Chapter 10
Water balance

Unit
1B

Unit content

Body systems
Organs within systems are organised for efficient functioning and interaction.

Systems:
- principal organs within the main body systems
- structural layout of at least two systems related to efficient functioning
- structure and function at cellular level related to tissue and organ levels
- interactions between systems.

Cells, metabolism and regulation
The body detects and responds to changes in its internal environment that are outside its tolerance limits. Dysfunctions are caused when tolerance limits are exceeded.

Tolerance limits:
- conditions resulting from exceeding tolerance limits *e.g. dehydration, water intoxication*
- individual difference related to tolerance limits *e.g. water*.

Figure 10.1 Drinking replaces water that is lost from the body

Do you drink less in winter than in summer?
Why does playing sport or eating lots of salty food make you thirsty?
Why do you produce more urine in cold weather than in hot weather?

The answer to all of these questions is that the fluids in the body are being kept at a constant concentration.

The cells of our bodies function best if their surrounding environment is kept constant at a level where they work efficiently. In Chapter 9 we discussed how body temperature was kept constant. This chapter discusses why there is a need to regulate the composition of body fluids and describes how the regulation is achieved. **Regulation** implies the adjustment of something so that there is little variation. The composition of the fluids in the body is regulated and the concentration of substances in our bodies normally stays fairly constant. This regulation is all a part of **homeostasis**—maintaining a constant internal environment.

The importance of regulating body fluids

Water makes up around 55% to 70% (by weight) of the human body. The water, together with important dissolved substances, forms the various fluids of the body. Fluid contained inside the cells is called **intracellular fluid**. Fluid outside the cells is **extracellular fluid**. The extracellular fluid is found in two places. Between the cells there are microscopic spaces filled with fluid, known as **intercellular fluid**. The second extracellular fluid is the fluid in the blood vessels, the blood **plasma** (see Fig. 10.2 and Table 10.1).

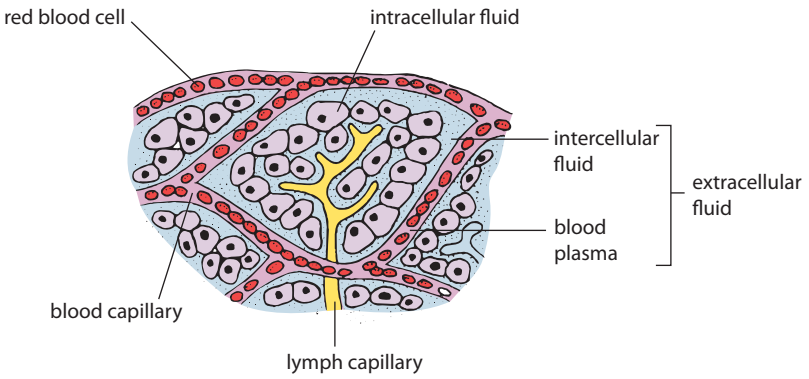

Figure 10.2 The body fluids

Table 10.1 Proportions of water in the various body fluids

Intracellular fluid	⅔ of total body water
Extracellular fluid	⅓ of total body water
Plasma	¼ of extracellular fluid
Intercellular fluid	¾ of extracellular fluid

The body fluids need to be constantly regulated to ensure the survival of the cells. Substances used by the cells, such as oxygen and glucose for respiration, must be continually replaced. At the same time, the chemical activity within the cell produces wastes. These wastes must be removed because if they accumulate the cells may die. The fluid surrounding the cells, the intercellular fluid, is important because cells get the things they need from this fluid. At the same time cell wastes are passed into the intercellular fluid.

The concentration of body fluids depends on the amount of water in the fluid. To keep the concentration of body fluids constant, the amount of water taken into the body must balance the amount of water that is lost.

Water intake

When you feel thirsty, you drink. Drinking replaces water that has been lost and returns the concentration of body fluids to the normal level.

In the hypothalamus of the brain (see Fig. 8.5 on page 92) there is a thirst centre. The **thirst centre** detects changes in the concentration of body fluids. If the concentration of body fluids increases, the thirst centre detects the change and makes you feel thirsty. You drink and the concentration of body fluids returns to normal.

Drinking fluids is not the only way water is taken into the body. A considerable amount of water is contained in the foods we eat. Some fruits, for example, contain a lot of water. Think about the last time you ate a piece of watermelon (see Fig. 10.3). It contains so much water that it is hard to stop some of the juice from trickling down your face!

