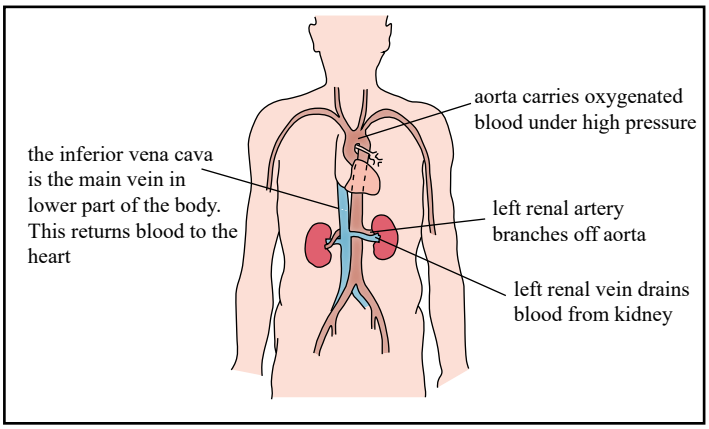
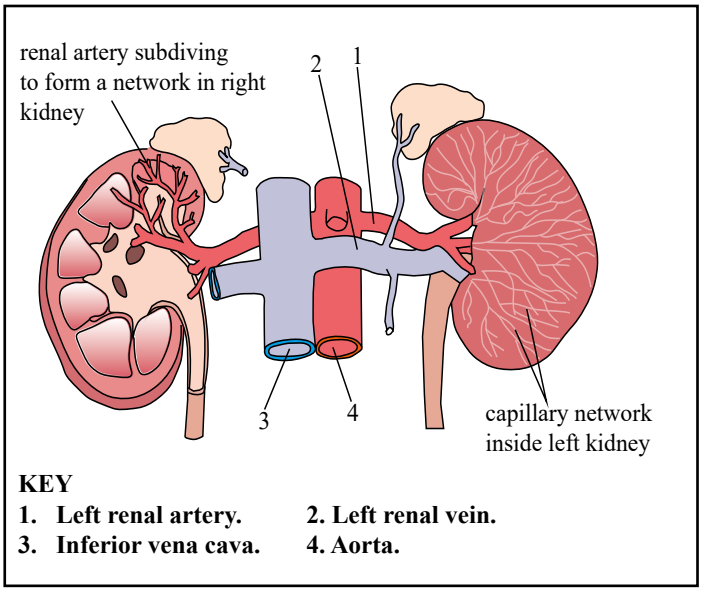
Fig. 2 How the kidneys are linked to the main blood vessels of the body



Inside each kidney there is a complicated network of capillaries.

Fig. 3 The detailed blood supply in each kidney



KEY

1. Left renal artery. 2. Left renal vein.
3. Inferior vena cava. 4. Aorta.

The right and left renal arteries branch from the **aorta**. Blood in these arteries is under high pressure.

The blood in the renal arteries transports:

- Oxygen,
- Waste products, like urea,
- Excess salts and water.

The renal veins drain blood from each kidney. The blood is under low pressure. Each renal vein joins to the **inferior vena cava**. The blood in the renal veins has:

- Less oxygen,
- More carbon dioxide,
- Reduced levels of urea,
- Less salt and water.

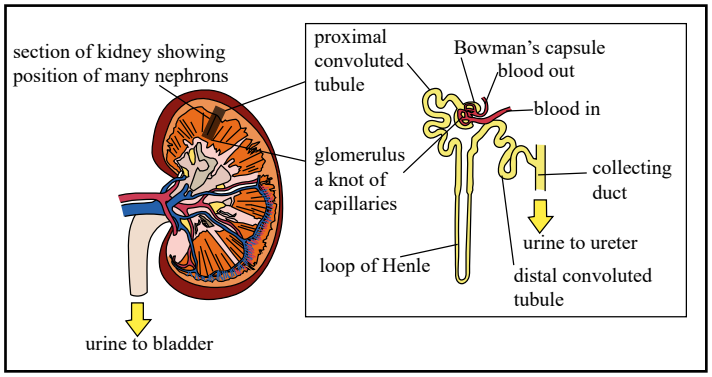
The renal artery and the renal vein both contain:

- The same levels of glucose,
- The same blood proteins,
- Red and white blood cells.

