THEME 2

The organism at work

Topic 1: Regulation of the internal environment

Performance objectives

1.1 List the main organs and substances involved in homeostasis (control mechanism)
1.2 Describe the structure and functions of these organs: kidney and liver
1.3 Name some kidney diseases and explain their symptoms and effects
1.4 Name some liver diseases and briefly explain their symptoms and effects
1.5 Discuss the treatment for diseases of the kidney and liver.

Homeostasis

The internal environment of an organism needs to remain within limits, so that the complex interacting set of metabolic chemical reactions can take place. The word **homeostasis** is used to describe this process. Homeostasis is a property of any system that allows internal conditions to remain stable and relatively constant.

Homeostatic processes act at the level of the cell, the tissue, the organ and for the organism as a whole. The main homeostatic processes include:

- maintenance of body temperature – warm-blooded or endothermic animals, such as mammals and birds, maintain a constant body temperature. All other animals show wide temperature variation. In endothermic animals, as body temperature rises the body loses heat by panting or sweating. If the body temperature falls, there is increased metabolic action through shivering.
- regulation of the pH of the blood at 7.35
- regulation of blood glucose concentration – in mammals this takes place through the hormones insulin and glucagon. Humans maintain their glucose concentrations at a relatively constant level.
- the **kidneys** regulate the levels of water and electrolytes in the blood – you learnt about the function of the kidneys in SS2 in the Topic: Excretion.
- behaviours such as drinking in response to thirst are also part of homeostatic mechanisms because the animal is responding to a fall in the water content of the blood.

The kidneys

You learnt about the structure and function of the kidneys in detail in SS2 in the Topic: Excretion.

The kidneys maintain homeostasis by:

- regulating the water content of the body through the action of the hormone ADH (osmoregulation)
- controlling the pH of the blood
- removing various cellular wastes and substances that are in excess, for example salts, urea and uric acid.

The urinary system

The urinary system is made up of two kidneys, two ureters, the bladder and the urethra. The blood circulatory system is associated with the urinary system in the form of the renal artery and vein.

Figure 1.1 shows how the urinary system is arranged in humans. The basic structure is the same in all mammals.

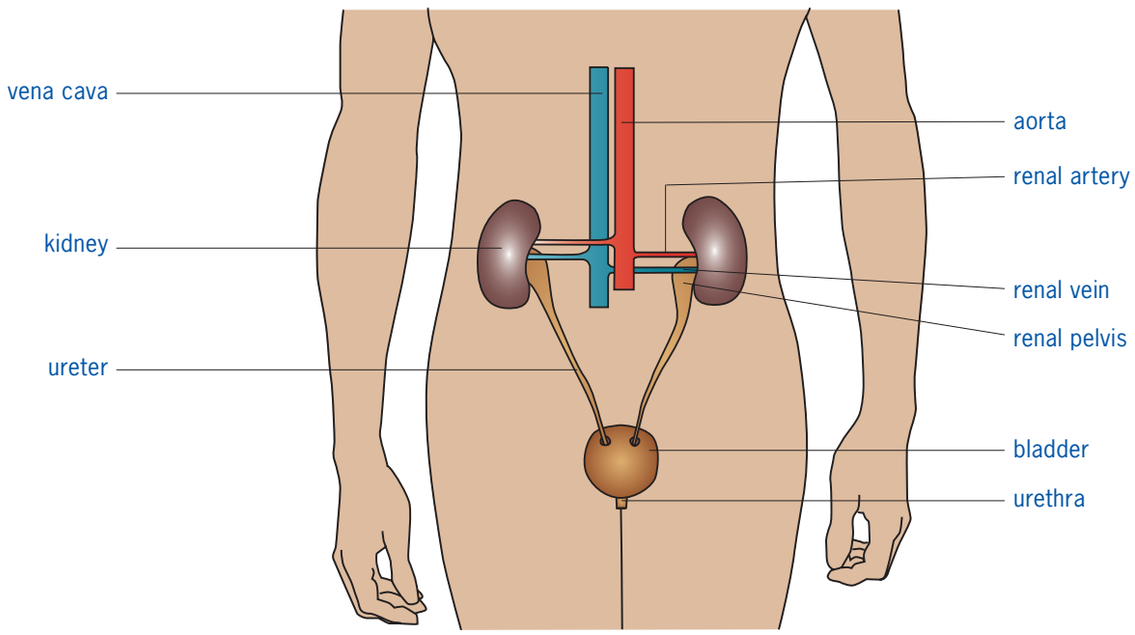

Figure 1.1 *The position of the kidneys and associated structures in the human body*

The nephron

The structural and functional unit of the kidney is the nephron. See Figure 1.2 for the structure of a nephron and its position in the kidney.