Figure 10.3 Some water is taken into the body through our food

Food also supplies water in another way. Remember the process of cellular respiration that was discussed in Chapter 2. Cellular respiration provides energy by breaking down glucose from food and producing carbon dioxide and water.

Glucose + Oxygen ⟶ Carbon dioxide + **Water**

The cells can use the water produced, but if there is already too much in the body fluids it will be excreted.

Water loss

Most of the water lost by the body is lost as **urine**. Urine contains nitrogen compounds such as urea. These compounds have to be dissolved in water; therefore some water *must* be lost from the body as urine in order to get rid of these wastes. The kidneys are able to regulate the concentration of urine. In this way they can regulate the amount of water lost from the body.

Sweating is another important way in which water is lost from the body. The amount of water loss in sweat will depend on the environment. In hot weather more water will be lost as sweat than in cold weather.

Although water loss from the kidneys and from sweating are the main ways water is lost from the body, small amounts are also lost when we breathe out. To function efficiently, the inner surface of the alveoli (see Chapter 5) must be kept moist. The moist surface helps the exchange of gases. However, some of the moisture evaporates and is lost in the air we breathe out (see Fig. 10.4). In a similar way, small amounts of water are lost with the faeces. For material to move through the alimentary canal, it must contain some water to keep it soft.

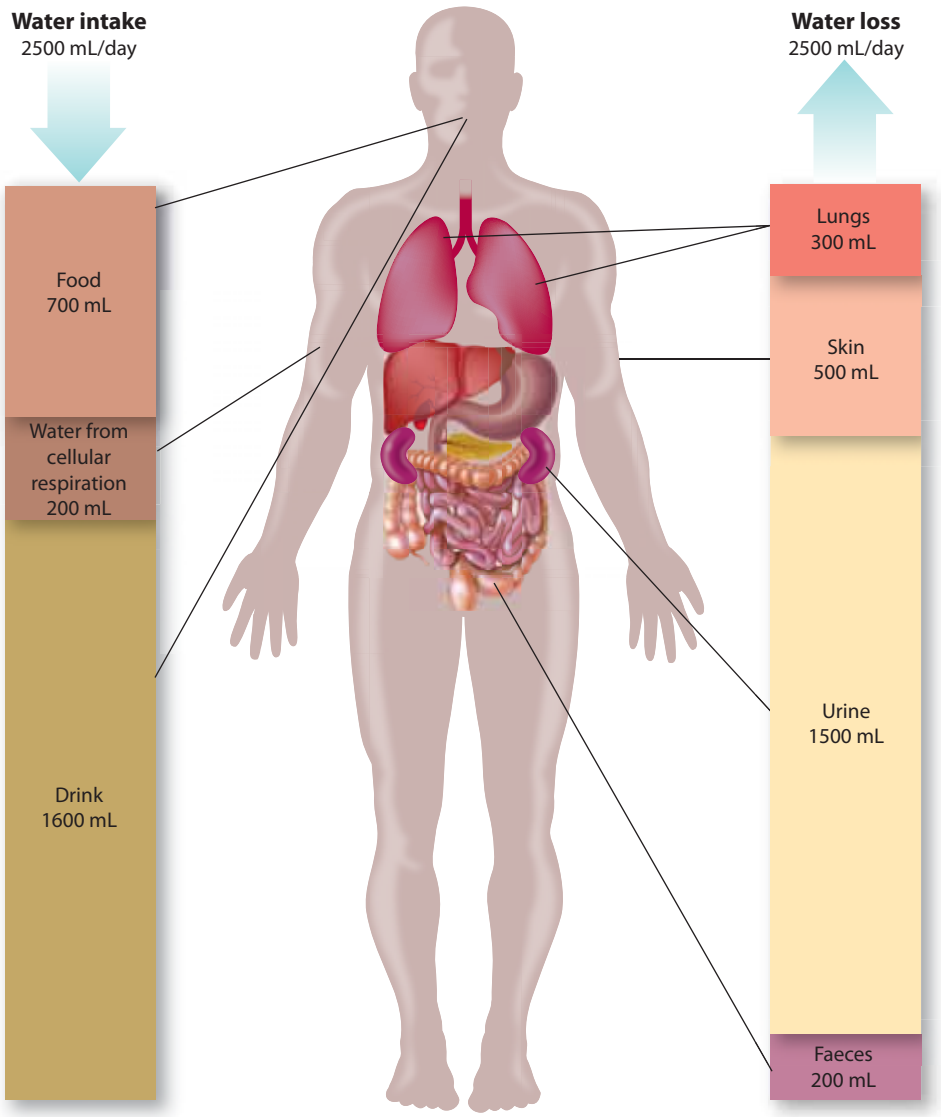

Figure 10.4 Daily fluid intake and loss

Regulating body fluids

When the body is losing water, secretion of saliva is reduced and the mouth feels dry. At the same time the amount of water in the blood decreases and the blood plasma becomes more concentrated. The more concentrated blood flowing through the hypothalamus stimulates the thirst centre. The dry mouth and stimulation of the thirst centre make the person feel thirsty. The person responds to the thirst stimulus by drinking and the mouth no longer feels dry.

