Ecosystem
Respiration *and* Photosynthesis

Ideas you have met before

Cells

One of the largest of the cell's organelles is the mitochondrion.

Energy is released in the mitochondrion.

Plants

Green plants need water and nutrients from the soil in order to grow. They make food in their leaves by photosynthesis using light energy.

In this chapter you will find out

Aerobic respiration

- Aerobic respiration uses glucose and oxygen to release energy.
- The energy released by respiration is needed for muscles to contract.
- Stamina sports rely mainly on aerobic respiration.

Anaerobic respiration

- Anaerobic respiration occurs when you do not have enough oxygen for aerobic respiration.
- Anaerobic respiration does not release as much energy as aerobic respiration.
- Brewing and baking are applications of anaerobic respiration (fermentation).

Photosynthesis

- Plants have adaptations that allow them to survive and grow, for example, stomata in the leaves.
- Plants have a network of vessels that transport water and minerals to their leaves and flowers.
- Healthy plants need certain essential minerals. Without these minerals they show symptoms of mineral deficiency.
- The amount of photosynthesis that takes place in a plant is affected by various factors, including the levels of carbon dioxide, light, water and temperature.

Understanding aerobic respiration

We are learning how to:

- Recall the equation for respiration and describe what it shows.
- Explain the importance of respiration.
- Describe an application of respiration in building molecules.

Your muscles need energy to contract and move bones. The food that you eat contains energy. But cells need to carry out a reaction to release this energy. This reaction takes place inside all your cells all the time, without you even thinking about it.

FIGURE 2.9.1a: You need energy to move.

How do you get energy?

You use **energy** in many ways, for example:

- to contract your muscles so that you can move
- to keep your body temperature at a suitable level and constant
- to grow.

You need to obtain this energy from your food. **Respiration** is the chemical reaction that releases energy from food that you have eaten.

Some of your food is digested in the intestines to convert it to **glucose**. The glucose travels in the bloodstream to all the cells of your body. Respiration takes place in the cells to release energy from the glucose.

FIGURE 2.9.1b: Glucose is a type of sugar.

1. State three ways in which you use energy.
2. From which food substance is energy released during respiration?
3. Suggest why you need energy even when you are asleep.

The respiration equation

Respiration is a series of reactions that takes place in the cells of animals and plants. Overall, the reaction can be shown by the equation:

glucose + oxygen → carbon dioxide + water (+ energy)

'Energy' is in brackets because it is not a substance.

This type of respiration, where oxygen is used, is known as **aerobic respiration**. Oxygen (from breathing) is carried from the lungs to all the cells of the body in the blood.

The waste products of respiration are carbon dioxide and water. These are taken away from the cells by the blood and breathed out from the lungs.

4. Explain what is meant by 'aerobic'.
5. Suggest why the circulatory system is so important for respiration.
6. Explain what the respiration equation tells us.

FIGURE 2.9.1c: Why is respiration sometimes compared with burning?

Building molecules

Building molecules requires energy from respiration. In order to grow bigger and to repair tissues, you need protein. Protein is made of complex molecules made of lots of smaller molecules, amino acids, joined together. When you eat protein, it is broken down into amino acids during digestion. Inside your body, you rebuild protein by joining amino acids back together. This process needs energy and that energy comes from respiration.

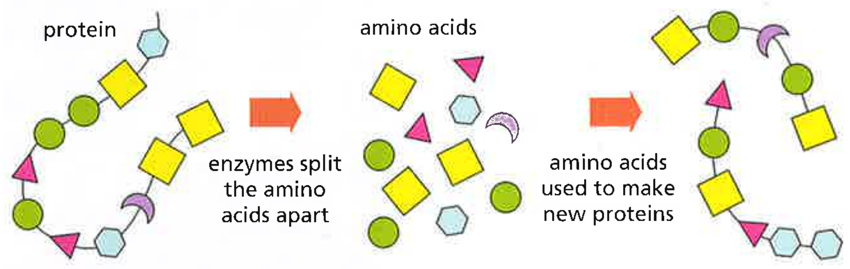

FIGURE 2.9.1d: Amino acids join to make proteins.

Plant cells have a strong cell wall made from cellulose. Plants make cellulose by joining glucose molecules together. The energy to do this comes from respiration.

7. Describe the purpose of cellulose in plants.
8. Suggest why bodybuilders eat foods high in protein.
9. Suggest how your body could make different proteins.

Did you know…?

Any excess energy that you do not need from respiration is stored as fats. If you do not use the energy stored in these fats, they stay in your body.

Know this vocabulary

energy
respiration
glucose
aerobic respiration

Exploring respiration in sport

We are learning how to:

- Describe what is meant by anaerobic respiration.
- Explain why some sports involve more aerobic or more anaerobic respiration.
- Explain what is meant by oxygen debt.

When athletes need to sprint, they cannot get enough oxygen to respire in the usual way. They need to work without oxygen for a short time, but also must release the energy that allows them to run. The body has mechanisms to manage without oxygen but there are consequences.

FIGURE 2.9.2a: When sprinting, the body is respiring without oxygen.

Respiration in sport

As sports have become more competitive and lucrative, sport science has emerged to help sportspeople to understand how their bodies work. When you exercise steadily, you gain enough oxygen to carry out aerobic respiration. So when jogging or swimming over a long distance, you respire in the normal way. However, when you exercise in short, energetic bursts the energy needed outweighs the oxygen that you can take in and you have to respire without oxygen. This type of respiration, without oxygen, is called **anaerobic respiration**.

Anaerobic respiration is important in sprinting and weightlifting. Other sports, which involve steady exercise as well as short bursts of high-energy exercise, rely on both aerobic and anaerobic respiration.

1. List some sports that involve:
   a) aerobic respiration
   b) anaerobic respiration.
2. Explain the main difference between aerobic and anaerobic respiration.
3. Suggest some sports or forms of exercise that rely on both aerobic and anaerobic respiration.

FIGURE 2.9.2b: Why does a circuit trainer need to use anaerobic respiration?

The results of anaerobic respiration

Anaerobic respiration can be shown in an equation:

glucose → **lactic acid** (+ energy)

Although anaerobic respiration does release some energy, it does not release as much as aerobic respiration does.

The lactic acid produced during anaerobic respiration builds up in muscles. This can be felt as an aching in muscles during or after exercise. After the short burst of vigorous exercise is over, you need to get rid of lactic acid using the oxygen that you breathe in. This oxygen is a 'payback' so that the body can rid itself of lactic acid – it is known as the **oxygen debt**. You may find yourself breathing deeply after exercise to repay this oxygen debt.

