

# Model of Cells – The Basic Units of Life

# Introduction

In this chapter, we will explore and learn about the model of cells, which is used to represent typical plant and animal cells. This model helps us infer and predict behaviours, functions and organisation of cells in multicellular organisms.

# **Learning Map**

This table shows the content covered in this chapter relating to the Primary Science (PS), Lower Secondary Science (LSS) and Upper Secondary Science (USS) syllabuses.

Content	PS	LSS	USS
Structures of an animal cell and their functions		1	1
Structures of a plant cell and their functions	1	1	1
Structures of typical plant and animal cells seen under a light microscope		1	1
Structures of typical plant and animal cells seen under an electron microscope			1
Using a light microscope safely and correctly		1	1
Biological drawing of a specimen seen under a light microscope		1	1
Cell organisation and division of labour		1	1

# **Prior Knowledge**

In Primary Science, you had learnt the following:

Topics: Cell system, human systems and plant systems

- · A cell is a basic unit of life.
- An animal cell has a cell membrane, cytoplasm and a nucleus.
- A plant cell has a cell wall, a cell membrane, cytoplasm, chloroplasts and a nucleus.

# 6.1 Understanding Cells with Advances in Technology

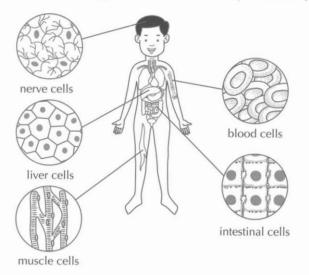
# **Learning Outcomes**

You should be able to:

- · \*identify the main structures in typical plant and animal cells
- · identify the important parts of a light microscope
- use a light microscope to observe a specimen
- appreciate that more scientific discoveries can be made with advances in technology
- understand the main functions of the various parts/structures of a typical plant and animal cells (Note: the abbreviation DNA is used to represent deoxyribonucleic acid)

<sup>\*</sup> denotes "Optional for N(A)"

- Cells are the basic building blocks that carry out all life processes in organisms.
- The human body is made up of different types of cells. Some examples of cell types are shown below:



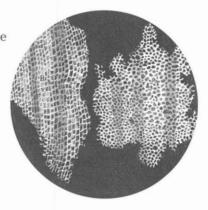
· Cells are too small to be seen with the human eye only. Therefore, an instrument is needed to examine cells and their structures.

# Microscopes

 A Dutch father-son team named Hans and Zacharias Janssen invented the first compound microscope in the late 16th century.

# **Enrichment**

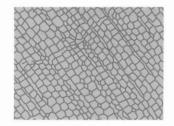
- · A compound microscope uses two lenses to obtain higher magnifications rather than using only one magnifying lens.
- The light microscope that we have in our science laboratory is a compound microscope.
- In 1667, an English scientist Robert Hooke famously published his book Micrographia. He is also the first to use the word "cells" to name the microscopic honeycomb cavities observed in the cork as seen in the figure.

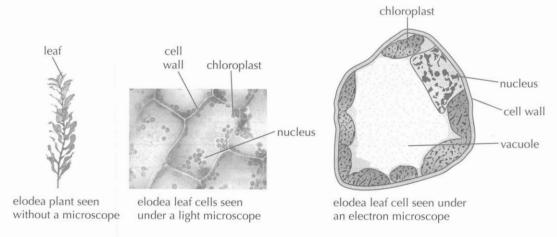


- With advances in technology, we can observe cells at a higher magnification and hence more details can be examined. The figure on the right shows a section of a cork under a fluorescence microscope.
- A microscope is used to observe and examine cells.
- Cells contain small structures such as nucleus. These small structures are not visible to us without the use of microscopes.
- There are different types of microscopes, such as light microscope, confocal microscope, fluorescence microscope and electron microscope. Hence, scientists can decide which microscope to use depending on how much details they want to observe.



The figures below show the structures of the elodea plant cell that can be observed under a light microscope and an electron microscope.

