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CHAPTER 1 Cell Biology

In this chapter, cell structure is considered, as well as the importance of the cell as a basic component of all living matter. Various adaptations of a cell are discussed together with the adaptations that a cell can undergo in order to perform different functions. The methods used by cells to absorb chemicals are described, as is the action of enzymes which are chemicals released by cells.

Cell structure and organisation

The basic unit of life is the ***cell***. The simplest living organisms have ***one*** cell only. Such organisms are described as ***unicellular***.

Bacteria (singular: bacterium) are examples of unicellular organisms.

Most other living organisms have many cells, and are described as multicellular.

All cells have the following structural features in common.

1. A ***cell membrane***, which ***controls*** the passage of substances into and out of the cell. One of the most important of those substances is ***water***. All other substances which pass do so ***in solution***. Since larger molecules are unable to pass through the cell membrane, it is described as ***partially permeable***.
2. ***Cytoplasm***, a jelly-like substance in which the chemical reactions of the cell (***metabolic*** reactions) take place, and which contains the nucleus.
3. The ***nucleus*** contains a number of ***chromosomes*** largely made of the chemical DNA. Chromosomes possess ***genes***, which are responsible for programming the cytoplasm to manufacture particular proteins.

When a cell divides, it does so by a process called ***mitosis***, during which each chromosome forms an ***exact replica (copy)*** of itself. The two cells formed are thus identical both with themselves and with the original cell.

Plant cells have the following additional structures (Figure 1.1):

1. A (***large, central***) ***vacuole***, which is a space full of ***cell sap*** (and, thus, sometimes called the ***sap vacuole***), which is a solution mostly of sugars. It is separated from the cytoplasm by the ***vacuolar membrane***.

NOTE

The cytoplasm and the nucleus make up the *protoplasm*.

NOTE

DNA stands for deoxyribonucleic acid.

NOTE

Plant cells undergoing cell division do not have a vacuole.

NOTE

Cellulose is a tough, insoluble carbohydrate.

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NOTE

Magnesium is a necessary component of the pigment chlorophyll.

2. The ***cell wall*** is a 'box' made of ***cellulose*** in which the cell is contained.

3. **Chloroplasts** – only if the cell is involved in the process of ***photosynthesis***. These are small bodies lying in the cytoplasm. They are green in colour because of the pigment ***chlorophyll*** which they contain.

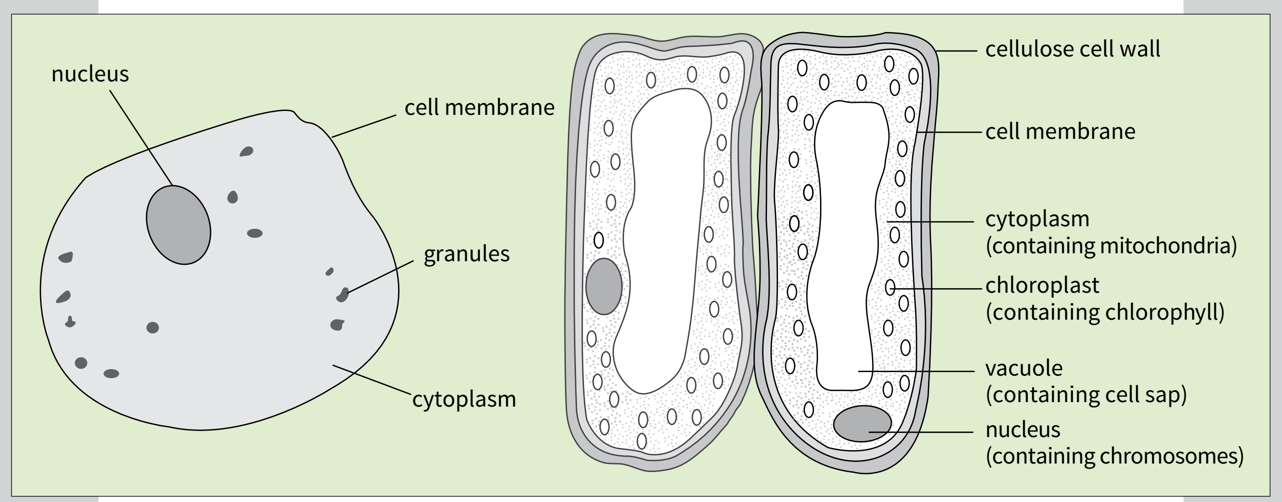

Figure 1.1 Animal cell (liver) and plant cells (palisade mesophyll cells from a leaf)

NOTE

Since, in plants, the cell membrane fits tightly against the cell wall, it is not usually easily visible.

