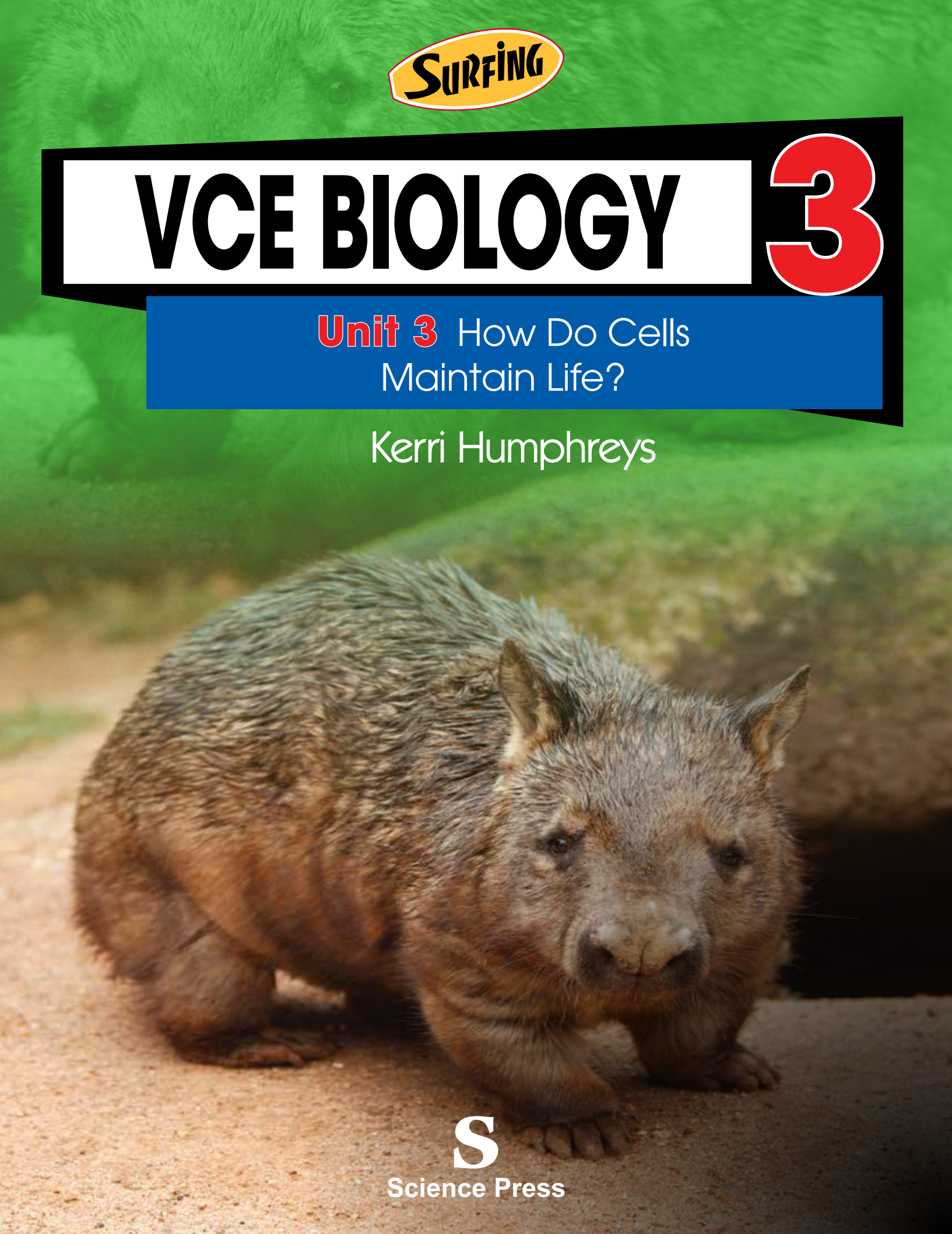
SURFING

VCE BIOLOGY 3

Unit 3 How Do Cells Maintain Life?

Kerri Humphreys



Science Press

First published 2017

Science Press
Bag 7023 Marrickville NSW 1475 Australia
Tel: (02) 9516 1122 Fax: (02) 9550 1915
sales@sciencepress.com.au
www.sciencepress.com.au

Contents

Introduction

This book covers the Biology content specified in the Victorian Certificate of Education Biology Study Design. Sample data has been included for suggested experiments to give you practice to reinforce practical work in class.

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory parts of the syllabus, along with questions and answers.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of the book contains an extensive set of summary questions. These cover every aspect of the topic, and are useful for revision and exam practice.

Words To Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.

SURFING

VCE BIOLOGY 3

Area of Study 1

How Do Cellular Processes Work?

1 Assumed Knowledge

1. The diagram shows a model of the plasma membrane.

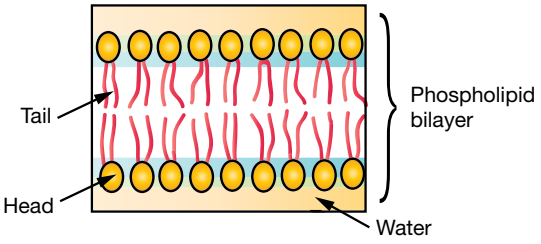


Figure 1.1 Lipid bilayer.

   (a) What is the name of this model?
   (b) Who proposed this model?
2. Distinguish between hydrophobic and hydrophilic.
3. The diagram shows a plant cell as seen under a light microscope.

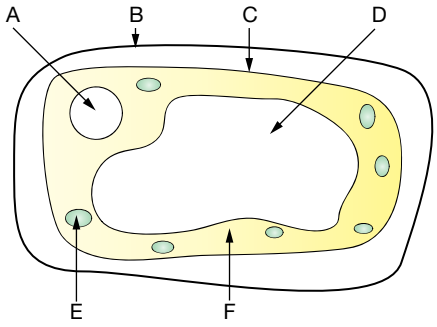


Figure 1.2 Plant cell.

   Identify the plasma membrane and then label all the other parts of the plant cell.
4. The diagram shows an animal cell as seen under a light microscope.

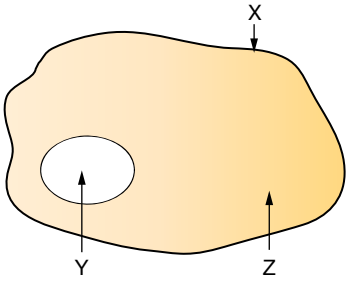


Figure 1.3 Animal cell.

   Identify the plasma membrane and then label all the other parts of the animal cell.
5. What is the function of the cell membrane?
6. Define diffusion.
7. Define osmosis.
8. Distinguish between active and passive transport.
9. What is cytosis?
10. Distinguish between exocytosis and endocytosis.
11. Describe a chloroplast.
12. Define photosynthesis.
13. Which group of organisms can photosynthesise?
14. Identify the materials required by multicellular organisms for photosynthesis.
15. Why is photosynthesis an important process in ecosystems?
16. Name the four basic groups of organic compounds.
17. What are inorganic compounds?
18. Define respiration.
19. Define a gene.
20. What is phagocytosis?
21. Identify the four main classes of macromolecules found in living organisms.
22. What does DNA stand for?
23. The diagram shows the structure of the DNA molecule.

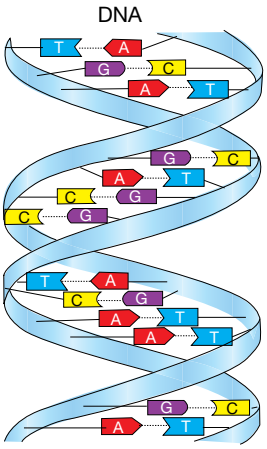


Figure 1.4 Structure of DNA molecule.

   Identify the shape of the DNA molecule.
24. What does RNA stand for?
25. What is a the shape of a bacterial chromosome?
26. What is a chromosome?
27. Define an allele.
28. What is an enzyme?
29. The diagram shows the structure of ATP.

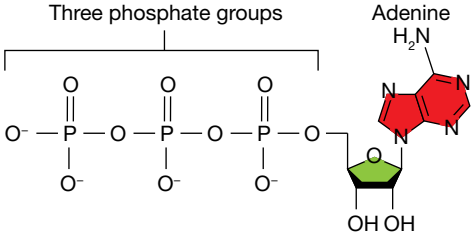


Figure 1.5 Structure of ATP.

