Cells and the cell theory

CELL THEORY

The **cell theory** is a foundation stone in the study of Biology. The cell theory states that:

- All organisms are made up of cells.
- New cells are produced from existing cells.
- The cell is the smallest organisational unit of a living thing.

There are two different kinds of cells—**prokaryotic** and **eukaryotic**.

Differences also occur within the group of eukaryotic organisms. A typical **plant cell** has **cellulose cell walls** that provide structural support, **chloroplasts** that are the site of photosynthesis, and **large vacuoles**. These features are not present in animal cells.

ORGANELLES

Organelles are subcellular structures with specialised functions (see Table 3.2).

Endosymbiotic theory

Mitochondria and chloroplasts are organelles that display some unusual features, including their own ribosomes and DNA in the form of a single circular chromosome. They also feature a double membrane and ability to replicate independently of the cells that contain them. Scientists believe these prokaryotic-like features suggest they have their origins around 1.5 billion years ago as free-living bacteria that were engulfed by other free-living bacteria in a relationship that offered mutual advantage. This is called the **endosymbiotic theory**.

Table 3.1 Cells and their features

Type of cell	Feature	Example
Eukaryote	Distinct organelles such as ribosomes as well as membrane-bound organelles including nucleus, mitochondria, endoplasmic reticulum, Golgi apparatus, lysosomes, vesicles	Organisms in Kingdoms Protista, Fungi, Plantae, Animalia, but not Bacteria and Archaea (bacteria, cyanobacteria)
Prokaryote	Lack membrane-bound organelles; nuclear material present as a single, circular thread of DNA; cell membrane surrounded by cell wall of protein and complex carbohydrate; relatively small cells; feature circular threads of DNA called plasmids	Organisms in Kingdoms Bacteria and Archaea

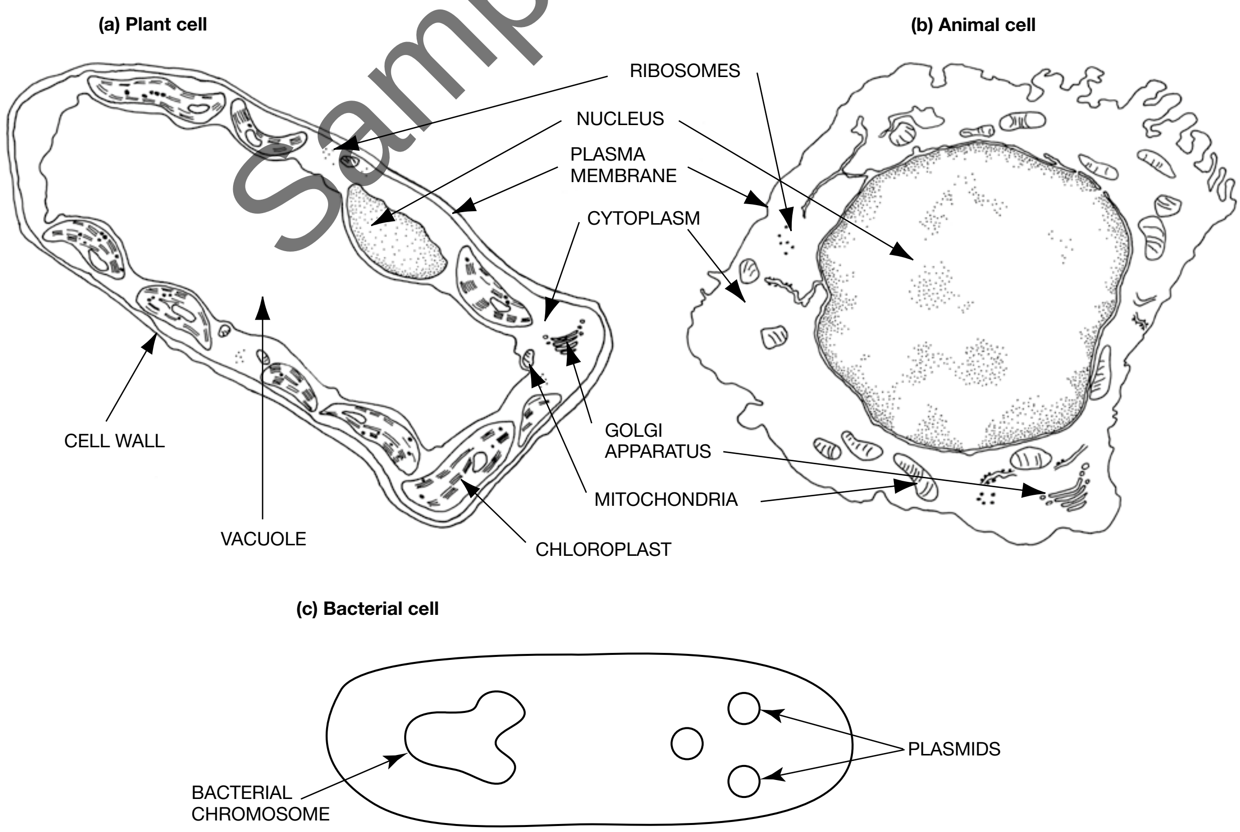


Figure 3.1 **(a)** Plant cell, **(b)** Animal cell and **(c)** Bacterial cell

Table 3.2 Organelles and their functions

Organelle	Function
Nucleus	Cell reproduction and control of cellular activities
Ribosomes	Protein production
Mitochondria	Aerobic respiration
Endoplasmic reticulum	Transport of materials such as proteins and carbohydrates within cell; involved in synthesis of substances, e.g. protein, lipids, glycogen
Golgi apparatus	Protein production completed; proteins packaged for dispatch from cell
Cell wall	Structural support in plants
Plasma membrane	Encloses cell contents; regulates passage of materials into and out of cell
Cytoplasm	Reservoir containing cell contents, including water, ions, dissolved nutrients, enzymes and organelles
Lysosomes	Contain enzymes responsible for breakdown of debris
Vacuole	Storage facility for fluid, enzymes, nutrients
Chloroplast	Photosynthesis

Biological molecules

The cells that make up living organisms are themselves composed of key chemical elements. Those that occur in greatest proportion include carbon, hydrogen, oxygen and nitrogen. These elements combine to form a variety of important biomacromolecules. Biologically important molecules can be grouped into two types—**organic** and **inorganic**.

