IB · DP · Biology

2 hours 15 questions

Structured Questions: Paper 2

2.3 Proteins

2.3.1 Proteins / 2.3.2 Protein Structure & Function / 2.3.3 The Variety of Proteins / 2.3.4 Skills: Molecules

Easy (5 questions)	/35
Medium (5 questions)	/52
Hard (5 questions)	/58
Total Marks	**/145**

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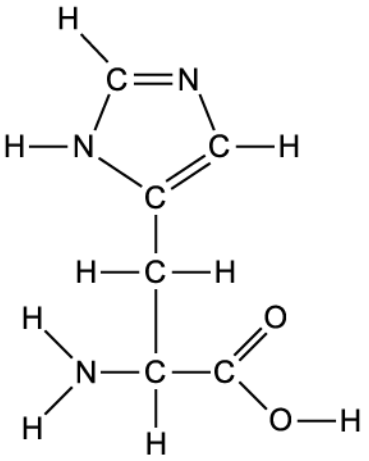
Easy Questions

1 (a) The image below shows the amino acid histidine.



Circle the section of the amino acid that is unique to histidine.

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(1 mark)

(b) State the type of reaction that occurs when two amino acids bond with each other.

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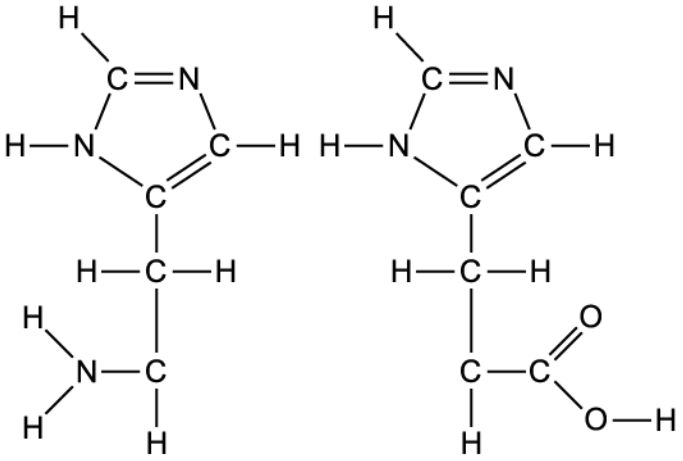
(1 mark)

(c) The image shows two histidine amino acids with the diagrams not fully complete.

Complete the image to include the structure of a peptide bond joining the two amino acids together into a dipeptide.



(1 mark)

(d) In a polypeptide with 100 amino acids, how many peptide bonds exist within the chain?

(1 mark)

2 (a) The protein Rubisco is an enzyme.

What is the function of the enzyme Rubisco in living organisms?

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(2 marks)

(b) Enzymes have a specific three-dimensional conformation that enables them to carry out their roles in living organisms.

Which part of the amino acid determines the conformation of the protein?

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(1 mark)

(c) In certain conditions, such as high temperatures, the 3D conformation of proteins can be lost.

(i) What is the scientific name given to when a protein loses its 3D conformation?

[1]

(ii) State one condition, other than temperature, that can cause the 3D conformation of a protein to be lost.

[1]