   Outline the importance of ATP.
30. What is a hormone?
31. Outline the function of the endocrine system.
32. Distinguish between an exocrine gland and an endocrine gland.
33. Explain why the pancreas is both an endocrine gland and an exocrine gland.
34. What is an antigen?
35. What is an antibody?

2 The Plasma Membrane

The plasma membrane separates a cell from its external environment and acts as a selective barrier around the cell. As a barrier the plasma membrane creates and maintains concentration gradients between its internal and its external environment and also maintains pH and charge differences.

The plasma membrane is important in cell-cell recognition and has receptor molecules for cell signalling.

The surface area of the plasma membrane is important as it determines the rates of chemical exchange into and out of the cell.

Fluid mosaic model

The fluid mosaic model proposed by SJ Singer and G Nicolson in 1972 identified the plasma membrane as made up of lipids and proteins with a lipid bilayer and proteins embedded in the bilayer. The proteins could go partway or completely across the membrane.

The structure is not static. There is lateral movement of the phospholipids, the proteins move about and hydrophobic interactions keep the structure held together.

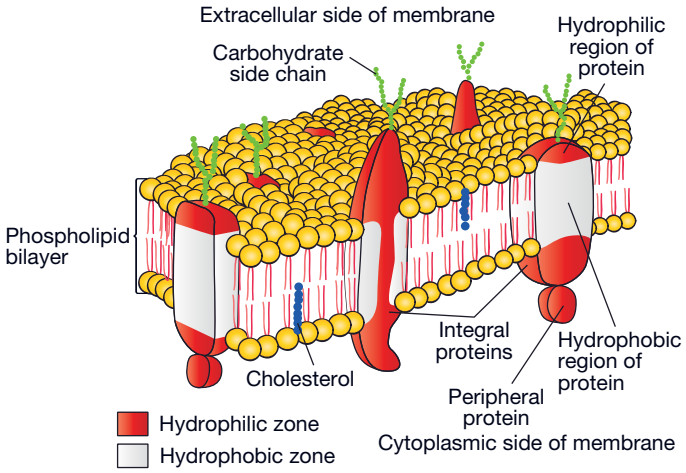


Figure 2.1 Plasma membrane.

There are two main types of membrane proteins – **integral proteins** which are transmembrane proteins that extend into and often completely span across the membrane and **peripheral proteins** which are bound to the surface of the membrane.

Phospholipids

The phospholipid bilayer is one of the main structural features of the plasma membrane. It consists of two layers of phospholipids with their fatty chains facing inwards away from water. The hydrophilic heads face outwards towards the water. There are scattered proteins embedded among the phopspholipids.

Since phospholipids have a polar hydrophilic head and a non-polar, hydrophobic tail, they are **amphipathic molecules** which are molecules with a **hydrophilic** (water loving) region and a **hydrophobic** (water hating) region.

Phospholipids consist of a glycerol backbone with two non-polar fatty acid chains. Triacylglycerols (fat molecules) have a glycerol backbone with three fatty acid chains. If one of the fatty acid chains of a triacylglycerol is replaced by a phosphate group it becomes a phospholipid. The phosphate group is ionised with a negative charge. The phospholipids can have additional polar groups, e.g. choline, serine and this increases their hydrophilic attraction. This leads to the formation of a range of different phospholipids.

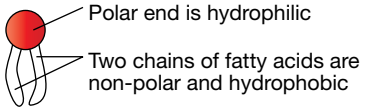


Figure 2.2 Phospholipid.

Cholesterol

Cholesterol is a steroid lipid that is an essential part of the plasma membrane especially in animal cells where it can make up to 50% of the plasma membrane. Cholesterol is smaller than the phospholipids, is less amphipathic and its OH groups that are hydrophilic are towards the surface of the membrane.

Cholesterol reduces the fluidity of the membrane by reducing phospholipid movement and also helps the membrane stay liquid at low temperatures, e.g. room temperature.

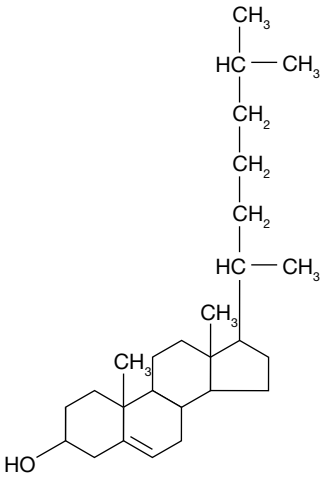


Figure 2.3 Cholesterol.

Membrane fluidity

Within a plasma membrane there is lateral movement of both phospholipids and proteins – hence the 'fluid' mosaic model. Adjacent phospholipids can switch positions about 10^7 times per second, which means that an individual phospholipid can move around 2 micrometres in one second.

The fluidity of the membrane depends on the types of lipids present in the membrane. The presence of saturated fatty acids (with all C–C single bonds) makes the membrane *less* fluid, e.g. will become solid at room temperature. While the presence of unsaturated fatty acid (with some double bonds C=C) makes the membrane *more* fluid. The double bonds cause the fatty acid chains to take on a 'bent' appearance that prevent tight packing of the phospholipids, e.g. will be liquid at room temperature.

Cells that can control the tail length of the fatty acid chains produce longer chains to make the membrane less fluid.

Membrane carbohydrates

The plasma membrane has carbohydrate side chains that are on the outside of the cell facing away from the cytoplasm. **Glycolipids** are carbohydrates bonded to the lipids, e.g. some glycolipids – blood antigens determine blood type. **Glycoproteins** are carbohydrates bonded to the proteins, e.g. act as identification tags for cell-cell or cell-protein binding or interactions.

Integral proteins

Integral membrane proteins (IMPs) are permanently attached to the membrane. They have hydrophobic regions which are anchored to the hydrophobic lipids. They have an alpha helix and complex structure.

Peripheral proteins

Peripheral proteins are not embedded in the lipid bilayer being completely on the membrane surface. They are loosely bound to the surface of the membrane by ionic and hydrogen bonding with the hydrophilic lipid and protein groups. They often found associated with the exposed part of an integral protein. They can be removed with high salt or alkaline conditions.

QUESTIONS

1. Outline the roles of the plasma membrane.
2. (a) What is the name of the current model of the plasma membrane?
   (b) When was this model first proposed?
3. Discuss why the plasma membrane is considered to be 'fluid' and not static.
4. Distinguish between hydrophilic and hydrophobic.
5. Identify the main interaction that keeps the plasma membrane intact.
6. Distinguish between integral proteins and peripheral proteins.
7. Define an amphipathic molecule.
8. Explain why phospholipids are amphipathic molecules.
9. The diagram shows the structure of a phospholipid.

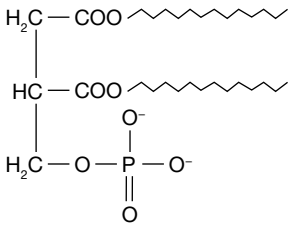


Figure 2.4 Structure of a phospholipid.

Copy this diagram and then annotate your drawing to identify the different parts of the phospholipid.

10. Compare the structure of a phospholipid with the structure of a triacylglycerol (fat molecule).
11. Discuss how cholesterol is involved in the structure of the plasma membrane.
12. At what rate can phospholipids move in the plasma membrane?
13. Discuss a factor that influences the fluidity of the plasma membrane.
14. Explain how double bonds affect the shape of phospholipids and the properties of the plasma membrane.
15. What are glycolipids and glycoproteins?
16. The diagram shows the structure of two different plasma membranes.

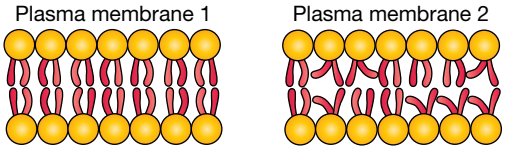


Figure 2.5 Two plasma membranes.

(a) Which of these membrane would be the most fluid?
(b) Explain why the membrane you chose would be more fluid than the other membrane.

17. The diagram shows a drawing of a plasma membrane. Identify structures X, Y and Z.

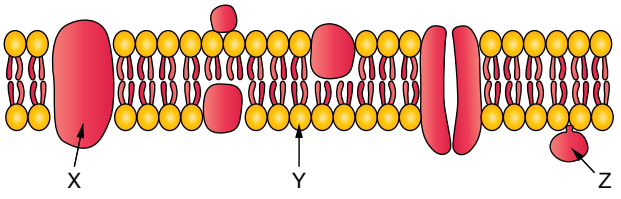


Figure 2.6 Plasma membrane.