If you look at a section of a kidney through the microscope, you will see that it is made up of millions of tiny tubules. These are the nephrons. Afferent means bringing something towards a body part. Efferent means taking something away from a body part.

A nephron is made up of the:

- Malpighian body (also called a renal capsule)
- renal tubule.

The functioning of the kidney

The functioning of the kidney will be illustrated by studying the functioning of one nephron. Three processes are involved:

- glomerular filtration or ultrafiltration
- tubular reabsorption
- tubular secretion or excretion.

All three processes take place at the same time. They are separated in this text to make it easier to understand the functioning of the nephron. Figure 1.4 is a schematic diagram of how a nephron functions.

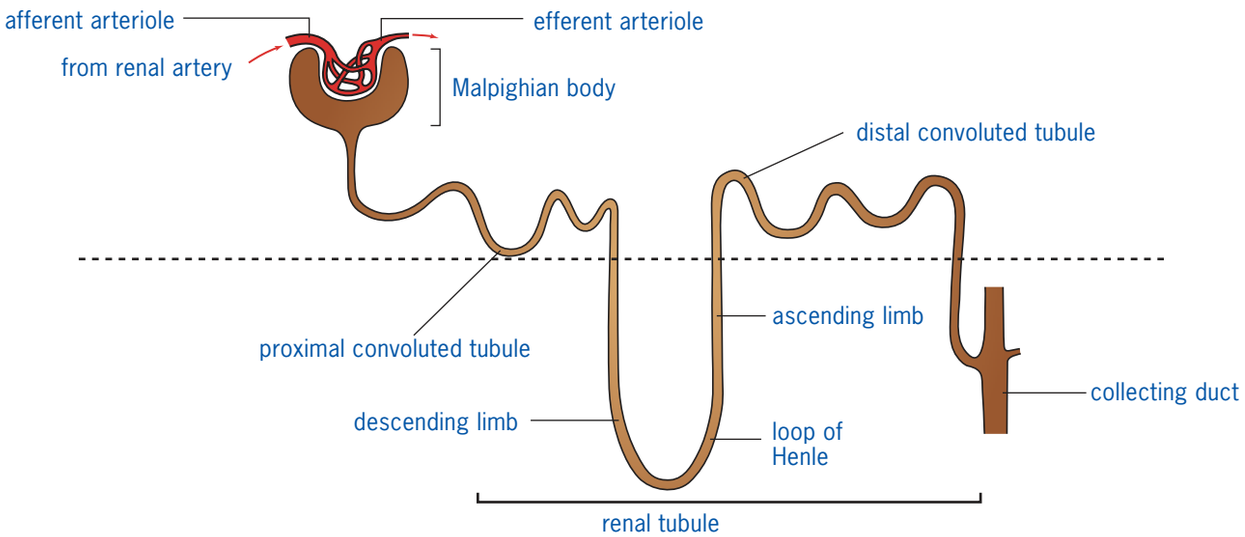

Figure 1.2 *The structure of a nephron (simplified)*

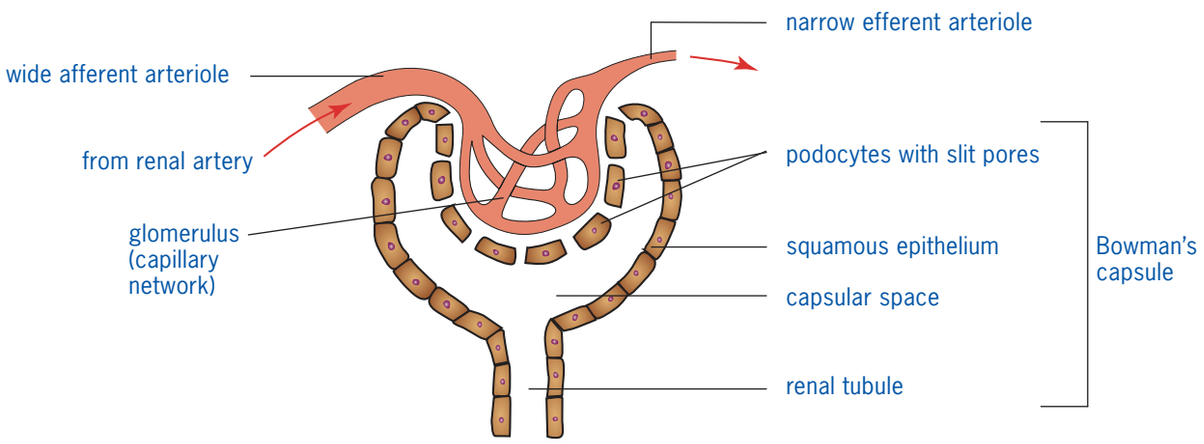

Figure 1.3 *The structure of a Malpighian body (simplified)*

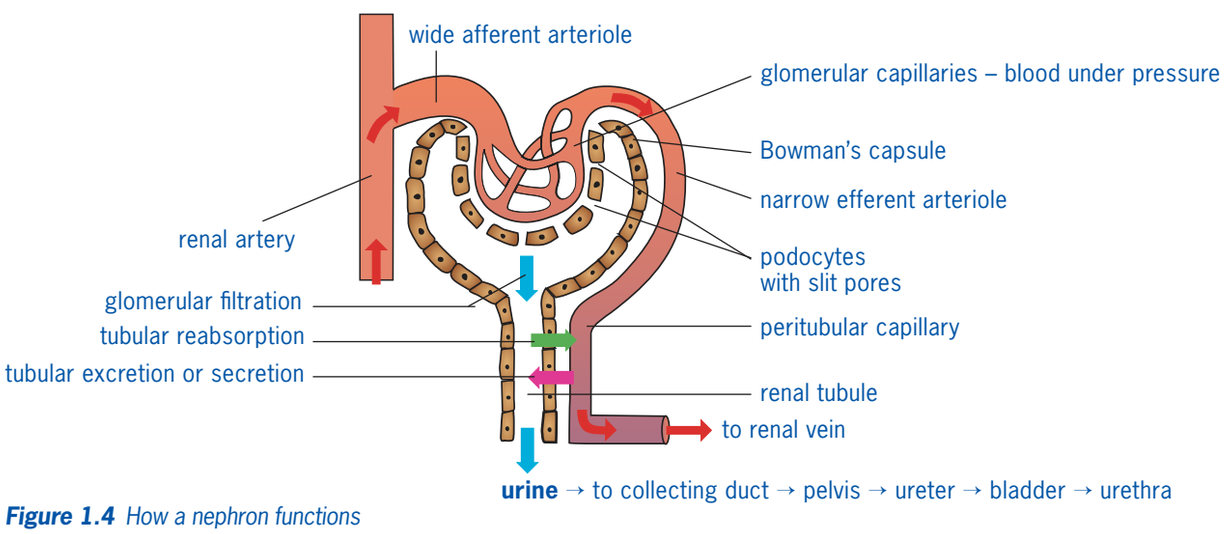

Figure 1.4 *How a nephron functions*

Glomerular filtration

Figure 1.5 is a diagram to show how glomerular filtration takes place.

