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Kidneys

Your body has to handle all sorts of variations, balancing its inputs and outputs, if it is to work efficiently. In this article we concentrate on one organ — the kidney — and the way it helps to keep things on an even keel.

GCSE key words
Homeostasis
Hormone
Kidney tubule
Diffusion
Osmosis

Our bodies work to balance their inputs and outputs in two ways. The processes involved are **homeostasis** and **excretion**.

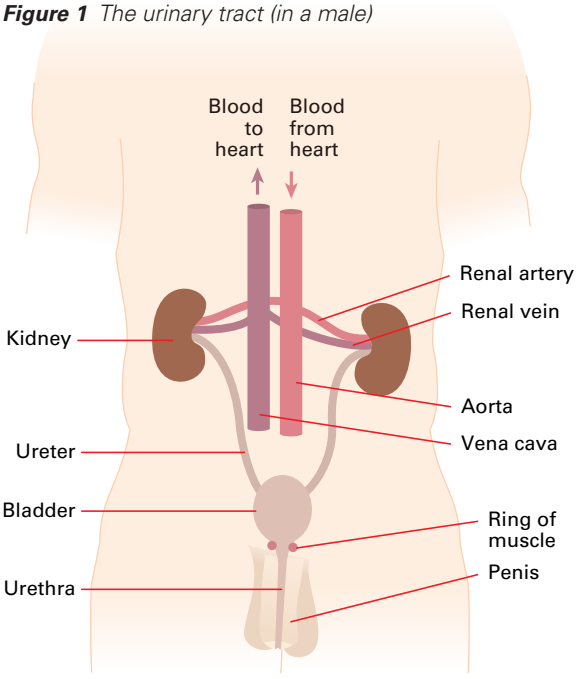
Homeostasis

This involves various mechanisms that keep the body's internal environment in a state of relative stability. Your endocrine system helps to maintain this steady state by regulating body processes that affect the concentration of chemicals, such as potassium, sodium and chloride ions, in blood, lymph and tissue fluid. It also controls the way that proteins, lipids and carbohydrates are utilised by your body.

The endocrine system works through **hormones**. These are specialised chemical substances, produced by endocrine glands and then released into the blood. They circulate around the body to regulate the action of particular target organs. The production and release of these hormones is controlled by the brain, which receives inputs from receptors in blood vessel walls around the body and in the brain itself.

- **Look up the homeostatic mechanisms the body uses to keep your internal temperature just right.**

Figure 1 *The urinary tract (in a male)*



Anything to do with the kidney is described by the adjective *renal*, hence renal artery, renal dialysis, and the adrenal gland that sits on top of a kidney.

Excretion

This involves getting rid of waste materials, which would otherwise build up. These include carbon dioxide, which is excreted when we breathe out, and urea, which is excreted via the kidneys. Urea and other nitrogen-containing products are produced when the body breaks down proteins.

The role of the kidney

Kidneys are part of the urinary tract (Figure 1). They help to maintain the internal environment of our bodies by filtering the blood. Each kidney contains over a million kidney tubules or **nephrons**. These filter water and soluble components from the blood (about 1700 litres/day) and then reabsorb sugar and amino acids, as well as the dissolved ions and the water the body needs (Figure 2). At the same time, urea, excess ions and excess water are excreted as urine, approximately 1.5 litres/day.

Look at the list in Box 1 of all the other things that kidneys do — no wonder we can't survive without them working properly.