	X	Y	Z
(A)	Peripheral protein	Phospholipid	Integral protein
(B)	Integral protein	Phospholipid	Peripheral protein
(C)	Peripheral protein	Cholesterol	Integral protein
(D)	Phospholipid	Cholesterol	Phospholipid

3 Crossing the Plasma Membrane

Many substances need to cross the plasma membrane, e.g. nutrients and water need to be supplied to cells and secretions and metabolic wastes need to leave the cell. The exchange of respiratory gases occurs across the plasma membrane.

Within cells internal membranes form small compartments to regulate the movement of substances inside the cell.

Diffusion of gases

All living things respire to release energy for use in cells to carry out metabolic activities. **Aerobic respiration** requires oxygen and there needs to be gas exchange across the plasma membrane – oxygen into the cell and carbon dioxide out of the cell. These gases enter and leave in aqueous solution. Maintenance of concentration gradients across the cell membrane allows these small molecules to diffuse across the membrane.

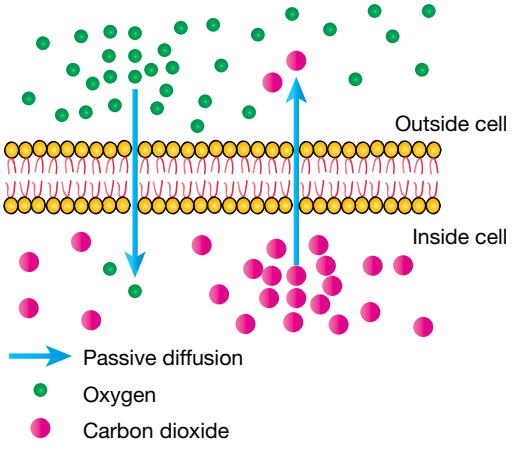


Figure 3.1 Diffusion across the plasma membrane for aerobic respiration.

Plant cells require carbon dioxide for **photosynthesis**. Gas exchange for photosynthesis involves carbon dioxide crossing the plasma membrane moving into the photosynthetic cell by diffusion and oxygen, the waste product of photosynthesis diffusing out of the cell across the plasma membrane.

Osmosis

Osmosis is the movement of water across a semipermeable membrane from an area of high water concentration to an area of low water concentration. Osmosis is a type of diffusion and is passive transport. Water is a polar molecule and can pass through the lipid bilayer through channel proteins called **aquaporins**.

These channel proteins form a hydrophilic channel that acts as a tunnel through the membrane and the movement is a type of facilitated diffusion. The water potential will predict the direction in which water will flow – either in or out of the cell.

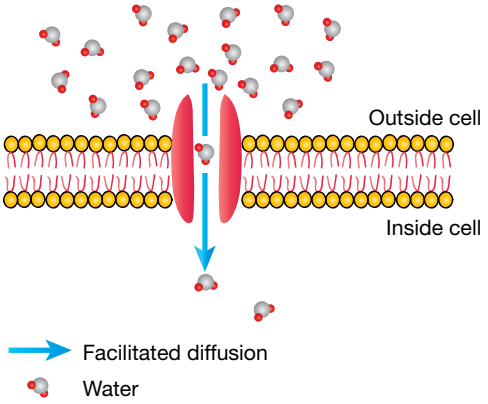


Figure 3.2 Aquaporins and facilitated diffusion of water across a plasma membrane.

Carrier protein channels and facilitated diffusion

Carrier proteins change their shape during the process of passing a solute across the plasma membrane. The movement of the solute can occur in either direction.

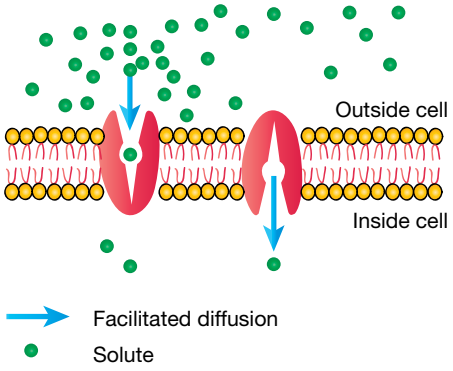


Figure 3.3 Carrier protein and facilitated diffusion.

Carrier proteins are usually very specific, e.g. glucose transporter carrier protein will only take glucose across the plasma membrane and will not take fructose which is an isomer of glucose.

Ion channels in the plasma membrane establish a resting membrane potential, shape action potentials (nerve impulse in neurons) and allow the passage of specific ions and electrical charge. **Gated ion channels** will open and close due to a stimulus, e.g. voltage-gated ion channels open with a change in membrane potential. **Gating** is the change in shape between the open and closed state of the channel. Movement through the ion channel is by facilitated diffusion.

Active transport and ion pumps

Active transport uses energy to take a solute from an area of low concentration to an area of high concentration – against the concentration gradient. There are specific carrier proteins that are transport proteins, e.g. sodium-potassium pump in animal cells which need energy to maintain homeostasis. Active transport can be divided into two types according to the source of energy used. **Primary active transport** uses energy from the breakdown of ATP or some other high energy phosphate compound. While **secondary active transport** uses energy that was stored in the form of ionic concentration differences between two sides of the membrane. Substances transported by primary active transport include sodium, potassium, calcium, hydrogen and chloride.

The **sodium-potassium pump** exchanges sodium ions for potassium ions across the plasma membrane to keep down the sodium ion concentration of a cell. It is nearly universal in animal cell membranes and common in many plant cells.

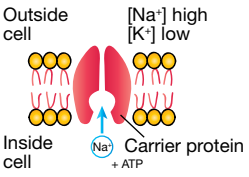
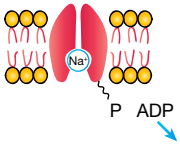
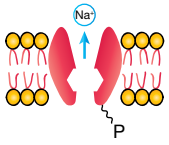
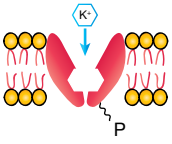
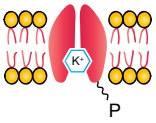
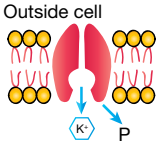
Sodium-potassium pump	What is happening
	Cells maintain a high Na^+ outside and low Na^+ concentration inside a cell and a high K^+ concentration inside a cell and low K^+ outside the cell. In the cell membrane carrier proteins have two states. From inside the cell Na^+ ions from the cytoplasm can fit into the carrier protein and bind to the sodium-potassium pump.
	Na^+ binding with the carrier proteins stimulates the chemical reaction phosphorylation using ATP and a phosphate group is attached to the protein. ADP is released.
	Phosphorylation makes the protein change shape causing the Na^+ to be released outside the cell. This is active transport of Na^+ across the cell membrane from the cytoplasm to the extracellular fluid.
	A K^+ ion from outside the cell binds to the carrier protein.
	The carrier protein now has a form that fits K^+ rather than Na^+. Facilitated diffusion occurs as no energy is used in the transport across the plasma membrane.
	The phosphate group is released from the carrier protein causing the carrier protein to release K^+ into the cytoplasm and the protein reverts back to its other state.

Figure 3.4 Sodium-potassium pump.

QUESTIONS

1. Identify the gases that need to cross the plasma membrane for aerobic respiration to occur in a cell.
2. Outline the gas exchange that occurs across the plasma membrane of a photosynthetic plant cell.
3. Define osmosis.
4. Outline how aquaporins are involved in the transport of water across the plasma membrane.
5. What are carrier proteins?
6. Define active transport.
7. Distinguish between the two types of active transport.
8. Construct a table to summarise at least four different ways substances can cross the plasma membrane.
9. What is the sodium-potassium pump?
10. Identify some functions of ion channels.
11. What is meant by gating of an ion channel?
12. The diagram shows two states of a sodium ion channel in a plasma membrane.

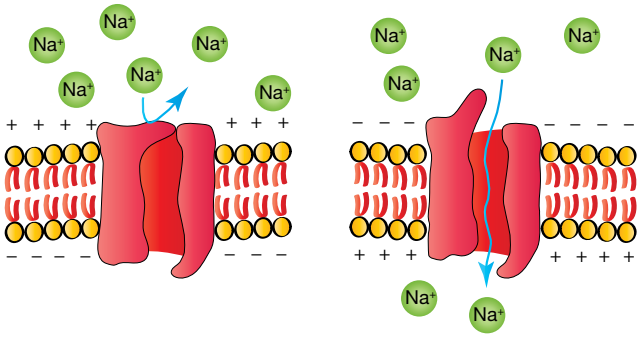


Figure 3.5 Sodium ion channel.