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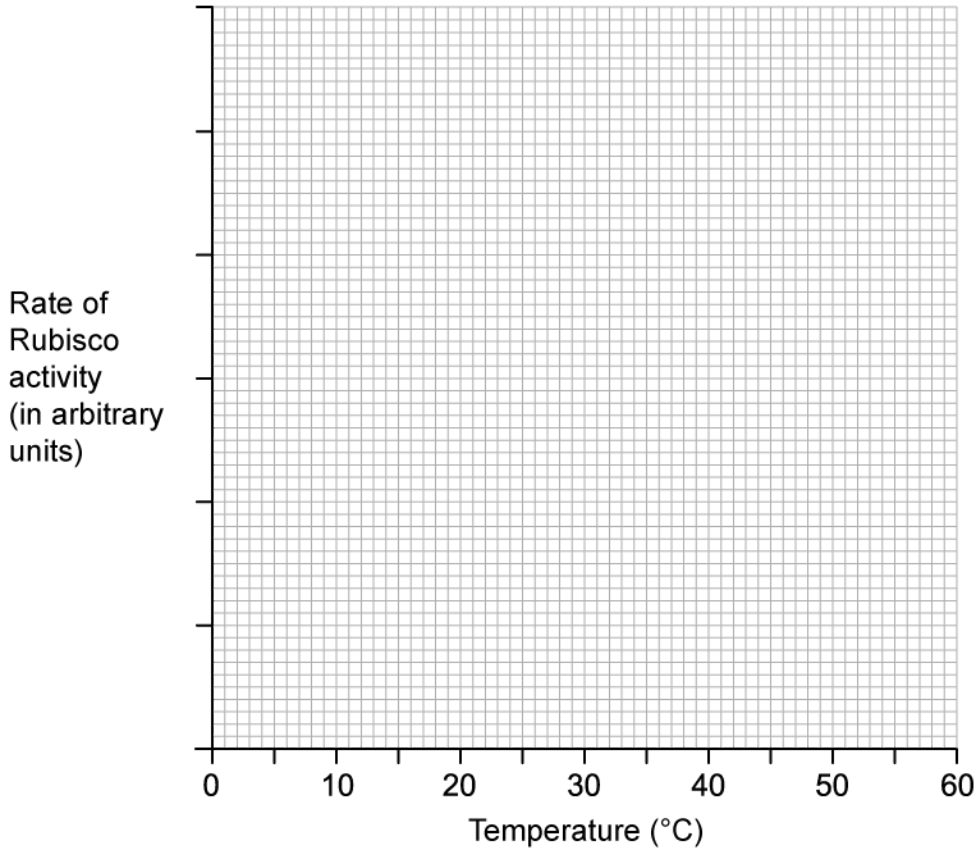
(2 marks)

(d) Sketch a graph to show how the rate of reaction of Rubisco changes over a range of temperatures.

Use the axes provided below.



[2]

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(2 marks)

3 (a) What is the name of the part of the cell where polypeptide synthesis takes place?

(1 mark)

(b) When a polypeptide is synthesised it is important that the amino acids are combined in the correct order to produce a functional protein.

Outline the process that allows the amino acids to be added to the polypeptide in the correct order.

(3 marks)

(c) After a polypeptide has been synthesised it must undergo a series of changes before it can become a functional protein.

Describe the changes that occur between polypeptide synthesis and the formation of the functional protein.

(3 marks)

(d) How might a change in the DNA affect the way that the process of protein folding occurs?

(2 marks)

4 (a) What is meant by the term proteome?

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(1 mark)

(b) There are two main categories of proteins: globular and fibrous.

The protein insulin is a hormone.

State whether insulin is a globular or a fibrous protein, and give a reason for your choice.

