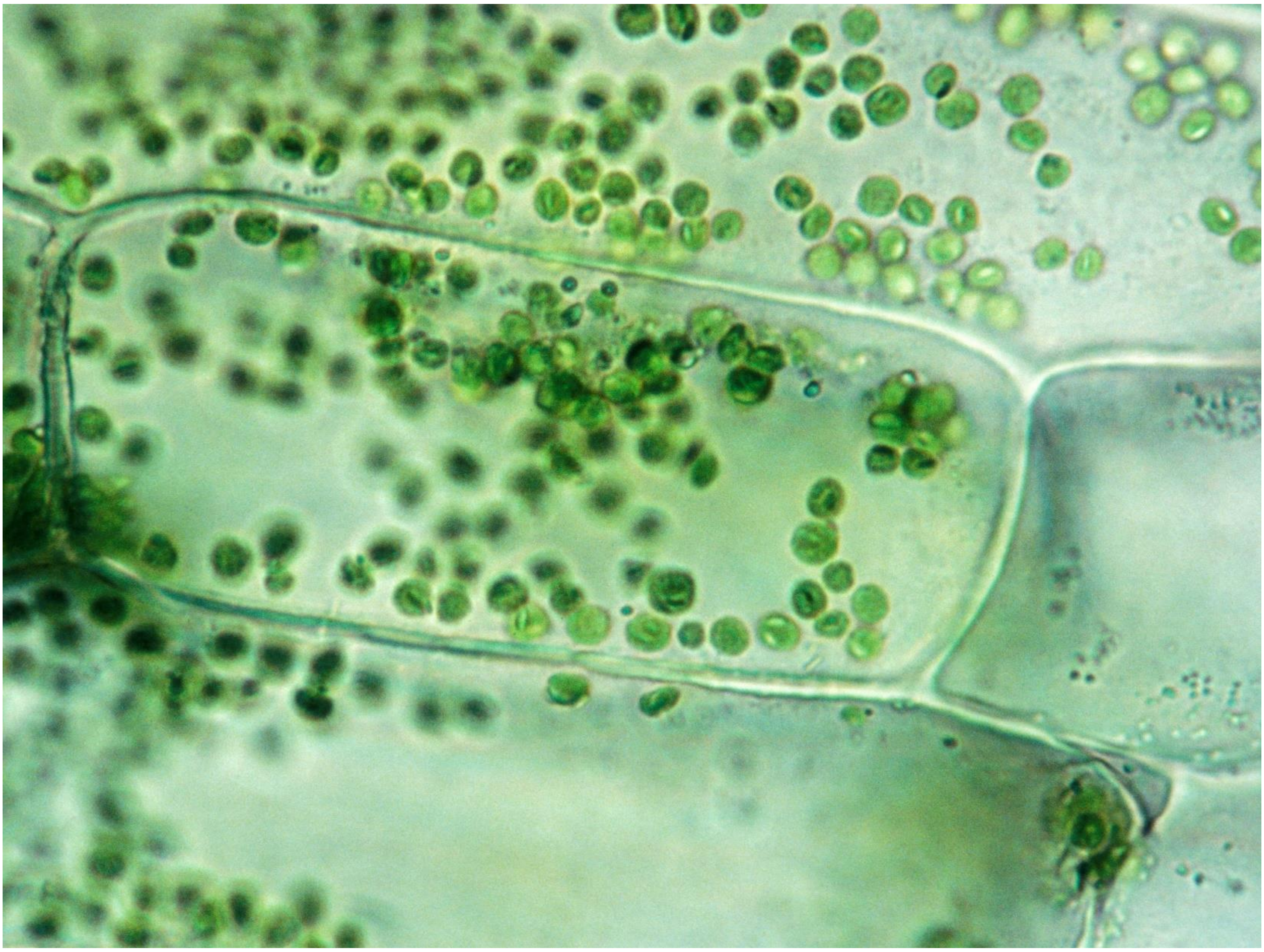
A-level Biology



Bridging Course - Week 2

Entry Requirements for Studying A-level Biology?

- Students who are expected to achieve at least a grade 7 in GCSE Biology Separate Science or a grade 7 in Combined Science.
- Students who have enjoyed their GCSE Biology course, and who enjoy extra reading and research.
- Students should be competent in both Mathematics and Chemistry.

What to expect from A-level Biology.

The study of A Level Biology compliments a large number of university courses such as Medicine, Dentistry, Biomedical Science, Genetic Engineering, Environmental Science along with many others. It can also provide academic credentials for unrelated courses such as Law and Architecture.
The course covers both animal, plant and environmental Biology, which will be taught through a combination of theory and practical work. This is a demanding A level, and students will need to be competent in both Maths and Chemistry.

This bridging course will provide you with a mixture of information about A-level Biology, and what to expect from the course, as well as key work to complete. Students who are expecting to study Biology at A-level, and are likely to meet the entry requirements, must complete the bridging course fully and thoroughly, to the best of their ability. You should complete all work digitally if possible, so it is available to print and place in your file at the start of the course. You will submit it to your teacher in September. All of the work will be reviewed and selected work will be assessed, and you will be given feedback on it. This work will be signalled to you. If you do not have access to the internet, please contact the school and appropriate resources will be sent to you. If you are thinking about studying Biology at A-level you should attempt this work to see whether or not you think studying a subject like this is right for you. If you later decide to study Biology, you must ensure you complete this work in full. This work should be completed after you have read and completed the Study Skills work that all of Year 12 should complete.

Course outline

Paper 1	Paper 2	Paper 3
What's assessed	**What's assessed**	**What's assessed**
• Any content from topics 1– 4, including relevant practical skills	• Any content from topics 5–8, including relevant practical skills	• Any content from topics 1–8, including relevant practical skills
Assessed	**Assessed**	**Assessed**
• written exam: 2 hours • 91 marks • 35% of A-level	• written exam: 2 hours • 91 marks • 35% of A-level	• written exam: 2 hours • 78 marks • 30% of A-level
Questions	**Questions**	**Questions**
• 76 marks: a mixture of short and long answer questions • 15 marks: extended response questions	• 76 marks: a mixture of short and long answer questions • 15 marks: comprehension question	• 38 marks: structured questions, including practical techniques • 15 marks: critical analysis of given experimental data • 25 marks: one essay from a choice of two titles

The topics that you will study over the two years are as follows;

Year 12

- Topic 1 - Biological molecules
- Topic 2 – Cells
- Topic 3 – Organisms exchange substances with their environment
- Topic 4 – Genetic information, variation and relationships between organisms
- Topic 5 – Energy transfers between organisms - Respiration and photosynthesis

Year 13

- Topic 5 - Energy transfers between organisms – Energy and ecosystems
- Topic 6 - Organisms respond to changes in their environment
- Topic 7 - Genetics, populations, evolution and ecosystems
- Topic 8 - The control of gene expression

The following work will introduce key aspects of the Year 12 content along with some of the skills required during the A-level Biology course. This week we will be looking at cells.

Recap Task

Last week we looked at the structure of the cell, and ways that this structure can be investigated. As we move into weeks 2, 3 and 4 try to notice the common link of how proteins are vital to the functioning of living things, how their structure is determined, and how this structure relates to their function.

To recap and assess your knowledge answer the following questions.

Q1.

(a) Structures **A** to **E** are parts of a plant cell.

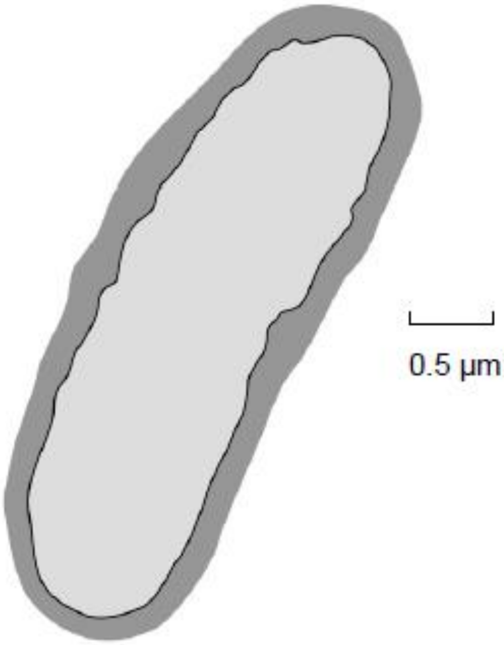
A Cell Wall
B Chloroplast
C Nucleus
D Mitochondrion
E Golgi apparatus

Complete the table by putting the correct letter, **A**, **B**, **C**, **D** or **E** in the box next to each statement.