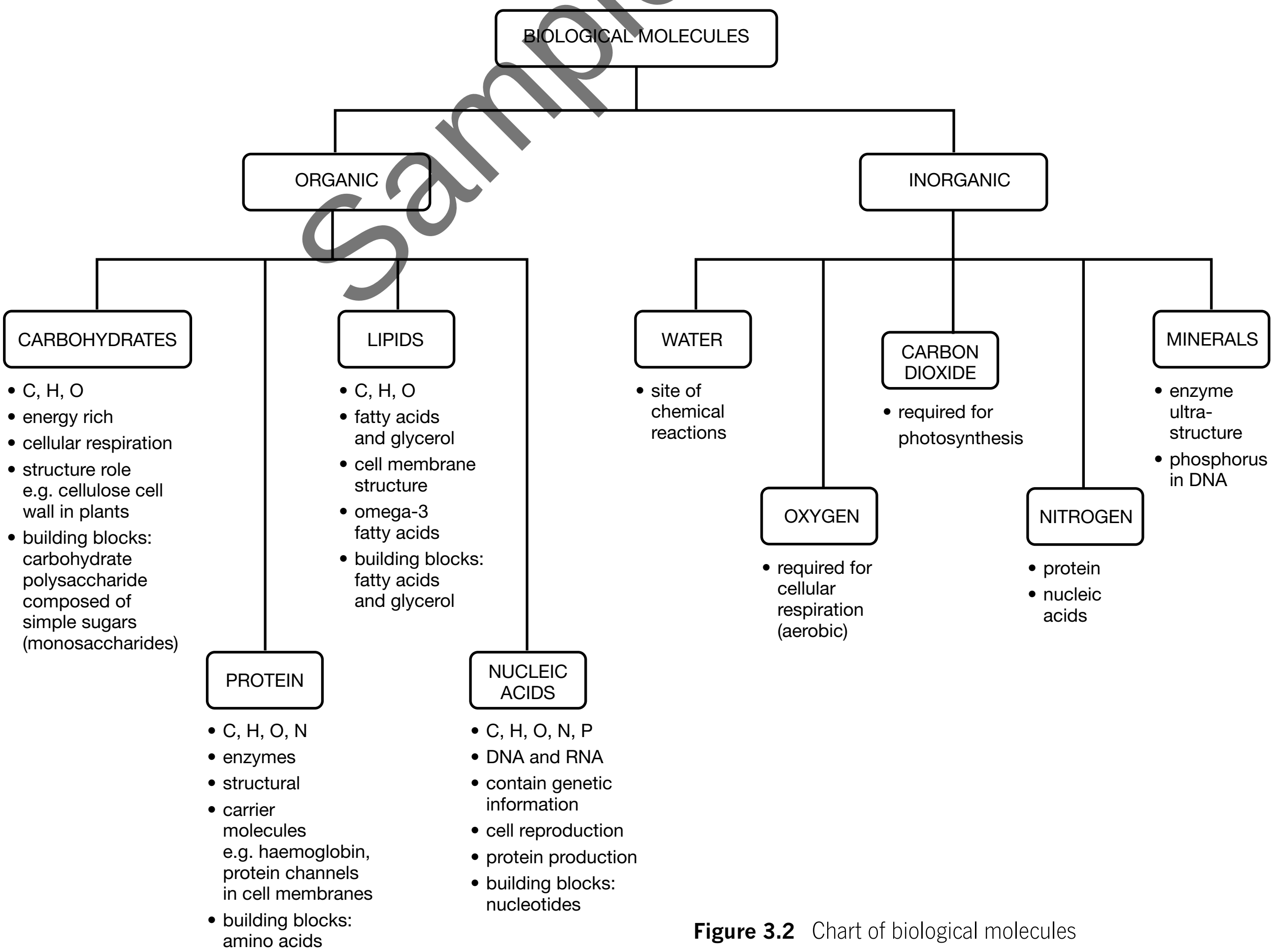


Figure 3.2 Chart of biological molecules

BIOMACROMOLECULES

Biomacromolecules are formed in condensation reactions. Essentially this involves a chemical reaction in which two smaller organic compounds are combined to form a larger organic compound and water is a by-product of the reaction. When polymers are constructed in this way the reaction is called **condensation polymerisation**.

This is true for the synthesis of all biomacromolecules, including lipids and polymers of carbohydrates, proteins and nucleic acids.

Compound		Compound		New compound		Water
A	+	B	→	A—B	+	H_2O
Examples:						
Carbohydrates glucose	+	glucose	→	maltose	+	water
Proteins amino acid	+	amino acid	→	polypeptide	+	water
Nucleic acids nucleotide	+	nucleotide	→	polynucleotide	+	water
Lipids glycerol	+	fatty acid	→	lipid	+	water

Plasma membranes

KEY ROLES

- Enclose cell contents—maintain structure of cell
- Regulate the movement of materials into and out of the cell—maintain a different composition within the cell compared with cell's external environment.

MEMBRANE FEATURES

- Protein receptors allow communication between cells, for example, by hormones, nerves, direct cell-to-cell contact; and allow cell recognition.

MEMBRANE COMPOSITION

The plasma membrane is composed of a phospholipid bilayer (two layers of phospholipid molecules) embedded with molecules of protein and cholesterol.

Phospholipid molecules have their *hydrophobic tails* directed into the centre of the plasma membrane and their *hydrophilic heads* directed towards the fluid medium on either side of the membrane.

Protein molecules serve as channels for facilitated diffusion and active transport.

Cholesterol molecules provide stability for the membrane and decrease permeability of the membrane to small, water-soluble molecules.

Carbohydrate molecules associated with proteins are involved in cell recognition.

The model of the plasma membrane is referred to as *fluid-mosaic* because of the 'fluid' nature of the phospholipid molecules, which are free to move about within the structure of each layer; 'mosaic' refers to the proteins scattered throughout the phospholipid layers.

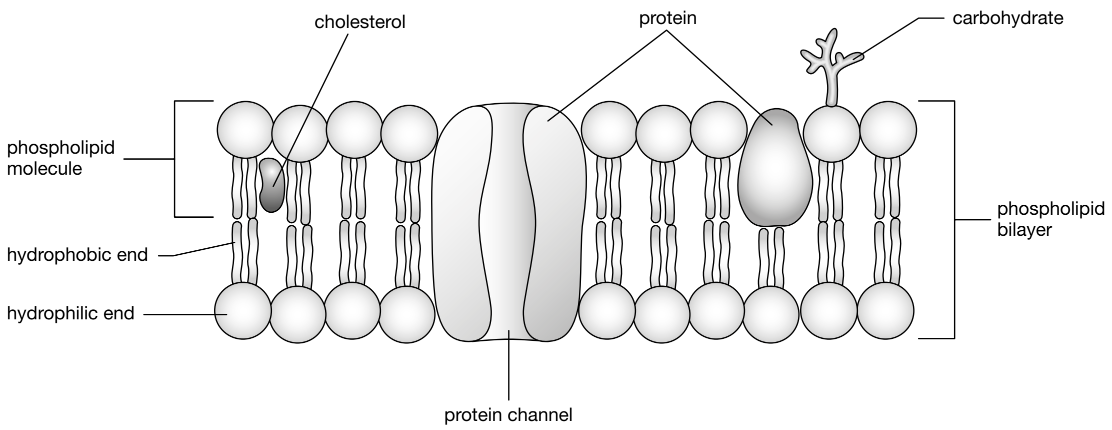


Figure 3.3 3D fluid-mosaic model of the plasma membrane

KEY KNOWLEDGE

MOVEMENT ACROSS THE MEMBRANE

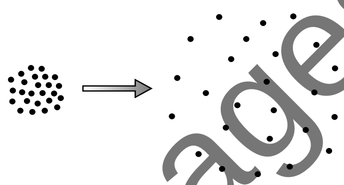
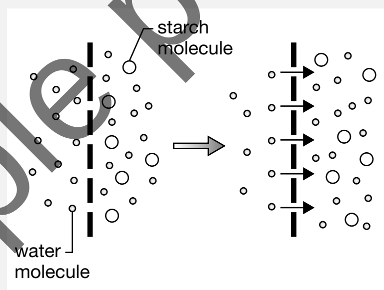
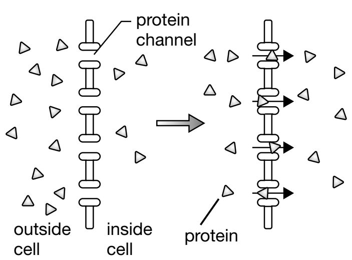
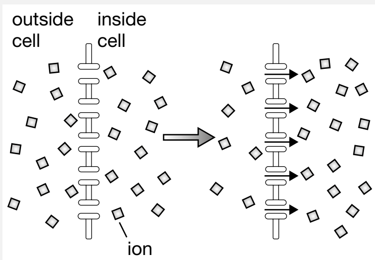
The exchange of materials between cells and their external environment occurs through the processes of:

- diffusion
- osmosis
- facilitated diffusion, or
- active transport.

The process in which substances move across the cell membrane depends on several factors—these include the lipid nature of the cell membrane and the size and polarity of molecules. **Hydrophilic** substances dissolve in water and do not readily pass across phospholipid membranes, while **hydrophobic** substances do not readily dissolve in water—such molecules can dissolve in the phospholipid membrane.

- Lipid soluble molecules (non-polar) such as chloroform and alcohol dissolve in the lipid bilayer and pass through.
- Water-soluble molecules tend to be repelled by the phospholipid bilayer, however very small molecules such as water and urea are small enough to pass directly between the phospholipid molecules.

Table 3.3 Movement across the cell membrane

Process	Description	Active or passive	Diagram	Example in organism
Diffusion	Movement of particles from an area of high concentration to an area of low concentration, along a concentration gradient	Passive (does not require energy)		Oxygen enters body cells (low in O_2 since continually using O_2 in cellular respiration) from the capillaries where it is in high concentration (O_2 replenished at lungs)
Osmosis	Special type of diffusion that involves movement of water molecules across a partially permeable membrane; water moves from an area of high concentration of free water molecules to an area of low concentration of free water molecules, i.e. low solute concentration to high solute concentration	Passive		Cells in kidney medulla absorb water by osmosis due to osmotic gradient between ion concentration in tissue fluid and the kidney tubules
Facilitated diffusion	Movement of particles from high to low concentration through protein channel in cell membrane	Passive		Small molecules such as amino acids and glucose enter cell via protein channel
Active transport	Movement of particles from an area of relatively low concentration to an area of high concentration, against a concentration gradient	Active (requires input of energy)		Uptake of ions by root hair cells of plants and uptake of nutrients by gut epithelium cells of animals, so that concentration within cells exceeds concentration in external medium

- Other small uncharged molecules such as oxygen and carbon dioxide also pass directly across the membrane between the phospholipid molecules.
- Large water-soluble molecules (polar) such as simple sugars and amino acids cannot pass directly across the membrane. The passage of these molecules depends on transport channels that span the membrane.

Some substances enter and leave cells by other means. When a section of the cell membrane wraps around a substance for import into the cell, pinching off to form a vesicle inside the cytoplasm, the process is called **endocytosis**. **Pinocytosis** refers to a similar process related to the import of liquid droplets. **Exocytosis** is the opposite of endocytosis and involves vesicles, such as those at associated with the Golgi apparatus, merging with the cell's plasma membrane to facilitate the export of substances.

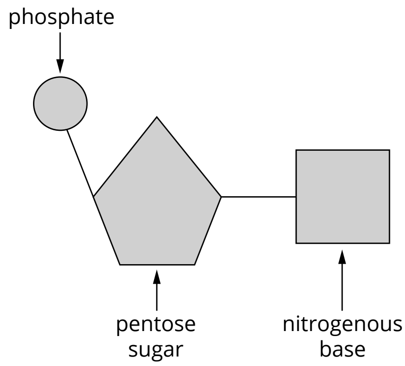


Figure 3.4b Nucleotide

Nucleic acids and proteins

Common to all living things on Earth is the presence of the genetic material, **DNA** (deoxyribonucleic acid). Its structure and function are universal.

