6 Model of Cells – the Basic Unit of Life

All living things are made up of cells. How can one building block make up the diversity of life that we see around us? Is every cell in all organisms the same? There are many different types of cells even in our bodies. While there are many different types of cells, there are common cell structures among these cells. The pattern of common cell structures helps us to classify organisms into their different kingdoms such as animals, plants, fungi, and bacteria. Using these common cell structures, we can create models of a typical plant and animal cell. These models are useful teaching tools that show the common cell structures found in plant and animal cells. They also serve as reference models for us to compare unknown cells against.

- Plant and Animal Cells (6.1)
- Microscope (6.2)
- Biological Drawing (6.3)
- Division of Labour (6.4)

6.1 Plant and Animal Cells

In 1665, a British scientist named Robert Hooke examined some cork under the microscope. The image reminded him of small rooms, also known as cells, that monks stay in. The term "cells" was thus coined.

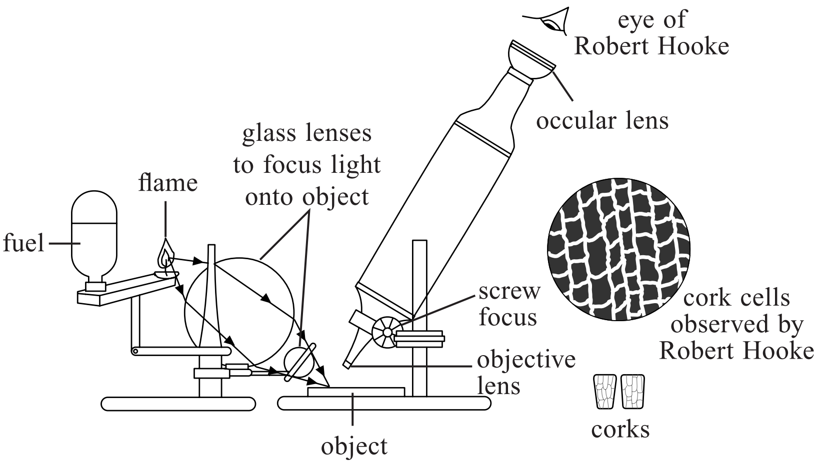


Fig 6.1 Robert Hooke observing cork cells

1. **Cells** are the basic building blocks of life.
2. Plants and animals are **multicellular organisms** as they are made up of many cells.
3. The following shows the cell structures that can be found in a typical animal cell and a typical plant cell.

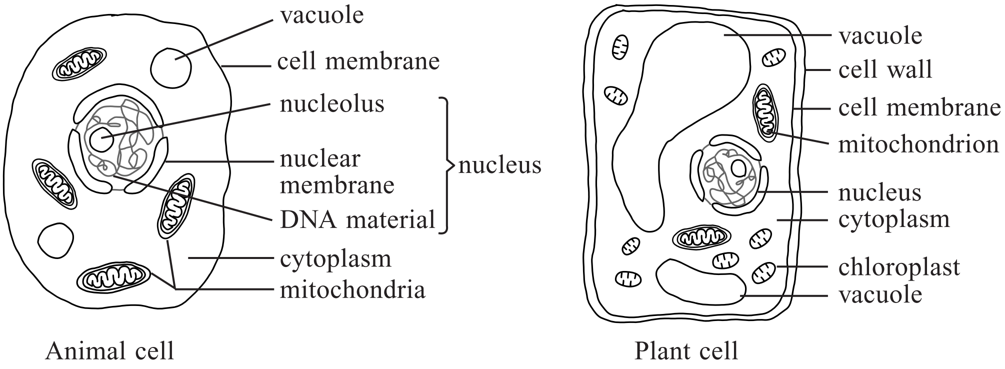


Fig 6.2 Parts of an animal cell and a plant cell

4. The table below shows the cell structures present in both the typical animal and plant cells and their functions.

Cell structure	Function(s)
Cell membrane	• Partially permeable (allowing only some substances to pass through). • Holds the cell or membrane-bound cell structures together. • Provides a compartment such that specific chemical reactions take place in a specialised environment.
Cytoplasm	• A liquid or gel where most chemical reactions take place. • Provides optimal environmental conditions for chemical reactions to take place.
Nucleus	• Controls the cell's activities. • Contains deoxyribonucleic acid (DNA) enclosed in a nuclear membrane. DNA is the genetic material that determines heredity. • DNA determines the type of proteins the cell can produce. • The nucleus membrane has nuclear pores that control the movement of substances in and out of the nucleus.
Vacuole	• Animal cells contain numerous small vacuoles. • Plant cells usually have one large vacuole. • Stores materials such as water, salts, proteins, carbohydrates and waste. • In plants, the vacuole is filled with cell sap and helps to maintain turgor pressure of the cell. Turgor pressure helps the cell to remain turgid and helps the plant to remain upright.

Cell structure	Function(s)
Extension Knowledge Mitochondrion	• Carries out cellular respiration (breaking down glucose in the presence of oxygen to release energy). • Energy released is used for chemical reactions and activities in the cell.
Cell wall	• Found in plant cells. Animal cells do not have cell walls. • Made up of cellulose and is permeable to allow movement of substances. • Supports and gives the cell its shape. • Prevents the cell from bursting. • Fungi and bacterial cells also have cell walls, but they are not made up of cellulose.
Chloroplast	• Contains the green pigment, chlorophyll, that traps light for photosynthesis. • Photosynthesis produces glucose and excess glucose is stored as starch.