Statement	**Letter**
Has stacked membranes arranged in parallel and contains DNA.	
Is made of polysaccharide.	
Is an organelle and is **not** surrounded by two membranes.	

(3)

A bacterium is shown in the diagram.

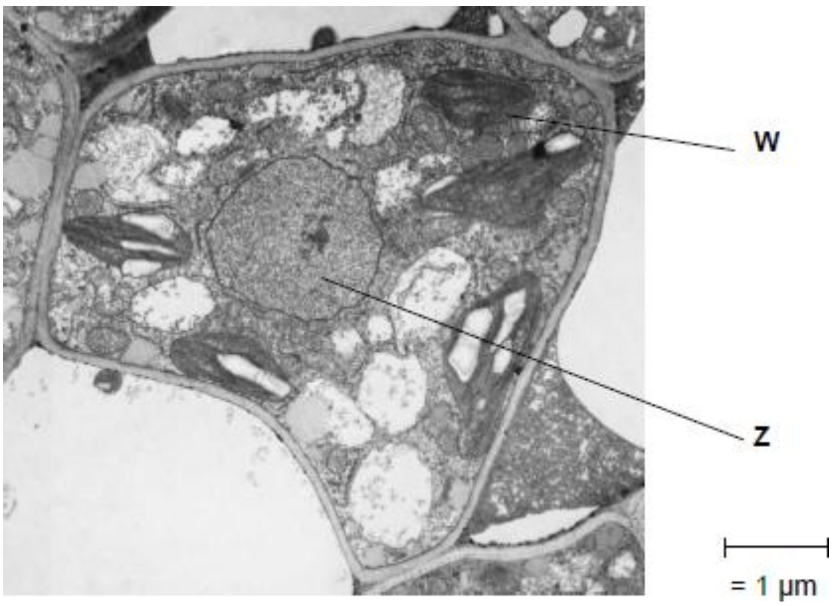


(b) Calculate the magnification of the image.

Magnification = ________________

(1)

The figure below shows a microscopic image of a plant cell.



(c) Give the name and function of the structures labelled **W** and **Z**.

Name of **W**____

Function of **W**____

Name of **Z** ____

Function of **Z** ____

(2)

(d) A transmission electron microscope was used to produce the image in the figure above. Explain why.

____

____

____

____

____

(2)

(e) Calculate the magnification of the image shown in the figure in part (a).

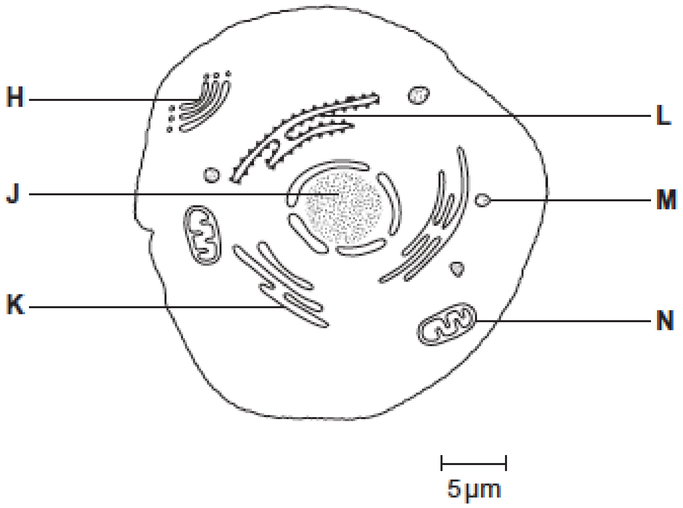
Answer = ____________________

(1)

(Total 7 marks)

Q2.

The diagram shows a eukaryotic cell.



(a) Complete the table by giving the letter labelling the organelle that matches the function.

Function of organelle	**Letter**
Protein synthesis	
Modifies protein (for example, adds carbohydrate to protein)	
Aerobic respiration	

(3)

(b) Use the scale bar in the diagram above to calculate the magnification of the drawing. Show your working.

Answer = ____________________

(2)

(Total 5 marks)

Mark schemes

Q1.

(a) B;

A;

E;

3

(b) × 20 000

Accept range from 18 000 to 22 000

1

(c) 1. **W** – chloroplast, photosynthesis;
2. **Z** – nucleus, contains DNA / chromosomes / holds genetic information of cell.

2

(d) 1. High resolution;
2. Can see internal structure of organelles.

2

(e) Length of bar in mm × 1000.

1

[9]

Q2.

(a)

Protein synthesis	**L;**
Modifies protein	**H;**
Aerobic respiration	**N;**

3

(b) 1800−2200;

1.8, 2.0 or 2.2 in working or answer = 1 mark.

Ignore units in answer.

1 mark for an incorrect answer in which student clearly divides measured length by actual length (of scale).

Accept I / A or I / O for 1 mark but ignore triangle.

Accept approx 60mm divided by 30µm for 1 mark

2

[5]

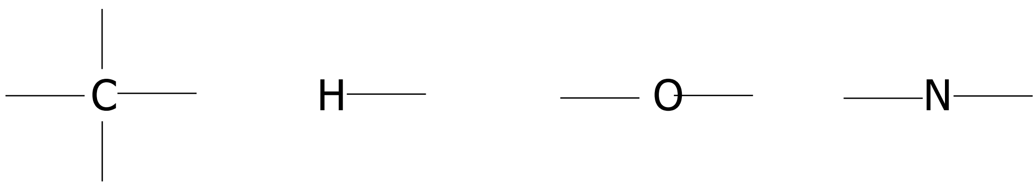
Biological Molecules

- Students will recap their previous knowledge of carbohydrates, lipids and proteins.
- Students will produce structural diagrams of the monomer of each type of molecule.
- Students will investigate the structure of proteins in detail.
- Students will analyse data on the rate of enzyme catalysed reactions.

1. Monomers and polymers

During your GCSE course you will have come across biological molecules at a very basic level in the context of digestion, and you should be able to recall the chemical test, functions and monomers for carbohydrates, lipids and proteins. You will also have looked at the structure of DNA. We will cover this in detail during the A-level course, but we will not look at DNA here.
A more detailed understanding of biological molecules is essential to the understanding of most of Biology. This week we are going to look in more detail at carbohydrates, lipids and proteins.

These molecules all have carbon, hydrogen and oxygen as the main part of their overall structure, with the addition of nitrogen and some other elements in proteins. Molecules are joined by covalent bonds (there are other forces involved – especially in proteins – which we will look at later.
For the purpose of this week's work it is worth remembering the following rules about bonding;

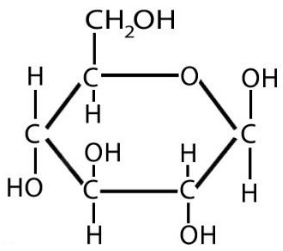


4 covalent bonds 1 covalent bond 2 covalent bonds 2 covalent bonds

Glucose is the monomer of glycogen. The chemical formulae for glucose is;

$$C_6H_{12}O_6$$

The structure of a glucose molecule is;



Notice that each carbon has 4 bonds, each oxygen has 2 and each hydrogen has 1.

Watch the following videos
https://www.youtube.com/watch?v=_zm_DyD6FJ0
https://www.youtube.com/watch?v=VGHD9e3yRIU

Read the following information from the text book.

1.3 Carbohydrates – disaccharides and polysaccharides

Learning objectives

- → Explain how monosaccharides are linked together to form disaccharides.
- → Describe how α-glucose molecules are linked to form starch.
- → Describe the test for non-reducing sugars.
- → Describe the test for starch.

Specification reference: 3.1.2

Study tip

Be clear about the difference between the terms 'condensation' and 'hydrolysis'. Both involve the use of water in reactions. However, condensation is the *giving out* of water in reactions while hydrolysis is the *taking in* of water to split molecules in reactions.

Hint

To help you remember that condensation is *giving out* water, think of condensation when you breathe out on a cold morning. This is water that you have *given out* in your breath.

In Topic 1.2 we saw that in carbohydrates, the monomer unit is called a monosaccharide. Pairs of monosaccharides can be combined to form a **disaccharide**. Monosaccharides can also be combined in much larger numbers to form **polysaccharides**.

