

## Obtaining nutrients

## Plants and animals have specialised structures to obtain nutrients from their environment

### Introduction

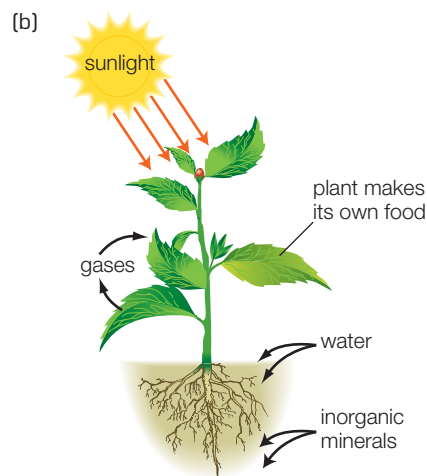
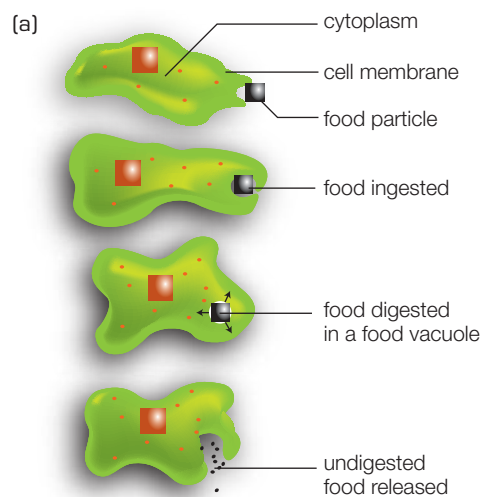
Organisms need to interact with their surroundings, taking up substances that they need for their functioning and getting rid of wastes which build up as a result of metabolic functions.

**Unicellular** organisms are so small that, in each organism, simple diffusion is adequate to supply the organism's requirements (e.g. oxygen for cellular respiration) and to remove waste products (e.g. carbon dioxide, urea and other metabolic waste substances). Water levels can also be maintained through the passive process of osmosis because the surface area to volume ratio of these organisms is large enough.

**Multicellular** organisms are larger in overall size and so their total surface area to volume ratio is smaller. As a result, passive transport would be insufficient to address their needs. This problem is overcome by the functional organisation of multicellular organisms:

- large organisms are made up of *numerous small cells*, so that each cell has its own large surface area to volume ratio. This leads to an increase in the efficiency of diffusion and osmosis in individual cells
- multicellular organisms are not simply thousands of similar cells lumped together. Cells have become *organised into groups* called **tissues** (e.g. blood tissue and skin tissue in humans, photosynthetic tissue and epidermal tissue in plants)
- some small multicellular organisms still rely on diffusion and osmosis for

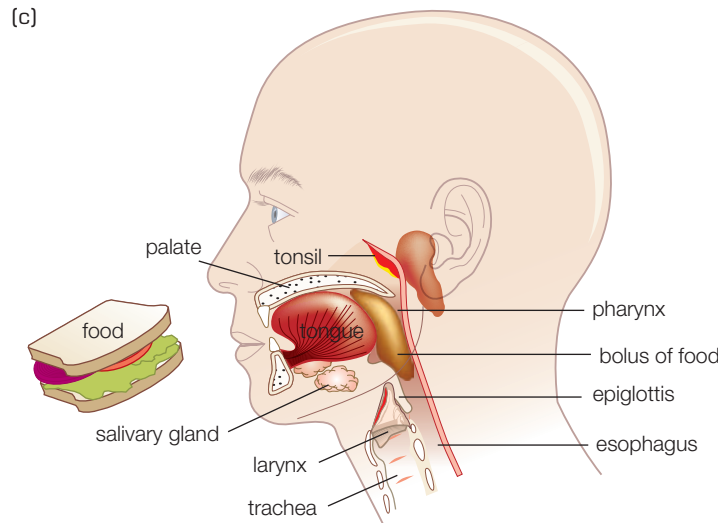
exchange between their cells and the surroundings, but large multicellular organisms have their tissues further organised into organs and systems, such as those which have developed for the efficient uptake of nutrients (digestive system) and gases (respiratory system).



continued . . .

**Figure 3.1** Uptake of nutrients in unicellular and multicellular organisms: (a) a unicellular organism—amoeba (**heterotroph**); (b) multicellular—plant (**autotroph**) absorbs water, inorganic nutrients and light, but makes its own food

**Figure 3.1** Uptake of nutrients in unicellular and multicellular organisms:  
(c) multicellular—human (heterotroph)

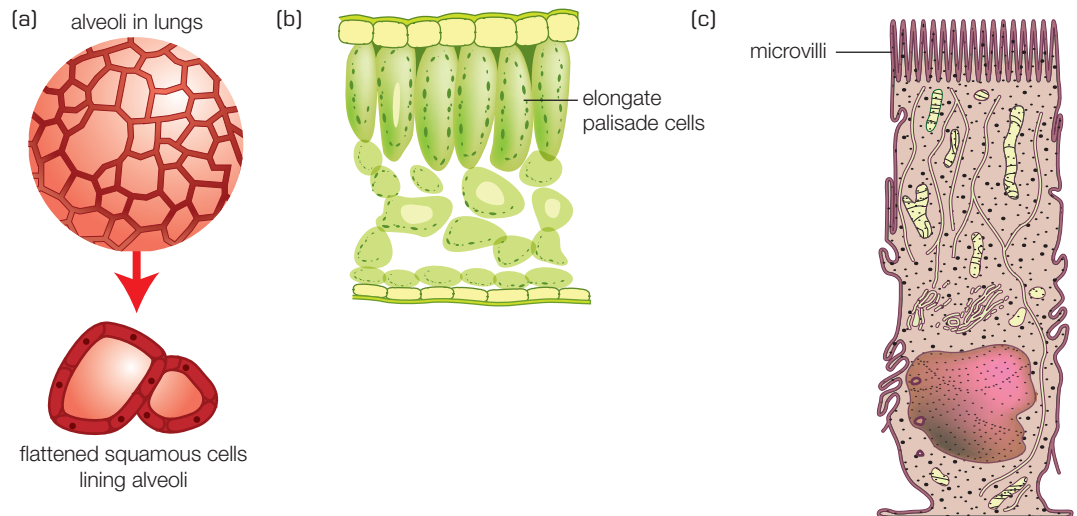


# 3.1

## Functional organisation in multicellular organisms: cells to systems

- *identify some examples that demonstrate the structural and functional relationship between cells, tissues, organs and organ systems in multicellular organisms*

**Figure 3.2** Cells that are structurally modified to increase surface area:  
(a) flattened, squamous epithelium of air sacs in lungs (light microscope view); (b) elongate palisade cells in a leaf (light microscope view); (c) an endothelial cell of the small intestine showing membrane folded to form **microvilli** (electron microscope view)



### Structure and function

In this chapter, we deal with the exchange of substances between cells and the environment, for example the uptake of nutrients by cells. The cells of those tissues involved in exchanging substances with the environment have special structural features to increase their surface area to volume ratio, allowing them to function more efficiently (see Fig. 3.2):

- cells may be flattened (e.g. in the tissue lining the air sacs in lungs) or elongate (e.g. photosynthetic cells in leaves), these shapes giving a greater surface area to volume ratio than cube-shaped cells
- the exposed edges of the cells may be extended into folds, for example root hair cells that absorb water and mineral salts in plants; or the cells lining the wall of the small intestine that absorb nutrients (see Fig 3.2c).

## Cell differentiation and specialisation

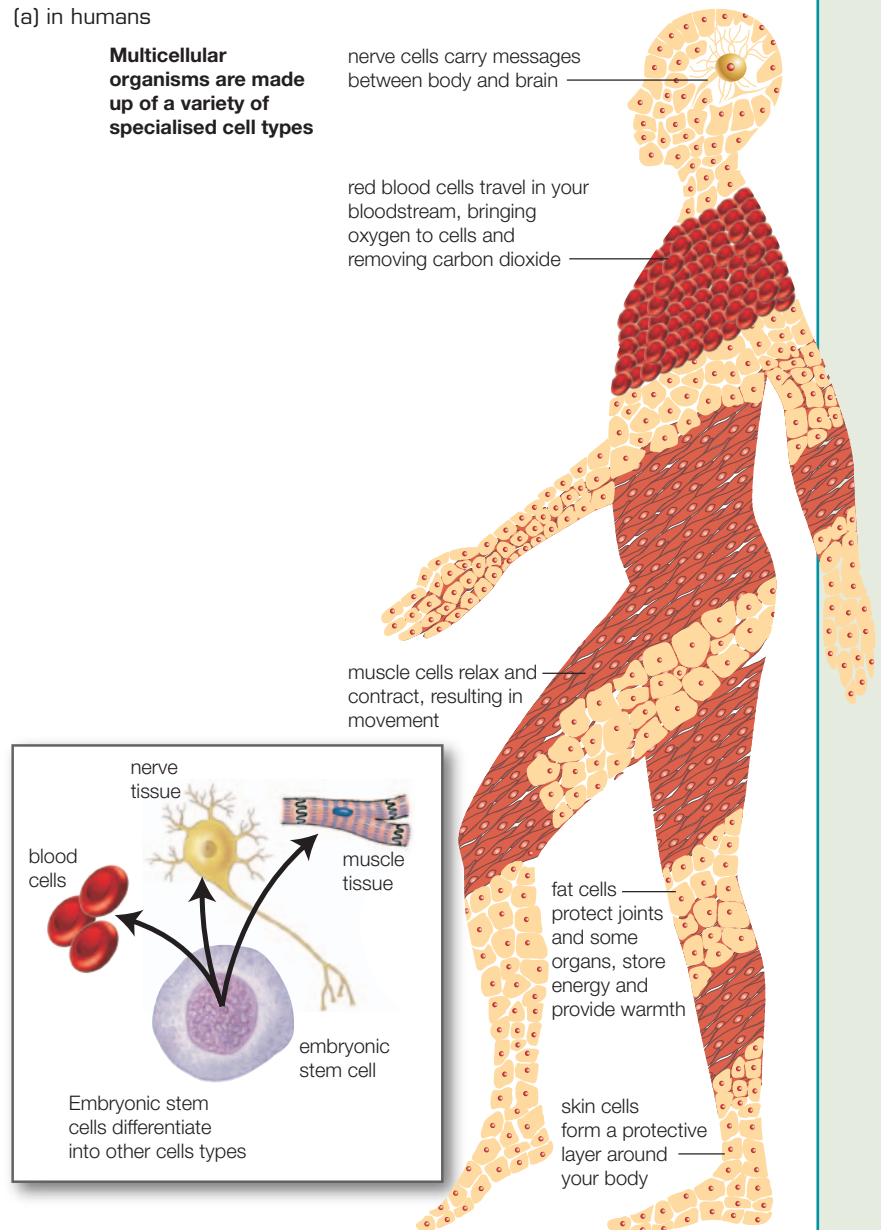
In multicellular organisms a *division of labour* occurs—different cell types (tissues) become structurally suited to carry out different functions. This increases their effectiveness in carrying out their functions: some cells are involved in obtaining nutrients, whereas other tissues function in movement, growth and excreting. (See Fig. 3.3.)

A division of labour is quite a common phenomenon to increase efficiency—think of a community of people living together. Young babies and children need to be fed and nurtured by adults. Within a community, most adults are capable of raising their children and maintaining an efficient and safe household, but specialised things such as medical treatment, education, the building of homes, installing electricity, protecting the community and keeping law and order are carried out by adults who are suitably qualified to do the job (e.g. doctors, teachers, builders, electricians, soldiers, police, magistrates and lawyers). The division of labour within a community shows similarities to that amongst cells of a living organism.

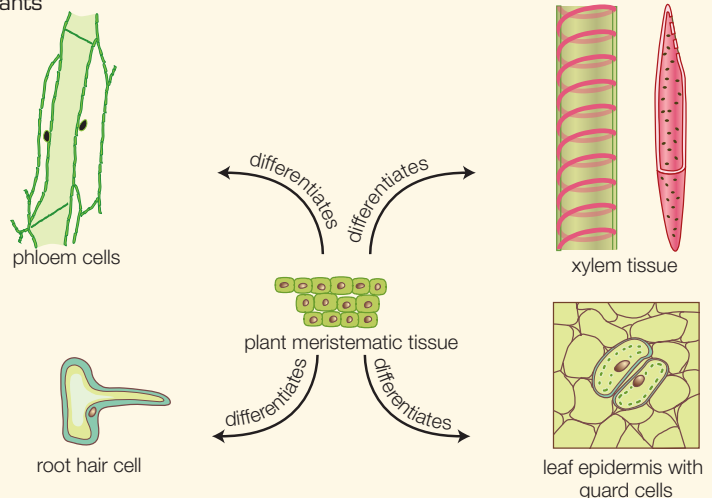
Young cells (called **embryonic cells**) are similar to each other in structure and, in early life, their only function is to divide and give rise to new cells. Embryonic cells require protection and nutrients to grow, but it is only once they begin to mature that they develop suitable structural changes that allow them to carry out specialised functions: some cells fight infection, others store nutrients, some process and transmit information, some secrete substances like hormones and others have a protective function.