Table 6.1 Functions of cell structures

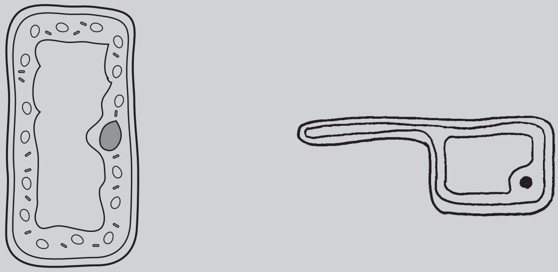
5. The table below compares the differences between a typical animal and plant cell.

Feature	Plant cell	Animal cell
Cell wall	A cell wall is present to support the cell and prevents the cell from bursting.	Has no cell wall.
Chloroplast	Has chloroplasts to carry out photosynthesis.	Has no chloroplasts and does not carry out photosynthesis.
Vacuoles	Usually has one or a few large vacuoles.	Has numerous small vacuoles.

Table 6.2 Comparing the plant cell and animal cell

SCIENCE AROUND US

Different types of cells have different cell structures. The cell structures they have are dependent on the function of the cell. The diagram below shows a palisade mesophyll cell found in a leaf and root hair cell found in the roots of a plant.



Palisade mesophyll cell Root hair cell

(a) State the difference in cell structures between these two cells.
(b) Explain the difference observed.

ANSWER

(a) *The palisade mesophyll cell has chloroplasts but the root hair cell does not.*
(b) *The palisade mesophyll cell is found in the leaves and needs chloroplasts to make food via photosynthesis.*
The root hair cell is found in the roots that are usually underground. They do not carry out photosynthesis and therefore does not require chloroplasts.

Structure of DNA

Extension Knowledge

In 1953, the double helix structure of deoxyribonucleic acid (DNA), determined by James Watson and Francis Crick marked a milestone in the history of science. Their discovery however, would not be possible without the X-ray crystallography images from Rosalind Franklin. This discovery gave rise to modern molecular biology and helped to explain the genetic code and protein synthesis.

1. DNA is made up of molecules called nucleotides. Each **nucleotide** is made up of a **deoxyribose sugar**, one **phosphate group** and a **nitrogenous base**. There are four different types of bases in a DNA. They are adenine (A), guanine (G), cytosine (C) and thymine (T).

2. A **DNA strand** is made up of many nucleotides joined together by phosphodiester bond. A DNA molecule is made up of two strands of DNA coiled into a **double helix**. The two DNA strands are **anti-parallel** to each other.

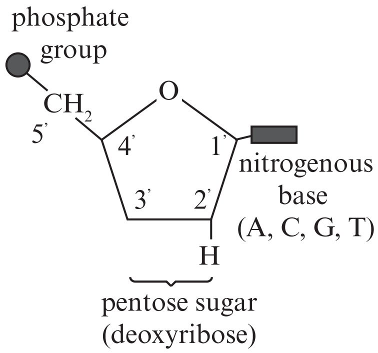


Fig 6.3 DNA nucleotide

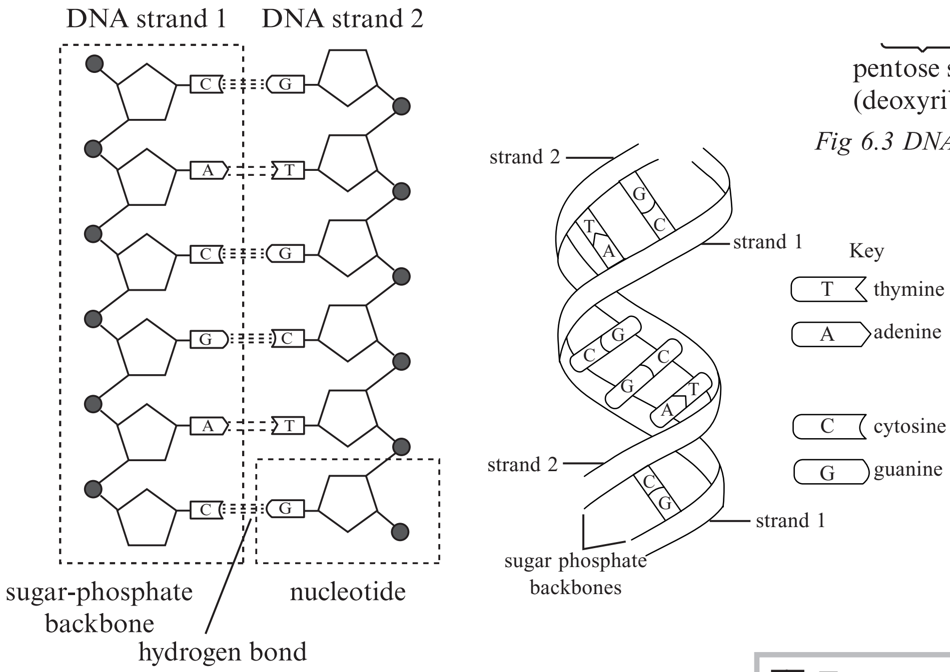


Fig 6.4 A DNA strand and a DNA double helix

3. Each chain has a sugar-phosphate backbone on the exterior of the helix and bases projecting into the interior of the helix.
4. The two DNA strands are held together by **hydrogen bonds** between each base in a pair. The bases on one DNA strand are paired to the other strand according to **complementary base pairing rule**.
   • Adenine always pairs with thymine. (A-T)
   • Guanine always pairs with cytosine. (G-C)

Note

The carbon atoms are numbered 1 to 5. The nitrogenous base (represented by a rectangular block) is attached to carbon number 1 while the phosphate group (represented by a circular block) is attached to carbon number 5.

