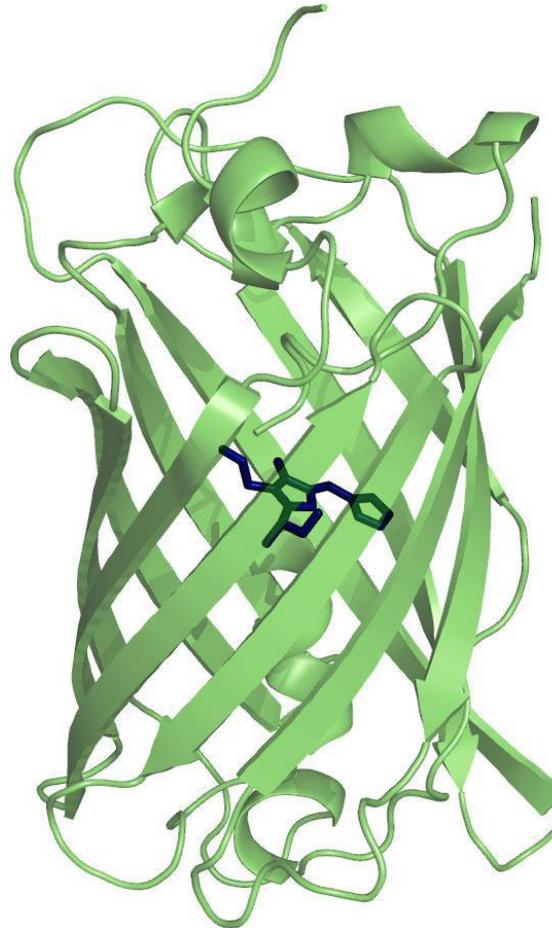


Proteins & Membranes



Material Covered

Structure of Proteins

1. Protein Structure
2. Globular and Fibrous Proteins

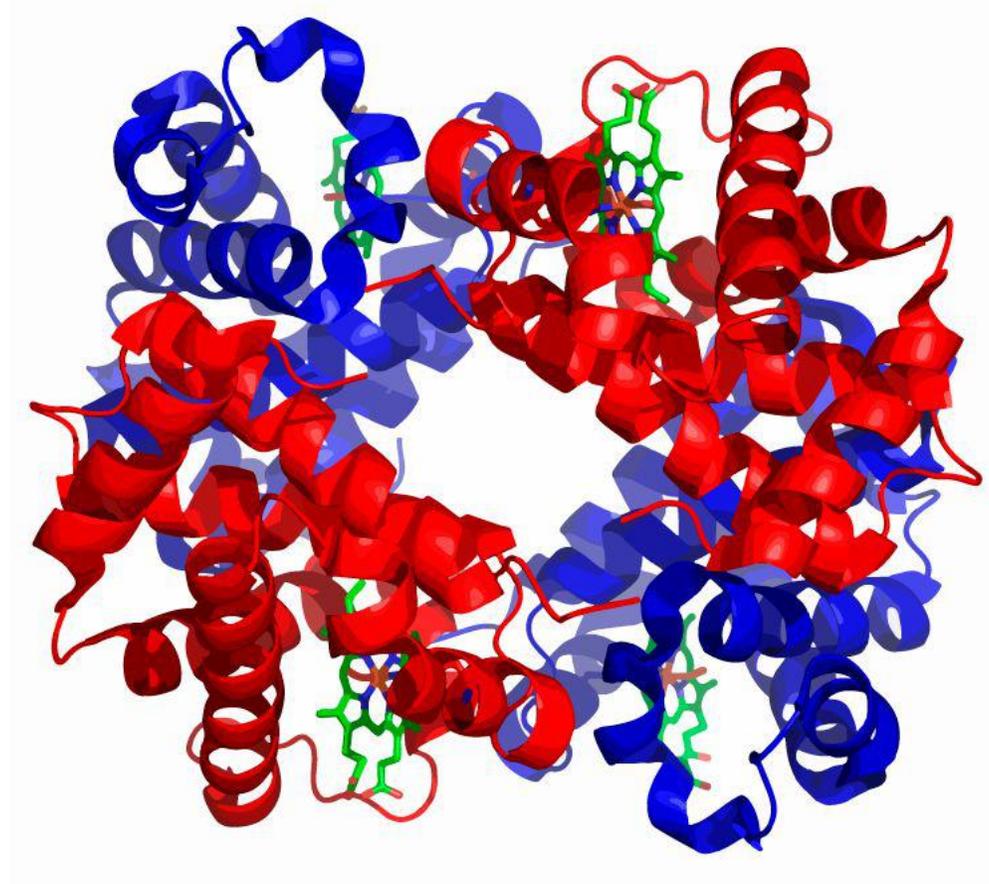
Function of Proteins

1. Membrane Proteins
2. Transport
3. Enzymes and Inhibition

Examples of Proteins

1. Haemoglobin
2. Antibodies

Structure of Proteins



Specification Points

AQA

3.1.4.1 General properties of proteins

Content	Opportunities for skills development
<p>Amino acids are the monomers from which proteins are made. The general structure of an amino acid as:</p> $\begin{array}{c} \text{R} \\ \\ \text{H}_2\text{N} - \text{C} - \text{COOH} \\ \\ \text{H} \end{array}$ <p>where NH₂ represents an amine group, COOH represents a carboxyl group and R represents a side chain. The twenty amino acids that are common in all organisms differ only in their side group.</p> <p>A condensation reaction between two amino acids forms a peptide bond.</p> <ul style="list-style-type: none"> Dipeptides are formed by the condensation of two amino acids. Polypeptides are formed by the condensation of many amino acids. <p>A functional protein may contain one or more polypeptides.</p> <p>The role of hydrogen bonds, ionic bonds and disulfide bridges in the structure of proteins.</p> <p>Proteins have a variety of functions within all living organisms. The relationship between primary, secondary, tertiary and quaternary structure, and protein function.</p> <p>The biuret test for proteins.</p> <p>Students should be able to relate the structure of proteins to properties of proteins named throughout the specification.</p>	<p>AT f</p> <p>Students could use, and interpret the results of, a biuret test for proteins.</p> <p>AT g</p> <p>Students could use chromatography with known standard solutions, to separate a mixture of amino acids and identify their components.</p>

OCR

2.1.2 Biological molecules

Learning outcomes	Additional guidance
(m) the levels of protein structure	To include primary, secondary, tertiary and quaternary structure AND hydrogen bonding, hydrophobic and hydrophilic interactions, disulfide bonds and ionic bonds.
(n) the structure and function of globular proteins including a conjugated protein	To include haemoglobin as an example of a conjugated protein (globular protein with a prosthetic group), a named enzyme and insulin. An opportunity to use computer modelling to investigate the levels of protein structure within the molecule. PAG10
(o) the properties and functions of fibrous proteins	To include collagen, keratin and elastin (no details of structure are required).

Specification Points

Edexcel A

Topic 2: Genes and Health

Students should:

- 2.9 i) Know the basic structure of an amino acid (structures of specific amino acids are not required).
- 2.9 ii) Understand the formation of polypeptides and proteins (amino acid monomers linked by peptide bonds in condensation reactions).
- 2.9 iii) Understand the significance of a protein's primary structure in determining its three-dimensional structure and properties (globular and fibrous proteins and the types of bonds involved in its three-dimensional structure).
- iv) Know the molecular structure of a globular protein and a fibrous protein and understand how their structures relate to their functions (including haemoglobin and collagen).

Edexcel B

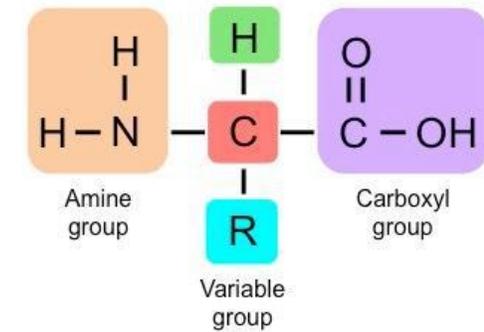
Topic 1: Biological Molecules

Students should:

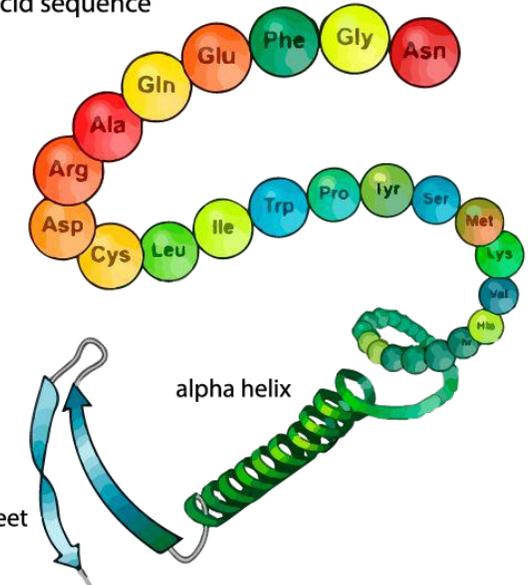
- 1.3 Proteins**
- ii Understand the formation of polypeptides and proteins (as amino acid monomers linked by peptide bonds in condensation reactions).
- 1.3 Proteins**
- iii Understand the role of ionic, hydrogen and disulfide bonding in the structure of proteins.
- iv Understand the significance of the primary, secondary, tertiary and quaternary structure of a protein in determining the properties of fibrous and globular proteins, including collagen and haemoglobin.

