

# Artificial Organs

## Outcomes:

### *Students will be expected to:*

- Provide examples of scientific knowledge that have resulted in the development of technologies (111-1)
- Describe how a community's needs can lead to developments in science and technology (112-2)
- Make informed decisions about applications of science and technology, taking into account environmental and social advantages and disadvantages (113-9)
- Propose a course of action on social issues related to science and technology, taking into account human and environmental needs (113-13)

## Introduction

We live in an "artificial age". Our homes are filled with artificial light, artificial wood, artificial plants and artificial scents. We drink beverages and eat snacks sweetened with artificial sweeteners, colored with artificial colorants, and flavored with artificial flavorings. We play mini-golf on artificial grass. Some people even alter their appearance with artificial nails, colored contacts, false eye lashes, and artificial hair color. Each of these products was developed through the application of technology and problem solving to everyday life. In the area of medicine, this application has led to the development of artificial organs or parts.

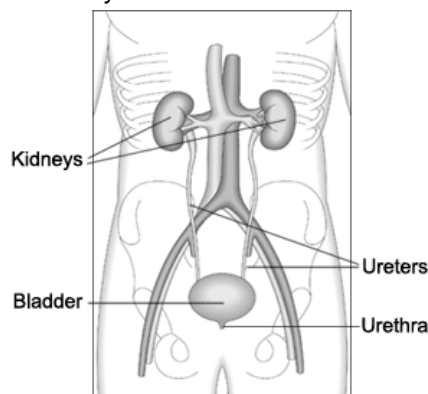
Organs are natural parts or structures in our body, such as our heart, lungs and kidneys, which are capable of performing some special function. The presence and proper functioning of these organs is essential to our life and well-being. If these organs become damaged or diseased we may experience poor health or even death. In some situations, the use of an artificial organ can assist or replace a damaged or diseased organ. This may improve an individual's quality of life and possibly their chance of survival.

A wide variety of artificial organs and parts are currently available for use or at various stages of development. This list includes the eye, ear (cochlear implants), heart,

kidney, larynx, liver, lung, pancreas, and skin. This module will focus on the artificial kidney as an example of artificial organ technology. The functions of the natural and artificial kidney will be investigated as well as the science behind them.

## What does your Kidney do?

Your kidneys are two-bean shaped organs, located on either side of your spine, just above the small of your back. As you will learn in this module, the kidneys are linked directly with the circulatory and excretory systems. The functions of these complex



organs are to clean your blood of toxins and regulate the amounts of other substances dissolved in blood.

The kidney:

- removes metabolic wastes like urea and uric acid from your blood. If not removed these wastes would accumulate and damage your body.

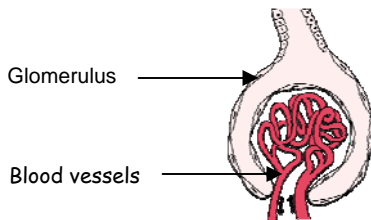
- removes substances such as drugs, pesticides, food additives and other toxic substances from your blood.
- keeps the concentrations of ions like potassium, calcium and sodium, and other substances in your blood at the correct levels.
- maintains the proper volume of water in your body.
- assists in maintaining your blood pH at the proper level.

## How does your kidney work?

Your entire blood volume gets cleaned 20-25 times a day. The actual cleaning occurs in tiny units inside your kidney called

**Nephron:** the functional unit of the kidney; it is responsible for the actual filtration and purification of the blood.

nephrons. Each kidney contains approximately 1 million nephrons. Blood containing wastes from the body enters the nephron through a knot of small blood vessels that