Similarities and differences between plant and animal cells are shown in the table below:

	animal cell	plant cell
similarities	cell membrane	
	cytoplasm	
	nucleus	
differences	no sap vacuole	sap vacuole
	no cell wall	cell wall
	no chloroplasts	may have chloroplasts
	never stores starch	may store starch
	around 10–20 μm in diameter	around 40–100 μm in size

NOTE

$1\,\mu m = \frac{1}{1000}$ mm

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Aim: To observe animal cells

1. Cut a cube of *fresh* liver, in section, approximately 1.5 cm square. (Frozen liver is not suitable as freezing damages the cells.)
2. Scrape one of the cut surfaces of the cube with the end of a spatula (the end of a teaspoon would do).
3. Transfer the cells removed to a clean microscope slide. Add one drop of ***methylene blue*** (a suitable stain for ***animal cells***) and one drop of glycerine.
4. Stir the cells, stain and glycerine together and leave for 30 seconds. (This time can be adjusted according to the depth of staining required.)
5. Carefully place a clean, dry cover slip over the preparation, and then wrap a filter paper around the slide and cover slip.
6. Place the slide on a bench and press firmly with your thumb on the filter paper over the cover slip. The filter paper should absorb any surplus stain and glycerine, and the slide is then ready for viewing with a microscope (medium to high power).

The following structures (Figure 1.2) should be visible:

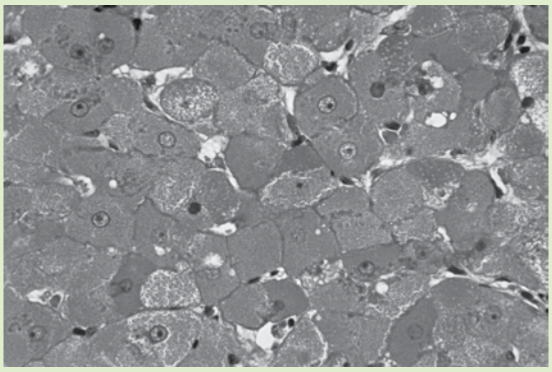

Figure 1.2(a) Stained liver cells

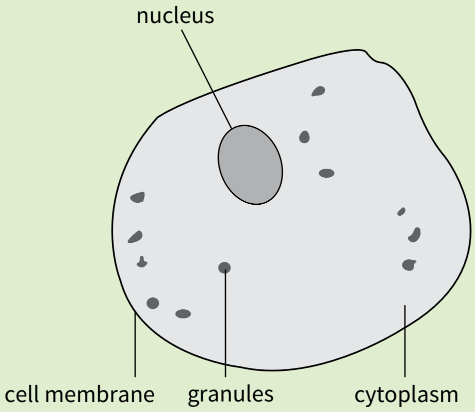

Figure 1.2(b) Animal cell (liver)

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Aim: To observe plant cells

1. Peel off the dry outer leaves of an onion bulb.
2. Remove one of the fleshy leaves beneath.
3. Preferably using forceps, but fingers would do, peel away the outer skin-like covering (***epidermis***) of the fleshy leaf.
4. Place three drops of dilute ***iodine solution*** on a clean, dry microscope slide. (Iodine solution is a suitable temporary stain for ***plant*** cells.)
5. Transfer a small piece of the epidermis (a 50–75 mm square is large enough) to the iodine solution (make sure it lies flat and is completely covered by the iodine solution).
6. Carefully place a glass cover slip on top of the preparation, remove any excess liquid with a piece of filter paper and transfer the slide to the stage of a microscope.

The following structural features (Figure 1.3) should be visible (owing to the large size of the onion cells, it may not be necessary to use the high power of your microscope).

