Unit F212: Molecules, biodiversity, food and health

2.1 Biological molecules

Notes & Questions
Biological Molecules

- All organisms are made of thousands of different molecules.
- In order to survive an organism must be able to take in or make all the molecules they require.
- The key Biological molecules are:
  - Carbohydrates, lipids, proteins, nucleic acids & water

1 Atoms, Elements, Molecules & Bonding

There is no specification point on this, however a basic knowledge will help with your understanding.

2 Water

Describe how hydrogen bonding occurs between water molecules, and relate this and other properties of water to the roles of water in living organisms.

Water creates interactions between the (+ve) hydrogen atoms and the (-ve) oxygen atoms. These interactions are referred to as **HYDROGEN BONDS**.
Water properties

1. **Cohesion** refers to the fact that water sticks to itself very easily.
2. **Adhesion** means that water also sticks very well to other things, which is why it spreads out in a thin film on certain surfaces, like glass. When water comes into contact with these surfaces, the adhesive forces are stronger than the cohesive forces. Instead of sticking together in a ball, it spreads out.
3. Water also has a high level of **surface tension**. This means that the molecules on the surface of the water are not surrounded by similar molecules on all sides, so they're being pulled only by cohesion from other molecules deep inside.
4. **Capillary action** is also a result of surface tension. This helps water travel up the xylem in plants. The water adheres to the inside of the plant’s xylem vessels, and makes the water rise.
5. **Ice is less dense** than water because water molecules form crystalline structures at freezing (32 degrees Fahrenheit or 0 degrees Celsius) temperatures. The thermal properties of water are also linked to its hydrogen bonds. This allows aquatic life to survive underneath the floating ice.
6. Water has a very high **specific heat capacity**, which is the amount of heat per unit mass required to raise its temperature by one degree Celsius. The energy required to raise the temperature of water by one degree Celsius is 4.2 joules per gram. Water also has a high **heat of vaporization**, which means that it can take a lot of heat without its temperature rising much. This plays a huge part in the climate, because it means that oceans take a long time to warm up. This is why evaporating water from a surface has a cooling effect.
7. Water is often known as the **universal solvent**. Substances that dissolve in water are **hydrophilic**. This means that they are as strong or stronger than water’s cohesive forces. Salt and sugar are both polar, like water, so they dissolve very well in it. Substances that do not dissolve in water are **hydrophobic**. This is the source of the saying "oil and water don’t mix." Water’s solvency is why the water that we use is rarely pure; it usually has several minerals dissolved in it.
2.1

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Protein

- Proteins make up 50% of a cell
- Proteins are made from the elements; Carbon, Hydrogen, Oxygen, & Nitrogen. Sometimes they include Sulphur.
- Proteins are used for;
  - Structural components (bones, skin, hair etc)
  - Enzymes
  - Hormones
  - Antibodies
  - Membrane channels & carriers - Facilitated diffusion/ Active transport
- However proteins are mainly for used for;
  - Growth of tissues,
  - Repair of tissues,
  - Metabolic activity.

Describe, with the aid of diagrams, the structure of an amino acid.

- Amino acids are the monomers of proteins.
There are 20 different amino acids, 10 of which are essential for life. These are unable to be synthesised by humans and must be consumed.
Vegetarians need to be careful that they consume these as meat has more protein available than vegetables.
Each amino acid has the same structure except the R-group which varies from amino acid to amino acid.

They all have the same general structure consisting of an Amino group and a Carboxyl (acid) group at opposite ends.
Between the amino and acid groups is a (alpha) Carbon which has a Hydrogen attached on one side and an R-group on the other.
It is the R-group which makes each amino acid different all other parts stay the same.

R-Groups
• Create the diversity of Amino acids
• R-groups can be;
  • Large (larger than the N-C-C)
  • Positively charged
Describe, with the aid of diagrams, the formation and breakage of peptide bonds in the synthesis and hydrolysis of dipeptides and polypeptides.
Dipeptide molecule

- Amino acids can be joined end-to-end to produce a repeating backbone.

\[ \text{N-C-C-N-C-C-N-C-C-N-C-C-N-C-C} \]

- **Dipeptide** = 2 amino acids joined by a peptide bond
- **Polypeptide** = many amino acids joined by peptide bonds.
- **Protein** = range from 1 polypeptide chain to many polypeptide chains bonded together.

**NB** - sometimes amino acids are referred to as residues as they have lost parts in the formation of the peptide bonds.

- Peptide bonds (like all covalent bonds) are very strong and as a result need to be catalysed by enzymes
- Enzymes that break peptide bonds (proteins) are called **Protease**.
- **Digestion** - Protease breaks polypeptides & proteins into amino acids during digestion in the stomach
- **Hormone regulation** - It is important hormones are broken down so their effects are not permanent. Cells which are targeted by hormones have proteases.
- **Ageing** - Older skin is less able to rebuild the protein callogen and other proteins that give the skin its smooth elastic properties

**Explain, with the aid of diagrams, the term primary structure.**

- Protein function is determined by the structure of that protein.
- This makes the structure of proteins essential to how they are able to carry out their function

- **Primary Structure**
  - The primary structure is formed from the chain of amino acids that forms a polypeptide.
  - The sequence of the amino acids in the chain is determined by the genetic code.
  - The structure of proteins is firstly determined by its unique amino acid sequence.
o The unique amino acid sequence of a polypeptide or a protein is called its **primary structure**.

o Different amino acids have different **R-groups**.

o As a result the unique sequence of amino acids will result in a unique sequence of R-groups.

o The R-groups will determine the folding, bonding and ultimately the shape and hence the function of the protein.

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**Explain, with the aid of diagrams, the term secondary structure with reference to hydrogen bonding.**

- The protein’s secondary structure is formed when the chain of amino acids (polypeptide) folds and coils.

- This chain of amino acids (polypeptide) can fold and coil into;
  - i Beta pleated sheets
  - ii Alpha Helices – 36 amino acids per 10 turns of the coil
    - a hydrogen bond is formed between the amino acids in the first and fourth position.

- These secondary structures are held by hydrogen bonds. Each hydrogen bond is very weak and can easily be broken, however, many of them can result in great stability of the overall protein molecule.

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An α-helix has 36 amino acids per 10 turns of the coil. H-bonds form between one amino acid and the one ‘four places’ along the chain.
Explain, with the aid of diagrams, the term *tertiary structure*, with reference to hydrophobic and hydrophilic interactions, disulphide bonds and ionic interactions.

- The tertiary structure is formed when the secondary structures (alpha helix and beta pleated sheets) fold back on themselves.
- Creates a 3-Dimensional structure.
- This level of structure is the most complex that a single polypeptide can become.
- This folding is generally separated by straight chains of amino acids (i.e. sequences where there is neither a beta pleated sheet or an alpha helices).
- While the secondary structure is stabilised by Hydrogen bonds. The tertiary structure is held by a number of different bonds and interactions.
- Tertiary structure is stabilised by;
  - Disulfide bonds
  - Ionic Bonds
  - Hydrogen Bonds
  - Hydrophobic & Hydrophilic interactions
2.1 Tertiary structure in proteins is stabilised by a number of bonds.