The structural unit of DNA is the **nucleotide**. Nucleotides are named according to the base each includes. The bases in DNA occur in complementary pairs:

Adenine (A) pairs with **Thymine (T)**
Cytosine (C) pairs with **Guanine (G)**

Nucleotides are chemically bonded together to form polymers called **nucleic acids**. Nucleic acids are essentially information molecules that contain the coded instructions for protein synthesis. The sequence of nucleotides in DNA is significant because of its role in protein production. A specific DNA sequence that codes for a particular protein is called a **gene**. The **genome** is the total complement of all of the genes in an individual organism. An organism's genome is intrinsically linked to its **proteome**. The proteome is the full complement of proteins in an individual.

The complementary strands of the DNA molecule are described as **antiparallel** because one runs 5´ → 3´ while the other runs 3´ → 5´. Figure 3.4 shows a simplified representation of the molecule illustrating this antiparallel arrangement.

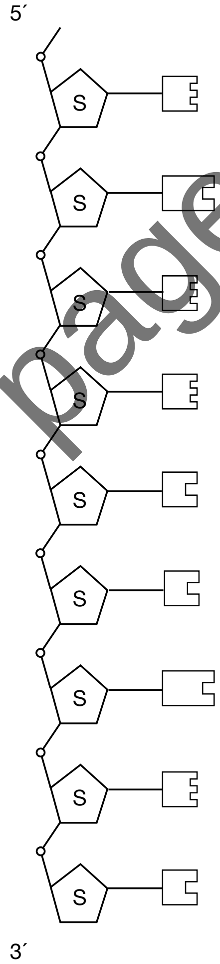


Figure 3.4c Nucleotide polymer—single-stranded DNA

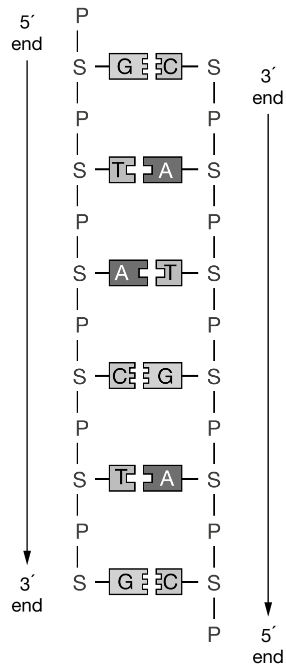


Figure 3.5 Nucleotides arranged in complementary pairs

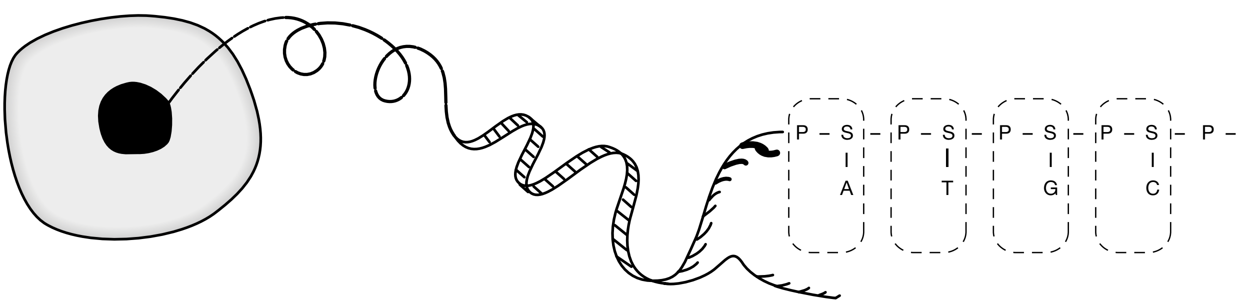


Figure 3.4a The DNA in the nucleus of cells unravels to reveal double helix

Nucleic acids occur in two forms—DNA (deoxyribonucleic acid), which contains the genes, and RNA (ribonucleic acid). There are three kinds of RNA. All nucleic acids are composed of nucleotides, however while DNAw contains the base thymine, in RNA thymine is replaced with uracil. DNA is a double-stranded molecule while RNA is single-stranded.

Table 3.4 The role of nucleic acids

	Role
DNA	Contains the instructions for protein synthesis
mRNA	Copy of the DNA template strand which takes instructions to the ribosomes in the cytoplasm
tRNA	Transfer RNA is the molecule that brings amino acids to ribosomes during protein synthesis.
rRNA	Ribosomal RNA is synthesised in the nucleolus and forms part of the structure of the ribosomes

Table 3.5 DNA features

	Feature	Examples
Purines	Double ring structure	Adenine, guanine
Pyrimidines	Single ring structure	Thymine, cytosine

GENE EXPRESSION

The sequence of nucleotide bases in genes represents the coded instructions for constructing polypeptides, the building blocks of proteins. The completed protein is the form in which the gene is expressed. Polypeptide production involves two key steps—**transcription** and **translation**.

Transcription

- DNA sequence is copied (transcribed) into a *messengerRNA* (mRNA) sequence
- Occurs in the nucleus
- DNA template strand is copied
- mRNA is single-stranded and contains the nucleotide base **uracil** instead of thymine
- Transcription begins at the **promoter region** of a gene, a section of DNA that identifies the beginning of the gene
- **Exons** are the coding regions of genes
- **Introns** are non-coding regions of genes
- Both exons and introns are transcribed, forming a copy of the gene called pre-mRNA
- Introns are subsequently cut out of the pre-mRNA, forming the final mRNA product

Transcription process

DNA molecule unzips
↓
enzyme RNA polymerase moves along DNA template strand adding bases according to complementary base-pairing rules
↓
mRNA strand produced

At the conclusion of transcription, the mRNA molecule leaves the nucleus through nuclear pores and moves to the ribosomes where translation occurs.

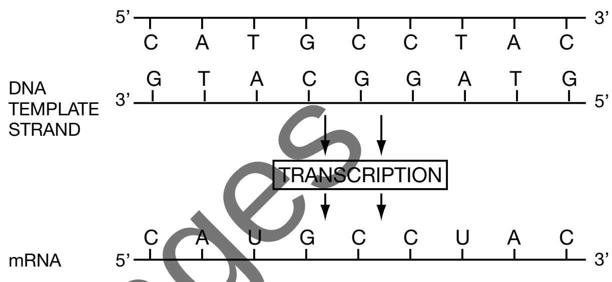


Figure 3.6 Transcription

Translation

- Sequence of bases in mRNA is translated into amino acid sequence (polypeptide)
- Each group of three bases (**codon**) in the mRNA codes for a particular amino acid—genetic code
- Occurs in the cytoplasm at the ribosomes

Translation process

ribosome moves along mRNA strand
↓
mRNA bases are read in groups of three called **codons** (in 5′ → 3′ direction)
↓
each codon specifies a particular amino acid (from the genetic code)
↓
tRNA molecule with complementary base triplet called an **anticodon** brings specified amino acid to ribosome
↓
amino acids are linked with peptide bonds to form a chain called a **polypeptide**

Translation stops when a 'stop' codon is reached. The polypeptide chain is complete.

The polypeptide chain folds to form a complex three-dimensional structure and is then referred to as a protein.

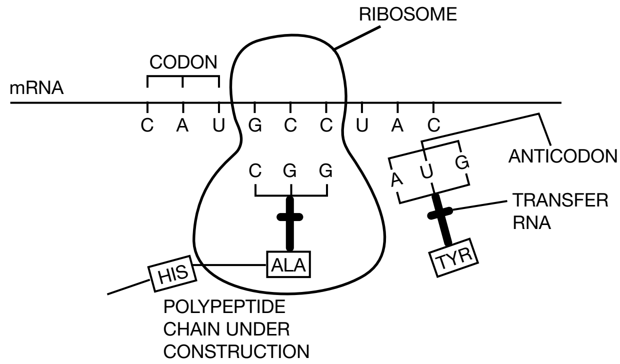


Figure 3.7 Translation

Table 3.6 shows the 20 amino acids used in proteins, and the codons that code for each amino acid. To use this table, select the first base of the codon from the first column, read across the row for the second base, and then find the third base from the last column.

Table 3.6 Genetic code

First position (5′ end)	Second position U	Second position C	Second position A	Second position G	Third position (3′ end)
U	Phe	Ser	Tyr	Cys	U
	Phe	Ser	Tyr	Cys	C
	Leu	Ser	STOP	STOP	A
	Leu	Ser	STOP	Trp	G
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	GluN	Arg	A
	Leu	Pro	GluN	Arg	G
A	Ileu	Thr	AspN	Ser	U
	Ileu	Thr	AspN	Ser	C
	Ileu	Thr	Lys	Arg	A
	Meth	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G

Amino acid abbreviations:

Ala	Alanine
Arg	Arginine
Asp	Asparagine
AspN	Aspartic acid
Cys	Cysteine
Gln	Glutamine
GluN	Glutamic acid
Gly	Glycine
His	Histidine
Ileu	Isoleucine
Leu	Leucine
Lys	Lysine
Meth	Methionine
Phe	Phenylalanine
Pro	Proline
Ser	Serine
Thr	Threonine
Trp	Tryptophan
Tyr	Tyrosine
Val	Valine

Gene structure and regulation

Cells in the body show specialisation in structure and function, yet they all contain the same genetic information. This occurs as a result of the 'switching on and off' of different genes in particular cells. For example, beta cells in the pancreas have genes for insulin production switched on, but genes related to haemoglobin production are switched off. Gene regulation contributes to the conservation of energy and resources in cells.