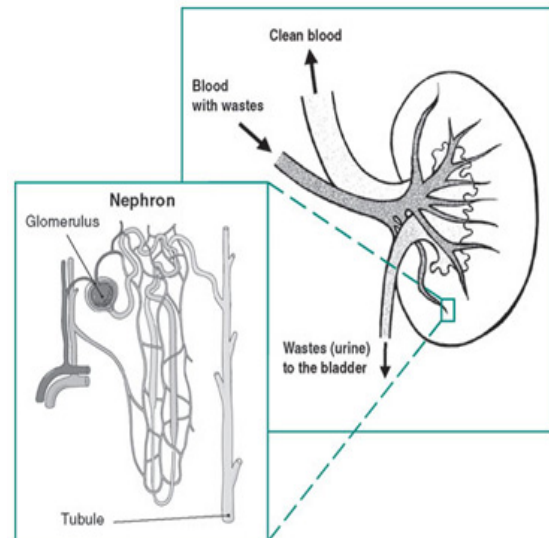


are surrounded by a structure called the glomerulus.

These blood vessels are under pressure and are against the wall of the glomerulus. The wall of the glomerulus is a semi-permeable membrane and acts as a filter. Certain substances are able to pass through, or permeate the membrane. These substances are referred to as the filtrate.

Other substances can not pass through the membrane and are filtered out. A good analogy would be straining cooked pasta through a colander. The colander functions like a semi-permeable membrane. It captures the cooked pasta but allows the water and dissolved substances to pass through as a filtrate.

In the nephron, when blood containing waste is forced against the wall of the glomerulus, blood plasma, wastes, water, ions like potassium, calcium and sodium,



**Nephron in relation to kidney.**

glucose and other small molecules are able to pass through the wall into the tubule.

Larger substances like red and white blood cells can not pass through the wall and remain in the blood. While the filtrate in the tubule contains wastes and unwanted substances it also contains substances that your body can still use.

**Blood plasma:** is the liquid in which the blood cells are suspended. It makes up about 55% of the total blood volume. Plasma is mainly water which has proteins, glucose, minerals and hormones dissolved in it.

The tubule of the nephron is surrounded by tiny blood vessels, called capillaries. By a process called diffusion, substances that your body can still use get reabsorbed. The filtrate within the tubule of the nephron contains water, ions, glucose and other useful small molecules at high concentrations. The filtered blood in the capillaries contains these useful substances at low concentrations. As a result, these useful substances in the tubule diffuse back into the capillaries. The amount of each substance that is reabsorbed is controlled to maintain the perfect concentrations in the blood stream. Excess material that is not reabsorbed remains in the tubule where it is swept away with wastes and other toxic

**Diffusion** occurs when there is a higher concentration of a dissolved substance on one side of a semi-permeable membrane than on the other. Particles of the dissolved substance will move from the more concentrated side across the membrane to the less concentrated side until the concentration on both sides is the same.

substances to form urine. Urine is stored in the bladder and is ultimately excreted from the body.

Through the processes of filtration and diffusion your kidney cleans your blood, controls its composition, and maintains an ideal concentration of substances in the blood.

## What is kidney failure?

If your kidneys become damaged or diseased they do not function as they normally would.

### Did you know?

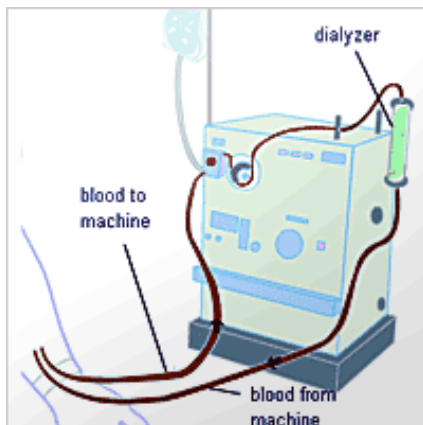
High blood pressure can damage the kidney by breaking the tiny arteries that feed the nephron. If these arteries break, the nephron is unable to perform its function. Untreated high blood pressure can result in the breaking of arteries in many nephrons. The greater the number of nephrons that become active, the less efficient the kidneys are in cleaning the blood, and kidney failure can result.

Wastes, other toxic substances, and water accumulate in your blood and the proper concentration of ions and other substances is not maintained. This inability of your kidneys to function properly is called kidney failure. Kidney failure is a serious health

concern which, if left untreated, may cause death within days or weeks.