1. Disulfide bonds
   The amino acid cysteine contains sulfur. Where two cysteines are found close to each other a covalent bond can form.

![Disulfide bond diagram]

2. Ionic bonds
   R-groups sometimes carry a charge, either +ve or -ve. Where oppositely charged amino acids are found close to each other an ionic bond forms.

![Ionic bond diagram]

3. Hydrogen bonds
   As in secondary structure. Wherever slightly positively charged groups are found close to slightly negatively charged groups hydrogen bonds form.

![Hydrogen bond diagram]

4. Hydrophobic and hydrophilic interactions
   In a water-based environment, hydrophobic amino acids will be most stable if they are held together with water excluded. Hydrophilic amino acids tend to be found on the outside in globular proteins, with hydrophobic amino acids in the centre.

![Hydrophobic interactions diagram]

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Disulphide Bonds
- Amino acid **Cysteine** contains sulphur.
- If two cystine amino acids are in close proximity they will form a strong covalent bond between them.

Ionic Bonds
- R-groups can carry a +ve or -ve charge.
- Where oppositely charged r-goups are found an ionic bond will form

Hydrogen bonds
- Like with secondary structures, where a lightly +ve part is close to a slightly -vely charged part a hydrogen bond will form.

Hydrophobic and Hydrophilic
- In a water based environment hydrophobic R-groups will move to an area without water while hydrophilic will move towards water.
- These interactions will have an influence on the protein shape.

Temperature and protein tertiary structure
- Increases the energy that molecules have.
- This kinetic energy in the protein will break apart some of the weaker Hydrogen bonds holding the tertiary structure in place.
- Most bonds are not strong covalent bonds and so break apart with the increase in temperature.
- If the protein is exposed to high temperatures the whole tertiary structure can unravel.
- No Shape = No Function
- The protein has been **DENATURED**.
- Even if cooled the protein does not return to its previous shape nor its function.
Tertiary Structures can be globular or fibrous.

- **Globular**
  - Proteins that have a compact globe or ball shaped 3-D structure.
  - They generally have **hydrophobic and hydrophilic parts**.
  - Hydrophilic parts are turn to the outside while hydrophobic parts to the inside.
  - These structures **tend to be water-soluble** as the hydrophilic R-groups allow water to gather around them.
  - Usually have metabolic roles
  - E.g Antibodies, Enzymes & Haemoglobin

- **Fibrous**
  - Form fibres made up of regular, repetitive sequences of amino acids.
  - They **tend to be water insoluble**.
  - Usually have structural roles
  - E.g Collagen & keratin.

**Explain, with the aid of diagrams, the term quaternary structure, with reference to the structure of haemoglobin.**

- Quaternary structures are made up from more than one polypeptide subunit joined together.
- Quaternary level proteins can only function if all subunits are present and functional
- Quaternary structures may involve two or more identical polypeptide subunits coming together – E.g. Collagen
- Or two or more different polypeptide subunits coming together – E.g Haemoglobin.
Haemoglobin

- Water soluble
- Globular protein
- Consists of 4 polypeptides
  - 2 alpha chains
  - 2 beta chains

- Function is to carry oxygen from the alveoli to body tissues and carbon dioxide from body tissue to alveoli.
- It can do this because it has a prosthetic group referred to in this case as a haem group (Hence the name haemoglobin)
- The haem group contains an iron ion (Fe^{2+})
  - Haemoglobin + Oxygen $\rightarrow$ Oxyhaemoglobin
- Contains many different amino acids
- Majority of the tertiary structures are alpha helices

![Haemoglobin Diagram]

Describe, with the aid of diagrams, the structure of a collagen molecule.

Collagen

- Fibrous Protein
- Water insoluble
- Function is to provide mechanical strength.
- Found in vessel walls, skin, bone, tendons, cartilage, connective tissue etc
Collagen molecule
- Constructed from 3 polypeptide chains wrapped around each other.
  - Each polypeptide chain is a coil itself and of around 1000 amino acids.
  - The 3 polypeptide chains are held together by Hydrogen bonds.
- Each Collagen molecule is covalently bonded (Cross linked) to 2 others (creating a total of 9 polypeptide chains), adding strength and forming a collagen fibril.
- The covalent bonds are staggered to provide greater strength
- About 300 collagen fibrils together form a collagen fibre
- Collagen does not contain a prosthetic group
- The majority of the tertiary structures are left-handed helices
- About 35% of amino acids found in collagen are the amino acid Glycine.

![Collagen Fibers](image)

**Compare the structure and function of haemoglobin (as an example of a globular protein) and collagen (as an example of a fibrous protein).**

<table>
<thead>
<tr>
<th></th>
<th>Haemoglobin</th>
<th>Collagen</th>
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</thead>
<tbody>
<tr>
<td><strong>Globular or Fibrous</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Water Soluble</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Amino acids</strong></td>
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<td></td>
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<td><strong>Main Tertiary structures</strong></td>
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<tr>
<td><strong>Prosthetic group?</strong></td>
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<td></td>
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<tr>
<td><strong>Number of Polypeptides</strong></td>
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<td><strong>Polypeptides same/different</strong></td>
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<tr>
<td><strong>Examples</strong></td>
<td></td>
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</tr>
<tr>
<td><strong>Function</strong></td>
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<tr>
<td></td>
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<td>Collagen</td>
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<td>---------------------------</td>
</tr>
<tr>
<td>Globular or Fibrous</td>
<td>Globular</td>
<td>Fibrous</td>
</tr>
<tr>
<td>Water Soluble</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Amino acids</td>
<td>many different</td>
<td>35% Glycine</td>
</tr>
<tr>
<td>Main tertiary structures</td>
<td>alpha -Helices</td>
<td>Left-handed Helices</td>
</tr>
<tr>
<td>Prosthetic group?</td>
<td>Haem</td>
<td>None</td>
</tr>
<tr>
<td>Number of Polypeptides</td>
<td>4</td>
<td>3 fibrous polypeptides</td>
</tr>
<tr>
<td>Polypeptides same/different</td>
<td>2 alpha chains &amp; 2 beta chains</td>
<td>Same</td>
</tr>
<tr>
<td>Function</td>
<td>Carry oxygen from alveoli to body tissues</td>
<td>Mechanical Strength</td>
</tr>
<tr>
<td>Examples</td>
<td>Haemoglobin</td>
<td>Cartilage, skin, bone</td>
</tr>
</tbody>
</table>

**NB** You should always write your answer as a comparison so stating a structure or function for both.

E.g Haemoglobin is a globular protein while collagen is a fibrous protein.

**NB** You should also be able to compare the structure and function of collagen and cellulose, as there are a lot of similar structural features which examiners like to test. (Cellulose is addressed later in this module).
4 Enzymes

Enzymes are large protein molecules made of 100s of amino acids.
- Most of these amino acids are involved in the maintenance of the primary, structure and tertiary structure.
- As enzymes are proteins they are affected by agents that have an effect on proteins
- Organisms that live in extreme environments must have enzymes that can deal with those conditions.