Genes are typically structured so that the transcription of the coding region is carefully regulated. A **regulatory gene** (which controls transcription) precedes the **structural gene** (which codes for the protein). The regulatory gene is composed of a **promoter region** and an **operator region**, both upstream of the structural gene. The promoter region regulates when transcription should begin; the operator effectively switches the gene on or off by allowing transcription to begin or cease. The structural gene contains introns and exons. Once the gene is switched to on, transcription proceeds. Transcription is halted by the **stop** region downstream of the structural gene. The ***lac* operon** model in bacteria serves as classic example of our understanding of gene function. An operon is a group of genes with a regulatory role in protein production. The *lac* operon (lactose operon) refers to a bacterial gene responsible for the production of a lactose-digesting enzyme.

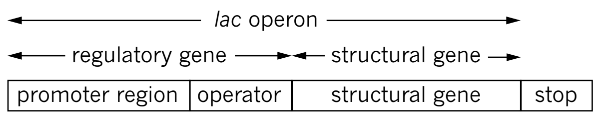


Figure 3.8 *Lac* operon

The expression of genes can be influenced by various environmental factors, such as temperature, light and pH.

Because all cells need to engage in life-sustaining functions such as cellular respiration, the genes that control these processes are switched on in all cells. Such genes are referred to as '*housekeeping*' *genes*.

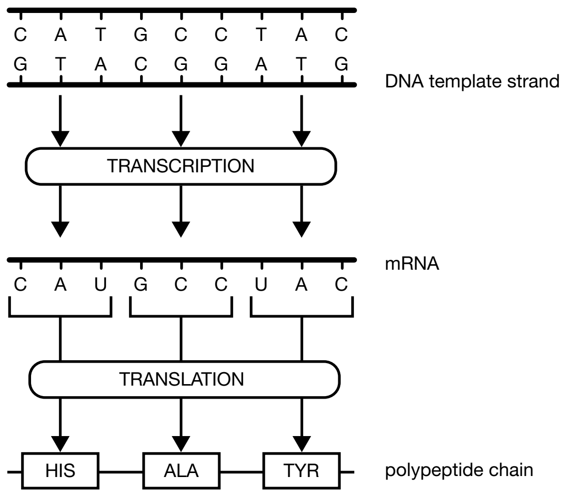


Figure 3.9 Summary of transcription and translation

Once polypeptide production is complete, the final formation of the protein can occur.

Table 3.7 Levels of protein structure

1	Polypeptide formation	*primary protein structure*
2	Polypeptide becomes coiled or pleated	*secondary structure*
3	Coiled polypeptide folds into 3-dimensional form	*tertiary structure*
4	Two or more 3-dimensional polypeptide molecules bonded together	*quaternary structure*

Proteins are key components of cells. There are many different kinds of proteins, each with a different function, and all are vital to the normal functioning of the organism.

The **proteome** is the total complement of all of the proteins in an individual organism. An organism's proteome is determined by the DNA sequence of its genome. **Proteomics** (the study of proteins, including their structure and function) is an expanding field of biology that has enormous potential for increasing our understanding of how organisms function and of diseases and their treatment and management, for the development of pharmaceuticals, and for shedding light on evolutionary relationships.

Bioinformatics (the use of computers and databases to manage biological information) is a vital tool in collecting and analysing biological information as well as making data accessible and manageable. For example, generating the DNA sequence of the human genome and making the data accessible are results of this technology.

GENES AND DEVELOPMENT

Homeotic genes are a group of genes that have a regulatory role in the development of organisms. They 'switch genes on and off' at appropriate times during development. For example, the genes controlling the production of fetal haemoglobin in mammals are 'switched on' in utero but are 'switched off' at birth, while the genes controlling production of adult haemoglobin are 'switched on'. Stem cells are undifferentiated cells, i.e. they have the capacity to become any specialised cell. Cells are also programmed to die at different stages of development or after a period of activity. Programmed cell death is called **apoptosis**.

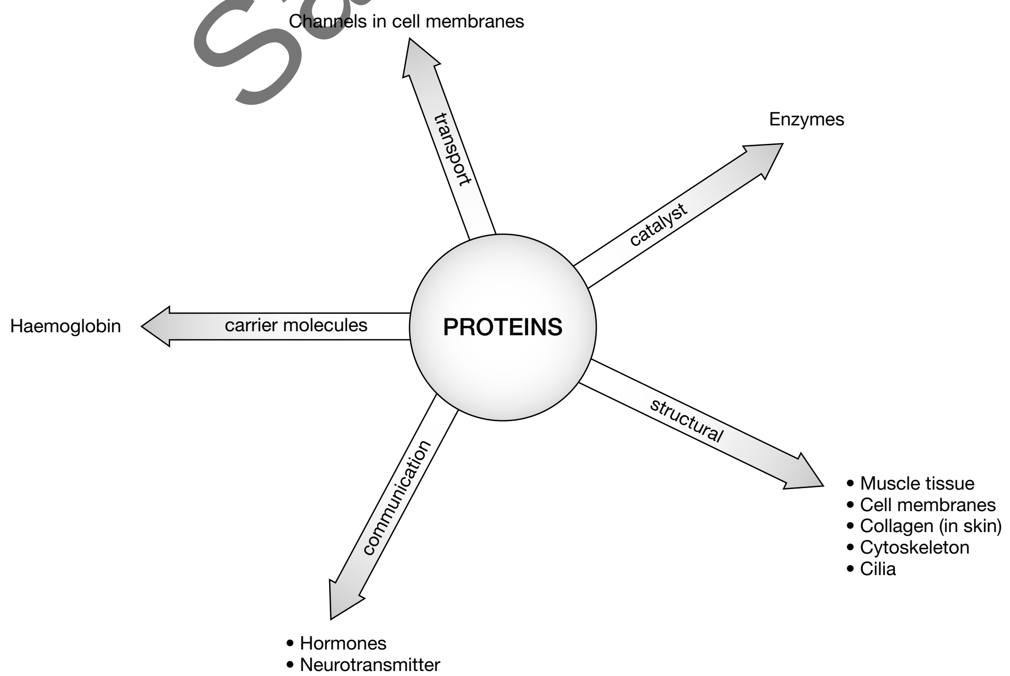


Figure 3.10 Proteins have many roles in living organisms

Structure and regulation of biochemical pathways

The **metabolism** of an organism is the sum of all the chemical reactions that occur within its cells. This includes the energy-transforming reactions of cells such as production of organic molecules, and the breakdown, recycling and excretory processes. Such biochemical processes are universal; that is, they occur in the cells of all living organisms to ensure the survival of the individual.

Enzymes are biological catalysts—they increase the rate of biochemical reactions in cells, e.g. the chemical reactions involved in cellular respiration and photosynthesis.

PROPERTIES OF ENZYMES

- composed of *protein*
- *substrate specific*—catalyse a chemical reaction involving a particular substrate molecule, and not any other. There are two theories used to explain how enzymes interact with their substrates: lock and key, and induced fit.

1 Lock-and-key

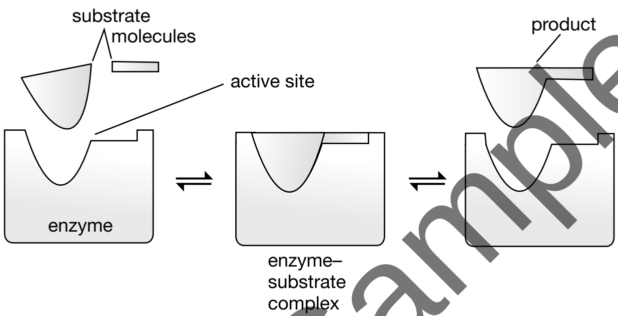


Figure 3.11a Model of enzyme 'lock-and-key' operation

2 Induced fit

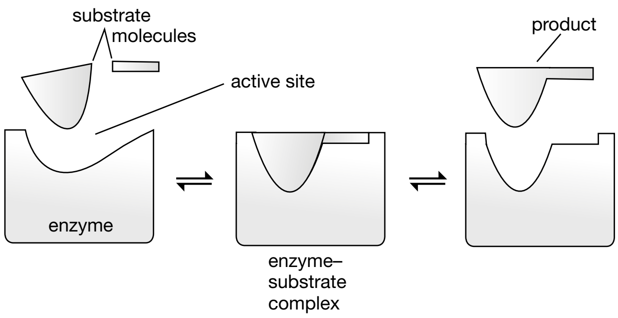


Figure 3.11b Model of enzyme 'induced fit' operation

- take part in chemical reactions but are *not used up or changed* by the process; released at the end of a reaction and so are available to be *used over and over again*
- have *optimal conditions* under which they work most effectively; will catalyse a reaction so that maximum product is produced per unit of time, e.g. optimal temperature for digestive enzymes in duodenum of humans is 37°C and pH 8
- *sensitive* to factors such as temperature and pH—when these conditions are not optimal, the activity of enzymes is reduced; extremes of such factors may lead to enzymes becoming **denatured**; when this happens the enzyme cannot recover its function because the shape of its active site has been permanently altered.