Outline what is happening in these two diagrams.

13. Glucose transporters are a wide range of membrane proteins. Explain why glucose transporters are needed in nearly all heterotrophic cells.
14. Which of the following best describes a carrier protein?
    (A) Links to the plasma membrane for transport.
    (B) Temporarily adheres to a membrane for facilitated transport.
    (C) Has hydrophobic and hydrophilic regions for transport.
    (D) Transfers a solute across a lipid bilayer.
15. Which of the following would *only* move by simple diffusion across a plasma membrane?
    (A) Oxygen, urea, glucose.
    (B) Carbon dioxide, sucrose, sodium ions.
    (C) Oxygen, carbon dioxide, urea.
    (D) Water, glucose, sodium ions.

4 Exocytosis

Cytosis is the passage of large 'packages' of material across a membrane. **Exocytosis** is the process when vesicles inside the cell fuse with the cell membrane and the contents of the vesicle are secreted from the cell. Exocytosis is used for the secretion of substances synthesised by a cell and for the elimination of indigestible remains in a food vacuole.

Secretory cells

There are many types of cells that are secretory.

Hormone secretion – the **endocrine glands** are the ductless glands that secrete hormones directly into the interstitial fluid from where they diffuse into the bloodstream, e.g. cells in the thyroid gland secrete thyroxine.

Digestive enzymes – tissues in the gastrointestinal tract secrete digestive enzymes, e.g. exocrine cells in the pancreas secrete pancreatic lipase and pancreatic amylase.

Antibody secretion – antibodies (immunoglobulins) are secreted by plasma B cells.

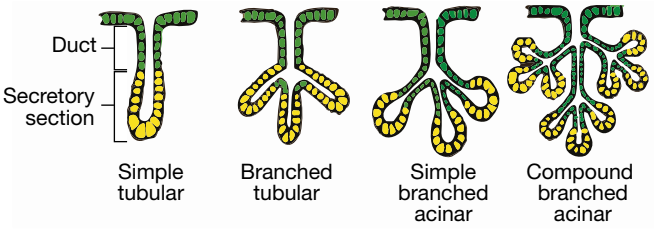


Figure 4.1 Exocrine glands release secretions into ducts.

Exocrine glands release secretions into a duct which goes to an epithelial surface, e.g. sweat glands, sebaceous glands, mammary glands.

Organelles involved in exocytosis

Ribosomes are particles made of ribosomal RNA and protein and they carry out protein synthesis. Free ribosomes in the cytosol produce proteins that function within the cytosol while **bound ribosomes** attached to the nuclear membrane or endoplasmic reticulum forming rough endoplasmic reticulum produce proteins that will become part of the plasma membrane or will be bound within another organelle, e.g. lysosome or will be packaged for secretion. If the protein is to be secreted it has a special sequence of amino acids at the beginning of the polypeptide chain that is a **signal sequence**. Secretory cells have large numbers of bound ribosomes.

Endoplasmic reticulum (ER) is a large network of membranes throughout the cell. Two types of ER are rough ER and smooth ER.

Rough ER is continuous with the outer membrane of the nuclear envelope which also has attached ribosomes. The bound ribosomes produce polypeptide chains which move into the lumen of the ER where they complete the formation of the protein molecule. **Glycoproteins** that have carbohydrates attached to the protein are formed at this stage. The secretory protein is then enclosed in a transport vesicle to travel through the cytosol.

Smooth ER produces lipids, e.g. oils, phospholipids and steroids, including steroid hormones.

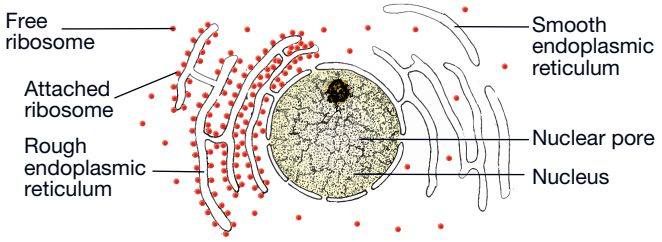


Figure 4.2 Endoplasmic reticulum.

Golgi apparatus – The Golgi apparatus is a stack of flattened membrane bound sacs called cisternae that is the site of synthesis of biochemicals and the packaging of biochemicals into swellings at the end of the sacs to form vesicles. It collects proteins and lipids made by ER. The membranes on the opposite sides of the Golgi apparatus have different thicknesses and composition with the side receiving the materials called the cis face and the side releasing the materials the trans face. The cis face is usually found near the rough ER and is the convex side of the stack faces. A transport vesicle from the ER adds its membrane and contents of its lumen to the cis face to form new cis Golgi cisternae.

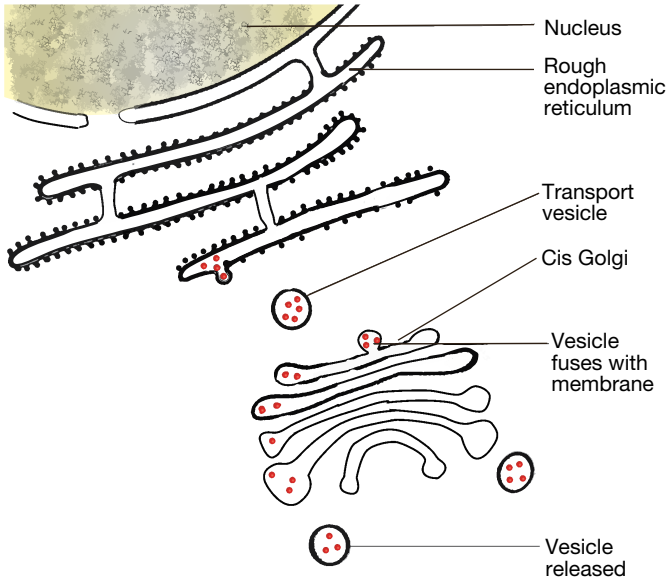


Figure 4.3 Transport vesicles move to Golgi apparatus.

As the product travels from the cis to the trans sides of the Golgi apparatus it is modified, e.g. Golgi enzymes modify the carbohydrate section of the glycoproteins. Small vesicles bud off the end of the first layer of the stack and transfer the substance to the next layer of the stack. This continues until the end of the stacks. New secretion vesicles form at the trans face and bud off. Some of these transport vesicles contain secretions that leave the cell.

Plasma membrane – The transport vesicles attach to the plasma membrane and are released from the cell in exocytosis.

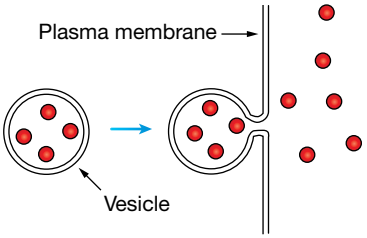


Figure 4.4 Exocytosis.

Milk secretion

Mammalian milk is an aqueous colloidal suspension of proteins, lipids, sugar, ions and water. The secretory cells of the mammary glands produce the proteins in the rough endoplasmic reticulum and the lipids in the smooth endoplasmic reticulum of the same cells. The sugar, mainly lactose, is produced by a soluble enzyme dissolved in the cytoplasm and released through the microvilli. The sodium and potassium ions are released by ion pumps and water follows the ions by osmosis.

QUESTIONS

1. Define cytosis.
2. Define exocytosis.
3. What is the function of exocytosis?
4. Identify some cells that are secretory.
5. Distinguish between endocrine glands and exocrine glands.
6. What are ribosomes?
7. Distinguish between bound ribosomes and free ribosomes.
8. Distinguish between rough endoplasmic reticulum and smooth endoplasmic reticulum.
9. Explain why the cells in the testes of males have large amounts of smooth endoplasmic reticulum.
10. What is the Golgi apparatus?
11. Compare what happens at the cis and the trans faces of the Golgi apparatus.
12. To which side of the Golgi apparatus do transport vesicles bring substances from endoplasmic reticulum?
13. What happens to substances in the Golgi apparatus?
14. The diagram shows a secretory cell of a mammary gland.