Enzymes are not alive

Enzymes act as biological catalysts, however, they are slower than industrial catalysts.

Enzymes are specific to only one reaction

Enzyme function is related to their shape.
- The shape of the enzyme is essential for the active site shape.
- The active site is an area (often fewer than 10 amino acids) of the enzyme where the catalytic activity of the enzyme occurs.

Do not produce a range of unwanted by-products

Metabolism can be described as enzyme-driven
- Respiration,
- Protein synthesis,
- Digestion
- Photosynthesis

An individual cell may contain over 1000 different enzymes.

Enzymes are needed for the formation and breaking of glycosidic, ester and peptide bonds.

Endotherms (warm-blooded organisms)
- Therefore they can maintain a constant body temperature.
- This means that enzymes in these organisms can work at a near-optimum temperatures.
- The advantages of this means that these organisms can have enzyme action at a continuous and optimum level which means that they can live successfully in a range of environments
- This comes a very high energy cost to the organism and so require a much greater food supply.

Enzymes require an aqueous environment (need to be in solution) in order to function. The aqueous environment allows both the enzyme and the substrate the ability to move and therefore collide with each other. If there was not an aqueous environment then there would be no collisions between enzymes and substrates, therefore no enzyme-substrates
formed and so no reactions. This is why dried peas do not go off as their enzyme action is reduced.

**State that enzymes are globular proteins, with a specific tertiary structure, which catalyse metabolic reactions in living organisms.**

G H S S C A T P

- Enzymes are globular proteins.
- The 3D shape is generally caused as a result of hydrophobic and hydrophilic R-groups
- They are generally soluble in water
- They act as catalysts speeding up reactions and not being used up in the process
- They are specific to one substrate
- They have a pocket or cleft called active site.
- They are affected by temperature and pH

**State that enzyme action may be intracellular or extracellular.**

- Intracellular enzymes – catalyse reactions within cells
  Lysins found in lysosomes in Neutrophils (White Blood Cells)

- Extracellular enzymes – catalyse reactions outside of cells
  Heterotrophs use digestive enzymes to break down the food they have consumed.
  Some organisms secrete enzyme out of themselves onto the food source (fungi) while others secrete enzymes into digestive spaces.
Describe, with the aid of diagrams, the mechanism of action of enzyme molecules, with reference to specificity, active site, lock-and-key hypothesis, induced-fit hypothesis, enzyme-substrate complex, enzyme-product complex and lowering of activation energy.

Activation Energy

- Covalent bonds (Ester, Polypeptide & Glycosidic) are too stable.
- They require a lot of energy in order to break them.
- Example
  - Maltose + Water = Glucose + Glucose
  - In a test tube maltose needs to be boiled in acid
  - This provides the correct conditions for maltose to collide with water molecules energetically enough to achieve hydrolysis

- This added energy is called **Activation Energy**.

- These conditions (boiling acid) are not suitable for a living cell to possess.
- A catalyst (enzyme) is needed to reduce this activation energy.
- Without these enzymes reactions would not occur fast enough to maintain life.
- Enzymes work by lowering the activation energy.
- This allows the reaction to occur at temperatures much lower than boiling and under more favourable conditions.
- This is because the **active site is complimentary to the substrate**

Lock-and-Key Hypothesis

- The enzyme has a specific active site, complementary to a specific substrate.
- This is usually described as the lock and key hypothesis as the substrate acts as a key to the active site lock.
Induced-Fit Hypothesis

- Substrate molecule collides with enzyme **active site**
- Enzyme change shape slightly
- **Active site** now fits more closely to the substrate molecule
- Substrate is held in place due to oppositely charged groups on the substrate and the amino acids of the active site = **Enzyme-substrate Complex**
- This change of shape of the enzyme puts mechanical strain on the substrate molecule. This destabilises the substrate and allows the reaction to occur more easily
- This changes the substrate into the product
- **Enzyme-product complex** is now formed
- Products no longer fit the active site and so leave the enzyme.
- Enzyme is now free and able to bind another substrate molecule
Describe and explain the effects of pH, temperature, enzyme concentration and substrate concentration on enzyme activity.

1 Temperature

Molecules in a gas or liquid naturally have kinetic energy and so are constantly moving around randomly. As a result they will be continually colliding with each other and the surrounding structures.

Heating a gas or liquid will increase the thermal energy and hence will increase the kinetic energy. The more kinetic energy the faster the molecules will move around, resulting in more collisions, and collisions with greater force.

Enzymes catalyse reactions on when the substrate and the enzyme’s active site collide creating an enzyme-substrate complex.

- If there is greater thermal energy,
- There will be greater kinetic energy,
- Hence a greater number of collisions between the enzyme’s active site and the substrate molecule.
- There will be an increase in the number of enzyme-substrate complexes formed.
- This will increase the overall reaction rate.
- There will be more products made.
- The amount of thermal energy that results in the highest number of successful collisions between the enzyme and the substrate is known as the optimum temperature (Not always 37°C).
Too Much!!

- Increasing thermal energy increases kinetic energy.
- An increase in kinetic energy doesn’t just make that molecule move around more, but, also results in the molecule vibrate more.
- These vibrations put strain on the bonds holding the molecule together.
- Enzymes are proteins, and proteins have a large number of weak bonds holding their structure together.
- If the enzyme is put under too much thermal energy,
- It will have too much kinetic energy,
- The molecules will vibrate too much,
- This will break the many weak Hydrogen and ionic bonds that hold the enzyme together.
- The enzyme unravels and loses its overall 3D structure,
- If the 3D structure of an enzyme is lost, the specific structure of the active site will also be lost,
- The enzyme can no longer form an enzyme-substrate complex with the substrate and so the number of overall reactions that take place decreases,
- The enzyme’s active sites have become DENATURED.

Conclusion.

- Increase thermal energy up to an optimum temperature and enzyme reaction rate increases due to an increase in successful collisions.
- Increase thermal energy past an optimum temperature and enzyme reaction rate decreases even though there are more collisions less of these are successful.
- **WHY?** The enzyme’s active sites are becoming DENATURED
2 pH

- pH is a measure of the Hydrogen ion (H\(^+\)) concentration, with values ranging from 1 - 14.
- pH 7 being neutral, pH 1-6 being acidic (greater H\(^+\) concentration) and pH 8-14 being alkaline (lesser H\(^+\) concentration).
- Hydrogen ions (H\(^+\)) are also known as protons and have a positive charge. They therefore will be attracted to negatively charged molecules and repelled from other positively charged molecules.
- Acidic solutions are sometimes referred to as proton donors because of the high concentration of hydrogen ions it contains.
- Proteins are held together by a large number of ionic and hydrogen bonds. These bonds are weak and are due to the attraction between oppositely charged groups on the amino acids that make up the protein.
- Because of the positive charge held by Hydrogen ions (H\(^+\)) they can interfere with the hydrogen and ionic bonds that hold the proteins tertiary structure in place.
- Increasing (acidic) or decreasing (alkaline) the concentration of Hydrogen ions (H\(^+\)) can alter the tertiary structure of the protein and hence its shape.