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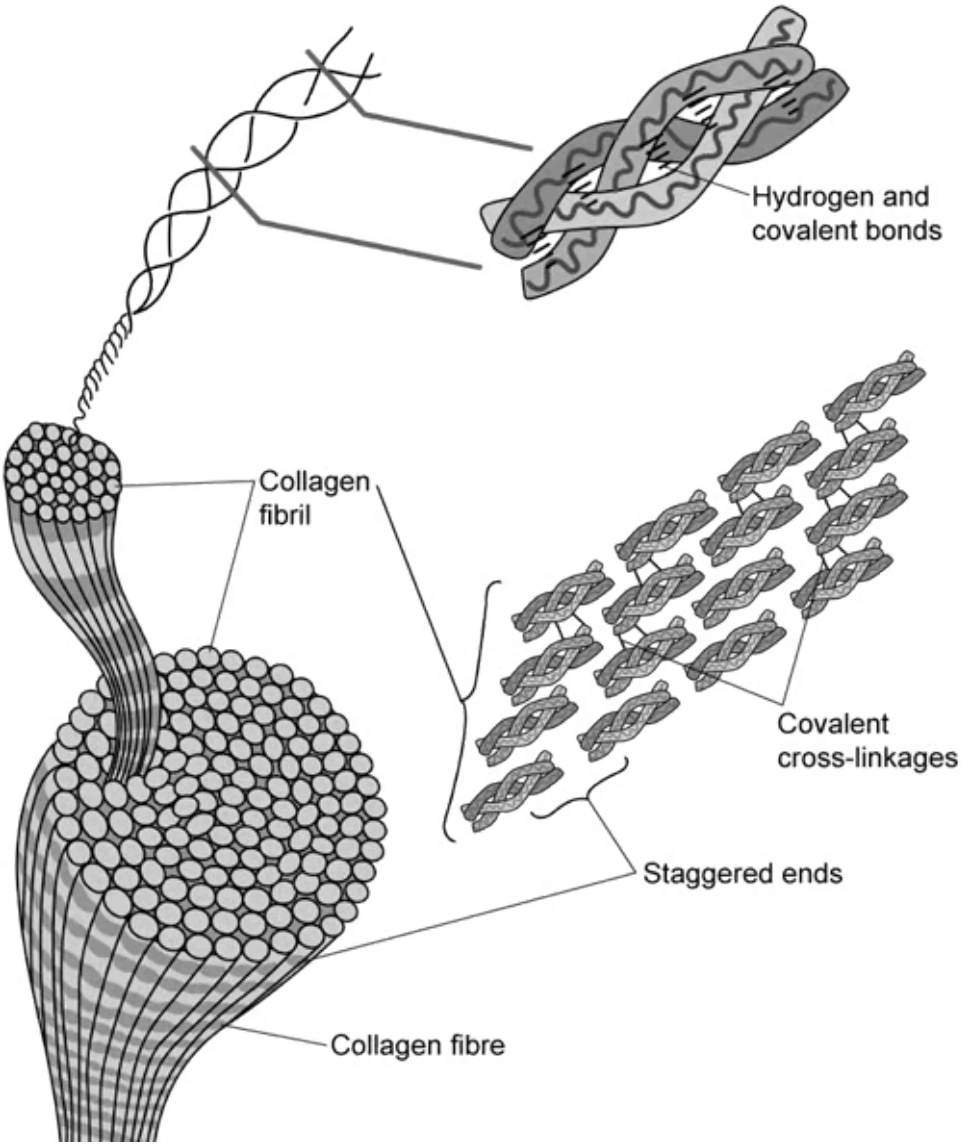
(2 marks)

(c) The image below shows the structure of collagen at various levels of detail.



Use the image to suggest two features of collagen that enable it to be a strong, structural protein.

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(2 marks)

(d) One of the polypeptide chains that forms a molecule of collagen contains 1049 peptide bonds.

Assuming all the chains that form collagen are identical in length, how many amino acids would be found in a single molecule of collagen?

Explain your answer.

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(3 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

Every individual has a unique proteome.

Explain how this is possible.

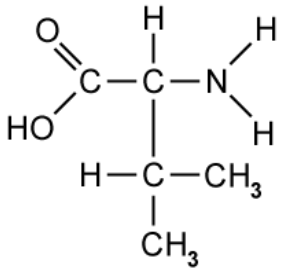
(3 marks)

(b) Describe the process of protein denaturing.

(4 marks)

Medium Questions

1 (a) The diagram below shows the structure of a commonly-occurring amino acid in nature.



Identify the word that best describes the chemical nature of this amino acid's R group from the following list: *saturated*; *hydrophobic*; *acidic*; *aromatic*. Give a reason for your answer.

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(2 marks)

(b) Nine of the twenty amino acids are described as 'essential amino acids' for humans.

Define and explain the term, 'essential' in this context.

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(2 marks)

(c) The amino acid alanine has a single methyl group (-CH_3) as its R group.

Draw the dipeptide formed when two alanine molecules join together.

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(3 marks)

(d) Calculate the number of combinations of the 20 commonly-occurring amino acids that can be joined together in a short polypeptide chain of 8 amino acids in length, in which each amino acid is different to the other seven.

Give your answer to 1 significant figure.

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(2 marks)

2 (a) Explain how the amino acid sequence determines the three-dimensional conformation of a polypeptide.

(3 marks)