Thirsty work

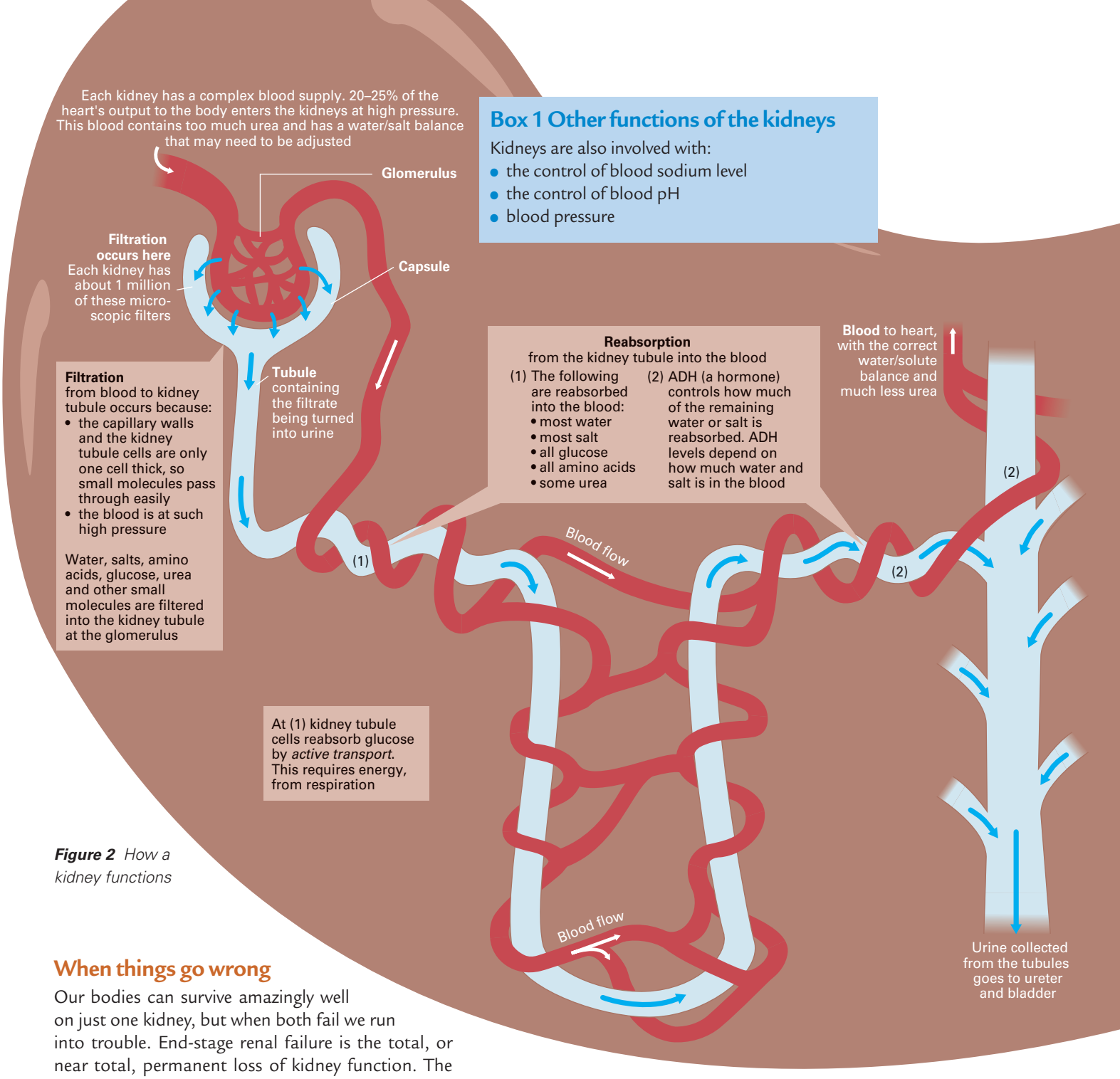
We get rid of water via the kidneys as urine, but we also lose water through sweat, in faeces and as water vapour when we breathe out. What happens when you run a race? The further and the faster you go, the more you sweat and lose water through the skin. As a result your blood becomes more concentrated. This triggers two mechanisms:

- Receptors in your brain note the changed concentration and these trigger your thirst centre, which makes you want to drink.
- The pituitary gland in your brain releases a hormone called ADH into the blood which causes the kidneys to reabsorb more water from the filtrate.

When you have drunk some water and stopped sweating, less ADH is released into the blood. Therefore less water is reabsorbed and your urine becomes more dilute. These processes are examples of **negative feedback**.

Table 1 *The urinary system*

Structure	Function
Kidneys	Filter waste from blood and produce urine
Ureters	Transport urine from kidneys to bladder
Bladder	Stores urine
Urethra	Transports urine from bladder to outside of body



Box 1 Other functions of the kidneys

Kidneys are also involved with:

- the control of blood sodium level
- the control of blood pH
- blood pressure

Figure 2 *How a kidney functions*

When things go wrong

Our bodies can survive amazingly well on just one kidney, but when both fail we run into trouble. End-stage renal failure is the total, or near total, permanent loss of kidney function. The commonest causes of end-stage renal failure in this country are diabetes, hypertension and glomerulonephritis (inflammation primarily affecting the glomeruli in the kidney).

It is important to monitor people with these conditions closely, so that if they start to develop renal failure, measures can be taken quickly to slow progression of the disease. This involves giving people medication to help keep blood pressure and diabetes as tightly controlled as possible. People may have renal failure for years (chronic renal failure) before they develop end-stage renal failure.

When kidneys fail they stop producing urine and we can no longer excrete urea and get rid of salts and water in excess of the body's needs. The body becomes uraemic — the waste products build up making you feel tired, sick, off your food, itchy and generally unwell. So what can be done to help the body combat these imbalances?

Dialysis

Unwanted substances can be filtered away artificially using a dialysis machine (Figure 3 on page 8).