FIGURE 2.9.2c: Why do we breathe deeply after vigorous exercise?

4. Explain what is meant by 'oxygen debt'.
5. Suggest why anaerobic respiration can only be sustained for short periods of time.
6. Compare the word equations for aerobic respiration and for anaerobic respiration.

Energy stores

Animals' bodies have developed ways of storing glucose. This means that they can slowly release energy as and when they need it.

Animals store energy in several ways:

- as **glycogen** in muscles
- as glycogen in the liver
- in fat reserves.

You can damage your body if you exercise too much without taking in sufficient energy as food. Once all other energy stores, such as glycogen and fat, have been used up, protein in the body can be used as a last resort.

7. Explain the benefits to an animal of storing glucose.
8. Suggest why using protein in your body as an energy source could be damaging.

Did you know...?

It takes 12 seconds for oxygen to be usable in respiration after you have breathed it in. So in a 100 m sprint, athletes are respiring entirely anaerobically.

Know this vocabulary

anaerobic respiration
lactic acid
oxygen debt
glycogen

Understanding anaerobic respiration

We are learning how to:

- Recall that plants and microbes carry out fermentation.
- Recall the word equation for anaerobic respiration in plants and microbes.
- Describe some evidence to show that anaerobic respiration can produce carbon dioxide.

Plants and microbes, like animals, sometimes need to respire anaerobically. As in animals, this process uses glucose to release energy. But the products of anaerobic respiration in plants and microbes differ from the products in animals.

FIGURE 2.9.3a: Why do these plants need to respire anaerobically?

Anaerobic respiration in plants

Just like animals, plants respire anaerobically when oxygen is in short supply. However, the products of anaerobic respiration are different:

- In animals, lactic acid is produced.
- In plants, ethanol and carbon dioxide are produced.

The type of anaerobic respiration that produces ethanol and carbon dioxide is called **fermentation**. It can occur in the roots when a plant is growing in boggy or waterlogged soil.

1. Describe the soil conditions needed to make a plant respire anaerobically.
2. Name the type of anaerobic respiration that produces ethanol and carbon dioxide.
3. Write a word equation for fermentation.

Fermentation in microbes

Microbes are tiny organisms that we cannot see with the naked eye – they include bacteria, viruses and fungi. Microbes often respire by fermentation.

Some microbes are capable of both aerobic respiration and fermentation, and use fermentation only when oxygen levels fall. Examples of microbes that do this are the bacterium *Escherichia coli* and the fungus **yeast**. Yeasts are a type of fungus found all around us. Some microbes are adapted to survive only in anaerobic conditions, for example, bacteria that live far below the ocean's surface.

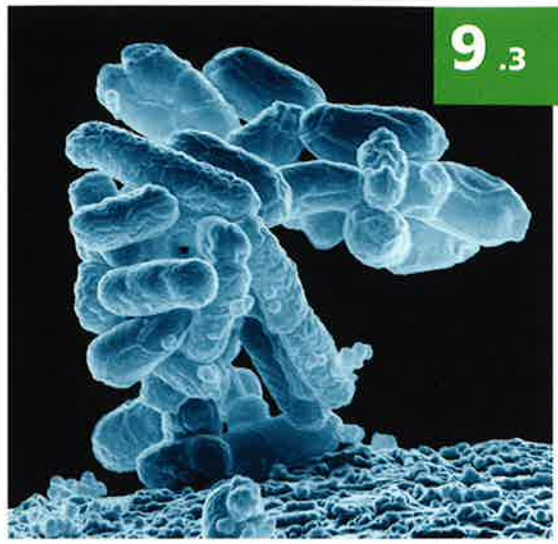

FIGURE 2.9.3b: Some bacteria, such as *E. coli*, can respire anaerobically when oxygen levels are low. The magnification here is approximately ×120 000.

4. Write a definition of 'microbes'.
5. Explain why it is an advantage for microbes to be able to respire both aerobically and anaerobically.
6. Suggest what would happen to microbes adapted to live without oxygen if they were suddenly exposed to oxygen.

Exploring anaerobic respiration

You can show that a gas is given off by fermentation. Mix some dried yeast with warm water in a conical flask to activate it. Then give the yeast some sugar as a source of food. If the conical flask is then covered with a balloon, any gas given off will collect in the balloon.

7. Describe what process is taking place in Figure 2.9.3c.
8. Explain why sugar is added to the yeast.
9. Explain why the balloon inflates during the activity.

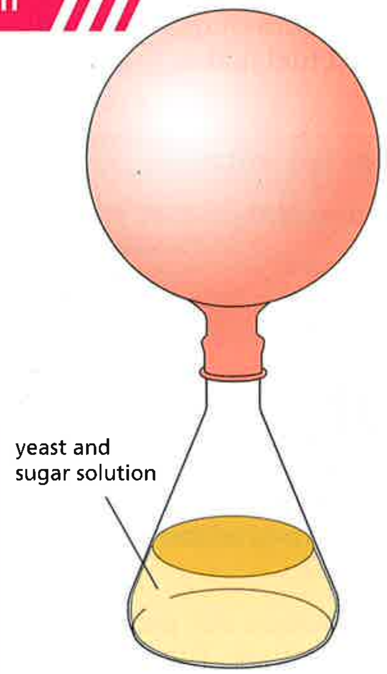

FIGURE 2.9.3c: Yeast is activated and sugar is added to the conical flask.

Did you know...?

Anaerobic respiration is thought to be a primitive way of releasing energy, stemming from the time when there was no oxygen in the atmosphere. It is now a successful strategy for coping when oxygen levels are low.

Know this vocabulary

fermentation
microbe
yeast

Investigating fermentation

We are learning how to:

- Describe some applications of fermentation.
- Identify dependent, independent and control variables in an investigation.
- Analyse data and suggest improvements.

Yeast is a simple organism that reproduces and ferments sugar rapidly. These features make it ideal to use in studies of fermentation. Fermentation by yeast has many applications – for example, in baking and brewing.

FIGURE 2.9.4a: Yeast is a microscopic fungal organism. The magnification here is ×1000.

Applications of fermentation

Fermentation is used in **brewing** and the production of alcoholic drinks, as one of the products of fermentation, is ethanol (a type of alcohol). The type of alcoholic drink produced depends on the source of the sugar used in the process. For example, wine uses grapes whereas beer is made using hops and barley.