Functioning of the Kidney

Each kidney is packed with microscopic tubules called **nephrons.**

Fig. 4 The position and structure of nephrons in the kidney

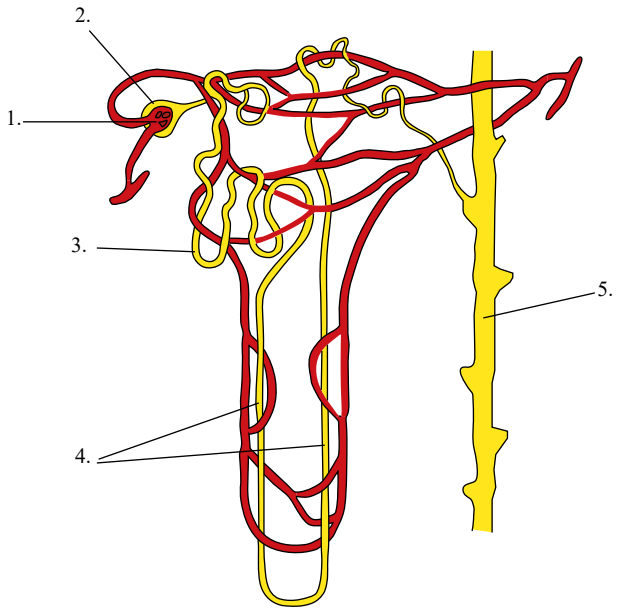


The kidney nephron is the filtering unit of the kidney. It carries out the processes of:

- Ultrafiltration,
- Selective reabsorption,
- Regulation of blood water levels.

Role of the Nephron

Fig. 5 A single kidney nephron and its blood supply



1. Blood under high pressure enters the **Bowman's capsule**.
2. The high **hydrostatic pressure** forces small molecules out of the blood into the nephron. The molecules include water, glucose, amino acids, urea, and salts. This process of filtering using high pressure is called **ultrafiltration**. Large blood proteins and blood cells do not get forced out.
3. In the **proximal convoluted tubule**, all the glucose is actively moved from the nephron back into the blood. Amino acids are also reabsorbed, as well as some water.
4. All along the **loop of Henle**, water and salts are moved back into the blood.
5. The final adjustment of the blood water levels takes place in the **collecting duct**. The permeability of this duct is controlled by a hormone called ADH. If ADH is present, more water passes back into the blood.

Why the Kidneys Fail

There are many reasons why the kidneys stop working:

- Injury to the kidneys (perhaps as a result of an accident),
- Overuse or overdose of drugs,
- High blood pressure or **hypertension**,
- Diseases like type 1 **diabetes**,
- Faulty genes.

If the kidneys fail, toxins in the body will build up and poison the cells.

Artificial Kidneys

Patients with failing kidneys are treated using an artificial kidney. Some patients may eventually need a kidney transplant.

There are several types of artificial kidney. They clean the blood or body fluids using a process called **dialysis.**

Kidney Dialysis

If a patient has kidney failure, their blood needs to be filtered mechanically. There are two ways of doing this: Haemodialysis, and Peritoneal dialysis.

> ***Exam Hint:-*** *Candidates need to know how these two processes work. A dialysis machine is complicated. Candidates should understand how the machine is set up and how it works. They should be able to label the different components. A simple annotated drawing showing the inside of a dialyser is all that a candidate would have to reproduce in the exam.*

Haemodialysis has been successfully carried out for many years. The technique uses a dialysis machine. Inside the machine, the patient's blood flows next to a specially prepared dialysis fluid. The blood and the dialysis fluid are separated by a thin membrane. The dialysis machine sets up diffusion gradients between the dialysis fluid and the blood.