Optimum pH

- All enzymes have an optimum pH. This is the pH at which the rate of reaction is highest.
- The optimum pH is the pH that gives the tertiary structure its best overall shape. This shape holds the shape of the active site so that it is complementary to the substrate.
- Enzymes have a narrow pH range in which they work.
- Minor changes in pH will result in a fall in the reaction rate because the shape of the active site is disrupted, however, they are not denature the enzyme.
- pH will only denature enzymes if the changes in pH are extreme.
- Enzymes are proteins, and so if they are exposed to pH conditions that are not optimum then the 3D shape of the enzyme is changed and hence so too is the shape of the active site.
- A change in the enzyme’s 3D shape will result in a change to the enzyme’s active site.
- This will result in fewer successful collisions and a decrease in overall enzyme reactions.
- pH will also affect the exposed charged R-groups in the active site as the increase or decrease in Hydrogen ions (H⁺) concentration will interfere with the ability of the active site and substrate binding with each other.

3 Enzyme concentration

The graph shows the summary of many investigations on the rate of reaction with different concentrations of enzymes

- Enzyme concentration increases results in more active sites available
- More enzyme-substrate complexes form
- Reaction rate increases
- This increase is only up to a point until all substrate molecules are occupying the active sites
- This is the maximum reaction rate for that fixed substrate concentration
- Repeating the experiment again with any increased concentrations of enzymes will not result in any further increases in reaction rate.
4 Substrate concentration

The graph shows the summary of Many investigations on the rate of reaction with different concentrations of substrates with a fixed amount of enzymes.

- **A** If there is no substrate then there will be no enzyme-substrate complexes formed and so there will be no reactions
- **B** As substrate concentration increases, successful collisions between substrate and enzyme’s active site increases. More enzyme-substrate complexes form, so more product is formed and the rate of reaction increases.
- **C** If the concentration of substrate increases further, a point will be reached where the reaction rate reaches a maximum value.

**Limiting Factors**

- A limiting factor is a factor of which its magnitude is limiting the reaction rate.
- Limiting factors in enzyme reactions will be;
  - Temperature
  - pH
  - Substrate concentration
  - Enzyme concentration
5 Initial reaction rate

- The initial reaction rate is the point where the enzyme and substrate first come into contact.
- This will be the point where the reaction rate is the highest.
- Substrate concentration decreases after this point and product concentrations increase reducing the likelihood of profitable collisions between enzyme and active site.
- The initial reaction rate gives the maximum possible rate of the reaction under those conditions.
- The initial reaction rate can be calculated by drawing a tangent from the steepest part of the curve.
- The gradient of the tangent gives the initial reaction rate.
  - \( \frac{x}{y} = \text{rate in cm}^3 \text{ per minute} \)
Describe how the effects of pH, temperature, enzyme concentration and substrate concentration on enzyme activity can be investigated experimentally.

Variables on enzyme reactions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Method of keeping constant</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Thermostatically controlled waterbath</td>
<td>Room temperature is too variable. Fluctuations in temperature will affect the enzyme-controlled reaction so the readings will not reflect the action of the independent variable.</td>
</tr>
<tr>
<td></td>
<td>Polystyrene sleeve to insulate</td>
<td></td>
</tr>
<tr>
<td>pH Value</td>
<td>pH Buffer solutions</td>
<td>Rate of reaction will be affected by pH of the solution, as pH will affect the shape of the active site.</td>
</tr>
<tr>
<td>Enzyme Concentration</td>
<td>Use accurately measured volumes of enzyme in the solution</td>
<td>Reaction rate depends on the concentration of the enzyme molecules present. Using accurately measured volumes of enzyme solution gives a constant concentration of enzyme molecules.</td>
</tr>
<tr>
<td></td>
<td>If using enzymes in living tissue, it is important that you take accurate measurements of the mass of the tissue.</td>
<td>In living tissue you must assume that all pieces of tissue contain the number of enzyme molecules.</td>
</tr>
<tr>
<td></td>
<td>If you are using whole pieces of living tissue, it is important that you keep the surface area constant as well as the mass.</td>
<td>The number of enzyme molecules in contact with substrate molecules will affect reaction rate. If the surface area of the pieces of tissue are different, the number of enzyme molecules exposed directly to the substrate will also be different.</td>
</tr>
<tr>
<td>Substrate Concentration</td>
<td>Use accurately measured volumes or mass of substrate in the solution</td>
<td>Reaction rate depends on the concentration of the substrate.</td>
</tr>
</tbody>
</table>

Time scales, rate and control tests

There are two main ways of measuring the reaction rates

1. Start the reaction, then measure the concentration of product (or substrate used) after a fixed period of time.
2. Monitor the reaction by taking readings of product formation (or substrate used) at a number of time intervals.

Reaction rate can be calculated by;
- Rate = 1/time

Control tests are often necessary to include. These are usually done with water instead of the enzyme. This proves that it is the enzyme action rather than anything else that affects the reaction rate.
The importance of repeats

- When investigating the effect of enzymes, you should repeat the investigation at least three times.
- Repeating the investigation will increase reliability of the results and helps to identify anomalous results.

Equilibration

- It is essential that enzymes and substrates are at the same temperature before the investigation begins and they come into contact with each other.
- Place the substrate and enzymes separately in a waterbath set to the correct temperature before the investigation, will ensure that both the substrate and the enzyme are at the correct temperature before the reaction starts.

Experimental Investigations – See OCR AS Biology Activities 23 – 28

**Explain the effects of competitive and non-competitive inhibitors on the rate of enzyme-controlled reactions, with reference to both reversible and non-reversible inhibitors.**

Inhibitors

- Any substance or molecule that slows down the rate of an enzyme-controlled reaction by affecting the enzyme molecule in some way.
- Some inhibitors affect only one type of enzyme molecule
- Some inhibitors affect many types of enzyme molecules
- Some inhibitors affect the enzyme’s active site while other affect another part of the enzyme molecule.

Competitive inhibitors

- Have a similar shape to the substrate
- They can occupy the active site of the enzyme, forming an enzyme-inhibitor complex
- These do no lead to the formation of the product as the inhibitor is not identical to the substrate.
- When an inhibitor is in the active site the enzyme reaction is inhibited as a substrate molecule cannot occupy the active site at the same time.
- This reduces the number of enzyme-substrate complexes that form.
- The level of inhibition depends on the concentrations of inhibitor and substrate. Where the numbers of substrate molecules are increased, the level of inhibition decreases because a substrate molecule is more likely then an inhibitor molecule to collide with an active site.
Non-competitive inhibitors

- Non-competitive inhibitors do not compete with the substrate for the enzyme’s active site.
- They attach to the enzyme in a region other than the active site. This site is known as an allosteric site.
- This attachment distorts the enzyme’s tertiary structure, and hence changes the shape of the active site.
- This results in the substrate not being able to bind to the active site, so enzyme-substrate complexes can form and so the reaction rate decreases.
- The level of inhibition depends on the number of the inhibitor molecules present.
- The reaction can stop completely if there is enough inhibitor molecules present.
- Increasing the substrate concentration will have no effect on this form of inhibition.
Reversible & Non-reversible inhibitors

- Generally competitive inhibitors do not bind permanently to the active site.
- The binding is usually temporary and competitive inhibitors are often referred to as reversible as removal of the inhibitor from the reacting mixture leaves the enzyme molecules unaffected.
- Many non-competitive inhibitors bind permanently to enzyme molecules.
- This inhibition is not reversible, and any enzyme molecules bound by inhibitor molecules are effectively denatured.