Note

In Fig 6.4, since the sequence of bases in strand 1 is $^{5'}$-CACGAC-$^{3'}$, by complementary base pairing, the sequence of bases in strand 2 is $^{3'}$-GTGCTG-$^{5'}$.

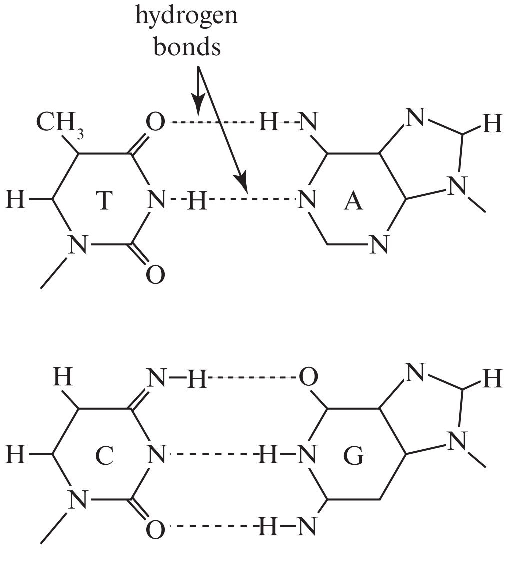


Fig 6.5 Complementary base pairing

Extra

Hydrogen bonds are a type of force of attraction between molecules such as water molecules. It explains why water has higher melting and boiling points than other simple molecular compounds like carbon dioxide.

5. Each gene is a unique sequence of nucleotides (or bases). Each gene sequence codes for a specific protein.
6. Genes are first **transcribed** to an intermediate molecule messenger ribonucleic acid (mRNA), and then **translated** to proteins.

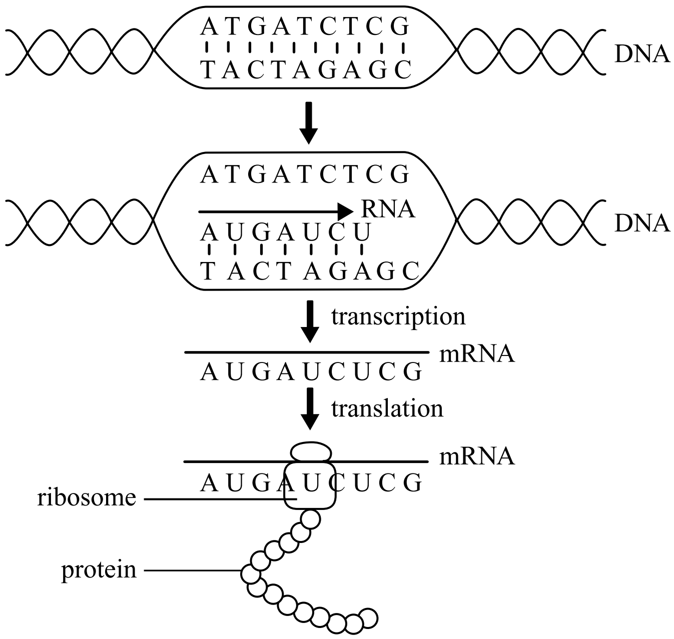


Fig 6.6 Transcription and translation

Note

In transcription, a DNA sequence is read and used to synthesise the mRNA.
In translation, mRNA sequence is read and used to synthesise protein. In RNA, uracil pairs with adenine instead as there is no thymine base.

7. A DNA molecule forms chromosomes when tightly coiled. Chromosomes are usually not seen in cells as DNA usually exists in a loosely coiled state known as chromatin.

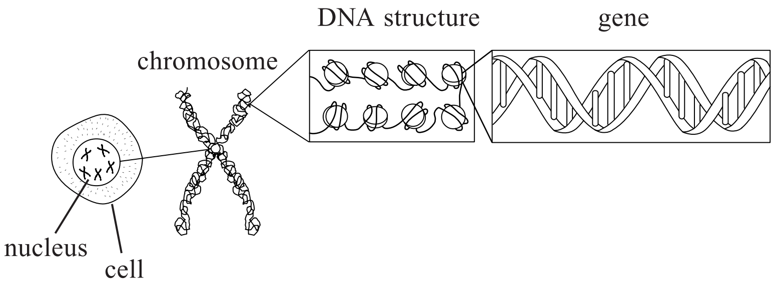


Fig 6.7 Chromosome

Extra

Chromosomes are usually not visible under the light microscope when the cell is not dividing. The DNA becomes highly condensed in a chromosome during cell division and becomes visible as dark distinct bodies under the light microscope.

Other Parts of the Cell

Extension Knowledge

Although all cells have similar cell structures, the number of each cell structure depends on the function of the cell. For example, a muscle cell will have a lot more mitochondria to release energy quickly for muscle movement.

1. Besides the parts discussed, the cell also contains several other cell structures (or organelles), for example, ribosomes, Golgi apparatus, rough endoplasmic reticulum and smooth endoplasmic reticulum.