(a) in humans

**Multicellular organisms are made up of a variety of specialised cell types**



(b) in plants



**Figure 3.3** Cell differentiation and specialisation: (a) in humans; (b) in plants



Division of labour analogies

When cells become specialised to perform a particular function, they are said to **differentiate**. They develop suitable structural features which allow them to carry out their functions and this makes them structurally *different* from other types of cells and from the embryonic cells from which they arose.

A group of cells that is similar in structure and works together to carry out a common function is called a *tissue*.

Once they have become specialised to form a particular type of tissue, *differentiated cells* lose their capacity to develop into other types of cells. Many even lose their ability to divide and give rise to the same type of cells. *Undifferentiated cells* that are able to divide and differentiate into other types of cells are known as **stem cells**.

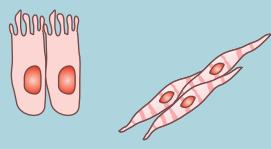
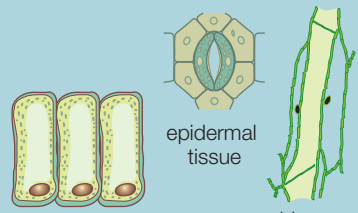
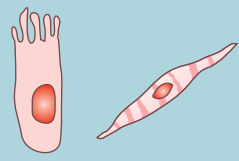
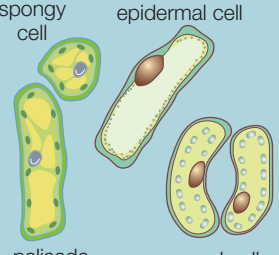
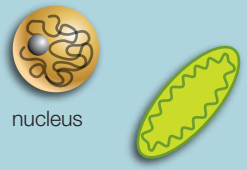
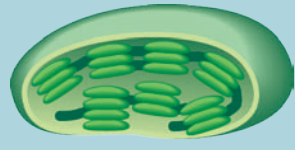


**Current interesting information**

Stem cells may be *embryonic* (found in embryos) or *adult* stem cells (e.g. neural stem cells lining the ventricles of the adult brain; blood-producing stem cells in bone marrow). Stem cell research is a current area of contention: embryonic stem cells can give rise to all other cell types and may be useful for the treatment of injuries and diseases, but this involves harvesting cells from living embryos. In contrast, the use of adult stem cells is non-destructive, but adult stem cells are only able to give rise to their own particular types of tissue (i.e. neural stem cells give rise to cells of the nervous system or blood-producing stem cells to blood cells). Current researchers are trying to induce adult stem cells to transdifferentiate into cell types that they do not normally produce.

**Functional organisation**

**Table 3.1** Functional organisation of living things: how living things are put together

Functional organisation of body		Animals/humans	Plants
Largest 	Multicellular organism		
	Systems	<p>stomach small intestine large intestine digestive system</p>	<p>xylem phloem transport tissue transport system</p>
	Organs	<p>stomach small intestines stomach and small intestine</p>	<p>roots leaves roots and leaves</p>

Functional organisation of body	Animals/humans	Plants
Tissues	 <p>gland tissue      muscle tissue</p> <p>gland tissue and muscle tissue</p>	 <p>photosynthetic tissue      epidermal tissue      phloem tissue</p> <p>photosynthetic tissue, epidermal tissue and phloem tissue</p>
Cells	 <p>muscle cell and gland cell</p>	 <p>spongy cell      epidermal cell</p> <p>palisade cell      guard cells</p> <p>plant cells</p>
Organelles	 <p>nucleus      mitochondrion</p> <p>nucleus and mitochondrion</p>	 <p>chloroplast</p> <p>chloroplast</p>
Molecules	 <p>glucose      amino acids      lipids</p> <p>sugar, amino acids and lipids</p>	
Smallest Atoms	 <p>carbon [C], hydrogen [H] and oxygen [O]</p>	

## 3.2

Just as similar specialised cells that perform a common function are arranged together to form tissues, so groups of tissues collectively form organs. An **organ** is an arrangement of different types of tissues, grouped together for some special purpose; for example, the leaf is an organ for making food in a plant and the heart is an organ for pumping blood in animals. A **system** is a collection of organs that all work together to achieve

an overall body function, for example the digestive system or nervous system in animals and the transport system in plants or animals. A multicellular organism is a living plant or animal composed of many systems which function together co-operatively to ensure its survival. When one or more of these systems malfunctions, the organism is no longer healthy and disease or even death may result.

## Autotrophs and heterotrophs

### ■ *distinguish between autotrophs and heterotrophs in terms of nutrient requirements*

#### Inorganic and organic nutrients

Living organisms need to obtain nutrients in the form of **organic** substances such as glucose, amino acids, fatty acids and glycerol, nucleotides and vitamins, as well as **inorganic** nutrients such as *minerals* (e.g. phosphates, sodium ions and chloride ions) and *water*. These nutrients, needed by living cells for their functioning, are used in two main ways:

1. as essential *building blocks* from which cells and living tissues are made
2. as a *source of stored energy* that can be converted to ATP, the form of chemical energy needed to power cell functioning.

Organic nutrients are the main supply of stored *energy* in living things, but they are also used extensively in the structure of cells. Inorganic nutrients are essential as structural parts of cells and tissues (e.g. iron in blood, calcium in bones and teeth) and they also play an essential part in assisting *enzymes*—the organic catalysts that control all chemical reactions within cells—but are not an energy source. Animals need to

‘eat’ food to obtain both organic and inorganic nutrients. In contrast, plants absorb inorganic nutrients from the soil, but they are able to manufacture (make) their own organic nutrients.

#### Autotrophs

Organisms such as plants that are able to make their own food are termed autotrophs (auto = self; troph = feeding). Most of these organisms produce their own food by the process known as **photosynthesis** (‘photo’ = light; ‘synthesis’ = manufacture); that is, they use the *energy of sunlight* to manufacture organic compounds, initially in the form of glucose, from water and carbon dioxide.

Although autotrophs are predominantly *green plants*, some bacteria and *unicells* are also able to make their own food. Most of them do this by the process of photosynthesis, but some bacteria are able to make organic nutrients by the process of *chemosynthesis*. This process relies on using *energy from breaking chemical bonds* to power their food-making, rather than using light energy as do photosynthetic organisms.

## Heterotrophs

Photosynthesis does not occur in animals. Animals are termed heterotrophs because they are unable to make their own food ('hetero' = different; that is 'feeding on something different'). Heterotrophs need to take in organic and inorganic nutrients by eating other organisms (they are *consumers*) to obtain nutrients and energy for their cells to function. Most heterotrophs are animals, but some *bacteria*, *unicells* and *fungi* also use a heterotrophic mode of nutrition.

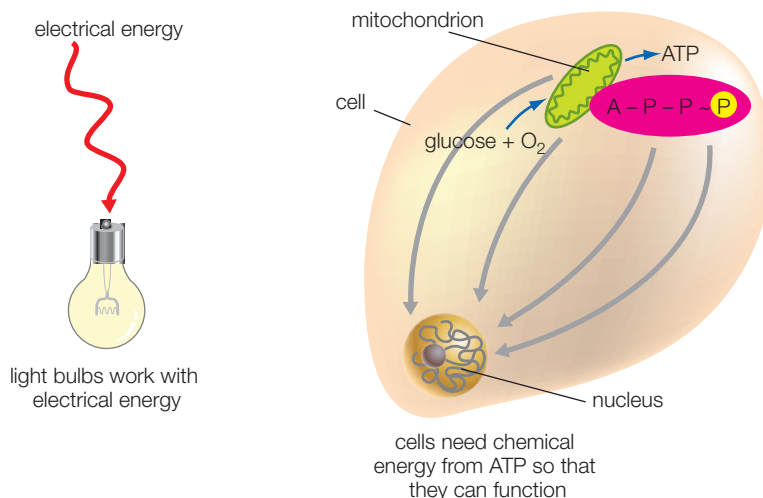
## Nutrients that provide cellular energy

All living things require energy in order to survive. Machinery in a factory or the lights in your home need energy in the form of electricity to function. In a similar way, the cells in living organisms require energy so that they can function. The energy required by living cells is not electrical energy but a type of *chemical energy* called **ATP (Adenosine TriPhosphate)**. (See Fig. 3.4.) So we ask, what then is the role of organic nutrients (and glucose in particular) in providing living things with energy? The energy

of ATP powers all cellular activities and can be produced by cells when they break down glucose—the energy trapped in glucose is released when it is broken down and can be captured and incorporated into the high energy compound, ATP. This process is known as *cellular respiration* and takes place in mitochondria in cells: glucose is combined with oxygen during this process, to produce ATP.

## Summary

In summary, autotrophs make their own food, whereas heterotrophs rely on other organisms as a source of organic nutrients. Organic nutrients are a source of energy for cell functioning. Organic nutrients can be broken down to release energy that is captured in ATP, the energy essential for cell functioning.



**Figure 3.4** Energy is required for things to work

## 3.3

## Autotrophic nutrition

In this section we will deal with:

- photosynthesis
- absorption of minerals
- obtaining light and gases.

## Autotrophic nutrition: photosynthesis

- *identify the materials required for photosynthesis and its role in ecosystems*



Table outlining the requirements for photosynthesis

## Requirements for photosynthesis

Carbon dioxide, water, chlorophyll and light are all essential for the chemical process of photosynthesis to occur in cells. Photosynthesis is the process by which all green plants and some unicellular organisms and bacteria make food: plants capture energy from **light** (radiant energy,) using **chlorophyll**, a green pigment present in plant cells. This energy is used to combine *carbon dioxide* (a gas obtained from the surrounding air) and *water* (which the plants absorb from the soil and then transport up to the leaves), to make sugars and oxygen. (See Fig. 3.5).

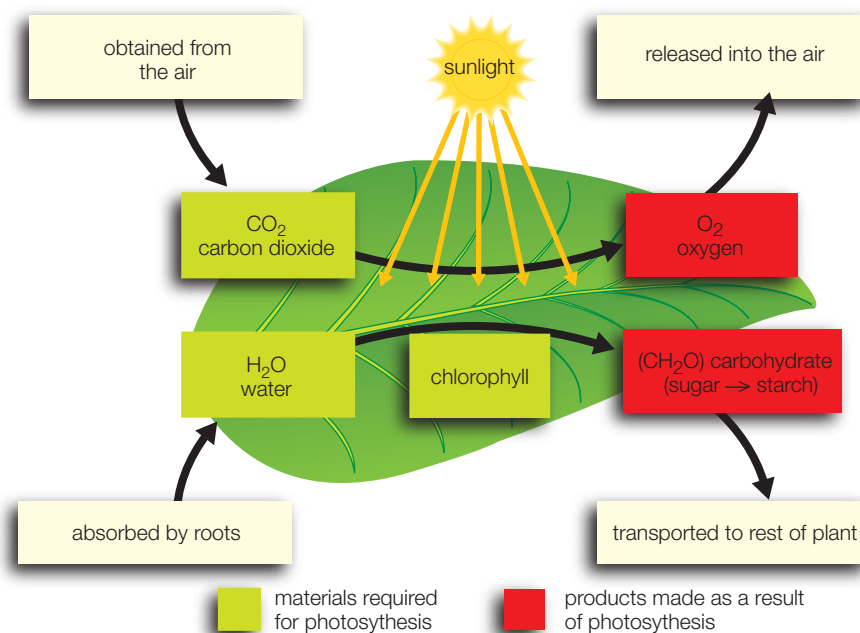
The water ( $\text{H}_2\text{O}$ ) and carbon dioxide ( $\text{CO}_2$ ) provide the basic chemical 'building blocks' (atoms) of

which the resulting sugar ( $(\text{CH}_2\text{O})_n$ ) is made. Oxygen ( $\text{O}_2$ ) is given out as a by-product of photosynthesis. The energy conversion involves a change from *radiant energy* (sunlight or artificial light) to *chemical energy* (stored in glucose). Chlorophyll is essential for this energy conversion to occur. This is an oversimplification of the process of photosynthesis, which involves a sequence or chain of many biochemical reactions, but these will be dealt with in more detail on pages 136–8.