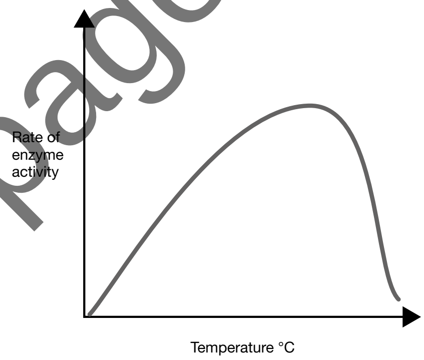


Figure 3.12 Rate of enzyme activity continues to increase with increasing temperature. Excessive temperature denatures enzymes and activity ceases

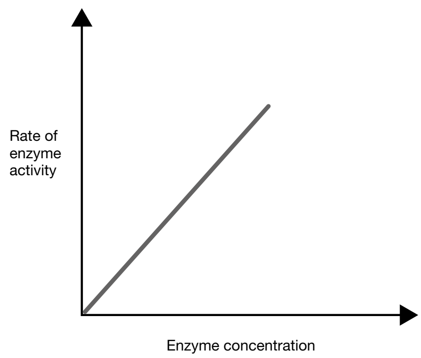


Figure 3.13 Rate of enzyme activity increases with increasing enzyme concentration

Enzymes are usually denoted by the suffix ‘ase’, e.g. maltase, lactase, protease, amylase, lipase.

The rate of enzyme activity is also dependent upon the:

- *concentration of substrate*—the higher the concentration of the substrate, the greater the rate of interaction between substrate molecules and enzymes, leading to increased rate of reaction
- *concentration of enzyme*—the more enzyme available to catalyse a reaction, the more rapidly the reaction will proceed until all enzyme molecules are fully engaged in the reaction.

REVERSIBLE AND IRREVERSIBLE ENZYME INHIBITION

The action of enzymes is also influenced by the presence of chemical competitors at the active site. Competitors inhibit enzyme action by binding to the active site of enzymes. This may be reversible or irreversible.

Penicillin is an example of an irreversible enzyme inhibitor—strong covalent bonds means the competitor is permanently attached to the active site of an enzyme involved in construction of the bacterial wall. This outcome renders pathogenic bacteria unable to survive. Hence its use in medicine.

Reversible inhibition occurs when molecules form weak, non-permanent bonds with the active site of enzymes. Reversible enzyme inhibition has an important regulatory role in cells. Inhibitors are in place when enzymes are not required and dissociate from the enzyme when the enzyme product is needed.

Activation energy: the energy expended to initiate a reaction; even catabolic reactions require an initial input of energy to start the reaction. Enzymes lower the activation energy, making it easier for the reaction to proceed

Coenzymes: small organic molecules important to the normal functioning of enzymes. ATP is a coenzyme that plays a critical role in the transfer of energy in reactions such as cellular respiration. NADH and NADPH represent coenzymes involved in the cycling of protons and electrons in energy transformations including cellular respiration and photosynthesis respectively. Acetyl coenzyme A is another example of a coenzyme important in cellular respiration.

Cofactors: inorganic ions important to the normal functioning of enzymes, e.g. Mg++

Energy transformations

Living organisms require energy for growth, movement, repair of damaged tissue and reproduction. Energy is obtained by the production of energy-rich organic compounds in **autotrophic** organisms such as plants, and by the consumption of plants and/or other animals by **heterotrophic** organisms. Different kinds of energy transformations are involved.

PHOTOSYNTHESIS

The ultimate source of energy for living things is the sun. **Photosynthesis** is the process in which green plants use chlorophyll to trap light energy and use it to combine water and carbon dioxide to produce energy-rich organic compounds (glucose). Oxygen is a by-product (Figure 3.14).

Photosynthesis involves the *synthesis of biomacromolecules* and is therefore described as **anabolic**. Since this process requires an *input of energy*, it is an **endergonic** reaction.

$$6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

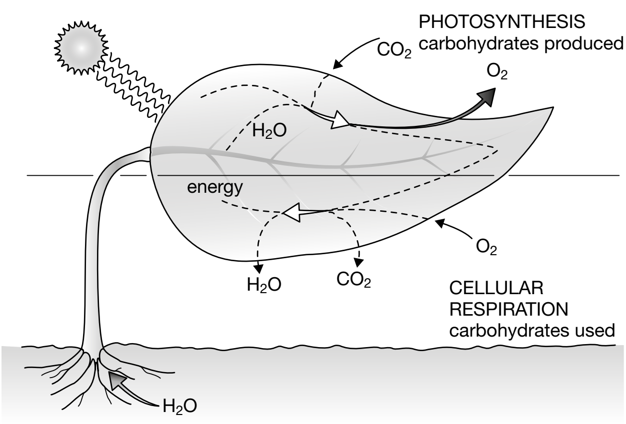


Figure 3.14 Summary of photosynthesis and respiration

Model membranes—structure and function

1 The diagram represents a fluid-mosaic model of a plasma membrane. Complete the diagram by adding labels and functions where indicated.

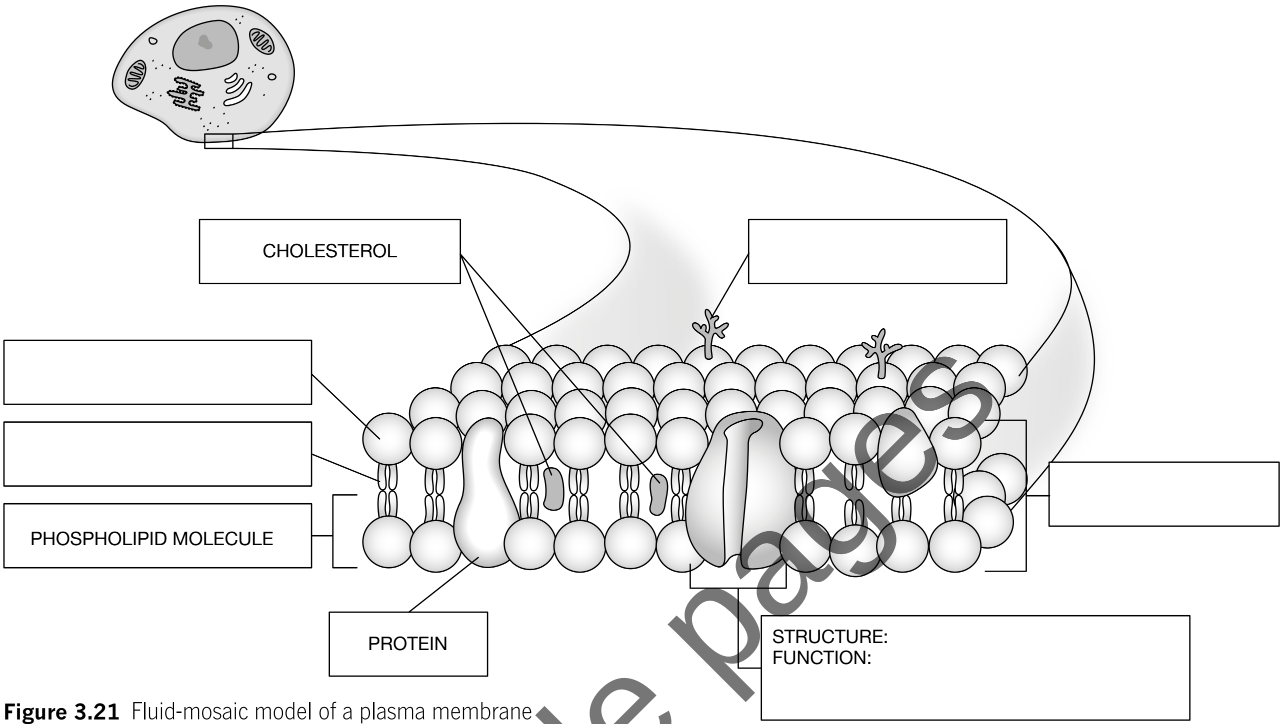


Figure 3.21 Fluid-mosaic model of a plasma membrane

2 Outline the features of plasma membranes that have led to their description as 'fluid-mosaic'.

3 Describe the role of the following molecules in plasma membranes:

a cholesterol:

b carbohydrate:

4 Plasma membranes play an important role in exchange of materials into and out of cells. Complete the table outlining these processes and identify the components of plasma membranes involved in each.