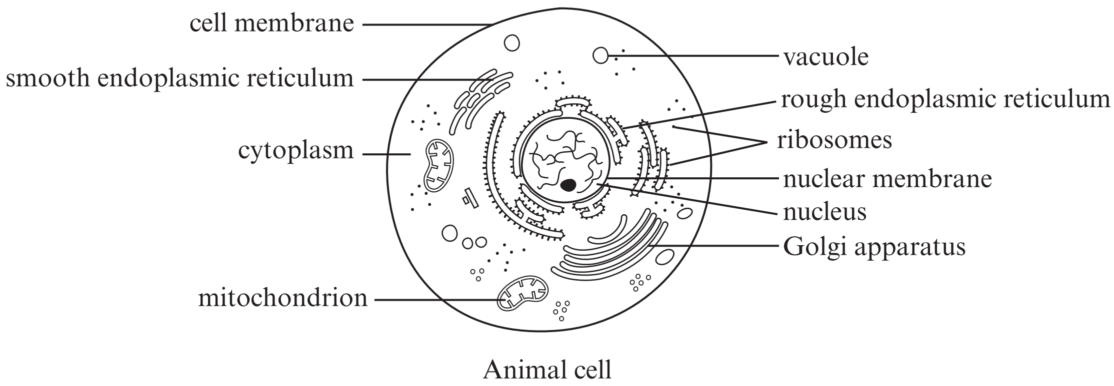


Fig 6.8 An animal cell

2. Ribosomes are cell structures that make proteins. The two types of ribosomes are:

Type of ribosomes	Function
Found freely in cytoplasm	Makes proteins that would be used in the cell.
Attached to rough endoplasmic reticulum	Makes proteins that would be secreted out of the cell and proteins found in cell membrane.

Table 6.3 Types of ribosomes

3. The Golgi apparatus is a structure that further modifies and packages the proteins for secretion.
4. The endoplasmic reticulum (ER) has different functions depending on its type. The two types of ER are:

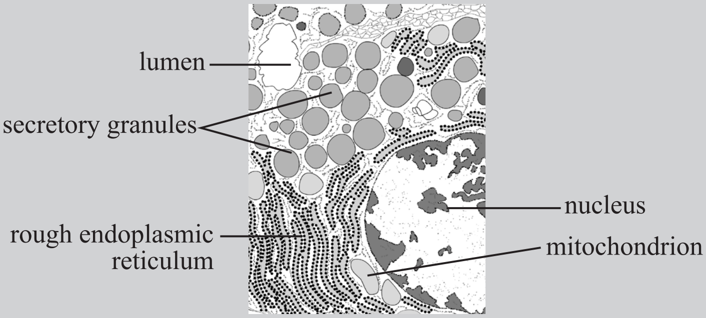
Types of ER	Descriptions
Rough endoplasmic reticulum (RER)	• Continuous with the nuclear membrane and is covered with ribosomes. • Transports proteins made by ribosomes to the Golgi apparatus.
Smooth endoplasmic reticulum (SER)	• Is not covered with ribosomes. • Makes fats and steroids such as hormones.

Table 6.4 Types of endoplasmic reticulum

SCIENCE AROUND US

Extension Knowledge

The pancreas in the human body produces and secretes enzymes, which help us digest food, as well as hormones such as insulin. Insulin helps your body cells to absorb sugar from your blood. Enzymes and insulin are both made up of proteins. The figure below shows cell structures of a pancreatic cell.



Study the figure above. Explain how the structure of the cell supports its function.

ANSWER

The pancreatic cell produces many secretory proteins such as enzymes and hormones. The cell has many rough endoplasmic reticulum to produce these secretory proteins. It also has many secretory granules to secrete these proteins out of the cell. The cell has a large nucleus to produce messenger RNA that translates into proteins. There are also mitochondria in the cell to produce sufficient energy for protein production and secretion.

6.2 Microscope

In the process of solving crimes, forensic science is often crucial to gather critical evidence. For instance, a forensic pathologist can use microscopes to study tissue, bone or other remains to determine the possible cause of death.