Experimental Investigations – See OCR AS Biology Activity 29

**Explain the importance of cofactors and coenzymes in enzyme-controlled reactions.**

Inorganic ion Cofactors

- In some enzyme-controlled reactions, the presence of certain ions can increase the reaction rate.
- Ions can combine with either the substrate or the enzyme, and this binding makes the enzyme-substrate complex form more easily.
- This happens because the ion can affect the charge distribution and in some case the shape of the enzyme-substrate complex
- E.g. Amylase requires chloride ions to successfully catalyse the breakdown of starch to maltose.

Coenzymes

- These are small, organic, non-protein molecules
- They bind to the active site temporarily at the same time or just before the substrate.
- They like the substrates are changed by the reaction
- Unlike substrates they are recycled.
- E.g. Vit B₃ (nicotinamide) role in respiration

Prosthetic groups

- A co-enzyme that is a permanent part of the enzyme.
- Vital to the functioning of the enzyme
- Contribute to the final 3D shape of the enzyme, including its charges.
- E.g. The enzyme carbonic anhydrase contains a zinc-based prosthetic group
State that metabolic poisons may be enzyme inhibitors, and describe the action of one named inhibitor.

Potassium Cyanide – Metabolic poison
- Non-competitive inhibitor for cytochrome oxidase (an electron transport protein in mitochondria)
- It decreases the use of oxygen and hence the amount of ATP synthesis
- Aerobic respiration ceases and anaerobic respiration leads to a build up of lactic acid in the blood.
- 100 – 200mg of cyanide can cause unconsciousness within 10 seconds, a coma within 45 minutes and death within two hours.

Ethylene glycol
- Ethylene glycol is found in antifreeze which is used in car engines.
- Ethylene glycol is itself not poisonous, but if taken in large quantities it can be broken down into Oxalic acid which is extremely poisonous and can lead to death.
- Ethylene glycol is broken down by the enzyme alcohol dehydrogenase into Oxalic acid.
- If someone is suspected of taking ethylene glycol then they are given large quantities of ethanol.
- This leads to severe but less likely to be fatal – alcohol intoxication.
- Ethanol acts as a competitive inhibitor to alcohol dehydrogenase.
- This reduces the production of Oxalic acid and allows ethylene glycol to be excreted harmlessly.

Snake Venom
Phosphodiesterases
- Interfere with the prey’s heart, causing a drop in blood pressure

Hyaluronidase
- A digestive enzyme which breaks down connective tissue allowing the toxins to penetrate tissues quickly

ATP-ases
- Breakdown ATP, disrupting the prey’s energy

Inhibitor for Acetyl Cholinesterase
- Inhibiting acetyl cholinesterase, results in inhibiting nerve transmission, resulting in paralysis.
State that some medicinal drugs work by inhibiting the activity of enzymes.

Chemicals that act as protease inhibitors (competitive inhibitors)
- Are used to treat HIV infections
- These chemicals prevent viruses from replicating by inhibiting the activity of proteases, which are required by the viruses to build new protein coats.

Penicillin
- Penicillin is an inhibitor for bacterial enzymes that forms cross-links in the bacterial cell wall of some bacteria
- Preventing bacterial reproduction.
5 Carbohydrates

Carbohydrates contain;

- Carbon
- Hydrogen
- Oxygen

Carbohydrates are given their name as each carbon is hydrated with a water molecule.

\[ C_n(H_2O)_n \]

Why do we need carbohydrates?

- Energy source - glucose in respiration
- Energy store - Starch
- Structure - cellulose

There are three types of sugars, grouped according to the amount of carbons they have

- 3 carbons - Triose sugars
- 5 carbons - Pentose sugars E.g. nucleotides
- 6 sugars - Hexose sugars (Most common sugars)

Pentose and hexose sugars tend to occur in nature as ring structures

What are the monomers of carbohydrates? Monosaccharides

Monosaccharides contain between 3 - 6 carbon atoms

- They all have the same properties;
  - Are soluble in water
  - Are sweet tasting
  - Can form crystals

- Disaccharides also have these properties.
Describe, with the aid of diagrams, the molecular structure of alpha-glucose as an example of a monosaccharide carbohydrate.
State the structural difference between alpha- and beta-glucose.

Glucose rings can form in two ways;

- Alpha (α) glucose
- Beta (β) glucose

They are the same molecule but have slightly different shapes
Different shaped forms of the same molecule are called isomers.

Alpha (α) Glucose
- Used in respiration as an energy source.
- Animals and plants have enzymes that can breakdown alpha glucose so that the energy can be released.

Beta (β) Glucose
- Animals and plants do not have the enzymes that can breakdown beta glucose.
- Beta glucose can therefore not be respired and so cannot be used for energy.
- Beta glucose is used for creating plant structures (cellulose).
Describe, with the aid of diagrams, the formation and breakage of glycosidic bonds in the synthesis and hydrolysis of a disaccharide (maltose) and a polysaccharide (amylose).

![Diagram of glycosidic bonds](image)

\[
\text{Glucose} + \text{Glucose} \rightarrow \text{Maltose} \rightarrow \text{Amylose}
\]

(Monosaccharide) (Monosaccharide) (Disaccharides) (Polysaccharide)

**Compare and contrast the structure and functions of starch (amylose) and cellulose.**

**Amylose (starch)**
- Made of alpha glucose monomers
- Amylose consists of many thousand glucose molecules joined together by 1,4 glycosidic bonds.
- This type of glycosidic bonding creates long chains.
- The long amylose chains coil into springs due to the shape of the glucose molecules and the glycosidic bonding.
- This makes the amylose molecule quite compact.
- Iodine molecules can fit into this coiled spring structure, causing it to change from yellow/brown to blue/black (starch tests).
- This molecule is not water soluble or sweet tasting.

**Cellulose**
- Made up entirely of beta glucose monomers
- This creates long straight chains rather than coiled spring like chains with alpha glucose
- 1 cellulose chain can contain 10,000 beta glucose monomers
- Several hundred cellulose chains are held together by hydrogen bonds to form cellulose molecules.
- 60-70 cellulose molecules are held together by hydrogen bonds to form a microfibril.
- Many microfibrils are held together to form a macrofibril
- Macrofibrils have great mechanical strength (close to that of steel)
- Found in plant cell walls
- Insoluble in water
Describe, with the aid of diagrams, the structure of glycogen.

