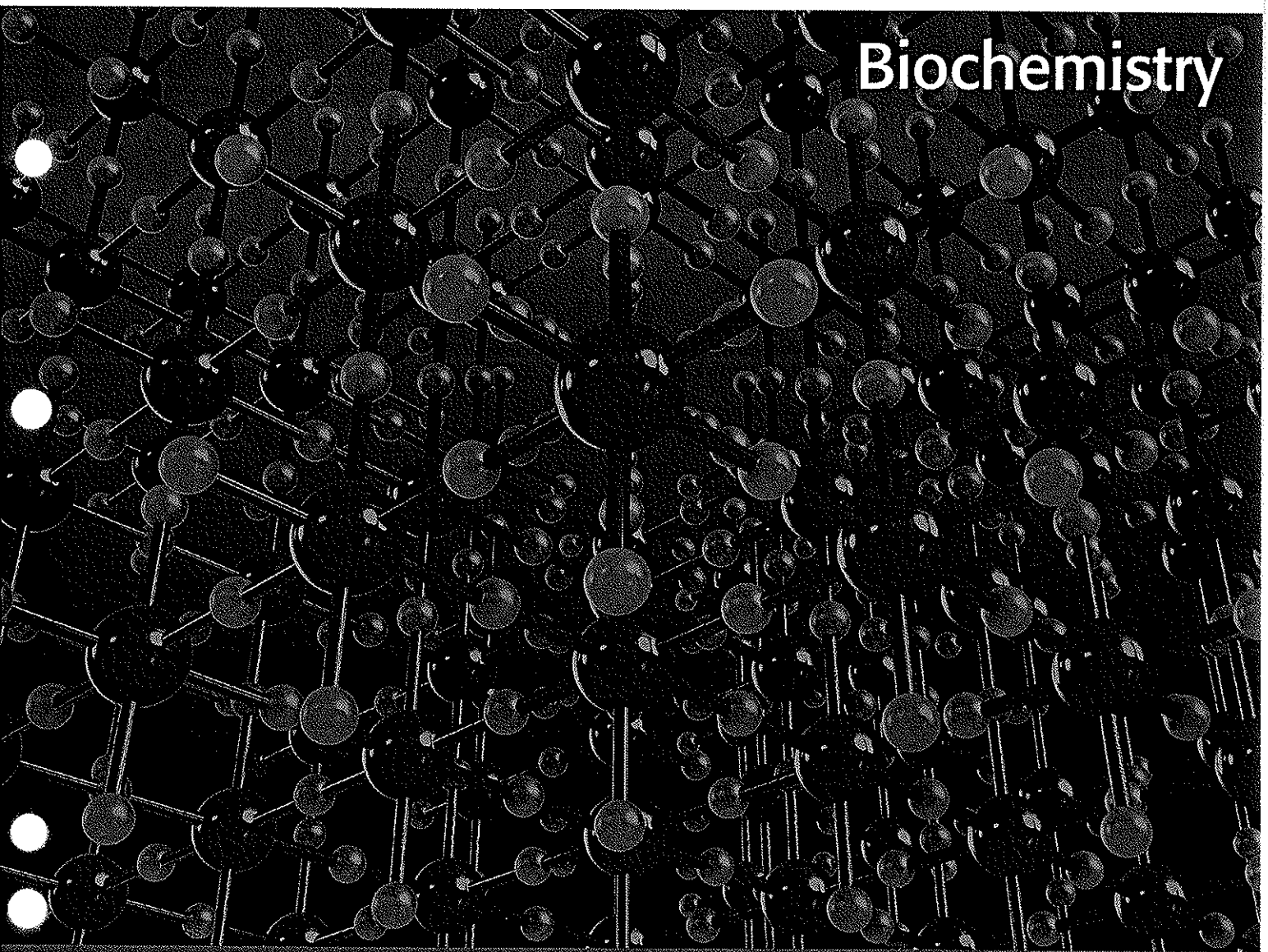
DOT POINT

OPTION B

Biochemistry



Notes

B1 Energy. © IBO 2007

B.1.1 Calculate the energy value of a food from enthalpy of combustion data. © IBO 2007

B.1.1.1 The chemical energy in food is contained in the chemical bonds such as C–C, C–H, C–O and O–H bonds. Each bond type has its own characteristic amount of energy. Complete the following sentences to revise prior knowledge.

(a) Bond energy is the amount of energy needed to ..... that bond. It is also the amount of energy ..... when that bond forms.

(b) It takes 414 kJ of energy to break 1 mole of C-H bonds. When 1 mole of C-H bonds forms, ... kJ of energy is released.

(c) In an exothermic reaction such as respiration or combustion, the energy used to break bonds is ..... (more/less) than the energy released when new bonds form.

(d) The SI unit for measuring energy is the .....

(e) The products of respiration of glucose in cells of the body are ..... and .....

(f) The major food group used for energy production is .....

(g) The major food group used by the human body for energy storage is .....

(h) The major food group which possesses the most energy per gram is .....

(i) The symbol for standard enthalpy change in a chemical reaction is .....

(j) The sign for the enthalpy change in an exothermic reaction such as combustion is always ..... (positive/negative/zero).

(k) The energy value of a food is determined by measuring the standard enthalpy of .....

(l) The apparatus used to measure the energy value of a food is called a .....

B.1.1.2 Foods provide us with the energy to carry out all the processes of life such as growth and movement. We can measure the energy value of different foods using a calorimeter.

(a) A 10.0 g sample of a food is combusted in a closed, insulated calorimeter in order to calculate the energy value of the food. The heat energy released is absorbed into 200.0 g water, increasing its temperature by 55.0°C. Assuming the energy absorbed by the calorimeter is negligible, calculate the heat energy released by the burning food. The specific heat of water is 4.18 J g^{-1} K^{-1}.

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(b) If an average serving of this food is 38.0 g, calculate the energy per serve.

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(c) Calculate the change in temperature that would be measured in the water of this calorimeter if a food combusted in it had an energy value of 20.0 kJ.

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B.1.1.3 150 g water is poured into a steel container with a mass of 200 g when empty. The temperature of this system is raised 30°C by the complete combustion of a sample of peanut butter. Calculate the energy value of the sample of peanut butter.

Specific heat of steel = 0.45 J g^{-1} K^{-1}

Specific heat of water = 4.18 J g^{-1} K^{-1}

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B.1.1.4 Explain why food packaging should contain information about the energy value of the food.

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B.1.1.5 Complete the table to compare the energy of combustion per mole and per gram for the substances listed.

Food	Formula	Enthalpy of combustion (kJ/mol)	Enthalpy of combustion (kJ/g)
Glucose		2808	
Stearic acid	$CH_3(CH_2)_{16}COOH$	11 381	
Ethanol		1364	

B.1.1.6 A particular food with a high-energy value when combusted in a calorimeter, was advertised as a suitable food for a weight loss diet. Comment on the suitability of including a high-energy food in a weight loss diet.

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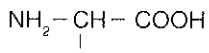
B2 Proteins. © IBO 2007

B.2.1 Draw the general formula of 2-amino acids. © IBO 2007

B.2.1.1 The building blocks of proteins are 2-amino acids.

(a) The diagram shows the functional group of 2-amino acids. Label the amino group, the carboxylic acid group and the 2-carbon atom.



(b) Identify the elements that make up 2-amino acids.

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(c) Explain why the amino acids that make up human proteins are called 2-amino acids.

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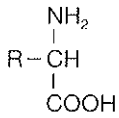
B.2.1.2 The general formula for 2-amino acids can be shown as below.



Using the formulas for 2-amino acids in the data sheets provided at the back of the book, complete the table to show the R group for each amino acid listed.

Amino acid	R group
Glycine	
Alanine	
Leucine	
Cysteine	
Aspartic acid	
Lysine	
Serine	

B.2.1.3 You will recall that a hydrophobic substance is one which avoids water. From the data sheet structures of the twenty 2-amino acids that make up proteins, identify three with non-polar (hydrophobic) side-groups.

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B.2.2 Describe the characteristic properties of 2-amino acids. © IBO 2007

B.2.2.1 Amino acids exist as zwitterions.

(a) Define the term zwitterion.

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(b) Amino acids have an amino group and an acid group which are both able to ionise. Draw the structure of glycine showing both amino and acid groups ionised.

(c) Account for the solubility of 2-amino acids in water.

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B.2.2.2 Complete the table to show the nature of the polar groups on each of the 2-amino acids at different pHs.

Name of 2-amino acid	Low pH (approximately pH 1)	Neutral pH (approximately pH 7)	High pH (approximately pH 11)
Glycine			
Lysine			
Aspartic acid			
Leucine			

B.2.2.3

(a) Amino acids are described as amphoteric. Justify this statement using equations involving a 2-amino acid with an alkyl side-chain (R).

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(b) Explain the action of amino acids as buffers in aqueous solution.

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B.2.2.4

(a) Define the isoelectric point (pI) of an amino acid.

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(b) The isoelectric point of glycine is pH 6.0. Identify the structure of glycine that exists at this pH.

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(c) Explain why the pI is a characteristic property of amino acids.

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B.2.3 Describe the condensation reaction of 2-amino acids to form polypeptides.

B.2.3.1 Recall what is meant by a condensation reaction.

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Answer Question B.2.3.2 by selecting the most correct alternative.

B.2.3.2 A peptide bond is formed in a condensation reaction between:

(A) The side-chain groups of two 2-amino acids.

(B) Any two species which join together with the elimination of a water molecule.

(C) –COOH and H_2N–C–, resulting in a –C–O–C– bond from the elimination of water.

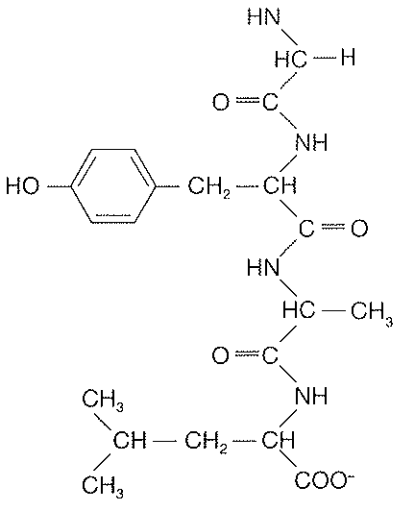
(D) The carboxyl group and the 2-amino group of two 2-amino acids.

B.2.3.3 Amino acids can join together by condensation reactions to form chains. Describe this reaction and include an equation.

B.2.3.4 Circle the peptide linkages and identify the amino acid sequence in the following diagram.

N-terminal end

Sequence



C-terminal end

B.2.3.5 Construct and name a dipeptide consisting of the 2-amino acids glycine and alanine with the glycine at the amino terminal end.

B.2.3.6 Complete the table to summarise the meaning of the following terms.

Term	Meaning
Peptide bond	
Dipeptide	
Tripeptide	
Polypeptide	
Protein	

B.2.4 Describe and explain the primary, secondary (α-helix and β-pleated sheets), tertiary and quaternary structure of proteins.

B.2.4.1 Each protein in an organism has its own unique structure.

(a) What is meant by the primary structure of proteins?

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(b) Outline the difference between the primary structure of the following two sequences.

(i) ala–gly–leu–asp–lys

(ii) lys–asp–leu–gly–ala

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(c) Discuss the importance of the primary structure in proteins.

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B.2.4.2 What is meant by the secondary structure of a protein?

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B.2.4.3 One common feature of the secondary structure of a protein is an α-helix.

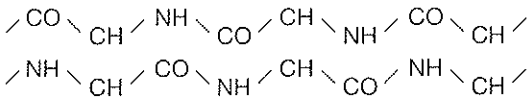
(a) Outlne the structure of the α-helix and identify a property conferred on the protein by this structure.

(b) Describe and sketch the bonding that holds the chain in the α-helix structure.

B.2.4.4 Another feature of the secondary structure of proteins is referred to as a β-pleated sheet.

(a) Outline the β-pleated sheet arrangement. Include a diagram.

(b) On the diagram below use a dotted line to show the positions of the hydrogen bonds in a β-pleated sheet. The amino acid side-chains have been omitted.



B.2.4.5 Contrast the hydrogen bonding in the α-helix and the β-pleated sheet. Tabulate your answer.

B.2.4.6 The tertiary structure of a protein is the folding or curling that determines its three-dimensional shape.

(a) Describe the tertiary structure of a named protein you have studied.

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(b) Indicate which of the following amino acids you would expect to find on the surface of a protein and which would occur in an interior position.

Valine, glutamic acid, leucine, arginine, phenylalanine.

On the surface .....

In an interior position .....

B.2.4.7 Non-covalent bonding between the amino acid side-chain groups helps to determine the tertiary structure of the protein. Explain how each of the following helps to determine tertiary structure.

(a) Hydrophobic side-chains.

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(b) Electrically charged side-groups (ionised side-groups such as COO^-).

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(c) Size of the side-chains.

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(d) Hydrogen bonding.

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B.2.4.8 Once the protein three-dimensional shape has been obtained, it may be stabilised by the formation of covalent bonds between cysteine side-chains that have been brought close together.

(a) From the data tables, draw the structure of cysteine.

(b) Explain the formation of the disulfide linkage between molecules of cysteine.

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B.2.4.9 Proteins have quarternary structure if they contain one or more polypeptide chains held together by bonds which are not covalent.

(a) Explain why only some proteins have quaternary structure.

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(b) Identify two proteins which do have quaternary structure and indicate how many chains they each have.

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(c) Identify the bonding holding the chains together in quaternary structure.

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B.2.4.10

(a) Complete the table to summarise the features of primary, secondary, tertiary and quaternary structure of proteins.

Structure	Distinguishing feature
Primary	
Secondary	
Tertiary	
Quaternary	

(b) Complete the table to summarise the bonding in primary, secondary, tertiary and quaternary structure of proteins.

Structure	Intermolecular or intramolecular	Covalent or non-covalent	Type(s) of bond(s)
Primary			
Secondary			
Tertiary			
Quarternary			

B.2.4.11 Sometimes a protein loses its secondary and tertiary structure. It is described as denatured and is unable to carry out its functions in the body. Identify some factors that could cause denaturation of a protein.

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B.2.5 Explain how proteins can be analysed by chromatography and electrophoresis.

B.2.5.1 Describe how proteins can be broken down to amino acids as the first step in analysing their composition. Include an equation in your answer.

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B.2.5.2 Once separated, the amino acids can be analysed by chromatography.

(a) Explain the principle behind separation by chromatography.

