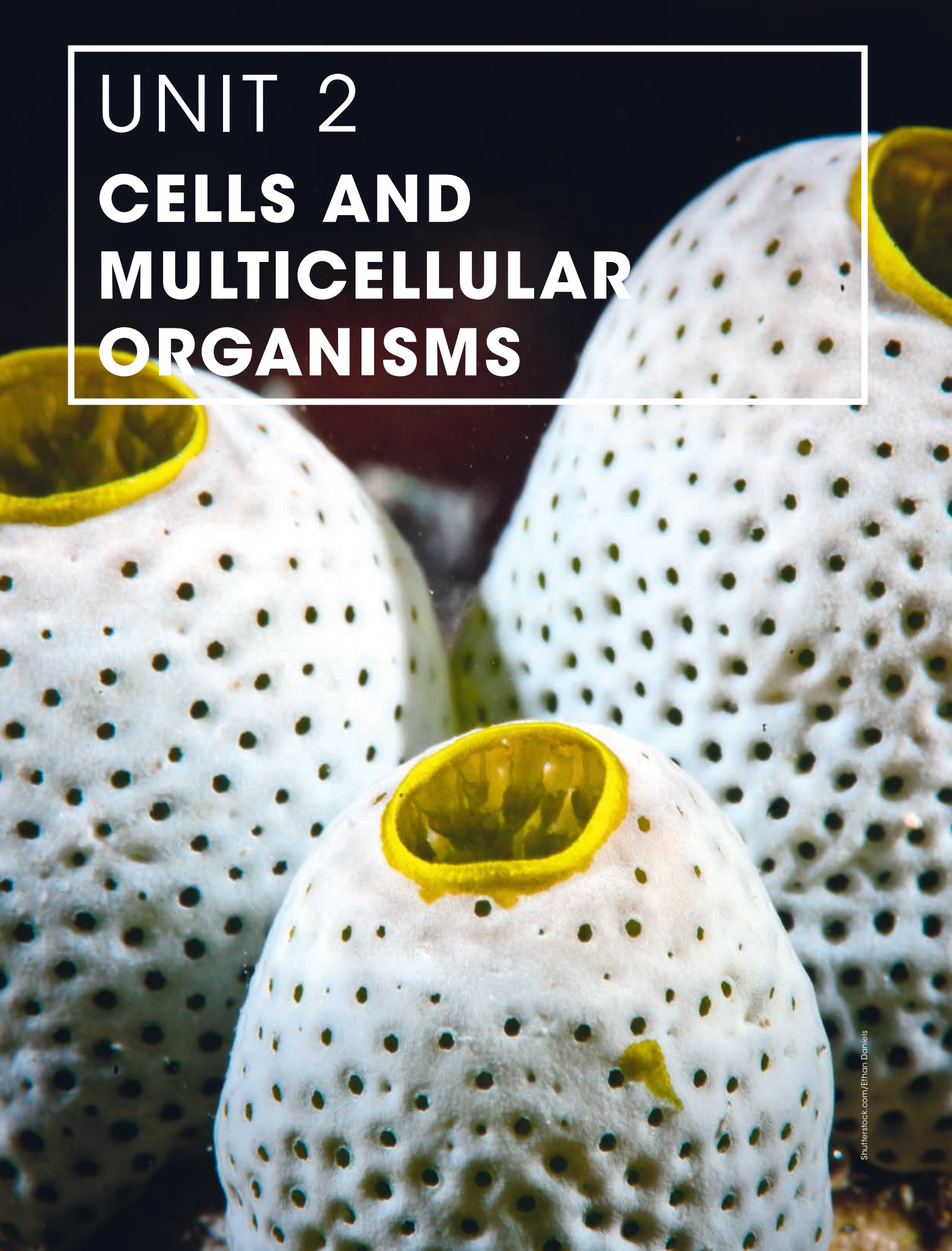
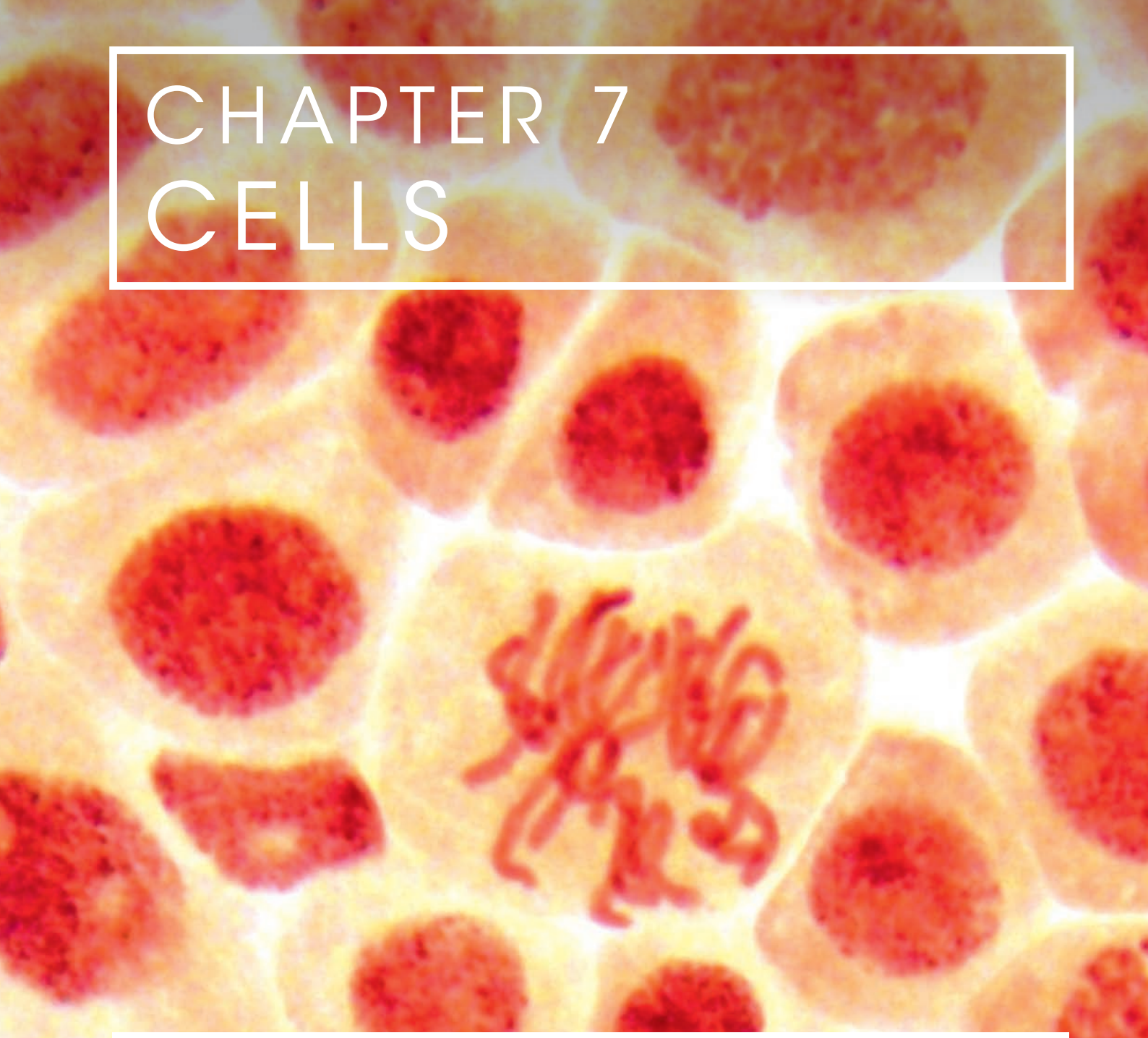
# UNIT 2
# CELLS AND MULTICELLULAR ORGANISMS



# CHAPTER 7
# CELLS



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**By the end of this chapter you will have covered the following material.**

## Science Understanding

- Cells require inputs of suitable forms of energy, including light energy or chemical energy in complex molecules, and matter, including gases, simple nutrients, ions, and removal of wastes, to survive (ACSBL044)
- Prokaryotic and eukaryotic cells have many features in common, which is a reflection of their common evolutionary past, but prokaryotes lack internal membrane bound organelles, do not have a nucleus, are significantly smaller than eukaryotes, usually have a single circular chromosome, and exist as single cells (ACSBL048)
- In eukaryotic cells, specialised organelles facilitate biochemical processes of photosynthesis, cellular respiration, the synthesis of complex molecules (including carbohydrates, proteins, lipids and other biomacromolecules), and the removal of cellular products and wastes (ACSBL049)

Figure 7.1 ▶ These sea shells were produced by the molluscs that once lived in them.

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Humans are one of 1.4 million different organisms that have been identified on Earth. This seems a large number but it probably represents only a third of all the species that exist on our planet.

Whether a bacterium, whale, fungus, tomato plant or snail, living things have certain characteristics in common: movement, growth and the ability to replicate or reproduce themselves. They detect and respond to changes in their environment, they take in food or matter and process it in a variety of ways that involve controlled transformation of energy, and they remove the waste products of their activities.

All parts of living things are not only made of **cells** but also the non-cellular products of the cells: the slime on the back of a frog, the extraordinary exoskeletons of many insects, the bark of trees, the skin of grapes and the fingernails of your hand. All living things produce substances that help them live. For example, bees produce the wax that forms their honeycombs, spiders produce the silk of their webs to trap their prey and ocean molluscs with a shell must secrete the calcium carbonate material to protect and support themselves.

# The cell is the basic unit of life

Over the past 150 years we have come to understand that all organisms are made up of cells, the basic structural and functional unit of an organism. A cell can be considered a discrete world in itself. It has many parts, each able to carry out specialised functions. It can take in simple nutrients and convert these into energy. Both oxygen and carbon dioxide can be taken in and used by some cells. A cell has the potential to reproduce itself and it even stores its own set of instructions for carrying out these activities. A cell is considered the basic unit of life because it is an easily recognised package. This is because all cells are surrounded by a membrane. This plasma membrane is a clear boundary between the internal and external environment of the cell.

Figure 7.2 ▼ The variety of organisms on Earth can look very different but they are all made up of cells: a) water flea, b) octopus and c) palm tree.


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A cell can survive on its own or has the potential to do so. Its structure is highly organised and many chemical processes and reactions occur within it. A cell senses and responds to specific changes in its environment.

Cells can be found in many shapes and sizes depending on where they are located in an organism and the job that they have to do. These cells arise from pre-existing cells. Some organisms consist of single cells, while others consist of millions upon millions of cells organised into functional groups.

# Seeing cells

We are indebted to the early microscopists for our knowledge of cell structure and function. Although their techniques were crude by today's standards, they paved the way for developments in microscopes that they would never have dreamed of.

In the early 1600s, Galileo Galilei put together some glass lenses in a cylinder and found that they magnified objects. Across Europe, from Italy, then in France and England, scientists began to explore the microscopic world, the existence of which had never been suspected. By the middle of the 17th century, a curator of experiments for the Royal Society of London, Robert Hooke, used a microscope to observe thinly sliced cork from a mature tree. When you look at Figure 7.4 you might be able to see a resemblance to what Hooke described as 'small rooms'. He used the Latin name 'cella' (small room) for these structures, having no idea that they were actually living components of the tree.

Anton van Leeuwenhoek, used his skills in making lenses to improve microscope magnification and image clarity.

Corbis

▲ **Figure 7.3**
An early compound microscope from Italy

# How small are cells?

Advances in biology over the last decades have pushed our view of the microscopic world to ever-decreasing sizes. Centimetres, millimetres and even micrometres or microns (μm) are often too large to measure objects. We are now in the 'nano age'.

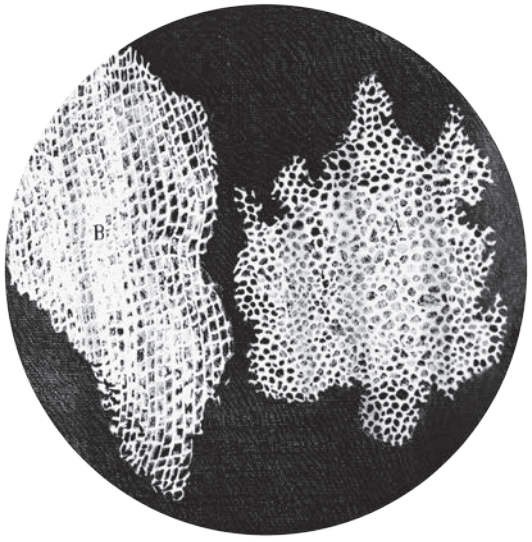
$$\begin{aligned} 1\,\text{metre (m)} &= 10^2\,\text{centimetres (cm)} \\ &= 10^3\,\text{millimetres (mm)} \\ &= 10^6\,\text{micrometres or microns (μm)} \\ &= 10^9\,\text{nanometres (nm)} \end{aligned}$$

$$1\,\text{cm} = \frac{1}{100}\,\text{m}$$

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

$$1\,\mu\text{m} = \frac{1}{1\,000\,000}\,\text{m}$$

$$1\,\text{nm} = \frac{1}{1\,000\,000\,000}\,\text{m}$$



Getty Images/Oxford Science Archive/Print Collector

▲ **Figure 7.4**
Robert Hooke's drawing of cork cells

# Different kinds of microscopes and microscopy

The type of microscope you use in your school laboratory is a light (or optical) microscope. This is the same type of microscope used by scientists when cells were first discovered. If you look at material with a simple light microscope, fine structures will not be visible. Light rays from a light source beneath the stage are transmitted through two glass lenses in series: the objective and ocular (eyepiece) lenses. Depending on their strength, these two lenses together provide magnifications of up to 400 times. More sophisticated technology is needed to view the smallest parts of cells.

**CELL SIZE**

Compare the size of a human hair to that of a red blood cell and an Ebola virus.