## What is kidney dialysis?

If kidney function falls below 10 to 15 percent, the use of an artificial kidney to assist the damaged or diseased organ may be necessary. The process of using artificial technology to clean your blood is called kidney dialysis. Kidney dialysis performs the functions of a normal kidney by passing your blood through an artificial kidney, or dialyzer.



To get your blood into the dialysis machine, doctors perform minor surgery, usually to your arm, to make an access point into your blood stream. A needle is inserted into the access allowing your blood to travel outside your body into the dialysis machine. The artificial kidney, a component of the dialysis machine, contains two parts, one for your blood and one for a sterile washing fluid called the dialysate. The two fluids are separated by a thin, semi-permeable membrane. The membrane has tiny, microscopic pores that act as a filter in the same way it does in the nephron. Most blood components are able to permeate the membrane but larger blood cells and proteins are filtered out.

## How does the artificial kidney work?

Dialysis treatments are usually performed three times a week and takes about four hours to complete. During this four hour period, your blood and fresh dialysate are continuously flowing through the artificial kidney. As the two fluids flow on opposite sides of the semi-permeable membrane substances diffuse back and forth between them. The dialysate contains the ideal concentration of water, ions, glucose and other important substances found in blood. During dialysis, these substances will diffuse across the membrane from the more concentrated fluid to the less concentrated fluid until the concentration is the same in both fluids. The continuous use of fresh dialysate ensures that your blood achieves the proper concentration of these important substances.

The dialysate contains many of the important substances found in blood and does not contain urea, uric acid or other wastes. As a result, wastes that have accumulated in the blood will diffuse across the membrane into the dialysate. These wastes are then carried away by the flow of the dialysate and forms a substance similar to urine which is flushed away.

## Conclusion

The artificial kidney is an example of the current use of artificial organs in medical science. Researchers are trying to develop a wearable dialysis machine or “artificial kidney”. While this machine does not yet exist, recent advances in nanotechnology offer great potential to develop a small, wearable pack that contains tubes and membranes to filter a person’s blood.

For some patients the use of artificial organ technology provides temporary assistance while a disease or condition is being corrected. For others it is a bridge until an organ becomes available for transplantation. For some it is a long term medical solution

and the means by which they are able to continue to live a happy and fruitful life.

Whatever the use, artificial organ technology has the potential to improve quality of life and provide patients a greater chance of survival. As technology continues to improve, artificial organ technology improves as well. Perhaps one day every human organ will be able to be replaced with an artificial one. Until that day, we will still rely on transplants to provide the optimal treatment for many organ diseases and problems.

## Questions

1. List the functions of the kidney.
2. When is kidney dialysis needed?
3. What is a semi-permeable membrane?
4. List 3 filters found within your home and identify the filtrate for each.
5. Explain why substances diffuse across a semi-permeable membrane.
6. Describe how the artificial kidney mimics the function of a natural kidney.
7. You have eaten several bags of salty potato chips at one sitting. As a result, the concentration of sodium ions in your blood has increased. Explain how your body will restore the concentration of sodium ions to the correct level.
8. The kidney functions to maintain blood pH at the proper level. pH is a measure of how acidic or basic a substance is. Assume that the blood of an individual in kidney failure is too acidic. How could a dialysis machine ensure the proper pH of the blood is restored?
9. A prescription bottle reads Take 1 Tablet Three Times Daily. Given your understanding of kidney function, explain why it is necessary to take repeated doses.

## Activity – Diffusion from Inside a Balloon

**Materials:** latex balloon (Caution: beware of potential allergies)  
Eyedropper  
vanilla extract  
box with cover, large enough to contain the inflated balloon (e.g. shoe box)

### Procedure:

1. Using an eye dropper, drop one or two drops of vanilla extract into a latex balloon.
2. Inflate the balloon and tie off the end.
3. Place the balloon inside the box with the cover attached.
4. After ten minutes, partially lift the cover off the box and observe the odor.

Record observations and provide a possible explanation.

## **References and Further Sources of Information**

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