Glycogen (Energy storage polysaccharide in animals)

- Sometimes referred to as animal starch
- Identical to starch in that it is made of alpha glucose monomers
- Large molecule that can be hydrolysed to release large quantities of glucose for respiration.
- Glycogen is slightly different to starch in that it has shorter 1,4 glycosidic bonded chains, and have a higher quantity of 1,6 glycosidic bonding creating many side chains.
- This high proportion of branching means that a lot of glucose can be released at the same time or easily and quickly stored in the glycogen molecule.
- Insoluble and so does not affect the water potential of the cell.
Explain how the structures of glucose, starch (amylose), glycogen and cellulose molecules relate to their functions in living organisms.

Amylose (starch)
- Made of alpha glucose monomers
- Amylose consists of many thousand glucose molecules joined together by 1,4 glycosidic bonds.
- This type of glycosidic bonding creates long chains.
- The long amylose chains coil into springs due to the shape of the glucose molecules and the glycosidic bonding.
- This makes the amylose molecule quite compact.
- Iodine molecules can fit into this coiled spring structure, causing it to change from yellow/brown to blue/black (starch tests).
- This molecule is not water soluble or sweet tasting.

Amylopectin (starch)
- Made of alpha glucose monomers
- Very similar to amylose molecule except it is a branched molecule.
- Has 1,4 glycosidic bonding as well as 1,6 glycosidic bonding (forms the branch joints).
- This makes the amylopectin molecule very compact.
- This molecule is not water soluble or sweet tasting.

Starch (Energy storage polysaccharide in plants)
- Made of alpha glucose monomers
- Starch is a large molecule made of both amylose and amylopectin.
- Insoluble and so does not affect the water potential of the cell.
- Forms granules.
Glycogen (Energy storage polysaccharide in animals)

- Sometimes referred to as animal starch
- Identical to starch in that it is made of alpha glucose monomers
- Large molecule that can be hydrolysed to release large quantities of glucose for respiration.
- Glycogen is slightly different to starch in that it has shorter 1,4 glycosidic bonded chains, and have a higher quantity of 1,6 glycosidic bonding creating many side chains.
- This high proportion of branching means that a lot of glucose can be released at the same time or easily and quickly stored in the glycogen molecule.
- Insoluble and so does not affect the water potential of the cell
- Forms granules
6 Lipids

- 5% of organic matter of a cell
- C, H, O (O in lower levels than Carbohydrates)
- Insoluble in water
- Room temperature
  - Solid lipid = Fat
  - Liquid lipid = Oil

Functions of Lipids
- Waterproofing
- Energy source
  - Used directly in Respiration
- Energy Store
  - In fat stores (Adipose cells)
- Membranes
- Insulation
  - Blubber & Insulation of nerve impulses - Myelin Sheath.
- Protection
  - Waxy cuticle on leaves
- Hormones
  - Steroids

There are two main molecules that are found in all fats and oils used for energy storage, supply and membranes.
- Glycerol
- Fatty acids

Glycerol
- Glycerol molecules are always the same in all lipids.
- 3 carbon molecule with 3 free OH groups.
Fatty Acids

- Fatty acids consist of an acid group and a hydrocarbon chain.
- The hydrocarbon chain can be anything from 2 - 20 carbons in length
- Most common fatty acids are around 18 carbons long
- Like amino acids there are some fatty acids that humans cannot make. These are called **essential Fatty acids** and must be ingested complete as part of our diet.

**Acid Group**

```
O=C
H    H    H    H    H    H    H    H    H    H    H    H    H    H    H    H    H    H    H    H
H    H    H    H    H    H    H    H    H    H    H    H    H    H    H    H    H    H    H    H
```

Saturated and unsaturated fatty acids

- The terms saturated and unsaturated are referring to the number of carbon atoms in the hydrocarbon chain that have a bound Hydrogen atom.
- The more saturated the hydrocarbon chain is with hydrogen atoms the more saturated it is, and vice versa.

**Saturated**

- Saturated fats are associated with poor diet.
- Many animal lipids contain a lot of saturated fatty acids. They are solid at room temperature and so referred to as **fats**. E.g. Lard

**Unsaturated**

- Unsaturated fatty acids have C=C bonds and so fewer hydrogen atoms can bind.
- If a fatty acid has only 1 C=C bond then it is referred to as a monounsaturated fatty acid, and if it has more than 2 C=C bonds it is referred to as a polyunsaturated fatty acid.
- Introducing C=C bonds changes the shape of the hydrocarbon chain. It pushes the molecules in the lipid apart making them more fluid.
- Many plant lipids contain a lot of unsaturated fatty acids. These are liquid at room temperature and referred to as oils.
Compare, with the aid of diagrams, the structure of a triglyceride and a phospholipid.

& Explain how the structures of triglyceride, phospholipid and cholesterol molecules relate to their functions in living organisms.

**Triglycerides**

- Consists of:
  - 1 Glycerol
  - 3 fatty acids
- They are joined by the acid end of the fatty acid to the OH group of glycerol by **Ester bonds** (covalent bonds) from condensation reactions.
- **Monoglyceride** is the term for when 1 fatty acid attaches to 1 glycerol.
- Insoluble in water and so are described as being **Hydrophobic**.
- As triglycerides are insoluble they do not affect the water potential of a cell
- They are used for protection, insulation and energy from respiration.
Phospholipid
- Consists of;
  - 1 Glycerol
  - 2 Fatty acids
  - 1 Phosphate group (instead of the 3rd fatty acid)
- Phosphate group is **Hydrophilic**
- Fatty acids are **Hydrophobic**
- Used for cell membranes. Hydrophilic and hydrophobic parts allow arrangement of the bi-layer.
- The bi-layer has no bonds and so has fluidity for molecule movements

![Phospholipid Diagram](image)

Cholesterol
- This lipid is not made from **fatty acids** and **Glycerol**.
- Cholesterol is a **small** molecule made of 4 carbon based rings
- Due to the small, narrow shape of cholesterol and its **hydrophobic** nature it can sit amongst the hydrophobic hydrocarbon chains of the phospholipids in membranes
- This allows cholesterol to influence the fluidity and strength of the membrane.
- Cholesterol is used for the production of steroid Hormones
  - Testosterone
  - Oestrogen
  - Vitamin D

  The lipid nature of these hormones allow them to pass freely through the phospholipid bilayer to reach target receptors. The receptor is usually in the nucleus so they also can pass through the nuclear envelope.
7 Nucleic Acids

DNA & RNA are made from nucleic acids

DNA (Deoxyribonucleic acid)
- Double stranded molecule twisted into a ‘Double Helix’
- Found in the nucleus of eukaryotic cells
- Holds the genetic code

RNA (Ribonucleic acid)
- Single stranded molecule
- Found in 3 different forms
  - mRNA - messenger RNA
  - rRNA - ribosomal RNA
  - tRNA - transfer RNA

State that deoxyribonucleic acid (DNA) is a polynucleotide, usually double-stranded, made up of nucleotides containing the bases adenine (A), thymine (T), cytosine (C) and guanine (G).