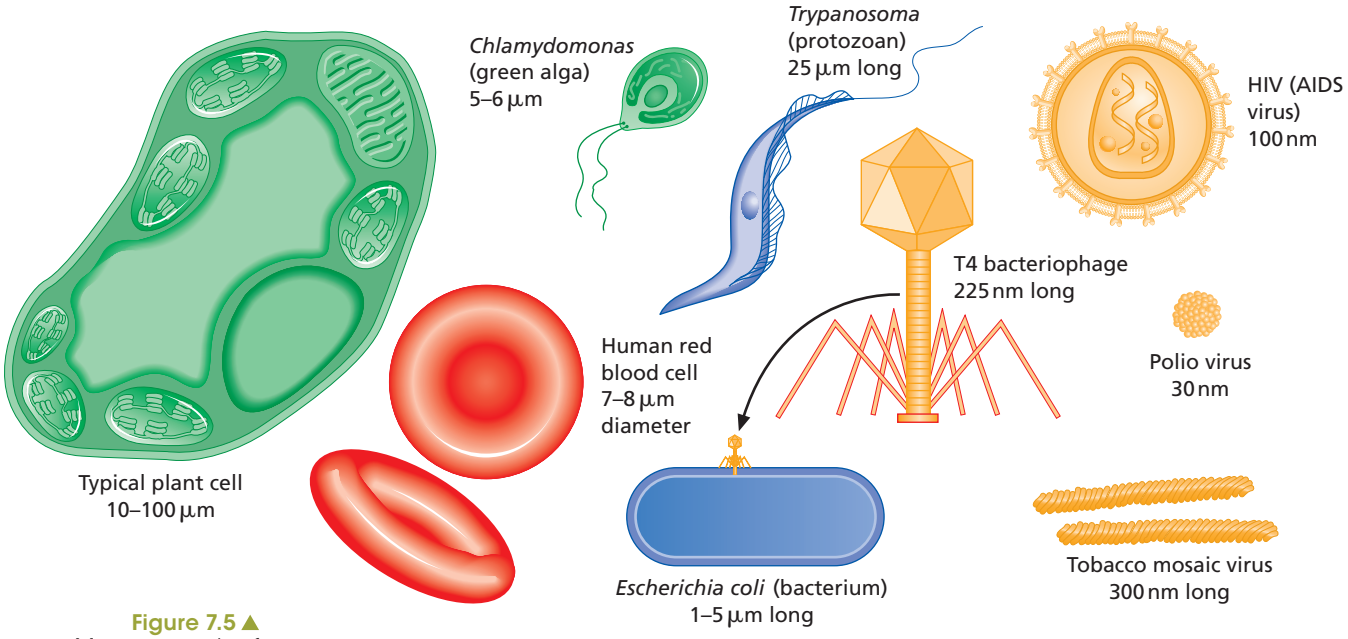



**Figure 7.5 ▲** Measurements of biological specimens (not drawn to scale)

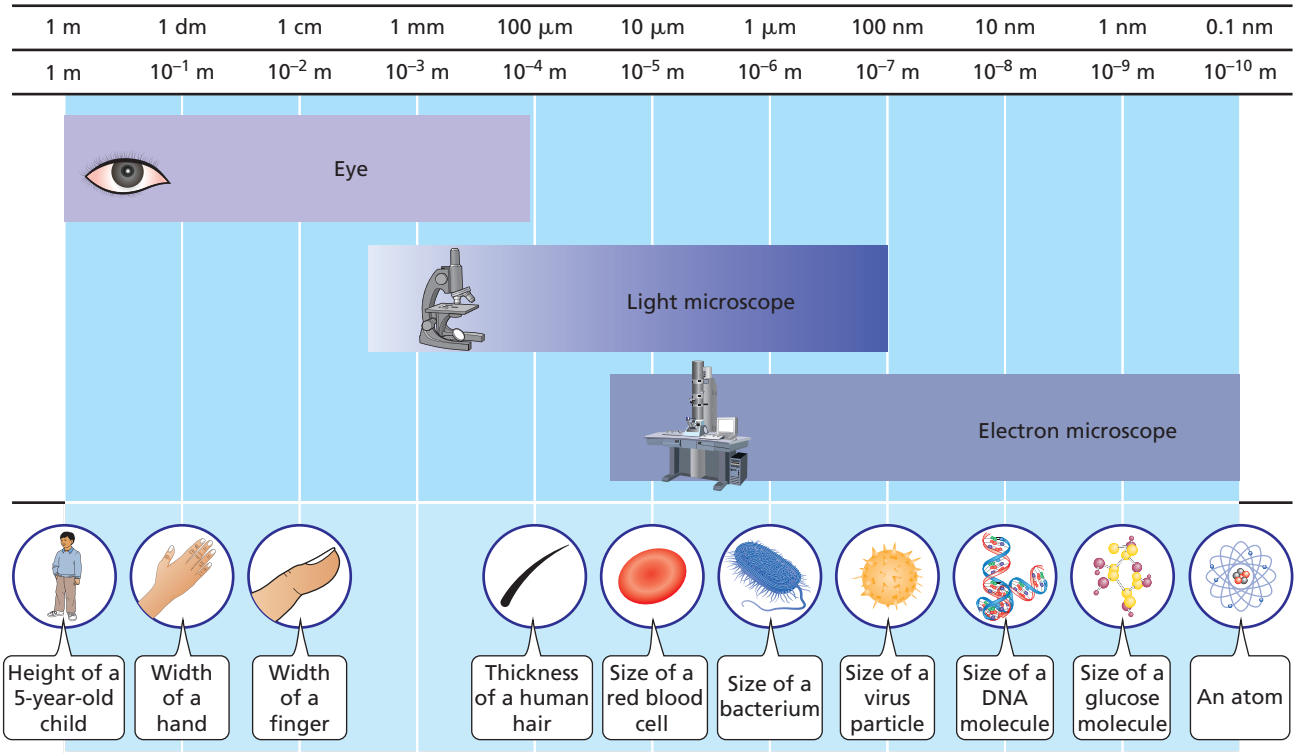



**Figure 7.6 ▲** Resolving power of microscopes compared to what can be seen by the naked eye

Since the 1950s, microscopic studies have been revolutionised by the development of the electron microscope. This instrument uses an electron beam instead of light, and electromagnets instead of glass lenses. The interactions between the electrons and the object are recorded on a photographic plate, which then forms a viewable image on a screen.

The electron microscope can give clear pictures that are magnified 1 000 000 times or more. A cell with a diameter of 10 µm can be magnified up to a diameter of 5 m. Features as small as one-tenth of a nanometre (one ten-billionth of a metre) can be seen, including individual atoms.

The electron microscope has had a profound effect on biology. Materials that were formerly believed to have little or no structure have been shown to have an elaborate internal organisation.

The electron microscope shown in Figure 7.7 is called a transmission electron microscope (TEM) because the electrons pass through the specimen. In the scanning electron microscope (SEM), solid specimens are bombarded with a beam of electrons, which causes secondary electrons to be emitted from the surface layers of the specimen. The TEM is the most common form of electron microscope and has the best resolution. It can magnify up to 1 500 000 times. The SEM has poorer resolution, but gives excellent three-dimensional images of surfaces.

Getty Images/Javier Larrea

▲ **Figure 7.7**
A transmission electron microscope (TEM) currently used in biological research

# The cell theory

In 1838, Matthias Schleiden saw that each individual cell within a whole plant developed as an independent unit. He thought that the nucleus probably had something to do with the development of each cell. In 1839, Theodor Schwann used his extensive knowledge of zoology and animal tissues to theorise that 'Animals as well as plants consist of cells and cell products – and even though the cells are part of a whole organism, they have, to some extent, an individual life of their own'.

These observations, along with microscopic examinations of a great variety of different materials, led Schleiden and Schwann to the belief that the majority of organisms are composed of cells. This belief is embodied in the cell theory, which was proposed by these two scientists in 1839. The cell theory states that all living things are composed of one or more cells. The cell is the smallest entity that retains the properties of life.

Cell division was described for the first time in 1849 and this led to more information being added to the cell theory. In 1859, Rudolf Virchow proposed that all cells come from pre-existing cells. This had not been appreciated before. Schwann had thought that new cells arose from tiny particles in the fluid between cells.

**The cell theory states that all living things are composed of one or more cells and all cells come from pre-existing cells.**

**SEM**

Try to get the best possible image for each specimen viewed in the virtual scanning microscope.

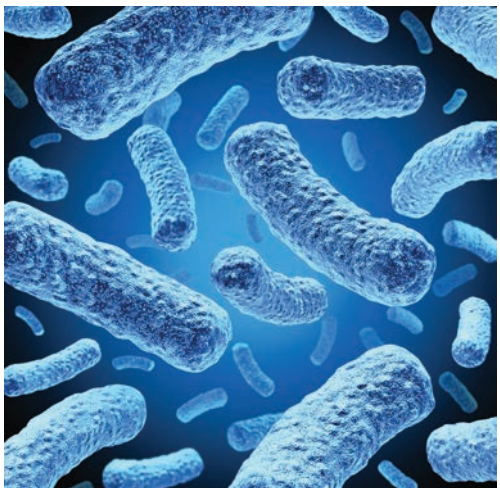
# Development of cell models require cross-disciplinary collaboration

Through a long history of experimentation and observation using increasingly sophisticated technologies we have come to know much more about the role of cells in living things and what they are composed of. We now have a better understanding of how their composition relates to what they do, and what they need to be able to do it.

Each cell can be thought of as a 'chemical factory' that is is programmed by information stored within the organism's genetic material, the **nucleic acid** molecule called **deoxyribonucleic acid (DNA)**. Like any factory, the cell has inputs – the variety of raw materials that are processed by specialised **enzymes** or '**protein** machines' – and outputs – the products of such activities. Some of the products are used within the cell, whereas others are packaged and exported for use elsewhere.

The development of sophisticated computer technologies has further advanced our knowledge, and in many cases taken the place of live modelling, due to the speed with which the computer model can test different scenarios compared with relying on natural life cycles.

▼ **Figure 7.8**
Bacterial cells take in materials from their environment such as water and nutrients. They produce wastes and in some cases products such as toxins.



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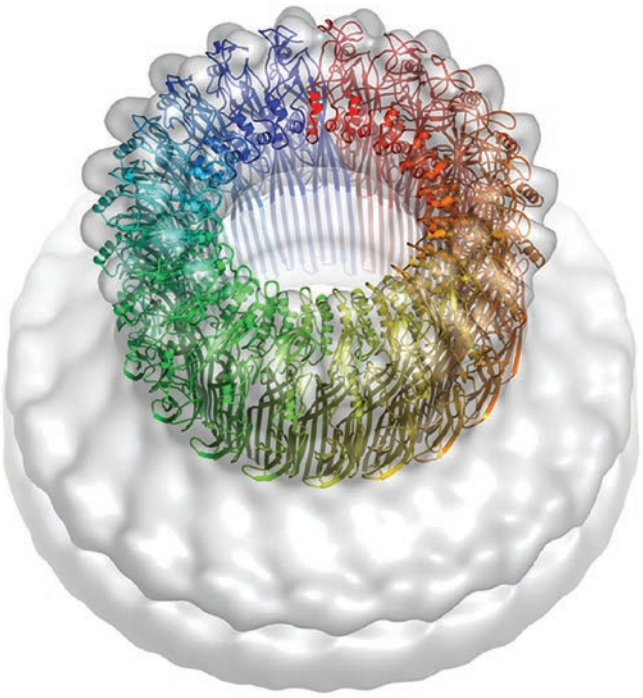


Australian Synchrotron (Helen Saibil, Birkbeck College)

**Figure 7.9 ▲**
Synchrotrons have added to our knowledge of structural biology by showing three-dimensional images of complex biomacromolecules. In this image, a perforin protein (rainbow colours) is shown attached to a cell wall (white). This image was created using megadata produced by the Australian Synchrotron.

Programs have been designed to model how molecules interact at the cellular level in complex networks of chemical reaction pathways. Computer models can predict how a cell's immediate environment can affect its functioning.

**Bioinformatics** is an important tool for modern biomedicine and biotechnology. It involves the application of information technology, statistics and mathematics to biological problems. Through the use of bioinformatics, scientists are accumulating large volumes of data and developing the ability to analyse it to understand and predict complex interrelationships.

The uses of particle accelerators, such as synchrotrons, have also added to our knowledge of structural biology. Three-dimensional images of **biomacromolecules** are being investigated through this area of particle physics. Findings from these investigations are having an impact on many areas of health and science, including fields such as immunology, neurobiology, cell biology, virology, physiology, molecular biology, medicine and biotechnology.

# EXPERIMENT 7.1

## MICROSCOPES AND CELLS

One of the main characteristics of living things is that they are made up of cells. However it was not until the late 1600s, with the invention of the light microscope, that cells were able to be seen and studied in detail. As microscopes have become more refined and powerful, we have been able to see more and more of the structures that make up cells.

### Aim

To revise and refine microscope use

To explore some of the structures of unicellular and multicellular organisms

### Materials

- light microscope
- prepared microscope slides, such as red blood cells, liver cells, striated muscle, *Paramecia*, *Euglenas*, pollen
- plastic ruler marked in millimetres or mini-grid (optional)

| What are the risks in doing this experiment? | How can you manage these risks to stay safe? |
|---|---|
| If you drop the microscope it could damage yourself or the lenses. | Handle the microscope with two hands. |
| A glass slide could break and cut you. | Clean up any broken glass using protective gloves and put glass into a safety container. |

### Procedure

1 Place a plastic ruler or mini-grid onto the stage so that you can see it when you look through the microscope. Work out the diameter across the fields of view of the different magnifications.

2 Select at least four different prepared slides. Examine each one carefully, first under low power and then under high power.

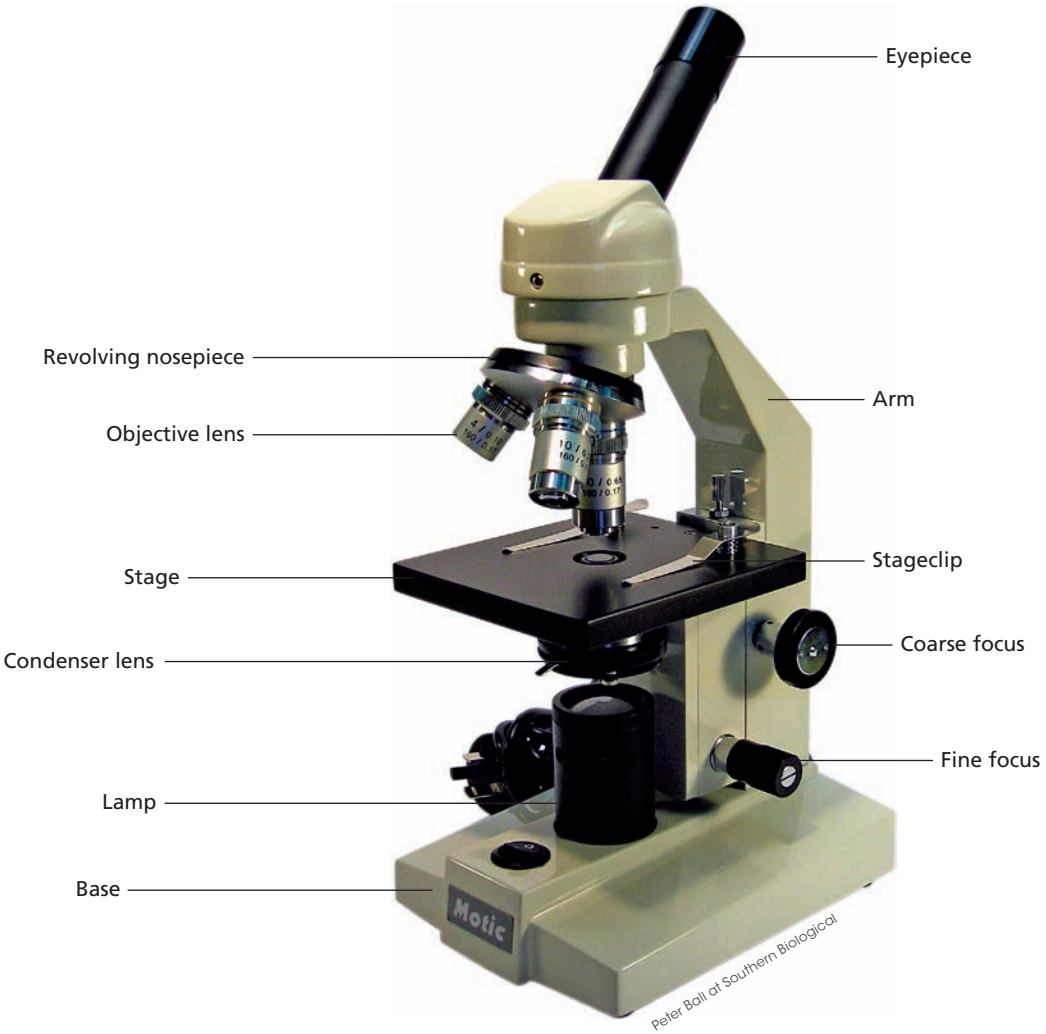



**Figure 7.10**
Parts of a light or optical monocular microscope

## Results

1 Create a table and record the diameter of the fields of view for each of the magnifications you used.

2 Draw each of the specimens as seen under high power. Make sure the magnification is shown and each specimen is labelled with its name. For each specimen state whether it is a unicellular organism or part of a multicellular organism.