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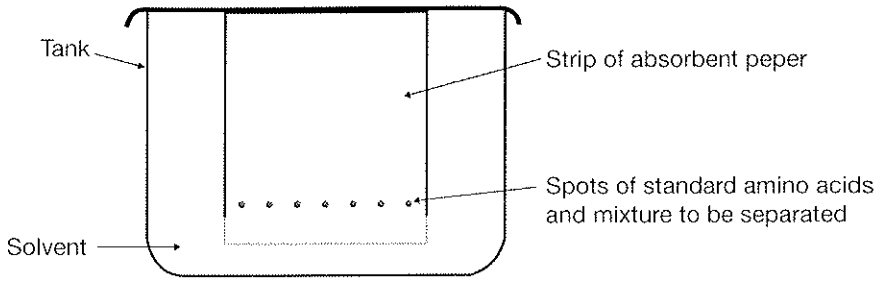
(b) Using the diagram below as a guide, identify steps in the process of paper chromatography.



(c) Outline the process of high-performance liquid chromatography (hplc).

B.2.5.3 Electrophoresis is a technique used for separating and analysing substances based on their electric charge. Components of a mixture move through a medium under the influence of an electric field.

(a) Identify the role of electrophoresis in the analysis of proteins

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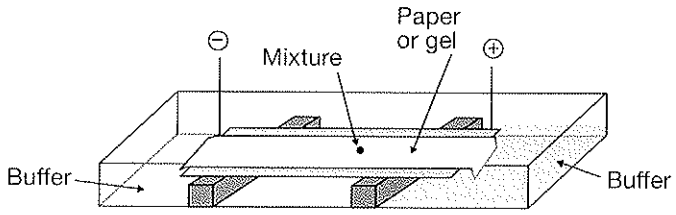
(b) The diagram shows possible equipment for electrophoresis. Explain the principle of separation by electrophoresis and draw a sketch next to it to show the type of results that could be obtained by this process.



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(c) Explain why the pH of the electrolyte must be controlled in electrophoresis.

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(d) Deduce the movement of an amino acid if the buffer used had a pH as indicated below.

(i) A pH equal to the isoelectric pH (pI) of the amino acid.

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(ii) A pH below the isoelectric pH (pI) of the amino acid.

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(iii) A pH above the isoelectric pH (pI) of the amino acid.

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(e) Electrophoresis was carried out on a mixture of the amino acids alanine, asparagine, aspartic acid and cysteine with a buffer of pH 8.0. Predict the direction and order of movement of the amino acids.

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B.2.6 List the major functions of proteins in the body.

B.2.6.1 Proteins are the most abundant organic chemicals within cells. Summarise the major functions of proteins in the body by completing the following table.

Type of protein	Functions	Examples
Enzymes		
Transport proteins		Haemoglobin carries oxygen.
Structural proteins		
		Insulin regulates blood sugar levels. Growth hormone controls growth in the young.
Antibodies		
Contractile proteins		
Food storage	Provide store of amino acids for the growing baby in milk or for the embryo in egg white.	

B3 Carbohydrates. © IBO 2007

B.3.1 Describe the structural features of monosaccharides. © IBO 2007

B.3.1.1 Complete the following sentences.

(a) The empirical formula of carbohydrates is .....

(b) Monosaccharide has the literal meaning of ....

(c) Monosaccharides can join together in long chains to form polymers called .....

(d) Carbohydrate is synthesised in plant leaves during the reaction called .....

(e) The molecular formula of glucose is .....

B.3.1.2 Monosaccharides contain between three and nine carbon atoms in an unbranched structure.

(a) Identify the structural feature of a monosaccharide that allows it to be classified as either:

(i) An aldehyde.

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(ii) A ketone.

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(b) Hydroxyl groups are an important structural feature of monosaccharides. Describe their occurrence.

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(c) Describe the intermolecular bonding that results in sugars being white, crystalline solids which are soluble in water.

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B.3.1.3 Sugars are recognised by the use of the suffix -ose. Hexoses (6-carbon sugars) are by far the most abundant, and pentoses (5-carbon sugars) the next most abundant.

(a) Complete this table of information about common monosaccharides.

Name	Number of carbons	Aldose or ketose	Occurrence
Glucose			
Fructose			
Galactose			
Ribose			

(b) Complete this table of information about common disaccharides.

Name	Contain the monosaccharide(s)	Occurrence
Sucrose		
Lactose		
Maltose		

B.3.2 Draw the straight-chain and ring structural formulas of glucose and fructose.

B.3.2.1 Explain why glucose and fructose are considered to be isomers.

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B.3.2.2 Monosaccharides exist in two forms that vary in their effect on polarised light. The biological form is called D-glucose. In solution, D-glucose exists in an equilibrium between a straight chain and a ring structure, the ring structure being the more common form.

(a) Draw the straight-chain structure of D-glucose, showing the numbering of the carbon atoms.

(b) Since C1 is asymmetric (chiral), the hydroxyl (OH) and hydrogen groups on C1 can vary in their position forming α- and β-glucose. Draw the ring structure of α-D-glucose and β-D-glucose.

α-D-glucose	β-D-glucose

(c) Describe the difference between the alpha and beta forms of glucose.

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B.3.2.3

(a) Compare the structures of D-glucose and D-fructose. Tabulate your answer.

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(b) Draw the 5-carbon ring structure of fructose showing both alpha and beta forms.

(c) Draw the 4-carbon ring structure of fructose showing both alpha and beta forms.

B.3.3 Describe the condensation of monosaccharides to form disaccharides and polysaccharides.

B.3.3.1 Monosaccharides join together by condensation reactions between two –C–OH groupings to form disaccharides and polysaccharides.

(a) Use an equation to illustrate the condensation reaction between two molecules with the general formula R–C–OH.

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(b) Identify the special name given to the C–O–C bond between monosaccharide units.

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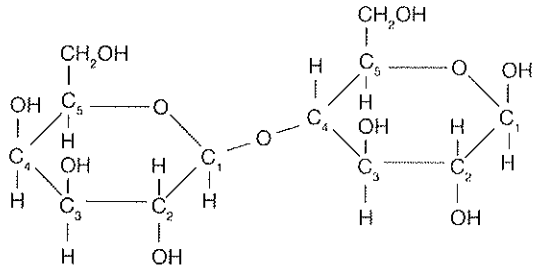
B.3.3.2 Draw the following disaccharides and trisaccharides.

(a) A disaccharide composed of two α-glucose units joined by a glycosidic link between carbons 1 and 4.

(b) A trisaccharide composed of three α-glucose units joined with a 1,4 and a 1,6 glycosidic linkage.

(c) A disaccharide with two β-glucose units joined in a 1,4 linkage.

B.3.3.3 The diagram below shows the structure of lactose, the disaccharide sugar in milk, formed from β-galactose and β-glucose. It has a 1,4 glycosidic link.



(a) Identify the difference between lactose and the disaccharide in Question B.3.3.2 (c).

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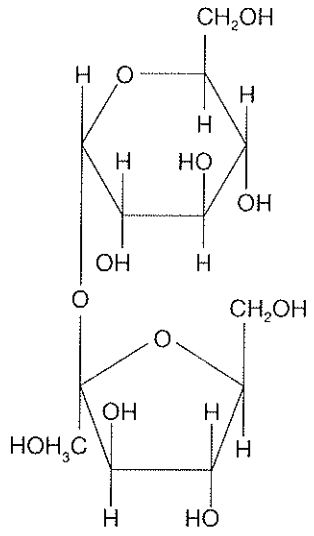
(b) Draw the structure of β-galactose.

(c) The diagram below shows the structure of sucrose (table sugar). Identify the two monosaccharides and the linkage between them.



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B.3.3.4 Compare the two forms of starch, amylose and amylopectin. Tabulate your answer.

B.3.3.5 Glycogen is a polysaccharide and it is the form in which glucose is stored in liver and muscle tissues in humans. Outline the structure of glycogen.

B.3.3.6 Cellulose is a polysaccharide found in the cell walls of plants. Outline the structure of cellulose and account for its suitability for this purpose.

B.3.4 List the major functions of carbohydrates in the human body.

B.3.4.1 Identify examples of ways in which carbohydrates carry out the following functions in the human body.

(a) Provide a source of energy.

(b) Provide energy storage (a reserve).

(c) Make up the structure of the body.

B.3.5 **Compare the structural properties of starch and cellulose, and explain why humans can digest starch but not cellulose.** © IBO 2007

B.3.5.1 Starch (amylose and amylopectin) and cellulose are both plant polymers of glucose. Complete the table to compare the structural properties of starch (amylose and amylopectin) and cellulose.

Polysaccharide	Monosaccharide present	Branched or unbranched	Linkage (glycosidic)	Molecular weight range
Amylose				
Amylopectin				
Cellulose				

B.3.5.2

(a) Starch is an important source of glucose in our food. Explain why humans can digest starch but not cellulose.

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(b) How do some herbivorous mammals such as cows and rabbits digest cellulose?

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B.3.6 **State what is meant by the term dietary fibre.** © IBO 2007

B.3.6.1

(a) What is dietary fibre? Include examples of compounds that are present in dietary fibre.

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(b) List some sources of dietary fibre in our diet.

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B.3.7 **Describe the importance of a diet high in dietary fibre.**

B.3.7.1 Describe the function of the following.

(a) Insoluble dietary fibre.

(b) Soluble dietary fibre.

B.3.7.2 Outline three conditions that a high-fibre diet can help to avoid.

B4 Lipids. © IBO 2007

B.4.1 Compare the composition of the three types of lipids found in the human body. © IBO 2007

B.4.1.1 Lipids are a diverse group of compounds found in living tissues. They are insoluble in water but soluble in polar substances. Identify the three main groups of lipids found in the human body and name an example of each.

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B.4.1.2 Triglycerides make up the largest group of lipids. They can be formed by condensation reactions of glycerol with fatty acids.

(a) State the structural formula and systematic name of glycerol.

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(b) What are fatty acids?

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(c) Describe the structure of triglycerides and include a general structural formula.

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B.4.1.3 Phospholipids are lipids which contain the phosphate group.

(a) Draw the general formula of phospholipids and describe their structure.

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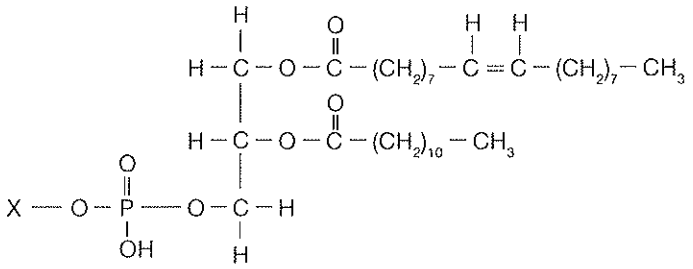
(b) The diagram shows a phospholipid. Use squares to label the fatty acids, glycerol, phosphate and alcohol groups within it.



(c) Explain why phospholipids are classified as polar.

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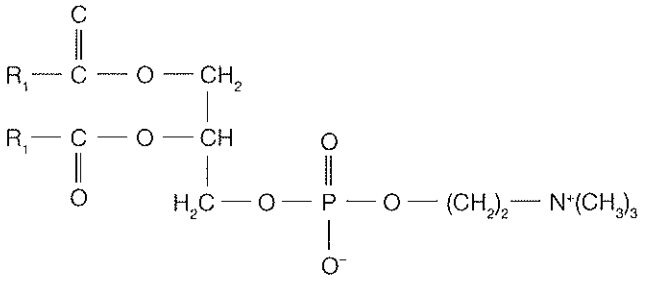
(d) The diagram shows the structure of a phospholipid called lecithin which is found in plant and animal tissues. Lecithins contain choline which is used to make acetylcholine for nerve transmission in the body. Label this diagram of lecithin to show its polar head, non-polar hydrocarbon tail and choline.



B.4.1.4 Compare the composition of triglycerides and phospholipids.

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B.4.1.5 Steroids are a group of lipids which have a characteristic fused carbon ring structure.

(a) Draw and describe the basic steroid ring structure.

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(b) The most abundant steroid is cholesterol. Show the structure of cholesterol.

B.4.2 **Outline the difference between HDL and LDL cholesterol and outline its importance.** © IBO 2007

B.4.2.1 Outline the importance of cholesterol in the body.

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B.4.2.2 Lipoproteins are complexes of lipids and proteins. Outline the function of lipoproteins in the body.

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B.4.2.3 Lipoproteins differ in their ratio of lipids to proteins. Complete the table to compare the difference in composition and function of high-density lipoprotein (HDL) and low-density lipoprotein (LDL) cholesterol.

Factor	HDL	LDL
Protein/fat ratio		
Cholesterol (%)		
Density		
Function		
'Good' or 'bad' lipoprotein		

B.4.3 **Describe the difference in structure between saturated and unsaturated fatty acids.**

B.4.3.1 Fatty acids are carboxylic acids which consist of a long hydrocarbon chain, with an acid group and a methyl group at opposite ends.

(a) Distinguish between saturated and unsaturated fatty acids.

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(b) Describe the difference between cis and trans fatty acids.

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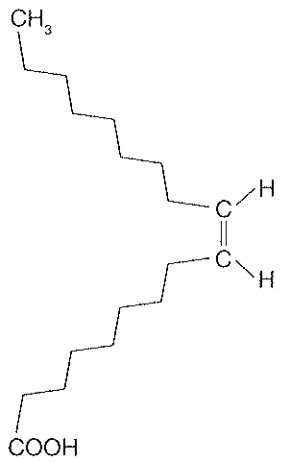
(c) The diagrams show the basic structures of two fatty acids. Identify which is a cis form and which is a trans form.

(i)



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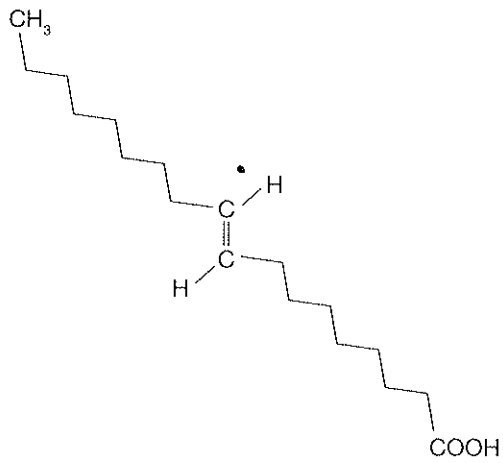

B.4.3.2 Complete the following table showing names and structures of some common fatty acids.

Common name	Systematic name	Formula	Saturated or unsaturated
Palmitic acid	Hexadecanoic acid		
	Octadecanoic acid		
Oleic acid	Cis-9-octadecenoic acid		
	Cis, cis-9,12-octadecadienoic acid		

B.4.3.3 Fatty acids form part of the structure of triglyceride lipids. Deduce whether the presence of cis or trans double bonds, as part of their fatty acid structure, would affect the state of lipids at room temperature. Justify your deductions.