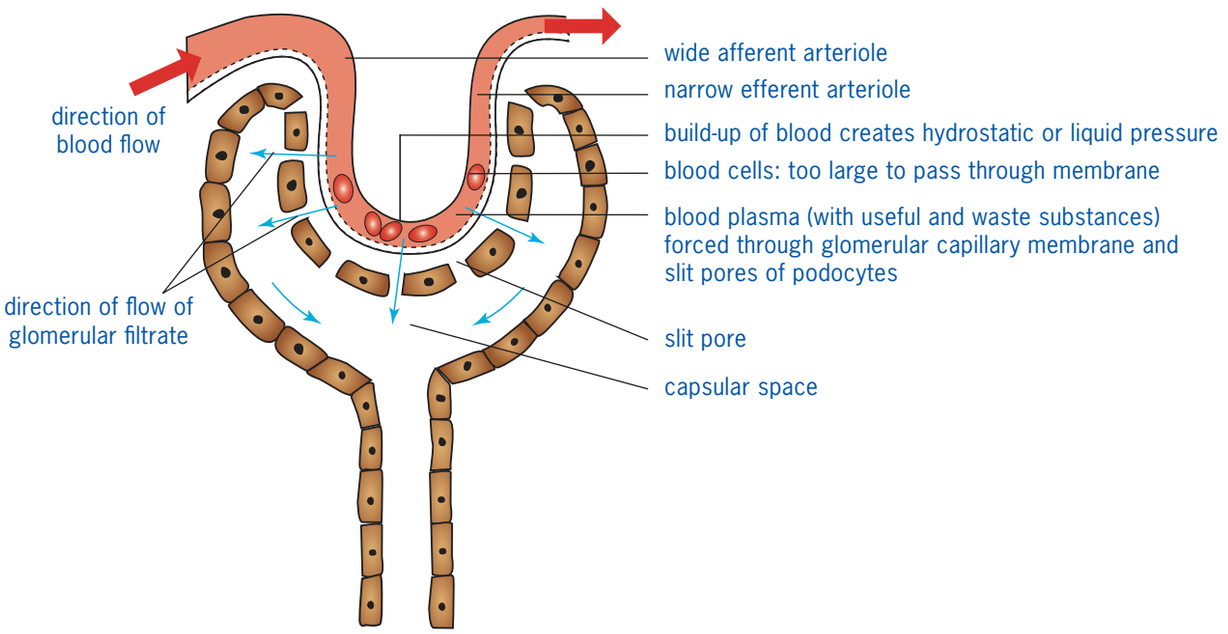

Figure 1.5 *A diagram showing glomerular filtration*

Blood is carried by the afferent arteriole to the glomerulus. Because the efferent arteriole is narrower than the afferent arteriole, blood in the glomerulus is under great hydrostatic or liquid pressure. Substances from the blood in the glomerulus are therefore filtered and forced out through the capillary walls, which have tiny pores, and through the tiny slit pores of the podocytes, into the cavity of the Bowman's capsule. Only those substances that are small enough to pass through the pores of the capillaries and slit pores of the podocytes pass into the capsular space. These include water, glucose, amino acids, glycerol, fatty acids, urea, uric acid, creatinine and salts. Blood cells and plasma proteins (for example fibrinogen, albumin, globulin) are too large to pass through the tiny pores of the blood capillaries and the slit pores of the podocytes and thus remain in the glomerulus.

The way that kidney structure is adapted to function

Kidney structure is suited to its function. We will take a look at the Malpighian body and the renal tubule in particular. The renal tubule is important in the homeostatic control of water and salts, which will be discussed later in the topic. The Malpighian body is adapted to suit its function as follows:

- The efferent vessel is narrower than the afferent vessel, so the blood in the glomerulus is under high hydrostatic pressure for filtration.
- Blood in the glomerulus is separated from the capsular space by the thin endothelial wall of the capillary and a single layer of podocytes, which act as an ultra-fine filter.
- The cup-shaped Bowman's capsule holds the first capillary network, so that the contents of the capillaries are able to easily filter through to the capsular space.

- The capillaries of the Bowman's capsule are made up of thin, flat squamous epithelium with pores. This allows only certain substances to pass through. Large particles cannot filter through.
- Podocytes in the inner wall of the Bowman's capsule have many slit pores between them, allowing for selective filtration.