- Monomers of nucleic acids
  - Made up of;
    1. Phosphate group
    1. Sugar molecule (Pentose)
    1. Organic nitrogenous base
  - These 3 components are joined through covalent bonds

- There are only 5 different nucleotides from which DNA & RNA are constructed.
- Each nucleotide are similar in that they all have a phosphate group and a pentose sugar (deoxyribose in DNA).
- The organic nitrogenous bases create the diversity in nucleotides.
  - Pyrimidines
    - Thymine (DNA), Cytosine (DNA & RNA) & Uracil (RNA)
    - Smaller than purines
  - Purines
    - Adenine (DNA & RNA) & Guanine (DNA & RNA)
    - Larger than pyrimidines
State that ribonucleic acid (RNA) is a polynucleotide, usually single-stranded, made up of nucleotides containing the bases adenine (A), uracil (U), cytosine (C) and guanine (G).

- Monomers of nucleic acids
  - Made up of:
    1. Phosphate group
    2. Sugar molecule (Pentose)
    3. Organic nitrogenous base
  - These 3 components are joined through covalent bonds

- There are only 5 different nucleotides from which DNA & RNA are constructed.
- Each nucleotide are similar in that they all have a phosphate group and a pentose sugar (ribose in RNA).
- The organic nitrogenous bases create the diversity in nucleotides.
  - Pyrimidines
    - Cytosine (RNA) & Uracil (RNA)
    - Smaller than purines
  - Purines
    - Adenine (RNA) & Guanine (RNA)
    - Larger than pyrimidines
Describe, with the aid of diagrams, how hydrogen bonding between complementary base pairs (A-T, G-C) on two anti-parallel DNA polynucleotides leads to the formation of a DNA molecule, and how the twisting of DNA produces its *double-helix* shape.

**Hydrogen bonding between nucleotides**

Hydrogen bonding takes place between an adenine-thymine base pair.

The two molecules must be correctly orientated for hydrogen bonding to occur.

Two helices are held in place by hydrogen-bonding to form DNA.
DNA has the structure of a twisted ladder called double helix.

Base pairing of the nitrogenous bases occurs through hydrogen bonds. These form the rungs of the ladder.

DNA has 2 nucleic acid chains which form the sides of the ladder.

This structure makes DNA very stable.

The side chains of the double helix run in anti-parallel with the nitrogenous bases pointing inwards.

The chains are always the same distance apart, as bases, when joined in pairs are the same length.

A Purine always binds with a pyrimidine.

Adenine always binds with Thymine with 2 hydrogen bonds

Guanine always binds with Cytosine with 3 hydrogen bonds.

Base pairing is referred to as being complimentary. A is complimentary to T as G is to C.

Outline, with the aid of diagrams, how DNA replicates semi-conservatively, with reference to the role of DNA polymerase.

In the semi-conservative model, the two parental strands separate and each makes a copy of itself. After one round of replication, the two daughter molecules each comprises one old and one new strand. Note that after two rounds, two of the DNA molecules consist only of new material, while the other two contain one old and one new strand.
In the **conservative** model, the parental molecule directs synthesis of an entirely new double-stranded molecule, such that after one round of replication, one molecule is conserved as two old strands. This is repeated in the second round.

In the **dispersive** model, material in the two parental strands is distributed more or less randomly between two daughter molecules. In the model shown here, old material is distributed symmetrically between the two daughters molecules. Other distributions are possible.

The semi-conservative model is the intuitively appealing model, because separation of the two strands provides two templates, each of which carries all the information of the original molecule. It also turns out to be the correct one.

**Stages of Replication**
- The double helix untwists
- The hydrogen bonds break and the DNA unzips exposing the bases
- Free DNA nucleotides are bonded to the exposed bases according to base pairing rules (A=T & G=C).
- Covalent bonds form joining the phosphates and sugars to the side chains.
- This continues until two new DNA molecules exist - each an exact copy of the original.

**Forming a nucleic Acid**
- The phosphate of 1 nucleotide joins to a sugar of a 2nd nucleotide through a covalent bond.
- This continues creating a chain with a sugar at one end (3’ end) and a phosphate at the other (5’ end).
- Chains of nucleotides joined together are referred to as nucleic acids.
2.1

- When nucleotides join to form nucleic acids they only bind nucleotides with the same sugar.
- **DNA** (deoxyribonucleic acids) only joins nucleotides with **Deoxyribose sugars**
- **RNA** (ribonucleic acids) only joins nucleotides with **Ribose sugars**

State that a gene is a sequence of DNA nucleotides that codes for a polypeptide.

A gene is a sequence of DNA nucleotides which code for a polypeptide.

The specific sequence of DNA nucleotides will create a specific sequence of amino acids in the polypeptide molecule.

The specific sequence of amino acids will determine the structure of the polypeptide secondary and ultimately tertiary structure of the polypeptide.

Outline the roles of DNA and RNA in living organisms (the concept of protein synthesis must be considered in outline only).

**Transcription**

DNA code is copied onto the mRNA

**Translation**

mRNA is translated into a sequence of amino acids
**Gout**

- Purine nitrogenous bases are broken down in the liver and Uric acid is produced and excreted in urine.
- Uric acid is insoluble at lower temperatures and forms crystals.
- Extremities of the body have low temperatures and so crystals are deposited in joints at extremities such as toes.
- Joints become very swollen and painful.

**8 Food Tests**

Biological molecules are tested for their presence using qualitative methods.

**Describe how to carry out chemical tests to identify the presence of the following molecules: protein (biuret test), reducing and non-reducing sugars (Benedict’s test), starch (iodine solution), and lipids (emulsion test).**

Experimental Investigations – See OCR AS Biology Activities 19 - 22

Follow the guide sheets to complete the tests for biological molecules;

- Starch
- Reducing sugars (most mono & Disacharides)
- Non-Reducing sugars (Sucrose)
- Proteins
- Lipids
Describe how the concentration of glucose in a solution may be determined using colorimetry.

- Using standard / known, concentration (of reducing sugar)
- Heat with Benedict's solution
- Use excess Benedict's solution
- Solution turns from blue, to green / yellow / orange / brown / brick red.
- Remove the precipitate
- Calibrate the colourimeter to zero
- Using a blank / water / unreacted benedicts solution
- Use red / orange filter
- Read the transmission / absorbance
- More transmission / less absorbance = more sugar present
- Obtain a calibration curve
- By plotting the transmission / absorbance against sugar concentration
- Carryout a reading for the unknown concentration of sugar
- Read the concentration of the graph using the transmission / absorbance reading
- If using a non-reducing sugar then follow procedure to obtain a reducing sugar before heating with benedicts.
Questions

1. The figure below represents a water molecule.

Water molecules are polar. As a result, they attract each other.