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B.4.4 **Compare the structures of the two essential fatty acids linoleic (omega-6 fatty acid) and linolenic (omega-3 fatty acid) and state their importance.**

B.4.4.1 Most fatty acids can be synthesised in the body. However, there are two which cannot be synthesised and thus must be present in our food.

(a) Name and write condensed structural formulas for these two essential amino acids.

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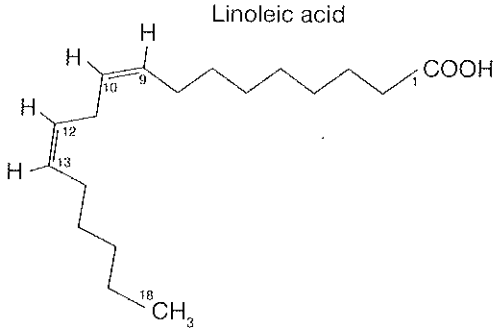
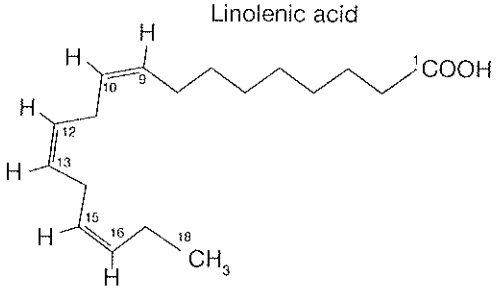
(b) Each of these two essential fatty acids has 18 carbon atoms. Using the structural formulas below, identify the main structural difference between their molecules.

Linoleic acid



Linolenic acid



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(c) Explain the omega terminology used with fatty acids.

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B.4.4.2 Outline the importance of linoleic and linolenic acids in the diet.

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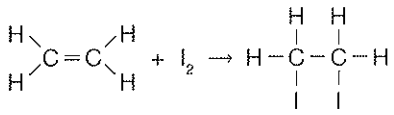
B.4.5 **Define the term iodine number and calculate the number of C=C double bonds in an unsaturated fat/oil using addition reactions.**

B.4.5.1 An addition reaction occurs when a double bond is broken and an atom or group is added to each atom involved in the double bond.

An addition reaction of iodine across a double bond can be illustrated as follows.



(a) How many moles of iodine are shown to be reacting here? .....

(b) Identify the mole ratio of iodine to fatty acid when an addition reaction occurs between iodine and a monounsaturated fatty acid.

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(c) Describe the colour change as iodine adds on across the double bonds in a fatty acid.

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B.4.5.2

(a) Define iodine number.

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(b) Outline the significance of iodine numbers.

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(c) Outline a procedure for determining the iodine number of a fatty acid.

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B.4.5.3 A sample of 0.015 moles of oleic acid reacts completely with 3.807 g of iodine. Calculate the following.

(a) The number of double bonds in oleic acid.

(b) The iodine number for oleic acid.

B.4.5.4 Linolenic acid ($C_{17}H_{29}COOH$) has three double bonds per molecule. Determine its iodine number.

B.4.6 Describe the condensation of glycerol and three fatty acid molecules to make a triglyceride.

B.4.6.1 You will recall that a condensation reaction is a chemical reaction in which two molecules are joined together with the elimination of a small molecule, usually water.

(a) Justify the description of esterification as a condensation reaction.

(b) Explain why fats and oils are referred to as esterified glycerol molecules.

B.4.6.2 Using structural formulas, construct an equation to show the formation of a named triglyceride from glycerol and stearic acid. Indicate which part of the reacting molecules forms water and circle the ester linkages in the triglycerol formed.

B.4.7 Describe the enzyme-catalysed hydrolysis of triglycerides during digestion.

B.4.7.1 Hydrolysis reactions occur during digestion. They involve the splitting of a covalent bond by reacting a chemical with water in the presence of an enzyme.

(a) Name the enzyme in the digestive system that breaks down triglycerides and explain why an enzyme is necessary for this reaction to take place.

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(b) Bile acids released from the gall bladder into the small intestine are necessary for lipid digestion. What is their function?

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B.4.7.2 The hydrolysis of a triglyceride is the reverse of the esterification reaction that forms fat.

(a) Describe the enzyme catalysed hydrolysis of triglycerides.

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(b) Using general structural formulas, write three equations to illustrate the sequential breakdown of a triglyceride to a diglyceride, then a monoglyceride and finally to glycerol and fatty acids.

B.4.8 Explain the higher energy value of fats as compared to carbohydrates.

B.4.8.1 Energy is released from digested foods during the process of respiration in cells of the body. During respiration, digested foods undergo oxidation.

(a) Compare the ratio of carbon:oxygen in fats and carbohydrates and relate this to their relative oxidation states.

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(b) Explain how the oxidation state of a food affects the energy released.

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B.4.8.2 Sucrose is the carbohydrate that makes up cane sugar and lauric acid is the main fatty acid in coconut oil and palm oil. Each of these compounds contains 12 carbon atoms per molecule.

(a) Draw structural formulas for each of these two compounds.

Sucrose

Lauric acid

(b) Write equations, using molecular formulas, to illustrate the oxidation of sucrose and lauric acid.

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(c) Compare the energy that would be released by bond formation in these two reactions.

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B.4.9 **Describe the important roles of lipids in the body and the negative effects that they can have on health.**

B.4.9.1 Complete the following table to describe the uses of lipids in the body.

Uses of lipids	Description of use
Energy storage	There is a layer of fat/lipid tissue, called adipose tissue, under the skin. This stores energy, mainly as triglycerides. Fats have more energy per gram than carbohydrates so are an efficient form of energy storage.
Insulation	
Protection of organs	
Membrane components	
Precursor to steroid hormones	
Essential fatty acids	
Control of fat deposition	

B.4.9.2 It is essential to include some lipids in the diet. However, if we eat excess lipids, they may have negative effects on health. Outline these negative effects of lipids in the diet.

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B5 Micronutrients and macronutrients. © IBO 2007

B.5.1 Outline the difference between micronutrients and macronutrients. © IBO 2007

B.5.1.1 Nutrients essential for optimal body functioning can be classified as macronutrients or micronutrients.

(a) Define what is meant by macronutrients and identify macronutrients needed by humans.

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(b) Define what is meant by micronutrients and identify micronutrients needed by humans.

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B.5.1.2 Complete the table to summarise the main functions of the macro and micronutrients listed.

Nutrient	Function
Carbohydrates	
Proteins	
Lipids	
Minerals	
Vitamins	
Water	

B.5.2 **Compare the structures of retinol (vitamin A), calciferol (vitamin D) and ascorbic acid (vitamin C).**

B.5.2.1 Using the structural formulas from the data sheets at the back of this book, describe the structures of vitamins A, C and D. In particular note the polar/non-polar nature of their structures.

B.5.2.2 Outline the functions of vitamins A, C and D.

B.5.3 **Deduce whether a vitamin is water- or fat-soluble from its structure.**

B.5.3.1 Based on their structures, compare the solubilities of the vitamins A, C and D in water and fat.

B.5.3.2 Identify structures present in water-soluble vitamins which contribute to their solubility.

B.5.4 **Discuss the causes and effects of nutrient deficiencies in different countries and suggest solutions.** © IBO 2007

B.5.4.1 What is meant by a balanced diet?

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B.5.4.2 Malnutrition has been defined as the insufficient, excessive or unbalanced consumption of nutrients.

(a) Outline causes of malnutrition.

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(b) Identify possible consequences of malnutrition.

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B.5.4.3 Discuss the effects of two forms of protein deficiency on babies and older children.

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B.5.4.4 Complete the table to summarise four examples of micronutrient deficiencies that cause disease.

Nutrient lacking	Name of deficiency disease	Symptoms

B.5.4.5 Malnutrition is a global problem. Discuss the occurrence and causes of malnutrition in the country in which you live and suggest ways to deal with this problem.

B6 Hormones. © IBO 2007

B.6.1 Outline the production and function of hormones in the body. © IBO 2007

B.6.1.1 Hormones are part of the endocrine system and they play important roles in the human body.

(a) What are hormones?

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(b) Outline how the endocrine system is controlled and coordinated.

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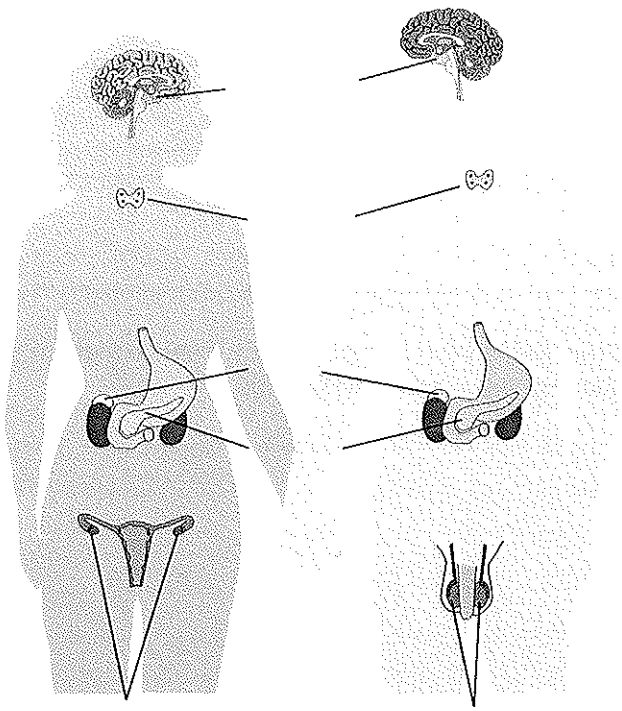
(c) Label the endocrine glands to show their position in the body.



B.6.1.2 Complete the following table to summarise some hormones, the glands that secrete them and their function in the body.

Hormone	Gland producing the hormone	Function of the hormone
Insulin		
Thyroxine		
Adrenaline		
Oestrogen		
Progesterone		
Testosterone		
Aldosterone		
Antidiuretic hormone (ADH)		

B.6.1.3 Identify hormones from the table in Question B.6.1.2 above that are derived from cholesterol and hence have the basic ring structure of cholesterol.

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B.6.2 **Compare the structures of cholesterol and the sex hormones.**

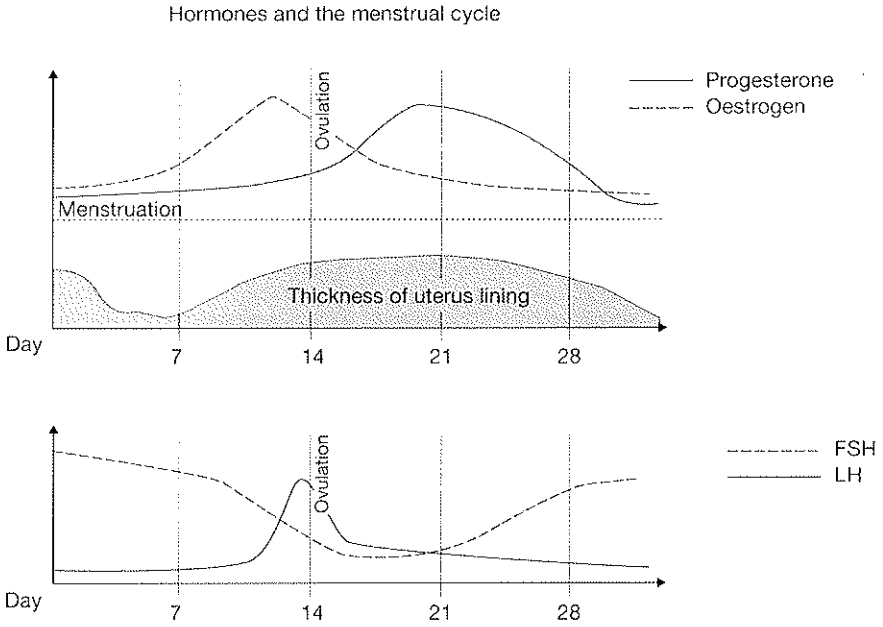
B.6.2.1 Draw structural formulas from the data sheets at the back of this book to show the basic structure of cholesterol and the named hormones.

Cholesterol	Progesterone
Testosterone	Oestradiol (the main oestrogen)

B.6.2.2 Compare the structures of the hormones you have drawn in Question B.6.2.1.

B.6.3 **Describe the mode of action of oral contraceptives.** © IBO 2007

B.6.3.1 The following graphs shows changes in hormone levels during a 28-day menstrual cycle.



(a) Describe fluctuations in the hormone levels and relate these to the events of the menstrual cycle.

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(b) If fertilisation occurs, what happens to the levels of oestrogen and progesterone?

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B.6.3.2 Oral contraceptive pills provide a popular way of preventing pregnancy. Describe the mode of action of the following.

(a) The combined contraceptive pill.

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(b) The minipill.

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B.6.4 Outline the use and abuse of steroids.

B.6.4.1 Outline uses of steroids.

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B.6.4.2 Outline the abuse of steroids.

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Notes

HL B7 Enzymes. © IBO 2007

B.7.1 Describe the characteristics of biological catalysts (enzymes). © IBO 2007

B.7.1.1 Enzymes are defined as biological catalysts.

(a) Justify this terminology.

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(b) What effect does an enzyme have on an equilibrium reaction?

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B.7.1.2 Enzymes are substrate specific.

(a) Define the term substrate with reference to enzymes.

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(b) What is meant by the specificity of an enzyme? Include an example.

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(c) Explain the specificity of enzymes in terms of protein structure.

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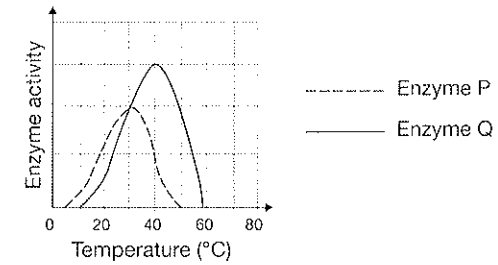
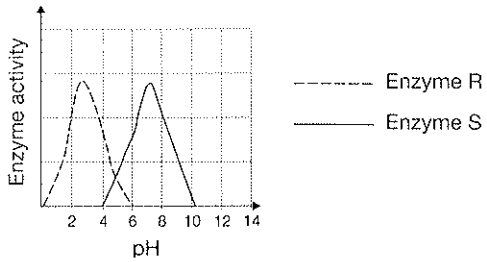
B.7.1.3 The two graphs below show the effect of temperature and pH on the reaction rate for enzyme-catalysed reactions. Based on these graphs, what can you deduce about the characteristics of enzymes?