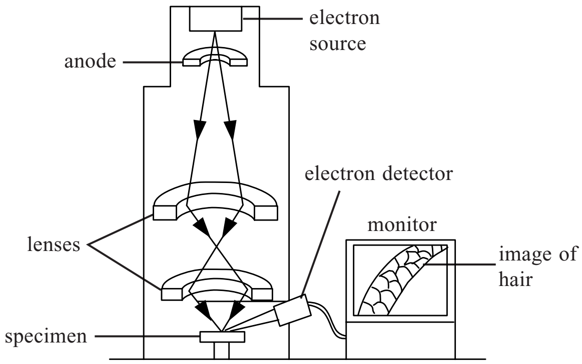


Fig 6.9 The electron microscope

1. A **microscope** is used to magnify a specimen to see structures which cannot be seen with the unaided eye.

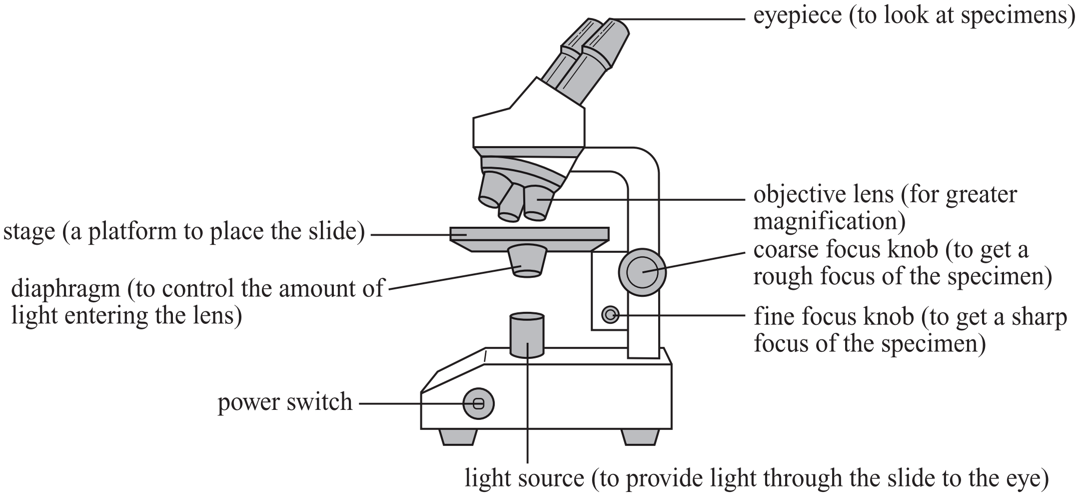


Fig 6.10 Parts of a light microscope and their functions

2. Under the light microscope, cell structures such as the cell wall, cell membrane and vacuoles are visible. These structures cannot be seen without the microscope.

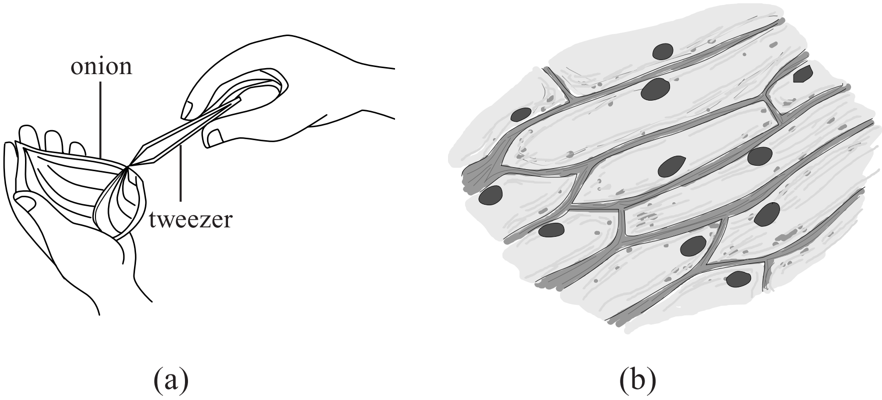


Fig 6.11 (a) Peeling off an onion epidermis (b) Image of a stained onion epidermis under the light microscope

3. The figures below shows how some of these cell structures appear under the microscope.

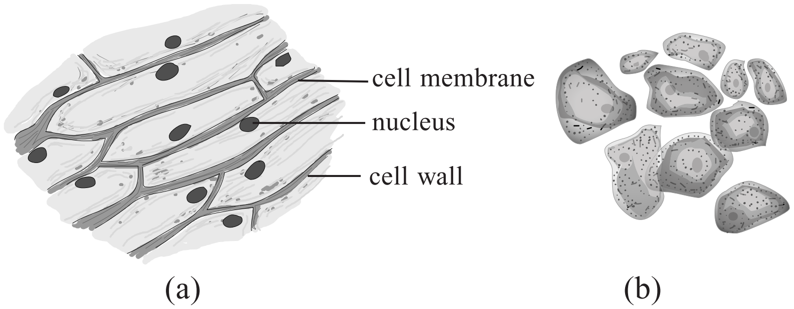


Fig 6.12 (a) Onion cells under microscope (b) Cheek cells under microscope

Extra

Some cell structures are difficult to discern due to a lack of contrast. Cell staining is a technique used to better visualise cells. It involves immersing a sample in a dye solution before observing the sample under a microscope.

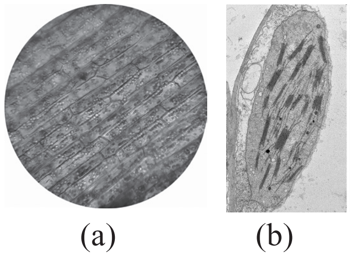


Fig 6.13 (a) Image of chloroplasts under light microscope (b) Image of chloroplasts under electron microscope

4. Some structures, such as the mitochondria, are too small to be seen under the light microscope. More powerful microscopes such as electron microscopes are needed. Electron microscopes also allow us to see more detailed structures.
5. Advances in technology help to advance science knowledge. For example, with the development of electron microscopes, scientists can see more microscopic structures. This helps them to observe and collect more evidence.
6. Not all plant and animal cells have all the cell structures that are found in a typical plant and animal cell. For example, root hair cells do not contain chloroplasts and red blood cells do not have nuclei.
7. The typical plant and animal cells serve as models for scientists to infer if an unknown cell discovered could be a plant or animal cell or another type of organism. It also allows scientists to make predictions on the functions of a cell.
8. Figure 6.14 shows an organism, *Euglena*. It contains the following cell structures.
9. From the cell structures that the *Euglena* contains, we can infer some of the cellular activities this organism carries out. For example, the presence of chloroplasts tells us that it can photosynthesise. The presence of a nucleus means the cell can make its own proteins. The flagellum is usually found in animal cells, and enables it to move around.