## Discussion

1 When a specimen is viewed through a microscope, it appears larger than it really is. Explain how you can determine exactly how much it has been enlarged.

2 State how many micrometres there are in a millimetre.

3 Choose three specimens that you viewed and describe at least three structural differences between them.

4 Copy and complete the following table.

| | Total magnification | Total magnification |
|---|---|---|
| **Objective lens** | **Eyepiece lens ×10** | **Eyepiece lens ×5** |
| ×4 | | |
| ×10 | | |
| ×40 | | |

**MICROSCOPES AND MAGNIFICATION**

Choose onion root mitosis in the dropdown box and increase the magnification to see the difference in definition and detail.

## QUESTION SET 7.1

### Remembering

1 List the characteristics living things have in common.

### Understanding

2 'Living things are made up of cells and the products of cells.' Explain what this means.

3 Draw a timeline to show the development of the cell theory.

### Evaluating

4 Evaluate the advantages and disadvantages of using different types of microscopes. Include the following types of microscopes (you will need to conduct some additional research to answer this question):

- a light microscope
- b SEM
- c TEM
- d scanning probe microscope

# Prokaryotic cells are the simplest

*Refer to the classification system in Chapter 2.*

The simplest type of cell is a **prokaryotic** cell. These cells are very small, typically ranging from 1–10 μm in length and 0.2–2.0 μm in diameter with a simple internal structure. Prokaryotic cells have no membrane-bound **organelles**, which are functional units found within more complex cells. Unlike more complex cells, prokaryotic cells experience difficulty performing several different functions at the same time. It is the lack of membrane-bound organelles that limits the versatility of these simple cells.

Prokaryotic cells exist as single cells and are grouped within two major classification domains: the Bacteria and Archaea.

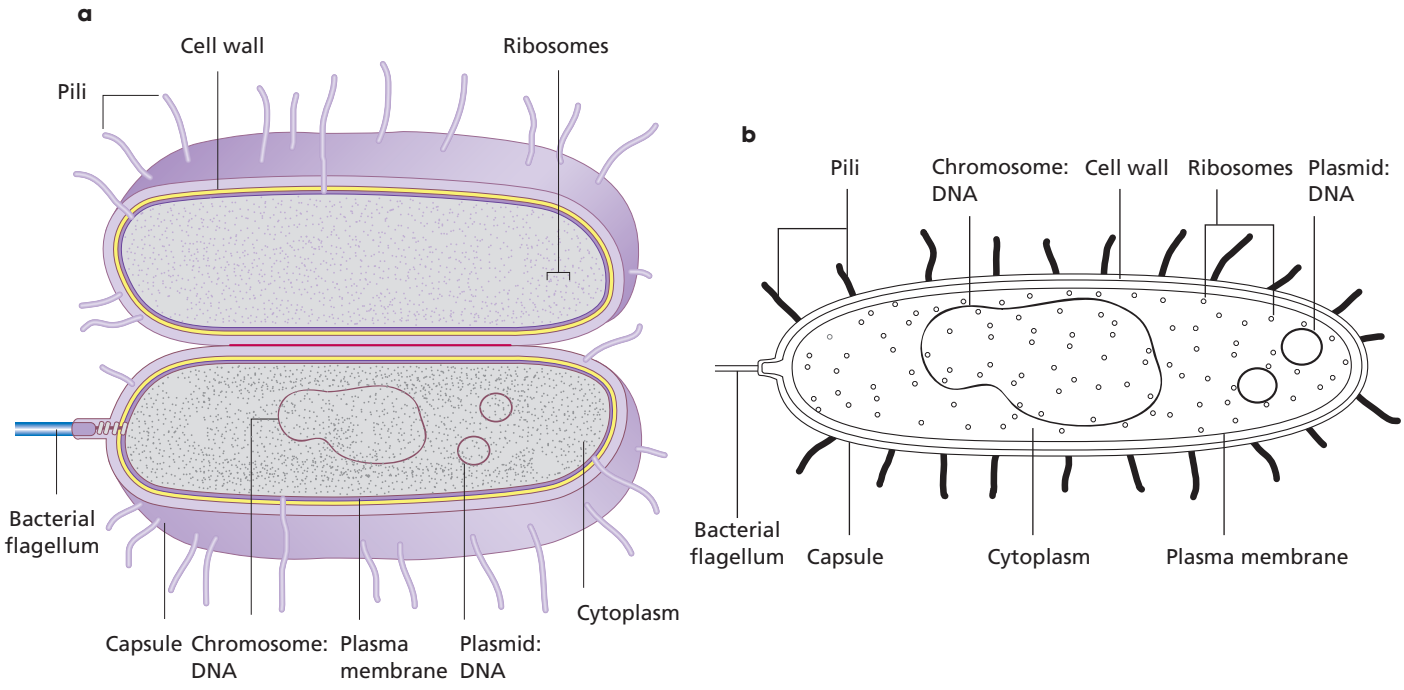



**Figure 7.11** ▼ a) A generalised diagram of a prokaryotic cell; b) a line drawing of the cell

WOW

### Exceptions to the rule

Not all prokaryotes fit comfortably with the description of typical prokaryotic characteristics. A sulfur-eating bacteria, *Thiomargarita namibiensis* has membrane-bound compartments to store nitrates; a rod-shaped bacterium *Epulopiscium fishelsoni* can grow to 0.7 mm long; and *Gemmata obscuriglobus*, found in a freshwater dam in Queensland, has its DNA enclosed in a membrane similar to the nucleus of a eukaryote cell.

## Cytoplasm

If you observe prokaryotic cells such as bacteria using a light microscope, the granular or 'spotty' substance making up the internal bulk of the cell will be visible. This is the **cytoplasm**. The chemical reactions that enable the cell to live are carried out here. The **cytosol** is the fluid part of the cytoplasm. It's often described as the 'soup' of the cell because it contains many dissolved substances. Collectively, the cytoplasm is made up of cytosol together with cell organelles.

## Ribosomes

The only distinguishable organelles, scattered freely throughout the cytoplasm of prokaryotic cells, are **ribosomes**. You would not be able to see these clearly by using a light microscope. They are too small. You would need to make an image of a cell with an electron microscope before the ribosomes became visible.

As all cell types contain ribosomes, they must be very important for cell functioning. Furthermore, some types of cells contain more ribosomes than others. Cells producing large amounts of proteins have the greatest numbers of ribosomes. This observation can be explained when we realise that ribosomes build up (synthesise) proteins from their building blocks, **amino acids**. Although your body produces most of the amino acids required for protein synthesis, some need to be supplied in the food you eat. It is the role of the digestive system to break down the proteins taken in as food into the amino acid building blocks. Proteins are needed for cell growth, repair and general cell functioning. So it makes sense that ribosomes are found in even the simplest prokaryotic cell.

*How the digestive system breaks down foods such as proteins is explained in Chapter 12.*

## Genetic material

The genetic code in DNA differs between the deadly disease-causing bacteria *Bacillus anthracis* (anthrax) and bacteria beneficial to humans such as *Lactobacillus acidophilus*. Despite their differences in function, both bacteria contain a single, circular chromosome, not visible using a light microscope. It lies in direct contact with the cytoplasm and carries instructions for the different types of proteins that will be synthesised in the ribosomes. Numerous small rings of DNA, called **plasmids**, may also be present in the cytoplasm. These can reproduce independently of the main chromosome.

# Eukaryotic cells are more complex

In **eukaryotic** cells, the internal structure is made up of various organelles (Figure 7.12), which can be viewed as 'membrane-bound' compartments. The membranes separate the organelles from the rest of the cell and some have membranes that fold, within which are sites of chemical activity. These organelles facilitate particular biochemical processes such as **cellular respiration** and **photosynthesis**. By maximising their surface area through the folding and stacking of internal membranes, a greater amount of chemical reactions can occur at the same time. Organelles also facilitate the synthesis of complex molecules and the entry and exit of substances. Membrane-bound organelles enable a cell to carry out hundreds of different chemical reactions simultaneously, without one reaction interfering with another. This is important when reactions are incompatible. Organelles also separate chemical reactions in time, such as when substances are stored and then later used in other reactions.

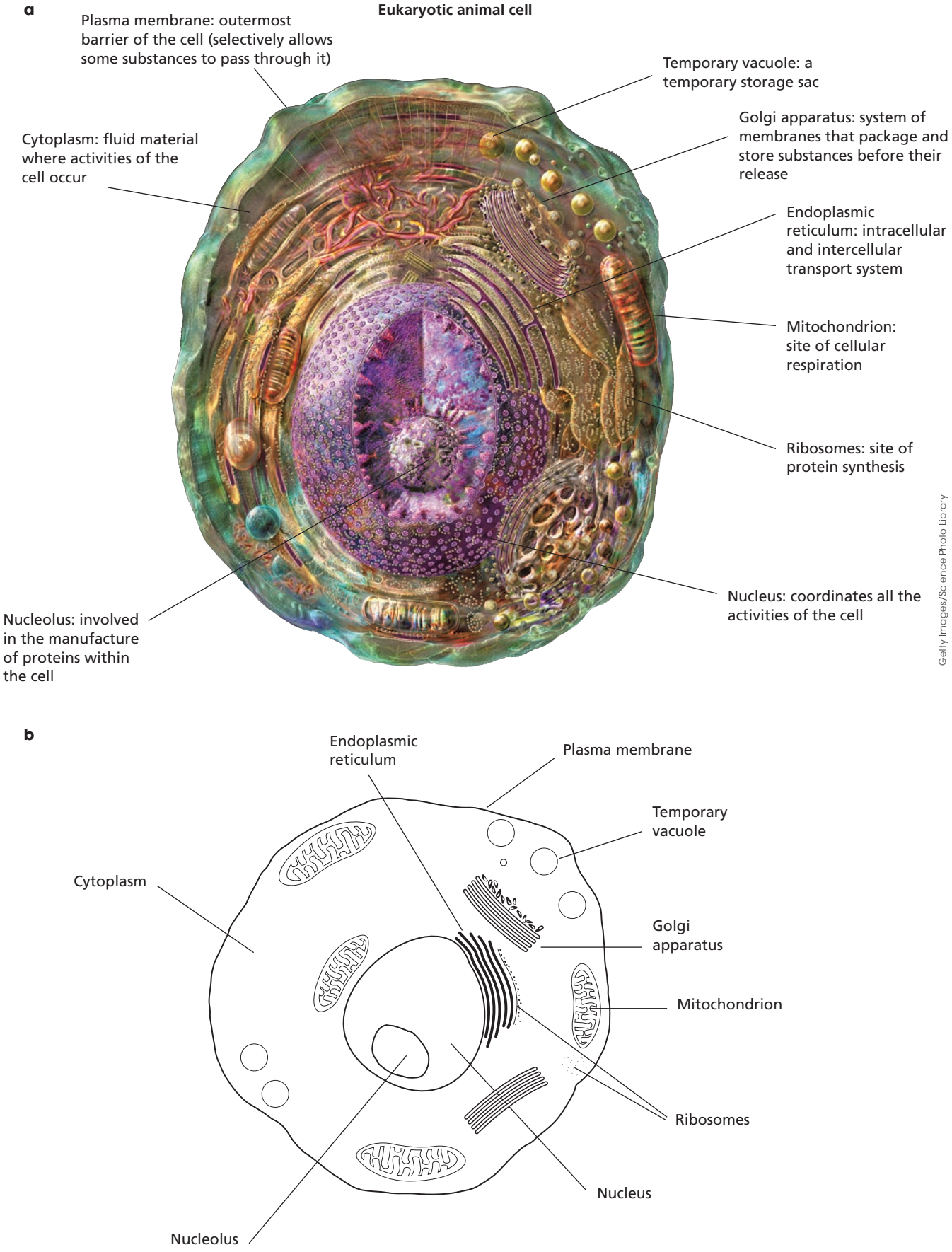
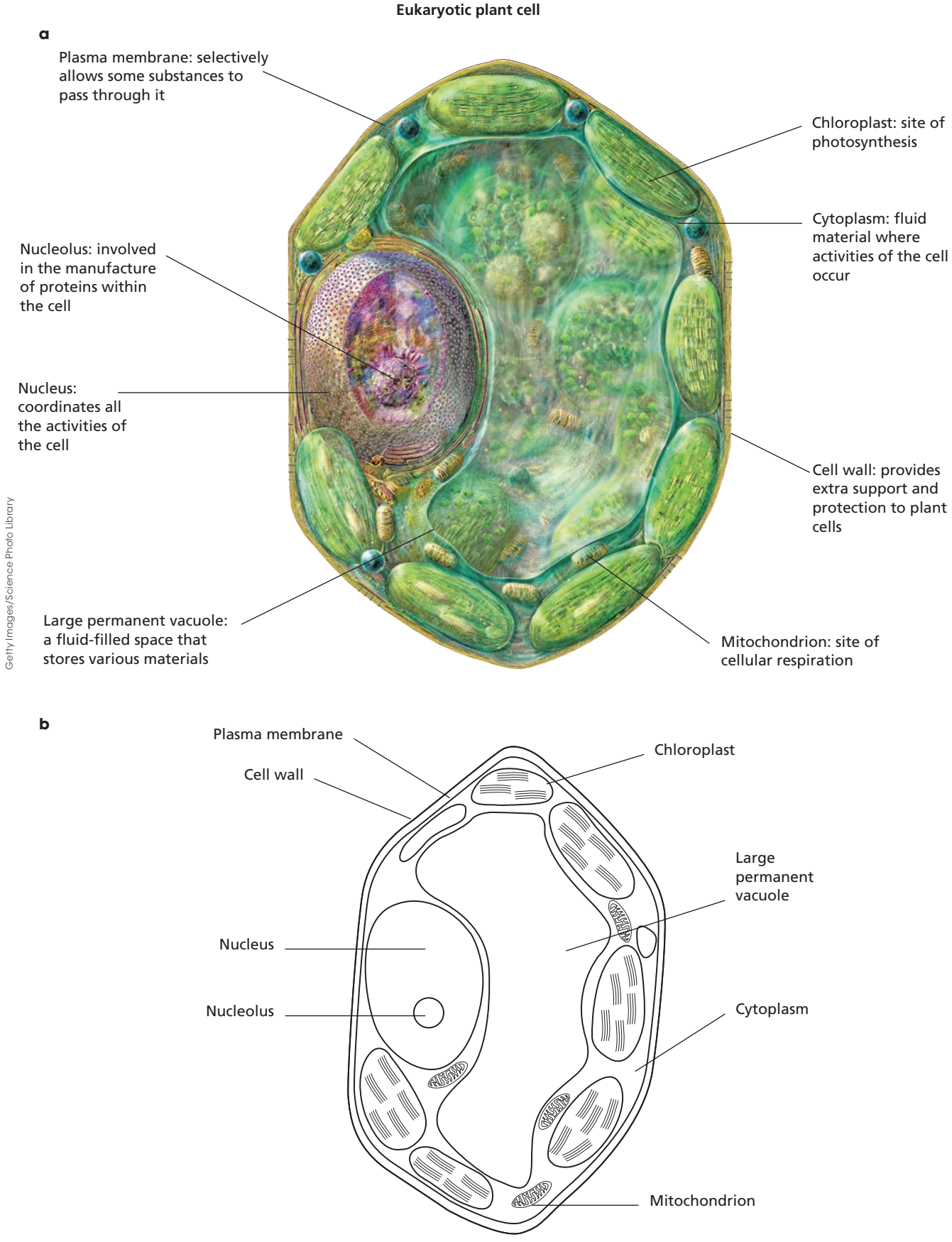