Graph A
Enzyme activity and temperature



Graph B
Enzyme activity and pH



Graph A

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Graph B

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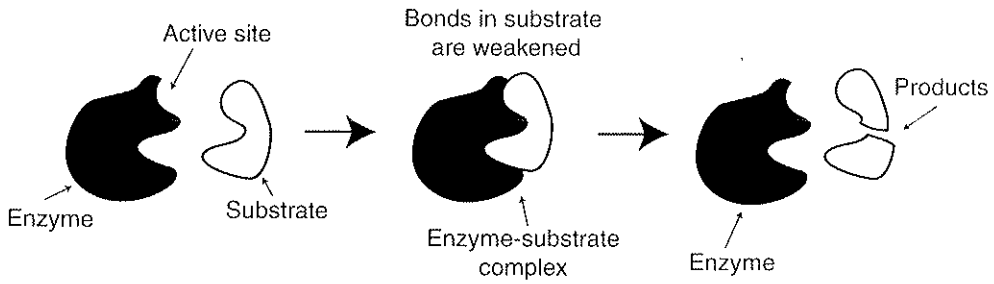
B.7.2 Compare inorganic catalysts and biological catalysts (enzymes).

B.7.2.1 Complete the following table to compare the properties of inorganic and biological (organic) catalysts.

Property	Inorganic catalyst	Biological catalyst (enzyme)
Organic or inorganic		
Quantity needed for reaction		
Is the catalyst changed chemically by reaction?		
Specificity		
Effect of temperature on catalysis		
Effect of pH		
Cofactors		
State		

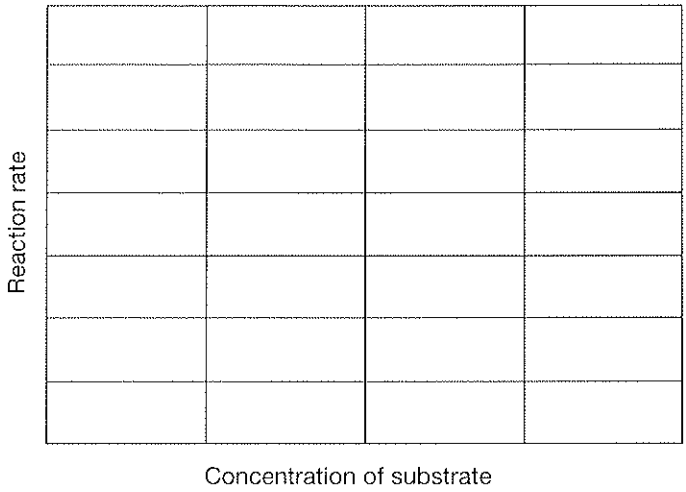
B.7.3 **Describe the relationship between substrate concentration and enzyme activity.**

B.7.3.1 Enzyme reactions proceed through a two-step mechanism which can be modelled by a diagram such as the following. Describe this process and express it as an equation.



B.7.3.2 Explain how the substrate concentration [*S*] influences the reaction rate of an enzyme-catalysed reaction.

B.7.3.3 On the following grid, sketch a graph to show the relationship between substrate concentration [S] and the rate of reaction.



B.7.4 Determine V_{max} and the value of the Michaelis constant (K_m) by graphical means and explain its significance.

B.7.4.1 The Michaelis-Menten equation relates velocity (V), maximum velocity (V_{max}) and substrate concentration [S] for enzyme catalysed reactions.

The equation is $V = V_{max}\,[S]/(K_m + [S])$ where K_m is the Michaelis constant.

(a) Identify the unit for the Michaelis constant.

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(b) Determine the effect on K_m when the reaction velocity is half the maximum velocity.
(Substitute $V = \frac{1}{2}V_{max}$ into this equation and simplify.)

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B.7.4.2 Describe how the V_{max} and the K_m can be derived graphically from experimental data.

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B.7.4.3

(a) Identify how the Michaelis constant (K_m) varies with enzyme activity.

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(b) Explain the significance of the Michaelis constant (K_m).

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B.7.5 Describe the mechanism of enzyme action, including enzyme substrate complex, active site and induced fit model.

B.7.5.1 Substrates bind to the active site of an enzyme to form an enzyme-substrate complex.

(a) Describe the mechanism for the formation of an enzyme-substrate (ES) complex.

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(b) Identify the type of bonding involved in formation of the ES complex.

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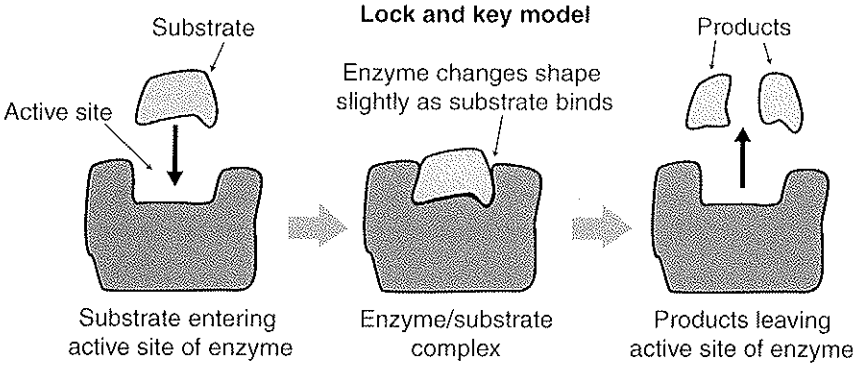
B.7.5.2 Explain what is meant by the induced fit model of enzyme action and compare this to the lock and key model shown below.



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B.7.6 Compare competitive inhibition and non-competitive inhibition.

B.7.6.1 Some chemicals can inhibit the action of specific enzymes.

(a) Define enzyme inhibition and outline its role in living tissues.

(b) Inhibition can be irreversible or reversible. Outline the bonding in the following.

(i) Irreversible inhibition.

(ii) Reversible inhibition.

(c) Reversible inhibition may be competitive or non-competitive. Identify the meaning of these terms.

B.7.6.2 A competitive inhibitor reduces activity by forming EI complexes at the active site which lowers the proportion of ES complexes able to be formed. A classic example of this is the action of the inhibitor malonate ($^-OOC - CH_2 - COO^-$) on the enzyme succinate dehydrogenase. This enzyme removes two hydrogen atoms from succinate ($^-OOC - CH_2 - CH_2 - COO^-$) in the following reaction.

$(^-OOC - CH_2 - CH_2 - COO^-) \rightarrow (^-OOC - CH = CH - COO^-) + 2H$

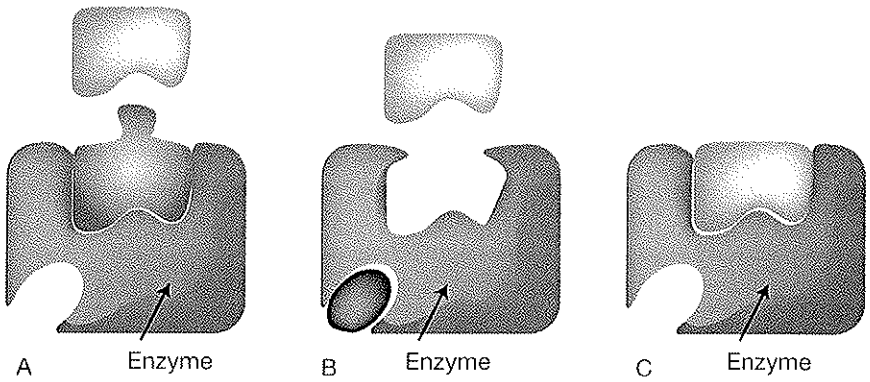
Suggest a mechanism for this inhibition.

B.7.6.3 Complete the following table to compare competitive and non-competitive inhibition.

Property	Competitive inhibition	Non-competitive inhibition
Reversibility		
Complex formed with enzyme		
Position of binding to enzyme		
Effect of increasing [S]		
Effect on V_{max}		
Effect on K_m		

B.7.6.4 Label the diagrams below to indicate which of the three models they represent and justify your answers.

- Enzyme activity with no inhibition.
- Competitve inhibition.
- Non-competitve inhibition.



B.7.7 **State and explain the effects of heavy metal ions, temperature changes and pH changes on enzyme activity.**

B.7.7.1 Heavy metals are metals with a density greater than 5 mg cc^{-1}.

(a) Identify four examples of heavy metals.

(b) Explain the effect of heavy metals on enzymes.

B.7.7.2 Recall and explain the effect of temperature on enzyme activity.

B.7.7.3 Recall and explain the effect of pH on enzyme activity.

HL B8 Nucleic acids. © IBO 2007

B.8.1 **Describe the structure of nucleotides and their condensation polymers (nucleic acids or polynucleotides).** © IBO 2007

B.8.1.1 Nucleotides and nucleic acids have many important functions in the body. For example, they are involved in metabolism and they make up the structural units of DNA and RNA.

(a) Name the three parts of a nucleotide.

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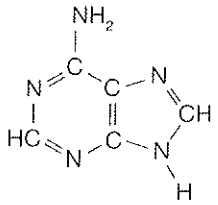
(b) The five bases that are found in nucleotides are shown below. Name these bases.

(i)



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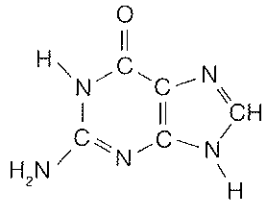
(ii)



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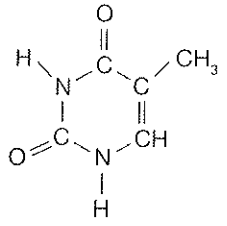
(iii)



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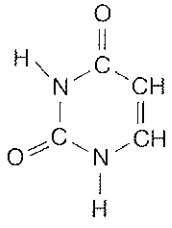
(iv)



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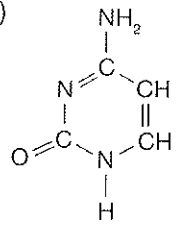

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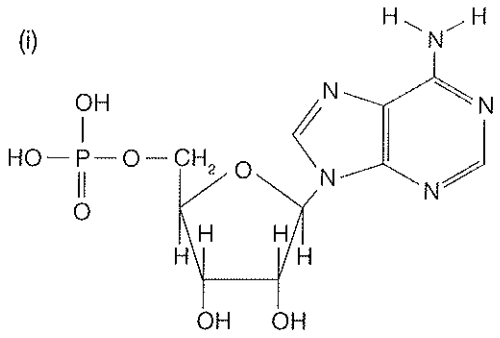
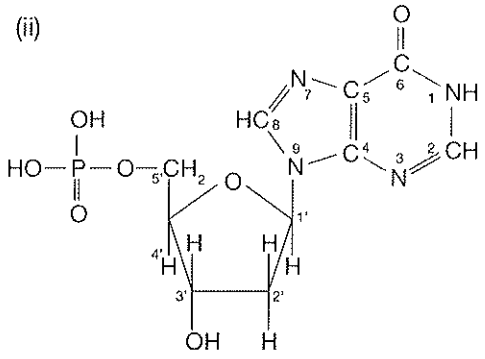
(c) The diagrams below show two nucleotides. Label the three main parts in each.

(i)



(ii)



B.8.1.2 Distinguish between a nucleic acid and a nucleotide.

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B.8.1.3 Describe the bonding and structure of nucleic acids. Include a diagram in your answer.

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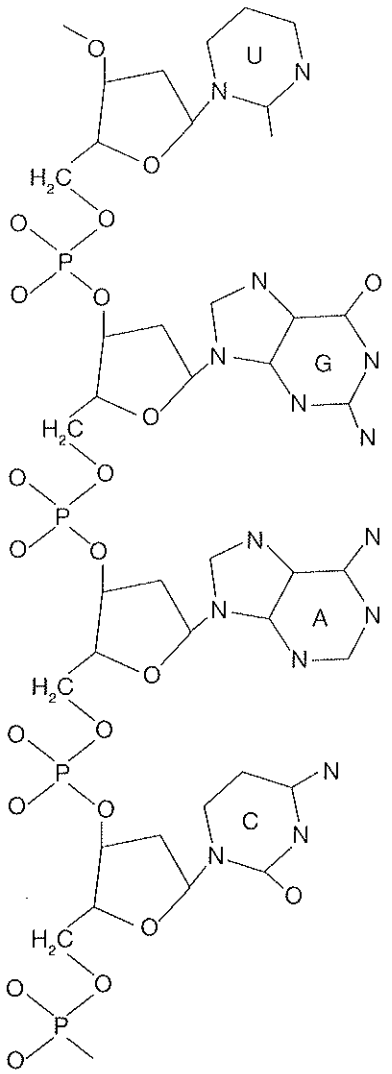
B.8.1.4 The diagram shows the basic structure of one nucleic acid (called ribosenucleic acid – RNA). On the diagram, draw a line around one of the nucleotides that makes up this nucleic acid.

RNA (single-stranded)



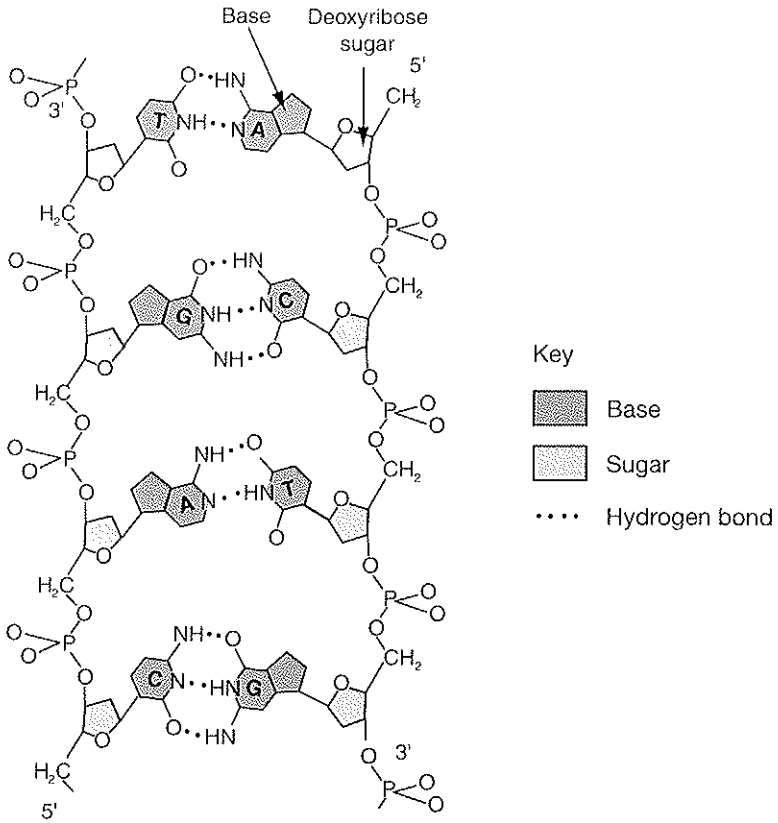
B.8.2 **Distinguish between the structures of DNA and RNA.** © IBO 2007

B.8.2.1 Complete the table to compare the structures of RNA and DNA.

