IB · HL · Biology

3 hours 17 questions

Structured Questions

Proteins

Formation of Proteins / The Variety of Proteins / Protein Structure: Effect of pH & Temperature / Amino Acid Diversity (HL) / Levels of Protein Structure (HL) / Globular & Fibrous Proteins (HL)

Easy (5 questions)	/36
Medium (6 questions)	/58
Hard (6 questions)	/63
Total Marks	**/157**

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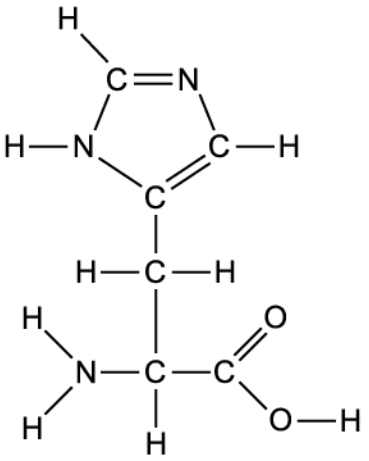
Easy Questions

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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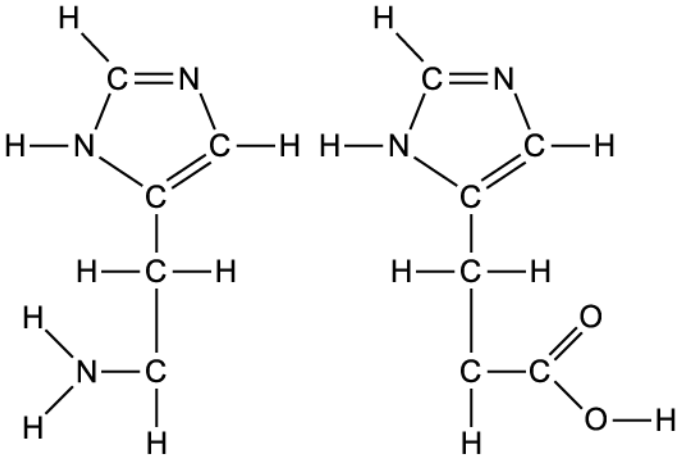
(1 mark)

(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) 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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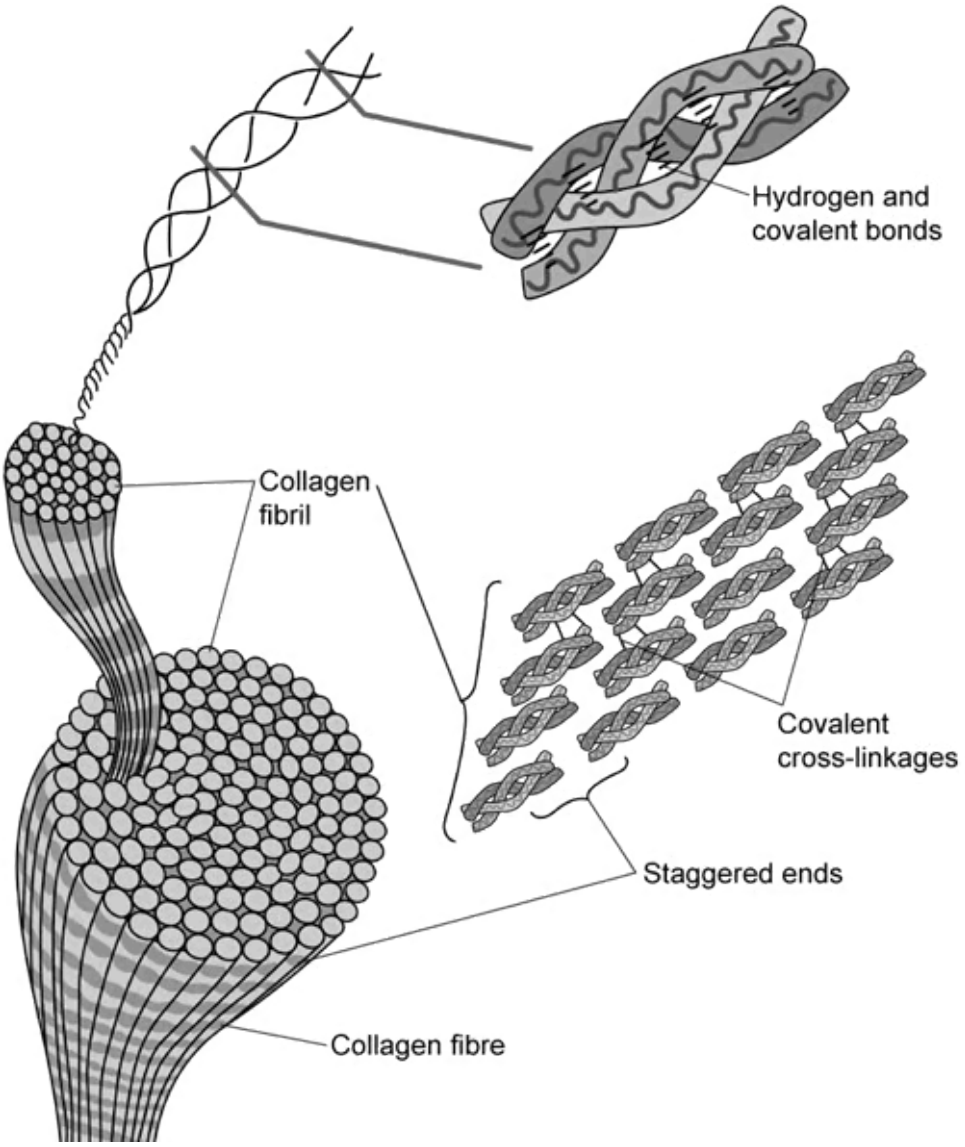
(2 marks)