Fermentation is also important in baking. Yeast and sugar are included in bread recipes because the carbon dioxide produced during the fermentation causes the bread to rise. Another application of fermentation is in the production of 'gasohol' – a fuel containing a mixture of gasoline and alcohol. Mixing alcohol with a **fossil fuel** makes the non-renewable fossil fuel last longer.

1. Describe three applications of fermentation.

2. Highlight an application of fermentation that relies on:

a) carbon dioxide being produced

b) alcohol being produced.

FIGURE 2.9.4b: Fermentation is important in wine making, baking and brewing.

Investigating fermentation

A group of students investigated the effect of temperature on fermentation. They mixed dried yeast with warm water, to activate it, in a conical flask. Then they added some sugar so that the yeast could respire.

As the mixture fermented, carbon dioxide was produced. The gas formed bubbles in the conical flask. The students counted the bubbles for one minute. The experiment was repeated, setting up identical flasks at different temperatures.

3. In the experiment, what was the:

a) **independent variable** (that the students changed)?

b) **dependent variable** (that the students measured)?

4. Suggest what the students might need to control (keep the same) in this experiment.

Analysing and evaluating results

Where an investigation measures one dependent and one independent variable, we can look for **correlation**. This means that we can describe a relationship between the two variables.

Table 2.9.4 shows the results of the investigation:

TABLE 2.9.4: How temperature affects fermentation.

Temperature (°C)	20	30	40	50
Number of bubbles per minute	14	26	60	16

We can describe a correlation using a sentence structure such as 'As the independent variable increases the dependent variable increases/decreases'.

At the end of an investigation, we should evaluate our experiment. We can consider how reliable our results were. For example, collecting more than one set of data allows us to check that the experiment is **repeatable**. If we obtain two or more sets of measurements that are similar, this suggests the results are repeatable and reliable. We can also consider whether we could improve the method that was used. For example, using more accurate measuring equipment improves the **accuracy** of our results. An example of improving accuracy would be to measure a child's height to the nearest mm rather than to the nearest cm.

5. Describe the correlation between temperature and number of bubbles.

6. Suggest what the **control variables** might be in this investigation (what the students might need to control or keep the same).

7. Suggest how the students could improve the reliability of their results.

Did you know...?

Fermentation has been used to preserve foods for about 10000 years. It is likely that it was discovered with the observation that milk fermented naturally. Fermentation of milk results in the production of cheese or yogurt, for example. People then realised that the products of milk fermentation lasted longer.

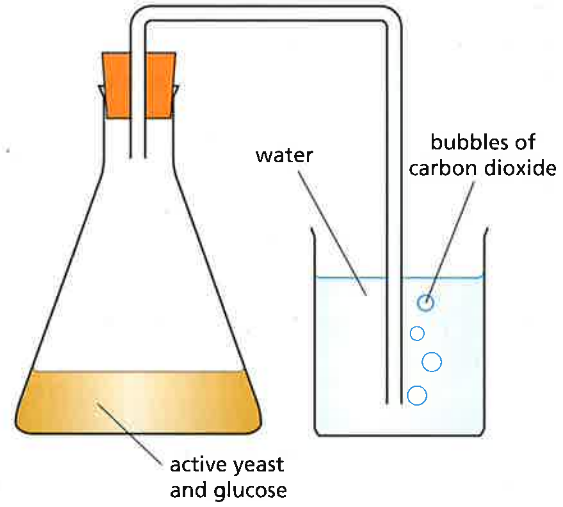

FIGURE 2.9.4c: Students counted the number of bubbles in one minute.

Know this vocabulary

brewing
independent variable
dependent variable
correlation
repeatable
accuracy
control variable

Comparing aerobic and anaerobic respiration

We are learning how to:

- Compare some similarities and differences between aerobic and anaerobic respiration.

The purpose of any respiration is to release energy in a form that an organism can use.

Aerobic and anaerobic respiration both release useful energy in cells. So, does it make any difference which type of respiration we use?

FIGURE 2.9.5a: The energy contained in food is released by respiration.

Comparing energy

The energy contained in food needs to be converted so that cells can use it – this is the purpose of respiration. Aerobic respiration uses glucose and oxygen as the reactants.

In anaerobic respiration there is only one reactant, glucose. Aerobic respiration is 19 times more efficient at generating energy than anaerobic respiration. However, because anaerobic respiration generates energy more quickly, sometimes your body switches to this type of respiration. For example, when you sprint you need to generate energy quickly for your muscles. Even though there is still some oxygen in your body, it is better to respire anaerobically in this situation.

1. Compare the efficiencies of aerobic respiration and anaerobic respiration.
2. Explain why it is sometimes preferable to respire anaerobically, even if some oxygen is available.
3. Suggest another situation in which anaerobic respiration would be preferable, even if oxygen is available.

FIGURE 2.9.5b: Energy can be released more quickly by anaerobic respiration.

Where in the cell?

Anaerobic respiration takes place in the cytoplasm of cells. Many chemical reactions occur in the cytoplasm – the first stage of aerobic respiration is one of them. But the next stage continues in the **mitochondria**. It is during this mitochondrial stage that most energy is released, so we usually say that aerobic respiration takes place in the mitochondria. Mitochondria are sometimes described as 'powerhouses'.

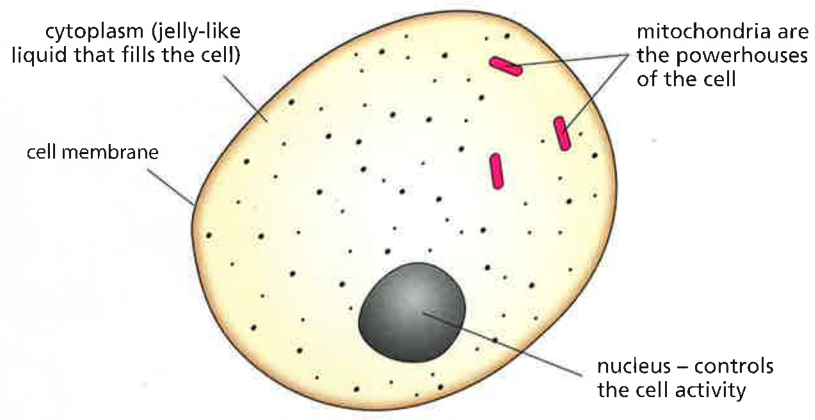

FIGURE 2.9.5c: An animal cell.