As the fluid is swallowed it passes down the alimentary canal and is absorbed into the blood capillaries through the walls of the stomach and intestines. In this way, drinking restores the concentration of the blood to its normal level, and the sense of thirst goes away (see Fig. 10.5).

The hypothalamus helps to regulate water intake through the thirst reflex but it also regulates water loss by controlling the volume of urine produced. Have you noticed how, in hot weather, you produce less urine than in cold weather? Also, in hot weather the urine is darker in colour (more concentrated) than in cold weather. These changes in urine volume and concentration are brought about by the hypothalamus.

The kidneys filter water from the blood but nearly all of it is reabsorbed into the blood from the kidney tubules. (See Fig. 5.18 on page 60). Part of this reabsorption is controlled by a hormone known as **antidiuretic hormone (ADH)**. Antidiuretic hormone is produced by the hypothalamus and released into the blood from the pituitary gland (the location of the pituitary gland is shown in Fig. 8.20 on p. 102). ADH controls the amount of water that can pass through the walls of the kidney tubules. When the concentration of ADH in the blood is high, the tubules absorb more water into the surrounding blood capillaries. This increased absorption of water from the fluid within the tubules increases the concentration of the urine that remains.

On the other hand, when the concentration of ADH in the blood is low, the tubules do not absorb as much water. The surrounding blood capillaries gain little water and the urine within the tubules remains fairly dilute. This action of the antidiuretic hormone in controlling water balance is an example of homeostasis (see Fig. 10.6). Control of body temperature, discussed in the previous chapter, is another example. In both cases, the body is balancing what is gained with what is lost (see Fig. 9.2 on page 109).

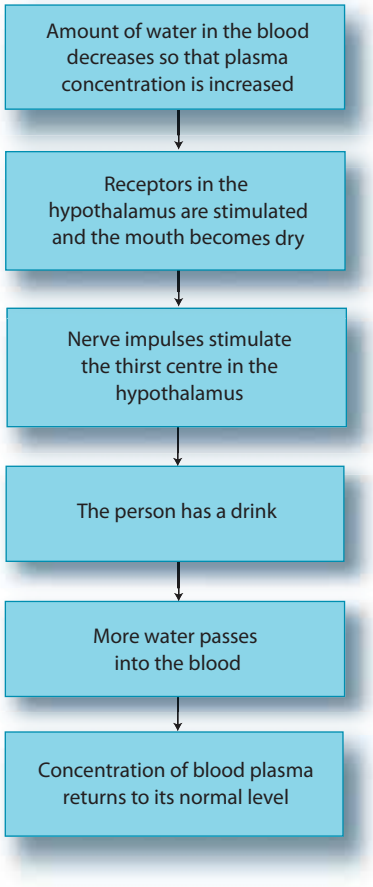

Figure 10.5 Regulation of drinking by the thirst mechanism

Water is continually being lost from the body in sweat, urine, faeces and exhaled breath. At times of strenuous activity this water loss can be quite high. As water is lost, the blood becomes more concentrated because it contains less water. As a result, the receptors in the hypothalamus are stimulated. The hypothalamus is then able to send messages to the thirst centre to activate drinking behaviour, and to the pituitary to release ADH. Both of these mechanisms increase the amount of water in the plasma of the blood.

Exceeding tolerance limits

Dehydration

Dehydration occurs when water loss is greater than water intake. The simplest way this can happen is by not drinking enough water. People lost or stranded in the desert, or adrift at sea, frequently have little water to drink, and quickly become dehydrated. Dehydration results in the amount of water in all the body fluids decreasing. This means there is less water in the blood, so the organs of the body receive less water. When the brain does not receive enough water, it can no longer function normally. Similarly, as other cells begin to dry out, their functioning is affected.