(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)

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

Every individual has a unique proteome.

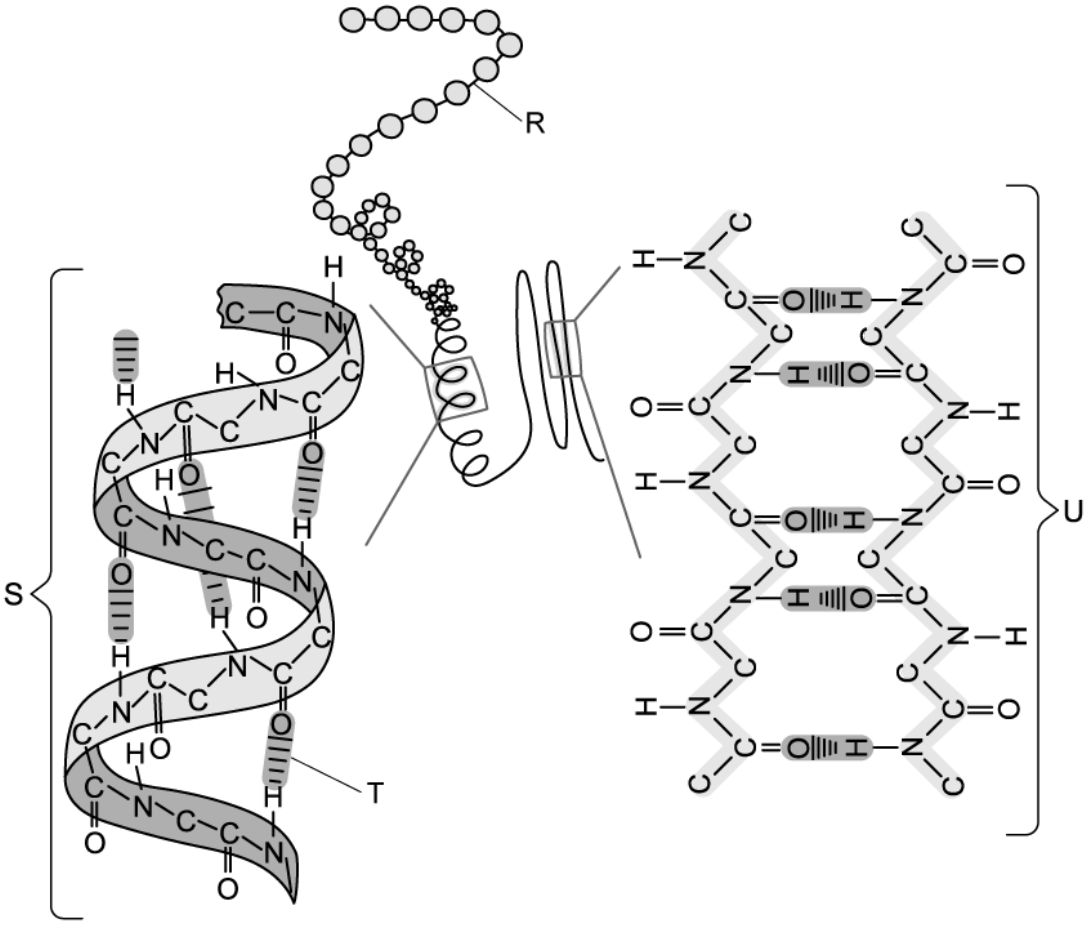
Explain how this is possible.

(3 marks)

(b) Describe the process of protein denaturing.