Disaccharides

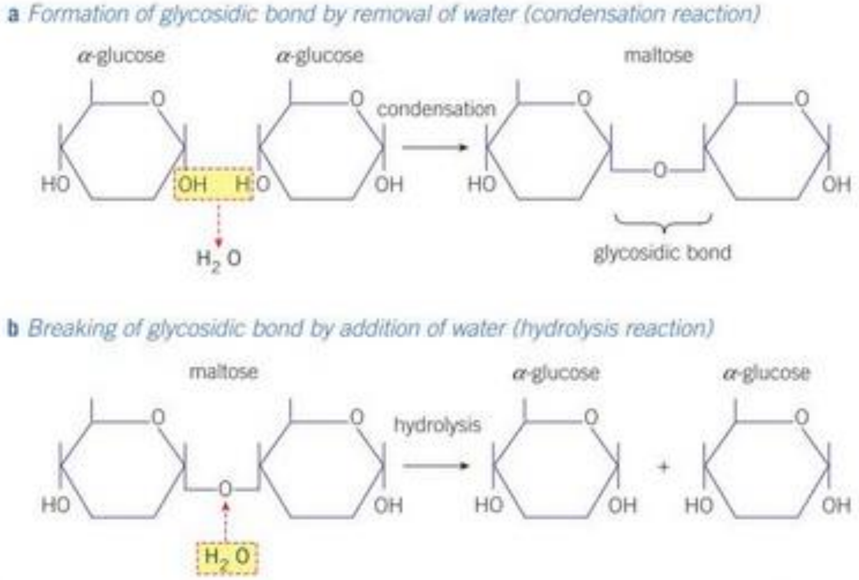
When combined in pairs, monosaccharides form a disaccharide. For example:

- Glucose joined to glucose forms maltose.
- Glucose joined to fructose forms sucrose.
- Glucose joined to galactose forms lactose.

When the monosaccharides join, a molecule of water is removed and the reaction is therefore called a **condensation reaction**. The bond that is formed is called a **glycosidic bond**.

When water is added to a disaccharide under suitable conditions, it breaks the glycosidic bond releasing the constituent monosaccharides. This is called **hydrolysis** (addition of water that causes breakdown).

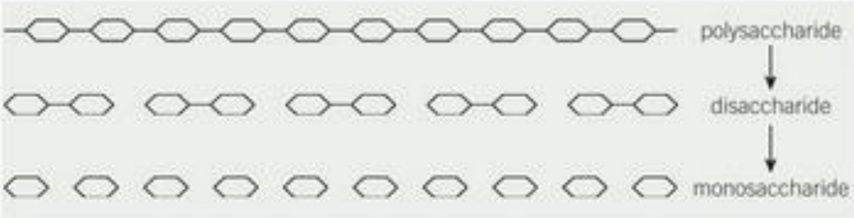
Figure 1a) illustrates the formation of a glycosidic bond by the removal of water (condensation reaction). Figure 1b) shows the breaking of the glycosidic bond by the addition of water (hydrolysis reaction).



▲ **Figure 1** *Formation and breaking of a glycosidic bond by condensation and hydrolysis*

Polysaccharides

Polysaccharides are polymers, formed by combining together many monosaccharide molecules. The monosaccharides are joined by glycosidic bonds that were formed by **condensation reactions**. As polysaccharides are very large molecules, they are insoluble. This feature makes them suitable for storage. When they are hydrolysed, polysaccharides break down into disaccharides or monosaccharides (Figure 2). Some polysaccharides, such as cellulose (see Topic 1.4), are not used for storage but give structural support to plant cells.



▲ **Figure 2** *The hydrolysis of a polysaccharide into disaccharides and monosaccharides*

Starch is a polysaccharide that is found in many parts of plants in the form of small granules or grains, for example starch grains in chloroplasts. It is formed by the joining of between 200 and 100 000 α-glucose molecules by glycosidic bonds in a series of condensation reactions. More details of starch and its functions are given in Topic 1.4.

Hint

Polysaccharides illustrate an important principle: that a few basic monomer units can be combined in a number of different ways to give a large range of different biological molecules.

1.4 Starch, glycogen and cellulose

In organisms, a wide range of different molecules with very different properties can be made from a limited range of smaller molecules. What makes the larger molecules different is the various ways in which the smaller molecules are combined to form them and small differences in the monomers used. You will look at some of these larger molecules by considering three important polysaccharides.

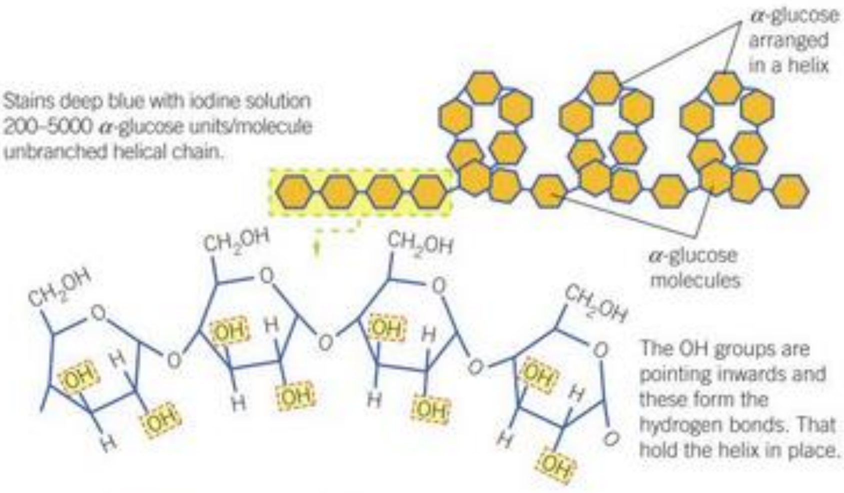
Learning objectives

- → Explain how α-glucose monomers are arranged to form the polymers of starch and glycogen.
- → Explain how β-glucose monomers are arranged to form the polymer cellulose.
- → Explain how the molecular structures of starch, glycogen and cellulose relate to their functions.

Specification reference: 3.1.2

Starch

Starch is a polysaccharide that is found in many parts of a plant in the form of small grains. Especially large amounts occur in seeds and storage organs, such as potato tubers. It forms an important component of food and is the major energy source in most diets. Starch is made up of chains of α-glucose monosaccharides linked by glycosidic bonds that are formed by **condensation reactions**. The chains may be branched or unbranched. The unbranched chain is wound into a tight coil that makes the molecule very compact. The structure of a starch molecule is shown in Figure 1.



▲ **Figure 1** *Structure of a starch molecule*

The main role of starch is energy storage, something its structure is especially suited for because:

- it is insoluble and therefore doesn't affect water potential, so water is not drawn into the cells by **osmosis**
- being large and insoluble, it does not diffuse out of cells
- it is compact, so a lot of it can be stored in a small space
- when hydrolysed it forms α-glucose, which is both easily transported and readily used in respiration
- the branched form has many ends, each of which can be acted on by enzymes simultaneously meaning that glucose monomers are released very rapidly.

Starch is never found in animal cells. Instead a similar polysaccharide, called glycogen, serves the same role.

▲ **Figure 2** *False colour scanning electron micrograph (SEM) of starch grains (blue) in the cells of a potato. Starch is a compact storage material.*

Glycogen

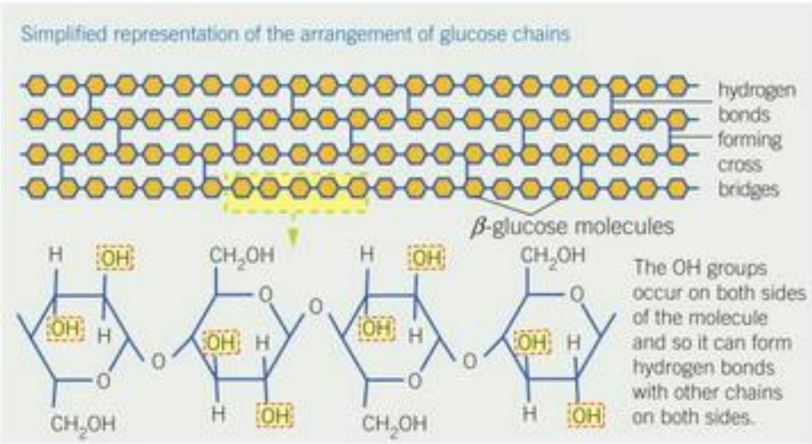
Glycogen is found in animals and bacteria but never in plant cells. Glycogen is very similar in structure to starch but has shorter chains and is more highly branched. It is sometimes called 'animal starch' because it is the major carbohydrate storage product of animals. In animals it is stored as small granules mainly in the muscles and the liver. The mass of carbohydrate that is stored is relatively small because fat is the main storage molecule in animals. Its structure suits it for storage because:

- it is insoluble and therefore does not tend to draw water into the cells by osmosis
- being insoluble, it does not diffuse out of cells
- it is compact, so a lot of it can be stored in a small space
- It is more highly branched than starch and so has more ends that can be acted on simultaneously by enzymes. It is therefore more rapidly broken down to form glucose monomers, which are used in respiration. This is important to animals which have a higher metabolic rate and therefore respiratory rate than plants because they are more active.