To find out about dehydration in sport go to http://au.health.yahoo.com/041101/25/1uwq.html

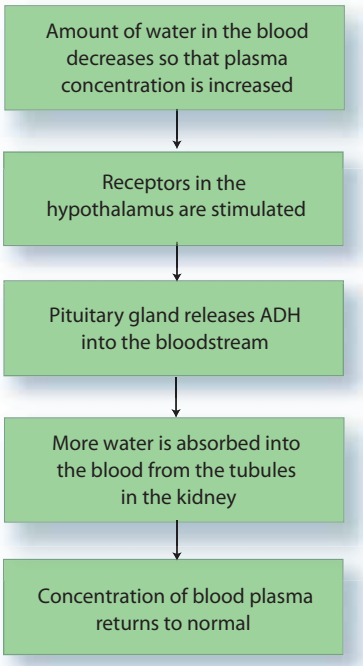

Figure 10.6 Control of water balance by ADH

People suffering from diarrhoea, especially very young children, are often at risk of becoming dehydrated. Elderly people, or those confined to bed, are frequently dependent on others to give them water, and may become dehydrated. Profuse sweating, and the overuse of drugs that cause an increase in urine output, can also result in dehydration.

Symptoms of dehydration usually become noticeable after a person has lost about 2% of the normal water volume in the body. The symptoms include severe thirst, headaches, low blood pressure and dizziness. If the dehydration is untreated, delirium, unconsciousness and death will occur.

Dehydration is best treated by taking in water that has a small amount of salt and glucose in it. The salt and glucose helps to replace that lost. Alcohol should not be drunk, as this would make the situation worse. In severe cases of dehydration, where fainting and unconsciousness occur, emergency treatment is necessary. Fluids with the correct balance of dissolved substances are given either by mouth or through a needle into a vein.

Figure 10.7 Athletes need to replace water lost through activity

Water intoxication

Having too much fluid in the body is far less common than having too little. The kidneys are very good at removing excess fluid by increasing the output of urine. However, if too much water is in the body, **water intoxication** may result. Water intoxication (sometimes called water poisoning) occurs if there is a high intake of water when the amount of salt in the body is low. This can happen when a person has lost a lot of water and salt through sweating, and replaces it with only plain water. The water dilutes the body fluids, and the cells tend to take in extra water by osmosis. This results in the cells swelling from the extra water they contain. As they become swollen, the intake of oxygen and the removal of wastes are affected. When this occurs in the cells of the brain, water intoxication is the result. In addition, many other cells in the body may be affected. The cell membranes may swell so much that they rupture, killing the cells.

The initial symptom for water intoxication is usually light-headedness, sometimes accompanied by vomiting and headache. A person with mild intoxication may require only fluid restriction. In more severe cases, drugs that increase urination may be given along with saline to correct the salt–water balance of the body fluids.

Read about cases of water intoxication in Australia at http://www.abc.net.au/dimensions/dimensions_health/Transcripts/s871112.htm

Craig Barrett, an athlete from New Zealand, was leading in the 50 km walk at the 1998 Commonwealth Games when he collapsed during the last kilometre of the race. Barrett had been sweating profusely and drinking a lot of water. He should have been consuming liquids containing dissolved substances to replace the salts lost in sweat. Fortunately Barrett was successfully treated.

Infants

Babies and young infants, especially up to the age of four, are not able to regulate water balance in the way that older children and adults can. They are prone to dehydration because they are not able to get themselves a drink to compensate for water lost through perspiration.

Other factors also make water regulation difficult in infants. The body of a newborn baby has a greater water content than older infants and children. This is because over half of the total body water of the newborn is contained in the extracellular fluid. In addition, a baby has a surface area to volume ratio that is two to three times greater than that of an older child or adult. Both these factors mean that the young infant is subject to greater and more rapid water loss, and poorer adjustment to a lack of intake of fluids. This puts infants in danger of exceeding tolerance limits if placed in a situation where they may lose large amounts of water.

Tragedies have occurred when young children have been left unattended in vehicles. It doesn't take long for distress and dehydration to occur. On a typical Australian summer's day, the temperature inside a vehicle can rise to 30 or 40°C higher than that outside within fifteen minutes. Leaving the windows open a few centimetres doesn't help as it only causes a slight drop in temperature. For these reasons it is against the law in most Australian states to leave young children unattended in a vehicle.

Working scientifically

Activity 10.1 Effect of drinking on urine production

This is an activity that you can do at home.

