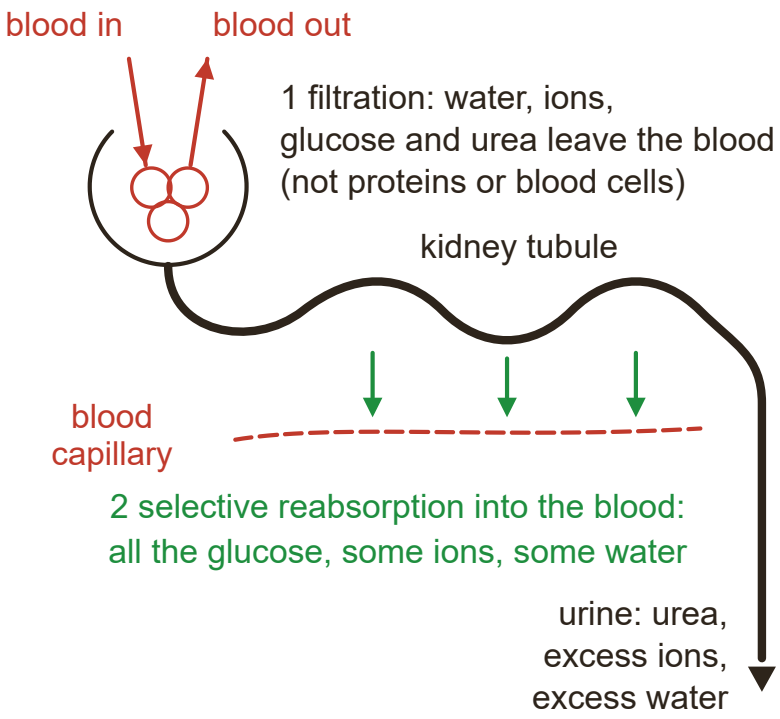
- Water leaves the body from the **lungs** when you breathe out. Water, ions and urea are lost from the **skin** in sweat.
- There is **no control** over these losses. Excess water, ions and urea are removed by the **kidneys** in **urine**.
- If body cells lose or gain too much water by **osmosis**, they do not function efficiently.
- In a more dilute solution than its cytoplasm, an animal cell gains water by osmosis, swells and may burst. In a more concentrated solution, it loses water and shrinks. Grade 8+ only

Making urea

- Digesting protein from the diet produces **excess amino acids**, which must be excreted safely.
- In the **liver**, excess amino acids are **deaminated** to form **ammonia**. Ammonia is **toxic**, so it is immediately converted to **urea**, which is carried in the blood to the kidneys. Grade 7+ only

How the kidneys work

- **Filtration**: small molecules (water, ions, glucose, urea) are filtered out of the blood into the kidney tubules. Proteins and blood cells are too large and stay in the blood.
- **Selective reabsorption**: useful substances (all the glucose, some ions and some water) are reabsorbed into the blood.

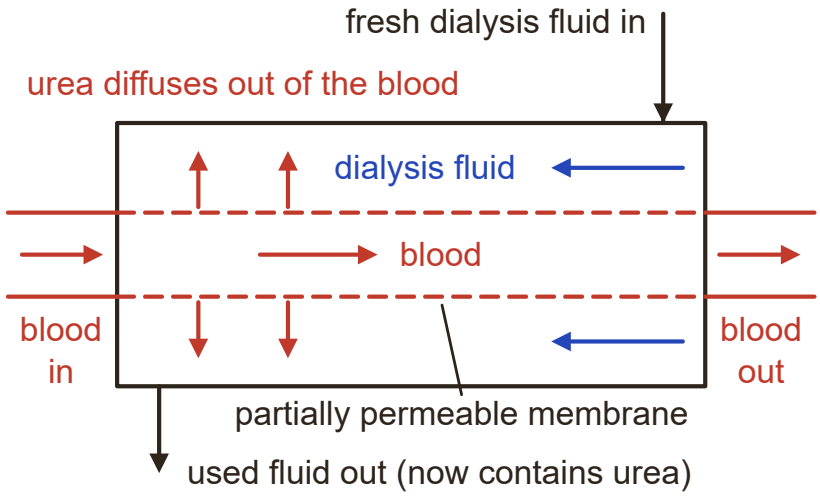


How the kidney makes urine: filtration, then selective reabsorption.

- Urine contains urea, excess ions and excess water. A healthy person's urine contains **no glucose** and no protein.
- Water level is controlled by **ADH**. When the blood is **too concentrated**, the **pituitary gland** releases more ADH, which makes the kidney tubules **reabsorb more water** into the blood. Less, more concentrated urine is produced. This is **negative feedback**. Grade 7+ only
- When the blood is too dilute, less ADH is released, so less water is reabsorbed and a larger volume of dilute urine is produced. Grade 7+ only

Treating kidney failure

- **Dialysis**: the patient's blood flows through a machine, separated from **dialysis fluid** by a **partially permeable membrane**.
- The fluid contains the **same concentration** of glucose and useful ions as normal blood, so these do not diffuse out. It contains **no urea**, so urea diffuses from the blood into the fluid. Excess ions and water are also removed.



Dialysis: urea diffuses from the blood into the fluid; glucose and useful ions stay in the blood.

- Dialysis drawbacks: several sessions of hours each week, usually in hospital; a restricted diet; infection risk from repeated needles; urea and ions build up between sessions; costly over time.
- **Transplant**: a healthy kidney from a donor. There is a shortage of donors, and the patient must take drugs for life to reduce the risk of **rejection**.
- Transplant benefits: a long-term solution with no dialysis sessions, fewer diet restrictions and a lower cost in the long run.