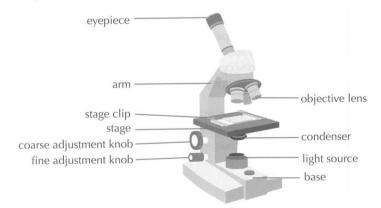




- A light microscope can magnify cells up to approximately 400 times. It uses visible light and lenses to magnify slide specimens.
- An electron microscope uses beams of electrons in a vacuum instead of light. It uses magnets instead of lenses.
- The electron microscope is especially useful in studying cell structures that cannot be observed under light microscopes, such as chromosomes in the nucleus. Hence, an electron microscope enables us to study cells more accurately.
- More scientific discoveries can be made with advances in microscope technology such as the development of the electron microscope and the fluorescence microscope.

# **Light Microscopes**

- The light microscope is a common scientific instrument used in schools.
- Important parts of a light microscope and their functions:

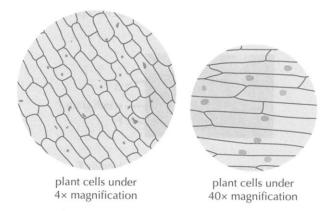


Part Function(s)		
eyepiece	<ul> <li>to observe the specimen</li> <li>to further magnify the image of the specimen by 10×</li> </ul>	
objective lens	to produce a magnified image of the specimen	
stage	to provide a platform to place the slide specimen	
stage clip	to hold the slide specimen in place	
condenser	to focus visible light onto the specimen	
light source	to provide visible light to shine on the specimen	
arm	<ul><li>to attach the eyepiece to the body of the microscope</li><li>to act as a handle to carry the microscope</li></ul>	
coarse adjustment knob	to move the stage up and down to obtain a clear image	
fine adjustment knob	to focus on the specimen for a sharp image	
base	to support the microscope	

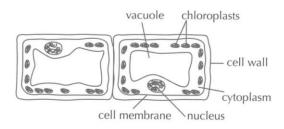
- The objective lenses of a light microscope come in various magnification powers, depending on the model of the microscope used. The most common magnifications are 4x, 10x, 40x and 100x.
- The lens in the eyepiece has a magnification of 10x. Hence, it further magnifies the image of the specimen observed.
- Therefore, the formula for calculating the total magnification of the lenses:

magnification power magnification power of Total magnification = the objective lens used of the eyepiece

 A wider field of view can be seen with a lower magnification power. However, more details can be seen when the specimen is magnified using a higher magnification power. This is illustrated by the figure below.



- Procedure for using a light microscope to observe a specimen and making a biological drawing:
  - (a) Place the microscope slide with the specimen on the stage. Secure the slide using the stage clips.
  - (b) Switch on the microscope. Adjust the condenser to focus and control the amount of light that passes through the specimen.
  - (c) Observe the specimen using the objective lens with the lowest power of magnification.
  - (d) Adjust the coarse and fine adjustment knobs to obtain a focused image of the specimen.
  - (e) Change to the objective lens with the next higher power of magnification.
  - (f) Adjust the coarse and fine adjustment knobs again to obtain a focused image.
  - (g) Adjust the position of the microscope slide to ensure we can observe the cell or its structures clearly before drawing the cell or its structures with a pencil.
  - (h) Label the biological drawing.
- Microscope drawings of cells are representations of what we observe. Hence, we should only draw what we can see under the microscope.
- The figure below shows a biological drawing of elodea leaf cells seen under 400x magnification. The labels of the cell parts, magnification and title of the drawing should be included.



drawing of elodea leaf cells seen under 400x magnification

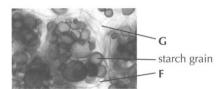


- All biological drawings must be done in pencil. Use a sharp pencil to draw clear, distinct and single lines.
- The lines of the biological drawing should not overlap.
- To illustrate darker areas on a specimen seen under the microscope, use stippling or dots. Do not shade any part of the cell in the drawing.
- Each label line must be straight and should not overlap with other label lines.

# Optional for N(A)

# Worked Example 1.

The figure below shows cells from a potato specimen seen under a microscope. The structures visible within the cells are starch grains.



(a) The cell part labelled as F gives the potato cell its regular shape. Identify F.

# **Answer**

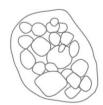
Cell wall



A potato cell is a plant cell. Based on the model of typical plant cells, the cell wall is the cell part that protects and gives the cell a regular shape.

(b) Make a biological drawing of the cell labelled G. You need not label your drawing.