Primary and Secondary Structure

- **Amino acids:** each amino acid contains an **amine group** (NH_2), **carboxyl group** (COOH) and a **variable (R) group** – all joined to a **central carbon** atom
- **Primary structure:** chains of amino acids linked together by **peptide bonds** formed by **condensation reactions** – producing **polypeptides**
- **Secondary structure:** the folding of the polypeptide chain into **alpha helices** and **beta sheets** due to **hydrogen bonds**



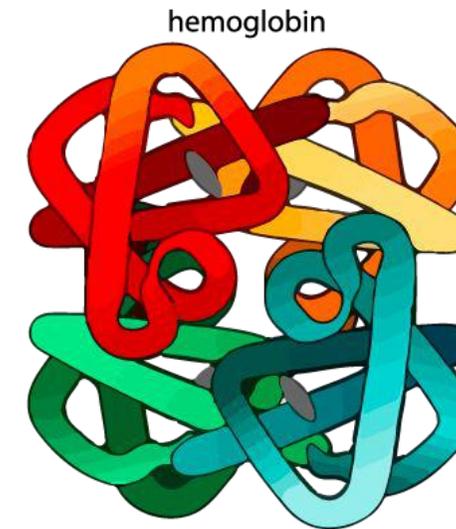
Primary structure
amino acid sequence



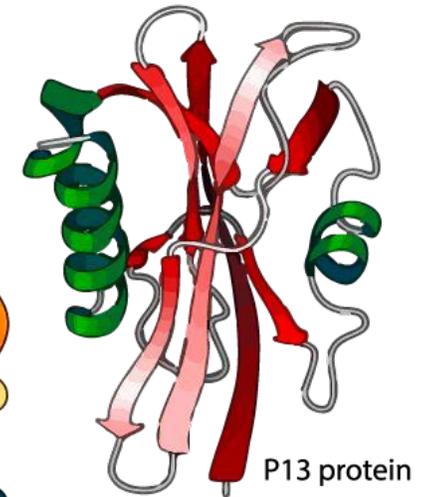
Secondary structure
regular sub-structures

Tertiary and Quaternary Structure

- **Tertiary structure:** the **overall 3-D shape** of the **polypeptide**
- The tertiary structure is formed by: **hydrophobic interactions, ionic bonds, hydrogen bonds, and disulfide bridges**
- **Quaternary structure:** the **overall 3-D shape** of **more than one polypeptide** in a protein as well as **prosthetic groups**
- **Not all** proteins have a **quaternary structure**



Quaternary structure
complex of protein molecules



Tertiary structure
three-dimensional structure

Exemplar Exam Question - Statement

1) Polypeptides are polymers of amino acids. These long chains fold into complex shapes and are responsible for many functions within the body.

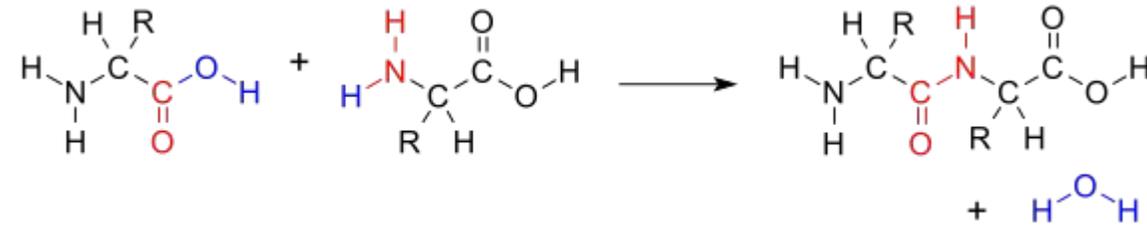
State the type of reaction which is required to form bonds between adjacent amino acid residues.

[1 mark]

Command: One/two word answer

Direction: Type of reaction which **forms** bonds

Context: **Protein structure**, “long chains” suggest a focus on **primary structure**



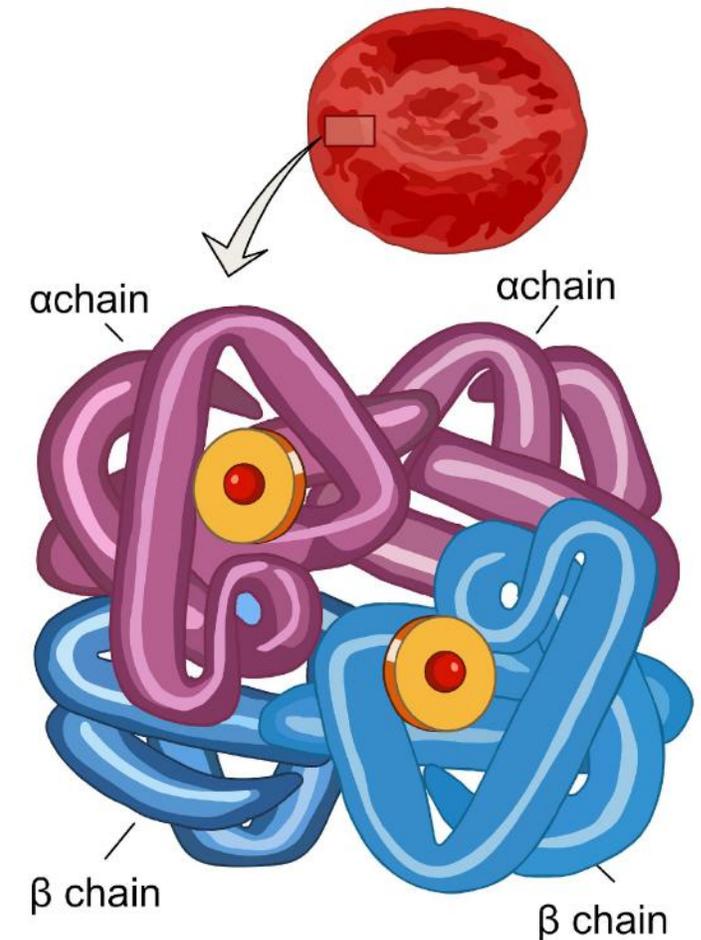
1) Polypeptides are polymers of amino acids. These long chains fold into complex shapes and are responsible for many functions within the body.

State the type of reaction which is required to form bonds between adjacent amino acid residues.

[1 mark]

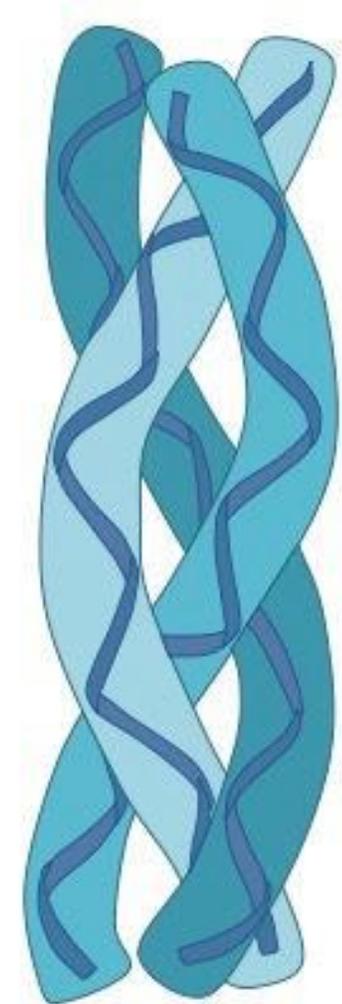
Globular Proteins

- Globular proteins are **spherical** in shape and **soluble** in water
- The **hydrophobic R groups** of the residues face in towards the **centre** of the protein and **hydrophilic R groups** are on the **outside**
- Their **specific shapes** allow them to function as **enzymes, hormones** (insulin) and **transport proteins** (haemoglobin)
- They can bind **cofactors** and may contain **prosthetic groups**



Fibrous Proteins

- Fibrous proteins have **regular, repetitive sequences** and are usually **insoluble** in water
- They form **fibres** which have a **structural** function
- The primary structure is a **long unbranched chain** which is tightly **wound**, eventually with other fibres to form a 'rope'
- Examples include **collagen, elastin** and **keratin**



Exemplar Exam Question – Simple Explanatory

2) Collagen is a fibrous protein which forms the walls of blood vessels, whilst haemoglobin is a globular protein which travels through the blood vessels.