The renal tubule is adapted to suit its function as follows:

- Tubules are convoluted, which means that they are very twisted. This creates a large surface area for maximum absorption and slows down the movement of the filtrate, allowing more time for absorption.
- Cuboidal cells lining the tubules have microvilli on their surface. This increases the surface area for absorption.
- The cells of the tubules contain numerous mitochondria. This supplies energy for active absorption.
- The second capillary network is in close contact with the tubules. This reduces the distance for reabsorption of useful substances into the capillary and excretion of waste substances into the tubules.
- The 'sodium pump' in the loop of Henle ensures that the medulla always has a high concentration of salts, so that water can be conserved according to the needs of the body.

Diseases of the kidney

Kidney stones

A kidney stone is a solid that forms in the kidneys from minerals in the diet. **Kidney stones** may contain calcium, uric acid or other solid compounds. The risk of developing kidney stones increases if you are dehydrated, or if you eat a lot of animal protein, sodium, refined sugars, fructose, high-fructose corn syrup, grapefruit juice, apple juice and cola. Some people are more likely to develop kidney stones than other people.

Kidney stones leave the body in the urine and many small stones are formed and passed in the urine without the affected person being aware of them. But if stones are large they can cause obstruction in different parts of the renal system. This causes intense pain, called renal colic, which may also cause nausea and vomiting.

Stones that are not causing symptoms can be left alone. But stones that cause obstruction and symptoms need to be removed, usually with surgery or with a technique that breaks the stones down into small fragments using ultrasound, which is called extracorporeal shock wave lithotripsy.

Kidney failure caused by overuse of painkillers

Kidney failure can be caused by taking painkillers every day over many years. This is called analgesic nephropathy. This is a chronic disease and the damage builds up slowly over time and eventually leads to irreversible kidney failure and the permanent need for dialysis or a kidney transplant.

This can occur with many different painkillers, but the common causes in Nigeria are Grandpa powders, paracetamol, and the anti-inflammatory drug, ibuprofen.

Athletes, particularly long-distance runners, who use painkillers or anti-inflammatories while running are at risk of acute kidney failure. They become dehydrated during the run and as a result the painkiller or anti-inflammatory damages the kidneys. These people sometimes need urgent dialysis and may have long-term damage to their kidneys.

Chronic kidney failure

Chronic kidney failure occurs when a person has had kidney disease for a long time and now the kidney is no longer able to function effectively.

This occurs in people who have undiagnosed or poorly treated high blood pressure and/or type 2 diabetes. Without regular kidney dialysis or a kidney transplant, the affected person will die from kidney failure. This is an increasingly common problem in Africa with the increase in diseases of lifestyle.

Kidney dialysis may also be necessary in acute kidney failure, which can occur after a person is badly injured or becomes very dehydrated.

Kidney dialysis is a process in which the ill person's entire blood volume is passed through a series of filters and returned to the body. This can be done using a kidney dialysis machine, which is done only in specialised hospital units. There are also simpler dialysis techniques that can be used in a person's home if he or she has access to a clean water supply. However, access to dialysis is usually limited in resource-poor countries unless the person has access to private health care.

Bilharzia

Bilharzia or schistosomiasis is a disease caused by parasitic flatworms that burrow into a person's skin when he or she swims in contaminated water. It is a serious disease in people who do not have proper sanitation facilities and affects about 20 million people in Nigeria, most of whom are children. The female flatworm lays her eggs in the small blood vessels in the wall of the urinary bladder. Each egg has a spike that cuts through the wall of the blood vessel. In this way numerous eggs enter the urine in the urinary bladder. One of the major symptoms of bilharzia is painful urination and a sign of the disease is blood in the urine. The eggs are discharged when the infected person urinates. The cycle continues when the larvae from the eggs infect a species of snail, which is the secondary host for the parasite.

Eggs or larvae can obstruct different parts of the urinary system and people who are not treated for the disease develop chronic kidney failure over many years. Bilharzia is treated with the drug praziquantel. This drug can reverse up to 90% of the damage caused by the parasite and a dose once a year will control and treat bilharzia.

The liver

The **liver** is a large organ that has a wide range of functions. Its functions include:

- detoxification of various products of metabolism
- protein synthesis
- production of substances that are necessary for digestion
- regulation of glycogen storage
- breakdown of red blood cells
- hormone production (which makes it a gland)
- breakdown of insulin and other hormones
- gluconeogenesis – the synthesis of glucose from certain amino acids, lactate or glycerol
- cholesterol and triglyceride synthesis
- detoxification of a wide range of substances.