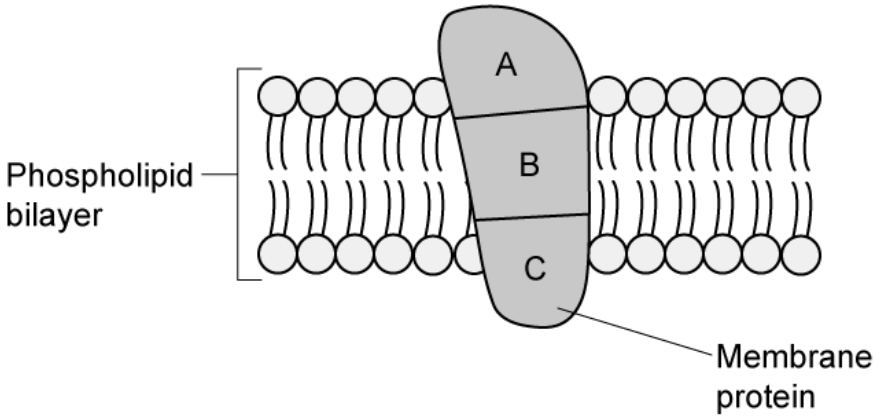
(b) Calculate, in pairs of nucleotides, the total length of a gene that codes for a polypeptide of 351 amino acids in length. In this gene, 40% of its DNA is non-coding.

(2 marks)

(c) Distinguish between the structures and properties of collagen and haemoglobin.

(3 marks)

(d) In cell membranes, proteins can be positioned within the phospholipid bilayer, in order to perform various functions. Some membrane proteins can span the entire bilayer as shown in the diagram below.



Explain why the amino acids in region B of the membrane protein tend to have

hydrophobic R groups towards the surface, whilst those in regions A and C tend to have hydrophilic R groups towards their surfaces.

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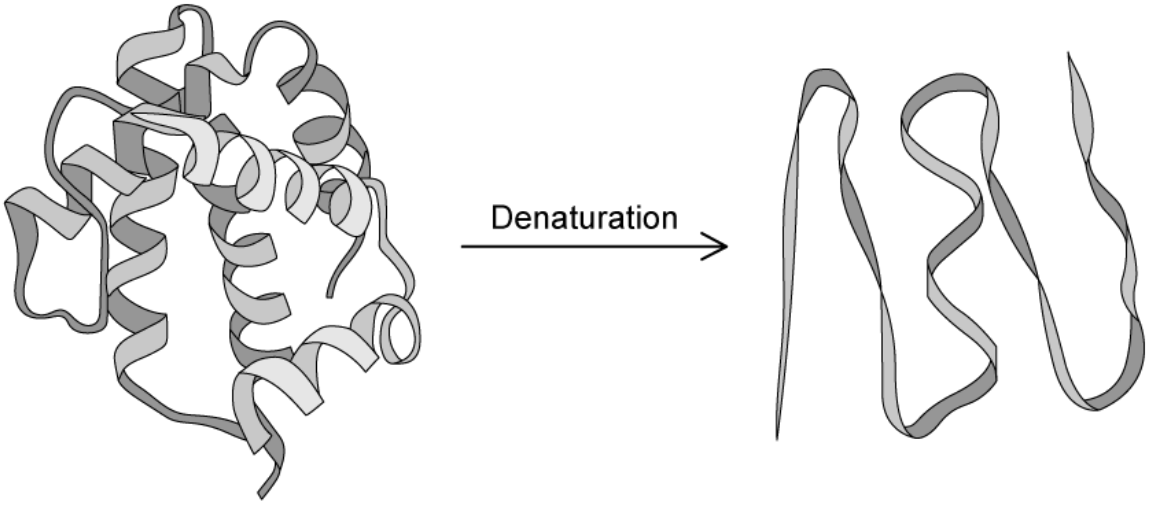
(2 marks)

3 (a) The image below shows the process of denaturation of a polypeptide.



Describe **one** change of conditions that can lead to such a denaturation and the effect this change has on the polypeptide's structure.

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(2 marks)

(b) Use your knowledge of the denaturation of proteins to explain the nutritional benefits of **cooking** protein-rich food like eggs before eating them.

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(4 marks)

(c) The proteins of many different extremophile prokaryotes have been studied extensively. A common feature among these proteins is a more tightly-packed hydrophobic core that prevents denaturation at high temperature or extremes of pH.

Suggest one benefit of humans developing detailed knowledge of these proteins and their structures.

(1 mark)

(d) State the source and the property of the enzyme *Taq* polymerase that allows it to be used in the Polymerase Chain Reaction when amplifying small amounts of genetic material.

(2 marks)

4 (a) Following partial hydrolysis of a naturally-occurring protein, samples of the polypeptides that were produced were identified.

Select from the table below the **two** molecular formulas that could be one of the naturally-occurring polypeptides.

Give reasons for your answer.