Give two ways in which the properties of globular and fibrous proteins differ.

[2 marks]

Command: Provide **two** reasons

Direction: **Contrast** globular and fibrous proteins

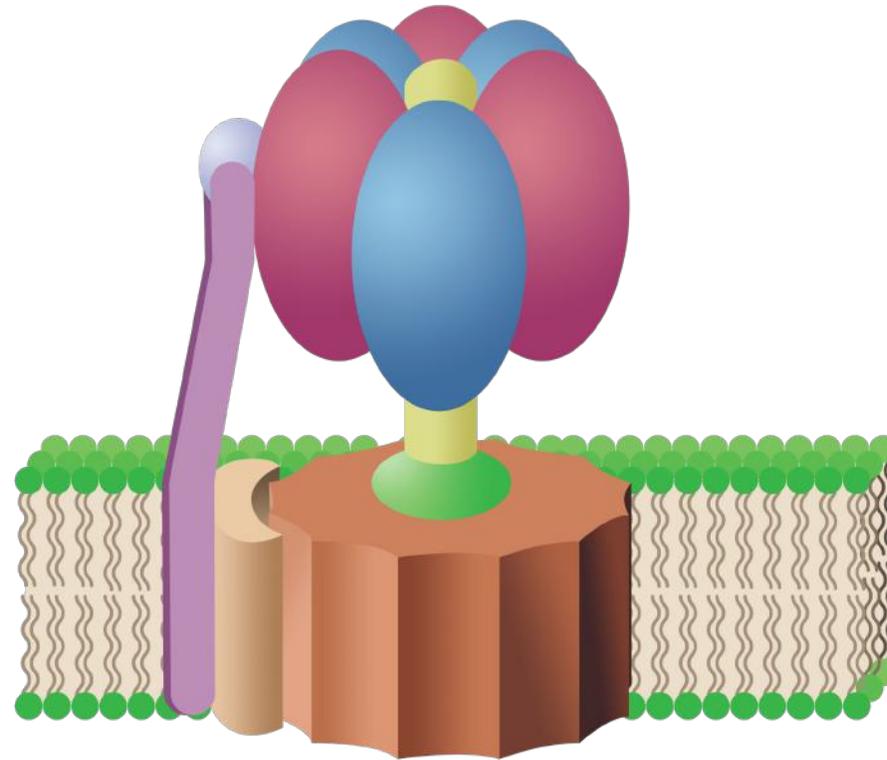
Context: Gives insight into different properties – collagen is structural as forms walls, haemoglobin is soluble as travels through vessels

2) Collagen is a fibrous protein which forms the walls of blood vessels, whilst haemoglobin is a globular protein which travels through the blood vessels.

Give two ways the properties of globular and fibrous proteins differ. **[2 marks]**

Globular proteins are almost spherical and soluble in water, whilst fibrous proteins form strong fibres and are insoluble in water.

Function of Proteins



Specification Points

AQA

3.1.4.2 Many proteins are enzymes

Content	Opportunities for skills development
<p>Each enzyme lowers the activation energy of the reaction it catalyses.</p> <p>The induced-fit model of enzyme action.</p> <p>The properties of an enzyme relate to the tertiary structure of its active site and its ability to combine with complementary substrate(s) to form an enzyme-substrate complex.</p> <ul style="list-style-type: none"> The specificity of enzymes The effects of the following factors on the rate of enzyme-controlled reactions – enzyme concentration, substrate concentration, concentration of competitive and of non-competitive inhibitors, pH and temperature. 	<p>MS 0.5</p> <p>Students could be given the hydrogen ion concentration of a solution in order to calculate its pH, using the formula:</p> $pH = -\log_{10}[H^+]$

3.2.3 Transport across cell membranes

Content	Opportunities for skills development
<p>The basic structure of all cell membranes, including cell-surface membranes and the membranes around the cell organelles of eukaryotes, is the same.</p> <p>The arrangement and any movement of phospholipids, proteins, glycoproteins and glycolipids in the fluid-mosaic model of membrane structure. Cholesterol may also be present in cell membranes where it restricts the movement of other molecules making up the membrane.</p> <p>Movement across membranes occurs by:</p> <ul style="list-style-type: none"> simple diffusion (involving limitations imposed by the nature of the phospholipid bilayer) facilitated diffusion (involving the roles of carrier proteins and channel proteins) osmosis (explained in terms of water potential) active transport (involving the role of carrier proteins and the importance of the hydrolysis of ATP) 	

OCR

2.1.4 Enzymes

Learning outcomes	Additional guidance
(a) the role of enzymes in catalysing reactions that affect metabolism at a cellular and whole organism level	To include the idea that enzymes affect both structure and function.
(b) the role of enzymes in catalysing both intracellular and extracellular reactions	To include catalase as an example of an enzyme that catalyses intracellular reactions and amylase and trypsin as examples of enzymes that catalyse extracellular reactions.
(f) the effects of inhibitors on the rate of enzyme-controlled reactions.	To include competitive and non-competitive and reversible and non-reversible inhibitors with reference to the action of metabolic poisons and some medicinal drugs, and the role of product inhibition AND inactive precursors in metabolic pathways (covered at A level only).

2.1.5 Biological membranes

Learning outcomes	Additional guidance
(b) the fluid mosaic model of membrane structure and the roles of its components	To include phospholipids, cholesterol, glycolipids, proteins and glycoproteins AND the role of membrane-bound receptors as sites where hormones and drugs can bind. M0.2 HSW1
(d) (i) the movement of molecules across membranes	To include diffusion and facilitated diffusion as passive methods

Specification Points

Edexcel A

Topic 2: Genes and Health

Students should:

- 2.10 i) Understand the mechanism of action and the specificity of enzymes in terms of their three-dimensional structure.
 ii) Understand that enzymes are biological catalysts that reduce activation energy.

Topic 2: Genes and Health

Students should:

- 2.2 i) Know the structure and properties of cell membranes.

Topic 2: Genes and Health

Students should:

- 2.4 i) Understand what is meant by passive transport (diffusion, facilitated diffusion), active transport (including the role of ATP as an immediate source of energy), endocytosis and exocytosis.
 ii) Understand the involvement of carrier and channel proteins in membrane transport.

Edexcel B

Topic 1: Biological Molecules

Students should:

1.5 Enzymes

- i Know the structure of enzymes as globular proteins.
 iii Understand that enzymes are catalysts that reduce activation energy.

Topic 4: Exchange and Transport

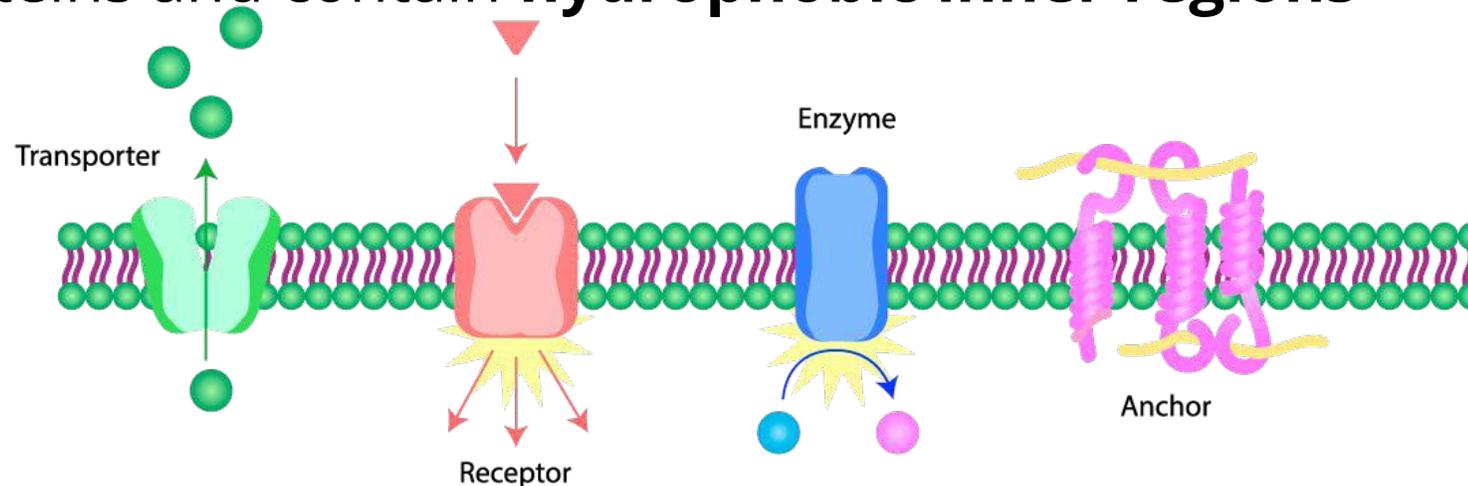
Students should:

4.2 Cell transport mechanisms

- i Know the structure of the cell surface membrane with reference to the fluid mosaic model.
 ii Understand how passive transport is brought about by:
 - diffusion
 - facilitated diffusion (through carrier proteins and protein channels)
 - osmosis.
 iii Understand how the properties of molecules affects how they are transported, including solubility, size and charge.
 v Understand the process of active transport, including the role of ATP.