### Answer





- From the photomicrograph (a photograph taken through a microscope) given, it is not easy to differentiate the cell wall and the cell membrane. Hence, for the outline of the cell, we can draw clear single lines without shading.
- The potato cell should follow the shape shown in the photomicrograph.
- The relative sizes of starch grains should be similar to those shown in the photomicrograph.
- (c) Before viewing the potato specimen under a microscope, the specimen is stained by soaking it with excess iodine on a microscope slide.
  - (i) What is the colour of the starch grains after getting stained with iodine?

# Answer

Blue-black/dark blue

(ii) Suggest a reason why specimens are usually stained before they are observed under a microscope.

### Answer

Specimens are stained so that we can observe the cell structures more clearly.



Tip

The cells are stained to enable us to see the cell parts and any other cell structures more clearly. Hence, we can identify the cell structures correctly and observe for any differences and changes in these structures for comparison. For example, the starch grains appear blue-black after getting stained with iodine, thus allowing us to identify this cell structure correctly.

# **Parts of a Typical Cell**

- Organisms have many different kinds of cells which exist in various shapes and sizes. However, all cells share some common features.
- A cell contains many small structures that can be seen under the microscope.
- Each structure/part carries out a specific function within the cell.
- The figure below shows the cell parts in a typical plant cell and their characteristics and functions:

# cytoplasm

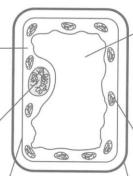
- · jelly-like substance that fills a cell
- place where many chemical reactions take place

### nucleus

- · controls all cell activities
- contains DNA, the genetic material that is passed down from parents to offspring

# cell membrane

- thin membrane layer underneath the cell wall
- partially permeable structure that controls the movement of substances in and out of the cell



plant cell

# vacuole

- usually a single large space surrounded by a membrane
- contains a liquid called cell sap that is made up of water and dissolved substances such as sugars and mineral salts

# chloroplast

- disc-like structure
- contains chlorophyll to make food through photosynthesis

# cell wall

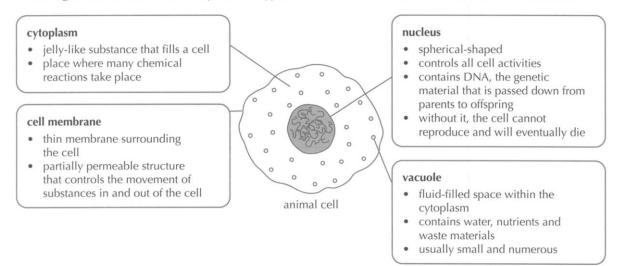
- thick layer surrounding the cell membrane
- · protects and supports the cell
- gives the cell a regular shape
- allows substances to move freely in and out of the cell



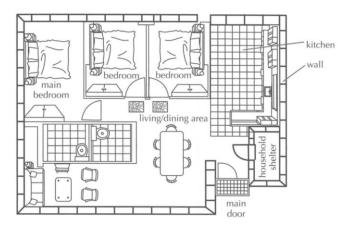
Tip .

All plant cells have cell walls, but only those cells from plant parts that make food for the plant contain chloroplasts.

• The figure below shows the cell parts in a typical animal cell and their characteristics and functions:



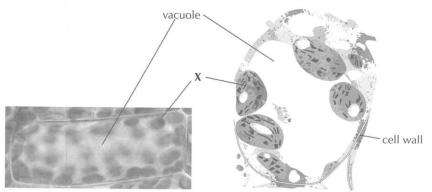
· We can compare the plant cell of a plant to a flat. The figure shows the floor plan of a flat.



Part of Flat	Part of Plant Cell	Common Roles/Functions
wall	cell wall	The wall surrounds the flat to protect it and gives its shape, just like the cell wall of a plant cell.
main door	cell membrane	The main door that controls the movement of people into and out of the flat, just like the cell membrane of a leaf cell.
main bedroom	nucleus	The main bedroom is like the nucleus that contains important information. The parents occupying the main bedroom control all activities in the flat.
kitchen	chloroplast	The kitchen is like the chloroplast where food is produced.
living/dining area	cytoplasm	The living/dining area acts like cytoplasm where most activities occur.
household shelter (storeroom)	vacuole	The household shelter (storeroom) is like the vacuole, which is used to store materials that are not needed immediately.