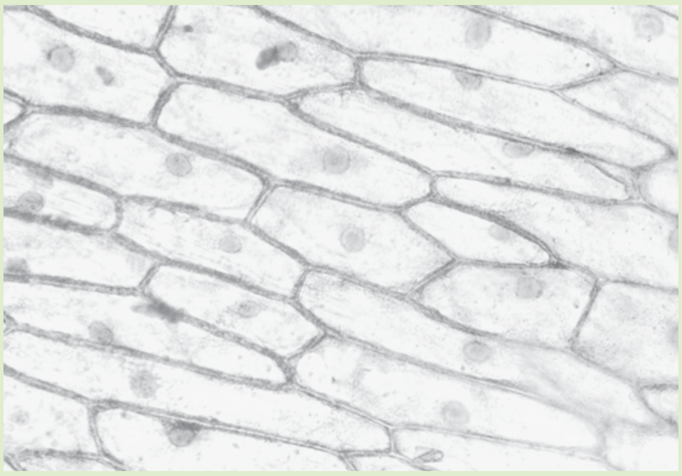

Figure 1.3(a) Onion cells

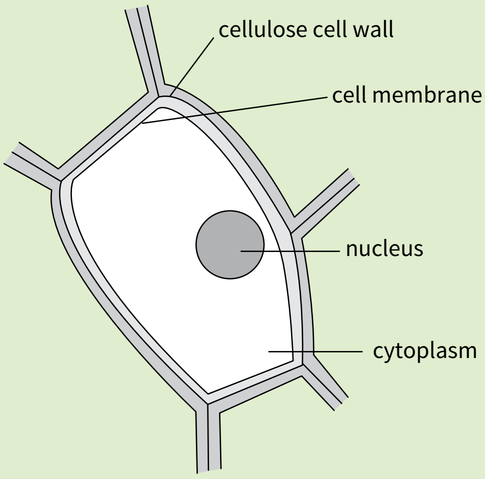

Figure 1.3(b) Leaf epidermal cell from an onion bulb

Specialised cells, tissues and organs

In unicellular organisms, one cell must be able to carry out ***all*** the functions of a living organism. In multicellular organisms, cells are usually modified to carry out ***one*** main function. The appearance of the cell will vary depending on what that main function is.

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Thus, ***there is a relationship between the structure and the particular function of a cell***.

Examples of this relationship are discussed here.

Root hair cell

Function

To absorb water and mineral ions (salts) from the soil.

How it is adapted to this function

The outer part of its cell wall (i.e. the part in direct contact with the soil) is in the form of a long, tubular extension (the ***root hair***, see Figure 1.4).

This root hair is

1. able to form a very close contact with the water film surrounding many soil particles, and
2. it greatly ***increases the surface area of the cell*** (Figure 1.4(b)) available for uptake of water and ions (also for the uptake of ***oxygen*** necessary for the respiration of all the cells in the root).