**Draw a second water molecule on the figure above.**

Your drawing should show:

- the bond(s) between the two molecules
- the name of the bond
- the charges on each atom.

[Total 3 marks]

2. Water is important in many biological reactions.

Complete the table below by writing an appropriate term next to each description.

<table>
<thead>
<tr>
<th>description</th>
<th>term</th>
</tr>
</thead>
<tbody>
<tr>
<td>the type of reaction that occurs when water is added to break a bond in a molecule</td>
<td></td>
</tr>
<tr>
<td>the phosphate group of a phospholipid that readily attracts water molecules</td>
<td></td>
</tr>
</tbody>
</table>

[Total 2 marks]
3. (a) Amino acids are the basic building blocks for proteins. The figure below shows the amino acid cysteine.

![Cysteine Structure]

(i) Complete the table by selecting the letter, J, K, L or M, that represents the following groups in cysteine.

<table>
<thead>
<tr>
<th>group</th>
<th>letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>carboxyl</td>
<td></td>
</tr>
<tr>
<td>R group</td>
<td></td>
</tr>
<tr>
<td>amine group</td>
<td></td>
</tr>
</tbody>
</table>

(ii) The primary structure of a protein consists of a chain of amino acids.

Describe how a second amino acid would bond to cysteine in forming the primary structure of a protein.

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[3]
(b) Each amino acid has a different R group.

Describe how these R groups can interact to determine the **tertiary** structure of a protein.

---

4. The diagram below is a drawing of an alveolus together with an associated blood capillary.

Oxygen diffuses from the alveolus into cell X. Cell X carries oxygen around the body in the blood stream.
2.1

(i) **Name** the compound inside cell X that combines with oxygen.

............................................................................................................................................

[1]

(ii) **Name** the metal ion required for the formation of the compound in (i).

............................................................................................................................................

[1]

[Total 2 marks]

5. The diagram below represents part of a collagen molecule.
(i) Collagen is a protein made of three chains of amino acids, twisted together like a rope. State the name given to a chain of amino acids.

...............................................................................................................................................................

(ii) Name the amino acid that forms a high proportion of the collagen molecule.

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(iii) Collagen has tremendous strength, having about one quarter of the tensile strength of mild steel.
Using information given in the diagram to help you, explain how the structure of collagen contributes to its strength.

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6. State the word or phrase that best describes a region on the surface of an enzyme molecule where a substrate can bind.

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[Total 4 marks]
7. State the word or phrase that best describes the energy that must be provided for a chemical reaction to take place.

..............................................................................................................................................

[Total 1 mark]

8. The diagram below represents an enzyme and a number of other molecules.

(a) Label on the diagram the active site of the enzyme.

(b) Write the letter of the molecule that is most likely to be the substrate for this enzyme.

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[1]
(c) Use the information in the diagram to explain enzyme specificity.

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[3]

(d) One hypothesis of the mechanism of enzyme action is the ‘lock and key’ hypothesis. Another hypothesis, the ‘induced fit’ hypothesis, involves the enzyme changing shape slightly to allow the substrate to fit perfectly. The substrate also changes shape slightly.

Suggest how the substrate changing shape slightly will assist enzyme action.

..........................................................................................................................

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[1]

[Total 6 marks]

9. A sucrose molecule is a carbohydrate molecule made by joining a glucose unit to a fructose unit.

(i) Name the bond that joins the units in a molecule of sucrose.

..........................................................................................................................

[1]

(ii) Name the type of reaction that breaks this bond.

..........................................................................................................................

[1]

[Total 2 marks]
10. Complete the table below, comparing gum arabic with some other polysaccharides.

<table>
<thead>
<tr>
<th></th>
<th>gum arabic</th>
<th>amylase</th>
<th>cellulose</th>
<th>glycogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>branched structure</td>
<td>yes</td>
<td></td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>heteropolysaccharide</td>
<td>yes</td>
<td></td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>found in animals/plants</td>
<td>plants</td>
<td></td>
<td>plants</td>
<td></td>
</tr>
<tr>
<td>function in organism</td>
<td>healing cuts</td>
<td></td>
<td>energy store</td>
<td></td>
</tr>
</tbody>
</table>

[Total 4 marks]

11. State the word or phrase that best describes a length of DNA that codes for a particular polypeptide.

.......................................................................................................................................................

[Total 1 mark]
12. Complete the following passage by inserting the most appropriate terms in the spaces provided.

Cellulose and collagen are both fibrous molecules. Cellulose, a carbohydrate, is the main component of the ……………… …………… in plants.

Cellulose is made of chains of many …… glucose molecules which are joined by 1,4 …………………………… bonds. Each glucose molecule is rotated ……………° relative to its neighbour, resulting in a ………………………… chain. Adjacent chains are held to one another by ………………………… bonds.

[Total 6 marks]

13. Deoxyribonucleic acid (DNA) is a polynucleotide.

(i) State how many different types of nucleotide are found in DNA.

.................................................................................................................................

[1]

(ii) Name the components of one of these nucleotides.

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[3]

[Total 4 marks]
14. DNA replication is described as semi-conservative. Below is a diagram showing the replication of a DNA molecule.

Explain what is meant by the term *semi-conservative replication*.

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[Total 3 marks]
15. State three ways in which the structure of DNA differs from that of RNA.

1 .................................................................................................................................

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2 .................................................................................................................................

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3 .................................................................................................................................

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[Total 3 marks]

16. A student was carrying out tests to determine which biological molecules were present in a food sample.

(a) (i) Describe a test that the student could carry out to discover whether this sample contained a lipid.

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[2]

(ii) State what would be seen if a lipid was present.

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[1]
(b) Describe how the **structure** of a phospholipid differs from that of a triglyceride.

You may use the space below for a diagram to help your answer.

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[3]

(c) (i) Describe a test that the student could carry out to discover whether the food sample contained protein.

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[1]

(ii) State what would be seen if protein was present.

........................................................................................................................................

[1]

[Total 8 marks]
17. (i) Describe the test that is used to indicate the presence of a reducing sugar, such as glucose, and state the observation that would be made if glucose was present.

description of test
......................................................................................................................................................
......................................................................................................................................................
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......................................................................................................................................................

observation if glucose is present
......................................................................................................................................................
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[3]

(ii) No change is observed if sucrose, a non-reducing sugar, is tested for in this way. The bond between the glucose and fructose units must first be broken. The test for a reducing sugar can then be carried out.

Describe how this bond can be broken chemically before carrying out the test for a reducing sugar.
......................................................................................................................................................
......................................................................................................................................................

[1]

[Total 4 marks]
The activity of an enzyme can be measured by testing for the concentration of its product at regular intervals.

Describe how the concentration of a reducing sugar can be measured using a colorimeter.

[Total 6 marks]
(ii) No change is observed if sucrose, a non-reducing sugar, is tested for in this way. The bond between the glucose and fructose units must first be broken. The test for a reducing sugar can then be carried out.

Describe how this bond can be broken chemically before carrying out the test for a reducing sugar.

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[1]

[Total 4 marks]