How to answer each type of question

Interpret data on filtrate and urine

3 to 5 marks | Grade 5

1. Compare the values in the filtrate and the urine.
2. Missing from the filtrate: too big to be filtered. Missing from the urine: reabsorbed.
3. More concentrated in the urine: water has been reabsorbed.

Example. The table shows the concentrations of some substances in the fluid filtered into a kidney tubule and in the urine of a healthy person.

Substance	Filtered fluid (g/dm^3)	Urine (g/dm^3)
Protein	0	0
Glucose	1.0	0
Urea	0.3	20

(a) Explain why there is no protein in the filtered fluid.
(b) Explain why there is no glucose in the urine.
(c) Suggest why urea is more concentrated in the urine than in the filtered fluid.

Model answer.

(a) Protein molecules are too large to be filtered out of the blood (1)
(b) All the glucose is reabsorbed into the blood (1) because it is useful / needed for respiration (1)
(c) Water is reabsorbed into the blood (1), so the urea left in the tubule becomes more concentrated (1)

Explain how ADH controls water balance

3 to 4 marks | Grade 7

1. Start with the change: the blood is too concentrated (or too dilute).
2. Say what the pituitary gland does to ADH release.
3. Say what ADH does in the kidney tubules and the effect on the urine.

Example. On a hot day, a person sweats a lot and does not drink.
Explain how their kidneys help to keep the water content of their blood within normal limits.

Model answer. The blood becomes too concentrated (1). The pituitary gland releases more ADH into the blood (1). ADH causes the kidney tubules to reabsorb more water back into the blood (1). So a smaller volume of more concentrated urine is produced (1).

Explain how dialysis works

3 marks | **Grade 5**

1. Use 'concentration gradient', 'diffuses' and 'partially permeable membrane'.
2. Glucose: same concentration on both sides, so no net diffusion.
3. Urea: none in the fluid, so it diffuses out of the blood.

Example. Explain why the dialysis fluid used in a kidney dialysis machine contains glucose but no urea.

Model answer. The fluid has the same glucose concentration as normal blood, so there is no concentration gradient and glucose is not lost from the blood (1). The fluid contains no urea, so there is a concentration gradient for urea (1), and urea diffuses from the blood into the dialysis fluid across the partially permeable membrane (1).

Evaluate dialysis and kidney transplants

4 to 6 marks | **Grade 5**

1. Give advantages and disadvantages of each treatment.
2. Use any data given, e.g. costs or waiting times.
3. Finish with a justified conclusion.

Example. Evaluate the use of a kidney transplant rather than dialysis to treat kidney failure.

Model answer.

Any three from:

after a transplant the patient does not need several long dialysis sessions every week	(1)
fewer restrictions on diet, so a more normal life	(1)
a transplant is cheaper in the long term	(1)
there is a shortage of donor kidneys, so there may be a long wait	(1)
risk of rejection, so drugs are needed for life, which increase the risk of infection	(1)
surgery carries risks	(1)
plus a justified conclusion, e.g. a transplant is better if a matching kidney is available, with dialysis used while waiting	(1)

Don’t lose marks

- Saying glucose is not filtered. It is filtered, but all of it is then reabsorbed.
- Saying ADH is made by the kidneys. It is released by the pituitary gland and acts on the kidney tubules.
- Saying urea is made in the kidneys. It is made in the liver; the kidneys excrete it.
- Saying dialysis fluid has no glucose so that glucose is not lost. It has glucose at the normal level so that none diffuses out.
- Using 'osmosis' for urea. Osmosis is only for water; urea moves by diffusion.

More tips

Memory tricks

- The kidney in two words: filter, then take back (reabsorb) what is useful.
- More ADH = more water kept = less, darker urine.
- Ammonia is awful (toxic); urea is the safe way to carry the waste.
- Dialysis fluid copies clean blood: normal glucose and ions, zero urea.

Exam technique

- In data questions, follow each substance from blood to filtrate to urine and explain each change as filtration or reabsorption.
- For ADH, give the full chain: blood too concentrated → pituitary → more ADH → tubules reabsorb more water → less, more concentrated urine.
- In 'evaluate' questions, cover both treatments and end with a justified conclusion.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **List ways water leaves the body**
From the lungs when you breathe out, from the skin in sweat, and from the kidneys in urine.

Grade 4 — **Describe how the kidneys produce urine**
Filtration of the blood, then selective reabsorption of useful substances such as glucose, some ions and water.

Grade 5 — **Explain why cell water content must be controlled**
If cells gain or lose too much water by osmosis, they do not function efficiently.

Grade 5 — **Describe the basic principles of dialysis**
Blood flows past a partially permeable membrane; urea and excess ions diffuse into the dialysis fluid.

Grade 5 — **Evaluate dialysis and kidney transplants**
Weigh up time, diet, cost, rejection risk and donor shortages.

Grade 7 — **Explain how urea is formed**
Excess amino acids are deaminated in the liver to form ammonia, which is converted to urea.

Grade 7 — **Explain how ADH controls water balance**
When the blood is too concentrated, the pituitary releases ADH, so the kidney tubules reabsorb more water.

Grade 8 — **Interpret osmosis diagrams of animal cells**
Explain why animal cells swell and may burst, or shrink, in solutions of different concentration.

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