## The role of photosynthesis in ecosystems

Photosynthesis is the initial pathway by which energy enters all ecosystems. Organisms that photosynthesise are

**Figure 3.5**  
Materials required for photosynthesis (and products of photosynthesis)





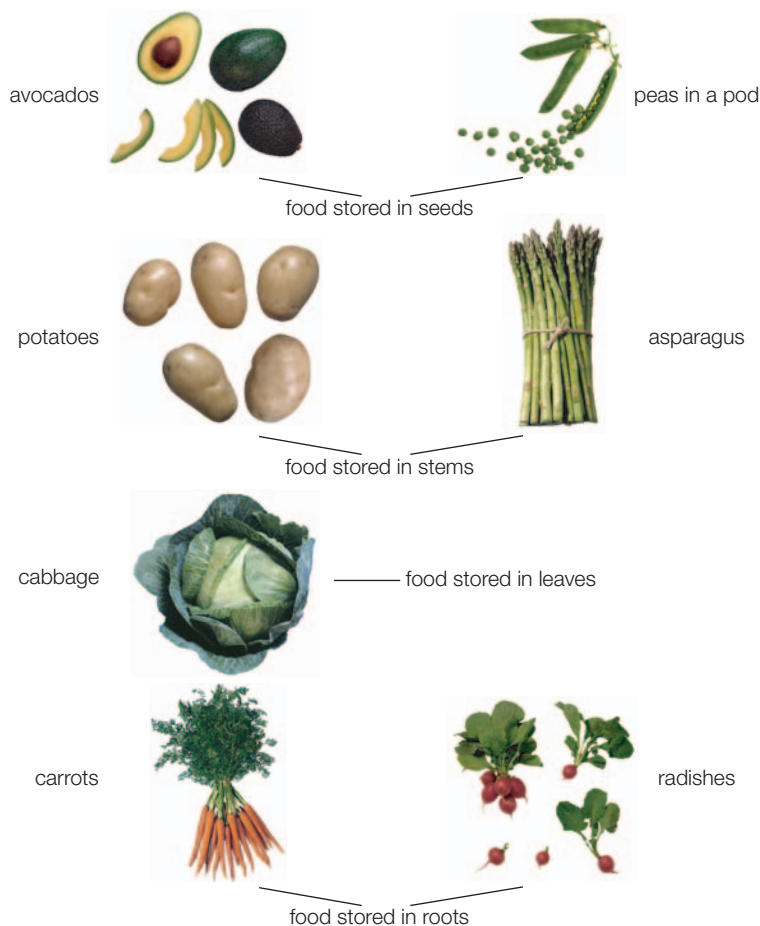
**producers.** Producers form the *basis of all food webs*, providing glucose (and other forms of stored food) for all living organisms, either directly (e.g. plants are eaten by herbivores) or indirectly (e.g. herbivores, which have eaten plants, are eaten by carnivores). Glucose, the product of photosynthesis, can be converted by plants into other organic compounds for storage. Glucose may be converted into and stored as:

- lipids (e.g. sunflowers and avocados which store their food as oils)
- proteins (e.g. legumes such as bean and pea plants)
- complex carbohydrates (e.g. potato plants).

These organic compounds, which rely on photosynthesis for their production, provide the structural basis of living cells and also provide a source of energy for all cellular processes (see Fig. 3.6).

Atmospheric *gases* essential to living organisms are *recycled* during photosynthesis—the process of photosynthesis provides oxygen for the respiration of all living things. It also removes carbon dioxide from the atmosphere and, since elevated carbon dioxide levels are harmful to living organisms and contribute to increased global warming, photosynthesis is beneficial to the environment.

*Fossil fuels* were formed from photosynthetic organisms approximately 300 million years ago. Huge tree ferns and other large leafy plants on land, as well as algae in the sea, sank to the bottom of the swampy oceans and were buried during the Carboniferous Period. Over many thousands of years, as a result of the pressure of the sand, clay and minerals that were deposited on top of them, they turned into coal, oil or petroleum and natural gas, which all serve as sources of fuel for us today.



**Figure 3.6** Plant organs that store organic compounds as food for consumers



**FIRST-HAND  
INVESTIGATION  
BIOLOGY SKILLS**

P11  
P12  
P13  
P14



Students can be guided in their planning of these experiments using the scaffold 'Five steps of investigation'.

## Investigating requirements for photosynthesis

- *plan, choose equipment or resources and perform first-hand investigations to gather information and use available evidence to demonstrate the need for chlorophyll and light in photosynthesis*

### Background information

To find out what plants need in order to *photosynthesise*, we can test what factors allow the plant to produce *starch*—starch is one of the common end products of photosynthesis (glucose is stored as starch).

It has been suggested that plants need light, carbon dioxide, chlorophyll and water to produce starch by the process of photosynthesis. Factors such as these affect the ability of a plant to photosynthesise and so are termed the *limiting* factors of photosynthesis. The syllabus requires you to test whether light and chlorophyll are necessary for photosynthesis. You can do experiments to find out if chlorophyll and light are factors needed for starch production. You will need to do a separate experiment for each factor, since only one factor at a time can be varied in any experiment to make it scientifically valid.

### Procedure

The following information will help you to design your experiments.

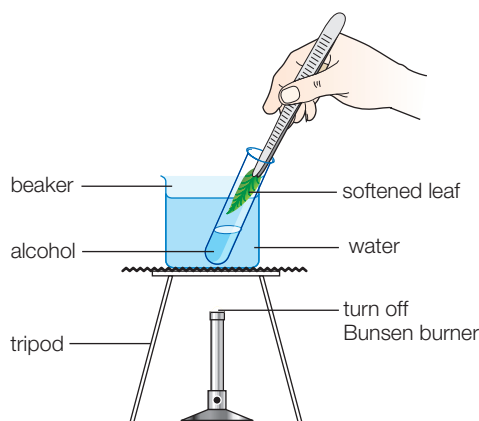
- For each experiment you should use a control: in the *control* leave out one factor, for example, light or chlorophyll. In the *experimental*, provide this factor that you have left out in the control to validate your experiment and show that it is that factor which is essential for starch production.

- To test a leaf for starch, the following method below should be followed:
  - place a leaf into a beaker of boiling water for 1 or 2 minutes, until it is soft (the length of time depends on the thickness of the cuticle of the leaf). Placing it in water softens the leaf tissue and breaks down the cell wall to allow substances to enter and leave the cells more easily. *Turn off the Bunsen burner before proceeding*
  - pour enough ethanol or methylated spirits into a test tube to cover the leaf. Place the leaf into the test tube of ethanol. Place the test tube into the hot water (with the flame beneath turned OFF) and leave it until the ethanol turns green and the leaf becomes pale. This step removes the chlorophyll from the leaf so that it does not mask any colour change that may be observed
  - remove the leaf from the test tube and rinse it in the hot water in the beaker. This will re-soften the leaf tissue
  - place the leaf on a watch glass and cover it with a few drops of dilute, fresh iodine solution. Leave it to stand for a 3 to 5 minutes so that the iodine can soak in. Give the leaf a quick rinse in water and examine it for dark (blue–black) patches which indicate the presence of starch.

### Choosing equipment and resources

- Read through the standard test for starch (above) and list the equipment you would need to safely carry out the investigation.
- To test whether light is necessary for photosynthesis, start with a plant that has no starch. To remove starch, put the plant in the dark for a few days.
- Expose the plant to light again, covering some leaves with aluminium foil or black paper to keep out the light. Alternatively, you could use an outdoor plant with some leaves covered or a black bag over part of the plant. Remember that it may take several days for these leaves to use up all the starch they already contain; however, you will need to perform the starch test before the exposed leaves begin to transport starch back to those lacking starch.

**Figure 3.7** Extracting chlorophyll using a water bath



- It is not possible to remove the chlorophyll from a leaf without killing the plant, so you should make use of nature and use a plant that has *variegated* leaves; that is, leaves that occur in nature that are partly green (tissue contains chlorophyll) and partly white/yellow (tissue contains no chlorophyll). Some examples are geraniums (*Coleus*), certain types of ivy and 'hen and chicken' plants (Crassulaceae).
- Decide what plant you will use for each experiment, taking into consideration the fact that using softer leaves with a thin cuticle will make it easier to break down the cell walls and expose the starchy contents for the iodine test.
- Make sure the control plant has everything that it needs, excluding the one factor that you want to test.

### Planning your investigation

(Refer to the biology skills table on pages x–xii.)

- Plan your investigation, preparing a written experimental procedure under the headings Aim, Hypothesis and Materials.
- Draw a diagram to illustrate the apparatus set up to use a water bath.
- Include a risk assessment and state what you will do to avoid risks and ensure a safe procedure.
- Plan and write out a method for your experiment (using a procedure text type).
- Remember to outline what you will do to make the test fair. For example:
  - identify dependent and independent variables
  - control all other variables
  - state how you will measure the independent variable
  - state any modifications made after a trial run
  - describe the controls.
- Prepare an appropriate way to record your results.
- Once your method has been checked by your teacher, conduct your experiment, record your results and use this evidence to state a valid conclusion from your results, looking at the aim of your experiment to ensure you 'answer' it. No inferences should appear in your conclusion.
- In your discussion, explain your results (any inferences should be made here), discuss whether your findings were what you expected and account for sources of any experimental errors. Describe how you could modify the experiment in the future to reduce error.
- Answer all discussion questions in the following list.

### Discussion questions

*To investigate whether chlorophyll is necessary for photosynthesis*

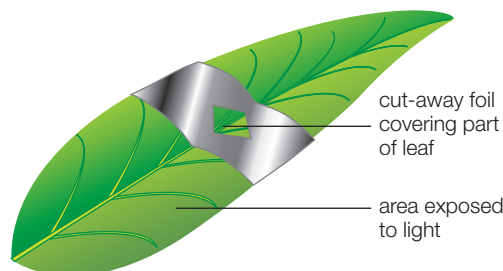
1. Is chlorophyll soluble in ethanol? **Justify** your answer using evidence from your experiment.
2. State why it is necessary to remove chlorophyll before testing the leaf for starch.
3. **Explain** why removing chlorophyll at this stage of the experiment does not interfere with the aim of the experiment.
4. **Identify** which part of a variegated leaf contains starch.

*To investigate whether light is necessary for photosynthesis*

5. **Explain** why a leaf that has been left in the dark is 'destarched'. Propose a suggestion as to what may have happened to the starch that was originally present in the leaf.
6. **Discuss** why it is safer to use a hot water bath to heat ethanol, rather than using a Bunsen burner.
7. **Explain** why, if a destarched leaf is covered with foil and the remainder of the plant is left exposed to sunlight for three or four days, the results of your experiment may show that starch is present in the covered leaf.
8. Propose how you would investigate whether carbon dioxide is necessary for photosynthesis.
9. If only part of a leaf is covered with tin foil, a 'starch print' could be obtained. Predict the expected results if the following destarched leaf (see Fig. 3.8) was left in sunlight for a day and then tested for the presence of starch. Draw a diagram to illustrate the predicted result.

*General questions*

10. **Discuss** why it is necessary to use a control.
11. **Explain** what is meant by non-destructive testing and how this was achieved in your experiment.



**Figure 3.8**  
Destarched leaf exposed to sunlight for 24 hours

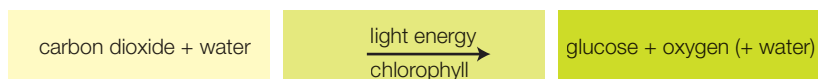
## 3.4

## Photosynthesis: biochemistry

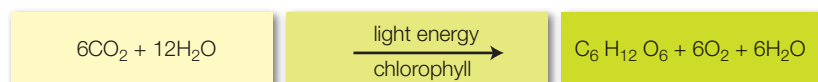
- *identify the general word equation for photosynthesis and outline this as a summary of a chain of biochemical reactions*

## Photosynthesis: equations and reactions

The word equation for photosynthesis is:



The balanced overall chemical equation is:



Although photosynthesis is often represented by the general equation shown above, it is not one chemical reaction but a series of many chemical reactions that take place in the chloroplasts of green plant cells and the cells of some photosynthesising bacteria.

Photosynthesis takes place in two stages. Each stage or phase is not a single chemical reaction, but consists of a series or chain of reactions:

1. the **light phase (photolysis)** involves the *splitting of water* using the energy of light (photo = light; lysis = splitting)
2. the **light-independent phase** (sometimes referred to as the **carbon fixation** stage) involves *using carbon dioxide to make sugar*. No light is used in this stage.

Each step of these reactions is controlled by a different enzyme (a chemical catalyst which speeds up reactions in living cells). These series of reactions have been outlined in a simplified form below.

**The light phase—photolysis**

Radiant energy from the sun (or an artificial source of light) is captured by chlorophyll in the thylakoids in the grana of chloroplasts. The energy is sufficient to excite an electron to a higher energy level, where it will break

away from the chlorophyll molecule. This series of reactions is occurring in each chlorophyll molecule in every chloroplast exposed to light. There are thousands of chlorophyll molecules in one chloroplast and so thousands of excited electrons are produced. (See Fig. 3.11.)

An excited electron can follow one of two pathways:

1. it may be used to split water into a hydrogen component ( $\text{H}_2$ ) and an oxygen atom (O). The oxygen atom combines with an oxygen atom from another chlorophyll molecule to form oxygen gas ( $\text{O}_2$ ), which is released by the plant. The hydrogen atoms will go on to be used in the next phase, the light-independent reaction.
2. it may be used to form ATP, a high-energy compound that provides the cell with the energy it needs for functioning.