Process	Description of process	Example of material exchanged	Component of plasma membrane involved
Simple diffusion			
Facilitated diffusion			
Osmosis			
Active transport			

Gadget gallery—cell organelles

1 Study the diagrams of the plant and animal cells shown. Identify the organelles indicated in the spaces provided.

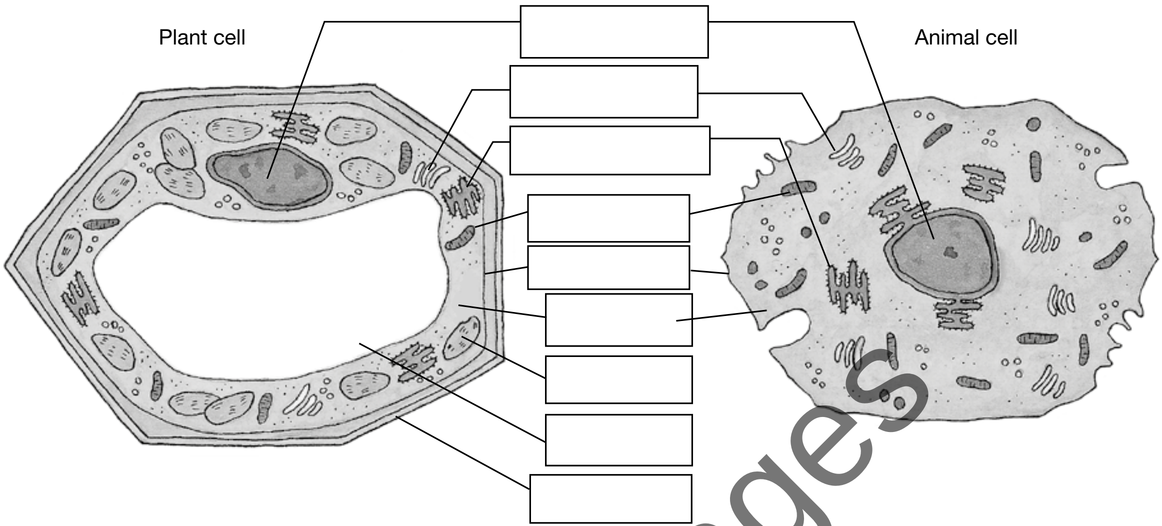
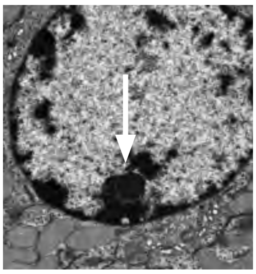
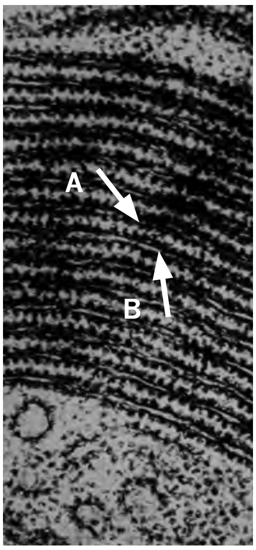
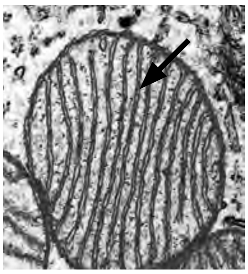
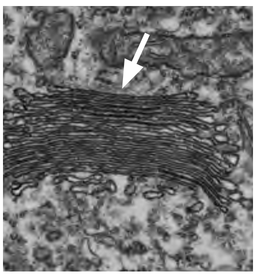


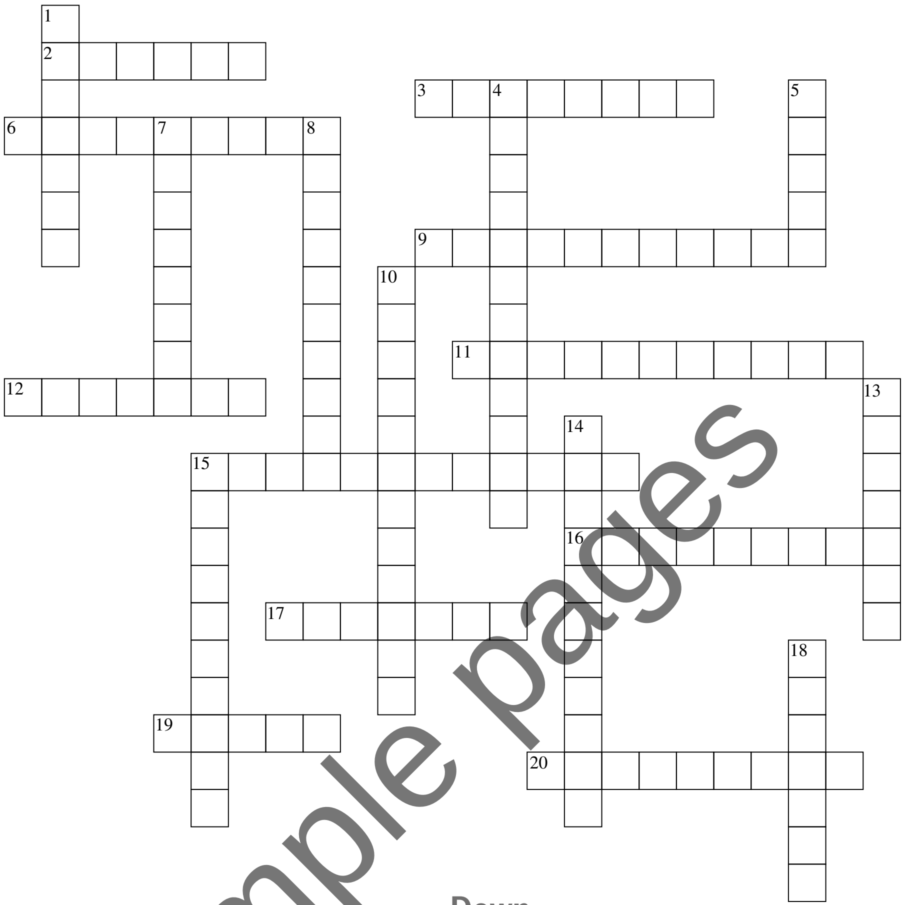
Figure 3.22 Organelles of plant and animal cells

2 Examine the electron micrographs of each of the different cell organelles in the table. Use the diagrams above to help you identify each. Complete the details in the table to provide a summary of the structure and function of each organelle.

	Name of organelle: nucleus Description: Function:		Name of organelle A: Rough endoplasmic reticulum Description: Function:
	Name of organelle: Description: Function:		Name of organelle B: Ribosome Description: Function:
	Name of organelle: Golgi apparatus Description: Function:		Name of organelle: chloroplast Description: Function:

Cells—crossword

Complete the crossword puzzle to help you check your knowledge and understanding of key terms and processes related to cells.



Across

2 Kind of molecule transport across plasma membranes that requires energy expenditure.

3 Bilayer that encloses cell contents as well as cellular organelles.

6 Type of organism whose cells feature a distinct nucleus and membrane-bound organelles.

9 Passive form of molecule transport across a plasma membrane through protein channels.

11 Process by which particles are engulfed by a cell—cell membrane wraps around particle creating a vesicle, which fuses with the cell membrane.

12 Organelle containing genetic material and concerned with control of cellular activities.

15 Chemical complex that forms the main structure of biological membranes.

16 Sub-cellular structure that has a specific function.

17 Type of complex compound containing both carbon and hydrogen.

19 Cellular apparatus characterised by flat, membranous sacs involved in the packaging of proteins for export from cells.

20 Passive movement of molecules along a concentration gradient.

Down

1 Fluid-filled storage organelle that also has a role in the turgidity of plant cells.

4 Organelle with folded inner membrane that is concerned with energy transformations in cells.

5 Organic compound composed of fatty acids and glycerol.

7 Site of protein production in cells.

8 Process by which particles are removed from cells; vesicle containing particles fuses with cell membrane to facilitate this removal.

10 Energy-rich, complex organic compound.

13 Complex organic compound with many functions, including structural roles and catalysing chemical reactions in cells.

14 Process by which liquid is engulfed by cells; cell membrane wraps around droplet forming a vesicle which fuses with the cell membrane.

15 Type of unicellular organism characterised by the absence of distinct, membrane-bound organelles.

18 Passive movement of water molecules across a semi-permeable membrane along a concentration.

WORKSHEET 4

Cell's user manual—a concept map

An organism's **genome** and its corresponding **proteome** can be likened to a dictionary in which the genome represents all of the words and the proteome outlines the meanings of those words. The genome includes all of the genes that are the instructions for building all of the proteins in the body. In this concept map you begin with the genome and follow the steps to finally reach the cell's functional destination—its proteome.

Use the boxes to write in the definition of terms. Add your own branches and words to the concept map to build a word picture of the key structures and processes that occur as the cell follows its genetic instructions to build its proteins.