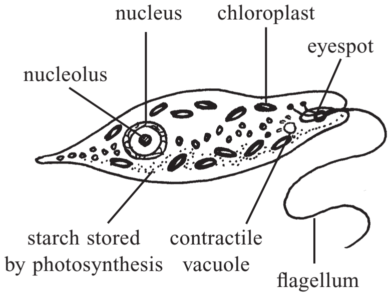


Fig 6.14 A Euglena

10. Scientists had difficulty classifying *Euglena* as it has both plant and animal cell characteristics. A new kingdom has since been created to group cells with similar characteristics as the *Euglena.* This kingdom is known as Protista.

6.3 Biological Drawing

An important skill in biology is drawing. Drawings can be considered a type of data collection as they highlight the important features of specimens.

Fig 6.15 Student observing a cell while drawing it.

1. Cells observed under the microscope can be represented using a biological drawing.
2. A biological drawing is an accurate record of what you observe under the microscope.
3. A good biological drawing should follow these guidelines:
    - Drawing should occupy most of the space provided (at least half).
    - Drawing consists of smooth and clean lines made using a sharp 2B pencil.
    - Drawing does not have any shading. If necessary, stippling should be used instead to show dense structures.
    - Cell structures are drawn in proportion to one another. The shape of cell structures should be accurate.
    - The label lines are drawn with a ruler, do not have arrowheads and cut across as little of the drawing as possible.
    - The label lines do not intersect each other.
    - Labels are written horizontally and next to the label lines.
    - Magnification of the drawing should be shown.

4. The diagram below shows an example of a good biological drawing.

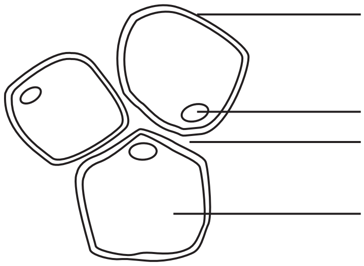


Fig 6.16 A biological drawing of three cells

Specialised Cells

Optional for N(A)

Specialised cells are specially designed to perform the functions for which they are intended. Each of these cell types have different structures and functions, ensuring that the cell can carry out the necessary body function that it is intended to complete.

In Animals

1. The **red blood cell** transports oxygen around the body.
2. The red blood cell contains the protein haemoglobin. Oxygen attaches to the haemoglobin and is transported together with the red blood cell.
3. The red blood cell is shaped like a biconcave disc as it does not have a nucleus.
4. The structure of the red blood cell supports its function of transporting oxygen around the body.

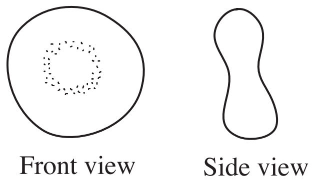


Fig 6.17 Red blood cell

Structure	Function
Absence of nucleus	Allows more haemoglobin to be packaged in one red blood cell
Biconcave shape	Results in a greater surface area to volume ratio to allow oxygen to move in and out of the red blood cell quickly
Flexible	Allows the red blood cells to squeeze through narrow capillaries

In Plants

1. The **root hair cells** absorb water and dissolved mineral salts from the soil into the plant.
2. The root hair cells have root hairs.

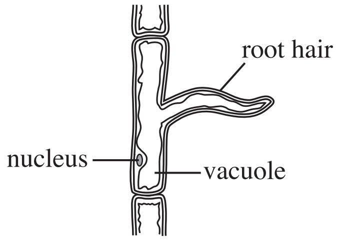


Fig 6.18 Root hair cell

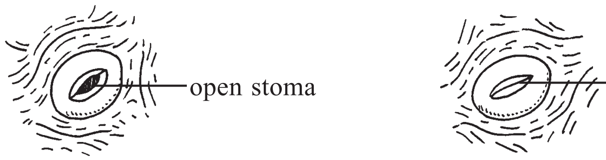
3. The structure of the root hair cell supports its function of absorbing water and mineral salts.

Structure	Function
Root hair	Increases the surface area of the roots for efficient absorption of water and mineral salts from the soil.
Thin cell wall	Easy absorption of water and mineral salts.

4. A **stoma** is a hole through which exchange of gases occurs. Plants 'breathe' through these stomata that are found on the surface of leaves.
5. Each stoma is made up of two **guard cells**. They control the size of a stoma.
6. When the guard cells are turgid (i.e. swollen), the stomata open up. When the guard cells are flaccid (i.e. soft) the stomata close.
7. During the day, stomata open up to allow carbon dioxide to move into the plant for photosynthesis and for oxygen to be released. Water is also lost through the stomata.
8. At night, photosynthesis does not occur, and less exchange of gases is required. The stomata close to prevent excessive water loss.

Note

In a multicellular organism, every cell contains the same DNA but different cells use this genetic information in different ways to carry out specific tasks. The nerve cells synthesise a lot of chemicals called neurotransmitters that are used to send messages to other cells. The muscle cells load themselves with protein-based filaments needed for muscle contractions.



Open and closed stoma

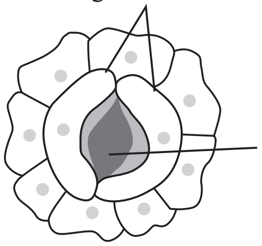


Fig 6.19 Gases move into and out of leaves via stomata

9. The structure of the guard cells support its function of controlling the movement of gases through the stomata.

Structure	Function
Thicker cell wall on the inner side of the guard cell that forms the stoma	Causes the guard cells to curve when the guard cells are turgid (i.e. swollen).
Contains chloroplasts	Guard cells can photosynthesise in the day, causing water to move into the guard cells in the day. At night, water moves out of the guard cells. This helps the guard cells to be turgid in the day and flaccid at night, causing the stomata to open and close respectively.