Cellulose

Cellulose differs from starch and glycogen in one major respect: it is made of monomers of β-glucose rather than α-glucose. This seemingly small variation produces fundamental differences in the structure and function of this polysaccharide.

Rather than forming a coiled chain like starch, cellulose has straight, unbranched chains. These run parallel to one another, allowing hydrogen bonds (Topic 1.6, Proteins) to form cross-linkages between adjacent chains. While each individual hydrogen bond adds very little to the strength of the molecule, the sheer overall number of them makes a considerable contribution to strengthening cellulose, making it the valuable structural material that it is. The arrangement of β-glucose chains in a cellulose molecule is shown in Figure 3.



The cellulose chain, unlike that of starch, has adjacent glucose molecules rotated by 180°. This allows hydrogen bonds to be formed between the hydroxyl (–OH) groups on adjacent parallel chains that help to give cellulose its structural stability.

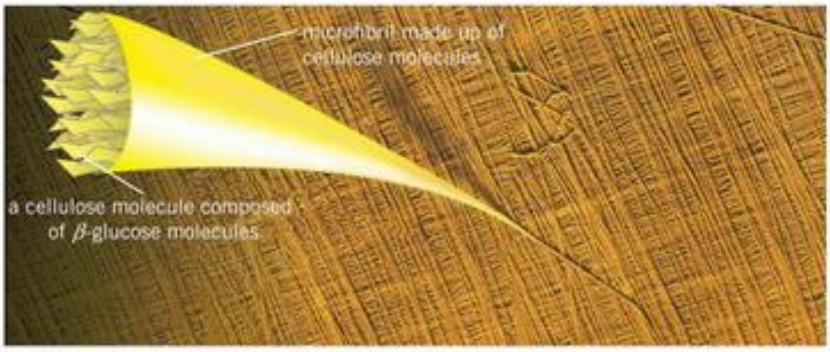
◀ **Figure 3** *Structure of a cellulose molecule*

The cellulose molecules are grouped together to form microfibrils (Figure 4) which, in turn, are arranged in parallel groups called fibres.

Cellulose is a major component of plant cell walls and provides rigidity to the plant cell. The cellulose cell wall also prevents the cell from bursting as water enters it by osmosis. It does this by exerting an inward pressure that stops any further influx of water. As a result, living plant cells are turgid and push against one another, making non-woody parts of the plant semi-rigid. This is especially important in maintaining stems and leaves in a turgid state so that they can provide the maximum surface area for photosynthesis.

In summary, the structure of cellulose is suited to its function of providing support and rigidity because:

- cellulose molecules are made up of β-glucose and so form long straight, unbranched chains
- these cellulose molecular chains run parallel to each other and are crossed linked by hydrogen bonds which add collective strength
- these molecules are grouped to form microfibrils which in turn are grouped to form fibres all of which provides yet more strength.



▲ **Figure 4** *Structure of a cellulose microfibril*

Synoptic link

More detail of the cell wall in plants is given in Topic 3.4 and its importance in supporting non-woody plant tissues is discussed in Topic 4.3.

1.5 Lipids

Learning objectives

- → Describe the structure of triglycerides and how this relates to their function.
- → Describe the roles of lipids.
- → Describe the structure of a phospholipids and how this relates to their function.
- → Describe the test for a lipid.

Specification reference: 3.1.3

Hint

Fats are generally made of saturated fatty acids, while oils are made of unsaturated ones.

Fats are solid at room temperature (10–20 °C), whereas oils are liquid.

Lipids are a varied group of substances that share the following characteristics:

- They contain carbon, hydrogen and oxygen.
- The proportion of oxygen to carbon and hydrogen is smaller than in carbohydrates.
- They are insoluble in water.
- They are soluble in organic solvents such as alcohols and acetone.

The main groups of lipids are **triglycerides** (fats and oils) and phospholipids.

Roles of lipids

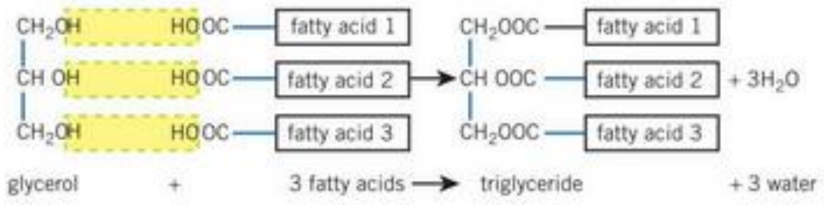
Lipids have many roles, one role of lipids is in the **cell membranes** (cell-surface membranes and membranes around organelles). Phospholipids contribute to the flexibility of membranes and the transfer of lipid-soluble substances across them. Other roles of lipids include:

- **source of energy**. When oxidised, lipids provide more than twice the energy as the same mass of carbohydrate and release valuable water.
- **waterproofing**. Lipids are insoluble in water and therefore useful as a waterproofing. Both plants and insects have waxy, lipid cuticles that conserve water, while mammals produce an oily secretion from the sebaceous glands in the skin.
- **insulation**. Fats are slow conductors of heat and when stored beneath the body surface help to retain body heat. They also act as electrical insulators in the myelin sheath around nerve cells.
- **protection**. Fat is often stored around delicate organs, such as the kidney.

Fats are solid at room temperature (10–20 °C) whereas oils are liquid.

Triglycerides

Triglycerides are so called because they have three (tri) fatty acids combined with glycerol (glyceride). Each fatty acid forms an ester bond with glycerol in a **condensation reaction** (Figure 1). **Hydrolysis** of a triglyceride therefore produces glycerol and three fatty acids.

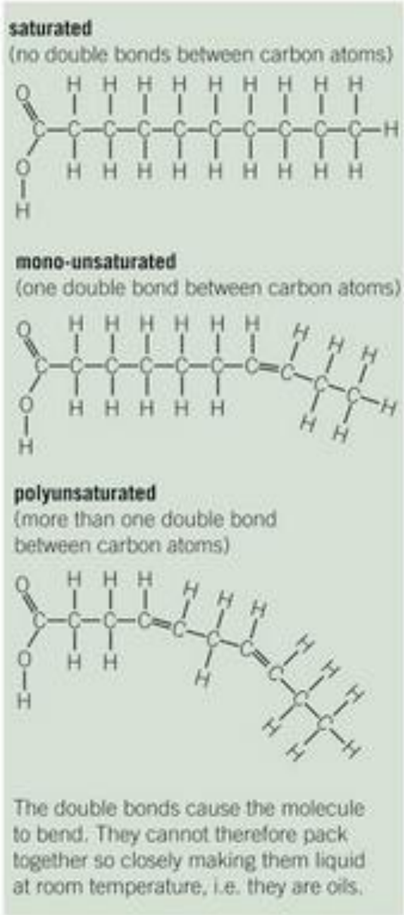


▲ **Figure 1** *The formation of a triglyceride. The three fatty acids may all be the same, thereby forming a simple triglyceride, or they may be different, in which case a mixed triglyceride is produced. In either case it is a condensation reaction*

As the glycerol molecule in all triglycerides is the same, the differences in the properties of different fats and oils come from variations in the fatty acids. There are over 70 different fatty acids and all have a carboxyl (—COOH) group with a hydrocarbon chain attached. If this chain has no carbon–carbon double bonds, the fatty acid is then described as **saturated**, because all the carbon atoms are linked to the maximum possible number of hydrogen atoms, in other words they are saturated with hydrogen atoms. If there is a single double bond, it is **mono-unsaturated** – if more than one double bond is present, it is **polyunsaturated**. These differences are illustrated in Figure 2.

The structure of triglycerides related to their properties

- Triglycerides have a high ratio of energy-storing carbon–hydrogen bonds to carbon atoms and are therefore an excellent source of energy.
- Triglycerides have low mass to energy ratio, making them good storage molecules because much energy can be stored in a small volume. This is especially beneficial to animals as it reduces the mass they have to carry as they move around.
- Being large, non-polar molecules, triglycerides are insoluble in water. As a result their storage does not affect osmosis in cells or the **water potential** of them.
- As they have a high ratio of hydrogen to oxygen atoms, triglycerides release water when oxidised and therefore provide an important source of water, especially for organisms living in dry deserts.