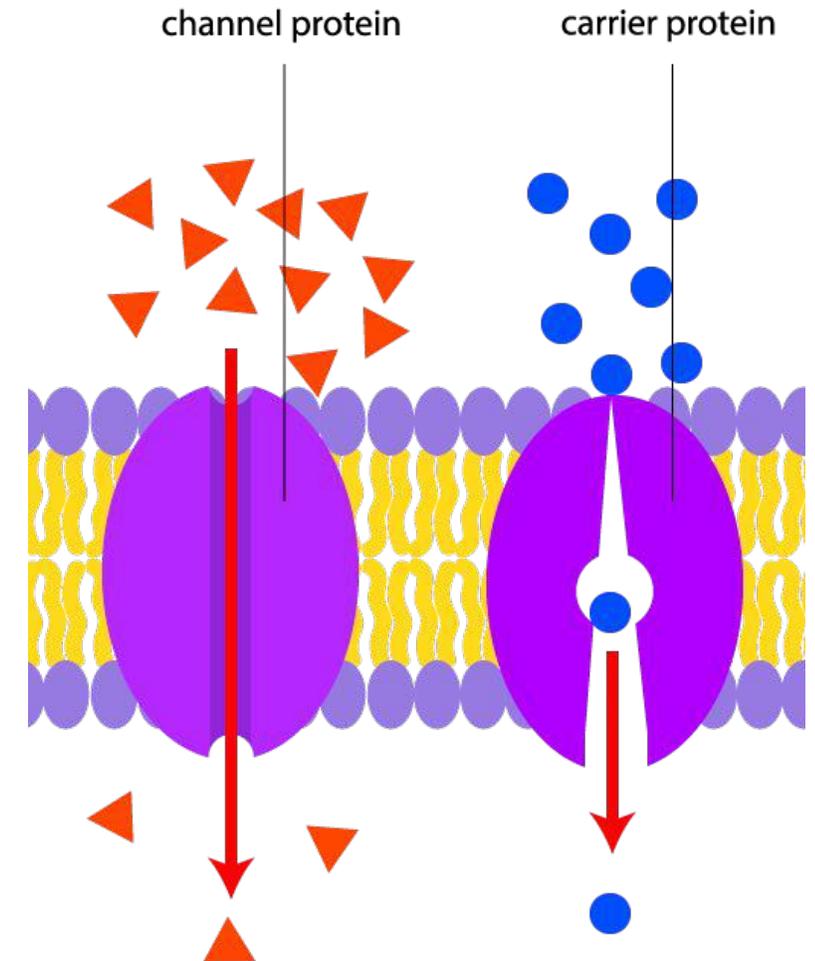
Membrane Proteins

- There are **many different** types of **membrane proteins**, including **receptors, enzymes** and **transporter** proteins
- **Proteins** which sit on only **one side** of the **membrane** are called **peripheral** or **extrinsic proteins** and have **hydrophilic surfaces**
- **Proteins** which are **embedded** into the **cell membrane** are **intrinsic** or **integral** proteins and contain **hydrophobic inner regions**



Membrane Transport Proteins

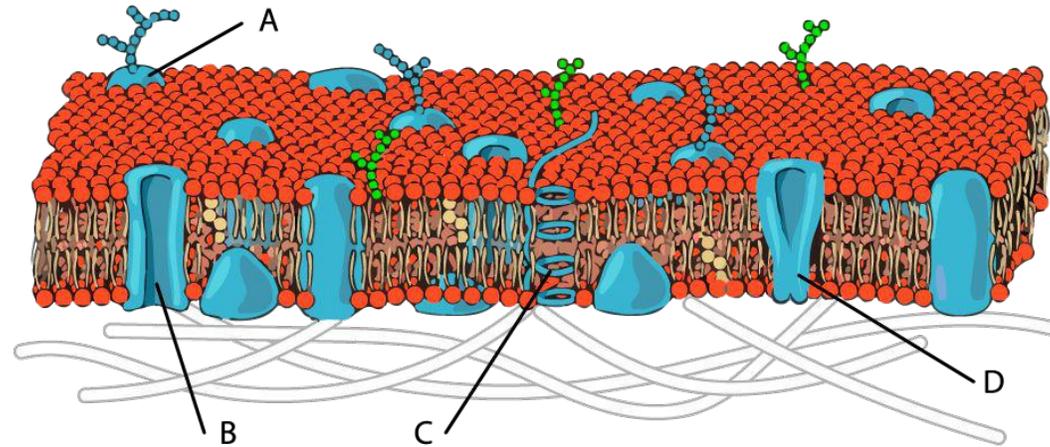
- Membrane transport proteins **always** span the **whole membrane** – they are known as **transmembrane proteins**
- **Channel proteins** are transport proteins with **water-filled open pores** which allow **specific molecules** to cross
- **Carrier proteins** are **closed** protein structures which undergo a **conformational change** to move **specific molecules** across the **membrane**



Exemplar Exam Question – Statement

Context

Figure. 1



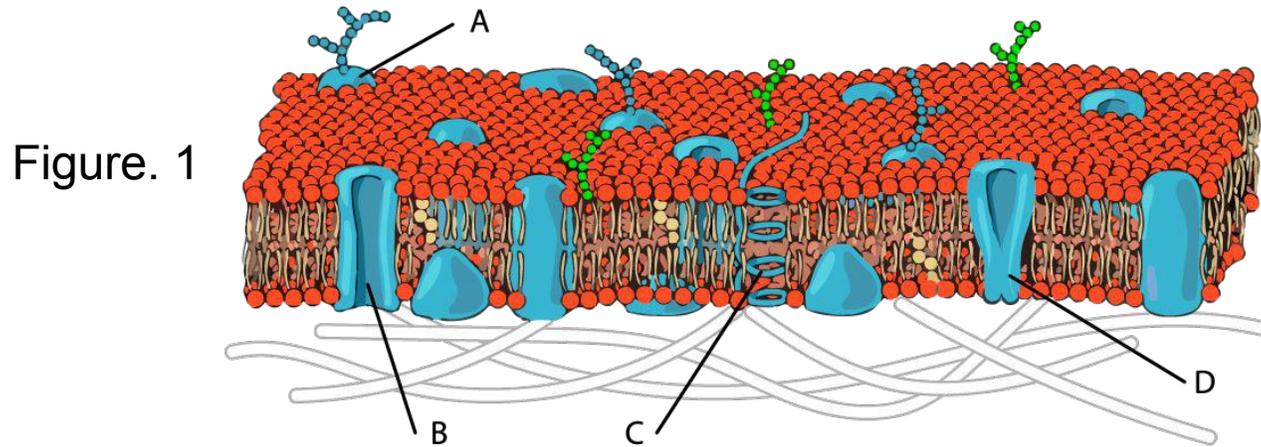
Command:
name B and D
proteins

3) Fig. 1 shows a typical cell surface membrane with four membrane proteins labelled. Proteins B and D transport substances across cell membranes.

Identify proteins B and D and state whether they are extrinsic or intrinsic proteins.

[2 marks]

Direction: recall what extrinsic/intrinsic proteins are



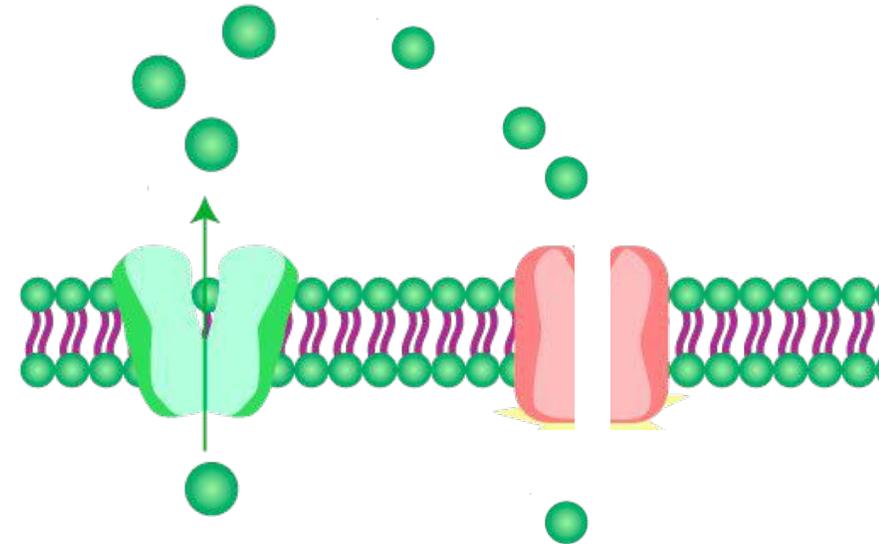
3) Fig. 1 shows a typical cell surface membrane with four membrane proteins labelled. Proteins B and D transport substances across cell membranes.