The liver is responsible for about 500 different functions, usually in combination with other organs.

The liver's main function is in digestion, which you learnt about in SS2 in the Topic: Digestion. The liver produces bile, which is stored in the gall bladder. Bile helps to break down and emulsify fats.

The structure of the liver

The liver is the largest organ and the largest gland in the body. It is divided into four **lobes** that are of unequal size and shape. Figure 1.6 shows only two lobes. The other two lobes cannot be seen from the upper surface of the liver. It is connected to two large blood vessels,

the hepatic artery and the portal vein. The blood supply of the liver is called the hepatic portal system. The hepatic artery carries oxygen-rich blood from the aorta. The portal vein carries blood that is full of digested nutrients from the gastrointestinal tract and from the spleen and pancreas. These blood vessels subdivide into small capillaries that are called liver sinusoids, which then lead to a lobule. This is shown in Figure 1.7.

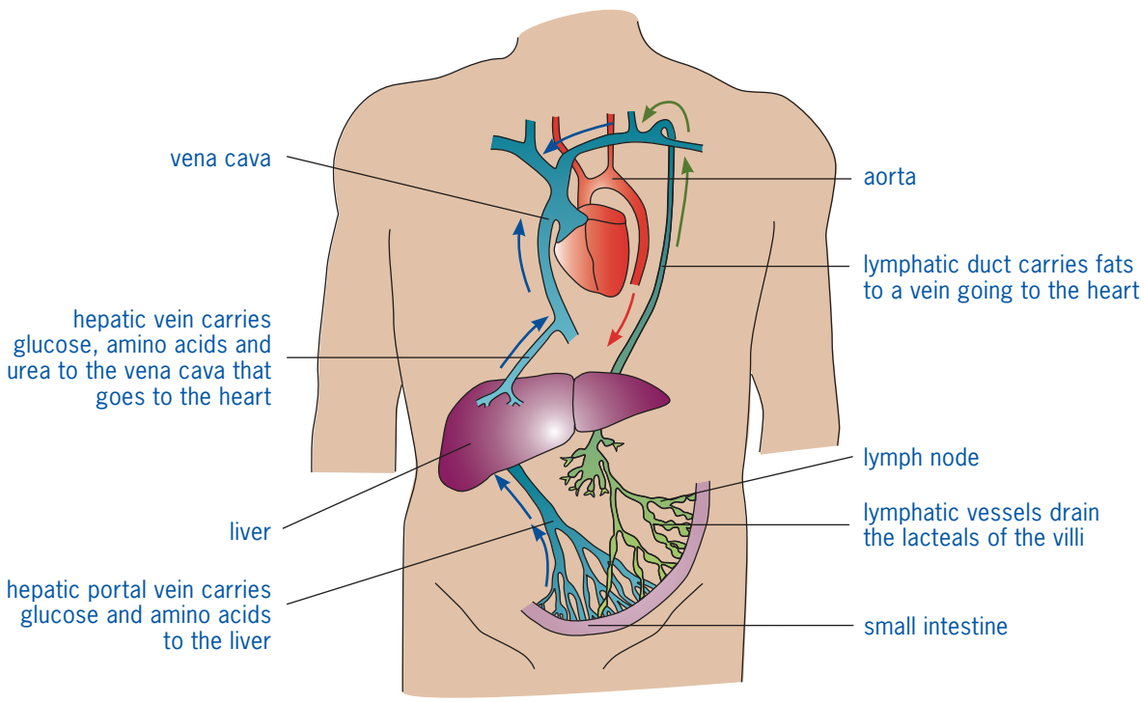

Figure 1.6 *The liver and its blood vessels in a human*

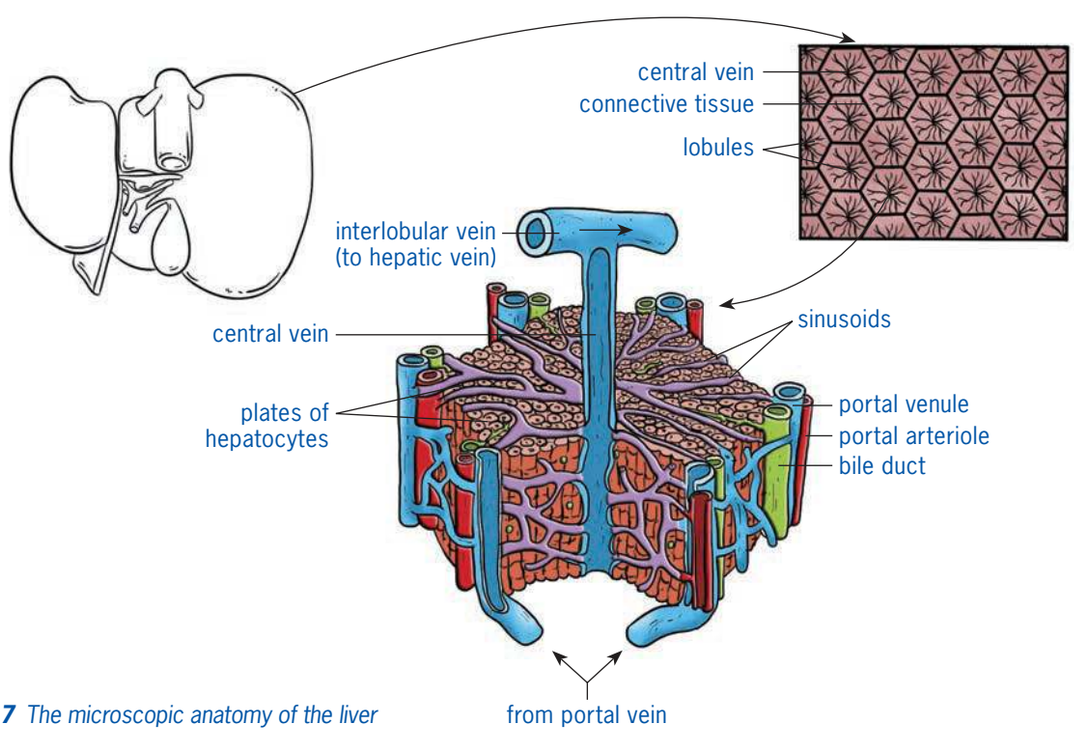

Figure 1.7 *The microscopic anatomy of the liver*

Activity 1.1 Dissection of the rat to show the liver and other organs

Work in groups

You will need:

- rat
- dissecting tray
- scalpel
- scissors
- forceps
- dissecting pins
- probe.