▲ **Figure 2** *Saturated and unsaturated fatty acids*

Study tip

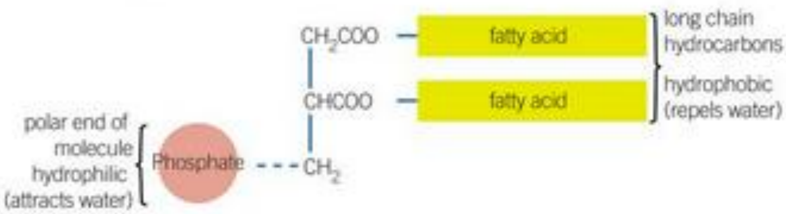
Do not use terms like 'water-loving' and 'water-hating'. Use the correct scientific terms '**hydrophilic**' and '**hydrophobic**'.

Phospholipids

Phospholipids are similar to lipids except that one of the fatty acid molecules is replaced by a phosphate molecule (Figure 3). Whereas fatty acid molecules repel water (are hydrophobic), phosphate molecules attract water (are hydrophilic). A phospholipid is therefore made up of two parts:

- **a hydrophilic 'head'**, which interacts with water (is attracted to it) but not with fat
- **a hydrophobic 'tail'**, which orients itself away from water but mixes readily with fat.

Molecules that have two ends (poles) that behave differently in this way are said to be **polar**. This means that when these polar phospholipid molecules are placed in water they position themselves so that the hydrophilic heads are as close to the water as possible and the hydrophobic tails are as far away from the water as possible (Figure 4).



Carbohydrates

1. **The monomers that make up all carbohydrates are glucose, fructose, and galactose. These are known a monosaccharides. Draw/copy and paste a diagram to show the structure of each of these monomers.**
2. **Disaccharides are made from 2 monosaccharides joined together. These include sucrose, maltose and lactose. Draw a diagram to show the composition of each of these monosaccharides. You do not need to draw out each disaccharide in detail – just use a shape to represent each one.**
3. **There are a number of polysaccharides, which are made from chains of monosaccharides. Thise include starch, glycogen and cellulose. Draw a diagram to show the composition of each of these polysaccharides. You do not need to draw out each disaccharide in detail – just use a shape to represent each one.**

Lipids

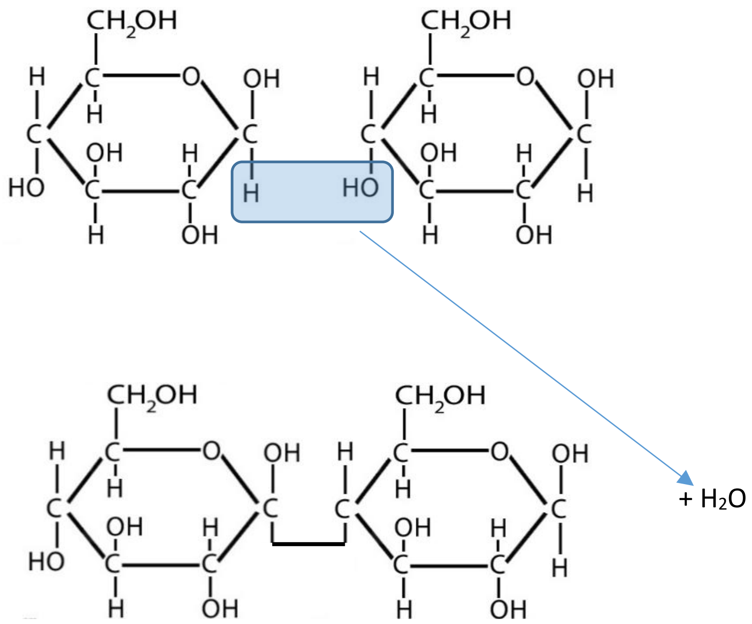
There are a number of different lipids, but we are only going to look at triglycerides.

1. **The monomers that make up a triglyceride are glycerol and fatty acids. Draw a diagram to show the structure of each of these. Include saturated and unsaturated fatty acids.**
2. **Draw a diagram to show the structure of a triglyceride.**

How do monomers join to form polymers?

All of the monomers in biological molecules join using a condensation reaction. This can happen between an OH and H group. Water is removed in a condensation reaction.

E.g. Two glucose molecules join together with a condensation reaction to form maltose.



1. **Draw a diagram to show how a fatty acid joins with glycerol in a condensation reaction.**

2.Proteins

Watch the following video https://www.youtube.com/watch?v=2Jgb_DpaQhM

Read the following information from the text book.

Proteins are usually very large molecules. The types of carbohydrates and lipids in all organisms are relatively few and they are very similar. However, each organism has numerous proteins that differ from species to species. The shape of any one type of protein molecule differs from that of all other types of proteins. Proteins are very important molecules in living organisms. Indeed the word 'protein' is a Greek word meaning 'of first importance'. One group of proteins, enzymes, is involved in almost every living process. There is a vast range of different enzymes that between them perform a very diverse number of functions.

Learning objectives

- Explain how amino acids are linked to form polypeptides – the primary structure of proteins.
- Explain how polypeptides are arranged to form the secondary structure and then the tertiary structure of a protein.
- Explain how the quaternary structure of a protein is formed.
- Describe the test for proteins.

Specification reference: 3.1.4.1

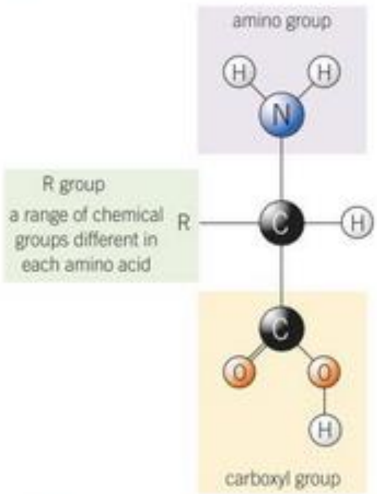
Structure of an amino acid

Amino acids are the basic **monomer** units which combine to make up a **polymer** called a polypeptide. Polypeptides can be combined to form proteins. About 100 amino acids have been identified, of which 20 occur naturally in proteins. The fact that the same 20 amino acids occur in all living organisms provides indirect evidence for evolution.

Every amino acid has a central carbon atom to which are attached four different chemical groups:

- amino group (—NH_2) – a basic group from which the amino part of the name amino acid is derived
- carboxyl group (—COOH) – an acidic group which gives the amino acid the acid part of its name
- hydrogen atom (—H)
- R (side) group – a variety of different chemical groups. Each amino acid has a different R group. These 20 naturally occurring amino acids differ only in their R (side) group.

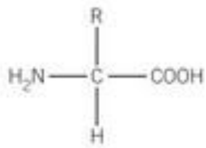
The general structure of an amino acid is shown in Figure 1.



▲ **Figure 1** *The general structure of an amino acid*

The formation of a peptide bond

In a similar way that monosaccharide monomers combine to form disaccharides (see Topic 1.3), so amino acid monomers can combine to form a dipeptide. The process is essentially the same: namely the removal of a water molecule in a **condensation** reaction. The water is made by combining an —OH from the carboxyl group of one amino acid with an —H from the amino group of another amino acid. The two amino acids then become linked by a new **peptide bond** between the carbon atom of one amino acid and the nitrogen atom of the other. The formation of a peptide bond is illustrated in Figure 3. In a similar way as a glycosidic bond of a disaccharide can be broken by the addition of water (hydrolysis), so the peptide bond of a dipeptide can also be broken by hydrolysis to give its two constituent amino acids.