**Figure 7.12 ▲**
a) A eukaryotic animal cell showing its plasma membrane and other organelles; b) a line drawing of the cell




▲ **Figure 7.13**
a) A eukaryotic plant cell showing its plasma membrane, cell wall and other organelles; b) a line drawing of the cell

Imagine the cell as an office building. There are many regions with separate rooms. Different activities and functions are happening in the different rooms. It may be that one room produces booklets for distribution, another room is responsible for taking orders from the public and in yet another room the weekly salary for each worker is determined. Each room can carry on its functions without interference from the other although they are all inside the same building.

## Nucleus

One of the most prominent organelles in a eukaryotic cell is the nucleus (plural, nuclei). This is clearly visible using both light and electron microscopes. The main molecule found within the nucleus is the same nucleic acid making up the prokaryotic chromosome – DNA.

Similar to prokaryotic cells, DNA is bundled into chromosomes that code for the production of proteins. These proteins carry out a variety of activities within the cell. But in eukaryotes, chromosomes are not circular but are rod shaped when visible during cell division. The number of chromosomes within the nucleus is characteristic of the species. For example, humans have 46 chromosomes in each of their body cells whereas dogs have 78.

The nucleus is said to be the control centre of the cell. By coding for different proteins at different times and in different cells, the nucleus can coordinate the activities of a cell. The membrane around the cell nucleus keeps the DNA of eukaryotic cells separate from the chemical reactions of the cytoplasm. This makes it easier for DNA to be copied and organised before cell division.

**INNER LIFE OF THE CELL**

View the clip and see if you can identify the structures and activities shown.

# Not all cells are specialised

Most of the cells of our body (e.g. blood, liver, brain and nerve cells) are specialised to perform particular functions. **Stem cells** are unspecialised cells that have the potential to develop into many different kinds of cell. Unlike most specialised cells, they also have the capacity to keep dividing.

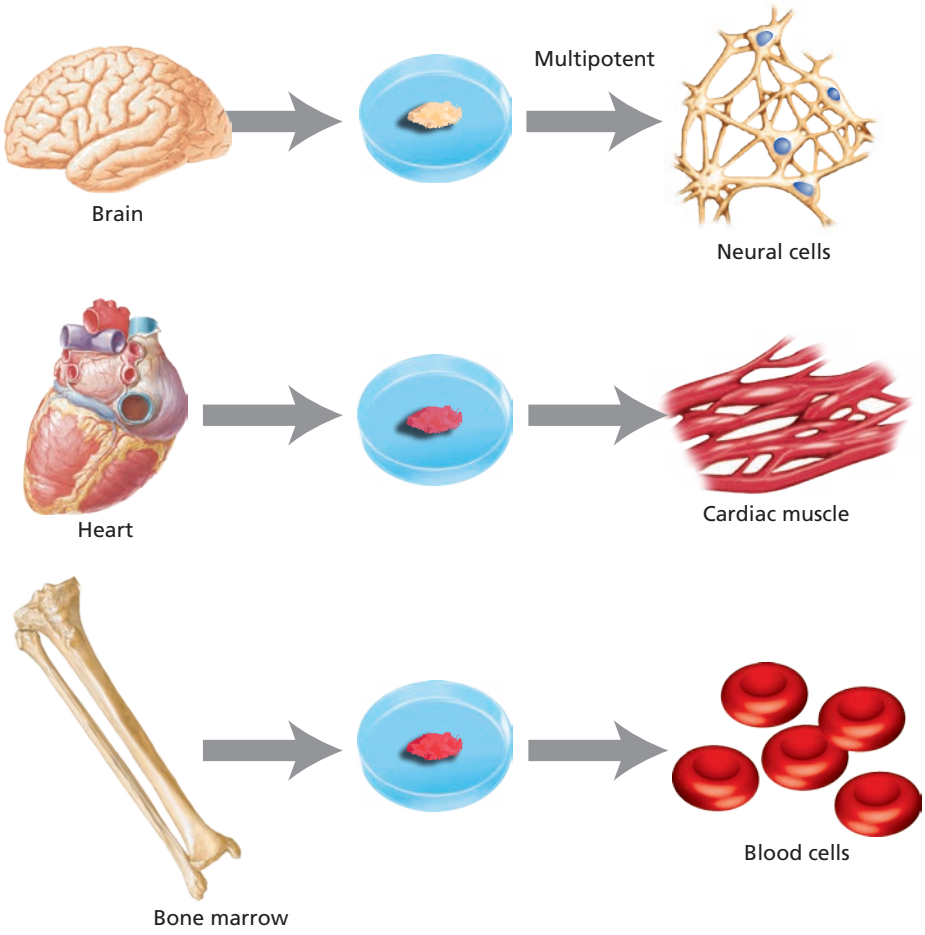



**Figure 7.14 ▶** Examples of adult stem cells; unspecialised cells that have the potential to develop into many kinds of cells

Stem cell research has an interesting history that has been somewhat tainted with debate and controversy. The first embryonic stem cell line was established in 1998, prompting concern over the use of embryos for research purposes. A few years later, stem cells were found in adults. These cells were limited in the type of specialised cells they could develop into compared with the many types of specialised cells embryonic stem cells could develop into.

International policies and debate amongst the public as well as religious groups, government officials and scientists have led to various laws and procedures regarding stem cell harvesting, development and treatment for purposes of disease research. The goals of such policies are to safeguard the public from unethical stem cell research and use while supporting new advancements in the field.

## Scientific literacy: Controversial stem cell therapy

In Italy, health officials are allowing a handful of patients to continue with a controversial stem cell therapy amid protests from scientists that the treatments are unproven and unsafe.

A company known as Stamina Foundation has been administering the therapy at a public hospital to people with a range of degenerative diseases. Their approach is based on stem cells derived from adult bone marrow, which can become mature bone and connective tissue.

The hospital agreed to host the research and assist with cell extraction and patient treatments, stirring protests from the medical community. 'The hospital is not even listed among the authorised stem cell factories,' says a director and gene therapy program coordinator. After an inspection, the country's drug regulator ordered an immediate halt to the foundation's stem cell treatments at the hospital.

The drug regulator's report said the foundation's treatment did not follow the official path required for clinical approval. So far no scientific publications describing its effectiveness are available.

But the halt sparked protests among patients' families who believed the treatment was working. Some appealed to the courts, and as a result a few patients were allowed to go ahead with the therapy. A group of stem cell researchers published an open letter to the country's Minister of Health, asking him to shut down all of the Foundation's treatments at the hospital.

The International Society for Stem Cell Research (ISSCR) urged the country's lawmakers to heed concerns of scientists around the world. The ISSCR president said, 'Stem cells have the potential to improve the treatment of many serious diseases but cell-based therapies present new challenges. In our enthusiasm to advance cures, we must not ignore the laws and regulations that exist to protect patients and ensure that medicines are manufactured under rigorous conditions and then proven safe and effective before being marketed by companies. Patients have been harmed when treatments circumvent the medical regulatory process.'

The ISSCR's Guidelines for Clinical Translation of Stem Cells emphasise that processing and manufacture of any cell product should be conducted under expert, independent review and oversight, to ensure as much as possible the quality and safety of the cells. Moreover, the ISSCR reiterates the value of a strong biological rationale for clinical interventions with stem cell-based products, based on rigorous evidence from pre-clinical studies and a plausible hypothesis for how cells are expected to improve a disease process.



### Questions

1. Describe what you know about the uses of stem cells in therapy.
2. Explain why new treatments undergo testing before being allowed for use.
3. Provide an argument for continued use of stem cell treatment from the point of view of patients with degenerative diseases in the public hospital described in the article.
4. Provide an argument against continued use of stem cell treatment from the point of view of the ISSCR.
5. Do you think the hospital would have been as willing to use stem cells if they were derived from embryos? Explain your answer.
6. Do you think the same amount of government money should be spent on researching stem cell treatments for both common diseases and rare genetic diseases? Discuss the benefits of funding all stem cell treatment research.

## Case study

# Stem cell tourism

Hundreds of people living with incurable conditions travel abroad each year for experimental stem cell therapies that aren't available under clinical trial regulations in their home countries. They are lured by the hope of biomedical miracles. For many patients whose mainstream treatment has reached its limits, the hope of even small improvements can seem enough to justify the high cost of travel and treatment.

As 'stem cell tourism' increases, one research team aims to ensure patients stay well informed and connected to mainstream support networks.

*High hopes, high risk? A sociological study of stem cell tourism* is an international project, led by Monash University's Professor Alan Petersen. The project is examining the factors shaping Australians' views and expectations of stem cell treatments offered abroad by capturing the experience of those who have travelled or contemplated doing so, including some who decided not to make the trip. Insights from this Australian Research Council-funded study will be used to make policy recommendations and improve outreach activities and educational resources.

Stem cell tourism attracts heated opinions. Some argue that treatments that have not met high regulatory standards for human trials are rightfully outlawed, to protect the community. Meanwhile, many patients and advocacy groups respond that potentially life-saving treatments at home are being tied up in red tape and should be available to consenting patients.

Jane Kotey

**Figure 7.15 ▲**
Jane Kotey is a PhD student based in the School of Political and Social Inquiry at Monash University.

Professor Petersen and fellow members of the research team are trying to tease apart the emotionally charged issues that influence patients to travel for treatment. The ultimate aim is to offer doctors and other health practitioners greater insight into the decisions and experiences of gravely ill patients, helping to keep communication open.

A project collaborator, The University of Melbourne's Associate Professor Megan Munsie, says general practitioners are increasingly being asked about stem cell therapies but do not feel adequately equipped to discuss options with their patients. She is concerned that more invasive methods for administering stem cells are becoming normal in foreign clinics. These methods are risky because little may be known about the behaviour of the implanted stem cells, and because they could also result in infection, bleeding or even more serious complications with some patients having lost their lives in pursuit of these treatments.

The project team includes Professor Steven Wainwright from the Centre for Biomedicine and Society at Brunel University, UK, postdoctoral researcher Dr Claire Tanner and PhD student Jane Kotey, both from Monash University.

### Questions

1. Describe 'stem cell tourism'.
2. Describe what motivates people to travel to other countries for stem cell treatment.
3. Evaluate if you think the research in this case study is important. Justify your answer.
4. Predict some possible effects on families of patients who travel abroad for stem cell treatment. Consider the financial, emotional and social effects.
5. Use information from this case study to give your opinion on whether it is possible to undertake research in a scientific field without having a qualification in science.

# EXPERIMENT 7.2

## INVESTIGATING CELLS

Living cells have a range of different structures that enable them to meet their needs for energy production and to carry out their specialised tasks. How do prokaryotic organisms, such as bacteria, compare in their basic structure to plant and animal cells?

### Aim

To compare and contrast the structure of eukaryotic and prokaryotic cells, and plant and animal cells

### Materials

- light microscope
- microscope slides
- coverslips
- mini-grid
- onion
- knife or single-edged razor blade
- tweezers or mounted needles
- eye dropper (optional)
- methylene blue stain with eye dropper
- paper towelling
- large beaker of water for used microscope slides and coverslips
- *Elodea* plant (or an alternative freshwater oxygenator available from the local aquarium or biological supplier)
- prepared slide of human cheek cells
- prepared slide of bacteria
- prepared slides of plant and animal tissues
- oil immersion lens
- oil immersion

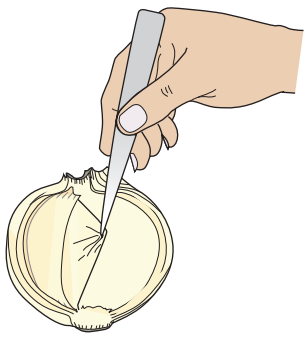
| What are the risks in doing this experiment | How can you manage these risks to stay safe? |
|---|---|
| The knife or razor blade is very sharp. | Take care when using the knife or razor blade and handle it carefully. |
| Cover slips break easily and can cut. | Take care with coverslips and do not push hard when placing them. |
| *Elodea* is a noxious weed. | Dispose of *Elodea* safely, away from waterways. |

### Procedure

#### Plant cell: Onion

Use the onion provided and cut off a piece. Peel a section of 'membrane' from between the two layers of onion. The membrane will be about as thin and flexible as plastic wrap.

1. Use the knife or razor blade to carefully cut the membrane until it is about the size of a quarter of a fingernail.
2. Have a microscope slide ready with a drop of cold water on it.
3. Place the small piece of membrane in the drop of water, making sure that it stays flat. You can stop it from curling or doubling over on itself by using tweezers or mounted needles.
4. Carefully place a coverslip on top of the onion membrane on an angle to push out any air bubbles. This is known as a 'wet mount'. Check that there is enough water to surround the onion membrane (which should sit well within the boundaries of the coverslip). The water will seep under the coverslip by itself.