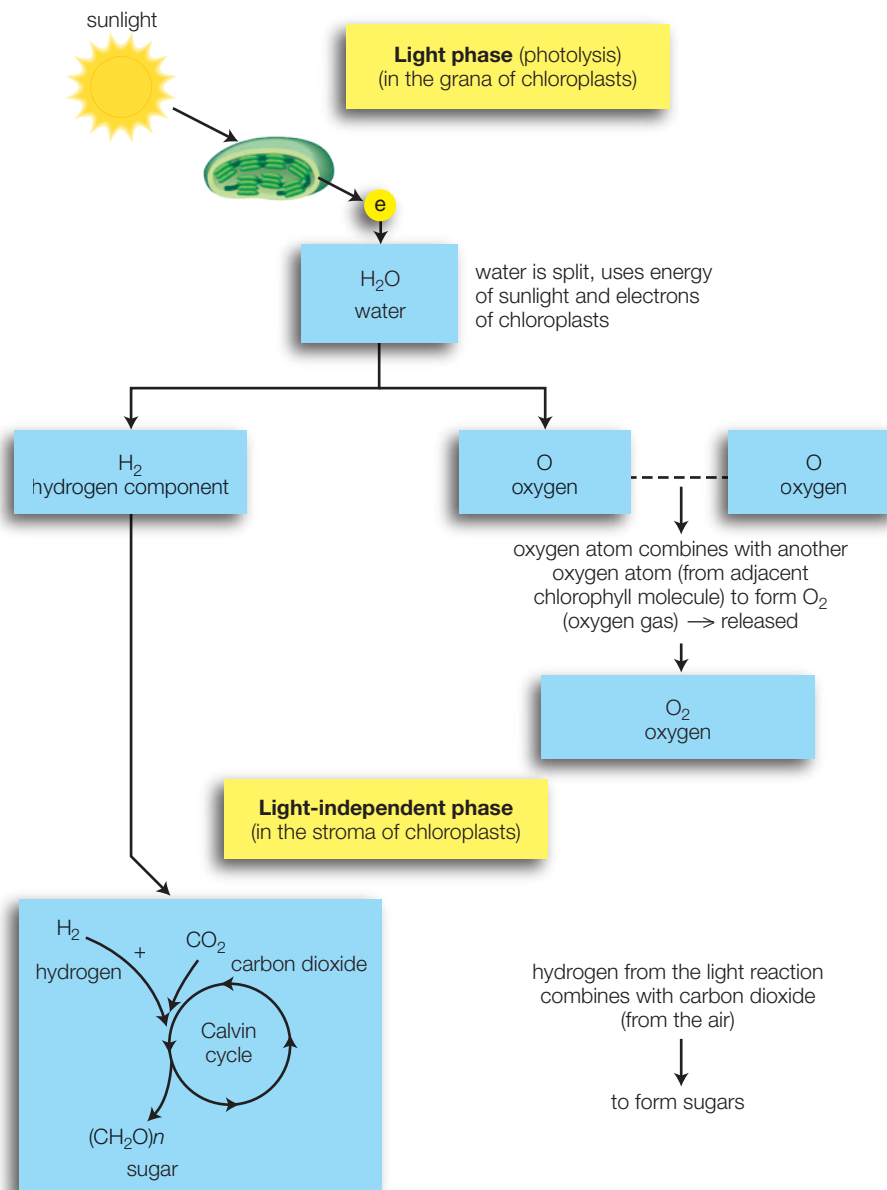
**The light independent phase—carbon fixation**

(See Fig. 3.11.) This phase uses carbon dioxide, but requires no chlorophyll and no light, so it is called the light-independent phase or carbon fixation phase:

- hydrogen atoms from the light reaction are carried to the **stroma** to begin this phase



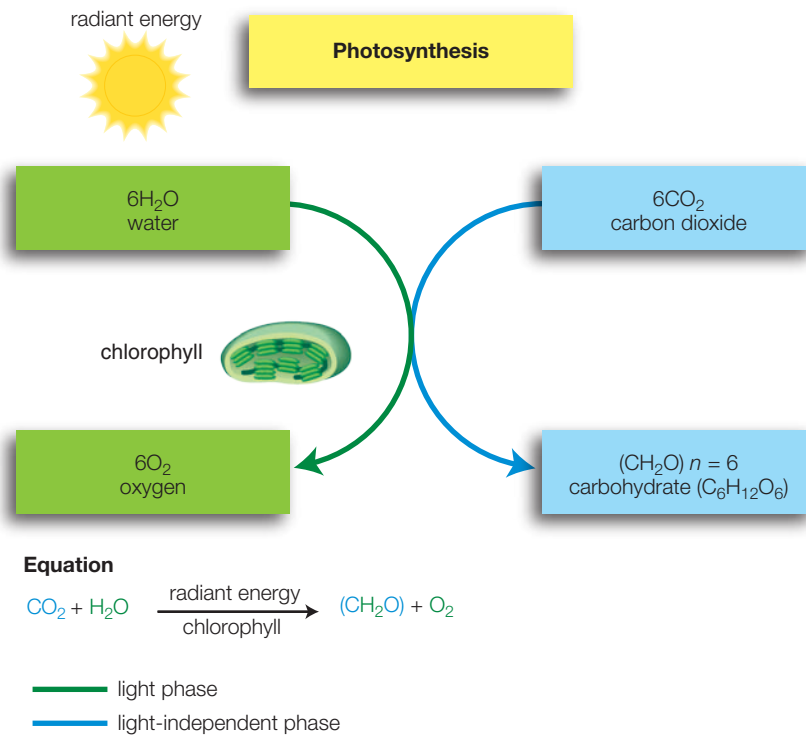
More detailed  
biochemistry



**Figure 3.9**  
Flowchart outlining the light and light-independent phases of photosynthesis

- carbon dioxide needed for this reaction was absorbed by the plant from the surrounding air. The *hydrogen* atoms go through a series of enzyme-controlled reactions, where they are *combined with carbon dioxide* to form a *sugar molecule* (glucose)
- this cyclical series of reactions is known as the Calvin cycle, named after Melvin Calvin, the Nobel Laureate who discovered it
- the *ATP* produced in the light reaction provides the necessary *energy* for the light-independent reaction to take place. The energy from ATP is incorporated into the new sugar compounds that are formed
- the *glucose* end-product of photosynthesis is converted to *starch*, the form in which food is most commonly stored in plants. Chloroplasts usually have large

**Figure 3.10**  
Flowchart summarising a simplified overall reaction for photosynthesis, colour-coded for the light and light-independent phases



starch grains stored in the stroma, evidence that photosynthesis has occurred. To experimentally test whether photosynthesis has occurred in a plant, you need to simply test for the presence of starch

- as mentioned previously, some plants convert starch into different organic storage compounds such as lipids or proteins, depending on the plant.

The light-independent phase of photosynthesis takes place immediately following the light phase (since it relies on products of the light phase) and so both phases occur during daylight. At night, because there is no light and therefore no source of radiant energy, neither the light dependent nor the light-independent phases take place—there is no photosynthesis at night.

### Summary of products of photosynthesis

- Light phase: the radiant energy of sunlight is captured by chlorophyll and used to split water into hydrogen and oxygen. The oxygen is released by the plant into the atmosphere. The hydrogen is carried on to the next phase.
- Light-independent phase: the hydrogen atoms from the light reaction are combined with carbon dioxide to form sugar molecules (C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> = glucose):
  - the carbon and oxygen atoms of the carbohydrate come from the carbon dioxide (CO<sub>2</sub>)
  - the hydrogen atoms of the sugar come from the water (H<sub>2</sub>O)
  - the oxygen that is released in the light stage also comes from the water.

## 3.5

## Autotrophic nutrition: obtaining water and inorganic minerals

- **explain the relationship between the organisation of the structures used to obtain water and minerals in a range of plants and the need to increase the surface area available for absorption**

Roots are the structures in plants for absorbing water and inorganic minerals. These structures have an extensive surface area which allows water and inorganic mineral salts to be absorbed efficiently. The outermost layer of plant organs is the epidermis and it is through epidermal cells in the root that the absorption of water and minerals occurs (see Fig. 3.1).

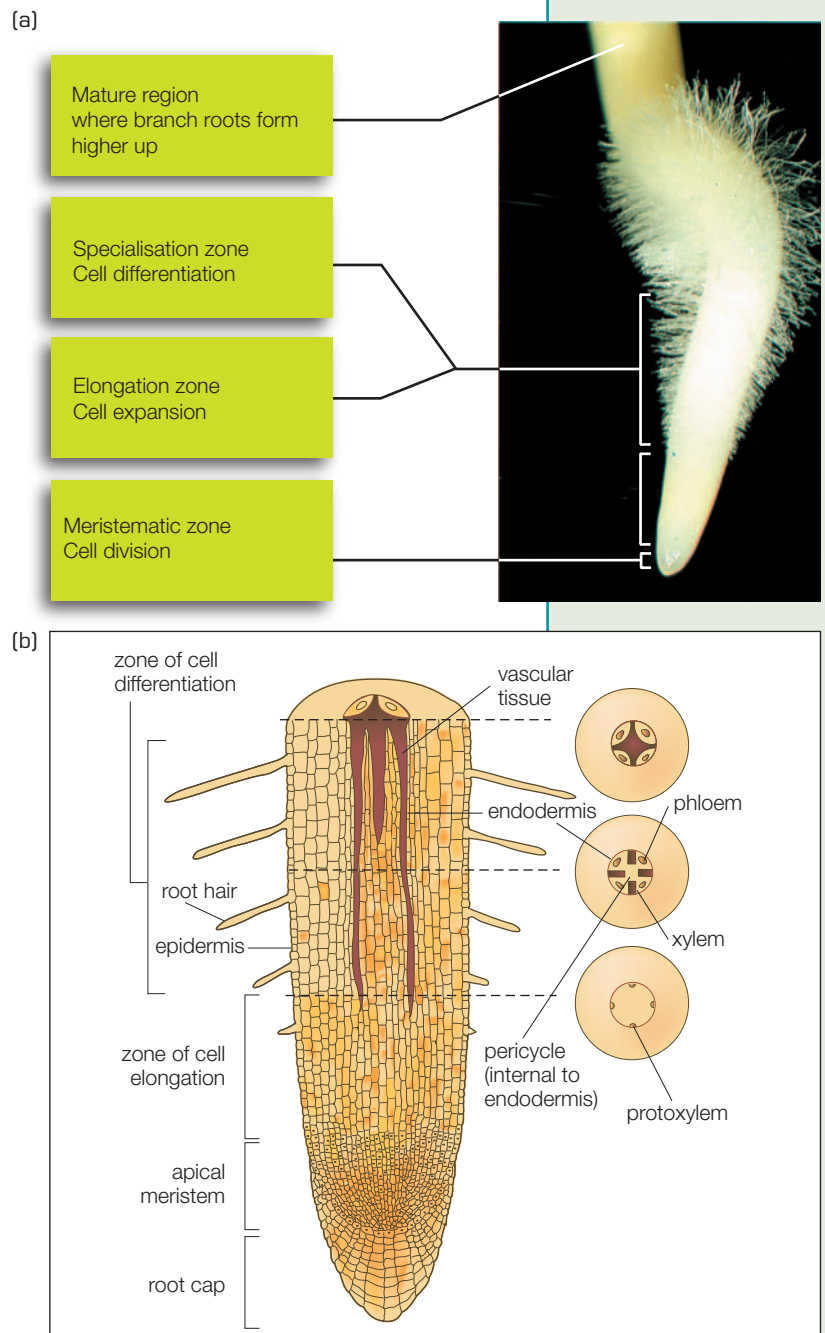
### Water uptake

Plants need to absorb large quantities of water and do so at a high rate to maintain their water balance. The uptake of water in roots occurs by the process of **osmosis**: when water in the soil is at a higher concentration than the cell sap of root cells, water will move from the soil into the root by osmosis. This is a *passive* form of transport and occurs *slowly*, so it is essential that the surface area of structures involved in absorption is increased.

### Uptake of minerals

The uptake of inorganic mineral salts is mainly by the process of **diffusion**: if the minerals are in a higher concentration in the soil than they are in the cells of the roots they will move *passively* into the roots. Remember that salts dissociate into ions—charged particles—when they are dissolved in water and it is in this form that they are absorbed. For example, the *mineral salt* sodium chloride (NaCl) will *dissociate* into sodium ions ( $\text{Na}^+$ ) and chloride ions ( $\text{Cl}^-$ ). These *ions* are absorbed into the roots mainly by diffusion but, if diffusion alone

**Fig 3.11** Roots of plants: (a) the structure of a root tip (external view); (b) longitudinal section through root tip showing the organisation of tissues (cross-sections are shown for three regions)



is inadequate (e.g. if it is too slow or if the concentration gradient is not significant), **facilitated diffusion** and **active transport** may also be involved.

### Increased surface area

The uptake of both water and mineral salts depends on a large area of contact between the roots and the soil water containing the dissolved minerals.