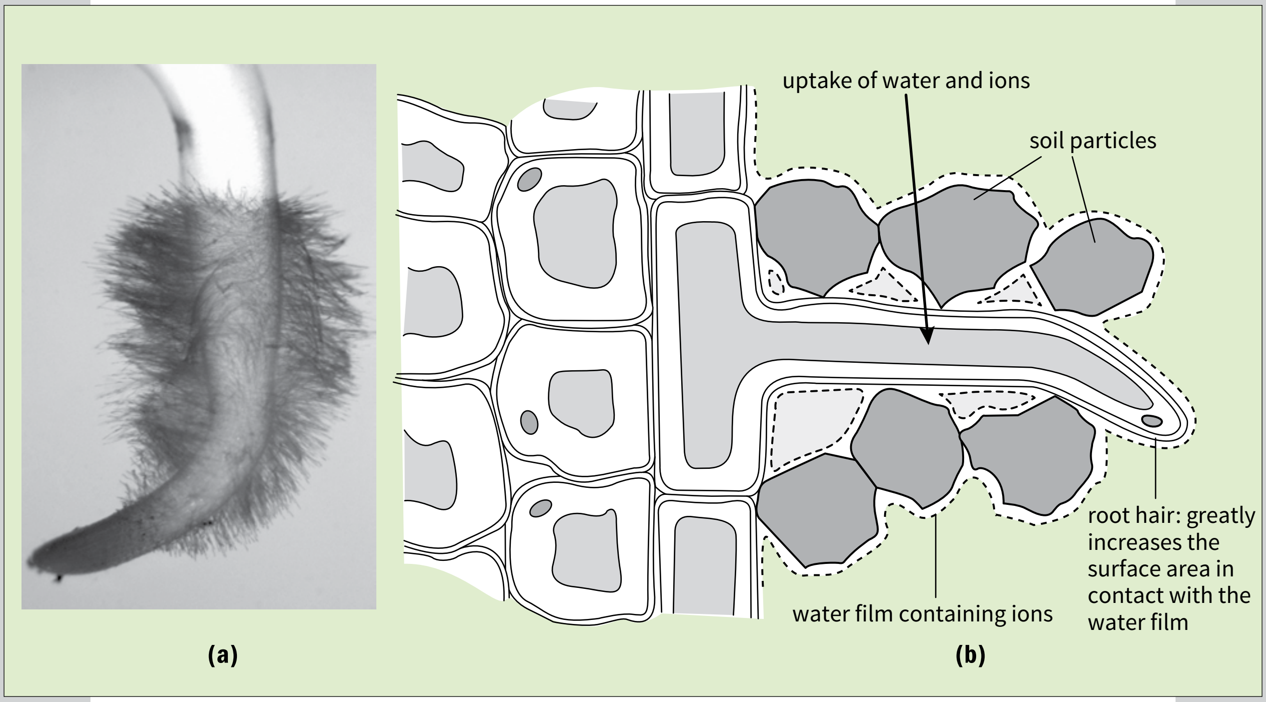

Figure 1.4(a) A root tip showing root hairs
(b) A root hair cell

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Xylem vessels

Functions

1. *To conduct water and ions (dissolved salts)* **from the roots to the stem, leaves, flowers and fruits.**

2. *To provide support* **for the aerial parts of the plant.**

How they are adapted to these functions

Conduction

Xylem vessels are long narrow tubes (see figure 1.5), stretching from the roots, via the stem, to the leaves. They are stacked end to end like drain pipes.

Support

1. Their walls have been strengthened by the addition of the chemical ***lignin***. (As the lignin in the walls builds up, it eventually kills the xylem vessels. There is then no layer of cytoplasm to restrict the flow of water and dissolved salts.)

2. Xylem vessels are part of the ***vascular bundles***, which run through the stems of plants like iron reinforcements in concrete pillars – thus resisting bending strains caused by the wind.

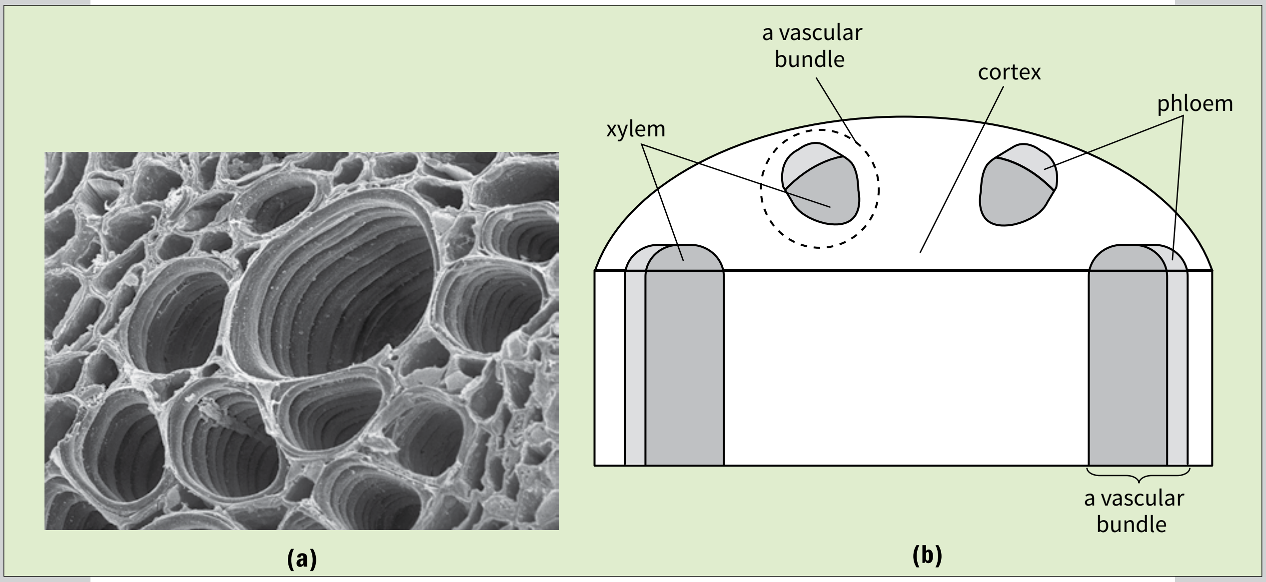

Figure 1.5(a) Xylem tissue in a plant stem
(b) A section through a stem cut to show the arrangement of tissues in vascular bundles

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Red blood cells

Function

To carry oxygen around the body.