▲ **Figure 2** *Simplified structural formula of an amino acid*

The primary structure of proteins – polypeptides

Through a series of condensation reactions, many amino acid monomers can be joined together in a process called **polymerisation**. The resulting chain of many hundreds of amino acids is called a **polypeptide**. The sequence of amino acids in a polypeptide chain forms the primary structure of any protein. As we shall see in Topic 8.1, this sequence is

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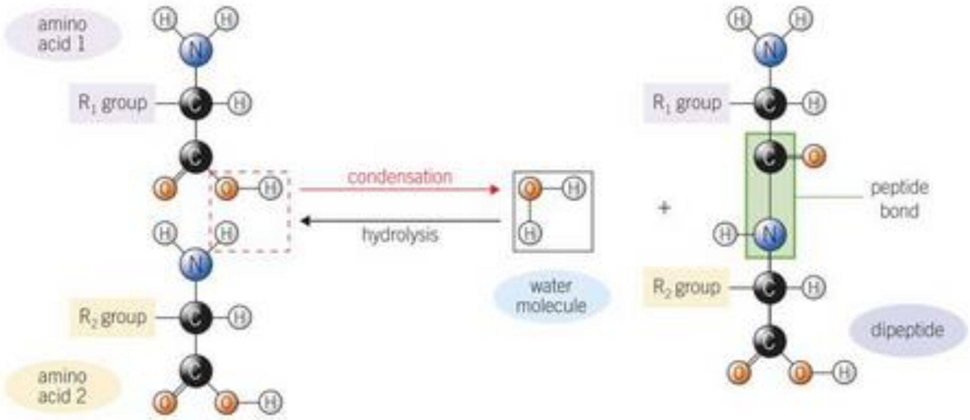


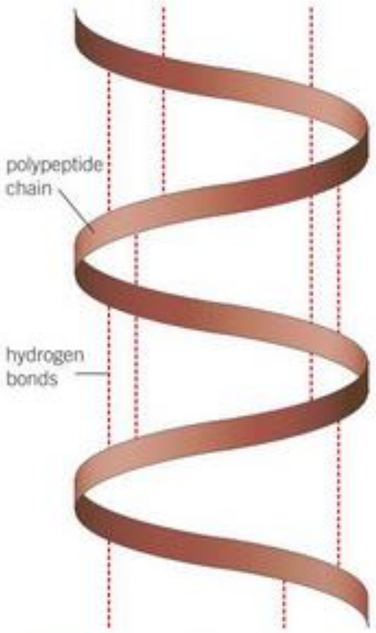
▲ **Figure 3** *The formation of a peptide bond*

Synoptic link

You will learn more about DNA structure in Topic 2.1, and its function in Topic 8.1.

Study tip

Distinguish between **condensation reactions** (molecules combine producing water) and **hydrolysis reactions** (molecules are split up by taking in water).



▲ **Figure 4** *Structure of the α-helix*

determined by DNA. As polypeptides have many (usually hundreds) of the 20 naturally occurring amino acids joined in different sequences, it follows that there is an almost limitless number of possible combinations, and therefore types, of primary protein structure.

It is the primary structure of a protein that determines its ultimate shape and hence its function. A change in just a single amino acid in this primary sequence can lead to a change in the shape of the protein and may stop it carrying out its function. In other words, a protein's shape is very specific to its function. Change its shape and it will function less well, or differently.

A simple protein may consist of a single polypeptide chain. More commonly, however, a protein is made up of a number of polypeptide chains.

The secondary structure of proteins

The linked amino acids that make up a polypeptide possess both —NH and —C═O groups on either side of every peptide bond. The hydrogen of the —NH group has an overall positive charge while the O of the —C═O group has an overall negative charge. These two groups therefore readily form weak bonds, called **hydrogen bonds**. This causes the long polypeptide chain to be twisted into a 3-D shape, such as the coil known as an α-helix. Figure 4 illustrates the structure of an α-helix.

Tertiary structure of proteins

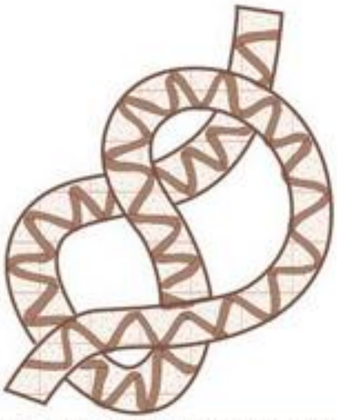
The α-helices of the secondary protein structure can be twisted and folded even more to give the complex, and often specific, 3-D structure of each protein (Figure 5). This is known as the tertiary structure. This structure is maintained by a number of different bonds. Where the bonds occur depends on the primary structure of the protein. These bonds include:

- **disulfide bridges** – which are fairly strong and therefore not easily broken.
- **ionic bonds** – which are formed between any carboxyl and amino groups that are not involved in forming peptide bonds. They are weaker than disulfide bonds and are easily broken by changes in pH.
- **hydrogen bonds** – which are numerous but easily broken.

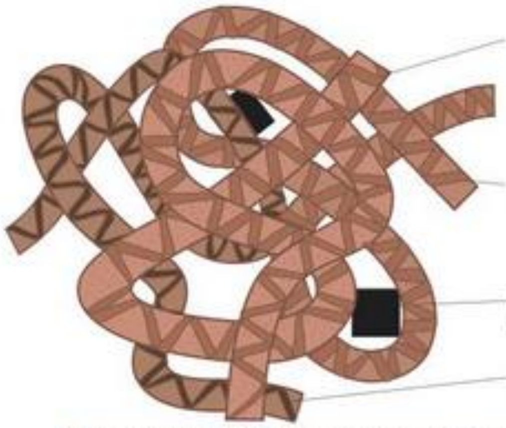
It is the 3-D shape of a protein that is important when it comes to how it functions. It makes each protein distinctive and allows it to recognise, and be recognised by, other molecules. It can then interact with them in a very specific way.

a The primary structure of a protein is the sequence of amino acids found in its polypeptide chains. This sequence determines its properties and shape. Following the elucidation of the amino acid sequence of the hormone insulin by Frederick Sanger in 1954, the primary structure of many other proteins is now known.

b The secondary structure is the shape which the polypeptide chain forms as a result of hydrogen bonding. This is most often a spiral known as the α-helix, although other configurations occur.



c The tertiary structure is due to the bending and twisting of the polypeptide helix into a compact structure. All three types of bond, disulfide, ionic and hydrogen, contribute to the maintenance of the tertiary structure.



d The quaternary structure arises from the combination of a number of different polypeptide chains and associated non-protein (prosthetic) groups into a large, complex protein molecule, e.g., haemoglobin.

▲ **Figure 5** *Structure of proteins*

Quaternary structure of proteins

Large proteins often form complex molecules containing a number of individual polypeptide chains that are linked in various ways. There may also be non-protein (prosthetic) groups associated with the molecules (Figure 5d), such as the iron-containing haem group in haemoglobin. Remember that, although the 3-D structure is important to how a protein functions, it is the sequence of amino acids (primary structure) that determines the 3-D shape in the first place.

Test for proteins

The most reliable protein test is the Biuret test, which detects peptide bonds. It is performed as follows:

- Place a sample of the solution to be tested in a test tube and add an equal volume of sodium hydroxide solution at room temperature.
- Add a few drops of very dilute (0.05%) copper(II) sulfate solution and mix gently.
- A purple coloration indicates the presence of peptide bonds and hence a protein. If no protein is present, the solution remains blue.

Hint

Think of the polypeptide chain as a piece of string. In a fibrous protein many pieces of the string are twisted together into a rope, while in a globular protein the pieces of string, usually fewer, are rolled into a ball.

Study tip

You can simply refer to adding **Biuret** reagent to test for protein. A purple colour shows protein is present – a blue colour indicates that protein is absent.

1.7 Enzyme action

Enzymes are globular proteins that act as catalysts. Catalysts alter the rate of a chemical reaction without undergoing permanent changes themselves. They can be reused repeatedly and are therefore effective in small amounts. Enzymes do not make reactions happen; they speed up reactions that already occur, sometimes by a factor of many millions.

Enzymes as catalysts lowering activation energy

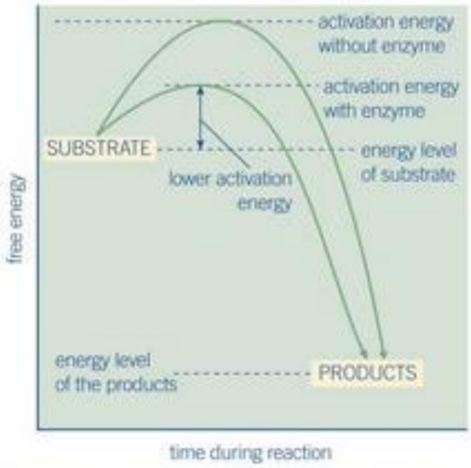
Let us consider a typical chemical reaction:

sucrose + water ⟶ glucose + fructose
(substrates) (products)

For reactions like this to take place naturally a number of conditions must be satisfied:

- The sucrose and water molecules must collide with sufficient energy to alter the arrangement of their atoms to form glucose and fructose.
- The free energy of the products (glucose and fructose) must be less than that of the substrates (sucrose and water).
- Many reactions require an initial amount of energy to start. The minimum amount of energy needed to activate the reaction in this way is called the **activation energy**.