An increased surface area in roots is achieved in the following ways:

- the *root hair zone* is in the younger part of each root, near the tip. In this region, the epidermal cells protrude outwards into the surrounding

soil, as microscopic extensions called root hairs. Their presence increases the surface area of a root up to 12 times. (See Fig. 3.11a.) The *growing regions* of the roots (the meristematic zone of cell division and the zone of elongation) are nearer to the root tip, protected by the root cap, while cells further away from the tip are older and more mature (see Fig. 3.11b). As a root grows, the older cells mature and differentiate. Root hairs which form in the young root hair zone should not be confused with much larger, macroscopic lateral or branch roots, which form in the mature region of the root where the cells have differentiated and are mature

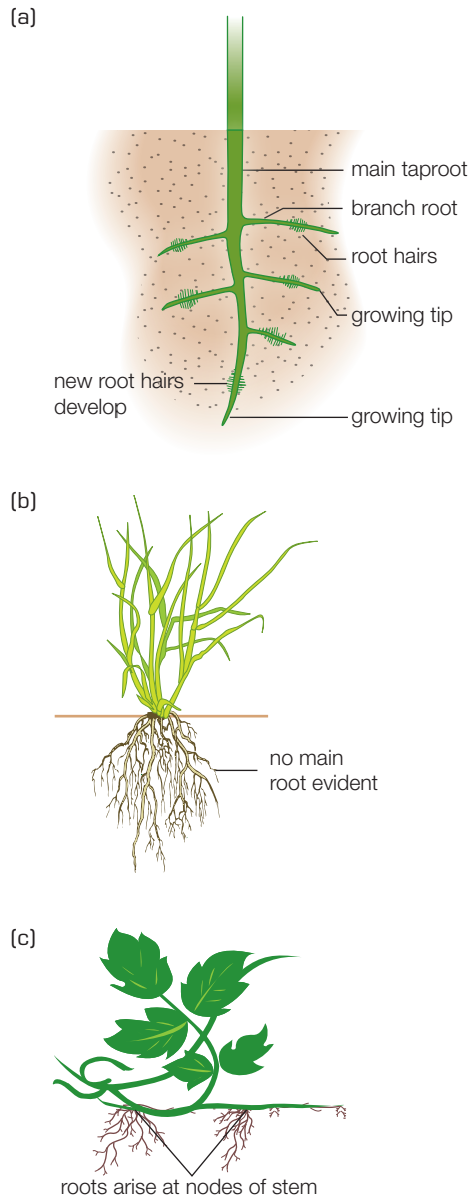
- *extensive branching* of root systems in the mature region increases the surface area of the root for absorption (and also provides good anchorage for the plant). Roots may branch in one of three ways, forming:

- a *tap root* system (one main root with many smaller branch roots which subdivide extensively)
- a *fibrous* root system (many main branches which subdivide) or
- an *adventitious* root system (the roots arise at regular intervals from the nodes of a stem, for example in creeping stems such as ivy or along horizontal stems such as grasses and onion bulbs). (See Fig. 3.12.)

- water enters the root through the epidermal cells across the entire surface of the root system. The flattened nature of these cells increases their exposed surface, but the surface area of general epidermal cells is smaller than that of root hair cells and so less water is absorbed per cell than in the root hair zone (see Fig. 3.13a).

**Figure 3.12**

Types of root systems:  
(a) a tap root system;  
(b) a fibrous root system;  
(c) an adventitious root system

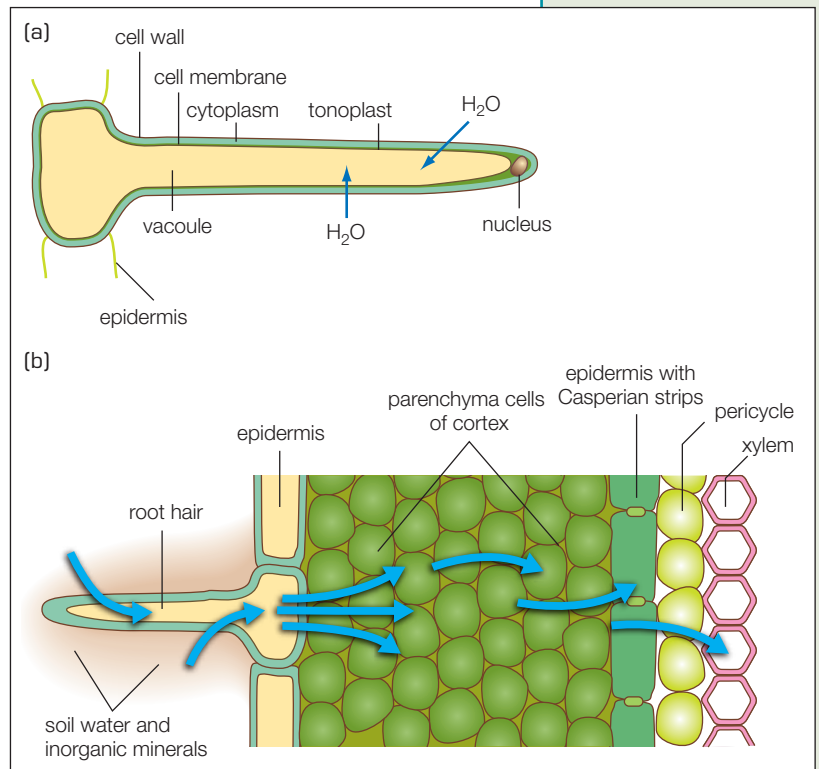




## Movement of water and minerals across roots

Water and minerals that enter the root through the epidermal cells, particularly through the root hairs in the root hair zone, move across the root to the water-conducting tissue called **xylem**, found in the centre of the root. Water moves by osmosis through the cells (cytoplasm or vacuoles), but may also move through the cell walls. The water and minerals then move across the cortex, along a gradient, into the central vascular (transport) tissue. Xylem transports water and dissolved mineral salts upwards from the roots to the rest of the plant, where it is needed for normal plant functioning.

**Figure 3.13** Water movement into a root: (a) absorption of water by root hair; (b) movement of water across the root



## Autotrophic nutrition: obtaining light and gases

### ■ explain the relationship between the shape of leaves, the distribution of tissues in them and their role

Leaves are the main photosynthetic structures in plants. Their primary function is to absorb sunlight and make food. They also carry out the function of transpiration.

#### The role of leaves

Plants need to *photosynthesise*:

- to absorb sunlight and carbon dioxide during the day
- to release oxygen
- to provide chlorophyll
- to make glucose and transport it to other parts of the plant where it can be stored as starch or other organic molecules.

*Transpiration* is needed to release water to cool the plant down and to create a suction pull to lift water from the roots to the top of a plant (similar to sucking water up a drinking straw—

the suction pull at the top causes water flowing in at the bottom to rise).

It is a common misconception that ‘plants do not respire, they photosynthesise instead’ or ‘plants only respire at night’. Both of these statements are untrue. Respiration is a function of *all* living cells; in leaves it is simply ‘masked’ or hidden by photosynthesis and so the observed exchange of gases by plants during the day differs from that at night and it is this that causes confusion. In all plant cells, chemical respiration occurs during both the day and the night. During the day:

- the oxygen required for cellular respiration comes from the oxygen produced as a by-product of photosynthesis. Photosynthesis usually occurs at a greater rate than

# 3.6

that of respiration during the day, so any excess oxygen not used during respiration is released by the plant to the outside environment

- the carbon dioxide released as a result of respiration during the day is used as a reactant for photosynthesis. With a high rate of photosynthesis, this carbon dioxide supply is usually insufficient so plants absorb more carbon dioxide from the air. The net gaseous exchange observed during the day is therefore that associated with photosynthesis, despite the fact that respiration is occurring.

a source of food and therefore energy, leaves must be extremely well suited to fulfill their role.

The structural features needed by a leaf for efficient photosynthesis are:

- a large surface area, with an outer layer able to absorb light and carbon dioxide
- pores in the leaf surface for the exchange of gases with the environment
- cells inside that contain chloroplasts (and chlorophyll) to trap the energy of sunlight
- a water transport system from the roots to the leaves
- a food transport system from the leaves to other parts of the plant.

### The structure of leaves in relation to their function

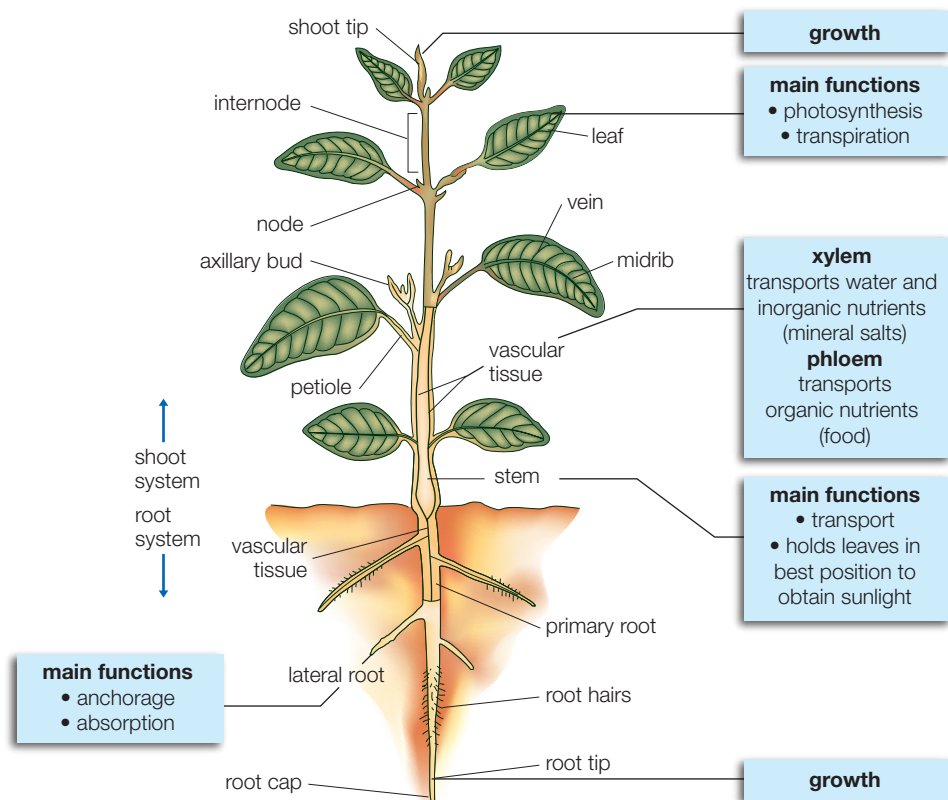
Leaves are structurally adapted to enable them to effectively function. They are made up of a number of different tissues, arranged in a highly organised way to maximise their efficiency in carrying out their functions. Since all life depends on photosynthesis in plants as

### Absorption of light and photosynthesis

Leaves have an enormous diversity of shapes and sizes, but most are *flattened in shape* and relatively thin, resulting in a large surface area that is exposed to the sun. This allows the maximum

**Figure 3.14**

The structure of a flowering plant showing the arrangement and functions of the organs of a young eucalypt, with primary stem and root (portion cut away to show vascular bundles)



absorption of light for photosynthesis. Because of the thin nature of the leaf *no internal cell is too far from the surface* to receive light. In all leaves the outermost layer of cells, the epidermis, is *transparent*, allowing the sun to penetrate through to the photosynthetic cells inside the leaf.

### Gaseous exchange

The surface of leaves is covered by a protective layer of cells, the **epidermis**. These are simple, flattened cells on the top surface (upper epidermis) and lower surface (lower epidermis) of leaves. Epidermal cells protect the delicate inner tissues and are able to secrete a waterproof cuticle to prevent the evaporation of water from the increased surface area of leaves. They are transparent to allow light to pass to the cell layers below.

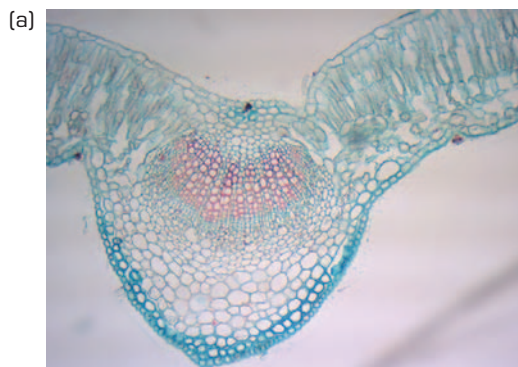
Within the epidermis, there are specialised cells called **guard cells** that control both the exchange of gases (such as carbon dioxide and oxygen) and the loss of water through leaves. Guard cells are bean-shaped cells that occur in pairs, surrounding a pore (opening) known as a stoma (plural stomata). Stomata occur on both the upper and lower surfaces of leaves but are usually more numerous on the under-surface of leaves. (Because water is lost in the form of water vapour,

a gas, this is discussed in more detail in Chapter 4, which deals with gaseous exchange in leaves.)