Fig. 6 The flow of blood from a patient through the dialysis machine

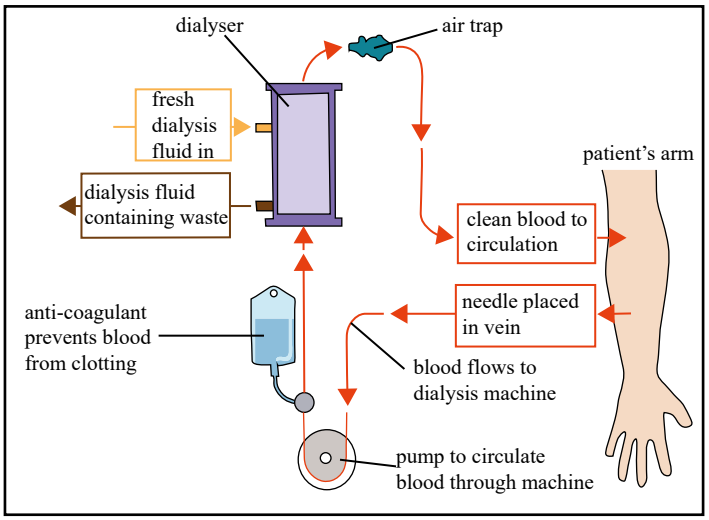
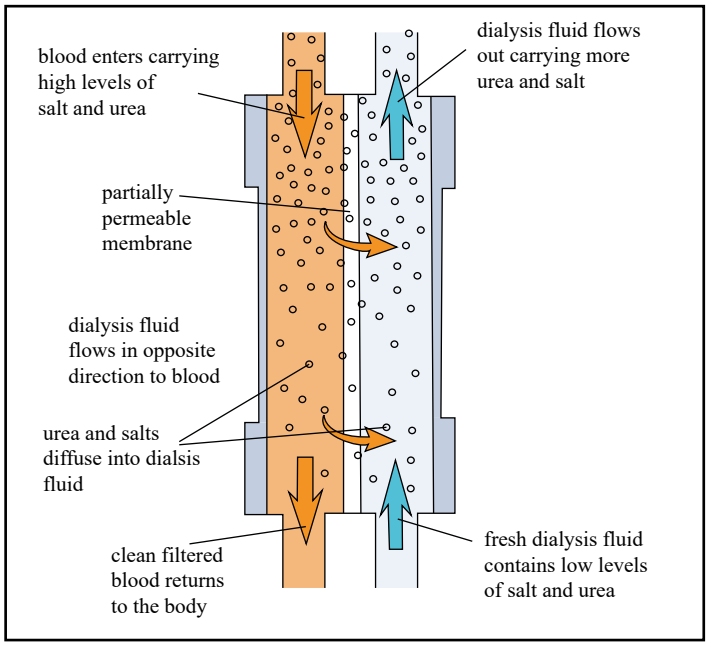


Fig. 7 How a haemodialysis machine filters blood



Inside the dialyser, the blood and fluid flow in opposite directions. This is described as being **counter current**. All along the membrane, diffusion gradients are set up.

Movement of Materials

Urea and salts

- The blood carries high levels of urea and salts.
- The dialysis fluid contains low levels of urea and salts.
- A diffusion gradient is set up on either side of the membrane.
- The urea and salts diffuse down the concentration gradient from the blood into the fluid.

Glucose

- Glucose levels in the blood are at the same concentration as in the fluid.
- No diffusion gradient is set up.
- There is no net movement of glucose in either direction across the membrane.
- This ensures that glucose is not lost from the blood.

Water

- The dialysis machine uses pressure to pull excess water across the membrane.
- The water moves from the blood into the dialysis fluid.

Other substances

- Large molecules, like proteins and blood cells, remain in the blood.
- They are too large to pass through the pores in the membrane.

Advantages of Haemodialysis

- The harmful waste materials are removed from the patient's blood.
- Water and salt levels in the body are controlled.
- The patient will not die from kidney failure

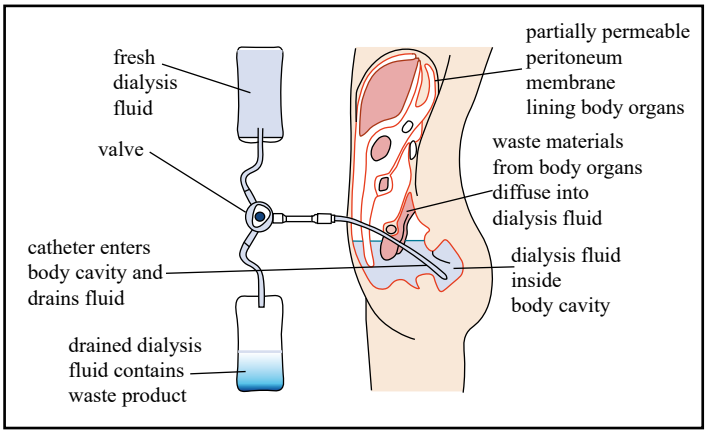
Disadvantages of Haemodialysis

- The machines are expensive.
- A haemodialysis session takes at least 4 hours.
- The patient needs to be attached to the machine several times a week. This restricts their activities.