Identify proteins B and D and state whether they are extrinsic or intrinsic proteins.

[2 marks]

Transport through Membranes

- **Passive diffusion:** **small** and **non-polar** molecules diffuse **down** their **concentration gradients** through the **membrane**
- **Facilitated diffusion:** uses **channel** and **carrier proteins** and allows **larger, polar** or **charged molecules** to diffuse through, **down** their **concentration gradients**
- **Active transport:** uses **carrier proteins** and **energy** from the **hydrolysis of ATP** to move molecules **against** their **concentration gradient**



Exemplar Exam Question – Extended Response

4) Small, non-polar molecules move through the plasma membrane via simple diffusion.

Outline the different ways that charged, polar and larger molecules move through membranes, compared to small, non-polar molecules.

Marks will be awarded for quality of written communication.

[5 marks]

Command: general description of, not much detail

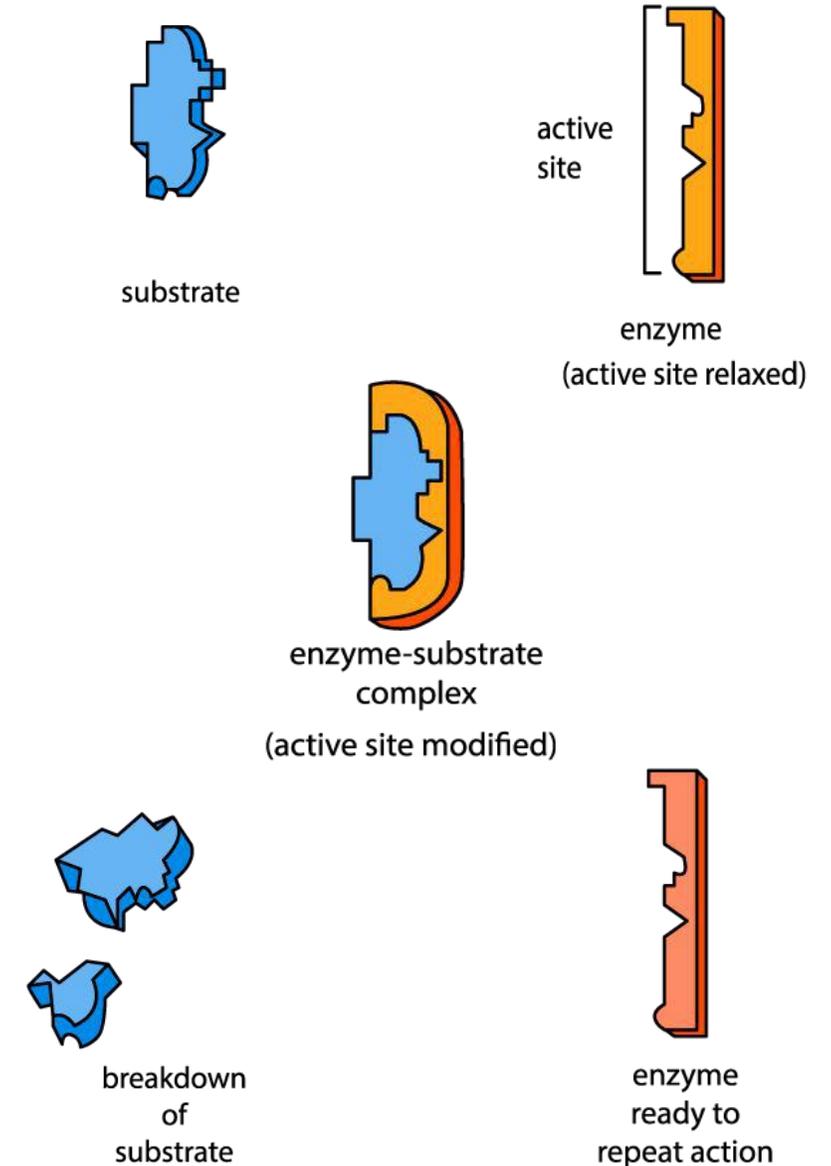
Direction: focus specifically on the three types of molecules

Context: movement of molecules through the plasma membrane

Charged, polar and larger molecules cannot use simple diffusion to cross membranes. Larger substances are transported using carrier proteins. These processes may use active transport, moving substances against concentration gradients or can also use facilitated diffusion, down concentration gradients. Polar and charged substances diffuse through channel proteins via facilitated diffusion or are transported by carrier proteins, either by facilitated diffusion or active transport.

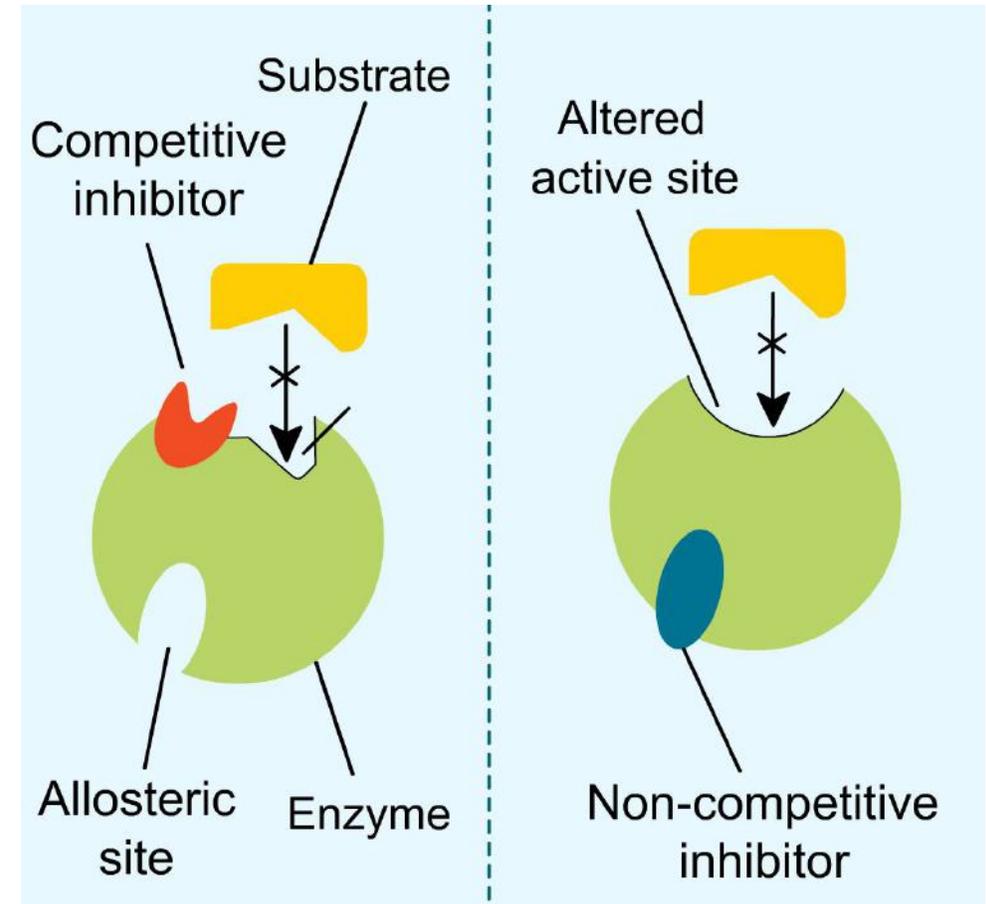
Enzymes

- Enzymes are **proteins** which act as **biological catalysts by reducing activation energy**
- One suggested **mechanism of action** for **enzymes** is the **induced fit model**:
 - The **proximity** of the **substrate** to the **enzyme** results in a **change** in the **shape** of the **active site** to make it **complementary**
 - This allows the active site to **mould** itself to the **substrate** forming a **stable enzyme-substrate complex**