### Photosynthetic cells and tissue distribution

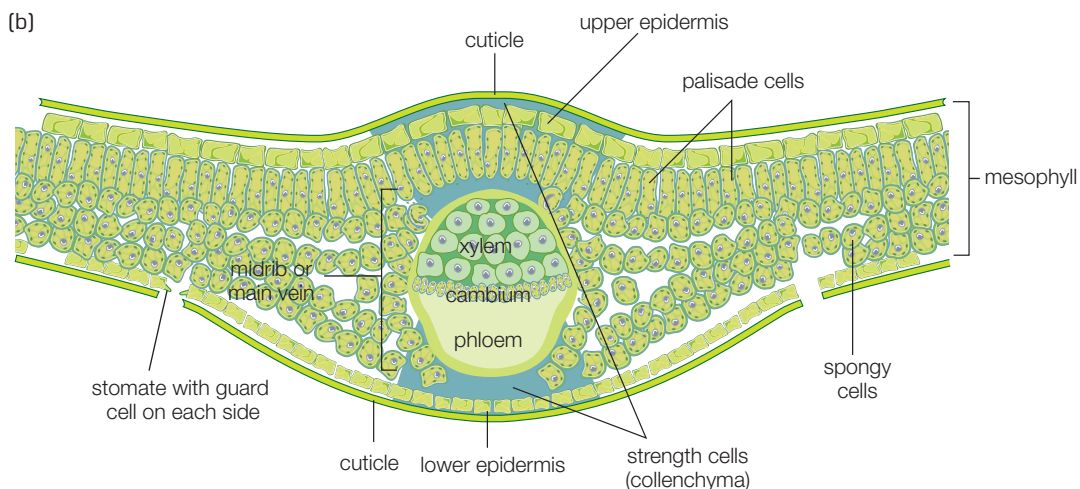
The cells that occur in the **mesophyll** or middle layers of the leaf are responsible for most of the plant's photosynthesis. Two main types of cell make up the mesophyll ('meso' = middle, 'phyll' = leaf)—**palisade cells** and **spongy cells**:

- *palisade cells* are elongate cells that contain numerous chloroplasts and they are the *main photosynthetic cells* in leaves. They are situated immediately below the upper epidermis (see Fig. 3.15a)
- *spongy cells* are the second most important *photosynthetic cells*. They have fewer chloroplasts than palisade cells and are irregular in shape. They have large intercellular



**Figure 3.15**

A dorsiventral leaf: (a) light micrograph cut in a transverse section; (b) plan diagram in a transverse section



air spaces, particularly beneath the stomata, and their main function is *gaseous exchange*. They are situated lower in the leaf, beneath the palisade tissue and above the lower epidermis in **dorsiventral** leaves.

The distribution of photosynthetic tissue in leaves is directly linked to the orientation of leaves on the plant. Most plants have leaves that are *horizontal*—with the upper surface facing the sun and the lower surface shaded.

In these plants the upper surface faces the sun while the lower surface is shaded. The tissue distribution in these leaves is different on the upper and lower surfaces and so the plants are said to have dorsiventral leaves.

Some plants have leaves that hang vertically and so both surfaces are exposed to the sun. (See Fig. 3.16.)

In plants that have leaves that hang *vertically* (e.g. adult leaves in some eucalypts), both surfaces are exposed to the sun. In these leaves, tissue distribution on the upper surface is the same as that on the lower surface, so there is an additional layer of palisade tissue beneath the spongy mesophyll,

just above the lower epidermis. Stomata are also equally distributed in both the upper and lower epidermis. As a result, the upper and lower halves of the leaf have the same pattern of tissue distribution and so these leaves are termed **isobilateral** ('iso' = the same; 'bi' = two; and 'lateral' = sides). (See Fig. 3.16.)

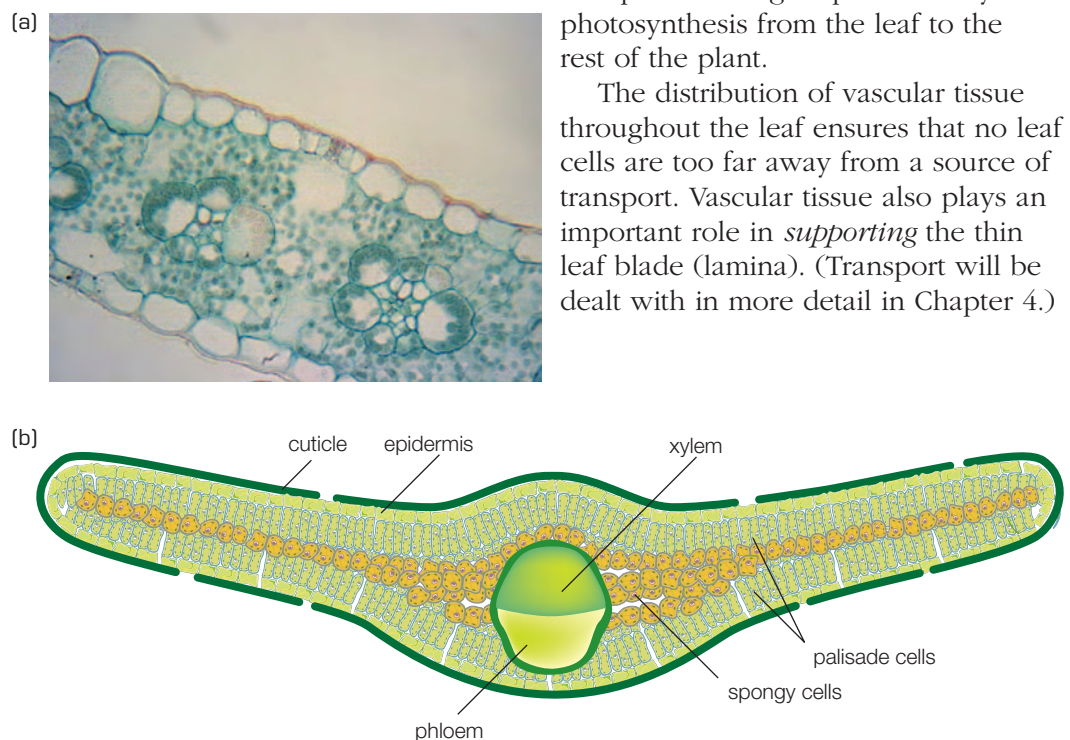
## Transport

The **vascular tissue** in the centre of the root is continuous, passing up the stem and into the leaves as 'veins' in the leaf, serving as the main transport tissue in the plant. (The term *vascular* means '*of vessels*', i.e. tissue arranged as vessels, as in transport vessels.) The main vein is called the **midrib** and many smaller veins branch out from it in certain types of plants (**dicotyledons**), such as eucalypts. In other plants (**monocotyledons**), such as grasses, all veins run parallel to each other. Veins are made of two types of tissue: xylem and phloem. *Xylem* transports *water* and *dissolved inorganic minerals* to the leaf for photosynthesis and *phloem* tissue transports the *sugars* produced by photosynthesis from the leaf to the rest of the plant.

The distribution of vascular tissue throughout the leaf ensures that no leaf cells are too far away from a source of transport. Vascular tissue also plays an important role in *supporting* the thin leaf blade (lamina). (Transport will be dealt with in more detail in Chapter 4.)

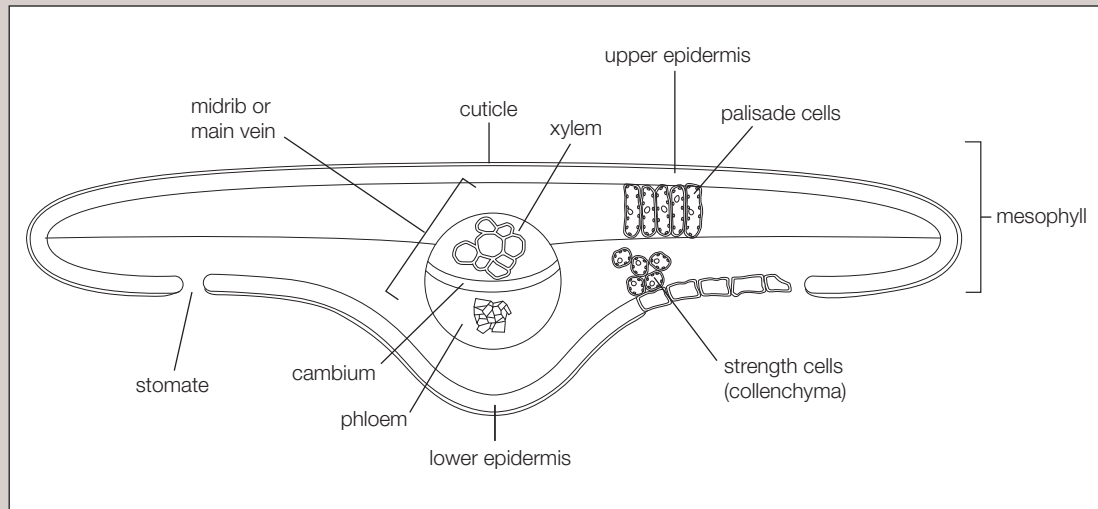
**Figure 3.16**

Isobilateral leaves:  
(a) photomicrograph of isobilateral leaf in transverse section;  
(b) diagram showing cell distribution



## STUDENT ACTIVITY

1. In the form of a table, compare the different types of tissue found in a leaf in terms of their structure, position within the leaf, functions, and structural features that suit them to their functions.



**Figure 3.17** Dorsiventral leaf plan diagram showing a few cells of each type

2. On Figure 3.17 shade each of the cell/tissue types listed in the table in a particular colour (refer to the Student Resource CD or the Teacher's Resource CD for a copy). Use a key to allow interpretation of the colours. Try to make the colours appropriate to the functions of the tissues (e.g. green for mesophyll, where dark green is palisade (more chloroplasts) and light green is spongy).
3. Draw and label a plan diagram of an isobilateral leaf (see Fig. 3.16), using the plan sketch of the dorsiventral leaf above as a guide. Shade the tissue types using the same key as you used for the dorsiventral leaf plan.



Table comparing tissues in leaves

## Heterotrophs obtaining nutrients

### Introduction

Heterotrophs are living things that must feed on others because they cannot provide their own energy supply by photosynthesis. The **carbohydrates**, lipids and proteins, originally made by autotrophs, are consumed by heterotrophs and are then broken down—large chunks of food are broken down into smaller units (simple, single molecules which are usually soluble) so that they can be easily absorbed.

In heterotrophs, obtaining nutrients and energy from food involves several steps:

- **ingestion** is the intake of complex organic food ('eating')
- **digestion** is the breakdown of the chunks of food into smaller, simpler, soluble molecules that can be easily absorbed. Physical digestion is mainly as a result of food being chewed, but food may also be broken down by the churning action of the muscular stomach wall.

# 3.7

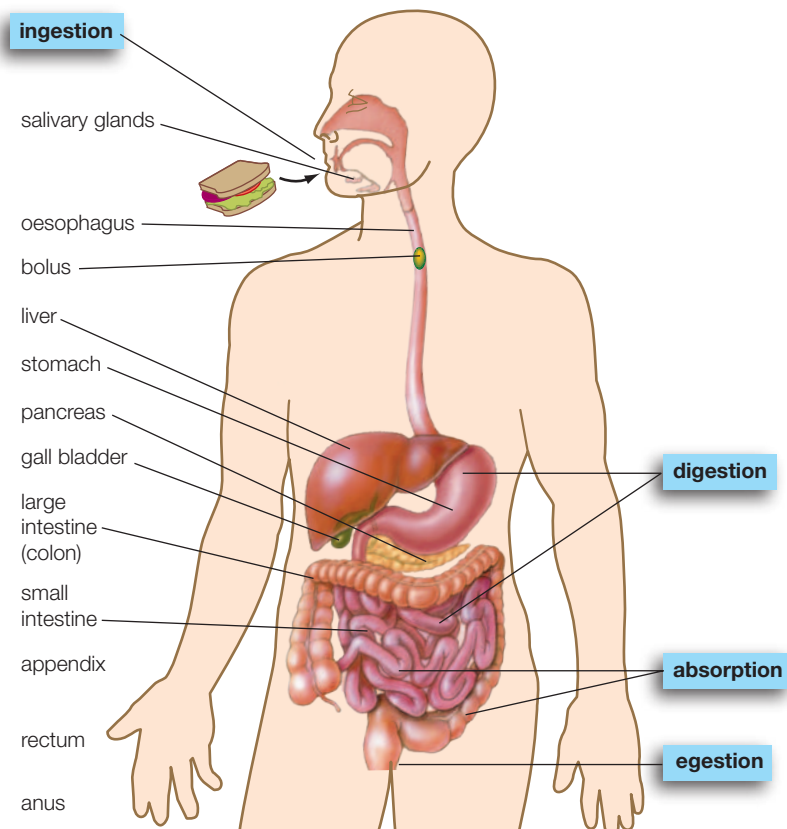
The aim of digestion is to obtain molecules small enough for absorption. These end products are: *amino acids* from proteins, *simple sugars* from carbohydrates and *fatty acids* and *glycerol* from lipids

- **absorption:** the basic units of food (glucose, amino acids, fatty acids and glycerol) are small enough to be absorbed across the wall of the digestive tract, into the bloodstream of the animal or, in simpler animals, directly into the cells
- **assimilation:** the end products of digestion can be built up by the body into useful substances, either as new biological material or as an energy source. For example, in mammals such as humans, blood transports the food molecules to where they are needed in the body and they can then be reassembled

by the cells of the body into *structural parts* (e.g. lipids and proteins that form a structural part of cell membranes; protein fibres in muscle tissue) or into *energy storage* (e.g. fatty tissue or fat beneath the skin, glycogen a form of 'animal starch'; protein cannot be stored)

- **egestion:** the elimination of undigested food as waste. For example, fibre such as cellulose that cannot be digested by humans acts as 'roughage', passing through the digestive tract and out of the anus. (*Note:* The process of egestion should not be confused with *excretion*, which is the elimination of chemical waste products of metabolism—that is, excretion involves chemical wastes that are actually made by the body, for example urea excreted in urine.)