1. Open the abdomen and locate the liver – a dark organ just under the diaphragm. It has four lobes but you can only see two from the top – find the other two lobes. You should find the median lobe, the right and left lateral lobes, and the caudate lobe, which is a small lobe wrapped around the stomach.
2. Find the stomach, which is a curved organ lying just under the liver. You can see the oesophagus at the top of the stomach where it comes through the diaphragm. If you lift the stomach, you should find the pancreas – a knobbly, glandular organ, which lies behind the stomach.
3. Look for the spleen – the same colour as the liver and attached to the greater curvature of the stomach.

Draw and label what you observe.

Diseases of the liver

There are more than 100 types of liver disease. Some of the more common types are described here. All liver disease can cause a condition called jaundice where the skin and the whites of the eyes become yellow.

Fasciolosis

Fasciolosis, also called liver rot, is caused by two parasitic trematode worms, *Fasciola hepatica* (common liver fluke) and *Fasciola gigantica*. The parasitic worms have a life cycle that includes freshwater snails, sheep, goats, cattle and humans. Treatment is with the drug triclabendazole.

Hepatitis

Hepatitis is an inflammation of the liver caused by different viruses and also by some liver toxins such as alcohol. Viral hepatitis is divided into hepatitis A, B and C. Hepatitis A is carried in water where sanitation is poor. Hepatitis B and C can be transmitted in blood and to a baby during the birth process. There are anti-viral drugs that can be used to treat hepatitis B and C, but treatment is often difficult. Hepatitis A usually gets better on its own.