Factor	RNA	DNA
Name		
Found		
Single or double strands		
Pentose sugar present in molecule		
Nitrogen bases present in molecule		
Functions in the body		

B.8.3 **Explain the double helical structure of DNA.** © IBO 2007

B.8.3.1 Use the diagram below to help describe the structure of the strands in DNA.



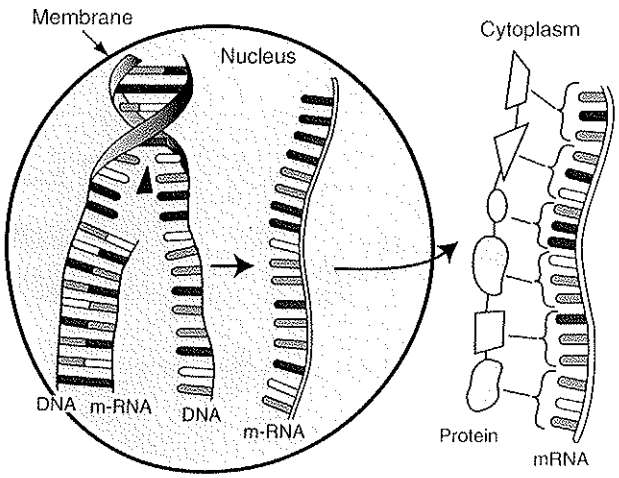
B.8.3.2 Explain why DNA is referred to as a double helix.

B.8.3.3 Describe how you could make a model of DNA.

B.8.4 **Describe the role of DNA as the repository of genetic information, and explain its role in protein synthesis.**

B.8.4.1 Describe the role of DNA in genetics.

B.8.4.2 The diagram below models the role of DNA in the process of protein synthesis.



(a) Outline the importance of DNA in protein synthesis.

(b) Use the diagram above to outline the mechanism by which DNA controls protein synthesis.

(c) Distinguish between transcription and translation in protein synthesis.

B.8.4.3 The table provides some triplet codes and an amino acid each will produce.

In the codes, A,G,C and T represent the nitrogen bases present in the DNA. A represents adenine, G represents guanine, C represents cytosine and T represents thymine.

Triplet code	Amino acid	Triplet code	Amino acid
AAA	Phenylalanine	GCA	Histidine
CGA	Alanine	CCA	Glycine
CAT	Valine	TCA	Serine
TCT	Arginine	GGG	Proline

Translate the following code in a DNA sequence into the correct sequence of amino acids it would generate.

CCA CAT CGA CCA GGG CGA CCA GCA GCA TCA TCT

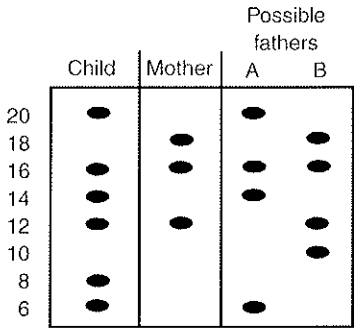
B.8.5 Outline the steps involved in DNA profiling and state its use.

B.8.5.1 DNA profiling involves the production of a genetic 'fingerprint'.

(a) Identify uses of DNA profiling and explain why it is suitable for these purposes.

(b) Outline concerns about the use of DNA fingerprinting.

(c) The simplified diagram shown represents sections of the DNA from a child, her mother and two people who could be fathers of that child.



Based on this evidence, which person would be most likely to be the child's father?

B.8.5.2 Outline the steps involved in DNA profiling.

B.8.5.3 Outline the possible use of DNA data banks and problems involved in this.

HL B9 Respiration. © IBO 2007

B.9.1 **Compare aerobic and anaerobic respiration of glucose in terms of oxidation/reduction and energy released.** © IBO 2007

B.9.1.1 Cellular respiration involves breaking down glucose to release energy. It is not a simple process but involves two main stages.

(a) The first step in cellular respiration is glycolysis. Describe this process.

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(b) In aerobic respiration, glycolysis is followed by the oxidation of pyruvate ions. This is a complex process involving many steps, with the final step being the reduction of oxygen. Write an overall equation for this process.

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(c) During strenuous exercise, oxygen is limited in muscle tissue and the second, aerobic stage of respiration cannot occur. Instead glucose is converted to pyruvate ions (glycolysis) which are then reduced to lactate ions. Write an equation for the conversion of pyruvate to lactate and suggest why this step is necessary.

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B.9.1.2 This process of cellular respiration takes place in living cells in the presence of enzymes. Complete the table to compare aerobic and anaerobic respiration.

Factor	Aerobic respiration	Anaerobic respiration
Air/oxygen present		
Oxidation/reduction of pyruvate		
End products		

B.9.1.3 When yeast is placed in warm glucose solution, and oxygen is excluded, the glucose is converted to pyruvate by the process of glycolysis. The pyruvate is then further metabolised to form ethanol. Write an equation to summarise this anaerobic reaction.

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B.9.1.4 The overall reaction for the aerobic oxidation of glucose to carbon dioxide and water can be written as $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$. Write this equation as two redox half-reactions, identifying the oxidation and reduction processes.

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B.9.2 Outline the role of copper ions in electron transport and iron ions in oxygen transport.

B.9.2.1 Metal ions are essential for the functioning of the human body.

(a) Identify properties of metal ions such as iron and copper that make them useful in organisms.

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(b) Describe the electron transport chain and outline the role of copper in electron transport.

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(c) Outline the role of iron in oxygen transport.

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B.1.1.1

(a) break, released

(b) 414 kJ

(c) less

(d) joule (J)

(e) carbon dioxide, water

(f) carbohydrates

(g) lipids

(h) lipids

(i) ΔH°

(j) negative

(k) combustion

(l) calorimeter

B.1.1.2

(a) $\Delta H = -mc\Delta T$

$= -200 \times 4.18 \times 55 = -45\,980$ J

$= -46$ kJ Heat energy released is 46 kJ.

(b) Energy $= \frac{45.980 \times 38}{10} = 175$ kJ per serve

(c) $\Delta T = -\frac{\Delta H}{mc}$

$= \frac{-(-20\,000)}{200 \times 4.18}$

$= 23.9°C$

Temperature would rise by 23.9°C.

B.1.1.3

Energy of peanut butter = energy absorbed by water + energy absorbed by steel

$= (150 \times 4.18 \times 30) + (200 \times 0.45 \times 30)$

$= 21\,510$ J $= 22$ kJ

B.1.1.4

For health reasons it may be necessary for a person to regulate their total daily energy intake, e.g. to maintain/lose/increase weight. Unless the energy value of packaged food is indicated on labels this is not possible.

B.1.1.5

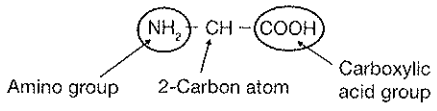
Food	Formula	Enthalpy of combustion (kJ /mol)	Enthalpy of combustion (kJ/g)
Glucose	$C_6H_{12}O_6$	2808	16
Stearic acid	$CH_3(CH_2)_{16}COOH$	11 381	40
Ethanol	C_2H_5OH	1364	30

B.1.1.6

In general, the inclusion of high-energy foods in a weight-loss diet would not be recommended unless it was to be eaten in very small quantities, or unless its high-energy value was due to the presence of a large proportion of a high-fibre substance such as cellulose which could not be easily broken down by the body to release its energy.

B.2.1.1

(a)



(b) Amino acids are made of carbon, hydrogen, oxygen, nitrogen and a small amount of sulfur.

(c) In carboxylic acids the carbon chain is numbered from the COOH group and the amino group is found on the next C, the 2-C atom.

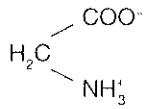
B.2.1.2

Amino acid	R group
Glycine	H–
Alanine	CH_3–
Leucine	CH_3–CH(CH_3)–CH_2–
Cysteine	SH–CH_2–
Aspartic acid	COOH–CH_2–
Lysine	NH_2–$(CH_2)_4$–
Serine	HO–CH_2–

B.2.1.3 Various. Any three of: leucine, isoleucine, alanine, valine, phenylalanine.

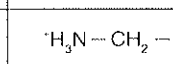
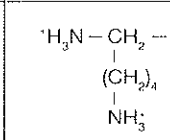
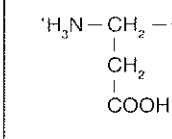
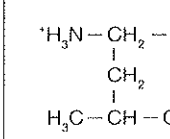
B.2.2.1 (a) A zwitterion is a dipolar ion, it has its positive and negative ions separated from each other.

(b)



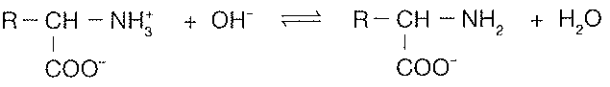
(c) 2-Amino acids are soluble in water because they contain polar NH_3^+ and COO^- groups which form hydrogen bonds with water molecules.

B.2.2.2

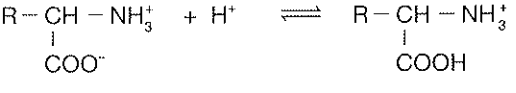
2-Amino acid	Low pH (approximately pH 1)	Neutral pH (approximately pH 7)	High pH (approximately pH 11)
Glycine			
Lysine			
Aspartic acid			
Leucine			

B.2.2.3 (a) An amphoteric substance is one which can act as an acid (reacting with a base) or a base (reacting with an acid). Amino acids can act as an acid or base as shown below.

Reacting as an acid:



Reacting as a base:



(b) Buffers are solutions that are able to resist a change in pH. Amino acids act as buffers at both acidic and basic pHs because they can react with both hydroxide (OH^-) ions and hydrogen (H^+) ions at these pHs (as shown in the equations in (a)). This means they can resist a pH change when acids and bases are added. However, most amino acids cannot buffer at a neutral pH (6-8).

B.2.2.4 (a) The isoelectric point is the pH at which the net charge on the amino acid is zero because the positive and negative charges balance. There would be no migration in an electric field at this point.

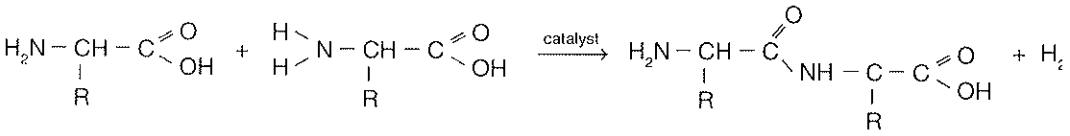
(b) $^{+}H_3N–CH_2–COO^{-}$

(c) Each amino acid has a unique pH value which is called the isoelectric point (pI) because its side-groups affect the pH at which the overall charge is zero. The side-chains may have groups that can ionise at certain pHs. Also side-chains affect the pH at which α-amino and α-COOH groups ionise.

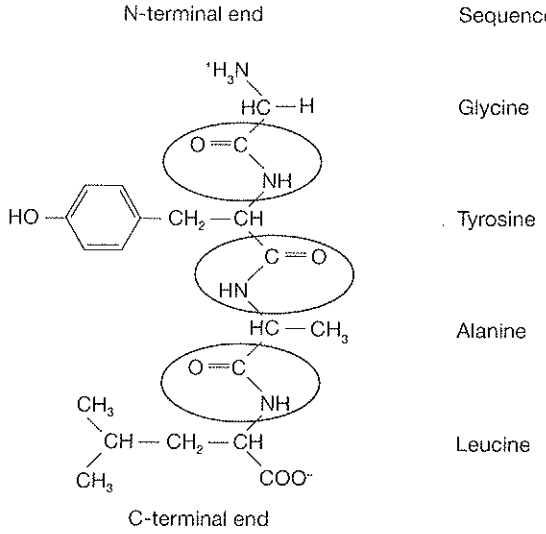
B.2.3.1 A condensation reaction is a chemical reaction in which a small molecule such as water is eliminated from the reactants.

B.2.3.2 D

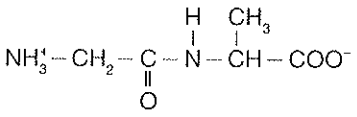
B.2.3.3 The α-carboxyl group of one amino acid condenses with the α-amino group of a neighbouring amino acid in the presence of a catalyst to form a peptide bond.



B.2.3.4



B.2.3.5



Glycylalanine

B.2.3.6

Term	Meaning
Peptide bond	Linkage formed by the condensation reaction between the α-amino and α-carboxylic acid groups of two amino acids.
Dipeptide	Molecule consisting of two amino acids linked by a peptide bond.
Tripeptide	Molecule consisting of three amino acids linked by peptide bonds.
Polypeptide	Chain consisting of many amino acids joined together in a linear sequence.
Protein	One or more polypeptide chains folded into a specific shape which gives the structure its special function.

B.2.4.1 (a) The specific sequence of the amino acids in the polypeptide chain; the composition, order and orientation of the different amino acids in the chain.

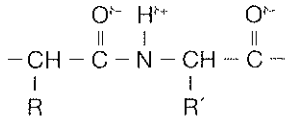
(b) The orientation of the amino acids is different. In sequence (i), the free amino group is on the alanine and the free –COOH group is at the lysine end of the chain. However, in sequence (ii), the free 2-amino group is on the lysine and the free –COOH is on the alanine end.

(c) Primary structure of a protein, its amino acid sequence, is important because the functioning of a protein depends on the final three-dimensional shape of the protein. The amino acid sequence contains the information for the correct folding. Interactions between the side-chains and the atoms in the peptide bonds, direct both the secondary structure and tertiary folding.

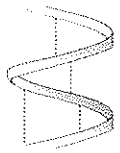
B.2.4.2 Secondary structure is the folding of parts of the polypeptide chain to form areas of α-helices and β-pleated sheets.

B.2.4.3 (a) An α-helix is a spiral, coiled structure in part of a polypeptide chain. Each coil has 3 to 4 amino acids in it. The parts of the chain involved in an α-helix are elastic.

(b) The =O on the carboxyl C and the H on the amino N atom in the peptide bond carry small charges, $\delta-$ and $\delta+$ respectively.

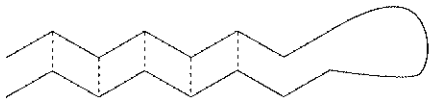


As the chain coils back on itself, hydrogen bonds form between the peptide bonds above and below each other in the coils.



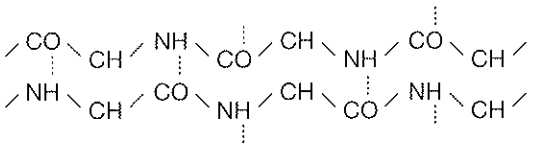
..... Intramolecular hydrogen bonding

B.2.4.4 (a) Parts of the polypeptide chains, when extended, can fold back on themselves so that they lie parallel to each other in an extended zigzag arrangement called a pleat. The R groups protrude above and below the structure. Beta-pleated sheets also form between different polypeptide chains, holding different chains together.