**Figure 3.18**  
The human digestive system



## 3.8

## Teeth and surface area

■ describe the role of teeth in increasing the surface area of complex foods for exposure to digestive chemicals

## Introduction

Most vertebrates have jaws and teeth that enable them to obtain and process foods. Fish, amphibians, reptiles and mammals all have teeth, but modern birds do not have teeth, only a beak. In this section, we will refer to vertebrates with teeth, mainly referring to mammals.

The digestion of foods involves two stages:

1. *mechanical* or *physical breakdown*, where food is chewed and large chunks are physically broken down into smaller bits
2. *chemical breakdown*, where digestive enzymes act on the food to chemically break down the large complex molecules into simpler, smaller molecules.

Digestive enzymes function more efficiently if the food to which they are exposed has a large surface area to volume ratio. Large chunks of food which are eaten are broken down by the teeth, exposing a greater surface area on which the chemicals can act. The volume of food is still the same, but the overall surface area to volume ratio is increased by chewing, increasing the rate of reaction with digestive enzymes. This can be demonstrated by performing a first-hand investigation to demonstrate the relationship between surface area and the rate of reaction (see page 149).

## Teeth of mammals

Four main types of teeth, each with specific functions, are present in mammals:

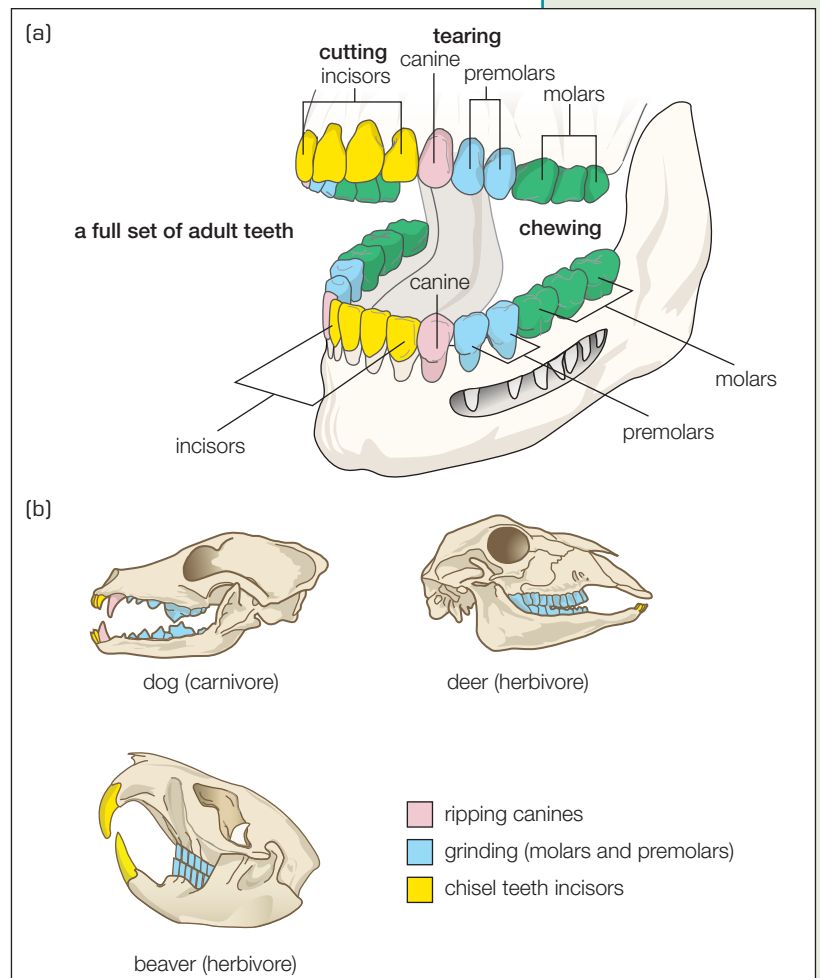
1. **incisors** (front teeth): to grasp, hold and bite food
2. **canines** ('eye' teeth or 'fangs'): used for stabbing and gripping prey and

for tearing flesh. Canines are long teeth that are conical in shape

3. **premolars** (cheek teeth): used for chewing and for cutting flesh and cracking hard body parts such as bones and shells. **Carnassial** teeth are modified premolars that shear and slice flesh in meat-eating animals
4. **molars** (back teeth): used for grinding and chewing. Molar teeth generally have ridges on them to help to crush and grind food.

Premolars and molars on the lower jaw work against those on the upper jaw to help break down the food and expose more surface area. Omnivores (animals that eat both plant and animal

**Figure 3.19** Teeth of mammals: (a) different types of teeth in humans; (b) different types of teeth in mammals



matter) have all four types of teeth present and the teeth do not show great variation in shape and size. The teeth of herbivores and carnivores differ in their structural detail and these adaptations equip each type of animal to best cope with its specialised diet. In some cases, particular types of teeth are absent altogether.

### Herbivores

**Herbivores** are heterotrophs that consume *plant material*, and many fall into one of two groups: *grazers* who eat grass and *browsers* who eat leaves and vegetation on shrubs and trees. Herbivores have front teeth adapted to tearing off vegetation and back teeth adapted to chewing an abrasive, high-fibre diet. They also have powerful jaw muscles to cope with all the chewing required in their diet.

The incisors are used to bite off vegetation and a wide range of front teeth are typical across the herbivore group of mammals, including those adapted to nibbling, gnawing, tearing or biting. The molars are broad crushing teeth with relatively large surface areas, an adaptation to deal with an abrasive, fibrous diet. The molars are specially equipped with ridges to help break open the cellulose cell walls of plants.

Cellulose in the cell walls of plant tissue presents a challenge to animals which eat it because:

- it is very difficult to break cellulose down physically as well as chemically (cellulose is indigestible to most animals and therefore cannot be used by many as an efficient source of energy)
- cellulose cell walls enclose and surround cells, preventing enzymes from reaching the high energy, starchy contents of the cell which *can* be digested to release energy and nutrients.

In herbivores, an enormous amount of chewing is needed:

- to break down the high-fibre cellulose walls physically and expose the starchy contents

- because large quantities of vegetation must be eaten to provide a sufficient supply of energy
- to increase the surface area of cell walls exposed to microbes which can digest cellulose.

Many herbivores have developed a mutualistic feeding relationship with microbes that live inside their gut. These microbes are able to produce an enzyme which can chemically digest cellulose to release energy. Chewing the food physically breaks down the cellulose and this serves a second purpose—the damaged cell walls have a greater surface area exposed to the microbes within the digestive tract to chemically break down the cellulose.

Canine teeth are absent in herbivore jaws, leaving a gap called the *diastema*, which assists manipulation of food onto the molars, keeping chewed and unchewed food separate.

### Carnivores

*Large carnivores* usually prey on other vertebrates. Their food is more difficult to obtain because they usually need to hunt and kill it. They have powerful jaws and well-developed canine teeth, conical in shape (coming to a point) and specialised for holding and killing prey and tearing meat from the bones. The meat is torn off in chunks, and many carnivores have molars with deep cusps to briefly chew the meat, increasing the surface area before swallowing it. Some carnivores such as cats have *carnassial* cheek teeth, adapted to for slicing and shearing meat, and they have lost their molars.

*Small carnivores* such as insectivores (where insects form the main part of their diet) have teeth adapted to piercing and penetrating the tough cuticle of their prey. They puncture and crush the exoskeleton with their premolars and molars and then use these teeth to shear the inner tissues.



## Investigating surface area and rate of reaction

- perform a first-hand investigation to demonstrate the relationship between surface area and rate of reaction

### Background information

In this experiment using antacid tablets and hydrochloric acid, we simulate the conditions of digestion in mammals. The antacid tablet represents the 'food' and the hydrochloric acid represents a digestive chemical. When an antacid tablet comes into contact with acid, it reacts with it, producing carbon dioxide bubbles, water and salt. The stomach of mammals naturally secretes hydrochloric acid to provide the correct environment for stomach enzymes to work. If too much acid is secreted by the stomach, digestive discomfort (sometimes referred to as 'heartburn') results. Antacid tablets are usually taken to relieve digestive discomfort.

### Aim

To demonstrate the relationship between surface area and rate of reaction.

### Hypothesis

(Students should formulate a hypothesis.)

### Equipment

- Three test tubes in a test tube rack
- Three antacid tablets
- 30–50 mL dilute hydrochloric acid
- Two spatulas or a pestle and mortar
- Stopwatch

### Safety

Avoid contact of skin or eyes with acid. If there is contact, rinse well with cool running water (tap for skin, water bottle for eyes).

### Method

- Place a whole antacid tablet, a tablet broken into quarters and a crushed tablet into three separate test tubes.
- Pour the same amount of hydrochloric acid into each test tube. (Pour enough acid so that the whole tablet is covered—the exact amount depends on the size of the tablet—and then use this same amount in the other test tubes.)
- Using a stopwatch, measure how long each test tube fizzes, until the tablet is completely dissolved.
- Record your results in a table.
- Write a conclusion for this experiment.

### Discussion questions

- Explain why it is necessary to avoid contact between hydrochloric acid and skin/eyes. **Describe** precautions that can be taken to prevent contact.
- Identify** the dependent and independent variables in this experiment.
- Describe** all other variables that were kept constant.
- What is meant by the *rate* of a reaction? Explain why a stopwatch was needed.
- What pattern or trend could you **identify** in the rate of reaction related to the surface area of the antacid tablets?
- Refer to the background information about antacid tablets and then explain why you belch (burp) after taking an antacid tablet. Give a reason why taking an antacid tablet may relieve digestive discomfort.

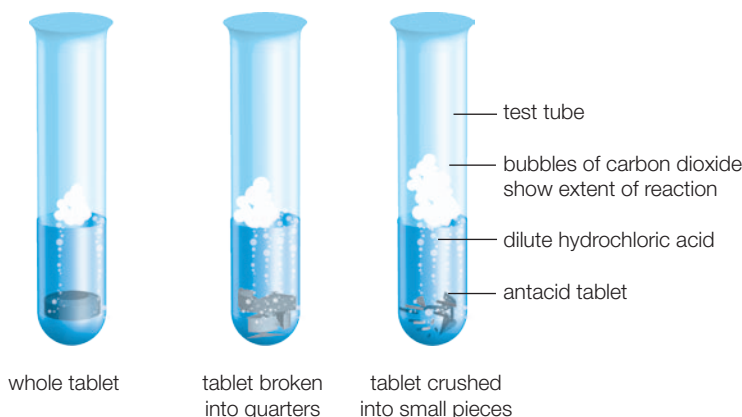
### FIRST-HAND INVESTIGATION

### BIOLOGY SKILLS

P12.1; 12.2; 12.4

P13.1

P14.1; 14.2; 14.3



**Figure 3.20**

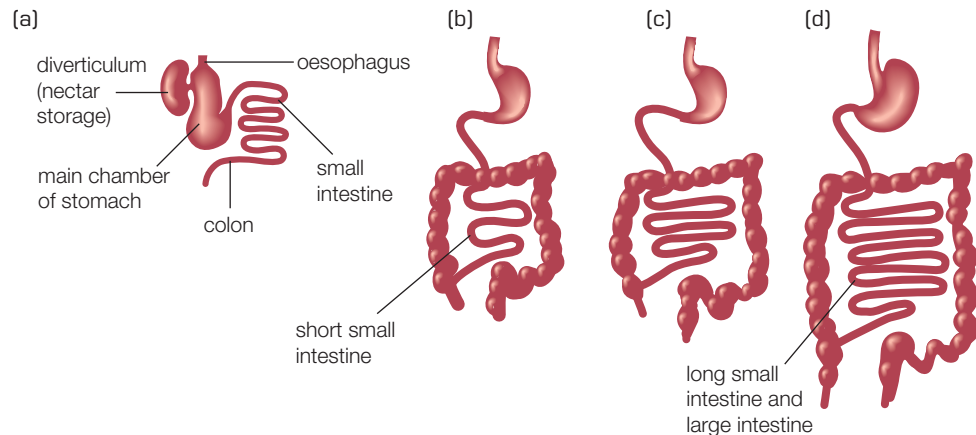
Experiment to demonstrate the relationship between surface area and rate of reaction using antacid tablets

## 3.9

## Digestive systems of vertebrates

- explain the relationship between the length and overall complexity of digestive systems of a vertebrate herbivore and a vertebrate carnivore with respect to:
  - the chemical composition of their diet
  - the functions of the structures involved

## Diet and the length and complexity of the digestive system

**Figure 3.21**

Diagrams comparing general length and complexity of animal digestive tracts: (a) gut of a honey possum; (b) gut of a carnivore; (c) a human gut; (d) gut of a herbivore

**Herbivores****Diet**

Plant material that is high in *fibres* (provided by the cellulose walls of plant cells) and *starch* (present in the plant cell contents) provides the main energy source in the diet of herbivores. Depending on what plants are eaten, sugars, proteins, oils and other nutrients also form part of a herbivore's diet, but usually in smaller amounts—the correct mix of nutrients, rather than the quantity, is important in herbivore diets.