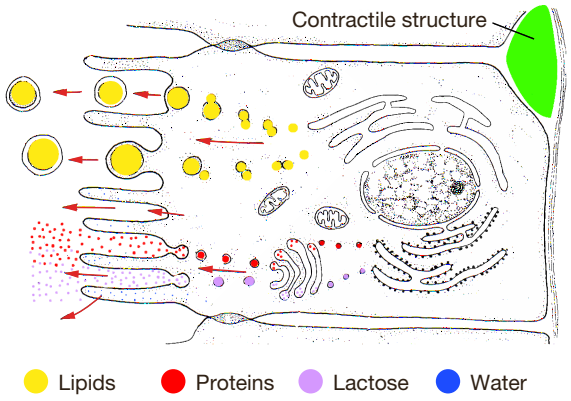


Figure 4.5 Mammary gland cell.

Identify the different components secreted by a mammary gland cell to produce milk and outline how these components come to be secreted.

15. Fibroblast cells secrete collagen. Collagen is a glycoprotein found in skin, bone and tendons are almost entirely made of collagen. It forms strong fibres outside cells and is important in the formation of the extracellular matrix around a cell. Draw a flow chart to show the steps that would occur in the secretion of collagen in a fibroblast cell.
16. What is the correct order of organelles involved in the synthesis, modification and export of a protein product from a cell by exocytosis?
    (A) Ribosome → rough endoplasmic reticulum → Golgi apparatus
    (B) Ribosome → smooth endoplasmic reticulum → Golgi apparatus
    (C) Ribosome → Golgi apparatus → rough endoplasmic reticulum
    (D) Ribosome → Golgi apparatus → smooth endoplasmic reticulum
17. Which side of a Golgi apparatus receives a transport vesicle?
    (A) Trans face.
    (B) Cis face.
    (C) Iso face.
    (D) Retro face.
18. What is synthesised at a ribosome?
    (A) Complete protein.
    (B) Polypeptide chain.
    (C) Glycoprotein.
    (D) Lipid molecule.
19. Which structures release secretions into ducts that lead to epithelial surfaces?
    (A) Golgi apparatus.
    (B) Lysosomes.
    (C) Endocrine glands.
    (D) Exocrine glands.

5 Endocytosis

Cytosis is the passage of large 'packages' of material across a membrane. **Endocytosis** is the process where a cell takes in macromolecules by forming vesicles from the plasma membrane. Endocytosis requires an energy input and is a form of active transport. Endocytosis is needed as the materials are large and cannot move across the plasma membrane by diffusion or with the assistance of carrier or channel proteins.

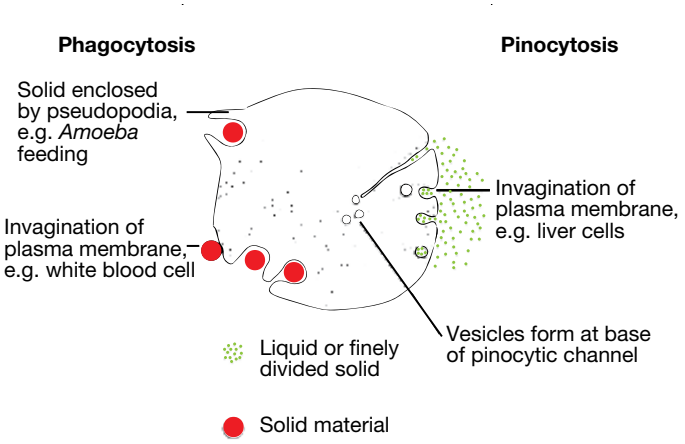


Figure 5.1 Phagocytosis and pinocytosis.

Pinocytosis

Pinocytosis is a type of endocytosis in which the cell takes in extracellular fluid and its dissolved solutes. It can occur by invagination of the plasma membrane or by the formation of vesicles at the base of a pinocytic channel. Invagination of the plasma membrane involves a small area that sinks inwards to form a pocket. As the pocket enlarges and sinks deeper into the cell the plasma membrane pinches in to form a vesicle that is now separated from the rest of the plasma membrane. In many instances the cell requires the molecules dissolved in the droplet and not the fluid. Pinocytosis is non-specific in the substances transported into the cell.

Phagocytosis

Phagocytosis is a type of endocytosis where large, particulate substances are taken into a cell. Phagocytosis is mainly carried out by macrophages, neutrophils and dendritic cells.

Some protozoans use phagocytosis as a feeding mechanism, e.g. *Amoeba* forms pseudopods that enclose the solid that is to be digested. Phagocytosis can occur by either the cell forming pseudopods that wrap around the particle to enclose it in a vesicle or by invagination of the plasma membrane.

Receptor mediated endocytosis involves the receptor proteins on the cell surface membrane. The particle to be taken in binds to a receptor site in a 'lock and key' manner. After binding the area forms an invagination that will become a vesicle that moves further inside the cell. If a bacteria has been engulfed by a neutrophil then lysosomes in the cell with attach to the vesicle and release digestive enzymes to break down and destroy the bacteria. Cholesterol travels in the blood as low density lipoproteins (LDLs) and specific LDL receptor sites on cell membranes allow cholesterol to be taken into a cell by receptor mediated endocytosis.

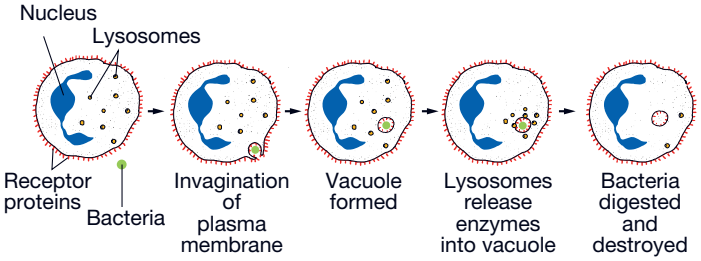


Figure 5.2 Phagocytosis by a neutrophil.

QUESTIONS

1. Define cytosis.
2. Define endocytosis.
3. Explain why endocytosis is needed for some substances to cross the plasma membrane.
4. Define pinocytosis.
5. Describe how pinocytosis occurs.
6. Define phagocytosis.
7. Describe how phagocytosis occurs.
8. Construct a table to compare pinocytosis and phagocytosis.
9. Draw a flow chart to show the steps involved in the invagination of the plasma membrane to form a vesicle.
10. The diagram shows a cellular process.

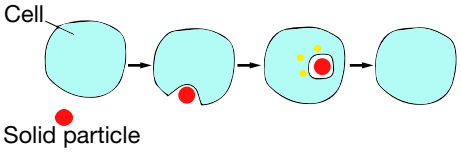


Figure 5.3 Cellular process.

What is this process?
(A) Exocytosis.
(B) Pinocytosis.
(C) Phagocytosis.
(D) Lysis.

11. What is the best description of the way cholesterol enters a cell?
(A) Exocytosis.
(B) Pinocytosis.
(C) Phagocytosis.
(D) Receptor mediated endocytosis.

6 Nucleic Acids

Nucleic acids are polymers composed of many nucleotide monomers that encode instructions for the synthesis of proteins in cells and through the actions of proteins for all cellular activities. Nucleic acids make up the genetic material of all living things as well as of viruses. Nucleic acids not only transmit hereditary information but by determining protein synthesis determine the structure, function and activities of cells.

There are two types of nucleic acids – deoxyribose nucleic acid (DNA) and ribose nucleic acid (RNA). Nucleic acids are long, thread-like macromolecules and hydrolysis of a nucleotide gives a pentose sugar (five carbon sugar), a nitrogenous base and phosphoric acid. The two possible sugars are ribose (from RNA) or deoxyribose (from DNA). There are two types of bases – the purines with a double ring structure and the pyrimidines with a single ring structure. There are two types of purines – adenine (A) and guanine (G) and three different types of pyrimidines – cytosine (C), thymine (T) and uracil (U).

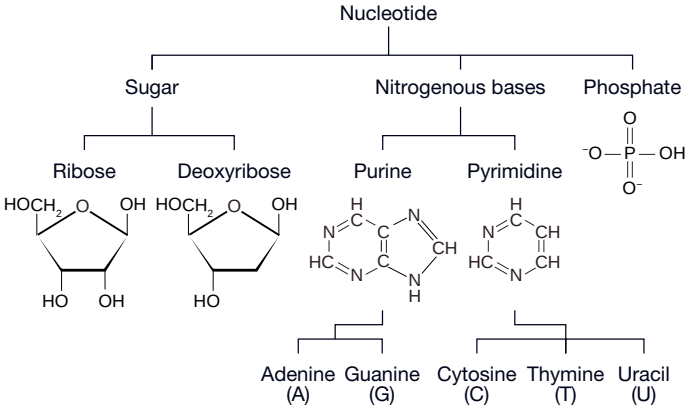


Figure 6.1 Nucleotides.