There is an activation energy level, like an energy hill or barrier, which must initially be overcome before the reaction can proceed. Enzymes work by lowering this activation energy level (Figure 1). In this way enzymes allow reactions to take place at a lower temperature than normal. This enables some metabolic processes to occur rapidly at the human body temperature of 37 °C, which is relatively low in terms of chemical reactions. Without enzymes these reactions would proceed too slowly to sustain life as we know it.



▲ **Figure 1** *How enzymes lower activation energy*

Learning objectives

- → Explain how enzymes speed up chemical reactions.
- → Describe how the structure of enzyme molecules relates to their function.
- → Explain the lock and key model of enzyme action.
- → Explain the induced-fit model of enzyme action.

Specification reference: 3.1.4.2

Hint

Free energy is the energy of a system that is available to perform work.

Hint

To help you understand the importance of enzymes, it is necessary to appreciate that they catalyse a wide range of reactions both inside the cell (intracellular) and outside the cell (extracellular). In doing so, enzymes determine the structures and functions of all parts of living matter from cells to complete organisms.

Amino Acids

Amino acids are the monomers of proteins.

1. **Draw a diagram showing the general structure of an amino acid.**
2. **There 20 different types of amino acid that make up proteins in humans. Explain what makes these 20 amino acids different.**

Protein structure

Proteins are built by ribosomes. The ribosomes read the sequence of RNA nucleotides, and this determines the sequence of amino acids in the protein. The sequence or order of amino acids in the protein is known as the primary structure. The protein is then further folded into the secondary and then tertiary structure. This creates a very specific 3D shape. This shape allows the protein to perform its function. If the shape of the protein changes then the protein will not be able to function properly.

1. **Create a summary table showing the differences between primary, secondary and tertiary protein structure.**

Some proteins combine to form a protein with more than one chain of amino acids. This is known as a quaternary structure. Examples of quaternary proteins are haemoglobin, antibodies, chlorophyll and collagen. We will look at these in more detail during the A-level course.

3. Enzyme activity

Enzymes are an example of a tertiary protein. Catalase is an enzyme that breaks down hydrogen peroxide (which is toxic) into water and oxygen in our cells. We can determine the rate of reaction by the volume of oxygen produced.

An investigation was carried out into the effect of temperature on the activity of catalase. The investigation was carried out at five different temperatures. At each temperature gas was collected in a gas syringe and the volume recorded every 30 seconds. The results show the volume of gas collected in ml.

	Time (s)					
Temperature (°C)	30	60	90	120	150	180
10	7	15	22	27	33	44
20	14	28	46	59	75	92
30	30	61	88	122	122	123
40	58	118	120	121	123	123
50	21	40	58	85	102	120

1. **On the same axes plot a graph with time (s) on the x axis and volume of gas on the y axis for each temperature.**
2. **For each temperature calculate the rate of gas production per second over the first 60 seconds of the investigation. Record these calculated results in a table.**
3. **Now plot a graph showing rate of enzyme activity against temperature.**
4. **Describe and explain your results.**
5. **Explain why when measuring the rate of gas production only the first 60 seconds of the investigation was used.**
6. **Explain why the results for 30°C and 40°C plateaued but the other temperatures did not.**

NB Below is some graph paper you can print out. If you would find it easier to do the graphs digitally or use Excel, that is fine.

4.Exam Questions

The answers for Q1, Q3, Q4 and Q5 are at the end of this document.

Q2 will be marked by your teacher and feedback given.

Q1.

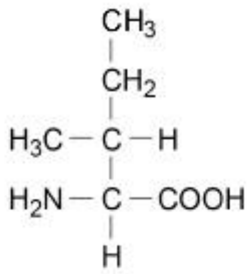
Scientists measured the mean amino acid concentration in white wines made from grapes grown organically and white wines made from grapes that were not grown organically.

(a) Which test could the scientists have used to identify that there are amino acids in white wine?

(1)

(b) All amino acids have the same general structure. The image below shows the structure of the amino acid isoleucine.

Draw a box around the part of the molecule that would be the same in all amino acids.



Isoleucine

(1)

(c) Name the chemical element found in all amino acids that is **not** found in triglycerides.

(1)

(Total 3 marks)

Q2.

(a) Glycogen and cellulose are both carbohydrates.
Describe **two** differences between the structure of a cellulose molecule and a glycogen molecule.

1. ____

____

____

2. ____

____

____

(2)

(b) Starch is a carbohydrate often stored in plant cells.
Describe and explain **two** features of starch that make it a good storage molecule.

1. ____

____

____

2. ____

____

____

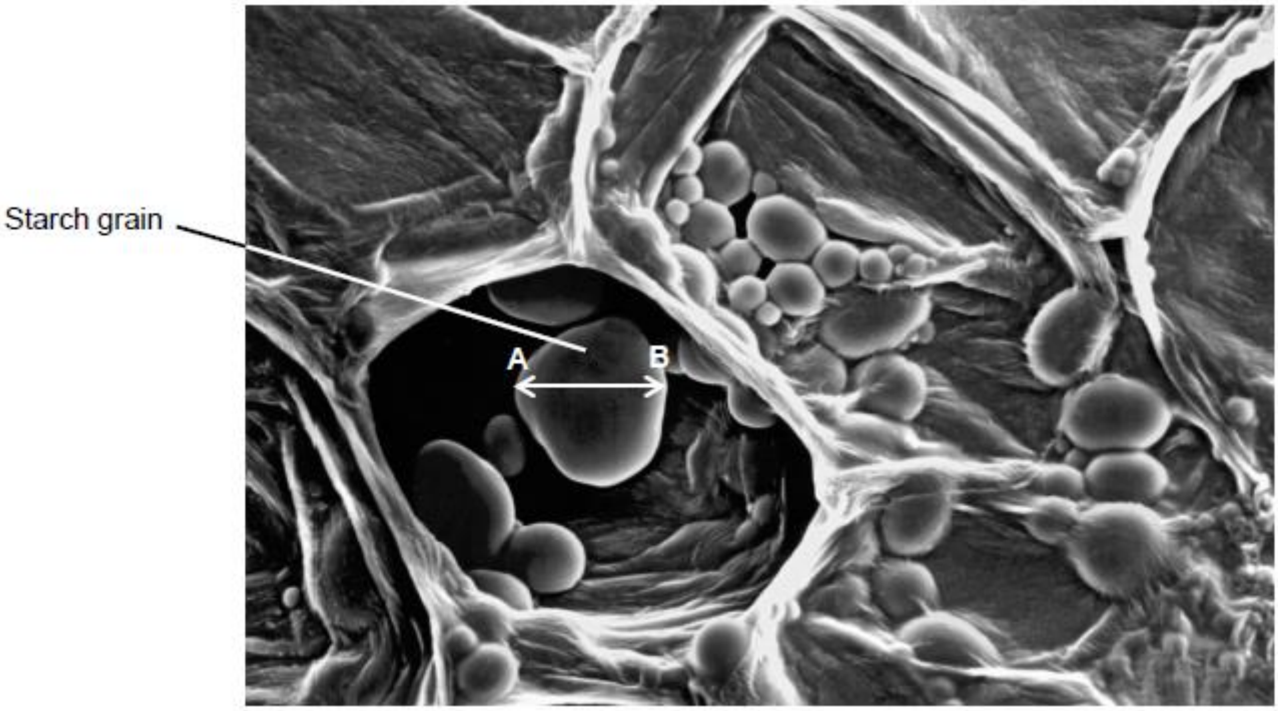
(2)

(c) Tick (✔) the box that identifies the test which would be used to show the presence of starch.

Acid hydrolysis test	☐
Benedict's test	☐
Emulsion test	☐
Iodine/potassium iodide test	☐

(1)

(d) The diagram shows a section through a plant tissue at a magnification of ×500.



Calculate the actual diameter of the starch grain between points **A** and **B**.

Answer = ____________________ µm

(2)

(e) What type of microscope was used to obtain the image shown in the diagram above?

Give **one** piece of evidence to support your answer.

Type of microscope ____

Evidence ____

(2)

(Total 9 marks)

Q3.

(a) What is a monomer?

(1)

(b) Lactulose is a disaccharide formed from one molecule of galactose and one molecule of fructose.