Cellulose and other cell wall thickenings are difficult to digest and they create a barrier around the cell contents which are capable of being digested (e.g. starch, sugar and protein). Furthermore, cellulose cannot be used as an efficient energy source unless microbes are present. *Herbivores* have adaptations of their digestive tract that enable them to deal with this diet. (Some plants have evolved further defence mechanisms, such as thorns or the production of toxins to protect them against being eaten. Herbivores

which eat these plants have even more specialised adaptations.)

**Digestive tract**

Most *large herbivores* rely on microbes in their gut to digest cellulose.

To allow for the slow process of **microbial fermentation**, the gut of these herbivores is complex and very long, relative to their body size (see Fig. 3.21d). A close relationship is evident between the digestibility of food (how difficult it is to digest) and the length and complexity of the digestive tract. An increase in the length of the digestive tract provides space to hold the large quantity of food that must be eaten, gives the maximum opportunity for microbial action to take place and allows time for the nutrients to be absorbed. The increased complexity is evident by the presence of highly specialised digestive organs which are necessary to break down the high-fibre diet.

*Small herbivores* often eat plant tissue that has much less cell wall material and is energy-rich. These include fruit eaters (e.g. fruit bats) and small herbivores



Worksheet on human digestive system

that live on a diet predominantly made up of nectar (e.g. the honey possum). The gut of these small herbivores is usually simple and short, in comparison to that of grazers and browsers, because the plant tissue in their diet is easier to digest, having a high sugar content and little or no fibre. (See Fig. 3.21a.)

## Carnivores

### Diet

Carnivores eat animal matter which is made up of cells the content of which is more accessible (animal cells have no cell wall, only a cell membrane, so their contents are more readily usable) and they are therefore more easily digested. Animal matter is high in protein, low in fibre and usually has a higher energy content than that of plants. The mineral content of animal matter is usually relatively constant. So even though the food of carnivores may be more difficult to obtain, it has high nutritional value and can be consumed in lesser quantities. The protein and fat in the diet are provided by the muscle, skin and internal organs of their prey; the small amount of fibre comes from cartilage and bones consumed. There is a small amount of fat and very little carbohydrates associated with their diet.

### Digestive tract

In carnivores, the gut is relatively short and unspecialised, as protein and fat is relatively easy to digest (compared to complex carbohydrates or cellulose). Very little undigested material is egested, due to the low fibre content of their diet. (See fig. 3.21b.)

## Functioning of the digestive system

### The human digestive system

Understanding the human digestive system gives us a good overview of the structures involved and the necessary functions for heterotrophic nutrition. (See Fig. 3.20 and Table 3.2.) Humans

are omnivores, eating both plant and animal material, so the organs are suited to digesting both types of matter. The prescribed study of digestive tracts of herbivores, carnivores and nectar feeders which follows can then be easily compared.

## Adaptations of parts of the digestive systems for specialised functions

Adaptations for feeding are thought to be one of the main forces behind the evolutionary process. If an adaptation in an organism makes it easier for them to obtain food or allows them to obtain nutrients from a type of food not sought by others, it is to their advantage because competition is reduced.

### Herbivores

Very few animals have the ability to chemically digest cellulose and release energy from it, because they lack the enzyme *cellulase*. To overcome this problem, most herbivores have modified digestive tracts which contain symbiotic micro-organisms (bacteria and/or protozoans) that help digest the cell walls and make this energy available to the host animal. The process is known as microbial fermentation. The microbes exist in an expanded region of the gut, which protects them from being continually lost with the passage of food. The expanded part of the gut may be the stomach (fore-gut fermenters) or the caecum (hindgut fermenters).

In **fore-gut fermentation**, for example the eastern grey kangaroo, microbes use most of the dietary glucose and protein from the plant material that they digest, but they release short chain fatty acids as energy for the host and some of the microbes are digested by the host, providing a source of amino acids. Cattle are *ruminant* fore-gut fermenters—that is, they regurgitate the contents of the first part of the stomach and re-chew

**Table 3.2** The digestive system of humans

	Part	Structure/position	Function
Mouth	Teeth	Four types, for biting, tearing, piercing and crushing food	To chew the food into smaller pieces that can be swallowed; increases the surface area exposed to digestive enzymes
	Salivary glands	Three pairs, emptying via ducts into the mouth cavity	Secrete saliva to: <ul style="list-style-type: none"> <li>■ moisten the food for easy swallowing</li> <li>■ begin chemical break down of food, in particular starch digestion</li> </ul>
	Pharynx (throat)	Muscular walls surrounding the opening to the <b>oesophagus</b>	To swallow food
	Oesophagus (gullet)	Long tube that lies behind the trachea (wind pipe) and their openings are separated at the top by a flap of cartilage, the epiglottis	Carries food from the mouth to the stomach, by waves of contraction called peristalsis. The epiglottis closes the windpipe during swallowing to prevent food entering the trachea
	<b>Stomach</b> (containing gastric juice)	Pouch-like organ with thick, strong muscular walls. Positioned in the upper abdomen, on the left-hand side of the body, immediately beneath the diaphragm	<ul style="list-style-type: none"> <li>■ Churns the food by involuntary muscle contraction, mixing it with digestive juices</li> <li>■ Stores the food and passes small amounts at a time into the small intestine</li> <li>■ Contains enzymes for protein digestion</li> <li>■ Contains hydrochloric acid which assists digestion and acts as an antiseptic, killing bacteria in food</li> </ul>
Intestines	<b>Small intestine</b> (duodenum, jejunum, ileum)	Long narrow tube, greatly coiled, between the stomach to the large intestine. It is the longest part of the human digestive tract (6–7 m in length) but has a narrow diameter (less than 4 cm). Its inner walls are greatly folded to increase the surface area for absorption.	<ul style="list-style-type: none"> <li>■ Receives digestive juices from the pancreas and liver, glands associated with the digestive tract:                             <ul style="list-style-type: none"> <li>—bile from the liver emulsifies fats;</li> <li>—pancreatic juice contains digestive enzymes</li> </ul> </li> <li>■ Chemical digestion of foods—lipids, proteins, starch and complex sugars</li> <li>■ Absorption of digested food</li> </ul>
	<b>Appendix</b> (remnant of caecum)	Small pouch-like structure that forms the first part of the large intestine	Plays no role in human digestion (equivalent to caecum in other animals)
	<b>Large intestine</b> (ascending colon, transverse colon and descending colon)	A tube that is shorter than the small intestine, but wider (diameter about 6 cm, length about 1.5 m)	Absorption of water, vitamins and minerals from food. No chemical digestion
	Rectum	Last part of the large intestine	Stores undigested material (and any unabsorbed substances) as faeces, to be passed out of the body
	Anus	The opening of the digestive tract to the exterior	Egestion of undigested material to the exterior
Glands	Liver		<ul style="list-style-type: none"> <li>■ Stores bile secreted by the gall bladder</li> <li>■ Releases bile into the duodenum of the small intestine to emulsify fats and expose more surface area to enzymes</li> <li>■ Centre of food metabolism: regulates the storage and release of the end products of digestion; changes excess amino acids into urea</li> </ul>
	Pancreas	An elongated gland opening via a duct into the small intestine	<ul style="list-style-type: none"> <li>■ Makes pancreatic juice with digestive enzymes and secretes it into the duodenum of the small intestine.</li> <li>■ Secretes insulin, a hormone that controls the level of glucose in the blood.</li> </ul>

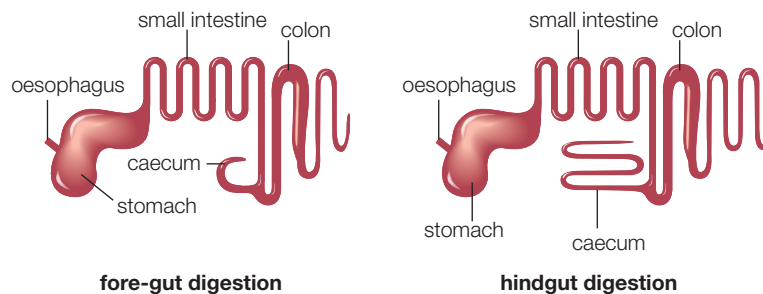
it, further reducing the size of food particles. This is commonly termed 'chewing the cud' or they are said to *ruminates*. Ruminants have a complex stomach composed of four parts: two chambers for microbial fermentation, one for storage and one which functions as a true stomach. Food remains in the fermentation chambers for a long time, giving microbes plenty of time to digest the cellulose.

**Hindgut fermentation**, for example in the koala, takes place in the hindgut (caecum), but is otherwise similar to foregut fermentation. The main difference is that microbes cannot

be digested by the host as a source of amino acids in hindgut fermenters, because they are in the large intestine where protein digestion no longer occurs and they are lost from the system by egestion. As a result, some hindgut feeders such as rabbits and ring-tail possums eat their egested faecal pellets to ingest and digest these nutrient-rich microbes.

### Carnivores

Carnivores have a simple stomach (which may be enlarged to store food), a short intestine relative to their body size and the caecum may be absent or, if present, greatly reduced in size.



**Figure 3.22**

Diagrams to compare fore-gut digestion and hindgut digestion in herbivores

## Digestive systems of mammals

- **identify data sources, gather, process, analyse and present information from secondary sources and use available evidence to compare the digestive systems of mammals, including a grazing herbivore, carnivore and a predominantly nectar-feeding animal**

### Identify data sources

- Remember to use a variety of sources and always assess the *reliability* and *accuracy* of your sources (see Biology skills table P12.4 e and f on page ix).
- Read the suggested background information on the previous pages (pages 150–3) and refer to other reference books as well.
- Identify some key scientific words that you might use in an Internet search for secondary sources. Here are some suggested words to start your search, keywords that you could type into a search engine such as 'Google': 'nectar-feeding

animals', 'digestive tracts of herbivores', 'digestive tracts of carnivores'.

- It is important to use scientific journals and publications to *validate* information.
- Acknowledge all sources appropriately in the form of a bibliography (see the Teacher's Resource CD and Student Resource CD for accepted formats for reference books, websites and journals).



Websites that may also assist as a starting point for your research are listed

### SECONDARY SOURCE INVESTIGATION

#### BIOLOGY SKILLS

P11.1; 11.3  
P12.3; 12.4  
P13.1  
P14.1; 14.3



Further information on identifying reliable and accurate sources and validating sources

## Gather and process information

Identify relevant material from your source which addresses the aspects of the digestive tracts which are to be compared. Some sources may deal with information general to herbivores, carnivores and nectar feeders, whereas others will deal with specific animals.

## Analyse and present information

Carefully examine the information you have gathered, identify the components that you need to compare and describe the relationships among them. Present your findings in the form of a table.

## Research task

1. Select three animals to compare: one animal from each of the feeding groups stated below in italics. You may use the list to help you with your choice of animal, or you may select any other animal of interest to you, as long as it belongs to one of the listed feeding groups.

Examples:

- *grazing herbivores*  
—kangaroos, sheep and cattle (fore-gut fermenters)  
—koalas, possums and horses (hindgut fermenters)
- *carnivores*: dogs; Tasmanian devil
- *nectar-feeding animals*: honey possum.

2. Read information on teeth and the overall complexity of digestive systems and then research your three named examples as described below:
  - compare the digestive systems of one named *grazing herbivore*, one *carnivore* and one *predominantly nectar-feeding animal*
  - consider the structure and functions of the various parts of the digestive tract and how the structures are modified to achieve optimal functioning, in coping with the type of diet of each animal
  - present your findings in the form of a table
  - acknowledge your sources in an appropriate bibliography.

## Suggested headings for table

- Main food source and its chemical composition
- Mechanical breakdown: teeth (shapes and explanations for this)
- Microbial action (fore-gut or hindgut fermenters and descriptions)
- Stomach (relative size and complexity; reasons why)
- Intestines (length relative to body size; how this relates to the type of food eaten)
- Caecum (relative size and complexity; reasons why)
- Chemical breakdown: time taken for food to digest
- Diagram
- Bibliography

## REVISION QUESTIONS



1. **Identify** where the oxygen gas produced by photosynthesis comes from. **Describe** how it is produced.
2. **List** the chemical *products* of photosynthesis.
3. Write the overall word equation for photosynthesis.
4. Explain why the light-independent phase must occur during the day and not at night.
5. **Describe** two ways in which plants increase the surface area of their absorbing structures.
6. **Explain** why an increase in surface area is necessary for the normal functioning of plants.
7. **Identify** the processes necessary for the uptake of water and mineral salts by roots.
8. State the meaning of the terms: *heterotroph*, *herbivore*, *ingestion*, *absorption*, *assimilation* and *egestion*.
9. **Describe** the role of both teeth and enzymes in the digestion of food (in relation of nutrition in animals) and give an example of each.
10. **Compare** hindgut fermentation with fore-gut fermentation, giving one similarity and two differences. For each, name an example of an animal that displays that mode of nutrition.
11. Carnivores obtain their food from other organisms. **Describe** two adaptations in carnivores which enable them to live on a diet of predominantly protein.



Answers to  
revision questions