▲ **Figure 7.16**
Preparing onion tissue

5 Focus on onion cells under low power and then switch to high power. Draw a diagram of a few cells, labelling the nucleus, cell wall and cytoplasm.

6 Put one drop of methylene blue stain next to one side of the coverslip (Figure 7.17). Use some paper towelling on the other side of the coverslip to absorb liquid and so draw the stain across under the coverslip.

7 Focus on the cells again and identify whether the stain has made any structures more visible.

8 Make a careful diagram of a few cells. Label the nucleus, cell wall and cytoplasm.

9 Use a mini-grid to measure the dimensions of an onion cell.

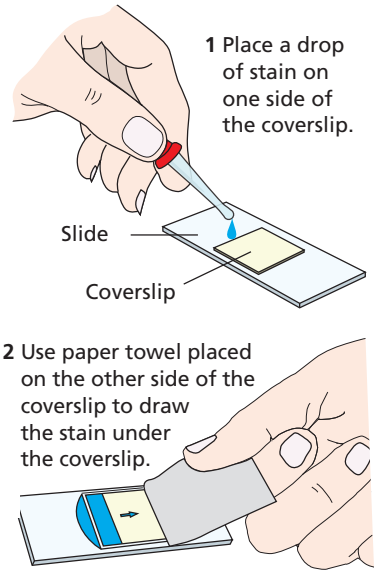



Figure 7.17 ▲
Staining a slide

### Plant cell: *Elodea* (or alternative)

10 Repeat steps 1 to 5 in the procedure using an *Elodea* leaf from the tip of the plant instead of the onion membrane. Float the tissue in warm water instead of cold water.

11 View the *Elodea* leaf on low and then high power. Watch it for a few minutes. What do you see happening to the cell contents? What does this suggest?

12 Make a careful diagram of one cell. Label the cell wall, nucleus, chloroplasts and cytoplasm.

13 Stain the *Elodea* cell using methylene blue by following the instructions in step 6 above. What differences do you see occurring within the *Elodea* cell? What does this suggest?

### Animal cell

14 Examine the prepared slide of a cheek cell under low power then high power. Make a careful diagram of one of the cells. Label the plasma membrane, nucleus, cytoplasm and any other structures that you can identify.

15 Your teacher may have prepared other animal and plant tissue slides for you. Take a look at each slide using the light microscope and see if there are any different cell structures that you can identify.

### Prokaryotic cell

16 Place a prepared slide of bacterial cells onto your microscope stage.

17 An oil immersion objective lens may be used to give a higher magnification (useful for observing bacteria). A drop of oil is placed on the coverslip above the specimen and the oil immersion objective lens is centred over the oil. Only use the fine adjustment for focusing.

18 Draw a bacterial cell.

## Results

1 Draw labelled diagrams of onion cells, an *Elodea* cell and a bacterial cell. Include the magnification used and size of the cell (in micrometres, μm).

2 Describe the similarities and differences between the three types of cells.

## Discussion

1 Describe what affect adding the methylene blue stain had on your ability to see different parts of the onion cell.

2 List what sorts of substances would need to be able to pass through the walls of onion cells.

3 Describe what you observed happening to the chloroplasts inside the *Elodea* cell. Name this process and explain why it is happening.

4 Note any differences you noticed in the *Elodea* cell once the cell had been stained with methylene blue. Account for these differences.

5 Compare the size of a bacterial cell to the plant and animal cells you have seen so far.

6 Outline what cell detail you can see inside the bacterial cells.

7 State two limitations of using a light microscope.

8 From your observations, suggest two differences between prokaryotic and eukaryotic cells.

9 Describe how the prepared slides that you used in this activity compare to the ones that you had to prepare using fresh materials. Explain whether one was better to use than the other.

10 Describe how the oil immersion technique assisted you in seeing the internal structure of the cell.

## QUESTION SET 7.2

### Remembering

1 a State where in cells you would find the cytoplasm.
  b Describe the relationship between the cytoplasm and cytosol.
2 Describe what plasmids are.

### Understanding

3 Name the organelle that controls the functioning of eukaryotic cells. Describe the main molecule found in this organelle and explain how it controls the cell's functioning.
4 Compare the structure of chromosomes found in prokaryotic and eukaryotic cells.

### Applying

5 If you were given an unknown cell, explain how you would be able to tell if it were:
  a eukaryotic or prokaryotic.
  b from a plant or an animal.
  Use Figures 7.11, 7.12 and 7.13 to justify your answers.

### Analysing

6 State the function of ribosomes. Explain why you would expect to find more ribosomes in a protein-producing cell than a skin cell.

### Evaluating

7 A large cell of 0.3 mm was observed. Ribosomes were present in the cytoplasm but no other organelles. Could this be a prokaryotic or eukaryotic cell? Justify your answer. Identify further evidence that would be useful in your argument.
8 Discuss the impact of having a large number of organelles with folded and stacked membranes on the functioning of a cell.

# Cells need energy

Wherever life exists, it depends on a source of energy and a supply of matter. Provision of energy is vital to ensure that all essential life processes take place. Organisms can obtain this energy from a variety of sources.

Some organisms are able to directly harness energy from the Sun. They use this energy to drive the chemical reactions involved in photosynthesis. Some organisms are able to harness the energy released by chemical reactions in **chemosynthesis**. These are **autotrophs**. Others rely on autotrophs to provide their energy for them, usually when consumed. These organisms are **heterotrophs**. Even though we describe the energy needs of whole organisms, it is important to consider cells within these organisms. Autotrophic organisms contain cells that can use energy from the Sun; for example, green plant cells. Individual cells of heterotrophic organisms require energy from other matter. In either case, if cells are supplied with enough energy, the whole organism can function efficiently.

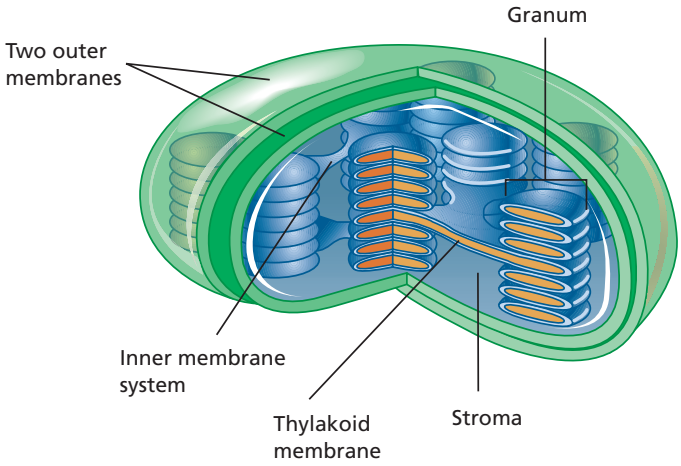
*Energy and the transfer of matter through ecosystems is discussed in Chapter 4.*

# Photosynthesis

Most life depends on the energy provided by our Sun, but not all cells can harness its energy. Cells that convert solar energy into chemical energy, such as green plant cells, use the pigment **chlorophyll**. Chlorophyll is able to absorb light energy and to make it available for use in photosynthesis. Some eukaryotic cells contain oval-shaped organelles called **chloroplasts**, which contain chlorophyll.

Photosynthesis is a series of reactions that occur in the **stroma** and **thylakoid membrane** system of the chloroplast (Figure 7.18). These were the organelles you saw streaming around the leaf cytoplasm in Experiment 7.2. During these photosynthesis reactions, carbon dioxide and water are combined to produce glucose, oxygen and water.

**Figure 7.18 ▶**
Generalised sketch showing the grana and stroma of a chloroplast




*Further details about the process of photosynthesis is found in Chapter 9, pages 286–8.*

The internal membranes of a chloroplast are folded many times. This provides more surface area for chemical reactions of photosynthesis to occur. Chloroplasts have their own genetic material – DNA and **ribonucleic acid (RNA)** – and ribosomes that are similar to those of prokaryotes, reflecting their evolutionary link with prokaryotes.

# Cellular respiration

All organisms, with the exception of the Kingdom Archaea, use glucose as the primary source of energy to drive the thousands of chemical reactions that occur constantly in each living cell. The chemical bonds in glucose are broken, providing energy in a form the cell can use. This chemical process is known as cellular respiration.

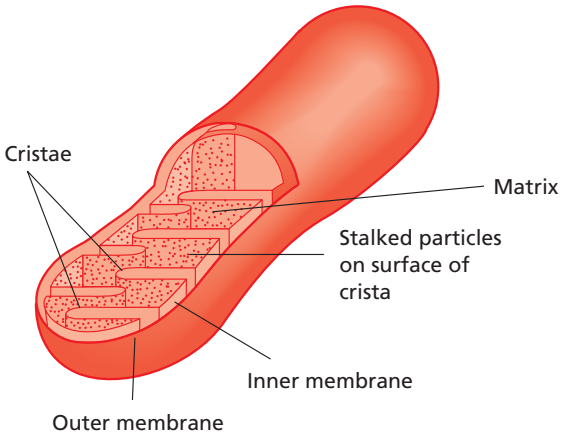
*You will learn more about this chemical process in Chapter 9.*

Cellular respiration is a series of chemical reactions that involve a reaction between glucose and oxygen to produce carbon dioxide and water. During certain stages of these chemical reactions, energy is released. This energy is used to build up molecules called **adenosine triphosphate (ATP)**. ATP is an energy-storage molecule that is used to power cellular processes.

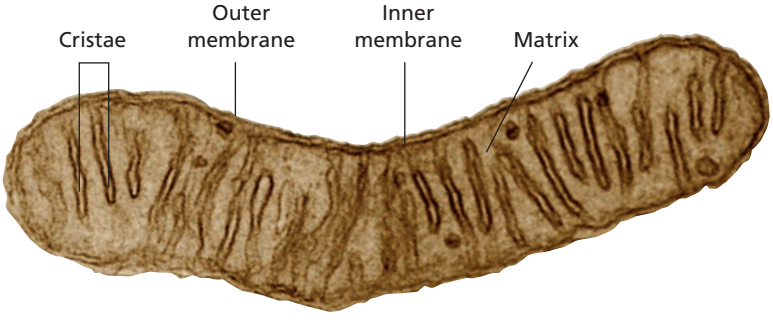
In eukaryotic cells, the first stage of cellular respiration takes place in the cytoplasm. The final stage occurs in **mitochondria**. Mitochondria are small, oval-shaped organelles found scattered throughout the cytosol of a cell. Each mitochondrion consists of an outer smooth membrane and a highly folded inner membrane. The folds in the inner membrane are called **cristae**, and they protrude into the inner space of the mitochondrion, a protein-rich fluid called the matrix. These cristae provide two important features to cellular respiration: the enzymes for cellular respiration are located mainly on the cristae, and the numerous folds of the cristae provide a large surface area for the chemical reactions to occur.

**Figure 7.19 ▼**
a) A generalised sketch and b) electron micrograph of a mitochondrion in longitudinal section. The stalked particles on the surface of the cristae are the site of ATP synthesis.

**a**




**b**

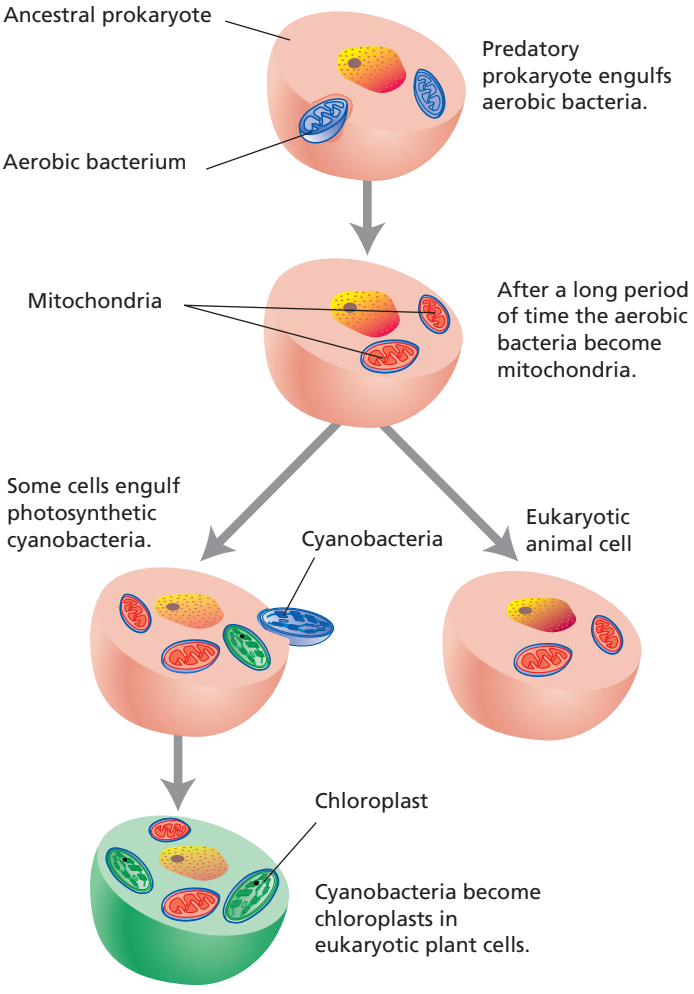


# Prokaryotes and eukaryotes have a common evolutionary past

The first eukaryotes appeared around 2 billion years ago. The **endosymbiotic theory** proposes that eukaryote cells were formed when a bacterial cell was ingested by another primitive prokaryotic cell. The larger prokaryotic cell would have ingested the smaller bacterial cell by engulfing it in a process known as phagocytosis. The bacteria escaped being digested and instead formed a symbiotic relationship with its host.

Scientists believe that mitochondria and chloroplasts evolved through this process of endosymbiosis, where one species lives inside another. To this day, mitochondria and chloroplasts make copies of themselves and split in two, like bacteria do, when they reproduce. Both mitochondria and chloroplasts can arise only from pre-existing mitochondria and chloroplasts. They cannot be formed in a cell that lacks them. Both mitochondria and chloroplasts have two membranes. The outer one is probably derived from the host membrane when it engulfed the bacteria and the inner one is probably the membrane of the ingested bacteria.

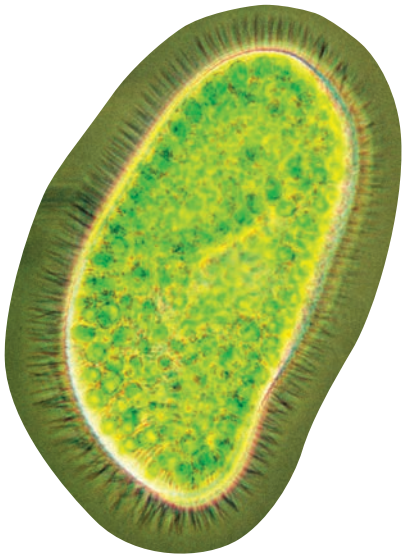
**The endosymbiotic theory proposes that eukaryote cells were formed when a bacterial cell was ingested by another primitive prokaryotic cell.**




▲ **Figure 7.20**
The theory of endosymbiosis explains how cells may have acquired mitochondria and chloroplasts.