You will need

Measuring cylinder or some other container for measuring volume of liquid; clock or watch; graph paper

What to do

1. Empty your bladder by urinating as completely as possible.
2. After fifteen minutes, urinate again, this time collecting the urine in a measuring cylinder. Record the volume of urine.
3. Drink a litre of water.
4. Fifteen minutes after drinking the water, urinate again, measure the volume of urine and record the result.
5. Repeat step 4 every fifteen minutes for ninety minutes.
6. Think about the following question and then plot your results on graph paper (see Chapter 1, pages 8–9 for instructions on plotting graphs).

- Which variable should be placed on the horizontal axis and which on the vertical axis?
- What labels will you place on each axis?
- What scale will you use so that all of your data will fit on the graph?
- What title should your graph have?

Studying your results

1. What was your rate of urine production, in mL per hour, before drinking the litre of water?
2. What was your rate of urine production, in mL per hour, after drinking the litre of water?
3. What proportion of the litre of water that you drank was excreted in ninety minutes?
4. Draw a flow chart to show the sequence of events from the time you drank the water to the time your kidneys began to increase water excretion.
5. Explain why the changes in urine production were necessary to maintain a constant level of water in the body.

Activity 10.2 Healthy drinks?

We all know that our bodies need water to remain healthy. Many people think they are providing adequate fluid balance by drinking fluids that contain other substances in addition to water: such as soft drinks, sport drinks, energy drinks, vitamin waters, juice, milk, tea, coffee and alcoholic beverages. However, what do the scientists say? These popular drinks may be enjoyable but are they providing adequate body hydration for health and vitality?

This activity will give you the opportunity to research the effects of various drinks on the water content of the body. Use the above list as a guide on where to start. Once you have gathered your information, write a report on the way our drinking habits can affect the water content of our bodies. Try to follow the format given in Chapter 1. In writing your report, address such questions as:

- Which is best for maintaining the water balance of the body: plain water or drinks containing dissolved substances?
- Do some drinks actually contribute to dehydration?
- What are some of the processes that occur in the body to cause fluid imbalance?
- Are there other consequences of consuming some of these fluids?

REVIEW QUESTIONS

1. What is homeostasis? Use water balance to explain your answer.
2. Distinguish between:
   (a) intracellular fluid and extracellular fluid
   (b) intercellular fluid and plasma
3. **(a)** Where is the thirst centre located?
   (b) What is the role of the thirst centre in maintaining water balance?
4. What are the main ways water is lost from the body? Which mechanisms provide the greatest loss in **(a)** cool weather and **(b)** hot weather?
5. Describe the role of ADH in maintaining water balance in the body.

6. What is dehydration and how does it affect the functioning of cells?
7. Explain how water intoxication may lead to the death of a person.
8. What physical attributes of young infants make it difficult for them to maintain their water balance within tolerance limits?

APPLY YOUR KNOWLEDGE

1. To maintain a constant level of body fluids, there needs to be a balance between water intake and water loss. Discuss the ways by which the body gains and loses water, and how a balance is maintained.
2. Describe the relationships that exist between the various extracellular fluids and the intracellular fluid.
3. During strenuous exercise the body could become dehydrated. Discuss the ways the body loses water during exercise and the ways it tries to compensate for this loss.
4. A person lost in the desert would suffer extreme dehydration. The thirst receptors would try and initiate drinking behaviour, but the lack of water would not allow this to happen. How would the body conserve water while still getting rid of wastes?
5. As part of an initiation ceremony for a club at an American university, a 21-year-old student was forced to drink an excessive amount of water while doing physical activity in a very cold basement. He collapsed and died of water intoxication. Describe how the excessive water intake would have led to his death.
6. The most efficient way for the body to get water is for a person to drink it. It is recommended that an adult drink eight to ten 250 mL glasses of water a day. Athletes and active teenagers should drink at least ten to twelve glasses of water daily. However, many foods and beverages contain water, which can make up part of this daily intake. Find out how much water is contained in a variety of fresh fruits and vegetables, canned fruits and vegetables, and milk. Calculate how much water you are taking in with the food you eat. How would this affect the amount of water you drink?
7. **(a)** People lost at sea without fresh water have sometimes tried drinking sea water. Would this be an effective way of replacing water loss? Explain.
   (b) People lost in the desert without water have sometimes tried drinking their urine. Would this be an effective way of replacing water loss? Explain.
8. In hot weather we tend to produce less urine and it is often dark in colour. In cold weather we tend to urinate more frequently and the urine is light in colour. Explain the reasons for these differences in urine volume and colour.
9. Nearly every summer, a young infant dies from dehydration in a car somewhere in Australia. Write a media release that you believe should be published to alert parents to the dangers of leaving children unattended in a car.