Other than both being disaccharides, give one similarity and one difference between the structures of lactulose and lactose.

Similarity

Difference

(2)

(Total 4 marks)

Q4.

(a) Name the monomers from which a maltose molecule is made.

____

(1)

(b) Name the type of chemical bond that joins the **two** monomers to form maltose.

____

(1)

A student wanted to produce a dilution series of a maltose solution so he could plot a calibration curve. He had a stock solution of maltose of concentration 0.6 mol dm^{-3} and distilled water. He made a series of dilutions from 0.1 to 0.6 mol dm^{-3}.

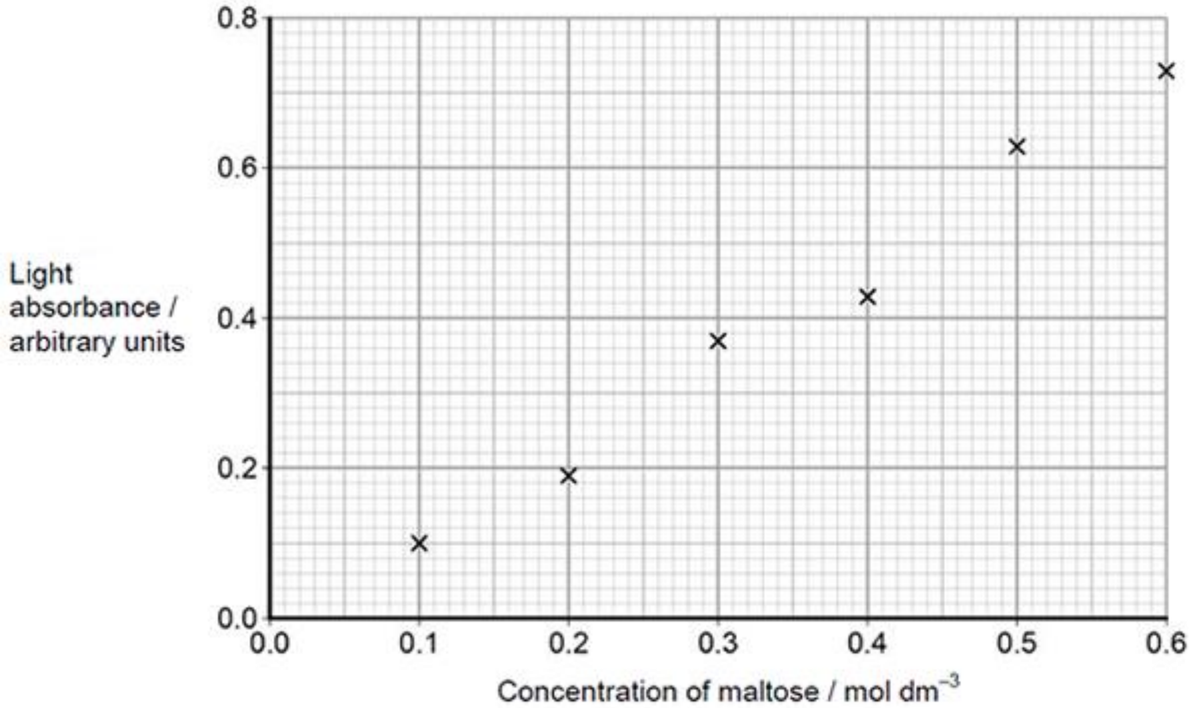
(c) Complete the table below by giving all headings, units and the concentration of the maltose solution produced.

Concentration of maltose solution / ________	**Volume of 0.6 mol dm^{-3} maltose solution / cm^3**	________ – ________ / ________
________	5	10

(2)

The student performed the Benedict's test on six maltose solutions ranging from 0.1 mol dm^{-3} to 0.6 mol dm^{-3}. He placed a sample of each solution in a colorimeter and recorded the light absorbance.

His results are shown in the graph below.



(d) Explain how you would use the graph to determine the maltose concentration with a light absorbance of 0.45 arbitrary units.

(2)

(Total 6 marks)

Q5.

(a) Describe how a peptide bond is formed between two amino acids to form a dipeptide.

(2)

(b) The secondary structure of a polypeptide is produced by bonds between amino acids.

Describe how.

(2)

(c) Two proteins have the same number and type of amino acids but different tertiary structures.

Explain why.

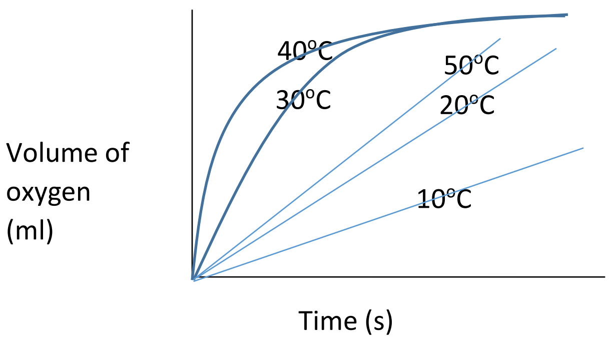
(2)
(Total 6 marks)

5.Help and mark scheme

You should be able to find the answers to part 1 and 2 quite easily in the text.

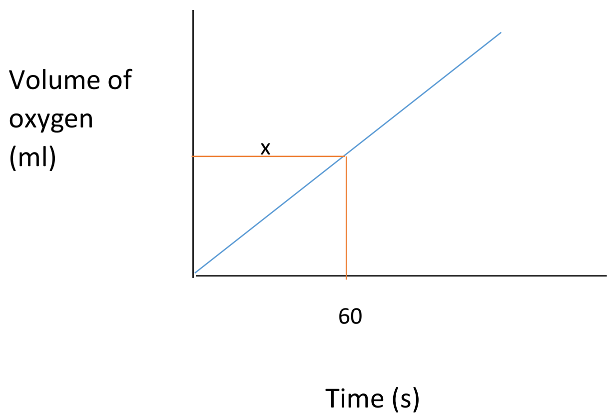
3. Enzyme activity

1.



The graph should look something like this.

2.



Rate =x(ml)/60(s)

4. Initial rise in rate with temperature as more kinetic energy so more enzyme/substrate collisions. Reaches peak at optimum temperature. Activity falls when enzyme is denatured. 3D shape of active site is changed.
5. This is the maximum rate of activity.
6. At 30 and 40°C all the hydrogen peroxide is converted to oxygen and water before the investigation so no substrate left for enzyme to work on.

Mark schemes

Q1.

(a) Biuret;

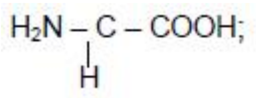
Ignore any other detail

Accept

- *Copper sulfate and sodium hydroxide*
- *$CuSO_4$ + NaOH*
- *Alkaline copper sulfate*
- *Copper sulphate and sodium hydroxide*
- *Alkaline copper sulphate*
- *Biurette*
- *Buiret*
- *Biruet*
- *Bieuret*

Reject burette or Beirut

1

(b) Draw around 

1

(c) Nitrogen;

Ignore N

1

[3]

Q3.

(a) (a monomer is a smaller / repeating) unit / molecule from which larger molecules / polymers are made;

Reject atoms / elements / 'building blocks' for units / molecules

Ignore examples

1

(b) **Similarity**

1. Both contain galactose / a glycosidic bond;

Ignore references to hydrolysis and / or condensation

Difference

2. Lactulose contains fructose, whereas lactose contains glucose;

Ignore alpha / beta prefix for glucose

Difference must be stated, not implied

2

[4]

Q4.

(a) Glucose (and glucose); **1**

(b) (α1,4) Glycosidic; **1**

(c) 1. Headings correct – mol dm^{-3} **and** volume of water / cm^3;

2. Concentration correct. ie 0.2; **2**

(d) Line of best fit drawn;

Read off value at 0.45. **2**

[6]

Q5.

(a) 1. Condensation (reaction) / loss of water;

Accept each marking point if shown clearly in diagram.

2. Between amine / NH_2 and carboxyl / COOH;

Accept between amino (group) and carboxylic / acid (group) **2**

(b) 1. Hydrogen bonds;

Accept as a diagram

Reject N - - - C / ionic / disulfide bridge / peptide bond

2. Between NH (group of one amino acid) and C=O (group);

OR

Forming β pleated sheets / α helix; **2**

(c) 1. Different sequence of amino acids

OR

Different primary structure;

If candidate assumes proteins are the same, accept effect of different pH/ temperature

2. Forms ionic / hydrogen / disulfide bonds in different places; **2**

[6]