Polypeptide Number	Number of amino acids long	Molecular formula
I.	12	$C_{30}H_{54}N_{10}O_{33}S_4$
II.	44	$C_{66}H_{86}O_{78}N_{59}S_3$
III.	6	$C_{18}H_{26}O_{18}N_{12}$
IV.	37	$C_{60}H_{102}O_{75}N_{42}S_{15}$

(3 marks)

(b) Identify the role that proteins play in the central dogma of gene expression.

(1 mark)

(c) A protein found in leaves is thought to be the most abundant protein in nature.

State its name and describe its basic function.

(2 marks)

(d) Explain why the genome of an organism is fixed, whereas the organism's proteome can vary.

(3 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

Use your knowledge of protein structure to explain the term, 'specificity' in the context of immunoglobulins and their mode of action.

(3 marks)

(b) Outline, with examples, the main roles that proteins play in organisms.

(4 marks)

For each of the proteins listed **A - D** below, state one aspect of its structure and one function that is enabled by the structural feature that you have stated.

(c)
A. Ribulose Bisphosphate Carboxylase (RuBisCo)
B. Spider silk
C. Immunoglobulins
D. Rhodopsin

(8 marks)

Hard Questions

1 (a) Albumin is a protein found in the plasma of the blood.

Albumin transports hormones, fatty acids, and other compounds in the blood, buffers blood pH, and maintains oncotic pressure, among other functions.

The gene that codes for human albumin is 16,961 DNA bases long. The protein is made up of 585 amino acids.

Calculate the ratio of non-coding to coding DNA in the albumin gene.

(3 marks)

(b) Albumin is a protein that can be found in a range of vertebrate species.

Different species have slight variations in the structure of the protein. For example, bovine (cow) albumin has 583 amino acids.

Cows and humans share a common ancestor.

Suggest why it is the case that the two types of albumin are similar, but not completely the same as each other.

(3 marks)

(c) Egg whites are mostly made of albumin.

When the albumin in egg white becomes denatured it causes the 'white' to change from being colourless to being opaque white.

A student wanted to investigate how temperature affects the denaturing of albumin.

Outline a method that the student could use in order to carry out this investigation.

(4 marks)

(d) When the albumin in the egg white is not denatured it is soluble in the liquid, however, when it denatures it becomes insoluble. This is the mechanism that causes the colour change.

Explain how the protein can have different properties before and after denaturing.

(2 marks)

2 (a) A theoretical polypeptide chain is 26 amino acids long.

Calculate how many different possible combinations of amino acids could exist within this chain.

Give your answer in standard form.

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(2 marks)

(b) An average sized polypeptide of around 400 amino acids in length is said to have an infinite number of possible amino acid combinations.

Explain why it is possible for such a vast variety of polypeptides to exist.

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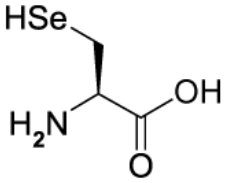
(2 marks)

(c) In some rare circumstances, some organisms have been found to contain unusual amino acids that are not shared with the majority of other organisms.

Selenocysteine is one of them, and is shown in the image below.



Using the image, state what makes selenocysteine so unusual compared to other amino acids.

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(1 mark)

(d) Some amino acids exist that have been man-made in a lab and have never been used naturally in the proteins of living organisms.

Describe the features that must exist in these molecules in order for them to be classified as amino acids.

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(3 marks)

3 (a) Insulin is a protein that is produced naturally by most people, however, people with insulin-dependent diabetes rely on injecting insulin to replace the protein that they cannot produce for themselves.

Explain why the insulin must be injected into the blood instead of taken orally.

(2 marks)

(b) Many years ago, insulin used to be taken from cows and pigs to treat people with diabetes.

Using your knowledge of protein structure, suggest why pig and cow insulin was less effective at regulating blood glucose levels than human insulin.

(2 marks)

(c) In modern medicine, human insulin is secreted from genetically modified bacteria into large industrial vats called fermenters. This allows the insulin to be extracted and purified for human use.

Outline why the insulin produced by the genetically modified bacteria is identical to insulin produced by a human.

(3 marks)

(d) Other organisms that can be genetically engineered to produce proteins for human medicine are goats.

Goats can be engineered to produce protein in their milk, for example, a protein called ATryn, which is used to reduce the risk of blood clots in human patients.