Alcoholic liver disease

Alcohol is toxic to the liver in excess and causes **fatty liver disease**, alcoholic hepatitis and **cirrhosis**. Cirrhosis is late scarring of the liver tissue, which prevents the liver from functioning correctly. The treatment is prevention – not taking alcohol in excess over long periods of time.

Liver cancer

Liver cancer that originates in the liver is called primary liver cancer. Many cancers in the liver are secondary disease from cancers in other parts of the body.

Treating liver disease

The liver is the only internal organ that is able to regenerate lost tissue. However, this regeneration does not fully restore the function of the liver and where there is a lot of damage the only treatment is liver transplantation.

Summary

- Homeostasis is a property of any system that allows internal conditions to remain stable and relatively constant.
- The kidneys maintain homeostasis by: regulating the water content of the body through the action of the hormone ADH (osmoregulation), controlling the pH of the blood, and removing various cellular wastes and substances that are in excess, for example salts, urea and uric acid.
- The liver is a large organ that is also a gland. It has many functions and is very important in detoxifying substances in the body.

KEY WORDS

Do you know the meanings of these terms? If not, look them up in the Glossary at the back of the book.

bilharzia	kidney
cirrhosis	kidney failure
fatty liver disease	kidney stones
hepatitis	liver
homeostasis	lobes of liver

How are you doing?

Use the Revision questions to check if there is anything you do not understand. Ask your teacher to explain.

Revision questions

1. What is homeostasis?
2. Briefly describe the main homeostatic processes in an organism.
3. How do the kidneys maintain homeostasis?
4. State some of the functions of the liver.
5. Name two diseases of the kidney and liver.

Topic 2: The endocrine system

Performance objectives

2.1 Describe the endocrine system
2.2 List some endocrine glands, their positions in the body and their functions
2.3 Describe the role that hormones play in homeostasis in the body
2.4 Describe where the glands are and which hormones they produce
2.5 Describe the function of these hormones
2.6 State the effect of over-production and under-production of these hormones.

Endocrine glands and hormones

The **endocrine system** is made up of **endocrine glands**, which produce **hormones**. Endocrine glands release hormones directly into the blood supply, from where they are transported to what are called target organs. The hormones have specific effects.

Hormones are organic chemical substances. They are made up of signalling molecules.

Hormones are used to communicate between organs and tissues to regulate physiological and behavioural activities.

Examples are digestion, metabolism, respiration, sensory perception, sleep, lactation, growth and development, and reproduction.

Figure 2.1 shows the major endocrine glands in the body and where they are situated.

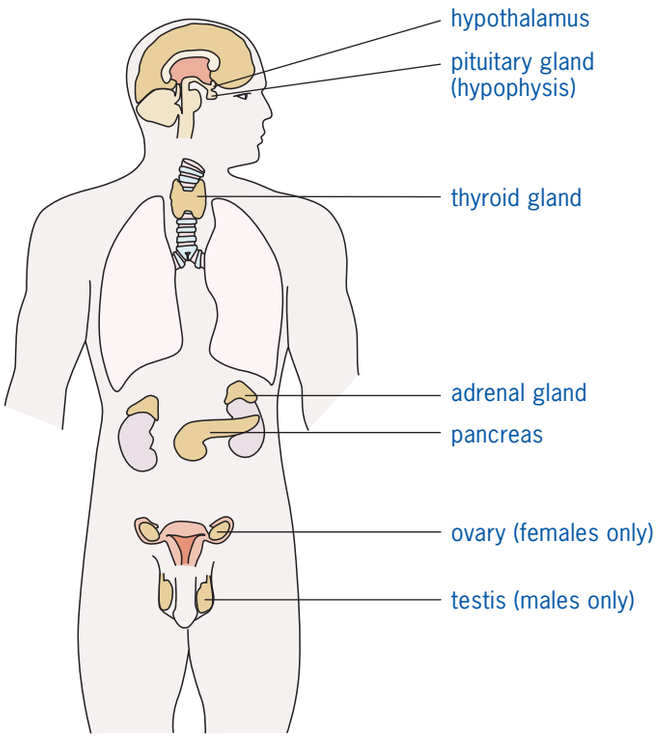

Figure 2.1 *The major endocrine glands in the human body*