···· Indicates hydrogen bonding

(b)



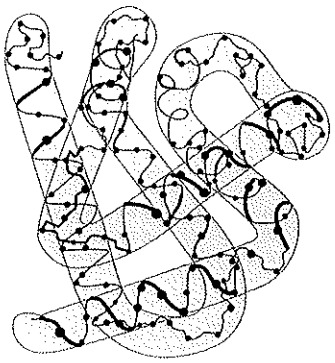
···· Indicates hydrogen bonding

B.2.4.5

Factor	α-helix	β-pleated
Orientation of hydrogen bonds	Hydrogen bonds are in the direction of the axis of the coil.	H bonds are at right angles to the direction of the sheet structure.
Frequency of hydrogen bonds	Form between amino acids close to each other in the same chain (about every fourth amino acid).	Form far apart in the same chain or in different chains.

B.2.4.6 (a) Various, e.g. myoglobin, the oxygen-carrying protein found within muscle cells. This is globular (nearly spherical) with 8 short α-helix segments linked by short segments with no regular secondary structure. The bends occur in these random coil parts of the chain.

Diagram – Various, e.g.



(b) Occur on the surface: glutamic acid, arginine.

Occur in an interior position: phenylalanine, valine, leucine.

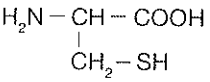
B.2.4.7 (a) Hydrophobic groups avoid contact with water, so the chain will fold to place these groups in the interior of the molecule, away from contact with water. The attraction of non-polar groups to other non-polar groups is called a hydrophobic interaction.

(b) Most electrically charged side-groups occur on the surface of the protein. These polar groups interact with water, forming ion-dipole bonds. This attraction to water means these groups are most stable when they are on or near the surface of the protein. This influences the folding.

(c) Size of the side-chains may limit the possible structure, e.g. long chains may prevent some folding options.

(d) Hydrogen bonding occurs between hydrogen atoms and $\delta+$ and $\delta-$ parts of side-chains that contain oxygen or nitrogen. These bonds are relatively strong and may form between amino acids widely separated in the primary sequence, causing folding to occur.

B.2.4.8 (a)



(b) Enzymes oxidise adjoining –SH groups forming a –S–S– linkage between the two amino acid side-chains.

Cysteine–SH + HS–cysteine ⟶ cysteine–S–S–cysteine

B.2.4.9 (a) Many proteins, e.g. myoglobin, are composed of only one polypeptide chain so the term quaternary structure does not apply.

(b) Various, e.g.

- Haemoglobin (the oxygen-carrying protein in blood) has four polypeptide chains, two alpha chains and two beta chains.
- Insulin (the hormone controlling blood sugar levels) has two chains.
- Collagen (structural protein of tendons and bone) is composed of three chains.

(c) Chains are held together mainly by non-covalent bonds; these include hydrophobic interactions, ionic bonds and hydrogen bonds. Disulfide bridges may form to stabilise the structure (as in insulin).

B.2.4.10 (a)

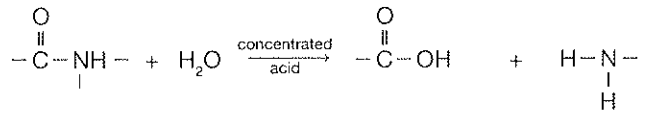
Structure	Distinguishing feature
Primary	The amino acid sequence of the polypeptide chain.
Secondary	The α-helix and β-pleated sheet structure of the chain.
Tertiary	The folding of the chain to a three-dimensional shape.
Quaternary	Interactions between chains in proteins with more than one chain.

(b)

Structure	Intermolecular or intramolecular	Covalent or non-covalent	Type(s) of bond(s)
Primary	Intramolecular	Covalent	Peptide.
Secondary	Intramolecular	Non-covalent	Hydrogen bonds.
Tertiary	Intramolecular	Non-covalent	Hydrophobic. Hydrogen. May be stabilised by disulfide bonds.
Quarternary	Intermolecular	Non-covalent	Hydrophobic. Hydrogen. Ionic.

B.2.4.11 Denaturation of a protein can be caused by high or low temperatures, extremes of pH, or high salt concentrations.

B.2.5.1 The protein is heated for several hours in a concentrated solution of a strong acid. This causes the peptide bonds to be hydrolysed and the individual amino acids are released.



Peptide bond + water ⟶ carboxylate group + amino group

B.2.5.2 (a) The separation depends on the relative affinity of each amino acid for a stationary phase and a mobile phase. Each amino acid has a different side-chain and hence different solubility in a solvent such as ethanol (the mobile phase) and it also has a different attraction to a solid medium through which it can travel (the stationary phase). Hence different amino acids will migrate through the solid at different rates and can be separated.

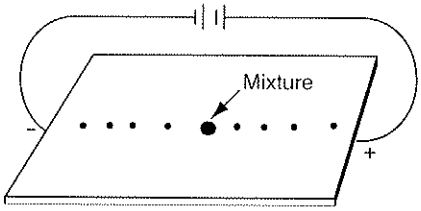
(b) Steps involved are:

- The amino acid mixture is spotted at one end of a sheet of absorbent paper.
- Drops of individual amino acids (standards) are spotted beside the mixture.
- The spots are allowed to dry.
- The paper is suspended so that the end near the spots is just under the surface of a liquid solvent.
- The solvent is allowed to slowly creep up the paper.
- When the solvent is near the top, the paper is removed and dried.
- The amino acid most soluble in the solvent moves the furthest, while the amino acid least soluble in the solvent and with the greatest attraction to the paper will remain nearest the starting point.
- Hence the amino acids are spread along the paper.
- A stain called ninhydrin is sprayed onto the paper. It reacts with amino acids so they show up as a pink/purple colour.
- The amino acids in the mixture are recognised by comparing their positions on the paper with the known standards.

(c) A column is packed with a solid material such as a silica compound with a very small particle size. A solvent is forced through the column under high pressure. If the stationary phase (solid) is polar, the solvent used would be a non-polar substance such as hexane. If a non-polar stationary phase is used, a polar solvent such as an alkanol is used. The sample is injected into the column and is separated into its components as it moves through the column. The separation depends on the relative attraction of each amino acid for the non-polar and polar phases. Amino acids with a greater attraction for the solid phase will be slower to move through the column. As the amino acids are eluted from the column in the solvent they are detected by their absorption of U/V light.

B.2.5.3 (a) Electrophoresis is used to separate proteins from a mixture and then to determine the amino acid composition once the protein is hydrolysed. Electrophoresis is a useful method for the separation of amino acids as they readily form ions.

(b) Separation during electrophoresis is based on the overall electric charge on the molecules causing movement when placed in an electric field. Because proteins and amino acids have charged polar groups such as COO^- and NH_3^+ they will migrate in an electric field (anions to the anode and cations to the cathode). In electrophoresis, a mixture of proteins, or of amino acids, is placed in an electric field and their different directions and rates of migration used to separate them.



Positive ions (+) ⟵ ⟶ Negative ions (–)

(c) Amino acids have different net charges at different pHs. Hence different separations are obtained with the same mixture when the pH is changed. The pH is chosen to gain the best separation and should be maintained throughout the procedure. A buffer is used to control pH.

(d) (i) Buffer pH = pI: the amino acid would not move from the starting position.

(ii) Buffer pH < pI: the amino acid would have an overall positive charge and would migrate to the cathode.

(iii) Buffer pH > pI: the amino acid would have an overall negative charge and would migrate towards the anode.

(e) All these amino acids will migrate to the anode as they will all be anions at pH 8. The greater the difference between the isoelectric pH and the pH of the buffer, the faster the movement. In the same time interval, aspartic acid will move the furthest, then cysteine, asparagine, and alanine in that order.

B.2.6.1

Type of protein	Functions	Examples Various, e.g.
Enzymes	Biological catalysts. They control the chemical reactions of living things.	Amylase breaks down starch in digestion. Cellulase in some micro-organisms breaks down cellulose. DNA polymerase replicates DNA.
Transport proteins	Carry oxygen, fats and other substances around the body in the blood. Move substances across cell membranes.	Haemoglobin carries oxygen. Serum albumin carries fatty acids in blood. Cytochrome c transports electrons in respiration.
Structural proteins	Give strength to ligaments and tendons and bind tissues together.	Collagen in bones and tendons. Keratin forms hair and nails.
Hormones	Move around in the blood from glands to target organs to regulate metabolism and cause a response to a stimulus.	Insulin regulates blood sugar levels. Growth hormone controls growth in the young.
Antibodies	Function as part of the immune system to inactivate foreign substances.	Immunoglobulins in blood provide immunity to viral infections such as measles.
Contractile proteins	Cause contraction of muscle cells and hence allow movement.	Actin and myosin.
Food storage	Provide store of amino acids for the growing baby in milk or for the embryo in egg white.	Casein in milk. Albumin in eggs.

B.3.1.1 (a) CH_2O

(b) one sugar

(c) polysaccharides

(d) photosynthesis

(e) $C_6H_{12}O_6$

B.3.1.2 (a) (i) Like other aldehydes they contain a carbonyl (C=O) group at the end of the carbon chain. (Such monosaccharides are called aldoses.)

(ii) Like other ketones they contain a carbonyl group within the carbon chain. (These monosaccharides are called ketoses.)

(b) A hydroxyl group (–OH) is attached to every carbon in a monosaccharide, except for the carbonyl carbon.

(c) Hydrogen bonding occurs in sugars. Hydrogen bonds form between the hydroxyl (OH) groups of nearby sugar molecules; the H in one molecule is attracted to an O in a nearby molecule. Sugars are soluble in water because hydrogen bonds form between the sugar and water molecules.

B.3.1.3 (a)

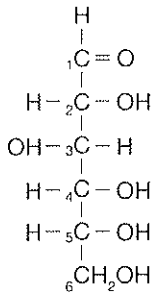
Name	Number of carbons	Aldose or ketose	Occurrence
Glucose	6 (hexose)	Aldose	Most common monosaccharide found in all cells. A product of photosynthesis.
Fructose	6 (hexose)	Ketose	Sugar that occurs in fruits.
Galactose	6 (hexose)	Aldose	Found as a component of lactose in milk, also in many fruits and vegetables.
Ribose	5 (pentose)	Aldose	Produced in the body from glucose and is a component of nucleic acids.

(b)

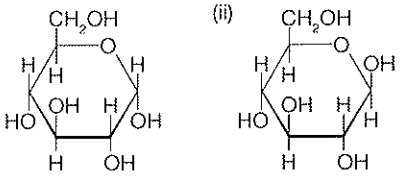
Name	Contain the monosaccharide(s)	Occurrence
Sucrose	α-Glucose and β-fructose	Common in plants especially sugar cane. Table sugar.
Lactose	β-Galactose and β-glucose	Milk sugar.
Maltose	Two α-glucose units	Product of digestion of starch by amylase. In cereals and grains. Used in brewing.

B.3.2.1 Glucose and fructose both have the same molecular formula $C_6H_{12}O_6$, but they have different structural formulas. This fits the definition of an isomer.

B.3.2.2 (a)



(b) (i) (ii)



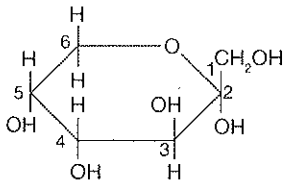
α-D-glucose β-D-glucose

(c) In the alpha form of glucose, the hydroxyl group (–OH) on C1 is below the ring and the hydrogen on C1 is above the ring. These are reversed in the beta form.

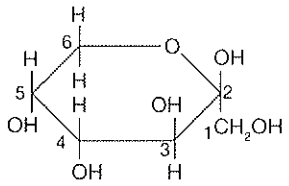
B.3.2.3 (a)

Factor	D-glucose	D-fructose
Carbonyl group (C=O)	On C1	On C2
Ring formation	Always forms a 5-carbon ring with oxygen. Ring is between the C=O on C1 and the OH (hydroxyl) on C5.	Can form a ring with 4 or 5 carbons and an oxygen atom. May form between C2 and C5 or C2 and C6.

(b)

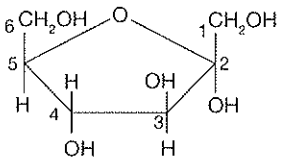


α-D-fructose

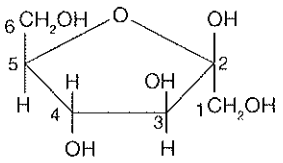


β-D-fructose

(c)



α-D-fructose

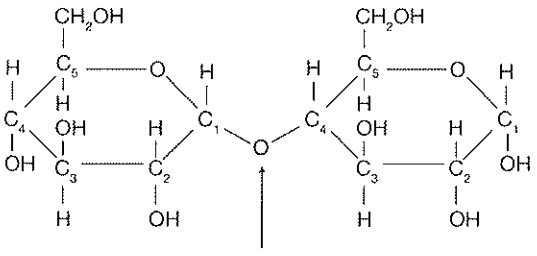


β-D-fructose

B.3.3.1 (a) $R\text{–}C\text{–}OH + HO\text{–}C\text{–}R' \rightarrow R\text{–}C\text{–}O\text{–}C\text{–}R' + H_2O$

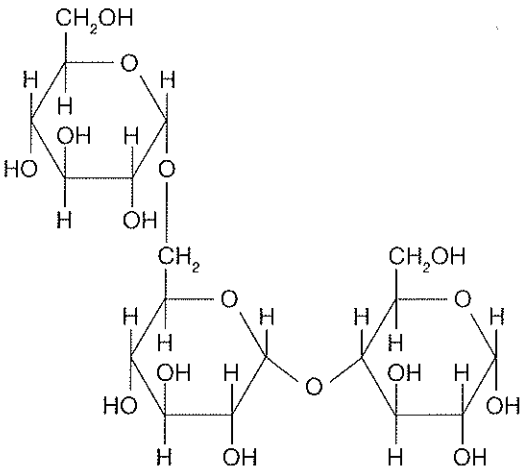
(b) Glycosidic linkage (glycoside).

B.3.3.2 (a) (This dissacharide is called maltose.)

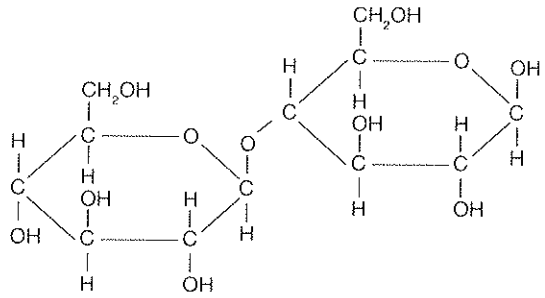


α-1,4-linkage

(b)

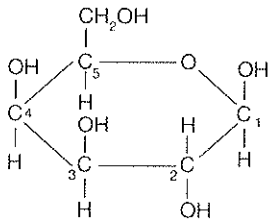


(c)



B.3.3.3 (a) The hydroxyl (–OH) group on the non-linked C4 is above the ring in lactose, but below the ring in the disaccharide shown in Question B.3.3.2(c).