6.4 Division of Labour

Optional for N(A)

Division of labour occurs in all aspects of life. In a supermarket, workers have specific tasks such as helping customers to check out their groceries, restocking the shelves and ordering new products. By focusing on specific tasks, this helps to increase the efficiency of the supermarket. In cells and organisms, division of labour also occurs to increase efficiency.

1. **Division of labour** is different parts working together to perform a specific function.
2. Division of labour is evident in cells. Each cell structure carries out specific functions.
3. The different structures work together for the cell to function and survive.
4. Multicellular organisms exhibit division of labour.
5. Cells of the same type are grouped together to form a **tissue** to carry out specific functions.
6. Tissues are grouped together to form an **organ** to carry out a specific function.
7. Different organs work together as a **system** to carry out a specific function.
8. Organ systems:

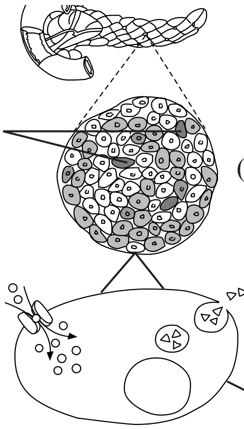


Fig 6.20
The pancreas is made up of different tissues which is in turn, made up of cells.

System	Organs	Function of system
Nervous	Brain, spinal cord, nerves	Transmission of electrical impulses between different parts of the body
Respiratory	Lungs, windpipe, nose	Absorption of oxygen and removal of carbon dioxide from the body
Digestive	Mouth, gullet, stomach, pancreas, liver, intestines	Physical and chemical breakdown of food substances and absorption of digested food
Circulatory	Heart, blood, blood vessels	Transport of oxygen, nutrients, water and mineral salts throughout the body
Excretory	Kidneys, bladder, skin	Removal of waste substances from the body
Muscular	Muscles	Enable movement of the body
Skeletal	Bones (skull, ribcage and spine)	Enable movement, protect internal organs and give shape and support to the body

9. The following shows a specific example of how division of labour occurs in the circulatory system.
   - The heart muscle cells group together to form heart muscle tissue known as myocardium. The heart muscle allows the heart to move.

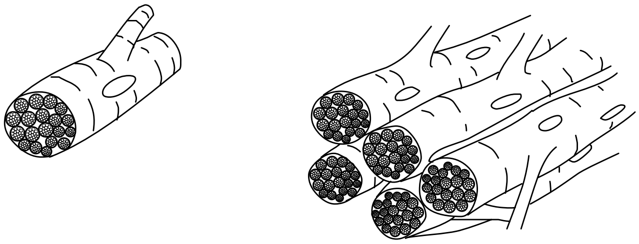


Fig 6.21 A heart tissue is made up of heart muscle cells.

   - The heart muscle tissue group together with connective tissues and other tissues. The connective tissues contribute to the elasticity of the heart. These tissues work together to allow the heart to function as a pump.

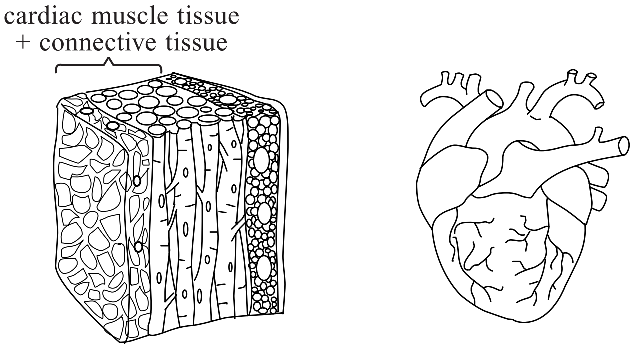


Fig 6.22 A heart consists of heart muscle tissue and connective tissues.

   - The heart works together with other organs, blood and blood vessels to transport substances around the body. The blood consists of blood cells and carries substances such as nutrients, wastes, carbon dioxide and oxygen. The heart pumps the blood around the body. The blood vessels form pathways to transport the blood efficiently to all parts of the body.

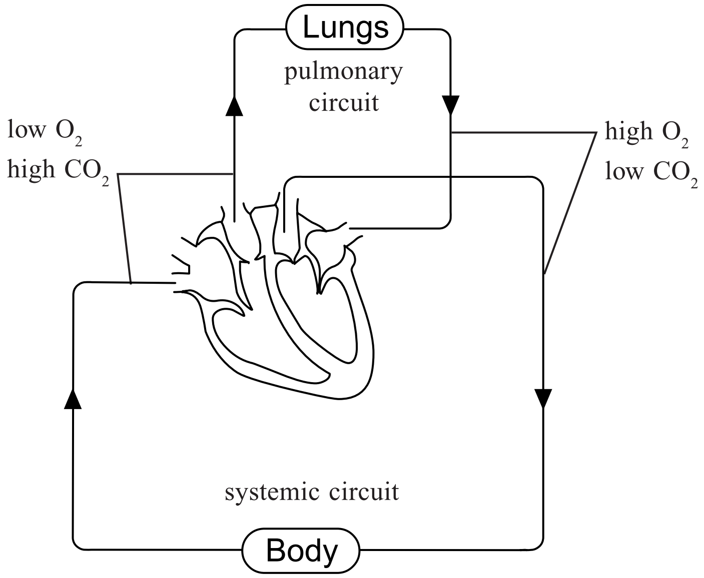
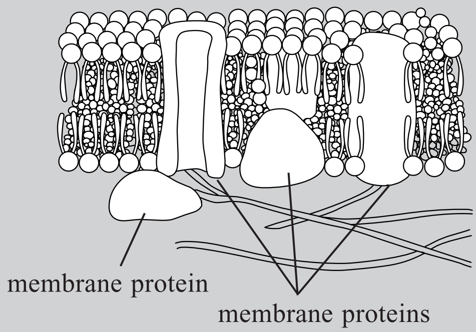


Fig 6.23 The circulatory system

SCIENCE AROUND US

The cell membrane contains many proteins embedded in it as shown in the figure below.