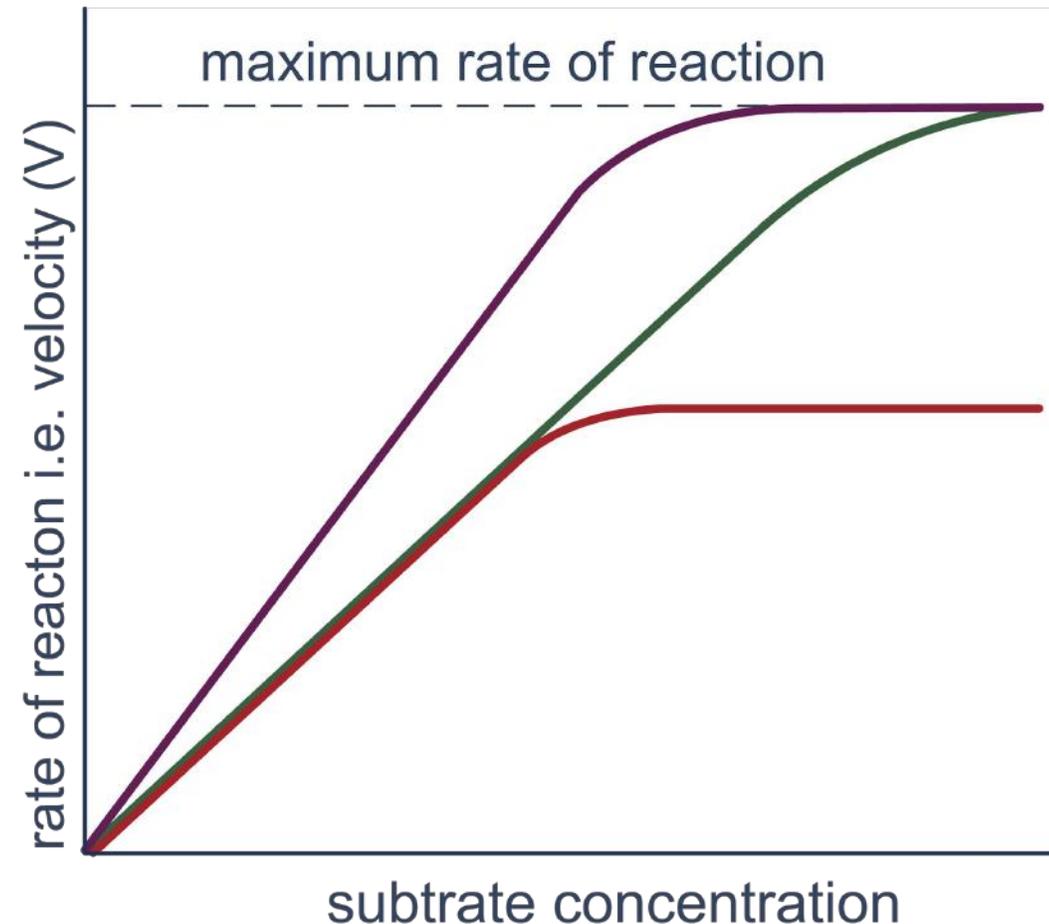
Enzyme Inhibition

- Enzymes can be inhibited **competitively** or **non-competitively**
- **Competitive inhibitors** bind to the **active site** of the enzyme and are **affected** by **substrate concentration**
- **Non-competitive inhibitors** bind to an **alternative site** on the enzyme called the **allosteric site** and are **unaffected** by **substrate concentration**



Quantifying Enzyme Inhibition

- Solutions containing **competitive inhibitors** are able to reach the **uninhibited maximum rate of reaction** with a **high enough substrate concentration**
- Solutions containing **non-competitive inhibitors** have a **reduced rate of reaction** and will **not reach the uninhibited maximum rate of reaction**



Exemplar Exam Question – Simple Explanatory

5) Explain why non-competitive inhibitors are unaffected by substrate concentration.

[2 marks]

Command: Give reasons

Direction: only focus on non-competitive inhibition

Context: substrate concentration and non-competitive inhibition

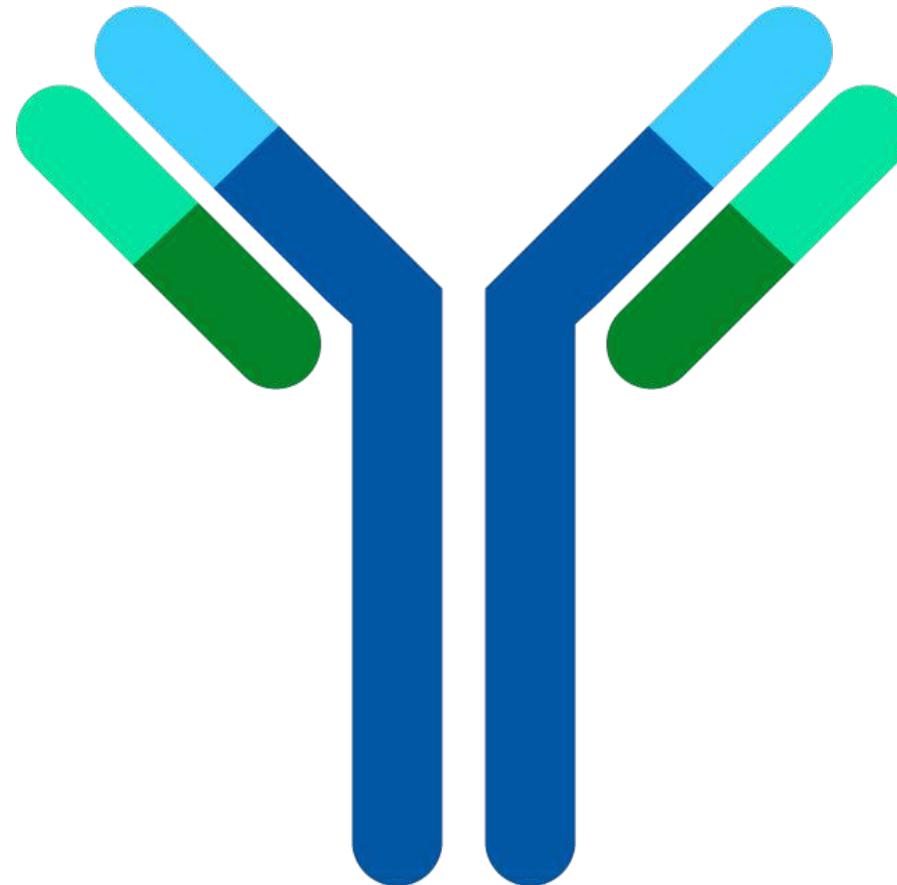
Exemplar Exam Question – Simple Explanatory

5) Explain why non-competitive inhibitors are unaffected by substrate concentration.

[2 marks]

Non-competitive inhibitors bind to allosteric sites on the enzyme so they do not need to compete with the substrate for the active site.

Examples of Proteins



Specification Points

AQA

3.3.4.1 Mass transport in animals

Content	Opportunities for skills development
<p>The haemoglobins are a group of chemically similar molecules found in many different organisms. Haemoglobin is a protein with a quaternary structure.</p> <p>The role of haemoglobin and red blood cells in the transport of oxygen. The loading, transport and unloading of oxygen in relation to the oxyhaemoglobin dissociation curve. The cooperative nature of oxygen binding to show that the change in shape of haemoglobin caused by binding of the first oxygens makes the binding of further oxygens easier. The effects of carbon dioxide concentration on the dissociation of oxyhaemoglobin (the Bohr effect).</p>	

3.2.4 Cell recognition and the immune system

Content	Opportunities for skills development
<p>The response of B lymphocytes to a foreign antigen, clonal selection and the release of monoclonal antibodies (the humoral response).</p> <ul style="list-style-type: none"> • Definition of antibody. • Antibody structure. • The formation of an antigen-antibody complex, leading to the destruction of the antigen, limited to agglutination and phagocytosis of bacterial cells. 	

OCR

2.1.2 Biological molecules

Learning outcomes	Additional guidance
(n) the structure and function of globular proteins including a conjugated protein	To include haemoglobin as an example of a conjugated protein (globular protein with a prosthetic group), a named enzyme and insulin.

3.1.2 Transport in animals

Learning outcomes	Additional guidance
(i) the role of haemoglobin in transporting oxygen and carbon dioxide	To include the reversible binding of oxygen molecules, carbonic anhydrase, haemoglobinic acid, HCO_3^- and the chloride shift. HSW8

4.1.1 Communicable diseases, disease prevention and the immune system

Learning outcomes	Additional guidance
(h) the structure and general functions of antibodies	To include the general protein structure of an antibody molecule.

Specification Points

Edexcel A

Topic 2: Genes and Health

Students should:

- 2.9 iii) Understand the significance of a protein's primary structure in determining its three-dimensional structure and properties (globular and fibrous proteins and the types of bonds involved in its three-dimensional structure).
iv) Know the molecular structure of a globular protein and a fibrous protein and understand how their structures relate to their functions (including haemoglobin and collagen).

Topic 6: Immunity, Infection and Forensics

Students should:

- 6.8 Understand the roles of antigens and antibodies in the body's immune response including the involvement of plasma cells, macrophages and antigen-presenting cells.

Edexcel B

Topic 4: Exchange and Transport

Students should:

4.5 Transport of gases in the blood

- i Understand the structure of haemoglobin in relation to its role in the transport of respiratory gases, including the Bohr effect.
ii Understand the oxygen dissociation curve of haemoglobin.