# Worked Example 2 -

The figure below shows plant cells seen under a light microscope and an electron microscope.



plant cell seen under a light microscope

plant cell seen under an electron microscope

(a) Identify cell part X and state its function in a plant cell.

#### Answer

Chloroplasts. Chloroplasts contain chlorophyll that traps energy from sunlight to make food for the plant during photosynthesis.



# Tips .

- More details can be observed under the electron microscope than the light microscope.
- Chloroplasts have an oval shape based on the typical model of a plant cell.
- Plant parts that make food contain chlorophyll to trap energy from sunlight needed during photosynthesis.
- (b) Study the vacuoles shown in the figure. Describe how the vacuoles seen in the plant cells differ from the vacuoles in the model of a typical animal cell.

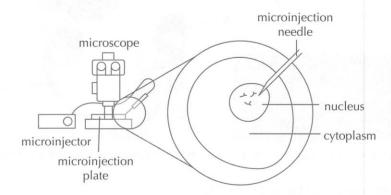
- The vacuole is larger/takes up more space in the plant cells than those in a typical animal cell.
- There is only one vacuole seen in the plant cell, but numerous vacuoles are found in a typical animal cell.



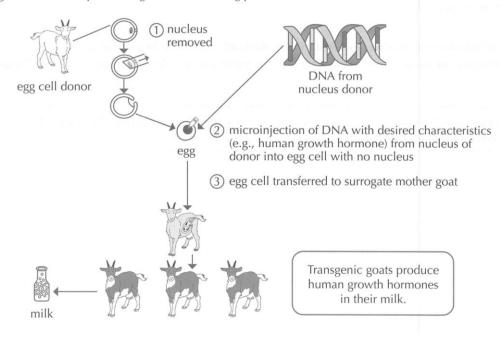
# ( Tip.

Based on the figure, the vacuole takes up most of the space in the plant cell. A typical animal cell contains numerous small vacuoles.

- The development of microscopes and technologies has enabled the technology for cloning cells to be developed.
- With this technology, the nucleus of a cell can be removed or inserted with precision.
- Microinjection is a technique of delivering foreign DNA into a living cell such as the egg cell using a glass micropipette.
- With a glass micropipette, the foreign DNA is inserted into the nucleus of a target cell placed under a microscope, as shown in the figure below.



- Transgenic animals are animals that contain DNA of another species in their cells. They have new and favourable characteristics.
- The young of the animals produced from cloning is genetically similar to the nucleus donor and possess similar characteristics.
- During cloning, the nucleus from the egg cell donor is removed to make space for the nucleus from the nucleus donor.
- The DNA from the nucleus donor is microinjected into the egg cell. The egg cell is then transferred to a surrogate mother.
- The transgenic embryo develops in the uterus (womb) of the surrogate mother during the cloning process.
- · The resulting animals are clones that contain genetic materials derived from the nucleus donor.
- The figure shows a simplified diagram of the cloning process.



# 6.2 **Using Models to Represent Typical Plant and Animal Cells**

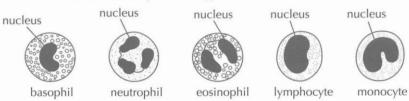
# **Learning Outcome**

You should be able to:

infer if an unknown cell is from a plant or animal by comparing its cell structures with those in the models of typical plant and animal cells

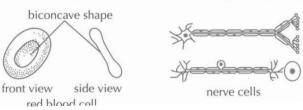
#### **Cell Models**

- Models are used to represent structures found in plant and animal cells. This helps us to visualise and explain the functions of these structures.
- The model of a typical animal cell contains characteristics that are commonly observed in animal cells. For example, a typical animal cell contains the cell membrane, cytoplasm, nucleus and numerous small vacuoles
- Similarly, the model of a typical plant cell contains characteristics that are commonly observed in plant cells. For example, a typical plant cell contains the cell wall, cell membrane, cytoplasm, nucleus and a large vacuole in the middle of the cell.
- Therefore, using cell models, we can
  - o make comparisons between animal and plant cells; and
  - o infer if an unknown cell is from a plant or animal by comparing it with the typical plant and animal cell models.
- However, there are also limitations of cell models in the study of science:
  - Cells from plants and animals usually come in in a variety of shapes and sizes that are different from those shown in the typical cell models.
  - The cell models are unable to show further details of each cellular structure.
  - Not all cell types have the same type of cell structures. These structures may not be present in the same proportion and shape.
  - For example, the figure below shows the various types of white blood cells found in humans. The shape and size of the nucleus vary in each type of white blood cell.