4. Draw a diagram of an animal cell and label where aerobic and anaerobic respiration take place.
5. Compare the amount of energy that is produced in the cytoplasm and in the mitochondria during aerobic respiration.

Respiration and enzymes

Enzymes are protein molecules that speed up reactions, they are sometimes called biological **catalysts**. Enzymes are involved in both aerobic and anaerobic respiration, without enzymes neither would happen. Enzymes break up glucose molecules to release energy. There are more enzymes involved in aerobic respiration than in anaerobic respiration.

6. Explain why respiration would not happen without enzymes.
7. Suggest why more enzymes are involved in aerobic respiration than in anaerobic respiration.
8. Enzymes are involved in many reactions in living organisms. Suggest another process that requires enzymes.
9. Draw a table to compare and contrast aerobic and anaerobic respiration

FIGURE 2.9.5d: Mitochondria are tiny organelles found in most cells. The magnification here is ×120 000.

Did you know…?

Carbon dioxide is toxic if it builds up in your body. This is because it takes the place of oxygen in the blood and you become starved of oxygen. Your breathing system is essential to remove the carbon dioxide produced during respiration.

Know this vocabulary

mitochondria
catalyst

Exploring how plants make food

We are learning how to:

- Describe a method to show that chlorophyll is essential for photosynthesis.
- Identify risks and control measures.

Plants do not need to eat other plants or animals to get their food. They make food using materials around them. What do they use to make food? How do they do it?

Making food

Plants allow us to survive. We use plants every day for food. All food is either a plant or comes from an animal that has eaten plants.

Green plants use water from the environment and carbon dioxide from the air to make the sugar **glucose**. Light from the Sun provides the energy needed for the reaction. This process is called **photosynthesis**. The reaction also produces oxygen, which is released into the air during the daytime.

$$\text{carbon dioxide} + \text{water} \xrightarrow{\text{light}} \text{glucose} + \text{oxygen}$$

The plant uses the glucose for new growth and respiration and also stores unused glucose as a carbohydrate called **starch**.

1. **a)** Name the reactants in photosynthesis.
   b) Name the products of photosynthesis.
2. Why does photosynthesis not happen at night?
3. What will happen to the amount of carbon dioxide in the air during the night?
4. Why is light not a reactant or a product in the reaction?

FIGURE 2.9.6a: These trees are giving out oxygen. Why is it important to conserve our trees?

Did you know...?

'Biomass' is the total mass of an organism. As plants photosynthesise and grow, their biomass increases.

Testing a leaf for starch

You can show that a plant has photosynthesised by testing its leaves for starch. This is done using a chemical called **iodine**. Iodine is an orange colour, but it turns blue-black when added to starch.

First, the leaf needs to be boiled in ethanol and then rinsed in warm water. This kills the cells and removes the green colour. Iodine is then added. If the leaf become blue-black, then starch is present, showing that photosynthesis has taken place.

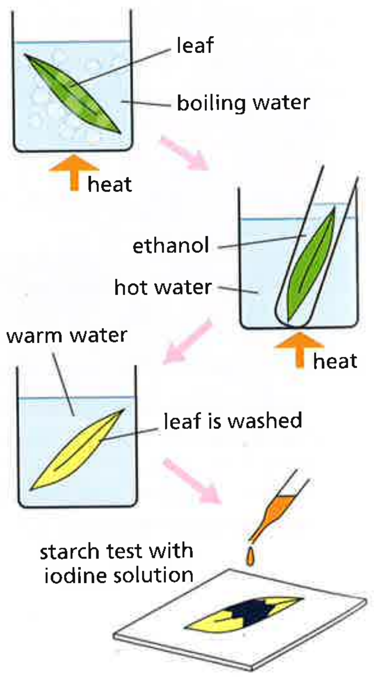

FIGURE 2.9.6b: Testing a leaf for starch.

Leaves have a green colour because they contain a pigment called **chlorophyll** that absorbs light energy. Chlorophyll is found in the chloroplasts in plant cells. Look at the plant in Figure 2.9.6c. Some parts of its leaves are green and some parts are white. By testing these variegated leaves for starch, we can show whether chlorophyll is needed to photosynthesise.

5. **a)** A leaf has been kept in the light for five days. What colour will it be when tested with iodine?
   b) The leaf is then kept in the dark for five days. Now what colour will it be when tested when with iodine? Explain your answer.
6. What do think would happen if you tested a leaf from the plant in Figure 2.9.6c for starch? Explain your answer.

FIGURE 2.9.6c: This plant has variegated leaves.

Considering the risks

Consider the method for testing a leaf for starch. Like most activities, this process has some hazards associated with it. A **hazard** is something that can cause you harm. **Risk** is the chance of harm occurring from the hazard. When planning any investigation, you must consider the hazards of the chemicals, apparatus and method being used.

Control measures must then be planned; these are actions to remove the hazard or reduce the risk. Examples are wearing eye protection, using chemicals at low concentration or using a less harmful chemical. A decision can then be made about whether the procedure should go ahead. If it was felt that there was still a big risk even with control measures in place, then alternative methods could be considered.

DILUTE IODINE SOLUTION	ETHANOL
LOW HAZARD	HAZARDOUS
	• Irritating to eyes • Highly flammable
Typical control measures to reduce risk	**Typical control measures to reduce risk**
• Use the lowest concentration and smallest amount possible. • Wear eye protection for all but the most-dilute solutions. • Handle iodine solid using forceps or, better, wear protective gloves as well. • Avoid breathing iodine vapour, eg, by the use of a fume cupboard.	• Keep away from sources of ignition. • No smoking • Do not breathe gas / fumes / vapour / spray. • Avoid contact with skin. • Wear eye / face protection.

FIGURE 2.9.6e: Hazard information for iodine solution and ethanol.

7. Look at the information in Figure 2.9.6e. What are the risks in the test for starch and how can they be controlled?

FIGURE 2.9.6d: Testing a leaf for starch: when a green leaf is boiled in alcohol the green colour is extracted. When iodine is added the leaf will turn blue-black if starch is present.

Know this vocabulary

glucose
photosynthesis
starch
iodine
chlorophyll
hazard
risk
control measure

Looking at leaves

We are learning how to:

- Relate the size of a leaf to the availability of light.
- Relate the internal structure of a leaf to its function.
- Evaluate the structure of a cell related to its function.