How they are adapted to this function

1. Their cytoplasm contains the pigment ***haemoglobin***, which combines (in the lungs) with oxygen to become oxyhaemoglobin.
2. They are ***small*** (7 μm × 2 μm) (and there are ***many*** of them) thus giving them a ***very large surface area*** for oxygen absorption (Figure 1.6).
3. They have a ***bi-concave*** shape, increasing their surface area for absorption still further.
4. They are flexible, allowing them to be pushed more easily through capillaries.

NOTE

Iron is a necessary component of the pigment haemoglobin.

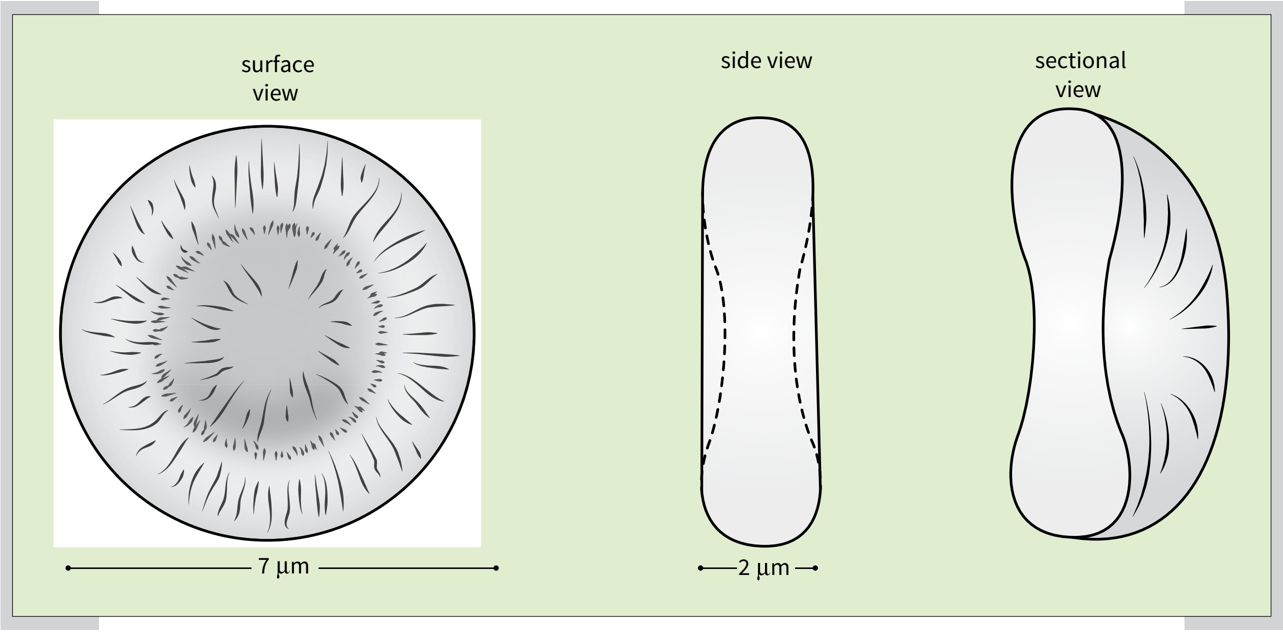

Figure 1.6(a) Red blood cells – surface, side and sectional views

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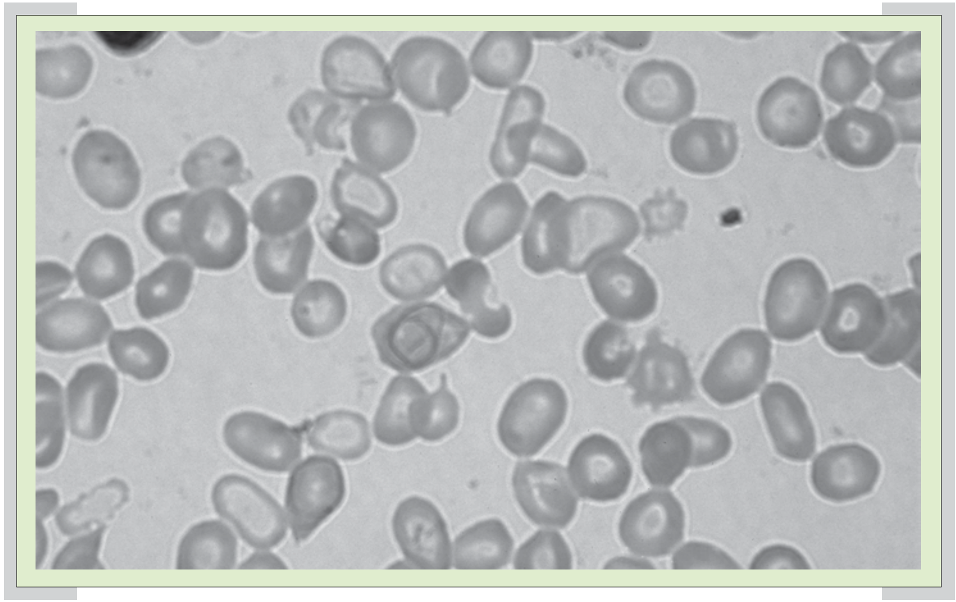