Blood leaves the body in tubes, passes through a pump and into the dialysis machine. It then enters thousands of semipermeable microtubules which make up a dialysis membrane. Between these microtubules, running in the opposite direction to the flow of blood, is dialysis fluid. The dialysing membrane

- **Water is reabsorbed by osmosis — from the tubule into the blood. Make sure you understand why osmosis occurs.**

- **List the ways your life would change if you had to have dialysis — what would you do about holidays?**

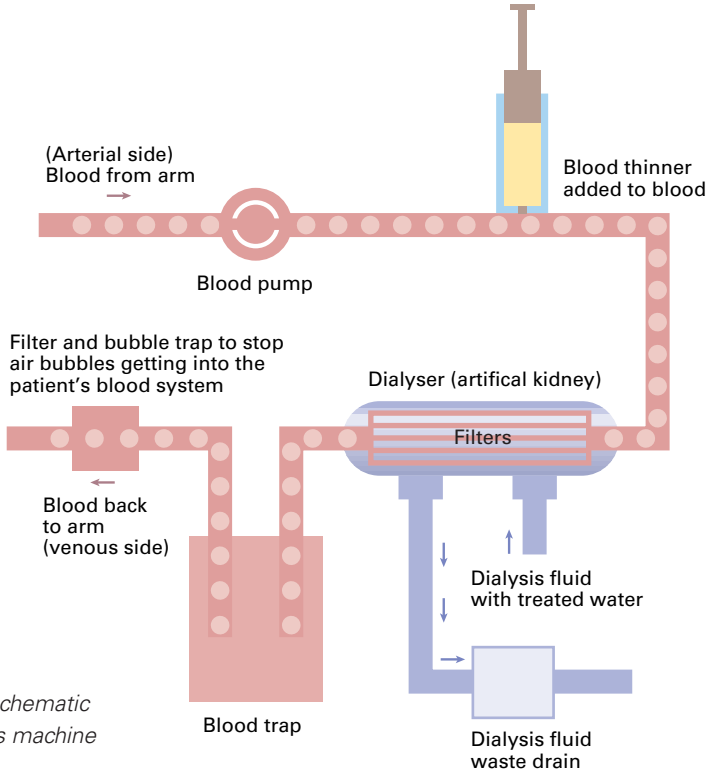


Figure 3 *Schematic of a dialysis machine*

Phototake Inc./Alamy

A dialysis patient

allows small particles, such as water and urea molecules and sodium and chloride ions, to pass through it. The particles move randomly and can pass both ways through the membrane. However, more particles will meet the membrane on the side with a higher concentration and pass through, thus giving a net flow from higher to lower concentration. This is the process of **diffusion**.

The incoming dialysis solution contains water, glucose, salts and various substances at the correct concentration for the body. Diffusion continues until the concentrations are the same. The blood leaving the machine has all these substances in the same concentration as the dialysis solution. The fresh dialysis solution does not contain urea so this diffuses out of the blood and is effectively excreted and taken away by the flow of dialysis solution. Proteins and blood cells are too big to pass through the membrane so they stay in the blood.

People with end-stage renal failure need to have regular dialysis. Most of them have dialysis three times a week and it takes up to 4 hours each time. Think about the impact this must have on their lives.

Renal transplants

A renal transplant can give a whole new lease of life to someone who has spent a long period of time trying to keep things under control by having regular dialysis and a multitude of medications.

Transplanted kidneys currently come from one of two sources:

- **A dead person.** Sometimes in an accident a casualty may suffer permanent and irreversible brain injury. He or she may need to be maintained on a life-support machine, and be tested to certify brain death. If such casualties have previously consented to donate their organs, and relatives give their permission, kidneys and other organs can be removed when the life-support machine is turned off. Kidneys may also be taken from donors who have died from causes such as cardiac arrest, but this has to be done very quickly before irreversible damage occurs.
- **A living person.** Since we can survive with one kidney, it is possible to donate a kidney to a close relative.

There are problems with kidney transplants. A kidney cannot be transplanted from any donor to any recipient. Many tests are needed to check if the donor and recipient are compatible. It is important that lots of variables match up, such as tissue type and blood type, in order that the recipient's body does not reject the kidney. The recipient also has to take immunosuppressive drugs for the rest of his or her life. These help to stop the recipient's immune system rejecting the kidney.

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Box 2 Arteriovenous fistula

For patients requiring regular haemodialysis difficulties can arise when trying to gain access to their veins. One solution is to form an arteriovenous fistula, an artificial connection between an artery and vein which is made surgically. This creates a pool of blood, into which needles can be inserted repeatedly for dialysis (Figure 4).

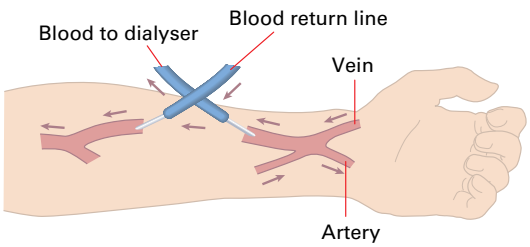

Figure 4 *A fistula*

- **Find out about another method of dialysis — continuous ambulatory peritoneal dialysis (CAPD).**
- **To find out more information on kidney donation see www.uktransplant.org**