Leaves are one of the major organs in a plant. They have a complex structure that allows them to photosynthesise and make glucose. What is special about leaves? How are they able to capture the Sun's energy to make food for the plant?

FIGURE 2.9.7a: Leaves have many different shapes and sizes, but they all have some features in common with each other.

How are leaves adapted?

Leaves have features that allow them to photosynthesise efficiently. Typically, leaves are thin, flat, broad, green and have a network of veins. They all contain a pigment called chlorophyll, which absorbs the Sun's energy and enables the plant to photosynthesise. Scientists use a technique called chromatography to look at chemicals in the pigment. The leaves are ground up, and the pigments are separated using a solvent. The pigments in chlorophyll are green and different shades of yellow.

1. What features do leaves have in common?
2. Why do leaves have these features?
3. What cells have you studied that are found in leaves?

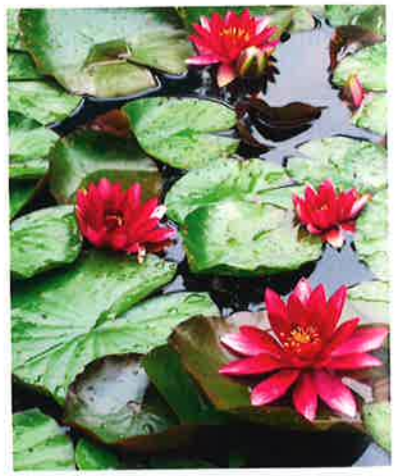

FIGURE 2.9.7b: Look at these leaves. How are they adapted to carry out their function?

Observing leaves

Look at the photograph in Figure 2.9.7a. It shows different types of plants growing to different heights.

Water lilies (Figure 2.9.7b) grow in fresh water. Their leaves float on the surface of the water.

The internal structure of a leaf is also adapted to allow it to photosynthesise efficiently. Look carefully at Figure 2.9.7c.

Leaves have:

- a waxy waterproof **cuticle**
- a transparent **epidermis**
- long, narrow **palisade cells** packed with chloroplasts, mainly at the top of the cells
- **spongy cells** that have a large surface area and large spaces between them.

Did you know…?

Diatoms are microscopic single-celled algae that live in water all over the Earth. About 20 percent of the oxygen in the atmosphere comes from photosynthesis by marine diatoms.

Look again at Figure 2.9.7c. Land plants have pores called **stomata** (stomata is the plural of stoma) on the underneath surface of their leaves. These stomata can open and close to control materials that flow in and out of the leaf. When a plant needs carbon dioxide, the stomata open, allowing the gas into the leaf. Two guard cells, one on either side of each stoma, control the opening and closing of the stoma.

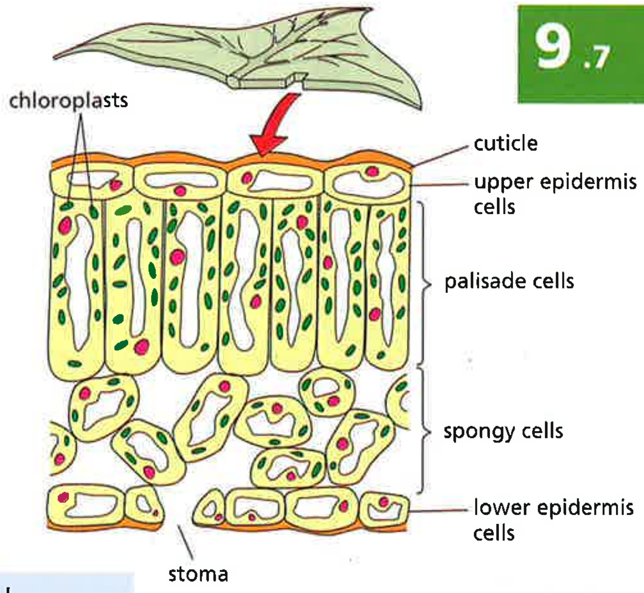

FIGURE 2.9.7c: Section through a leaf showing the different types of cell.

4. What do you notice about the size of the leaves growing at different heights in the forest?
5. Why is this important to the plants that grow to these heights?
6. How do gases move in and out of a leaf?
7. Suggest when stomata are most likely to be open, during the day or night. Explain your answer.
8. Name the different types of cells in a leaf and describe their features.

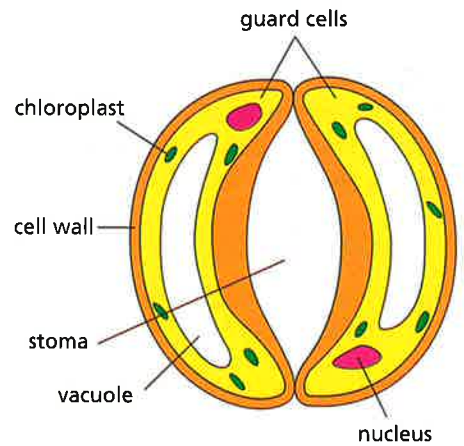

FIGURE 2.9.7d: An open stoma.

Evaluating leaf adaptations

Look closely at the different types of cells in the leaf section shown in Figure 2.9.7c. Each cell type has special adaptations to help it perform its function and maximise the amount of photosynthesis taking place.

- Light passes through the cuticle and epidermis until it reaches the palisade cells.
- The palisade cells absorb as much light as possible, to ensure that the rate of photosynthesis is as high as possible.
- The spongy cells capture the remaining light.
- Their surface area and the air spaces allow gases to diffuse through the leaf.

9. Evaluate the adaptations of each type of cell. How do these adaptations ensure that the cells perform their function efficiently?

Know this vocabulary

cuticle
epidermis
palisade cell
spongy cell
stomata

Ecosystem

Exploring the movement of water and minerals in plants

We are learning how to:

- Identify and explain how water and minerals move through a plant.
- Evaluate the cell structures that allow the movement of water and minerals through a plant.

Water is needed in cells to support the plant and to photosynthesise. Minerals in the soil dissolve in water. How do plants get the water and minerals they need? How do they move through the plant?

Taking water in

Plants take in water and dissolved minerals through their roots. The roots grow downwards and can also spread out underground to absorb water and minerals from a large area. Roots anchor plants firmly in the ground.

Water and minerals move from the roots, up the stem or tree trunk to the leaves and flowers. Water in plant cells causes them to swell and become rigid.

1. Name two functions of the roots.
2. Look at Figure 2.9.8b. Why do these plants have differently shaped roots?
3. Why does water move to the leaves?