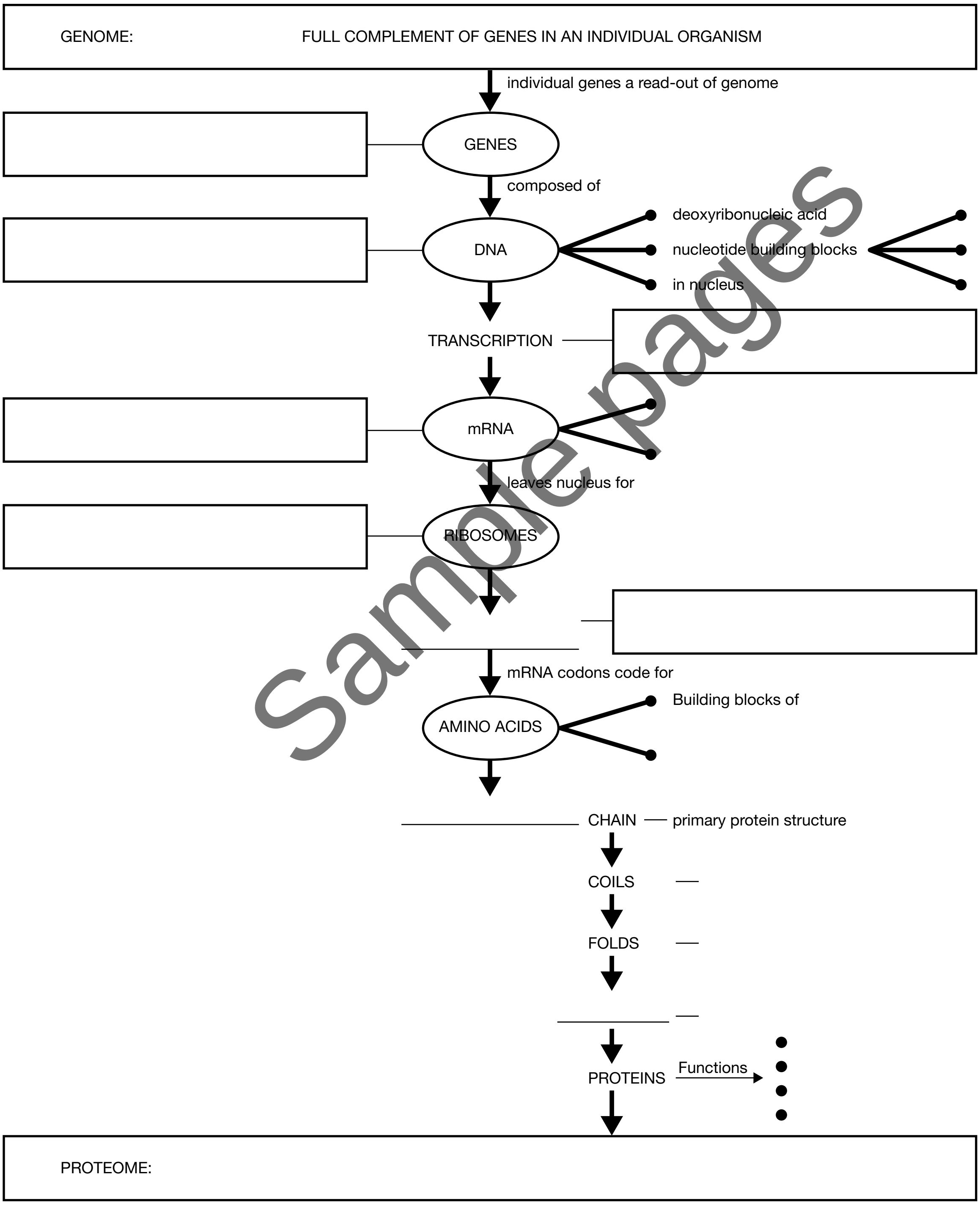


Figure 3.23 Concept map—cell's user manual

Genetic dictionary—reading the code

DNA is a biological book of words and meanings that can be likened to a dictionary where:

- the words represent the **genes**
- the definitions are an expression of what each word means. In this case, the **expression of a gene** is the protein for which it codes.

The diagram shows each step involved in reading the DNA sequence of a gene segment. By following each step, the final meaning is revealed.

1 Use your knowledge of complementary base-pairing rules and the genetic code to add in the missing instructions in the diagram below.

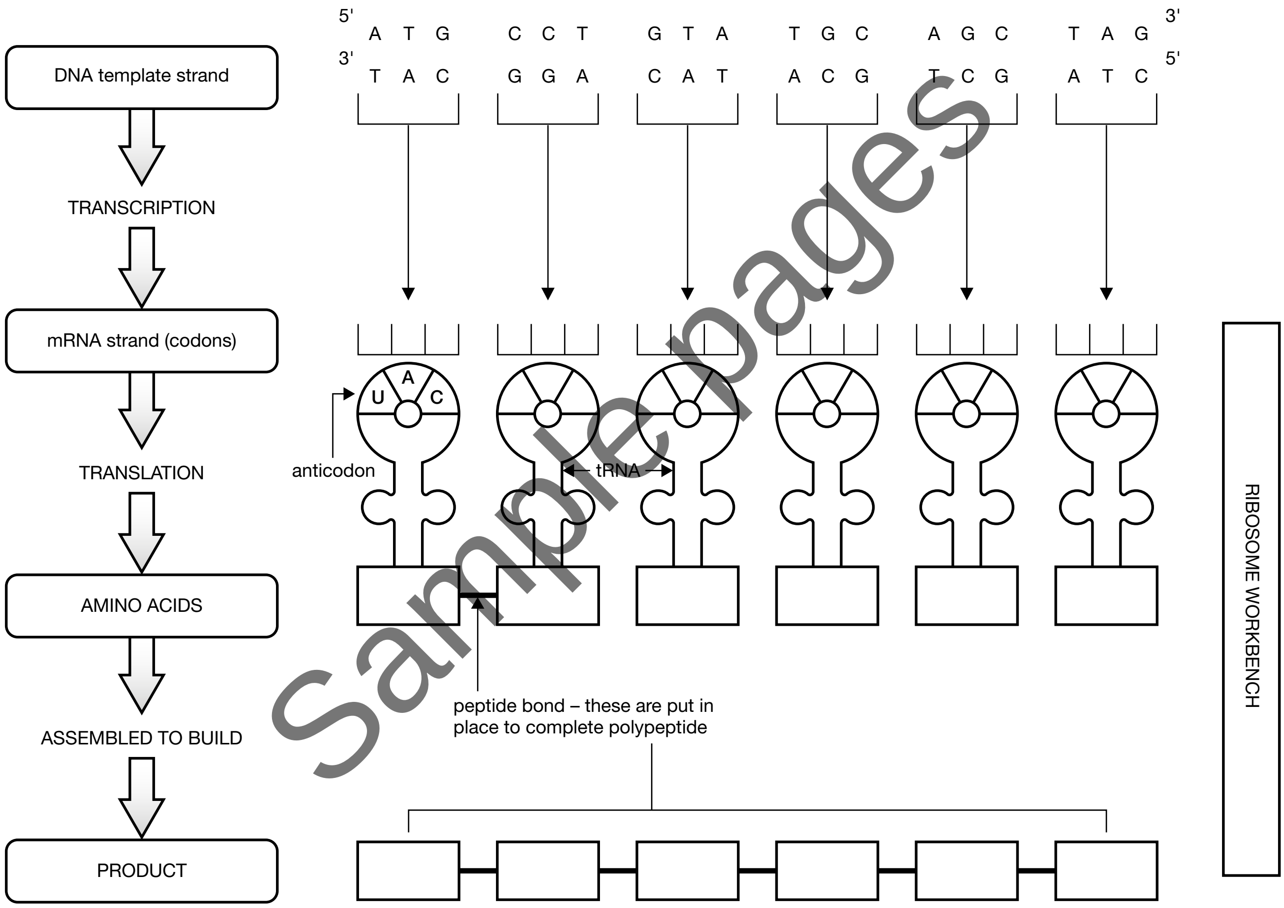


Figure 3.24 DNA contains the genetic instructions for building polypeptides.

PRACTICAL ACTIVITY 1

Partially permeable membranes—diffusion and osmosis

PURPOSE

To investigate the movement of particles in solution across a partially permeable membrane.

BACKGROUND INFORMATION

To test for the presence of starch, add a few drops of iodine/potassium iodide solution to the test solution. If starch is present the solution will change to a blue-black colour.

To test for the presence of glucose, dip a Clinistix into the test solution. If glucose is present, the Clinistix will change from pink to purple.

MATERIALS

- dialysis tubing
- iodine/potassium iodide
- Clinistix
- 5% starch solution
- glucose solution
- thistle funnel
- 2 gas jars
- retort stand and clamp
- test tubes
- test tube rack
- rubber bands
- 50 mL beaker

PART A PRESENTING PARTIAL PERMEABILITY

PROCEDURE

1 Pour glucose solution into a 50 mL beaker to a depth of about 1 cm. Dip in the coloured tab of a Clinistix.

1 Describe your observations. ______________________________

____

2 Fill a gas jar with water until it is about three-quarters full. Test the water in the same way with a new Clinistix.

2 **a** Note the result. ______________________________

b Explain why you have tested the water in the gas jar with the Clinistix.