**INNER LIFE OF THE CELL: MITOCHONDRIA**

View the clip and try to identify the structures and activities shown.



Getty Images/Science Photo Library

▲ **Figure 7.21**
Light micrograph of *Paramecium bursaria*, a single-celled protozoan. The smaller green cells within the *Paramecium* are unicellular green algae, which live symbiotically in the organism.

**ENDOSYMBIOSIS**

View the narrated animation about the theory of endosymbiosis – how chloroplasts and mitochondria evolved in eukaryotic cells.

Mitochondria are similar in size to small bacteria and they have their own genetic material, which, like that in bacteria, is contained on a circular DNA molecule. Mitochondria contain ribosomes and RNA molecules so that they can make their own proteins. It is likely mitochondria evolved from bacteria able to carry out aerobic cellular respiration, living within a host cell.

Scientists believe that chloroplasts arose from primitive cyanobacteria that were ingested by eukaryotic cells already containing mitochondria around 1 billion years ago. This explains why not all eukaryotic cells contain chloroplasts but they all contain mitochondria. Chloroplasts have their own DNA, RNA and ribosomes similar to those of prokaryotes. They harness energy from light, storing it in the bonds of **organic** molecules such as glucose. These organic molecules provide energy to the host. The environment within the host cell provides **inorganic** compounds, such as carbon dioxide and water, and also protects the chloroplasts from predators and from drying out. A eukaryotic cell that contains chloroplasts no longer needs to engulf other cells to obtain food. This may explain why plant cells have lost the ability to change shape rapidly to engulf other cells by phagocytosis. Instead, they have developed a tough and protective cell wall.

Once both heterotrophic and photosynthetic eukaryotes had evolved, the heterotrophs repeatedly engulfed photosynthetic cells to utilise their autotrophic abilities. Many animals living today engulf algae for this purpose. Usually each of the partners in these relationships can live independently of the other.

## QUESTION SET 7.3

### Remembering

1 List the evidence that has led scientists to believe that mitochondria and chloroplasts were once free-living organisms.

2 Describe the probable event that triggered the endosymbiotic relationship between primitive cyanobacteria and the eukaryotic cell that ingested it.

### Understanding

3 Distinguish between the energy sources used by autotrophs and heterotrophs.

4 Name the organelle that allows cells to access energy so they can carry out activities. Explain how it does this.

5 Describe the probable origin of chloroplasts.

6 Distinguish between:

- a chemosynthesis and photosynthesis.
- b cellular respiration and photosynthesis.
- c heterotrophic and autotrophic.

### Applying

7 Explain why you would expect human muscle cells to contain more mitochondria than a cell in your big toe.

### Analysing

8 Suggest why it was advantageous for eukaryotic cells to nurture the bacteria that eventually became mitochondria.

# Specialised organelles synthesise complex molecules

Every living cell is involved in synthesising large molecules that are needed not only to build the body parts of organisms but also to maintain the biochemical processes that keep them living: communication, transforming energy and relaying genetic information.

These large molecules are called biomacromolecules and are grouped into four main classes based on their chemical composition and structure. The four classes are complex **carbohydrates**, **lipids**, proteins and nucleic acids. Each of these groups is further subdivided according to their slight differences in structure and, therefore, in function.

*Many molecules found in living matter are larger and more complex than those in non-living material. With the exception of water, most molecules in living organisms contain the element carbon. These complex carbon-containing molecules are known as organic compounds.*

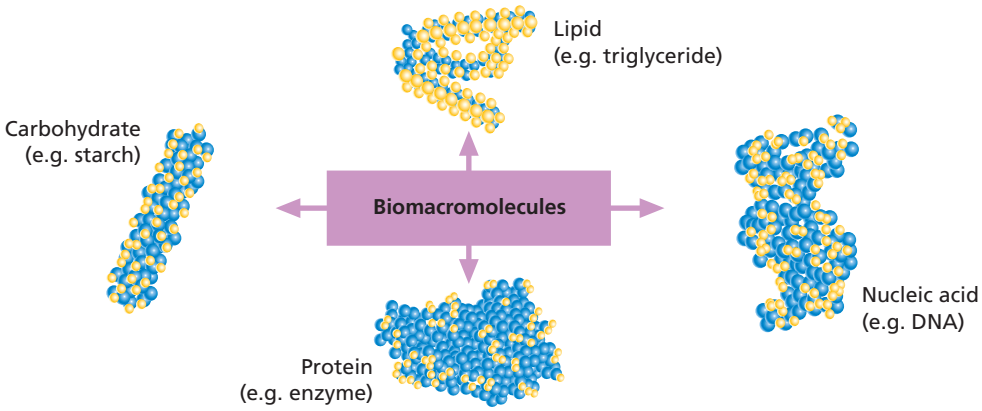



**Figure 7.22**
The major groups of biomacromolecules

Some organisms are able to synthesise their own biological macromolecules. Others build them from organic compounds that they have ingested. Autotrophs build their own organic compounds from the inorganic materials that they take in from their surroundings. For example, seaweeds, eucalypts, grasses and microscopic algae all produce simple sugars (the basic building unit) through the process of photosynthesis using the inorganic materials, water and carbon dioxide. Using simple sugars, autotrophs then build the other kinds of organic compounds (such as sucrose, starch and cellulose) that they need.

*Of the inorganic compounds, water and minerals are among the most important. Carbon dioxide is termed 'inorganic' as it is not a complex molecule. Living things contain both organic and inorganic compounds.*

Some autotrophic organisms, such as certain kinds of bacteria, are able to build or synthesise their organic requirements through chemical processes other than photosynthesis. These chemosynthetic autotrophs or chemotrophs are typically found in extreme conditions, such as in the depths of the ocean near hydrothermal vents, in thermal springs, or in places deprived of oxygen or light.

Heterotrophs, such as humans, have to synthesise their own biomacromolecules from existing organic compounds. They use the chemical energy in the food they ingest. Heterotrophs have to take in a range of organic compounds, such as protein, in their food. They then break this down into simpler substances such as amino acids in the process of digestion. These are then synthesised into the kinds of organic compounds that are required by the organism.

*Chapter 11 includes more detail about the process of digestion.*

Large biomacromolecules are synthesised onsite inside the cell. Proteins, nucleic acids and complex carbohydrates are built up by linking smaller repeating molecules, each called a **monomer**. These form long chains called **polymers**. Even though lipids are large biomacromolecules, they are not polymers; they are composed of distinct chemical groups of atoms.

# Carbohydrates

**CARBOHYDRATES**

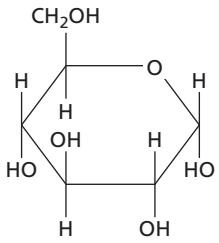
View the animation to assist your understanding of simple and complex carbohydrates.

Carbohydrates are the most common compounds in living things. We see and hear about them constantly in relation to our diet. Their name gives a clue to the composition of carbohydrates. Each molecule consists of carbon, hydrogen and oxygen atoms in the ratio of 1:2:1, giving the general formula for carbohydrates as $n(CH_2O)$.

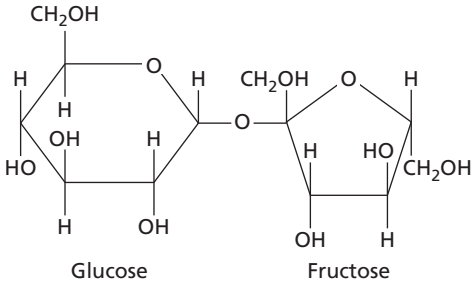
Carbohydrates are classified as **monosaccharides**, or simple sugars (Figure 7.23a), **disaccharides** (Figure 7.23b) and **polysaccharides** (Figure 7.23c) depending on the complexity of the linkages of the monomers. The product of photosynthesis, glucose, is a monosaccharide.

**Figure 7.23** ▶ a) Glucose is a monosaccharide. b) Sucrose is a disaccharide; a glucose and fructose sugar are joined. c) Cellulose is a polysaccharide; many glucose units are joined.

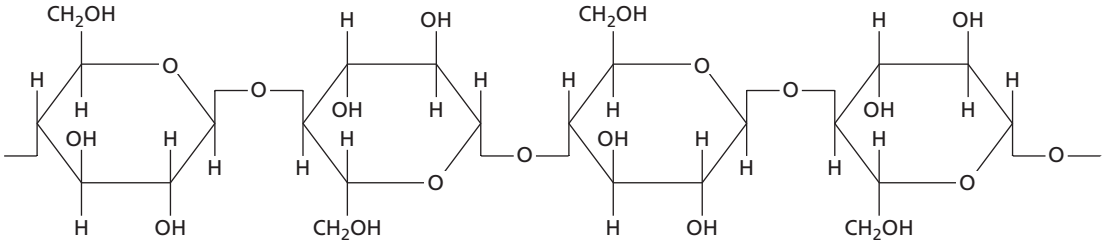
**a** **Glucose**



**b** **Sucrose**




**c** **Cellulose**



Organisms use carbohydrates as an energy source and for structural components. Carbohydrate molecules can combine with other atoms or groups to form important compounds; for example, **glycoproteins**, which are a combination of carbohydrate and protein molecules.

# Lipids

**LIPIDS**

View the animation to assist your understanding of lipids.

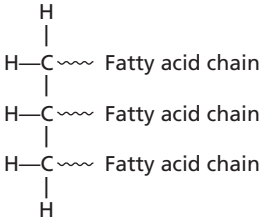
Lipids are a diverse group of molecules and include fats and oils, terpenes, waxes, phospholipids, glycolipids and steroids. They all contain the elements carbon, hydrogen and oxygen, and are insoluble in water. In cells, lipids have three important functions:

1 energy storage (they have approximately twice the amount of energy as carbohydrates)
2 structural component of membranes
3 specific biological functions (e.g. transmission of chemical signals both within and between cells).

Cells also excrete lipids that function to protect the cell or the organism to which it belongs.

The fats and oils of plants and animals are typically composed of **triglyceride** molecules (Figure 7.24). Their name gives a clue to their composition ('tri' = three), in terms of the number of fatty acid chains attached to a glycerol backbone.

Lipids such as phospholipid and cholesterol, required for particular purposes such as making membranes, are synthesised in the tubular cavities of the **endoplasmic reticulum (ER)**.




▲ **Figure 7.24**
A triglyceride molecule contains a glycerol unit and three fatty acid chains.

*See page 175 for more about the endoplasmic reticulum.*

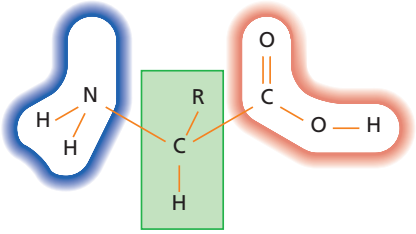
# Proteins

Virtually everything a cell is, or does, depends on the proteins it contains. They contribute to building many different structures and parts and, as enzymes, control the thousands of chemical reactions that maintain life processes.

Your body produces more than one million new red blood cells each second. A range of different proteins is found embedded within the membranes of these cells. For example, channel proteins penetrate through the membrane and select substances to pass through the membrane. This means that your existing red blood cells need to produce proteins for one million plasma membranes and organelle membranes each second.

Like lipids, proteins are made up of the elements carbon, hydrogen and oxygen. However, they are different to these compounds in that they always contain nitrogen. In addition, sulfur is often present, and sometimes phosphorus and other elements. These elements combine to form the building blocks of proteins, amino acids. Amino acids are made into proteins in the ribosomes.

More than 100 different kinds of amino acids can be found in cells, but only 22 join together to form a protein or polypeptide. Of these amino acids, 20 are 'standard' and are found in eukaryotes, including humans. The other two 'non-standard' amino acids are found only in some simple microbes. It is the order and number of amino acids that make different types of protein. The ordering of amino acids in proteins is determined by the genes in our chromosomes. It is rather like arranging 20 kinds of beads in different ways to make different necklaces of different lengths. The necklace chains can then be arranged differently in loops and folds to give each protein its characteristic features.




▲ **Figure 7.25**
Chemical diagram of an amino acid where the R group can represent a number of different chemicals. Many amino acids join together to form a polypeptide.

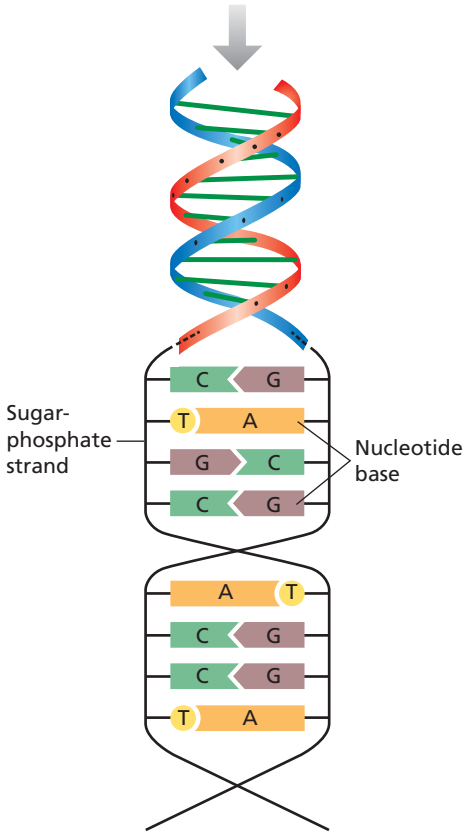
Plants can synthesise their own amino acids but animals depend on obtaining some of them from their diet. Your body produces most of the amino acids required for protein production. Of the 20 standard amino acids, 9 are called 'essential' because they cannot be synthesised by cells in your body. These essential amino acids, such as phenylalanine and tryptophan, must therefore be taken in as food. Others may be conditionally essential for some ages or medical conditions. Essential amino acids may also differ between species.

The whole set of proteins produced by a cell is called its **proteome**. The study of proteomes is **proteomics**, a term first used in 1994 by Marc Wilkins of Macquarie University, Sydney. Functional proteomics refers particularly to what proteins do in different cells and tissues.

Many aspects of protein structure were first identified by the 'father of structural biology', Linus Pauling (1901–94). Since then many scientists have followed in his footsteps, including world-renowned Australians Sir Gustav Nossal and Peter Doherty, in unravelling the structure and function of a whole range of different kinds of proteins in the fields of immunology and microbiology (for more information on this see Unit 4).

Fairfax Syndication/The Age/John Woudstra

▲ **Figure 7.26**
Sir Gustav Nossal researches proteins and immunology.




▲ Figure 7.27
DNA is a double-stranded molecule made of four different kinds of nucleotides.

# Nucleic acid

Cells carry out many and varied tasks, usually at the same time. To be an efficient system a cell needs to have some way of coordinating all of these activities. This is a main function of the nucleus.