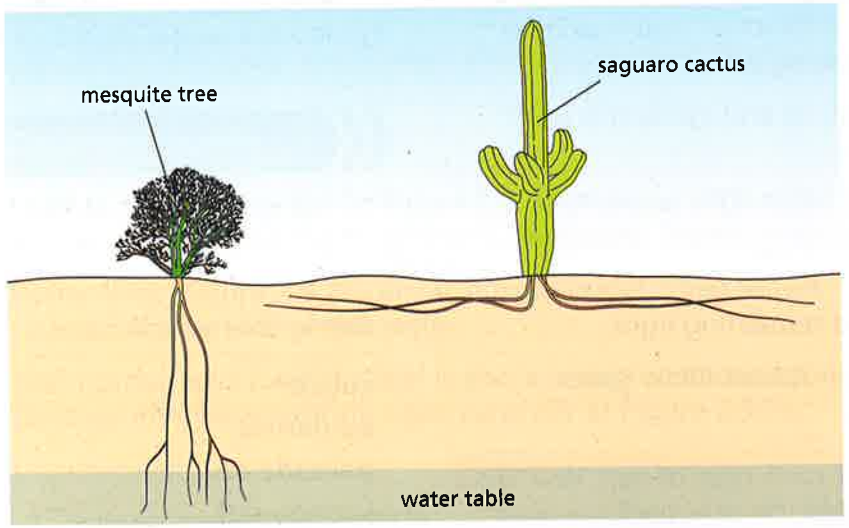

FIGURE 2.9.8b: Plants native to the Sonoran Desert in the Western USA. Why do these plants have differently shaped root systems?

FIGURE 2.9.8a: The saguaro cactus.

FIGURE 2.9.8c: How is the saguaro cactus adapted to prevent water loss?

Keeping the water

Plants can lose water from the leaves through the stomata, which let in carbon dioxide. Stomata close in hot conditions.

The loss of water from a leaf is called **transpiration**. Plants lose most water when it is dry, hot and windy. Leaves have a waxy cuticle to prevent water loss (see Figure 2.9.8c). The cuticles of desert plants are much thicker and waxier compared to other plants. Their leaves are often small or needle-like, which also prevents too much water loss.

Some plants have curled or folded leaves. The curl reduces the surface area of the leaf. It also traps moist air to help reduce transpiration further.

4. What is transpiration?
5. In what conditions will plants lose least water?
6. Describe how plants can reduce water loss.
7. Draw a diagram to show the movement of water through a plant.

Looking at cells

Water and minerals move from the roots up the plant, in a series of cells in the stem. These **xylem cells** form a pipeline through the plant.

The roots of the plant have special cells called **root hair cells**. These have long, hair-like extensions that penetrate between the soil particles. They have a large surface area through which they can absorb water.

The guard cells are also important for controlling water loss. When the guard cells are swollen with water, they open the stomata to let excess water leave the leaf. When the guard cells contain little water, they close the stomata.

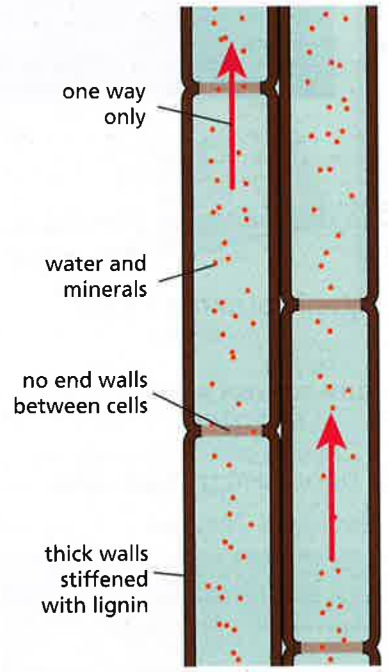

FIGURE 2.9.8e: How are these xylem cells adapted to their function?

8. How effective are the adaptations of xylem, stomata and root cells for transpiration?

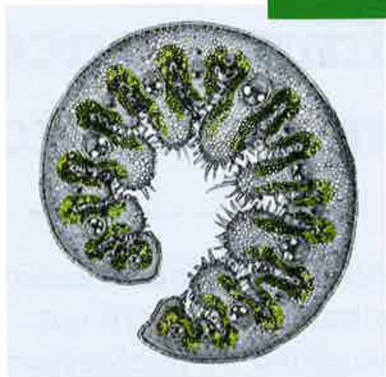

FIGURE 2.9.8d: A section through a blade of marram grass. The curled shape helps reduce water loss.

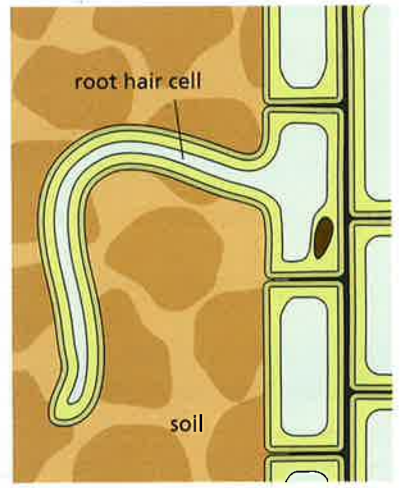

FIGURE 2.9.8f: Why does a root hair cell need a large surface area?

Did you know...?

The tallest plants in the world are the giant redwood trees in California. They can reach over 100 m in height. Water travels in the xylem cells from their roots right up to the highest leaves.

Know this vocabulary

transpiration
xylem cells
root hair cell

Ecosystem

Investigating the importance of minerals to plants

We are learning how to:

- Identify the minerals essential to healthy plant growth.
- Explain the effects of a deficiency in essential minerals.
- Describe the advantages and disadvantages of different soil treatments.

All plants require essential elements that are not supplied by photosynthesis – minerals that are found in soil and absorbed by the plant through its root system. What minerals do plants need? What happens if they do not get them? How can we help plants that we grow to get the minerals they need?

FIGURE 2.9.9a: Is this plant healthy? How do you know?

Mineral deficiency

Poor plant growth may be due to a deficiency, or shortage, of one or more minerals.

- Plants that do not have enough nitrates have poor growth and yellow leaves.
- Plants with too little magnesium cannot make chlorophyll.
- Phosphorus **deficiency** causes poor root growth and discoloured leaves.

1. What is a mineral deficiency?
2. Predict how a plant would grow if it had a lack of magnesium.

FIGURE 2.9.9b: What do plants need to be healthy?