Describe how the parts of the cell work together to produce a membrane protein.

ANSWER

The DNA contains the genetic sequence for production of the membrane protein. Within the nucleus, conditions are optimal for transcription of DNA into mRNA. The nucleus contains nuclear pores that helps the mRNA to move into the cytoplasm for translation to occur. Within the cytoplasm, ribosomes on rough endoplasmic reticulum translate the mRNA into protein that will be embedded within a membrane.

Note

Membrane proteins are synthesised at the rough endoplasmic reticulum. Answers that describe synthesis of membrane proteins at ribosomes/free standing ribosomes are incorrect.

Genetic Engineering

Extension Knowledge

Since the 1930s, chemical methods or ionising radiation have been used to change the DNA of organisms to introduce new traits. This was a random process and it was not known what changes had actually occurred in the DNA. In recent years, researchers have developed tools to enable the manipulation of specific genes with greater precision. This means genetic modification is more targeted and there are fewer unintended changes elsewhere in the DNA. These gene-editing technologies open up possibilities of new treatments for some genetic diseases and to improve commercial crops.

Note

A plasmid DNA is typically a small, circular double-stranded DNA molecule mainly found in bacteria. It contains a gene that is advantageous for survival, such as an antibiotic resistant gene.

1. All organisms have genetic material made up of DNA.
2. Therefore, genes can be transferred between cells of different organisms. These organisms may be of the same species or different species.
3. Genes can be transferred using recombinant DNA technology.
4. The diagram below shows how human insulin is produced using recombinant DNA technology.

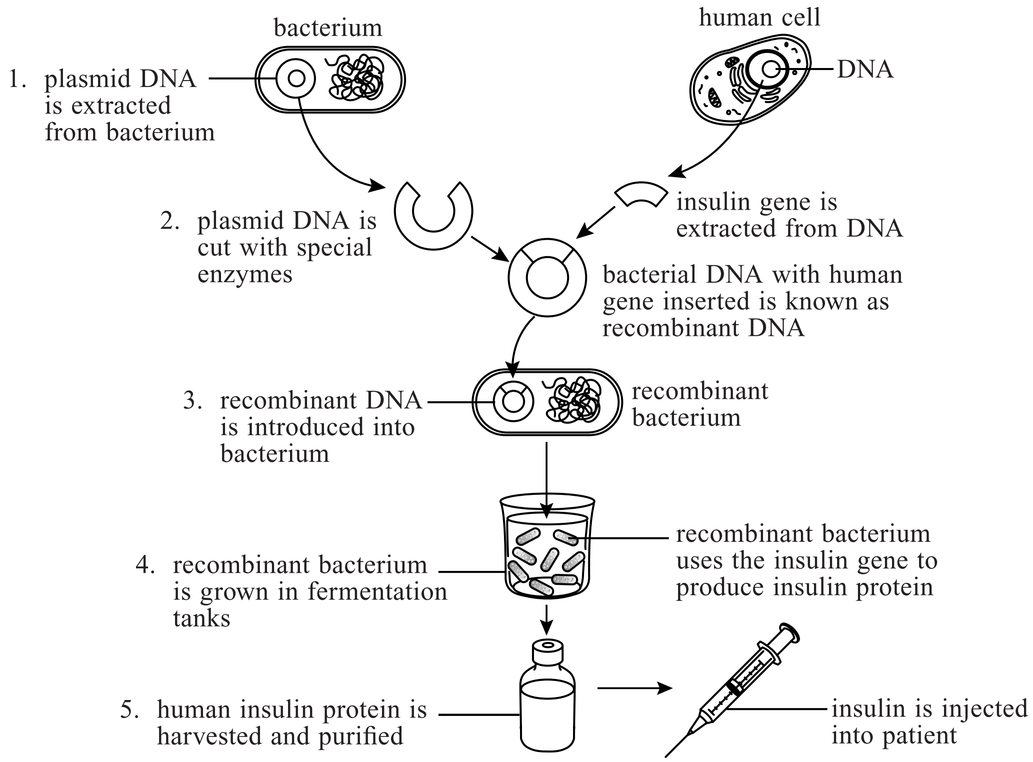


Fig 6.24 Using bacteria to manufacture insulin

5. Genetic engineering allows scientists to produce genetically modified organisms such as corn that is resistant to pests. This will reduce the amount of pesticides farmers use on their crops.
6. However, genetic engineering has social and ethical implications.
   - The ability to genetically engineer cells opens the door to create designer babies, whose genetic makeup has been selected or altered for a specific purpose.
   - When human genes are inserted in non-human organisms, what percentage of human genes does an organism have to contain before it is considered human?
   - If a plant contains genes from an animal, should vegetarians eat them?
   - Should all genetically modified food be labelled for consumers to make an informed decision? However, if they are labelled, would this cause wariness among the consumers?