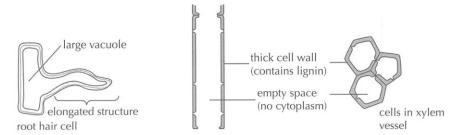


# **Inference of Cell Types**

- In a multicellular organism, cells are modified to perform specialised functions.
- These cells exist in a variety of shapes and sizes according to their functions. They can look very different from the typical animal and plant cells.
- For example, in humans, red blood cells do not have nuclei so as to be able to transport oxygen more efficiently, while nerve cells have long fibres to conduct nerve impulses quickly.



• In plants, root hair cells do not have any chloroplasts but have an elongated structure to absorb water rapidly. The xylem vessel is made up of cells that have an no cytoplasm but have a thick cell wall. Guard cells are sausage-shaped cells that monitor the size of the stomata.

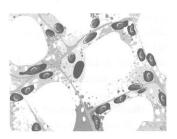




- Cells that perform a specialised function in a multicellular organism are known as specialised cells.
- For humans, red blood cells, muscles cells, nerve cells and sperm cells are common examples of specialised cells.
- For plants, root hair cells, xylem and guard cells are common examples of specialised cells.

# Worked Example 3 ...

The figure shows some cells seen under the microscope.



What are the type and main feature of the cells?

	Type of Cell	Main Feature of the Cells
A	plant cell	large nucleus
В	plant cell	large vacuole
С	animal cell	large nucleus
D	animal cell	large vacuole

### Answer

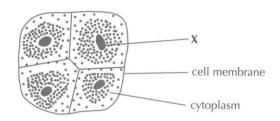
В



Based on the cell models of typical plant and animal cells, a typical plant cell has a large vacuole, while a typical animal cell has numerous small vacuoles. The large vacuoles shown in the figure is very prominent.

# Worked Example 4 ...

The figure shows some human cheek cells.



(a) Identify the cell structure labelled X.

### Answer

Nucleus



The nucleus of a typical cell is usually spherical. It contains DNA that makes it appear darker as compared to other cell structures under the microscope. Hence, we should use stippling, dots or dark colour to represent the nucleus in diagrams.

(b) What characteristics of human cheek cells shown above suggest that it is an animal cell?

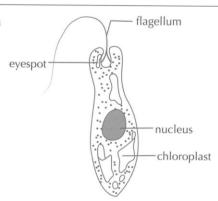
The human cheek cells have no cell walls nor a regular shape.



Refer to the cell models of typical plant and animal cells. Animal cells have irregular shapes and no cell walls.

# Worked Example 5 \_

The figure on the right shows a biological drawing of a cell as observed by a student under a microscope.



(a) Give one reason why the cell above is plant-like.

### Answer

It contains chloroplast.



Based on the cell models of typical plant and animal cells, chloroplasts can be found only in a typical plant cell in plant parts that make food for the plant. Animal cells do not contain chloroplasts.

(b) Give one reason why the above cell is animal-like.

### Answer

It has a flagellum. / It has no cell wall.



# Tips.

- A typical animal cell does not have cell wall. Cell walls are typical features of plant cells.
- Plant cells do not have flagellum (tail), so the cell shown in the figure is animal-like. Animal cells such as sperm cells have flagellum to help them to move.

# 6.3 **Organisation of Cells for the Efficient Function** of the Whole Organism

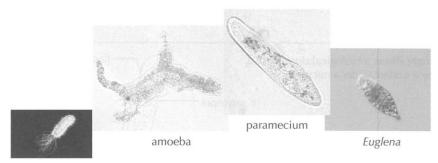
# **Learning Outcomes**

You should be able to:

- · differentiate a unicellular organism from a multicellular organism
- understand the different levels of cellular organisation in multicellular organisms to allow them to work efficiently
- \*explain the importance of division of labour at cellular and multicellular levels

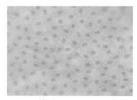
# **Cellular Organisation**

- The diversity of cells can be simplified by classifying them according to similarities in their structures or functions.
- We can classify living organisms into two groups: unicellular and multicellular.
- · Unicellular organisms consist of only one cell. For example, bacterium, amoeba, paramecium and Euglena.