(b)



(c) Sucrose contains α-glucose and β-fructose with a 1,2 linkage.

B.3.3.4

Amylose	Amylopectin
Chains of α-D-glucose units.	Chains of α-D-glucose units.
Long unbranched chains.	Branched chains.
1,4 glycosidic linkages.	1,4 links and 1,6 branching links about every 24-30 glucose units.
Smaller molecules.	Many more glucose units.
Lower molecular weight.	Higher molecular weight.
Soluble in water.	Insoluble in water.

B.3.3.5 Glycogen is a polymer consisting of chains of α-D-glucose with 1,4 glycosidic links and with frequent 1,6 branches. The branching occurs on average every 8 to 12 glucose units.

B.3.3.6 Cellulose is a linear polymer of β-D-glucose units linked 1,4. The very long, linear chains lie parallel and pack together closely, held by extensive hydrogen bonding. This bonding between long chains makes cellulose fibrous, rigid and insoluble; properties which make it suitable to provide structural support to plant cells.

B.3.4.1 (a) Carbohydrates provide energy – sugars such as glucose are broken down in respiration to produce energy.

(b) Carbohydrates store energy – glycogen granules, stored in the liver and muscles, can be broken down by enzymes to glucose when needed for energy production.

(c) Carbohydrates contribute to body structure:

- Polysaccharides are a major component of cartilage.
- Ribose is part of nucleic acids (DNA and RNA).
- Polysaccharides with small amounts of protein attached (called proteoglycans) are part of the extracellular matrix that binds cells together.
- Ribose is part of the energy carrying molecule ATP.

B.3.5.1

Polysaccharide	Monosaccharide present	Branched or unbranched	Linkage (glycosidic)	Molecular weight range
Amylose	α-D-glucose	Unbranched	α-1,4	Variable from 10^4 to 5×10^4
Amylopectin	α-D-glucose	Branched	α-1,4 and α-1,6	5×10^4 to 10^8
Cellulose	β-D-glucose	Unbranched	β-1,4	Very variable up to 3×10^6

B.3.5.2 (a) Humans digest starch using an enzyme called amylase which is present in both saliva and pancreatic digestive juice. This enzyme attacks α-1,4 links.

Digestion of cellulose requires the presence of the enzyme cellulase to break down β-1,4 links and this enzyme is not present in humans so they cannot digest cellulose.

(b) Most animals (including mammals) do not produce cellulase. However, many herbivorous mammals such as cows and rabbits have micro-organisms in their alimentary canal which break down cellulose to glucose.

B.3.6.1 (a) Dietary fibre (roughage) is any substance that is eaten but passes undigested through the human alimentary canal. It is mostly plant material, e.g. cellulose, lignin and pectin, that is not hydrolysed by enzymes secreted by the human digestive system. Bacteria in the large intestine may break down some of this fibre.

(b) Various, e.g. vegetables, whole grain cereals, fruits and foods processed from plants such as whole grain bread.

B.3.7.1 (a) The major function of insoluble dietary fibre is to add bulk to faeces and help move the food waste along the intestine more quickly.

(b) Soluble fibre helps to retain water in the faeces, allowing wastes to pass through the intestine more easily. In the large intestine, some of this material is digested by bacteria to short chain fatty acids such as propanoic and butanoic acids. These acids are absorbed and may help lower blood cholesterol and glucose levels. Some plant carbohydrates, e.g. pectin are water soluble.

B.3.7.2 Various, e.g.

Constipation. Hard faeces do not pass easily along the large intestine causing discomfort, pressure and effort to pass through the anus.

Haemorrhoids. Strain and pressure in the large intestine causes swollen, painful blood vessels in the rectum and anus. This may result in bleeding from the bowel.

Diverticulitis. Small hernias (or weak, swollen areas) in the wall of the digestive tract can be caused by long-term constipation.

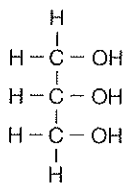
Irritable bowel syndrome (IBS) refers to symptoms such as pain and bloating, which are experienced when the bowel is not working properly or people eat foods to which they are sensitive.

A low-fibre diet has also been linked to colon cancer, suggesting that a high-fibre diet can help prevent colon cancer.

B.4.1.1 Three groups of lipids are:

- Triglycerides – fats and oils such as tristearin.
- Phospholipids, e.g. lecithin.
- Steroids, e.g. cholesterol.

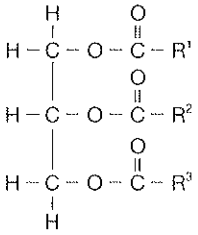
B.4.1.2 (a)



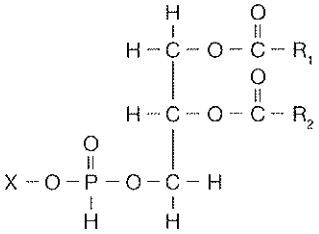
1,2,3-Propanetriol
(or propan-1,2,3-triol)

(b) Fatty acids are naturally occurring carboxylic acids (general formula R–COOH) with long, straight hydrocarbon chains containing 12 or more carbons. They have even numbers of carbons in their chains and may have one or more double bonds.

(c) Triglycerides consist of three fatty acids, each of which is esterified to one of the three –OH groups of glycerol. The hydrocarbon chains of the fatty acids (R^1, R^2 and R^3) are usually straight chains of from 12 to 20 carbon atoms and may be saturated or unsaturated.



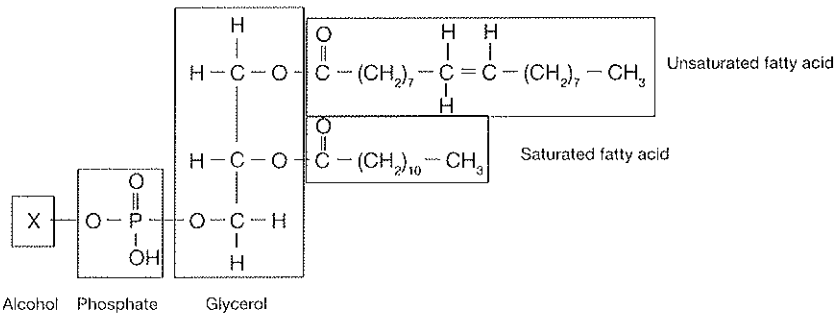
B.4.1.3 (a)



Where X is an alcohol.

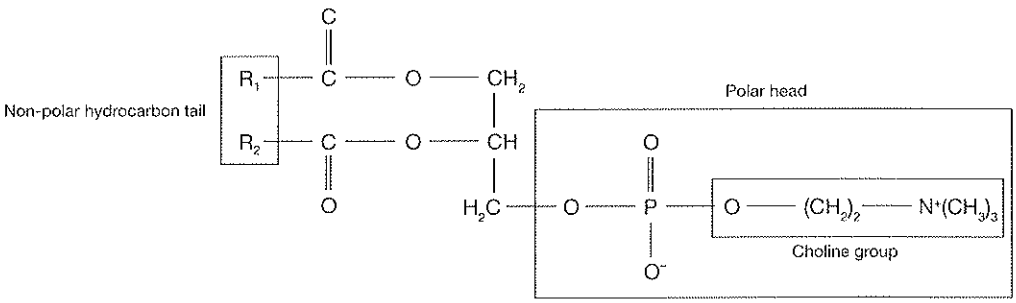
In phospholipids, two hydroxyl (–OH) groups of glycerol are esterified to fatty acids, but the third hydroxyl (–OH) group of glycerol is esterified to a phosphate which in turn is esterified to an alcohol such as ethanolamine or choline.

(b)



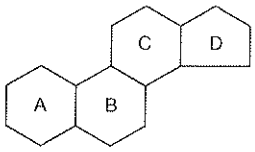
(c) Phospholipids are classified as polar because the phosphate group is ionised at physiological pH, giving the phospholipids a polar end. The attached alcohol may also have a polar group.

(d)

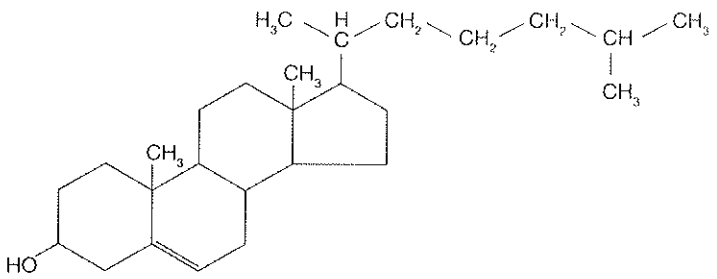


B.4.1.4 Triglycerides and phospholipids both have a glycerol backbone with esterified fatty acids. Triglycerides have three fatty acids, but phospholipids have two fatty acids and a phosphate group. Triglycerides are non-polar, but phospholipids have a polar head.

B.4.1.5 (a) Steroids have a basic structure of four fused rings. Three are cyclohexane rings (labelled A, B and C) and one ring is a cyclopentane (labelled D).



(b)



B.4.2.1 Cholesterol is a precursor to cholic acid and a number of hormones (e.g. the sex hormones oestrogen and testosterone). It also forms an essential part of bile (important in fat digestion) and vitamin D (essential for healthy teeth, bones and cartilage). Cholesterol is also essential for the formation of cell membranes and it regulates their permeability and fluidity.

B.4.2.2 Lipoproteins act as lipid transport systems; they provide a means for lipids to travel in the blood. They are necessary because lipids are not water-soluble, and blood is mostly water. The lipids, including cholesterol, are transported inside a layer of protein. This package is the lipoprotein. The outer protein layer is water-soluble so it allows the lipids inside to be carried in the blood.

B.4.2.3

Factor	HDL	LDL
Protein/fat ratio	Higher protein:fat ratio (more protein than fat.	Lower protein:fat ratio (more fat than protein).
Cholesterol (%)	Approximatey 30%	Approximatey 50%
Density	High	Low
Function	Cholesterol transporter – carries it from tissues to the liver to be broken down and recycled or eliminated from the body.	Cholesterol transporter – carries cholesterol from the liver where it is synthesised to the tissues where it is used or stored.
'Good' or 'bad' lipoprotein	Good – can absorb and remove cholesterol deposits from arteries.	Bad – causes deposition of cholesterol in arteries. This forms a plaque, making arteries narrow and thus increasing the risk of heart attacks and strokes.

B.4.3.1 Fatty acids without any double C–C bonds in the carbon chain are described as saturated, whereas fatty acids with double C=C bonds are said to be unsaturated. Those with one double bond are monounsaturated, those with more than one double bond are polyunsaturated. Animal fats are mainly saturated, but plant lipids are mostly unsaturated.

(b) The arrangement around the double bond in naturally occurring unsaturated fatty acids is normally cis; the hydrogens on the carbons in the double bond are on the same side of the molecule. In trans fatty acids, the hydrogen atoms are on opposite sides of the molecule.

Fatty acids with saturated chains have a long, straight structure. A cis double bond causes a bend in the chain. A trans double bond forms a straight structure.

(c) (i) is the cis form; it is bent at the double bond. (ii) is the trans form; it has a straighter molecule.

B.4.3.2

Common name	Systematic name	Formula	Saturated or unsaturated
Palmitic acid	Hexadecanoic acid	$CH_3(CH_2)_{14}COOH$	Saturated
Stearic acid	Octadecanoic acid	$CH_3(CH_2)_{16}COOH$	Saturated
Oleic acid	Cis-9-octadecenoic acid	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	Unsaturated
Linoleic acid	Cis,cis-9,12-octadecadienoic acid	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	Polyunsaturated

B.4.3.3 Molecules with trans double bonds have straight chains so can pack together more closely and hence have higher melting points. Lipids with saturated fatty acids are solids at room temperature (animal fats).

Molecules of similar size with one or more bends in the chains (cis bonds) cannot pack so closely together and hence have lower melting points. So lipids with cis double bonds are liquids (oils) at room temperature, e.g. olive oil, peanut oil.

B.4.4.1 (a) Linoleic acid $CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$

Linolenic acid $CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$

(b) Linoleic acid has two double bonds, whereas linolenic acid has three double bonds.

(c) The position of the double bond is given by numbering the carbons from the opposite end of the chain to the carboxylic acid group. This carbon, in the end methyl group is called the omega carbon. Linoleic acid is called an omega-6 fatty acid because the C=C bond nearest to the omega carbon (in the methyl group) is 6 carbon atoms away. Linolenic acid is called an omega-3 fatty acid because its closest C=C bond to the omega C is 3 carbon atoms away.

B.4.4.2 These fatty acids are essential in the diet because they cannot be made in the body and they are needed for cell membrane formation and for the synthesis of prostaglandins (which control metabolism inside cells). Linolenic acid assists brain growth and functioning and linoleic acid promotes health of the circulatory system. When these fatty acids are lacking from the diet, symptoms include lethargy, depression and reduced brain function.

B.4.5.1 (a) 1 mole.

(b) One mole of iodine to one mole of fatty acid. Each double bond requires one mole of iodine.

(c) Iodine is a red-brown colour. The products of the reaction are colourless. Therefore the colour change is from red-brown to colourless if fatty acid is added to iodine or from colourless to red-brown if the iodine is added to the fatty acid.

B.4.5.2 (a) Iodine number is the number of grams of iodine that reacts with 100 g of a fatty acid.

(b) Iodine numbers distinguish saturated from unsaturated triglycerides. The iodine number indicates the degree of unsaturation of a fatty acid – the number of double bonds present in a molecule. The higher the iodine number, the greater the level of unsaturation (the more double bonds).

(c) Add a solution of iodine of known concentration dropwise to a measured mass of fat/oil until the iodine colour persists. Record the volume of iodine solution used and calculate the mass of iodine, and then the iodine number.

B.4.5.3 (a) Molar mass of iodine = 253.8 g.

Moles of iodine used = 3.807/253.8 = 0.015 moles iodine.

0.015 mol oleic acid reacts completely with 0.015 mol iodine, a 1:1 ratio.

Therefore there is one double bond per molecule.

(b) Molar mass oleic acid ($C_{17}H_{33}COOH$) = 282.52 g.

Mass oleic acid used = 0.015 × 282.52 g = 4.2378 g.

3.807 g I_2 reacts with 4.2378 g oleic acid.

3.807/4.2378 g I_2 reacts with 1 g oleic acid.

0.89834 g I_2 reacts with 1 g oleic acid.

0.89834 × 100 g I_2 reacts with 100 g oleic acid = 90 g.

Iodine number = 90 (90 g I_2/100 g fatty acid.)