The nucleic acids DNA and RNA are found in the nucleus. A molecule of DNA is composed of two long strands of subunits called **nucleotides**. They are wound around each other to form a double helix (Figure 7.27). DNA codes for the production of proteins that carry out and control the many activities within a cell. When a cell divides, new DNA is synthesised.

Each DNA molecule is large. They are too large to move through the nuclear membrane. It is the job of another type of nucleic acid, **messenger RNA (mRNA)** to transfer the DNA code to the ribosomes for protein synthesis. The order of nucleotides in mRNA is determined by the order of nucleotides in a section of DNA. After synthesis of a strand of mRNA has been completed, it moves from the nucleus to ribosomes in the cytoplasm. The order of nucleotides in the mRNA determines the order of amino acids in protein synthesis.

**A gene is a segment of DNA used to make a polypeptide via mRNA. mRNA is a temporary copy of a gene that contains information to make the polypeptide.**

A dark-staining structure within the nucleus is called the **nucleolus**. One or more of these can be seen in cells when they are not dividing. The nucleolus is responsible for the synthesis of a type of nucleic acid called ribosomal RNA and the assembly of ribosomes from ribosomal RNA and proteins.

## QUESTION SET 7.4

### Remembering

1 Name the four main types of biomacromolecules found in all organisms.
2 Define 'organic compounds'.
3 State which biomacromolecules are polymers.
4 Describe the chemical composition of a carbohydrate.
5 State where in a cell you would expect to find DNA and RNA.

### Understanding

6 Explain why lipids are also called triglycerides.
7 Distinguish between:
  a monosaccharides, disaccharides and polysaccharides.
  b DNA and RNA.
  c monomer and polymer.

### Applying

8 Explain why there are so many different kinds of protein.

### Analysing

9 Plants contain more carbohydrate but less fat than animals. Explain possible reasons why they differ.

# Specialised organelles remove cellular products and wastes

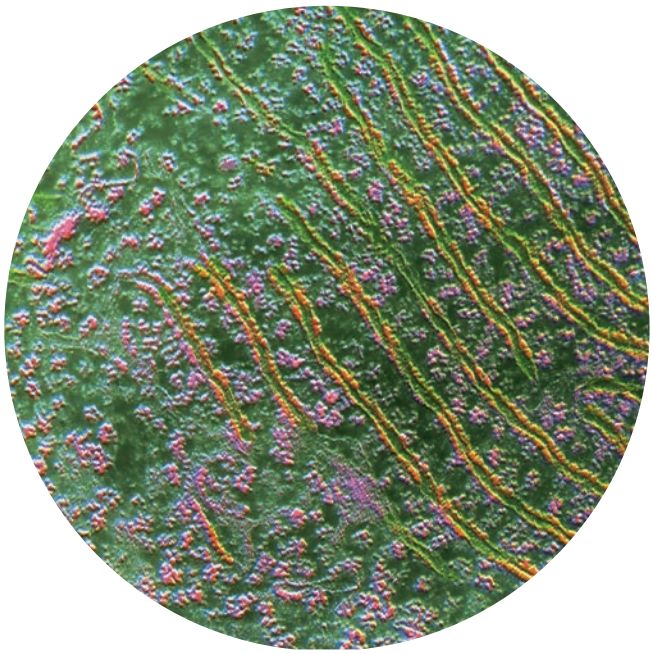
Cellular products are often produced in one part of the cell and used in another part of the cell. Sometimes these products are required for use in other cells. Wastes need to be removed and are transported out of the cell. Through observations and experiments such as labelling protein cell products with fluorescent dyes or tracking radioactively labelled atoms, specialised cell organelles that facilitate transport have been identified.

## Endoplasmic reticulum

How do proteins produced in ribosomes move to other parts of the cell? It is through the endoplasmic reticulum (ER) that substances are able to move around the cell. The ER is an interconnecting system of thin membrane sheets dividing the cytoplasm into compartments and channels. The membrane of the ER is able to pinch off into small sacs called **vesicles** and deliver proteins to all parts within the cell. The ER is therefore an **intracellular** transport system.

Most of the ER in cells is studded with ribosomes, and thus is known as **rough endoplasmic reticulum (rough ER)**. In this way, the proteins produced by the ribosomes can move directly into the ER and move about the cell. However, if some proteins are not required by the cell in which they are made then they can be exported or secreted into other cells. Such proteins include enzymes and hormones. Therefore, the ER is also an **intercellular** transport system helping to move proteins from one cell to another.

In certain parts of some cells, the ER has no ribosomes attached to it and is known as **smooth endoplasmic reticulum (smooth ER)**. The amount and function of this smooth ER depends on the type of cell it is located in. Its main role is to transport proteins, synthesise lipids and to assist in the manufacture of plasma membranes. In liver cells it also detoxifies drugs and in adrenal cortical cells it produces the steroid hormone. Some carbohydrates are produced on smooth ER. It is also a place for storage of calcium ions, which are necessary for muscle contraction and interactions between some membrane proteins.

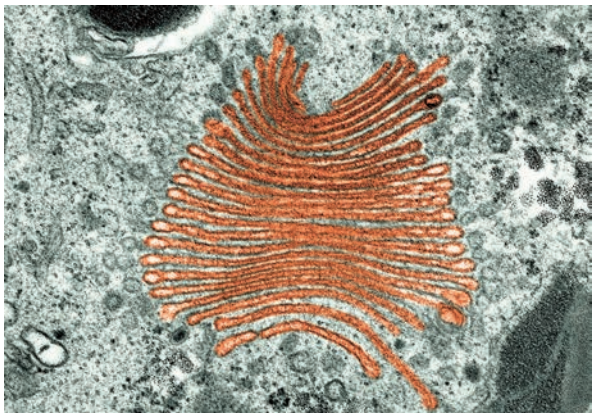


▲ **Figure 7.28**
Rough ER studded with ribosomes

## Golgi apparatus

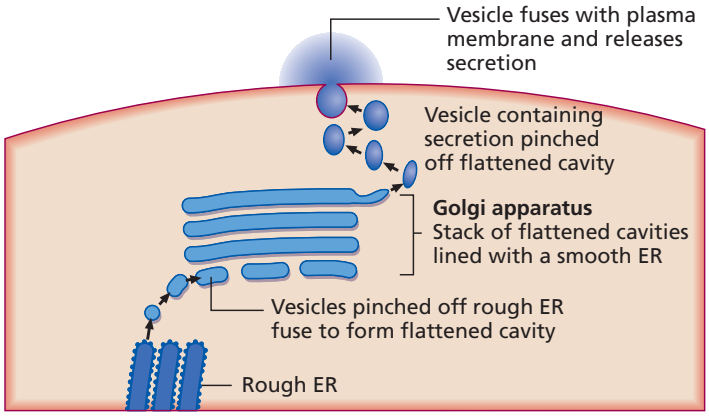
Consider a grass-eating animal such as a kangaroo. The cells in grass have a tough cell wall. In order to be able to digest and absorb the nutrients from inside the grass cell, the cell wall must be broken down by enzymes. Cells in the digestive glands of the kangaroo produce such enzymes. Being protein, the digestive enzyme is produced initially by the ribosomes on the rough ER. It moves through the channels within the ER where it is secreted within the cytoplasm of the cell. From there it moves into the **Golgi apparatus** (also known as Golgi body) where different enzymes put the final touches to it, and it is packaged and stored before being secreted from the cell to move into the intestines of the kangaroo. This is where it can begin its work digesting the cellulose in the cell wall of the grass.

The Golgi apparatus consists of a system of membranes within the cytoplasm. Parts of the Golgi apparatus membrane are able to pinch off into small vesicles. It is these vesicles that move to the plasma membrane, where they join to the membrane and discharge their contents to the outside of the cell.



Getty Images/Science Photo Library

▲ **Figure 7.29**
Electron micrograph of the Golgi apparatus (magnification ×80000)






▲ **Figure 7.30**
How the Golgi apparatus removes a secretion from a cell

# Lysosomes

Inevitably, organelles within the cytoplasm of cells reach their 'use by' date and wear out. Instead of wasting the raw materials that make up these organelles, the cell has a clever method of recycling and reuse. This is the job carried out by **lysosomes** ('lysis' = to break apart), one of the special organelles found within the cytoplasm of animal cells. Lysosomes are formed by the Golgi apparatus. They contain digestive enzymes that are responsible for splitting complex chemical compounds into simpler ones, such as when proteins are broken down into amino acids. These simpler ones can then be used as building blocks for new compounds and organelles.

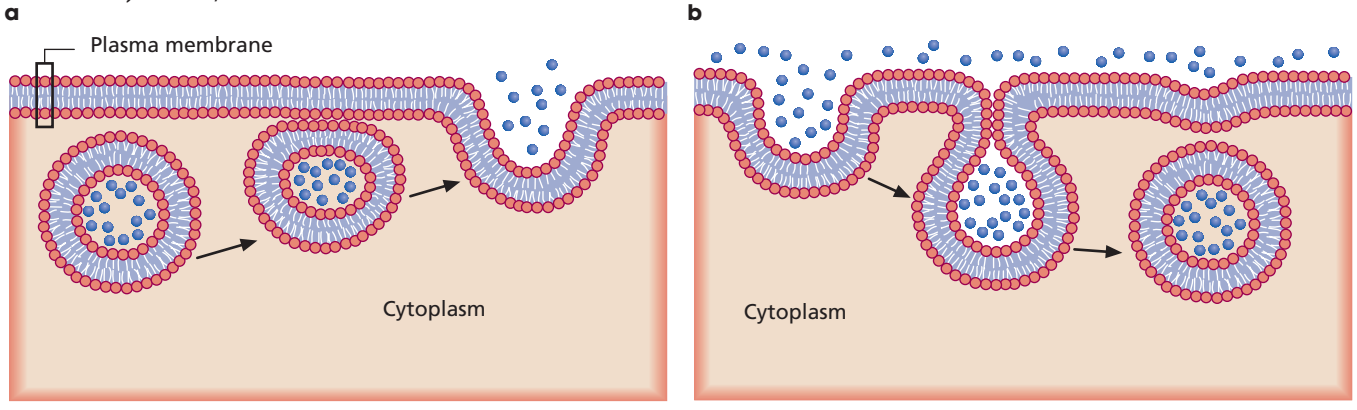
Sometimes lysosomes may destroy the entire cell. This happens when the lysosome membrane ruptures, releasing the enzymes, which then digest the contents of the cell, killing it in the process. This is known as **apoptosis** or programmed cell death.

# Plasma membrane

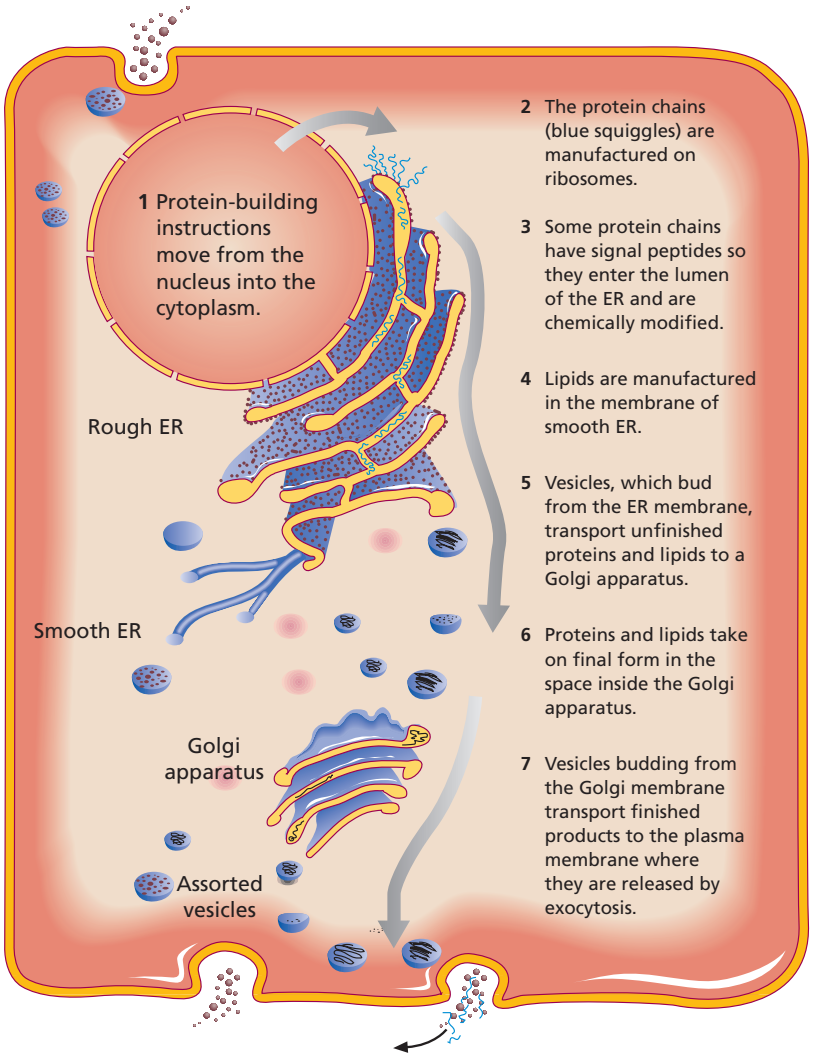
Molecules must also be able to move in and out of cells. Many molecules are too large to move passively across the plasma membrane, so there must be another way. The plasma membrane has an ingenious solution to this problem. It can engulf large particles and liquids within its environment in a process known as **endocytosis**. It encloses the material within it to form an endocytic vesicle, which then stores or transports the material within the cytoplasm.

Conversely, exocytic vesicles are associated with transporting large molecules and particles across the plasma membrane and out of the cell. During **exocytosis**, a small membrane-bound vesicle moves to the cytoplasm to the plasma membrane, where it joins with it and then releases its contents to the exterior of the cell.

**Figure 7.31 ▼**
The process of a) exocytosis and b) endocytosis




Cellular products move through a cellular transport system, are packaged, and are then released from the cell through the plasma membrane.




**◀ Figure 7.32**
Protein pathways; includes details of the production, transport and secretion of proteins in cells

# QUESTION SET 7.5

## Remembering

1 Describe the main roles of the endoplasmic reticulum.
2 Outline one similarity and one difference between endocytosis and exocytosis.

## Understanding

3 Explain the role of the Golgi apparatus in the transport of materials out of the cell. Describe the kinds of materials it packages.

## Applying

4 Predict the function of a cell that contains more rough ER than smooth ER.
5 Describe how lysosomes are like cell recycling stations.

## Analysing

6 Small sac-like vesicles joining and detaching from cell membranes are seen using an electron microscope.
   a Name these vesicles.
   b Describe the function of these structures.
   c Name the process described.
   d An observer described these structures as lysosomes. What would you say to argue against this observation?