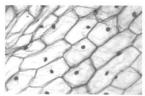


bacterium

Multicellular organisms consist of more than one cell. For example, most animals and plants contain more than one cell.

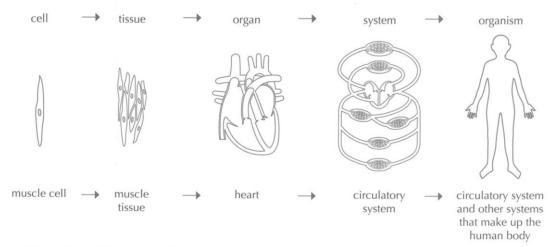


cells in an animal



cells in a plant

<sup>\*</sup> denotes "Optional for N(A)"



- o Cell: Cells are the basic building blocks of an organism.
- Tissue: A living tissue is made from a group of cells with a similar structure and function, which all work together to perform a specific function.
- Organ: An organ is made of a group of different tissues, which all work together to perform a specific function.
- System: A system is made of a group of different organs, which all work together to perform a specific function.
- o Organism: An organism is made up of several different systems.
- · There are two transport systems in plants:
  - o Transport of water and mineral salts from the roots to all parts of the plant
  - Transport of food produced by photosynthetic parts of the plant such as leaves to other parts of the plant
- The table below shows the levels of cellular organisation in the water transport system of a flowering plant and the circulatory system of the human body.

Level of Organisation	Transport System in a Flowering Plant	Circulatory System in the Human Body
Cell	Root hair cell  Absorbs water and mineral salts from the surroundings into the plant	Muscle cell  Found in the heart and blood vessel
Tissue	Root tissue     Made up of root hair cells to perform the same function of absorbing water and mineral salts from the surroundings into the plant  Xylem tissue (water-carrying tubes)     Mainly made up of xylem vessels to carry water to all parts of the plant	<ul> <li>Muscle tissue</li> <li>Made up of muscle cells that form the wall of the heart to perform the same function</li> <li>Made up of muscle cells that line the blood vessels to perform the same function</li> <li>Blood tissue</li> <li>Made up of a variety of cells such as red blood cells to perform the same function</li> </ul>

Level of Organisation	Transport System in a Flowering Plant	Circulatory System in the Human Body
Organ	Mainly made up of different tissues that work together for the absorption of water and mineral salts  Stem     Mainly made up of different tissues that work together to carry water and provide mechanical support for the plant	<ul> <li>Heart</li> <li>Made up of different tissues such as the muscle tissue and blood tissue to perform a specific function</li> <li>Blood vessels</li> <li>Made up of different tissues such as the muscle tissue, elastic tissue and connective tissue to perform a specific function</li> </ul>
System	Plant transport system  Mainly made up of different organs such as the roots and stem that work together to transport water and mineral salts in the plant	Human circulatory system     Made up of different organs such as the heart and blood vessels that work together to transport substances in the body
Organism	<ul> <li>Flowering plant</li> <li>A flowering plant is an organism that is made up of the different systems working together to perform various functions in the plant for its growth and survival.</li> </ul>	Human     A human is an organism that is made up of different systems working together to perform various functions in the body for its growth and survival.

## Optional for N(A)

### **Division of Labour**

- Division of labour is the organisation and breakdown of work into small and specific functions in a coordinated way for maximum efficiency.
- Division of labour in living organisms can occur at two levels: multicellular and cellular levels.
- At the multicellular level, each type of cell is specialised in performing a specific function in multicellular organisms.
- Organisation of cells ensures that the whole organism functions effectively and efficiently by allowing
  different parts of an organism to perform various functions in a coordinated way. Hence, these different
  functions can be performed simultaneously.
- The table below shows how division of labour allows the circulatory and digestive systems to work
  efficiently in the human body.