Peritoneal Dialysis

Peritoneal dialysis also uses a partially permeable membrane. This natural membrane called the **peritoneum** lines the body cavity. Dialysis fluid is passed into the body cavity. Diffusion gradients are set up between the dialysis fluid and the blood. The dialysis fluid absorbs materials from any blood vessels in the body cavity. Peritoneal dialysis is used for patients who cannot use haemodialysis.

Fig. 8 How a patient would undergo peritoneal dialysis



Advantages of Peritoneal Dialysis

- No needles are used after the catheter has been put in place.
- The patient is able to have more freedom of movement.
- Patients do not have to follow a very restricted diet
- It is suitable for patients who still have some function in their kidneys.

Disadvantages

- There is a risk of infection from the catheter
- Patients who are obese may not be able to have a catheter inserted.
- People often gain weight.
- The procedure can be carried out for a few years, but patients ultimately have to have haemodialysis.

Exam Hint:- *Questions on dialysis focus on which materials pass across the dialysis membrane from the blood. Candidates should know the details of how diffusion gradients are set up and maintained.*

Artificial Kidneys for Transplant

One solution to kidney failure is a kidney transplant. The disadvantages of this are:

- The kidney needs to be from a closely matched donor.
- Transplanted kidneys are recognised as foreign by the immune system.
- Patients with donated kidneys need to take anti-rejection drugs.
- There is a severe shortage of kidneys for transplantation.

A group of American scientists are working on the first implantable artificial kidney. This kidney uses living kidney cells and specialised microchips.

- The trial or prototype kidney uses living kidney cells and nanotechnology.
- Kidney cells can be cultured in a laboratory.
- The kidney cells are placed onto a framework and allowed to grow.
- The microchips are able to recognise chemicals in the blood. They can identify which are waste products and which are useful nutrients.
- The living kidney cells carry out the filtering.

The whole structure is described as a **bioreactor** as it is built up from living cells and non-living components. It is about the size of a small teacup.

Fig. 9 The artificial kidney

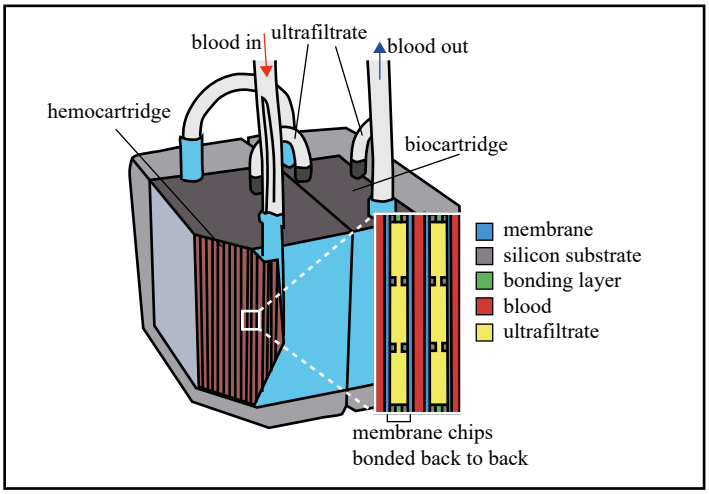
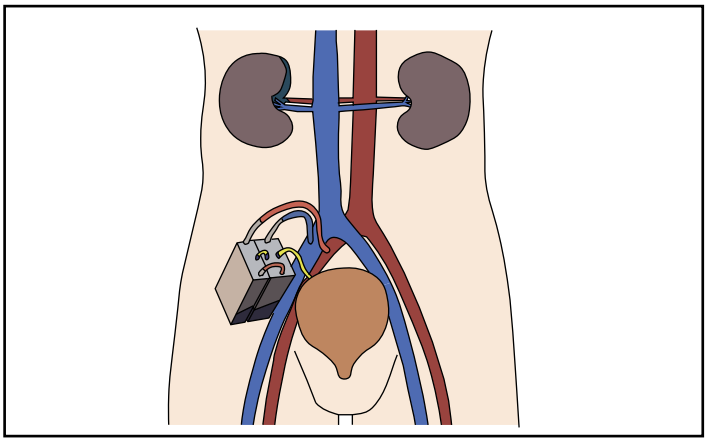


Fig. 10 The transplated artificial kidney in a patient



The first human trials for this artificial kidney are expected to take place in 2017.

Advantages

- A plentiful supply of bioreactors would be available.
- There would be no further need for dialysis

Disadvantages

- The technology is very new and is still being trialled. It may not be successful.
- Blood clots in the body may destroy the filtering process.

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