Topic 6: Microbiology and Pathogens

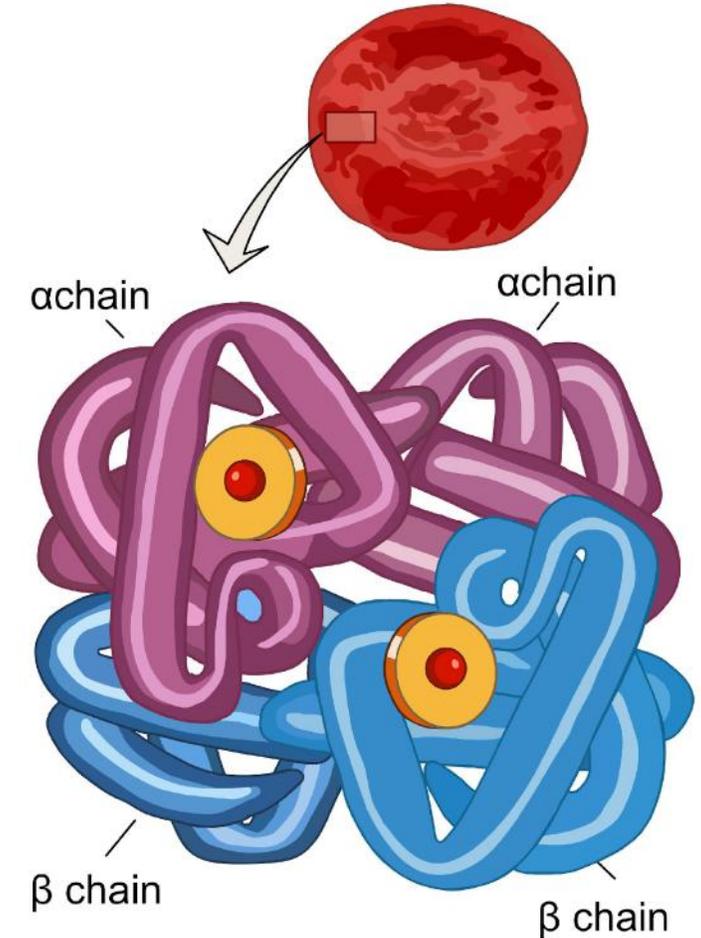
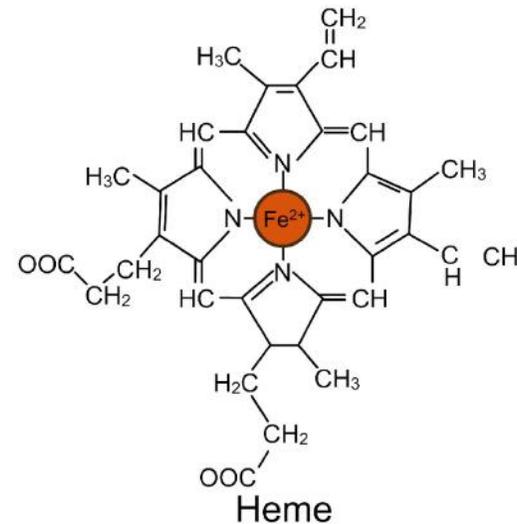
Students should:

6.7 Response to infection

- ii Understand the development of the humoral immune response, including the role of:
- antigen presenting T cells
 - T helper cells and cytokines
 - B cells
 - clonal selection
 - plasma cells
 - antibodies.

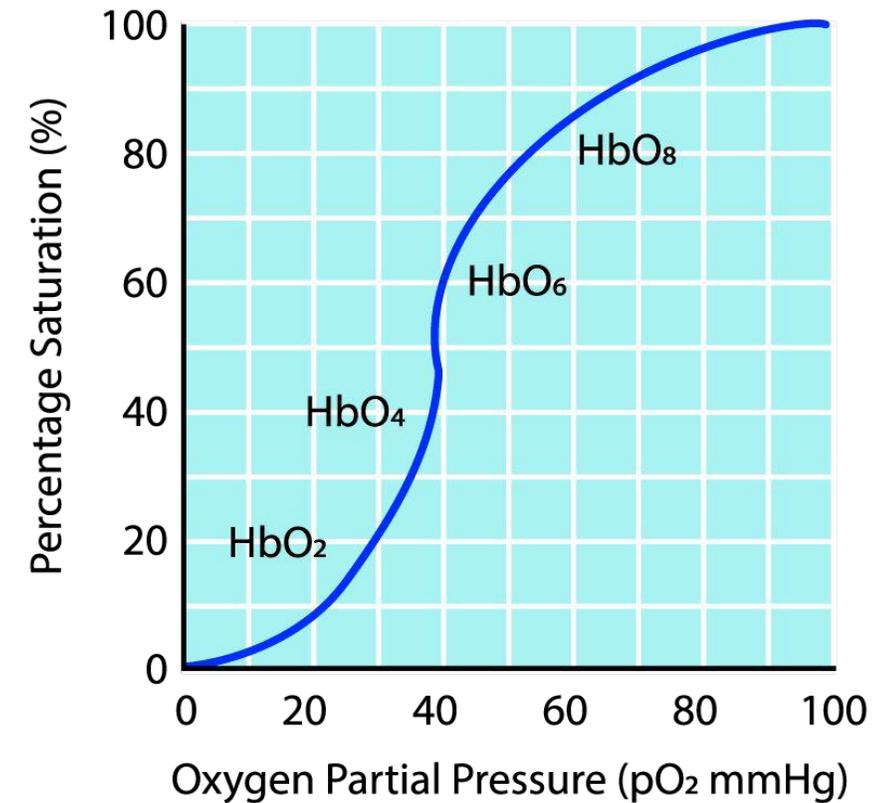
Haemoglobin Structure

- Haemoglobin contains four polypeptide chains - **two α -chains** and **two β -chains**
- It is **globular**
- It is conjugated & contains **prosthetic iron-containing haem groups in each chain**
- Each haem group can bind **one O_2 molecule** (four in total)



Haemoglobin Function

- Haemoglobin in erythrocytes **transports oxygen** from the **lungs** to **respiring tissues** to allow aerobic respiration
- It undergoes **conformational changes** when binding **oxygen** – **cooperative binding**
- Binding of the first **O₂ molecule** changes the **orientation** of the **haem groups** making it **more accessible** to O₂



Edexcel A: Do not need to know about oxygen disassociation

Exemplar Exam Question – Explanatory

6) Red blood cells are crucial for the transport of oxygen to tissues in mammals. Many molecules of haemoglobin are present within each red blood cell and contribute to their function.

Describe the role of haemoglobin in oxygen transport in mammals.

[3 marks]

Command: write what the role of haemoglobin is – not why

Direction: focus only on oxygen transport functions of haemoglobin

Context: haemoglobin in red blood cells – important for function

6) Red blood cells are crucial for the transport of oxygen to tissues in mammals. Many molecules of haemoglobin are present within each red blood cell and contribute to their function.

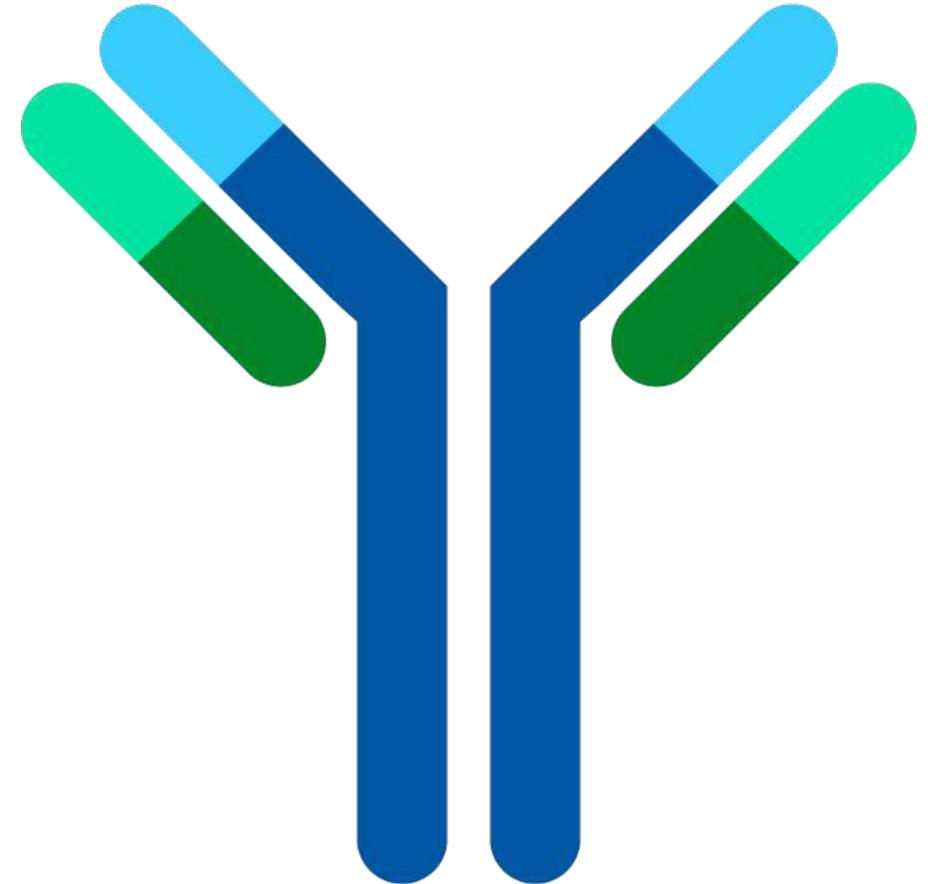
Describe the role of haemoglobin in oxygen transport in mammals.