Figure 1.6(b) Photomicrograph of red blood cells

How cells combine to improve their efficiency

One cell working on its own would achieve very little in an individual plant or animal. Thus it is usual to find many similar cells lying side by side and working together, performing the same function.

Many similar cells working together and performing the same function are called a **tissue.**

Examples of tissues

- xylem tissue in the vascular bundles of a plant
- muscular tissue in the intestine wall of an animal

Different types of tissue often work together in order to achieve a combined function.

Several tissues working together to produce a particular function form an **organ.**

Examples of organs

- the leaf of a plant – an organ for the manufacture of carbohydrates during photosynthesis
- the eye of an animal – the organ of sight

Several different organs may be necessary in order to carry out a particular function.

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A collection of different organs working together in order to perform a particular function is called an **organ system.**

Examples of organ systems

- the sepals, petals, stamens and carpels (i.e. the flowers) of a plant – for reproduction
- the heart, arteries, veins and capillaries in an animal, i.e. the circulatory system

An **organism** is ***a collection of organ systems working together.***

The increasing order of cell organisation found within any living organism is thus

cell → tissues → organs → organ systems → organisms

Movement in and out of cells

Diffusion and osmosis

For plants and animals to stay alive, chemicals must be able to move easily:

- from one part of a cell to another
- into and out of a cell
- from one cell to another.

It is an advantage if this movement requires no effort (or, more correctly, no expenditure of energy) on the part of the organism, and, so long as there is no obstruction, chemical molecules carry out this process by ***diffusion***.

Before diffusion can occur, there must be a ***concentration gradient*** of the molecules, i.e. a region of their (relatively) high concentration immediately beside a region of their (relatively) low concentration.

Diffusion can then be defined as ***the movement of molecules from a region of their higher concentration to a region of their lower concentration, down a concentration gradient.***

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NOTE

A simple demonstration of diffusion: Close all the windows in a room, and then spray one corner of the room with an aerosol fly-killer or body deodorant. Measure the time it takes for the smell of the spray to be detected by people sitting in different parts of the room.

Examples of diffusion

1. In plants:
   - the movement of ***carbon dioxide*** into leaves during photosynthesis. Carbon dioxide in solution moves ***from the water film*** surrounding the mesophyll cells inside a leaf ***to the chloroplasts*** in the mesophyll cells.
   - the movement of ***water vapour*** from the water film surrounding the mesophyll cells inside a leaf ***through the intercellular spaces*** of the leaf and ***out through the stomata*** (during ***transpiration***).
2. In animals:
   - the movement of ***oxygen*** after it has dissolved in the moisture lining the air sacs of the lungs ***through the walls*** of the air sacs (alveoli) into the blood.
   - the movement of ***carbon dioxide***, in solution, ***from the cells*** through tissue fluid ***into the blood*** in blood capillaries.

Understanding the processes of diffusion and osmosis

The movement of molecules by diffusion

Suppose a container is divided into two sections using a piece of cloth (Figure 1.7). A ***dilute*** sugar solution, which contains a lot of water, is poured into one side of the container. A concentrated sugar solution, which contains less water, is poured into the other side. The container is left to stand for a few minutes.

When checked, the concentration of the solution has changed on both sides of the container. Each side now has the ***same*** concentration of water and sugar.

By ***diffusion***, both the water molecules and the sugar molecules would move down their respective concentration gradients, i.e. from high concentration to low concentration, until both sides were at the same concentration. The pores in the cloth would form no obstruction to the movement of the molecules in either direction.