(4 marks)

4 (a) The diagram below shows the secondary structure of a protein.



Identify structures **S** and **U**.

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(2 marks)

(b) The structure of a protein is held together by different types of chemical bonds.

Label the bonds **R** and **T** in the diagram.

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(2 marks)

(c) Describe how the bond at **T** forms and the way it contributes to the secondary structure of a protein.

(2 marks)

(d) Explain how a mutation would affect the primary structure of a protein.

(1 mark)

(e) Proteins are large, complex molecules that have several levels comprising their structure.

Describe the tertiary structure of proteins.

(6 marks)

5 (a) The parasite *Plasmodium* causes the disease malaria when injected into the human bloodstream.

Computers can be used to analyse and sequence data in biological research. Using computers in this way, scientists can analyse the proteome of the *Plasmodium* parasite to understand better its metabolic pathways including the enzymes which catalyse them.

Define what is meant by the term *proteome*.

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(1 mark)

(b) So far over 300,000 chemicals have been screened to identify 19 new chemicals that can be used to treat malaria.

Calculate the percentage chance of finding a chemical that can be used to treat malaria.

Give your answer in standard form.

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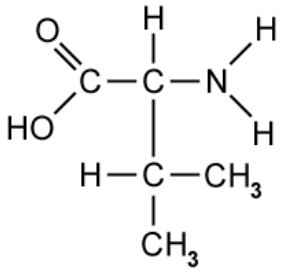
(3 marks)

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)

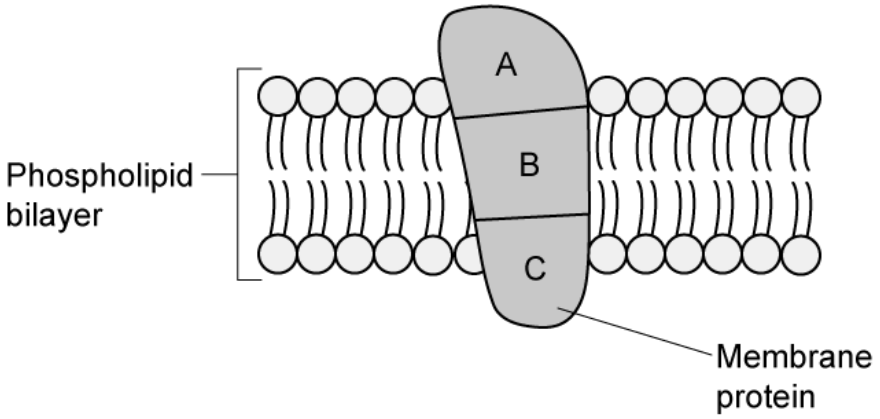
(b) Calculate, in pairs of nucleotides, the total length of a gene that codes for a polypeptide of 351 amino acids in length. In this gene, 40% of its DNA is non-coding.

(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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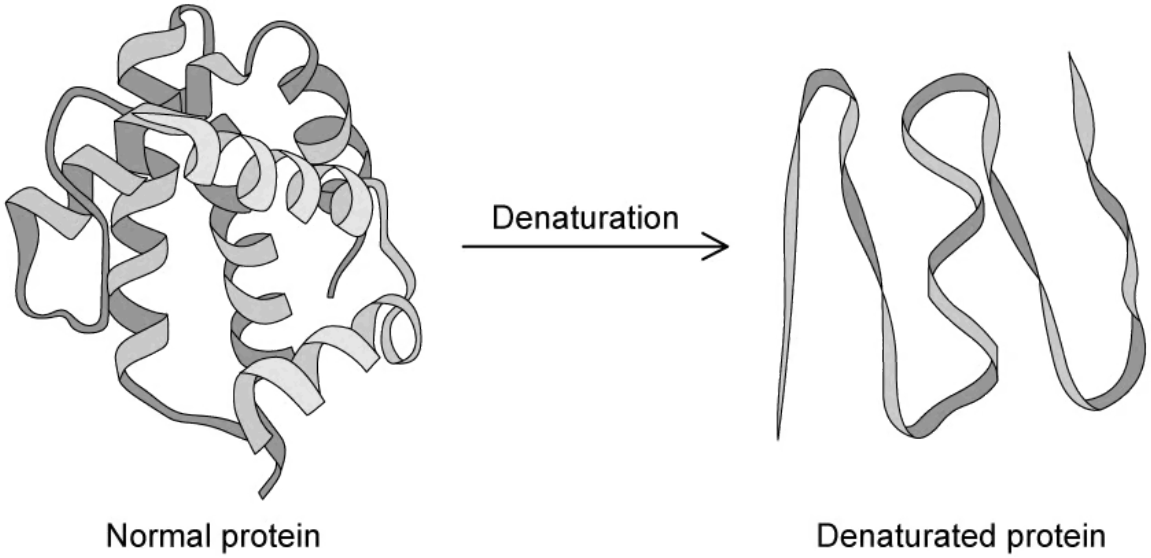
(2 marks)

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) 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)

6 (a) The table below shows some of the events which take place in protein synthesis.