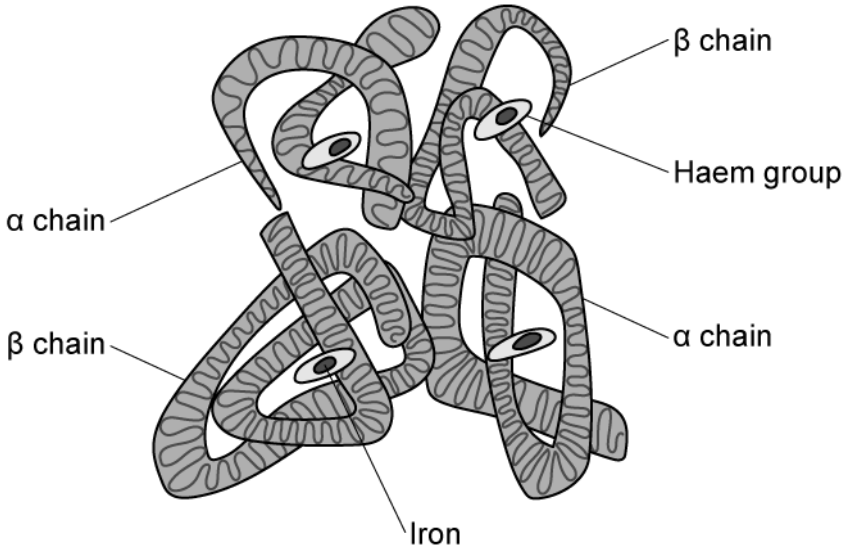
The goats can be milked and then the protein is extracted to be given to patients.

Compare and contrast this method of producing proteins for human medicine to the use of genetically modified bacteria for the same purpose.

(5 marks)

4 (a) Haemoglobin is an example of a protein.

Using the diagram below and your own knowledge, describe the structure of haemoglobin.



(3 marks)

(b) During a human's lifetime, they use different forms of haemoglobin.

Fetal haemoglobin varies in structure to normal haemoglobin and it is adapted to absorb oxygen when the oxygen concentration is lower.

Why would this benefit the foetus?

(3 marks)

(c) Foetal haemoglobin is phased out quite early on in development and is replaced with adult haemoglobin.

This is an example of how the proteome changes throughout an individual's lifetime.

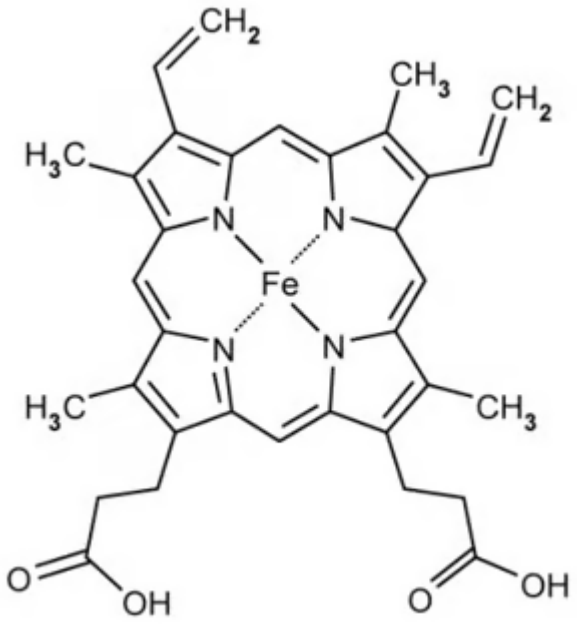
Unlike the proteome, the genome remains fixed.

Outline how it is possible for the proteome to vary throughout an individual's lifetime, even though the genome stays the same.

(2 marks)

(d) The image below shows the part of haemoglobin that binds to oxygen to deliver it around the body.

Is this an amino acid? Explain your reasoning.



(3 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

State the essential properties of membrane-bound proteins.

(3 marks)

(b) Explain why studying the proteomes of a variety of different species is beneficial to humans.

Use specific examples in your answer.

(5 marks)

(c) If a person has been infected with the influenza virus in the past they possess the necessary immunoglobulins to provide immunity to that virus again in the future.

Influenza viruses contain RNA as their genetic information.

State, with reference to RNA and protein structure, why it is possible for people to get the flu several times in their life.

(7 marks)