Essential minerals

When plants photosynthesise, they make glucose from carbon, hydrogen and oxygen. To convert these to protein, the element nitrogen must be added. Most plants obtain their nitrogen from the soil in the form of nitrates.

Minerals are needed to make proteins, chlorophyll and energy-storage molecules. Not all minerals have the same importance for the plant. The major minerals that plants use in large quantities are called 'macroelements'. Phosphorous, potassium and nitrogen are the main macroelements. Others are sulfur, calcium and magnesium.

3. Explain how plants get the minerals they need.
4. What are macroelements?
5. Name the three main macroelements.

Putting it right

Farmers grow many plants in specially selected fields. As the plants grow, they extract nutrients from the soil. Because the farmer harvests the crops from the fields, the soil becomes depleted of nutrients.

Tests can be done to establish which minerals are deficient, or a general purpose NPK **fertiliser** or **manure** can be added to the soil. (N, P and K are the symbols for the three macroelements:
N = nitrogen;
P = phosphorus;
K = potassium.)

FIGURE 2.9.9c: Fertilisers contain NPK.

FIGURE 2.9.9d: Why do farmers use fertilisers?

Commercial fertilisers release minerals quickly into the soil for the plants. However, they can get into waterways and cause algae in the water to grow very quickly. Many farmers prefer to use manure because it is natural, improves soil quality and releases the minerals much more slowly than commercial fertilisers. This means that manure has longer-term effects.

6. What is a fertiliser?
7. What is in an NPK fertiliser?
8. If farmers have fertile healthy soil, why do they need to use fertilisers?
9. Why do you think some farmers use manure and some use commercial fertilisers?

Did you know…?

Many zoos sell elephant dung as manure. The nutrient-rich manure improves nutrient-depleted soils, helping farmers to ensure good soil for planting crops in.

Know this vocabulary

deficiency
fertiliser
manure

Investigating photosynthesis

We are learning how to:

- Identify the factors that can affect photosynthesis.
- Predict the results of investigations.
- Interpret data on photosynthesis.

Photosynthesis happens in all green plants. In this process the plant uses raw materials in the environment to make glucose. What factors can affect how fast a plant photosynthesises? How will these factors affect photosynthesis?

Photosynthesis

Green plants all over the world use carbon dioxide and water from the environment to make glucose. Glucose is needed for the plants to grow and increase their biomass. Plants in some habitats grow at a much faster **rate** than others. For example, mosses growing in cold tundra habitats grow very slowly, whereas plants in the rainforest grow much more quickly.

FIGURE 2.9.10a: Will these trees photosynthesise at the same rate?

1. Write the word equation for photosynthesis.
2. What variables will affect how much photosynthesis takes place in a plant?
3. Look at Figure 2.9.10a. Will these trees photosynthesise at the same rate? Explain your answer.

Variables affecting photosynthesis

The **concentration** of carbon dioxide in the air will affect the rate of photosynthesis. Carbon dioxide and water are the reactants in the reaction – the higher the concentration of the reactants, the greater the amount of photosynthesis, as shown in Figure 2.9.10b.

Choloropyhll in the chloroplasts absorbs light energy. The more choroplasts a leaf has, the more light it can absorb to carry out more photosynthesis.

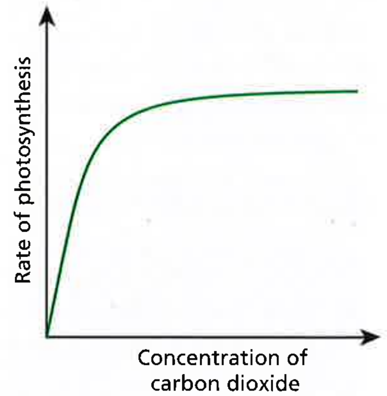

FIGURE 2.9.10b: How does the concentration of carbon dioxide affect photosynthesis?

A student is carrying out an investigation to see how the amount of light a plant receives affects the rate of photosynthesis. She uses some pondweed with the apparatus shown in Figure 2.9.10c. She counts how many bubbles of oxygen are given off by the pondweed in one minute, at different distances from a lamp.

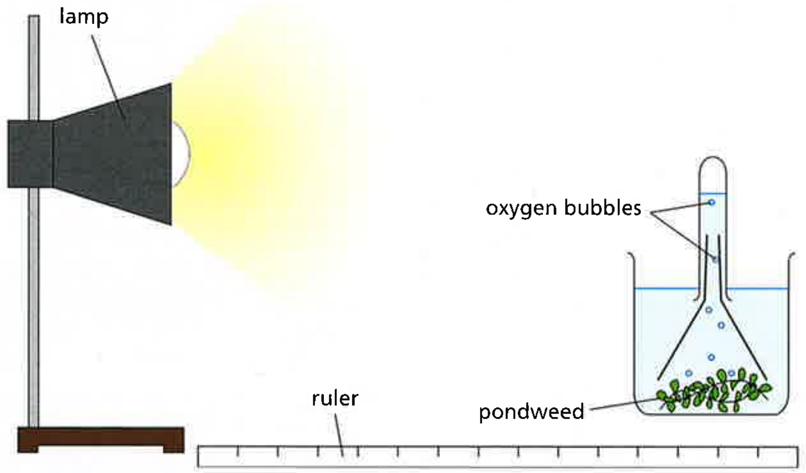

FIGURE 2.9.10c: Apparatus used in an investigation to see the effect of light on photosynthesis.

Did you know...?

Rainforests produce over 20 per cent of the Earth's oxygen. This is why it is so important to look after them and stop the trees being destroyed.

4. How do we know that plants photosynthesise less in winter than in summer?
5. How does the amount of light available to a plant affect the rate of photosynthesis?
6. How does temperature affect the rate of photosynthesis?
7. a) Why does the student think that counting bubbles is a good way to measure photosynthesis?
   b) What variables does the student need to control?
   c) What errors might occur in the investigation?

Interpreting data

A student's grandfather wants to grow tomatoes as quickly as possible in his greenhouse over the winter. The student carries out an investigation to find the temperature at which tomatoes photosynthesise the most.

8. Using the investigation results shown in Figure 2.9.10d to help you, explain how the rate of photosynthesis changes from dawn to nightfall.
9. What is the best temperature for the student's grandfather to use in his greenhouse? Explain why.