____

____

3 Set up the equipment as shown in Figure 3.34.
Set up the retort stand to support the thistle funnel first. Then secure the dialysis tubing. Moistening the dialysis tubing will help to open the ends. Tie one end firmly closed with a rubber band. Tie the other end so that it is securely fastened to the thistle funnel. Gently pour glucose solution into the thistle funnel until the level rises about 2 cm up the stem of the funnel. Place the gas jar beneath the thistle funnel. Use the clamp to lower the dialysis tubing completely into the water solution. Leave the set-up undisturbed for 30 minutes (longer if possible).

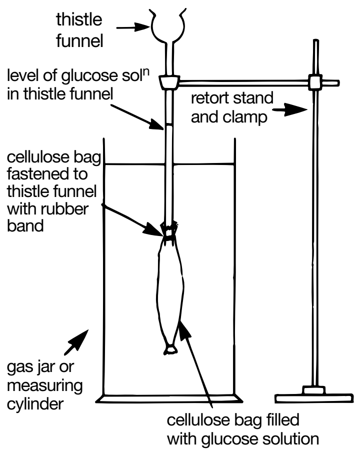


Figure 3.34 Equipment set-up for experiment

3 **a** Use the Clinistix to once again test the solution in the gas jar. Describe your observations. ______________________________

b Explain what has happened. ______________________________

____

____

____

PART B MODELLING OSMOSIS

PROCEDURE

1 Pour starch solution into a test tube to a depth of about 1 cm. Add a few drops of iodine/potassium iodide solution.

4 Describe any colour change that occurs.

____

2 Fill the second gas jar with water until it is about three-quarters full. Add several drops of iodine/potassium iodide solution.

5 **a** What colour is the solution?

____

b What does the colour of the solution indicate about the presence of starch?

____

3 Use the equipment listed to construct an experimental set-up similar to the one shown in Figure 3.35(a).

Prepare the set-up in the same way as you did for Part A, except that this time you will pour starch solution into the thistle funnel/dialysis tubing. Place the gas jar beneath the thistle funnel. Lower the dialysis tubing completely into the water and iodine/potassium iodide solution. Leave the set-up undisturbed for 30 minutes (longer if possible).

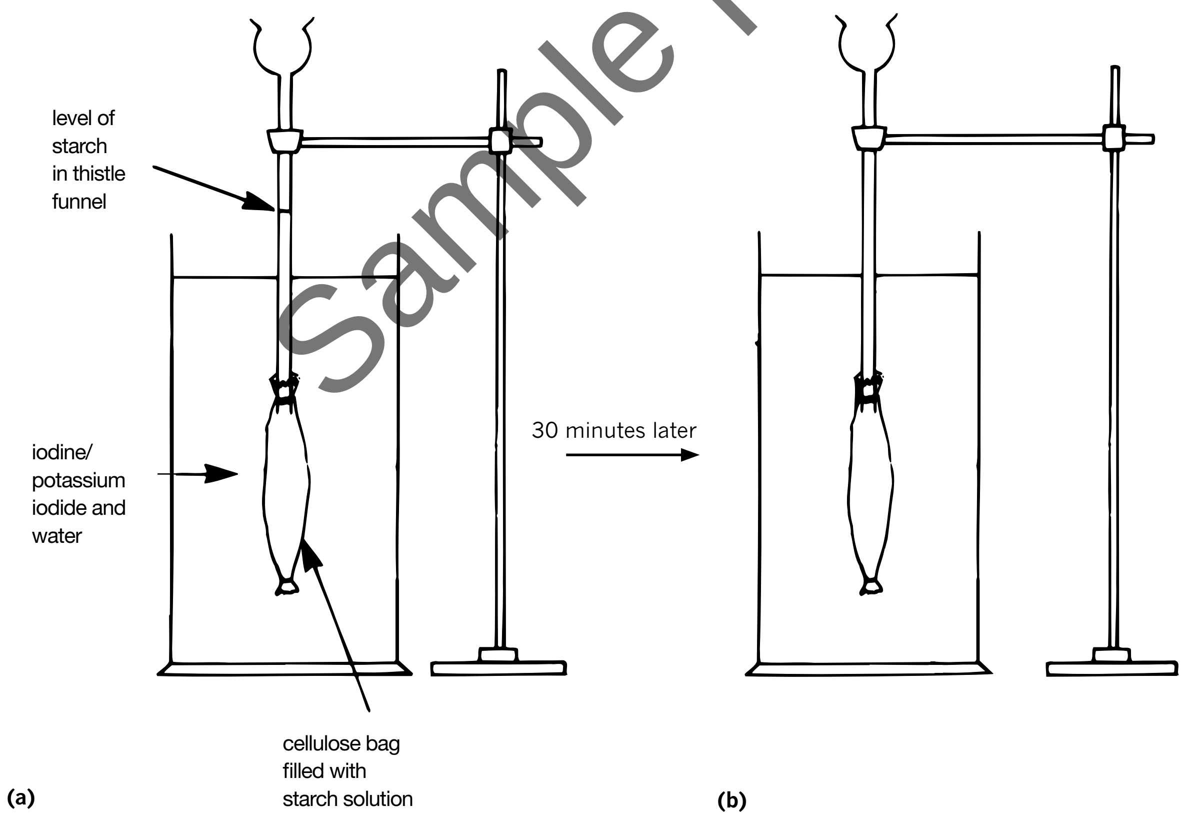


Figure 3.35 Equipment set-up—**(a)** before **(b)** after

6 Use coloured pencils to colour Figures 3.35(a) and 3.35(b) to reflect your observations at the start of the activity and again after 30 minutes.

7 Describe any changes you observe.

8 Account for the colour changes you have observed. Where did the molecules of water, iodine/potassium iodide and starch begin and where did they move to?

CONCLUSIONS

In this activity, you considered evidence that indicates some kinds of molecules move across partially permeable membranes while others do not.

Write the definition for:

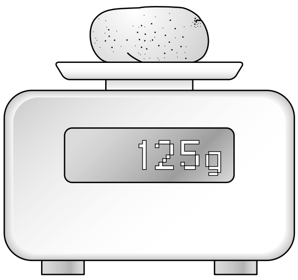
9 **a** osmosis

b diffusion

10 Explain why some kinds of molecules are able to pass through partially permeable membranes and others are not. Use specific examples.

MATERIALS

- 6 30 mL disposable drink sample cups or 100 mL beakers
- marking pen
- dissecting board and scalpel
- dissecting needle
- paper towel and tissues
- cork borer no.6 (6 mm) or bigger
- centimetre ruler
- stock solutions of distilled water, and 0.5%, 1%, 2%, 5% and 10% sodium chloride
- access to top-loading electronic balance accurate to two decimal places (0.01 g)
- millimetre graph paper
- potatoes



Porous potatoes—osmosis in living cells

PURPOSE

To investigate osmosis in living cells.

PROCEDURE

1 Set out six sample cups and label them in the following way: 0% NaCl, 0.5% NaCl, 1% NaCl, 2% NaCl, 5% NaCl and 10% NaCl.
2 Cut a number of cores from a fresh potato using a no.6 (or bigger) cork borer. Push the cores out of the borer using the blunt end of a pencil. Trim the ends square and cut twelve 2 cm-long cylinders.
3 Weigh two cylinders using a top-loading balance.

1 Record the mass for the potato cylinders in Table 3.12.

4 Place the first two potato cylinders in the sample cup labelled 0% NaCl.
5 Repeat this process for each of the sample cups in order.
6 Note the time, then fill each cup to the same depth with the respective NaCl solutions.
7 After 30 minutes, remove the potato cylinders from the 0% NaCl solution using a dissecting needle. Place them on paper towel. Gently roll the potato cylinders against the paper towel to absorb excess surface water, then quickly move them to the balance for weighing. After weighing the cylinders, return them to the cup.

2 Record their final mass.

8 Repeat this drying and weighing process for the cylinders in each of the different NaCl solutions. You will need to work rather quickly to minimise the difference in time that the cylinders are exposed to the different solutions.

3 Complete the calculations in Table 3.12 using the formula provided. Note: The change in mass may be negative in some cases.

$$\%\text{ change in mass} = \frac{\text{mass change (+ve or –ve)} \times 100}{\text{initial mass}}$$

4 Remove a potato cylinder from each cup in turn. Observe the appearance and feel of each. Describe your observations.

____

____

____

____

Table 3.12 Change in mass of potato cylinders

	% NaCl					
	0	0.5	1	2	5	10
Initial mass (g)						
Final mass (g)						
Change in mass (g)						
% change in mass						

5 Use the millimetre paper provided to graph the percentage change in mass of the potato cylinders against the concentration of NaCl. Be sure to label the axes fully and accurately.

6 Which of the cups contained solutions that were:

a less concentrated than the cytosol concentration?

____

b more concentrated than the cytosol concentration?

____

c about the same concentration as the cytosol concentration?

____

7 Use your knowledge of osmosis and cell membranes together with the observations made in this activity to explain what has occurred in the potato cells in each of the sample solutions grouped in **6**. Use diagrams to complement your explanations.

____
____
____
____
____
____
____