A	mRNA nucleotides join with exposed DNA bases and form a molecule of mRNA
B	Peptide bonds form between the amino acids
C	tRNA molecules bring specific amino acids to the mRNA molecule
D	The introns are spliced from the pre-mRNA to produce mRNA
E	A ribosome attaches to the mRNA molecule
F	The two strands of a DNA molecule separate
G	The mRNA molecule leaves the nucleus

Identify the correct order of letters to show the sequence of events during protein synthesis, starting with the earliest.

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(3 marks)

(b) Haemoglobin is a protein made of alpha and beta polypeptides. Each alpha polypeptide has 141 amino acids and each beta polypeptide has 146 amino acids.

Deduce the total number of peptide bonds present in one alpha polypeptide **and** one beta polypeptide.

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(1 mark)

(c) Haemoglobin is a quaternary protein.

Describe the structures of haemoglobin that make it a quaternary protein.

(2 marks)

(d) State the types of bonding present in the different levels of protein structure.

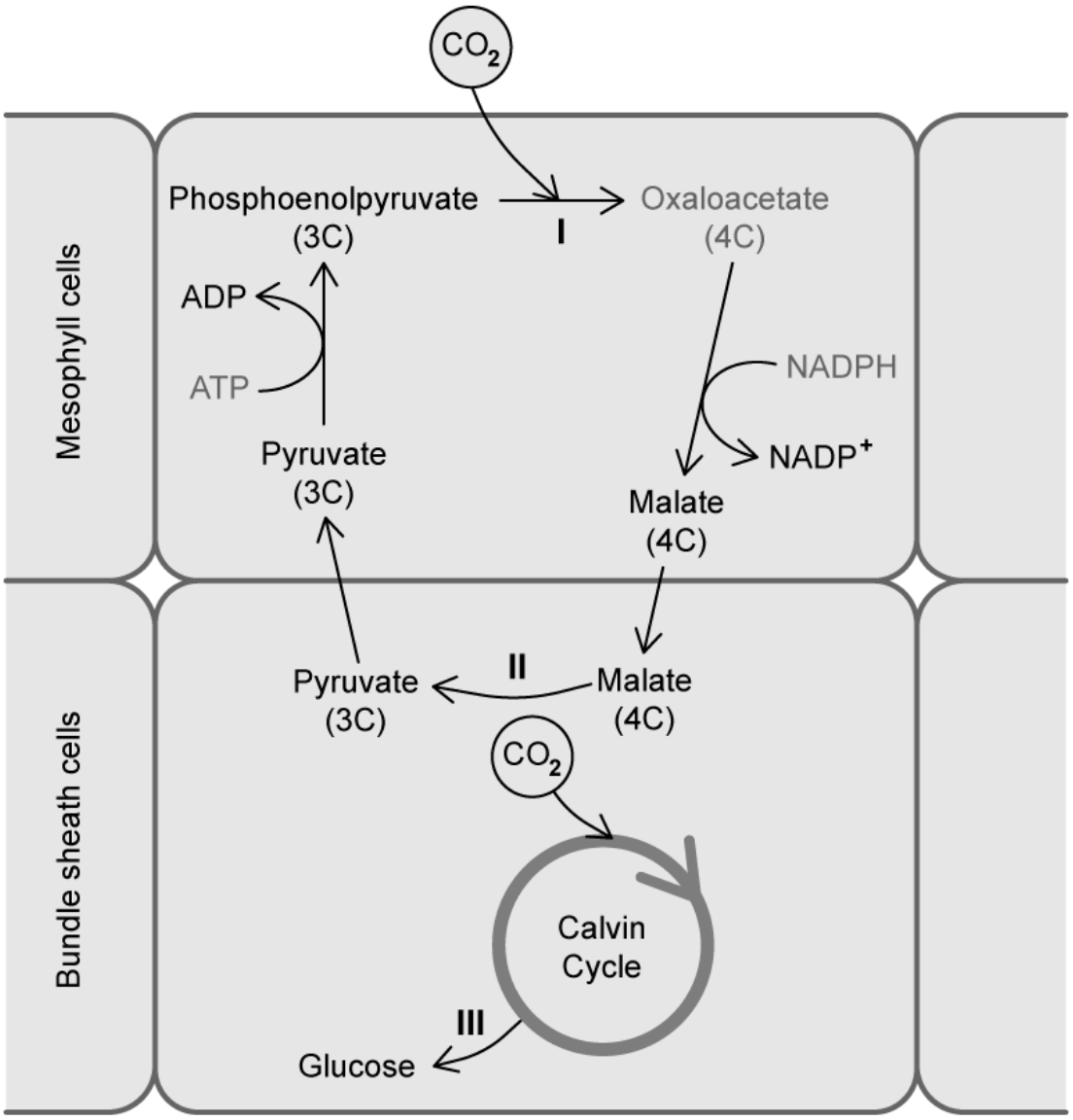
(3 marks)