# CHAPTER SUMMARY

- Living things are characterised by their ability to move, grow and replicate or reproduce themselves.
- Living things can use the energy in food for their activities and they are able to remove wastes.
- All living things are made of cells and the products of cells, and new cells arise only from previously existing cells.
- Organisms can be single-celled or multicellular.
- Life on Earth originated billions of years ago but there are many questions around how, where and exactly when this happened.
- Development of different kinds of microscopes have advanced our understanding of cell structure.
- The simplest type of cell is a prokaryote. They exist as single cells. Prokaryotic cells belong to the Bacteria and Archaea Kingdoms.
- Circular chromosomes and ribosomes are found in the cytoplasm of prokaryotic cells.
- Eukaryotic cells are complex cells containing membrane-bound compartments with specific metabolic functions.
- Organelles separate chemical reactions physically; for example, when reactions are incompatible. Organelles also separate chemical reactions in time; for example, when substances are stored and then later used in other reactions.
- Autotrophs are able to use energy from the Sun or from chemical reactions to provide their energy needs.
- Heterotrophs rely on autotrophs to provide their energy needs.
- Chloroplasts, containing the pigment chlorophyll, are organelles in eukaryotic cells that use the energy in sunlight to convert carbon dioxide and water to glucose and oxygen.
- Cellular respiration is the series of chemical reactions that break down glucose and use oxygen to produce carbon dioxide and water. The energy released by this process is used to build up the energy storage molecule ATP.
- Mitochondria are the organelles in eukaryotic cells where aerobic cellular respiration takes place.
- The endosymbiotic theory proposes that eukaryote cells were formed when a bacterial cell was ingested by another primitive prokaryotic cell.
- Carbohydrates, lipids, proteins and nucleic acids are the main biomacromolecules of living things.
- Cells assemble biomacromolecules from small organic compounds including simple sugars, fatty acids and glycerol, amino acids and nucleotides.
- The most complex carbohydrates are polysaccharides such as starch. The simplest are monosaccharides such as glucose. Glucose is synthesised in chloroplasts.
- Lipids are insoluble in water. They have many important cellular functions. Lipids are synthesised in the endoplasmic reticulum.
- Proteins are made up of one or more polypeptide chains of amino acids. The sequence of amino acids is unique for each kind of protein, giving rise to its unique structure, chemical behaviour and function. Proteins are synthesised in ribosomes.
- DNA and RNA are polymers of nucleic acids. The nucleus has an important role in their synthesis.
- Many proteins are modified and lipids are assembled in the endoplasmic reticulum and the Golgi apparatus.
- Vesicles package compounds ready for storage, intracellular movement or secretion out of the cell.
- Large molecules and particles can move into and out of the cell via endocytosis and exocytosis.

# CHAPTER GLOSSARY

**adenosine triphosphate (ATP)** a high-energy compound composed of adenine and ribose and three phosphate groups attached; it releases energy for cellular reactions when its last phosphate group is removed and it is converted to ADP

**amino acid** a nitrogen-containing compound that is the building block of proteins

**apoptosis** the programmed series of events that lead to cell death as a result of the dismantling of internal contents of the cell

**autotroph** an organism capable of making its own food from inorganic substances using light (through photosynthesis) or chemical energy (through chemosynthesis); green plants, algae and certain bacteria

**bioinformatics** the science of managing and analysing biological data using advanced computing techniques

**biomacromolecule** a molecule that has an important structural or functional role in cells

**carbohydrate** an organic compound that serves as a structural component and a major energy source in the diet of animals; includes sugars, starches, celluloses and gums

**cell** the basic structural unit of all life forms on Earth

**cellular respiration** a series of cellular biochemical reactions and processes using glucose and oxygen and producing carbon dioxide and water; the energy released is used to convert ADP to ATP

**chemosynthesis** the synthesis of organic substances using energy from chemical reactions

**chlorophyll** the green pigment found in chloroplasts; it is able to absorb light energy, making it available for photosynthesis

**chloroplast** a membrane-bound organelle (type of plastid) found in the cytoplasm of plants and algae containing the green pigment chlorophyll; its main function is photosynthesis and storage of carbohydrates

**cristae** the folding of the inner membrane into the matrix of the mitochondria, thus increasing the total surface area of the inner membrane

**cytosol** the part of the cytoplasm containing highly organised fluid material with dissolved substances; excluding the organelles

**cytoplasm** all the fluid, dissolved materials and organelles between the plasma membrane and the nuclear membrane

**disaccharide** two linked monosaccharide molecules

**DNA (deoxyribonucleic acid)** an information molecule that is the universal basis of an organism's genetic material; it contains instructions, written in a chemical code, for the production of proteins by the cell

**endocytosis** the movement of solids or liquids into a cell from the environment via vesicle formation

**endoplasmic reticulum (ER)** an organelle in eukaryotic cells consisting of an interconnecting system of thin membrane sheets dividing the cytoplasm into compartments and channels; lipid synthesis occurs here

**endosymbiotic theory** the theory suggesting that chloroplasts and mitochondria arose from ancient prokaryote cells that were ingested by other prokaryote host cells

**enzyme** a specific protein catalyst that acts to increase the rate of a chemical reaction within the cell by lowering the amount of energy required for the reaction to proceed

**eukaryote** a complex type of cell with a nucleus and membrane-bound organelles; a member of Domain Eukarya

**exocytosis** the movement of solids or liquids from a cell to the environment via vesicle formation

**glycoprotein** a protein molecule with an attached carbohydrate chain

**Golgi apparatus** a collection of membranes that package and store substances into vesicles in preparation for their release from the cell

**heterotroph** an organism that cannot synthesise its own organic compounds from simple inorganic material; it depends on other organisms for nutrients and energy requirements

**inorganic** a compound that is not organic; simpler carbon compounds such as carbon dioxide ($CO_2$), carbon monoxide (CO) and carbonates such as calcium carbonate ($CaCO_3$) are classed as inorganic

**intercellular** occurring between cells

**intracellular** occurring within a cell

**lipid** a type of organic molecule that includes fats and oils; insoluble in water

**lysosome** an organelle within the cytoplasm containing digestive enzymes

**mitochondria** an organelle within the cytoplasm that is the site of aerobic cellular respiration releasing energy for the cell

**monomer** a small molecule that acts as a building block for macromolecules

**monosaccharide** a simple sugar, such as glucose, which cannot be broken down into smaller sugar molecules

**messenger RNA (mRNA)** the ribonucleic acid formed in the nucleus; its sequence is complementary to DNA; it travels to the cytoplasm where its information is read by ribosomes to add amino acids together to form proteins

**nucleic acid** a large organic molecule made up of nucleotides; DNA and RNA are the information-carrying molecules of the cell

**nucleolus** a site for assembling protein and RNA that will later form ribosomes; visible in a non-dividing cell

**nucleotide** an organic compound composed of a sugar, a phosphate group and a nitrogenous base

**organelle** a specialised structure or compartment within a cell that has a specific function

**organic** describes complex, carbon-containing compounds

**photosynthesis** a chemical reaction using energy from the Sun to convert carbon dioxide and water into glucose and oxygen

**plasmid** a small, circular piece of DNA that is found in bacteria and is able to replicate independently of the cell's main chromosome

**polymer** a large molecule built up from linking smaller molecules together

**polysaccharide** complex carbohydrates that are made up by linking together simple sugars

**prokaryote** a simple type of cell that lacks a nucleus and membrane-bound organelles; a member of Domains Archaea or Bacteria

**protein** a large organic molecule, built up of amino acids; it has specific structural and functional roles in living things

**proteome** a complete collection of proteins in any given cell or organism

**proteomics** the study of proteomes, including the way they work and interact with each other inside cells

**ribosome** a small structure in all cells that builds amino acids into complex proteins; this organelle is not bound by a membrane

**ribonucleic acid (RNA)** the single-stranded nucleic acid that functions in transcribing and translating information from DNA into proteins

**rough endoplasmic reticulum (rough ER)** ER with ribosomes attached

**smooth endoplasmic reticulum (smooth ER)** ER with no ribosomes attached

**stem cell** an unspecialised, immature cell capable of being transformed into different kinds of specialised, differentiated cells

**stroma** the jelly-like semifluid interior of a chloroplast

**thylakoid membrane** the interconnected, folded membranes within chloroplasts

**triglyceride** a simple lipid formed by linking glycerol with three fatty acids

**vesicle** a small, membrane-bound sac in cytoplasm that transports, stores or digests substances

# CHAPTER REVIEW QUESTIONS

## Remembering

**1** Match each structure with its function.

| Organelle/structure | | Function | |
|---|---|---|---|
| **i** | nucleus | **a** | collecting and packaging centre of the cell |
| **ii** | endoplasmic reticulum | **b** | photosynthesis and storage |
| **iii** | lysosome | **c** | transport of substances around the cell |
| **iv** | mitochondria | **d** | control centre of the cell |
| **v** | Golgi apparatus | **e** | aerobic respiration, which releases energy to the cell |
| **vi** | chloroplast | **f** | breakdown of materials |

## Understanding

**2** Distinguish between:
- **a** structure and function.
- **b** a chloroplast and chlorophyll.
- **c** organic and inorganic.
- **d** rough and smooth endoplasmic reticulum.

**3** **a** Compare the structure and function of mitochondria and chloroplasts.
- **b** Outline the evidence for a common evolutionary origin.

**4** Explain how only 20 standard amino acids can account for the many different kinds of proteins found.

## Applying

**5** **a** Describe features that are common to all cells.

**b** Describe features that are unique to:

**i** prokaryotic cells.

**ii** eukaryotic cells.

**6** Certain cells have densely packed mitochondria and the cristae (infolded projections of a mitochondrion) are very close together. What would you predict about the function of such cells? Explain your reasoning.

**7** Explain why some organisms are able to live without light but others cannot.

**8** A cell has been likened to a factory or an office. This type of analogy is useful when considering the structures and functions of cells. A factory is a place where products are made, exported from the factory and distributed for sale. Raw materials and energy are needed for the manufacture of the products.

**a** Using the following components of a factory, describe a structure or function of a cell that is similar. For example, a factory has outside walls; all cells have a membrane and some types of cells also have cell walls.

Factory: goods manufactured; business plans; photocopying room; manufacturing area; warehouse; management offices; assembly workers, warehouse packers; doors; hallways; power source

**b** Outline one difference between a factory and a cell.

**c** Suggest another analogy of a cell.

**9** Explain why you think it is an advantage to a eukaryotic cell to possess different types of organelles.

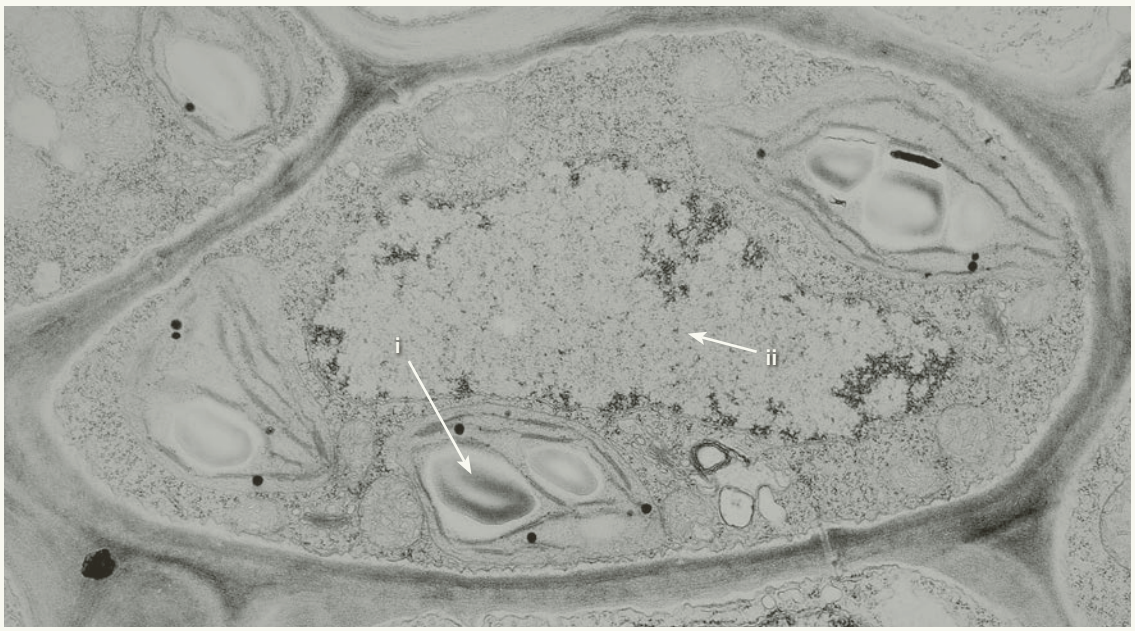
## Analysing

**10** **a** State whether the cell shown in Figure 7.33 is from a prokaryote or eukaryote. Give reasons for your answer.

**b** Identify whether this photograph was taken from of a cell viewed with an electron or light microscope. Give your reasons.

**c** Some organelles may be present in this cell but are not shown in the photograph. Suggest why this might be the case.

**d** Name the organelles with arrows pointing to them.




Getty Images/Visuals Unlimited/Martha J. Powell

**◀ Figure 7.33** Photograph of an unidentified cell

**11** One of the jobs of our white blood cells is to engulf potentially dangerous bacteria and destroy them. Explain why there are a large number of lysosomes present in white blood cells.

**12** If you were asked to classify a particular type of cell, name the structures you would look for. Suggest whether the structures present would allow you to predict the function of the cell.

## Evaluating

**13** What is the name given to the study of the structure and function of proteins? Outline reasons why scientists would want to study all the proteins of an organism rather than each protein in isolation.

**14** The freshwater bacterium *Gemmata obscuriglobus* has its DNA packaged in a membrane envelope. Recently, Australian scientists showed the bacterium 'swallows' large particles in a process similar to endocytosis. Explain why scientists are now questioning whether *G. obscuriglobus* is classified correctly as a bacterium.

**15** If plant cells can make their own food, explain why they need mitochondria.

**16** A student examines a human cheek cell under a light microscope. As she cannot see any mitochondria, she says there are none present in these types of cells. Outline arguments you would use to convince her she is incorrect.

**17** Radioactively labelled amino acids were supplied to a pancreatic cell that produces digestive enzymes to be released into the digestive system.

- **a** In which organelles of the cell would they be subsequently detected? List them in order.
- **b** In what form would they appear in these organelles? You might like to present your answer as a diagram.

## Creating

**18** Predict what would happen to a cell if its ribosomes failed to work.

**19** Suggest why it is said that carbon is the element on which all life depends.

**20** Explain why it is useful to identify the features that are characteristic of all living organisms.

## Reflecting

**21** Predict what our world would be like today if electron microscopes had not been developed. Suggest how your life would be different.

**22** Try to define the word 'life'. Does this present any difficulties?