Level of Organisation	Division of Labour		
	In human circulatory system	In human digestive system	
Cell	Muscle cell     Found in the heart to keep the heart pumping      Found in the blood vessel to regulate blood flow and pressure	Muscle cell  Found in the stomach and intestines where it helps with digestion and transport of food	

Level of	Division of Labour		
Organisation	In human circulatory system	In human digestive system	
Tissue	Muscle tissue  Made up of muscle cells that help in the contraction and relaxation of the heart  muscle tissue made of smooth muscle cells in blood vessel  Blood tissue  Made up of a variety of cells such as red blood cells to transport oxygen in the body	Muscle tissue  Made up of muscle cells that help in the contraction and relaxation of the stomach to mix food with digestiv juices  Made up of muscle cells that help in the transport of the food in the small intestine  Connective tissue  Made up of blood and other fluids that carry digested food away from the small intestine	
Organ	<ul> <li>Made up of different tissues such as the muscle tissue, elastic tissue and blood tissue to pump blood into blood vessels</li> <li>Blood vessels</li> <li>Made up of different tissues such as the muscle tissue, elastic tissue and connective tissue to transport and regulate blood flow</li> </ul> muscle tissue elastic tissue lumen containing blood	Stomach  Made up of different tissues such as the muscle tissue and connective tissue that help in food digestion  Small intestine  Made up of different tissues such as the muscle tissue and connective tissue to transport food  The inner wall of the small intestine is highly folded to increase the exposed surface area in order to increase the rate of absorption of digested food.	
System	<ul> <li>The organs in the circulatory system each have a specific function.</li> <li>These organs work together to allow efficient transportation of substances in the body.</li> </ul>	<ul> <li>The organs in the digestive system each have a specific function.</li> <li>These organs work together to allow efficient digestion and absorption of food.</li> </ul>	
Organism	A human is an organism that is made up or perform various functions in the body for		

- Division of labour also happens at the cellular level where different cell structures have different roles.
- Each cell structure has a specific function where different cell structures work together in a coordinated way to allow the cell to work efficiently.
- The table below explains the division of labour in a root hair cell and a red blood cell.

Cell	Division of Labour
cell wall cell membrane cytoplasm vacuole protrusion in root hair cell	<ul> <li>The long protrusion of the root hair cell increases the surface area exposed to its surroundings to absorb water and mineral salts more rapidly.</li> <li>The cell membrane controls the movement of water and mineral salts into and out of the cell.</li> <li>The cell wall prevents the root hair cell from bursting when the cell takes up a lot of water.</li> </ul>
no nucleus so that the cell can hold more haemoglobin  cytoplasm that contains haemoglobin  side view  biconcave shape	<ul> <li>Cytoplasm in the red blood cell contains haemoglobin that binds to the oxygen molecules.</li> <li>Red blood cells have no nucleus so that they can hold more haemoglobin. Hence, each red blood cell can transport more oxygen molecules.</li> <li>Red blood cells have a biconcave shape (flattened disc shape) to increase their surface area for oxygen absorption.</li> </ul>



Red blood cells are specialised cells. They do not have nucleus in order to perform their task efficiently. However, each red blood cell only lives for about four months due to this loss of nucleus.

# Worked Example 6

The figure on the right shows the side view and top view of an animal cell as seen under a microscope.



side view



(a) Identify the type of cell shown in the figure.

### Answer

Red blood cell



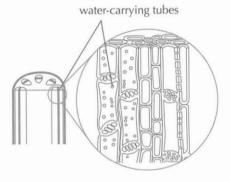
The typical characteristics of a red blood cell include its biconcave shape and the absence of a nucleus.

(b) State one key characteristic of the cell identified in (a). How does this characteristic help the cell to carry out its function efficiently?

# **Answer**

A red blood cell has no nucleus. This allows it to hold more haemoglobin and hence transport more oxygen around the human body.

The figure below shows the cross-section of part of a stem.



- (a) At which level of organisation of cells are the water-carrying tubes?
  - A Cell
  - **B** Tissue
  - C Organ
  - **D** System

# Answer

R

(b) Explain your answer in (a).

#### Answer

Water-carrying tubes are tissues as they are made up of the same type of cells to carry water from the roots to other parts of the plant.



Tip

Tissue is made from a group of cells with similar structure and function, which all work together to perform a specific function. The figure shows that the water-carrying tubes are made up of a group of similar cells.