(e) Explain why cellular enzymes are made predominantly from protein.

(5 marks)

Hard Questions

1 (a) Suggest, with a reason, which label (**I**, **II**, or **III**) indicates a catabolic reaction.



(2 marks)

(b) The diagram in part (a) illustrates how life is based on certain biochemical compounds.

Identify which major group of carbon-containing compounds is dominant in this diagram.

(1 mark)

(c) Fats and cholesterol are essential to structures and functions in the bodies of animals and therefore need to be transported in blood.

Discuss how these molecules are transported.

(3 marks)

(d) Draw a labelled diagram of a generalised amino acid.

(4 marks)

2 (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)

3 (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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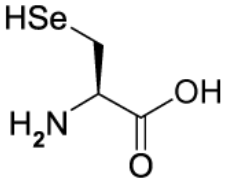
(2 marks)

(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)

4 (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)

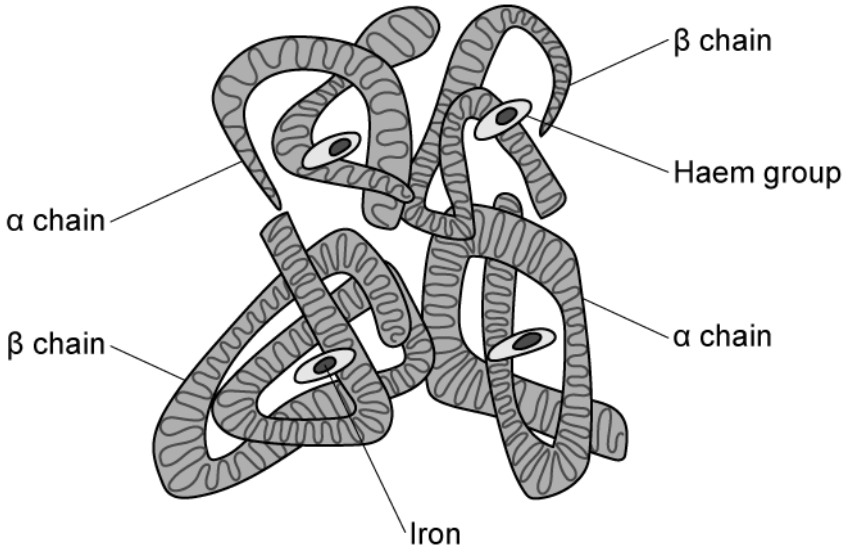
(c) In modern medicine, human insulin is secreted from genetically modified bacteria into large industrial vats called fermenters. This allows the insulin to be extracted and purified for human use.

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

(3 marks)

5 (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.

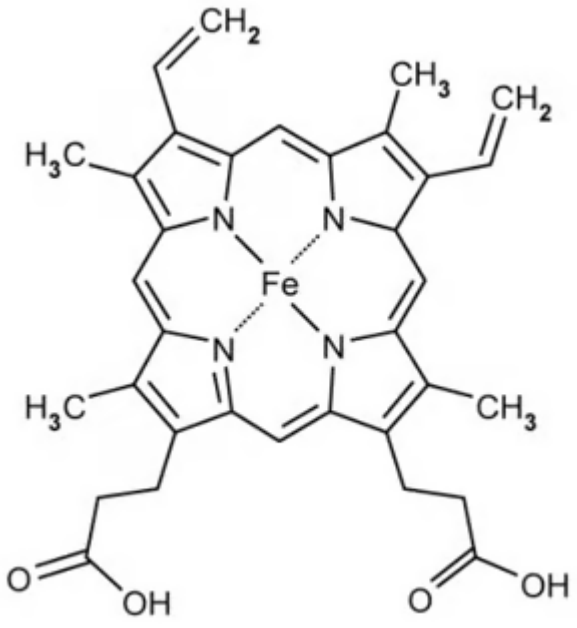
Unlike the proteome, the genome remains fixed.

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)

6 (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)