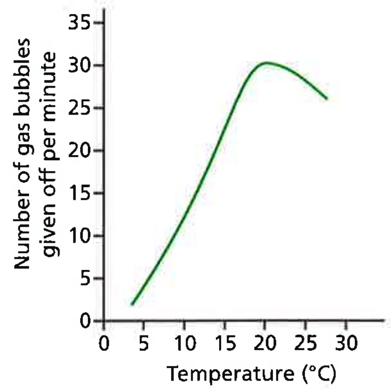

FIGURE 2.9.10d: Results of the investigation.

Know this vocabulary

rate
concentration

Checking your progress

To make good progress in understanding science you need to focus on these ideas and skills.

Describe the purpose of respiration.	Describe and explain the process and purpose of respiration, including using an equation.	Explain the role of respiration in building up complex molecules.
Define anaerobic respiration and give examples of sports that use anaerobic respiration.	Explain why some sports rely mainly on aerobic respiration while others require anaerobic respiration.	Describe and explain the effects on the body of anaerobic respiration and explain 'oxygen debt'.
Identify some living things that carry out anaerobic respiration.	Describe some applications of anaerobic respiration (fermentation).	Analyse data linked with a fermentation investigation and suggest improvements.
State that green plants need sunlight to grow and to make food.	Identify water and carbon dioxide as the raw materials for photosynthesis, and glucose and oxygen as the products.	Explain the chemical changes involved in photosynthesis and the roles of light and chlorophyll.

Describe how gases enter and leave a leaf and how light energy for photosynthesis is captured.	Describe how cells in the leaf and root are adapted for their functions.	Relate and explain how the structure of palisade, mesophyll and guard cells allows them to perform their function.
Describe how levels of light, temperature and carbon dioxide affect the rate of photosynthesis.	Explain how levels of light, temperature and carbon dioxide affect the rate of photosynthesis.	Apply learning about the factors affecting photosynthesis to solve problems.
Name some of the nutrients needed by plants and supplied by fertilisers; state how they enter the plant dissolved in soil water.	Explain why nutrients are needed by plants, how spreading manure adds them to the soil and how water passes through the plant.	Explain how mineral deficiencies affect plants and how different factors affect the rate of transpiration.

Questions

KNOW. Questions 1–9

See how well you have understood the ideas in this chapter.

1. Respiration mainly takes place in: [1]

a) mitochondria **b)** the nucleus **c)** the cell wall **d)** the vacuole.

2. Fermentation produces: [1]

a) glucose **b)** ethanol **c)** oxygen **d)** lactic acid.

3. Aerobic respiration produces the gas: [1]

a) oxygen **b)** nitrogen **c)** glucose **d)** carbon dioxide.

4. Describe the differences between aerobic and anaerobic respiration. [4]

5. Where do plants get their food from? [1]

a) Plants absorb food from the soil.
b) Plants absorb nutrients from rain through their leaves.
c) Plants make food in their leaves using carbon dioxide and water.
d) Plants absorb nutrients from the soil and food is made from these in the roots.

6. Which of these does NOT affect the rate of photosynthesis? [1]

a) temperature **b)** light **c)** chlorophyll **d)** oxygen concentration.

7. Which of these is an important element needed for healthy plant growth? [1]

a) cobalt **b)** potassium **c)** iodine **d)** aluminium.

8. Describe how palisade cells are adapted to photosynthesise. [2]

9. Describe how to test a leaf for starch. What would a positive result be? [4]

APPLY. Questions 10–15

See how well you can apply the ideas in this chapter to new situations.

10. Explain why a student is not describing the full picture when she says that animals respire and that plants and algae photosynthesise. [2]

11. During an uphill sprint, why does a runner use anaerobic respiration instead of aerobic respiration? [1]

a) It doesn't release as much energy but it does release energy more quickly.
b) It releases more energy.
c) It forms lactic acid in animals.
d) It releases energy more slowly.

12. Which row in Table 2.9.12 correctly matches the sport to the *main* type of respiration used? [1]

	Sport	Type of respiration used
a)	long-distance swimming	anaerobic
b)	marathon running	aerobic
c)	weightlifting	aerobic
d)	sprinting	aerobic

TABLE 2.9.12

13. Stomata close when water is in short supply. Name a disadvantage of closed stomata. [1]

a) Water is not lost. **b)** Nutrient uptake is reduced.
c) Photosynthesis increases. **d)** Water is lost.

14. What effect will increasing the light intensity have on transpiration? [1]

a) It will stay the same. **b)** It will drop.
c) It will rise. **d)** It will stop completely.

15. Look at Figure 2.9.12a. This single-celled organism lives in pond water. How does it get food? Explain how you know this. [2]

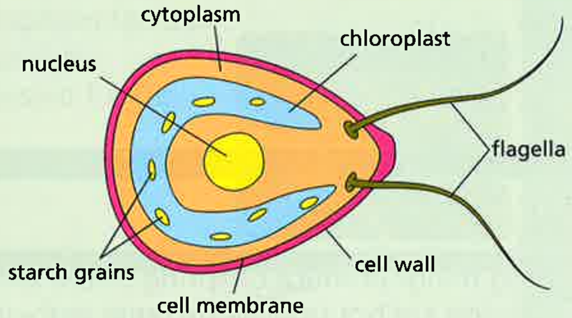

FIGURE 2.9.12a: Chlamydomonas – a unicellular organism.

EXTEND. Questions 16–17

See how well you can understand and explain new ideas and evidence.

16. Two types of microbe, A and B, are being considered for use by a brewing company. Microbe A respires aerobically and anaerobically, whereas microbe B only respires anaerobically. Suggest which microbe may be most useful based on this information, and suggest what other factors should be considered before choosing which microbe to use. [4]

17. Marram grass grows on sand dunes.
It has rolled leaves. Why do you think it has: [2]

a) sunken stomata and rolled leaves?
b) a thick, waxy cuticle?

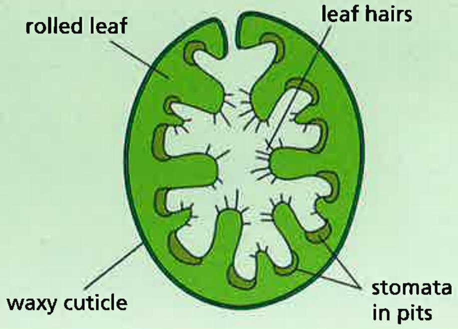

FIGURE 2.9.12b: The leaf blade of the marram grass is rolled towards the mid vein.