Nucleotides

A **nucleotide** is a three-part molecule consisting of a pentose sugar covalently bonded to nitrogenous base and a phosphate group. There are four different nucleotides found in DNA.

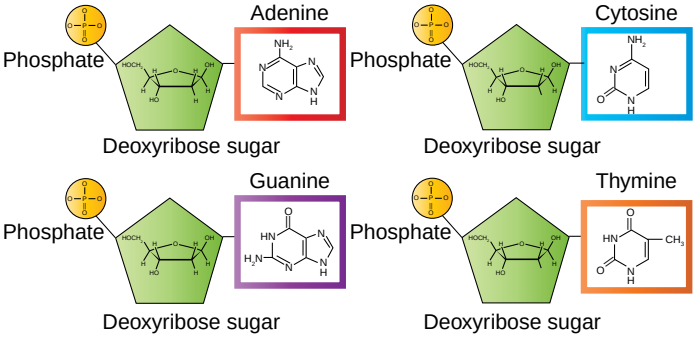


Figure 6.2 Nucleotides found in DNA.

The nucleotides are joined by **phosphodiester linkages**. The phosphate has covalent bonds that attach to the sugars of adjacent nucleotides forming a sugar-phosphate-sugar-phosphate backbone of the double helix structure.

DNA is formed by two nucleotide chains wrapped together to form a double helix with the bases A, G, T and C.

RNA is a single nucleotide chain with the bases A, G, U, and C though it is temporarily bound to DNA while it is being formed.

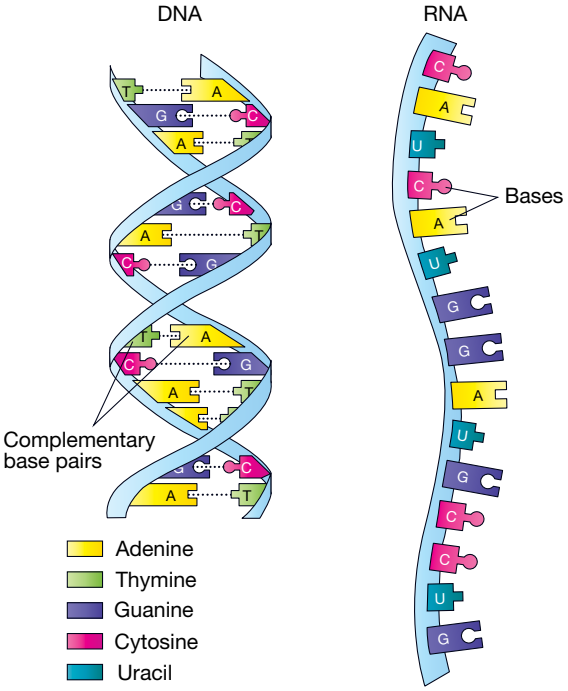
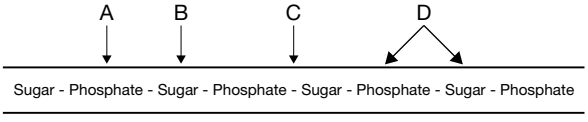


Figure 6.3 DNA and RNA.

QUESTIONS

1. Define a nucleic acid.
2. Outline the importance of nucleic acids.
3. What are the two types of nucleic acids?
4. Identify the components of nucleic acids.
5. What are the two types of sugars found in nucleic acids?
6. Identify the two types of nitrogenous bases and give examples of each type.
7. Define a nucleotide.
8. What forms the backbone structure of the double helix of DNA?
9. Construct a table to compare the sugars and bases found in DNA and RNA.
10. Which point in the diagram shows the point of attachment of a nitrogenous base to the sugar-phosphate chain to form a nucleic acid?



7 Proteomics

Proteomics is the study of proteomes and their functions in large scale investigations of the biochemistry and genetics of gene products. The **proteome** is the entire complement of proteins that is or can be expressed by a genome, cell, tissue or organism.

Functional proteomics looks at specific proteins to determine their significance and their DNA sequence providing information about how protein networks operate and how they produce particular cellular phenotypes.

There is great protein functional diversity in cells, tissues and living organisms. About two thirds of the total dry mass of many cells is protein and these proteins are vital for the structural components of cells, for growth and repair of cells, for regulating reactions in cells, for transport, for cellular communications and for defence against foreign substances. Only plants with a high cellulose content are less than half protein.

Proteins consist of amino acid subunits joined to form polypeptide chains and the shape of the protein determines its function. The sequence of amino acids is determined by the sequence of nucleotides in a gene. This is why DNA sequencing provides information about the structure of proteins and the nature of the proteome.

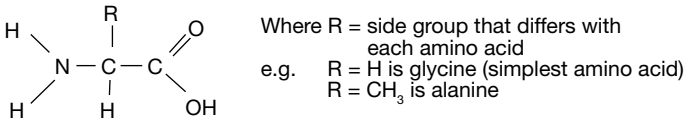


Figure 7.1 The basic unit of a protein is the amino acid.

Enzymes

Enzymes catalyse organic reactions and control the rate of metabolism. They are involved in the breakdown of a substrate (catabolic enzyme) or the building of larger molecules from their substrate (anabolic enzyme). The **substrates** are the reactants that undergo the chemical reaction catalysed by the enzyme. Enzymes are globular proteins and have an active site formed by the folding of the polypeptide chain into a specific shape. The shape of the enzyme's active site matches the shape of the substrate in a 'lock and key' manner.

Catalase is an enzyme that controls the breakdown of hydrogen peroxide into water and oxygen. Most cells form hydrogen peroxide (H_2O_2) as a waste product of aerobic respiration.

Pepsin breaks down protein in the stomach**.**

DNA polymerase builds DNA molecules reading the existing DNA strand and inserting the correct nucleotides into the new strand.

Hormones

Hormones act on specific target cells to change their functioning. Hormones are globular proteins that are secreted by endocrine cells directly into the interstitial fluid.

Insulin is a hormone that is produced in the pancreas in the beta cells of the islets of Langerhans. When blood sugar exceeds a certain level insulin is released and it causes the liver to take up glucose and store it as glycogen.

Thyroxine (T_4) is a hormone secreted by the thyroid gland and influences the oxygen consumption in cells stimulating and maintaining metabolic activities.

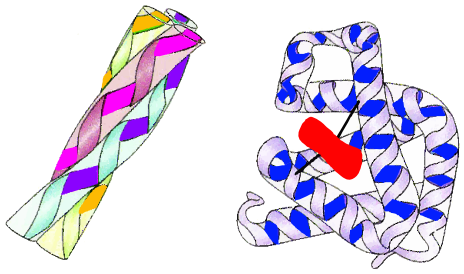


Figure 7.2 Fibrous and globular proteins.

Structural proteins

Structural proteins that are **fibrous proteins** form long fibres or sheets. They have a regular repeated sequence of amino acids and cross-links between the fibres produce properties to make the fibre tough, supple or elastic. Structural fibrous proteins include collagen, keratin and elastin. **Collagen** fibres form a rope with three helical polypeptides wound around each other. Strands are held together by hydrogen bonds. Collagen accounts for around half the total protein in the human body. Structural proteins form intracellular filaments and provide the contractile mechanism of all muscles.

Structural proteins that are **globular proteins** are polypeptide chains tightly folded into a compact spherical shape. **Tubulin** forms microtubules that are long hollow tubes that make up the cytoskeleton of cells and help form the spindle for cell division.

Transport proteins

Proteins are involved in transporting molecules across cell membranes and in the bloodstream. Transport proteins include haemoglobin and myoglobin. **Haemoglobin** is a conjugated globular protein with four subunits (haem). Each haem has an iron atom that can bind with oxygen. Haemoglobin transports oxygen from oxygen rich areas, e.g. capillaries around alveoli to other areas where the oxygen is unloaded.

Receptor proteins

Cell membrane proteins detect chemical signals and recognise particular signal molecules, e.g. identifying hormones such as adrenaline (also called epinephrine). Adrenaline will cause a faster heart rate and increases blood flow to the muscles. Receptor proteins also have important roles in embryonic development and sensory reception. G protein-linked receptors work with the help of a G protein with different G protein-linked receptors being stimulated by different signal molecules and for recognising different G proteins inside the cell.