[3 marks]

Haemoglobin has a high affinity for oxygen, binding to it in the lungs (regions of high partial pressure) and forming oxyhaemoglobin. It then transports the bound oxygen to respiring tissues where the oxygen is released. Oxygen is released at low oxygen partial pressures (respiring tissues) due to a reduction in haemoglobin oxygen affinity.

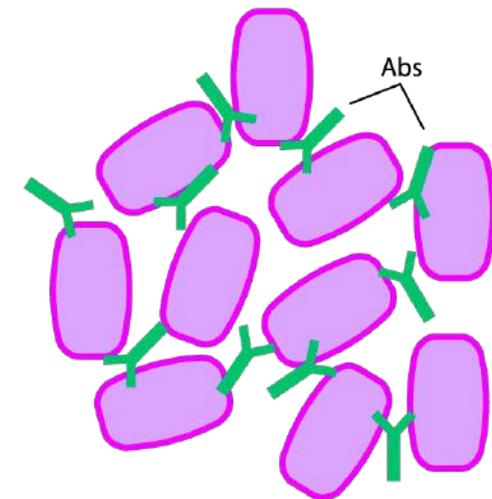
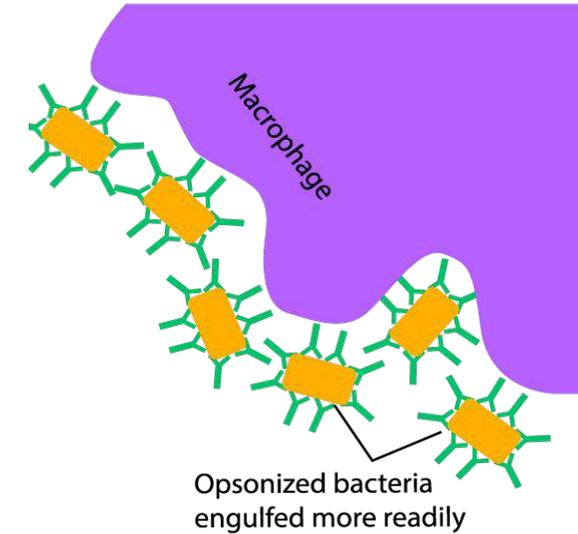
Antibody Structure

- **4 polypeptide chains:**
 - 2 **light** chains
 - 2 **heavy** chains
- There are 3 regions:
 - **Variable** regions – contain **antigen binding sites**
 - **Hinge** region
 - **Constant** region – bind to receptors on cells
- **Antigen binding sites** are specific to **individual antigens**



Antibody Function

- Antibodies prepare the **pathogen** for **destruction** but do **not** destroy them
 - Cause **agglutination** of bacterial cells
 - Serve as **markers** for **phagocytosis**
- The **three** regions have different functions:
 - **Variable** region binds to **antigens** on pathogens or to **toxic chemicals** they may secrete
 - **Constant** region is a binding site for **phagocytes**
 - **Hinge** region lets each antibody bind to **two different pathogens**



Exemplar Exam Question – Extended Response

7) Compare antibodies with haemoglobin to discuss the relationship between structure and function in proteins.

[6

marks]

Command: Compare the structure and function of antibodies and haemoglobin (similarities and differences)

Direction: Use the comparison to explain how structure and function are related.

Context: protein structure and function

Both haemoglobin and antibodies are globular proteins with 4 polypeptide chains which are soluble in polar solvents. They use their solubility to travel around the body in the blood, but antibodies travel to sources of infection, whilst haemoglobin transports oxygen and carbon dioxide. Antibodies have different variable regions which allows them to bind to a variety of antigens, whilst the structure of haemoglobin is constant between molecules, containing four haem groups which allow haemoglobin to bind oxygen.

AQA:
25 mark
essay
question

Exemplar Exam Question – Extended Response

Compare antibodies and haemoglobin: Structure

Antibody	Haemoglobin
Primary structure is variable , resulting in antibodies that are complementary to different antigens .	Constant primary structure . All haemoglobin molecules are the same .
Globular protein, soluble in polar solvents.	Globular protein, soluble in polar solvents.
Quaternary structure of 4 polypeptide chains .	Quaternary structure of 4 polypeptide chains .
Not a conjugated protein.	Conjugated protein, one haem group per polypeptide chain.

AQA:
25 mark
essay
question

Exemplar Exam Question – Extended Response

Compare antibodies and haemoglobin: Function

Antibody	Haemoglobin
Travel in the blood to get to sites of infection within the body- uses the circulatory system to get to where it can perform its role .	Travel in the blood to deliver oxygen and remove carbon dioxide – uses the circulatory system to perform its role .
Binds to biological macromolecules , determined by the specificity of the variable region .	Prosthetic haem groups within the polypeptide chains bind to oxygen .
Can perform a variety of different roles , the type of antibody and its shape affect what role it can perform.	Has two roles (oxygen to cells, carbon dioxide away from cells) that can be performed by identical molecules .
Whether or not binding will occur depends solely on complementarity between antibody and antigen.	Extent of binding is affected by affinity and partial pressures of oxygen and carbon dioxide.
Main function: Protection against pathogens as part of the humoral immune response.	Main function: Transport of oxygen and carbon dioxide in the blood.

Mini Mock Paper



Mini Mock Paper

a) The secondary structure of proteins contains alpha helices and beta sheets.

Which bonds are responsible for forming the secondary structure of proteins?

[1 mark]

Mini Mock Paper

b) A student investigated the activity of two different enzymes from ectothermic organisms. Though both enzymes were involved in respiration, one was present in organisms that originated from a temperate climate, whilst the other originated from a tropical climate. The results are shown below:

Enzyme	Rate of Reaction at Set Temperature / au				
	10°C	20°C	30°C	40°C	50°C
Temperate	0.2	0.5	0.9	0.3	0.1
Tropical	0.1	0.2	0.4	0.8	0.6

Describe and explain the results.

[4 marks]

Mini Mock Paper

Mini Mock Paper

c) Haemoglobin is a globular, conjugated protein with a quaternary structure. It is responsible for transporting oxygen around the body which it does by binding to oxygen molecules in the lungs, and releasing them near the tissues.

Describe the structure of haemoglobin based on the information provided above and your own knowledge, and suggest how the structure of haemoglobin aids its function.

Marks will be available for quality of written communication.

[6 marks]

Mini Mock Paper Answers



Mini Mock Paper

a) The secondary structure of proteins contains alpha helices and beta sheets.

Which bonds are responsible for forming the secondary structure of proteins?

[1 mark]

Hydrogen bonds

Mini Mock Paper

b) A student investigated the activity of two different enzymes from ectothermic organisms. Though both enzymes were involved in respiration, one was present in organisms that originated from a temperate climate, whilst the other originated from a tropical climate. The results are shown below:

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Describe and explain the results.

[4 marks]

Mini Mock Paper

At low temperatures, the rate of reaction is slow for temperate and tropical enzymes. The rate of reaction increases faster for the temperate enzyme and peaks at 30°C, suggesting it has a lower optimum temperature which would allow it to function more efficiently at the lower temperatures of a temperate climate. Conversely, the higher optimum temperature of the tropical enzyme would allow it to function more efficiently at the higher temperatures of a tropical environment. Both enzymes have a greater rate as the temperature and therefore kinetic energy increases as more successful collisions occur however with too much K.E, the enzymes denature.

Mini Mock Paper

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[6 marks]

Mini Mock Paper

As haemoglobin is a globular protein, it is round, compact and soluble. The hydrophilic R groups of its amino acids will be pushed to its surface. As haemoglobin is conjugated and has quaternary structure, it contains permanently bound prosthetic groups and multiple (four) polypeptide chains. The solubility of haemoglobin allows it to exist within the erythrocyte cytoplasm, in close proximity to oxygen. The haem prosthetic group is crucial for binding oxygen molecules through the Fe^{2+} ion, whilst changes in quaternary structure can dictate its oxygen binding affinity – with a high affinity for oxygen in the lungs and a low affinity for oxygen at the respiring tissues.