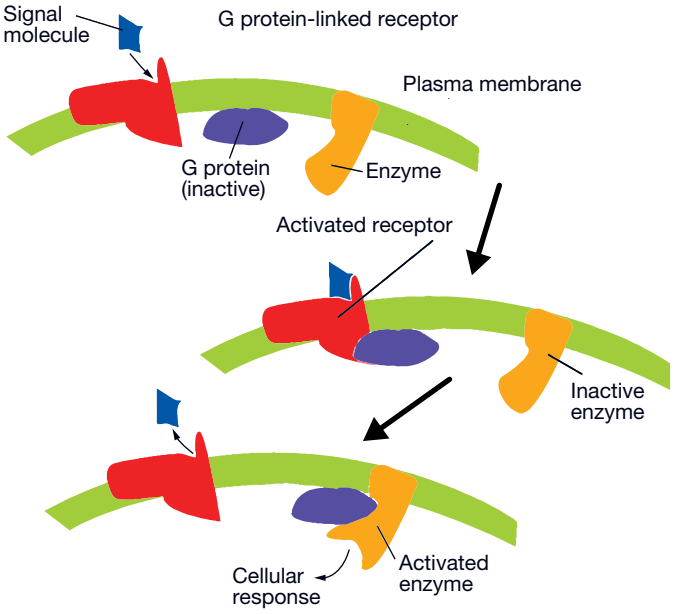


Figure 7.3 G protein-linked receptor.

Gene regulatory proteins

Gene regulatory proteins bind to specific regulatory sequences of DNA and act to switch a gene on and off and thus control the transcription of genes.

Defence proteins

Defence proteins help organisms fight infection, heal damaged tissue and evade predators.

Immunoglobulins (Ig) are large Y shaped proteins that are made by plasma B cells and function as antibodies. They are divided into five classes that differ in their distribution in the body and the way they act against the antigen. Immunoglobulin A (IgA) is produced by mucosal linings and is found in tears, saliva and sweat.

Fibrin proteins form blood clots and scabs at a wound side.

Threonine deaminase (TD) is an enzyme made by plants, e.g. tomato plants to deter herbivores, e.g. leaf-eating caterpillars. TD disrupts the digestion of the caterpillar as it degrades the threonine before the herbivore can absorb it starving the herbivore of an essential amino acid.

Conjugated proteins

Conjugated proteins are protein molecules combined with another kind of molecule. **Lipoproteins** are proteins combined with lipids and are mainly found in plasma membranes or carry hydrophobic molecules in the blood, e.g. carrying cholesterol in low density lipoproteins (LDL). **Glycoproteins** are proteins combined with carbohydrates and are important in plasma membranes, e.g. where a carbohydrate section is found on the external surface of the cell forming hydrogen bonds with water and other molecules in the extracellular fluid.

QUESTIONS

1. Define proteomics.
2. What is functional proteomics?
3. Define the proteome.
4. Outline the importance of proteins in living things.
5. Identify the main component of proteins.
6. Outline the relationship between DNA and the proteome.
7. What is an enzyme?
8. The diagram shows a reaction involving an enzyme.

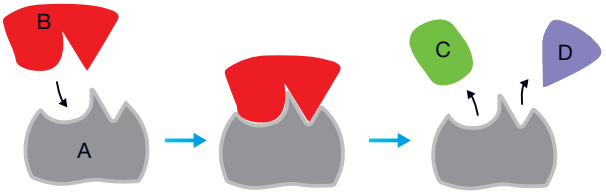


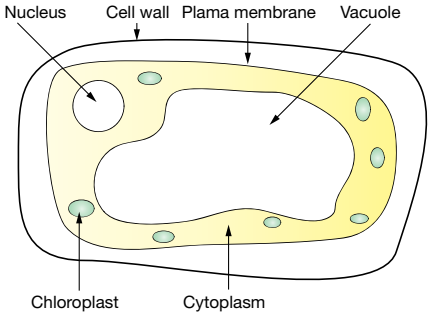
Figure 7.4 Reaction involving an enzyme.

   (a) Identify the enzyme in this reaction and explain its function.
   (b) Identify the reactants and the products.
   (c) What type of reaction is shown in this diagram?
9. What is a hormone?
10. Outline the action of a specific hormone.
11. Distinguish between fibrous proteins and globular proteins.
12. What are transport proteins?
13. Use an example to describe the function of a protein receptor.
14. Outline the function of gene regulatory proteins.
15. Use an example to describe the function of a defence protein.
16. What are conjugated proteins?
17. Construct a table to show the functional diversity of proteins.
18. What is the best description of the proteome?
   (A) A three-dimensional polymer constructed of different amino acid monomers.
   (B) The complete complement of genes in an organism's genetic material.
   (C) The study of the structure and function of proteins.
   (D) The entire complement of proteins that is or can be expressed.

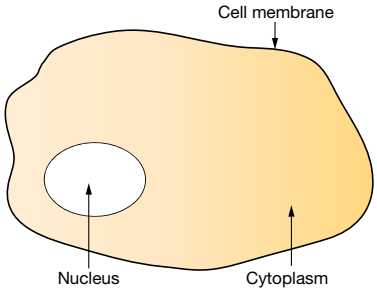
Answers

1 Assumed Knowledge

1. (a) The model is the fluid mosaic model.
   (b) This model was proposed by Jonathon Singer and Garth Nicolson in 1972.
2. Hydrophobic means water hating and hydrophilic means water loving,
3. Plant cell – plasma membrane is part C.



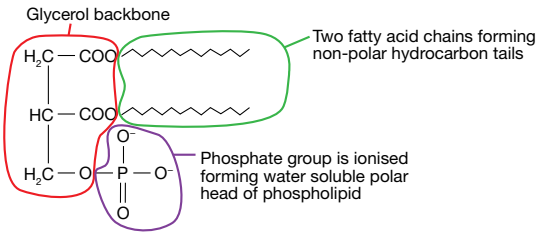
4. Animal cell – plasma membrane is part X.



5. The cell membrane surrounds the cell contents and forms a barrier from the external environment. It controls the substances that can enter or leave the cell.
6. Diffusion is the movement of a substance from an area of high concentration to an area of low concentration of that substance.
7. Osmosis is the movement of water across a semipermeable membrane from an area of high concentration of water to an area of low concentration of water.
8. Active transport requires an input of energy to move a substance against a concentration gradient while passive transport does not require an input of energy and moves a substance down a concentration gradient.
9. Cytosis is the passage of large 'packages' of material across a membrane.
10. Exocytosis is the process when vesicles inside the cell fuse with the cell membrane and the contents of the vesicle are secreted from the cell. Whereas endocytosis is a process where a cell takes in macromolecules by forming vesicles from the plasma membrane.
11. A chloroplast is a green organelle found in green tissues of plants that captures sunlight in photosynthesis to manufacture sugars from carbon dioxide and water.
12. Photosynthesis is a process where the energy of sunlight is used to convert carbon dioxide and water into sugars and oxygen.
13. Groups of organisms that can photosynthesise include plants, algae and photosynthetic bacteria.
14. Carbon dioxide and water are needed for photosynthesis using light energy and in the presence of chlorophyll.
15. Photosynthesis is important in ecosystems as it converts light energy into chemical energy to begin most food chains on Earth and also provides oxygen which is needed for respiration.
16. The four basic groups of organic compounds are proteins, carbohydrates, lipids and nucleic acids.
17. Inorganic compounds are molecules that do not contain carbon (excluding some carbonates and simple oxides of carbon)
18. Respiration is the chemical reactions in which cells obtain energy from food.
19. A gene is a distinct unit of heredity information made up of a specific nucleotide sequence in DNA or RNA in some viruses.
20. Phagocytosis is a type of endocytosis where large, particulate substances are taken into a cell.
21. Four main classes of macromolecules are carbohydrates, lipids, proteins and nucleic acids.
22. DNA stands for deoxyribose nucleic acid.
23. DNA has a double helix shape.
24. RNA stands for ribose nucleic acid.
25. Bacteria have circular DNA.
26. A chromosome is one very long DNA molecule and associated proteins consisting of hundreds or thousands of genes arranged along its length. Chromosomes carry the genetic material.
27. An allele is an alternate form of gene that may produce distinguishable phenotypes.
28. An enzyme is a chemical made by living things and its function is to control the rate of a specific chemical reaction that occurs in the body.
29. ATP is adenosine triphosphate and is a molecule composed of three phosphate groups and adenosine (ribose sugar combined with adenine). ATP releases free energy when its phosphate bonds are hydrolysed and is the main source of energy in cells.
30. Hormones are chemical signals that travel in the blood and body fluids and act on specific target cells to cause a specific response for internal communication and regulation and maintaining homeostasis.
31. The endocrine system produces hormones to control body changes and processes.
32. Endocrine glands are ductless glands that secret hormones while exocrine glands secrete into ducts that lead to an epithelial surface.
33. The pancreas is an exocrine gland as it has acinar cells that produce digestive enzymes and duct cells that secrete sodium bicarbonate solution into the ducts that empty into the pancreatic duct. Thus the acinar cells and duct cells are part of the exocrine section of the pancreas. The pancreas is also an endocrine gland as it secretes the hormones insulin (from beta cells) and glucagon (from alpha cells) into extracellular spaces. These hormones then diffuse into the circulatory system. Thus the pancreas is also an endocrine gland.
34. An antigen is a substance that causes an immune response by binding to receptors of B cells, antibodies or of T cells.
35. An antibody (or immunoglobulin) is a protein secreted by plasma B cells in response to a particular antigen.

2 The Plasma Membrane

1. The role of the plasma membrane is to: 1. Separate a cell from its external environment. 2. Act as a selective barrier around the cell creating and maintaining concentation gradients between its internal and its external environment. 3. Maintain pH and charge differences between its internal and external environment. 4. Function in cell-cell recognition.
2. (a) The current model of the plasma membrane is the fluid mosaic model.
   (b) The fluid mosaic model was proposed by SJ Singer and G Nicolson in 1972.
3. The structure of the plasma membrane is not static as there is lateral movement of the phospholipids and the proteins move about within the structure.
4. Hydrophobic means water hating and hydrophilic means water loving.
5. The hydrophobic interactions between the lipids and proteins keep the structure of the plasma membrane held together.
6. Integral proteins are transmembrane proteins that extend into and often completely span across the membrane whereas peripheral proteins are bound to the surface of the membrane.
7. An amphipathic molecule is a molecule with a hydrophilic (water loving) region and a hydrophobic (water hating) region.
8. Since phospholipids have a polar hydrophilic head and a non-polar, hydrophobic tail, they are amphipathic molecules.

9. 

10. Both phospholipids and triacylglycerol (fat molecule) have a glycerol backbone. However, triacylglycerol has three fatty acid chains while phospholipids have two fatty acid chains and a phosphate group.
11. Cholesterol is a steroid lipid that is an essential part of the plasma membrane especially in animal cells where it can make up to 50% of the plasma membrane. Cholesterol reduces the fluidity of the membrane by reducing phospholipid movement and also helps the membrane stay liquid at low temperatures, e.g. room temperature.
12. Adjacent phospholipids can switch positions about 10^7 times per second, which means that an individual phospholipid can move around 2 micrometres in one second.
13. The fluidity of the membrane depends on the types of lipids present in the membrane. The presence of saturated fatty acids (with all C–C single bonds) makes the membrane *less* fluid, e.g. will become solid at room temperature. While the presence of unsaturated fatty acid (with some double bonds C=C) makes the membrane *more* fluid.
14. The presence of double bonds in the fatty acids of the phospholipids means the fatty acid is unsaturated. This causes the chain to take on a 'bent' appearance. This prevents tight packing of the phospholipids making the membrane more fluid.
15. Glycolipids are carbohydrates bonded to the lipids, e.g. some glycolipids such as blood antigens determine blood type. Glycoproteins are carbohydrates bonded to the proteins, e.g. acting as identification tags for cell-cell or cell-protein binding or interactions.
16. (a) Plasma membrane 2 would be the most fluid.
    (b) Plasma membrane 2 has bent fatty chains. This means there are double bonds present and they are unsaturated fatty acids. The bent fatty acid chains prevent close packing of the phospholipids which makes the membrane more fluid. The fatty acid chains of the phospholipids in plasma membrane 1 are straighter which means the fatty acids are saturated. The phospholipids in membrane 1 can be closely packed and the membrane will be less fluid.
17. B

3 Crossing the Plasma Membrane

1. For aerobic respiration to occur in a cell, oxygen needs to enter the cell and carbon dioxide as a waste product needs to leave the cell.
2. In a photosynthetic plant cell carbon dioxide dissolves in the surface film of water and then diffuses across the plasma membrane into the cell. Oxygen as a waste product of photosynthesis diffuses out of the cell across the plasma membrane.
3. Osmosis is the movement of water across a semipermeable membrane from an area of high concentration of water to an area of low concentration of water.
4. Aquaporins are channel proteins that form a hydrophilic channel that acts as a tunnel through the membrane. This allows water to move down a concentration gradient either in or out of the cell depending on the water potential by facilitated diffusion.
5. Carrier proteins are transport proteins in the plasma membrane that change shape during the process of passing a solute across the membrane. They are very specific with some passing a solute by facilitated diffusion and others passing a solute by active transport.
6. Active transport uses energy to take a solute from an area of low concentration to an area of high concentration – against the concentration gradient.
7. Primary active transport uses energy from the breakdown of ATP or some other high energy phosphate compound. While secondary active transport uses energy that was stored in the form of ionic concentration differences between two sides of the membrane.

8.

Type of transport	Description
Simple diffusion	Small non-polar molecules, e.g. oxygen and carbon dioxide move across the plasma membrane by simple diffusion down a concentration gradient, e.g. for aerobic respiration and photosynthesis.
Channel proteins	Channel proteins form a tunnel through the plasma membrane allowing facilitated diffusion to occur down a concentration gradient, e.g. movement of water in osmosis using aquaporins.
Carrier proteins and facilitated diffusion	Carrier proteins change shape as they move solutes across the plasma membrane. Facilitated diffusion occurs when the solute moves down a concentration gradient, e.g. glucose transporter channels.
Carrier proteins and active transport	Carrier proteins change shape as they move solutes across the plasma membrane. Active transport involves an input of energy, e.g. movement of sodium-potassium ions using a sodium-potassium pump.

9. The sodium-potassium pump is a transport system that pumps ions against a concentration gradient exchanging sodium ions for potassium ions across the plasma membrane to keep down the sodium ion concentration of a cell. It is nearly universal in animal cell membranes and common in many plant cells.
10. Ion channels in the plasma membrane establish a resting membrane potential, shape action potentials (nerve impulse in neurons) and allow the passage of specific ions and electrical charge.
11. Gating is the change in shape between the open and closed state of the channel. Ion channels change shape and open or close due to specific stimuli.
12. Sodium ion channel state A shows the closed gate conformation of the transport protein. It is maintaining the resting potential with the sodium unable to enter. Sodium ion channel state B shows the open gate conformation allowing the sodium ions to move into the cell by facilitated diffusion down the concentration gradient. The diagram shows the gating of the sodium ion channel.
13. Heterotrophic cells need an energy source to carry out the functions of life. Nearly all heterotrophic cells use the energy bonds in glucose as their energy source releasing the energy in respiration. Glucose needs to be able to enter the cells and glucose transporters allow glucose to enter by facilitated diffusion down a concentration gradient. If there is a high concentration of glucose within a cell then active transport is needed to move the glucose against the concentration gradient.
14. D
15. C

4 Exocytosis

1. Cytosis is the passage of large 'packages' of material across a membrane.
2. Exocytosis is the process when vesicles inside the cell fuse with the cell membrane and the contents of the vesicle are secreted from the cell.
3. Exocytosis is used for the secretion of substances synthesised by a cell and for the elimination of indigestible remains in a food vacuole.
4. There are many cell types that are secretory, e.g. endocrine cells secrete hormones such as cells of the thyroid gland which secrete thyroxine, exocrine cells secrete into ducts, e.g. cells of the gastrointestinal tract secrete digestive enzymes, plasma B cells secrete antibodies.
5. Endocrine glands are ductless glands that secrete hormones whereas exocrine glands secrete into ducts that lead to an epithelial surface.
6. Ribosomes are particles made of ribosomal RNA and protein and they carry out protein synthesis.
7. Free ribosomes are found unattached in the cytosol and produce proteins that function within the cytosol. While bound ribosomes are attached to the nuclear membrane or to endoplasmic reticulum and produce proteins that will become part of the plasma membrane or will be bound within another organelle, e.g. lysosome or will be packaged for secretion.