B.4.5.4 1 mol linolenic acid requires 3 mol iodine for reaction.

278.48 g linolenic acid requires 3 × 253.8 g I_2.

100 g linolenic acid requires (3 × 253.8/278.48) × 100 = 273 g I_2.

Therefore the iodine number is 273.

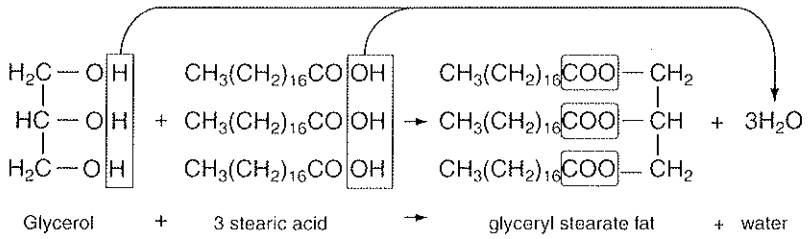
B4.6.1 (a) Esterification is a chemical reaction in which the hydroxyl group (–OH) of an alcohol reacts with the –COOH of an alkanoic acid to form a compound called an ester and a molecule of water is eliminated.

$R^1OH + RCOOH \rightleftharpoons RCOOR^1 + H_2O$

This fits the definition of a condensation reaction as 2 molecules join and water is eliminated.

(b) Fats and oils are a type of ester as they are made from an alcohol (glycerol) and a carboxylic acid (a fatty acid). They are made by the esterification of the alcohol glycerol and fatty acids and water is eliminated during this process.

B.4.6.2

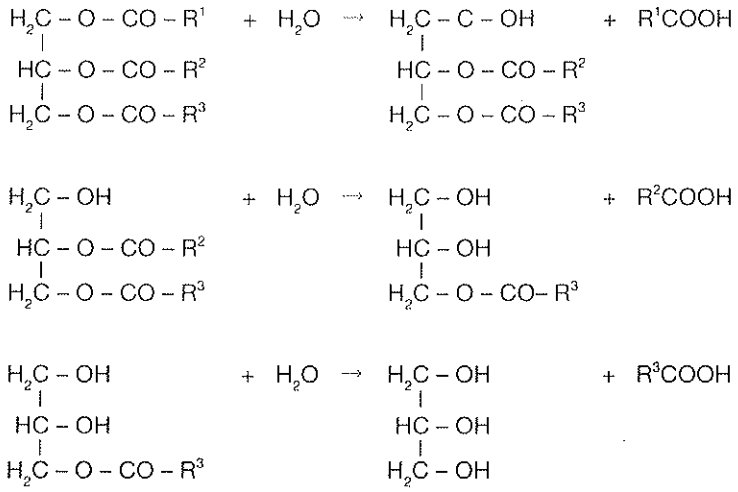


B.4.7.1 (a) The enzyme lipase acts as a catalyst for the breakdown of triglycerides during digestion. Triglycerides are stable compounds, so without a catalyst this reaction would be very slow. The enzyme speeds up the reaction.

(b) Lipids are not water-soluble and the digestive enzymes are in aqueous solution. The bile emulsifies (breaks up) the lipids so that the enzyme can act on them.

B.4.7.2 (a) The covalent bonds in the ester that occur between the carboxylic acid and the –OH groups of the glycerol are split. A molecule of water is also split and added on across each of the three ester bonds forming fatty acids and glycerol.

(b)



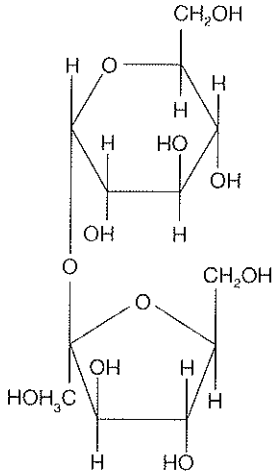
B.4.8.1 (a) The empirical formula of carbohydrates is CH_2O; they have 1 oxygen atom for every carbon atom, so the ratio of carbon:oxygen is 1:1. Carbohydrates contain a lot of C–O and O–H bonds.

Fatty acids have 1 oxygen atom to more than 6 carbon atoms (depending on the length of the hydrocarbon chain) so their carbon:oxygen ratio is at least 6:1. They have mainly C–H bonds.

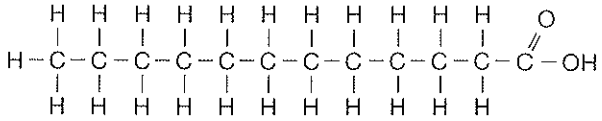
This means that fats are less oxidised than carbohydrates.

(b) Fats are less oxidised than carbohydrates so, during respiration, more oxidation can take place, releasing more energy. Fats release 38 kJ per gram compared to carbohydrates which, with more oxidised carbons, release only 17 kJ per gram.

B.4.8.2 (a) Sucrose



Lauric acid



(b) Sucrose: $C_{12}H_{22}O_{11} + 12O_2 \rightarrow 12CO_2 + 11H_2O$

Lauric acid: $C_{11}H_{23}COOH + 17O_2 \rightarrow 12CO_2 + 12H_2O$

(c) Per mole, lauric acid produces 1 extra mole of water (H–O–H), so it releases slightly more energy as these two H–O bonds form. The formation of H–O bonds releases 464 kJ per mole. So the formation of 1 extra mole of water (with 2 O–H bonds in each) releases 2 × 464 = 928 kJ of energy.

(Note that more energy is released from new bond formation in products made during the oxidation of the fatty acid than the oxidation of the carbohydrate.)

B.4.9.1

Uses of lipids	Description of use
Energy storage	There is a layer of fat/lipid tissue, called adipose tissue, under the skin. This stores energy, mainly as triglycerides. Fats have more energy per gram than carbohydrates so are an efficient form of energy storage.
Insulation	The layer of adipose tissue acts as a heat insulator to reduce heat loss from the body and help maintain a constant internal body temperature.
Protection of organs	Deposits of lipid around vital organs such as the heart, kidneys and eyes have a cushioning effect for those organs, helping to protect them from injury.
Membrane components	Membranes are bilayers of phospholipids which form the boundary around cells and organelles. The outside layer is hydrophilic and interacts with the surrounding aqueous environment while the hydrophobic part of the phospholipids forms the barrier. Cholesterol is also important as a membrane component.
Precursor to steroid hormones	Lipids are precursors to steroid hormones which have a variety of functions in the body, e.g. sex hormones and cortisone. Lipids are also precursors to other essential nutrients such as vitamin D and bile salts.
Essential fatty acids	The essential fatty acids are necessary for brain function and prevention of cardiovascular disease.
Control of fat deposition	Polyunsaturated fatty acids in lipids help to reduce the deposition of fat in arteries by lowering the level of low-density lipoproteins (LDL).

B.4.9.2 When we eat more kilojoules than we use (fat or carbohydrate), the excess is stored as fat, and the person can become overweight or obese. This can cause strain on vital organs such as the heart and joints, and can increase the risk of health problems such as type 2 diabetes. Also too much saturated fat (e.g. with lauric, myristic and palmitic acids) or trans fatty acids, can lead to elevated levels of 'bad' cholesterol (LDL) and a higher risk of cardiovascular disease.

B.5.1.1 (a) Macronutrients are chemicals required by the body in relatively large amounts to allow for growth and body maintenance. They are required in amounts > 0.005% of body weight. Macronutrients include carbohydrates, fats, proteins, water and some mineral ions (sodium (Na), magnesium (Mg), potassium (K), calcium (Ca), phosphorus (P), sulfur (S), chloride (Cl^-).

(b) Micronutrients are chemicals required in only very small amounts, less than 0.005% of body weight. They are chemicals that are essential for cell functioning and they are mainly used as enzyme cofactors. Micronutrients include vitamins (e.g. vitamins A, B, C and D) and trace minerals (e.g. manganese (Mn), molybdenum (Mo), zinc (Zn), iodine (I), selenium (Se), cobalt (Co), copper (Cu) and boron (B)).

B.5.1.2

Nutrient	Function
Carbohydrates	Main energy source.
Proteins	Structural (e.g. collagen, keratin). Enzymes (e.g. amylase, lipase). Transport (e.g. in lipoproteins).
Lipids	Energy source. Energy storage. Membrane structure. Hormone precursor.
Minerals	Strong bones and teeth (Ca, P). Haemoglobin (Fe). Cofactors for enzymes (e.g. Mg, Mn, Zn). Nerve impulses (Na, K). Maintaining water balance.
Vitamins	Various. Mainly cofactors for enzymes and are therefore essential for the functioning of the enzyme concerned.
Water	Solvent for body chemicals.

B.5.2.1 Vitamin A (retinol) is a primary alcohol with a 6-carbon ring and a 9-carbon side chain. The side-chain has alternating single and double bonds. There are also three methyl side-groups on the ring and two on the side-chain. Although there is an hydroxyl (OH) group, retinol is predominantly a non-polar hydrocarbon compound and is hydrophobic.

Vitamin C (ascorbic acid) is a polar molecule with a ring composed of 4 carbons and 1 oxygen, a carbonyl group and 2 hydroxyl (–OH) groups. It has a short 2-carbon side-chain, with both carbons having polar OH groups attached. It is a polar molecule.

Vitamin D (calciferol) is a bigger molecule than the other two – it has two 6 carbon rings with one fused to a 5-carbon ring. It has a branched, 6-carbon hydrocarbon side-chain and a 2-carbon link between the ring structures. There is one OH group, but the molecule is predominantly non-polar.

B.5.2.2 Vitamin A is needed for the formation of the light-sensitive pigment called rhodopsin, which occurs in the rods of the retina. Because of its system of alternating double and single bonds, vitamin A is able to absorb and react to light.

Vitamin C is a strong antioxidant (it can be readily oxidised) and it is necessary for the formation of the connective tissue protein collagen. It is also required for the functioning of some enzymes. Because vitamin C is not soluble in fats it cannot be stored in the body and must be consumed regularly.

Vitamin D is used in the uptake and metabolism of calcium and phosphorus and is therefore essential for healthy bones and teeth and for muscle action. It also plays a role in the immune system.

B.5.3.1 Vitamin A is fat-soluble due to its non-polar nature. It is absorbed from foods rich in fats. It is hydrophobic and not soluble in water.

Vitamin C on the other hand is polar due to the presence of four polar hydroxyl (OH) groups. This makes it very water-soluble as it can form hydrogen bonds with water. It does not have a hydrophobic area.

Vitamin D is fat-soluble and very hydrophobic due to its non-polar nature. It is not soluble in water.

The fat-soluble vitamins, A and D, can be stored in fat tissue.

B.5.3.2 The water-soluble vitamins have many polar groups which interact with water. These include –OH, $-NH_2$, C=O. They may have charged phosphate groups on the surface.

B.5.4.1 A balanced diet is one which contains all the macronutrients and micronutrients (including vitamins and minerals) required by the body each day in the quantities and proportions needed for it to function, grow and develop in a healthy manner.

B.5.4.2 (a) Malnutrition occurs when any of the necessary food requirements are deficient in the diet. This may be due to not enough food, poor quality food, poor eating habits, poverty, famine, or illness which affects the ability to eat. People with plenty to eat may experience malnutrition if they do not eat a balanced diet.

In underdeveloped countries, war, failure of crops, poor sanitation and poverty are major causes whereas in developed countries neglect of children, little education, poor knowledge about food and economic difficulties are more likely causes.

(b) Malnutrition in children leads to their failure to grow and develop. They will be underweight, lethargic, susceptible to disease and possibly retarded. In adults, malnutrition can cause weight loss, fatigue and lowered immunity. Prolonged malnutrition may result in death.

B.5.4.3 Marasmus and kwashiorkor are two forms of protein deficiency disease. Marasmus is more common in babies and leads to body wasting, failure to grow, irritability and eventually, infections and dehydration. Kwashiorkor is more common in older children and affects millions of children around the world. It leads to slow growth and development, swelling, muscle weakness, mental apathy, being underweight and frequent infections.

B.5.4.4 Various, e.g.

Nutrient lacking	Name of deficiency disease	Symptoms
Iodine	Goitre	Swelling in the neck due to an enlarged thyroid gland, lack of the hormone thyroxine, tiredness and weight gain.
Vitamin C	Scurvy	Bleeding under the skin due to breakdown of capillary walls. Soft and bleeding gums.
Vitamin D	Rickets	Softening and deformities of bones due to poor absorption and metabolism of calcium and phosphorus.
Vitamin A	Night blindness	Difficulty seeing at night or in dim light.

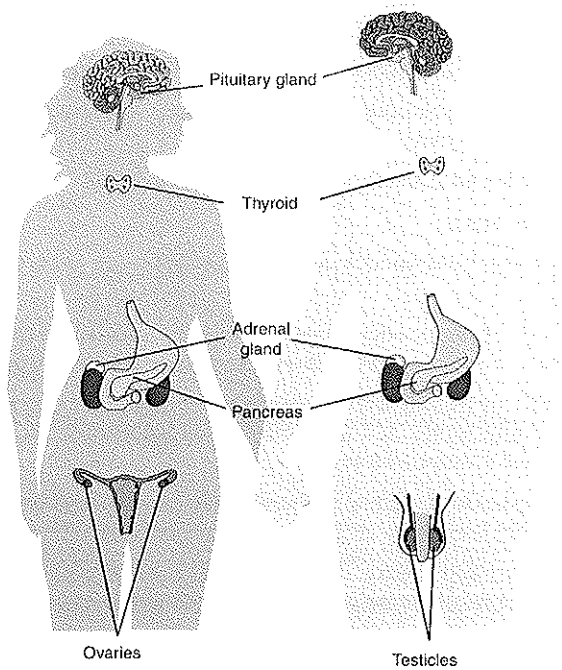
B.5.4.5 Various. In your answer you could discuss:

- The extent of the problem.
- Details of any common dietary deficiencies.
- Reasons for inadequate nutrition.
- The effects of malnutrition on the individual and the country.
- Possible solutions such as improvements in agricultural practices – addition of trace elements to soil, genetically modified crops, improved water supplies, provision of supplements, e.g. vitamins and minerals.
- Education to improve knowledge about a balanced diet and ways to achieve this.
- Monitoring and reporting by health authorities.

B.6.1.1 (a) Hormones are chemical messengers that are involved in the chemical coordination of the body. They are produced by special glands, called endocrine glands (e.g. the pancreas, thyroid, adrenal, ovary and testis). Hormones are released directly into the blood stream. They travel in the blood to their target tissue or organ where they have a specific job to do. Hormones bind to a specific receptor on or in their target.

(b) Only very small amounts of hormones are needed. If too much of a hormone is produced, a negative feedback mechanism stops any further production. The pituitary gland, situated underneath the brain, is the master gland. It releases a number of hormones many of which control the release of hormones from other glands.

(c)

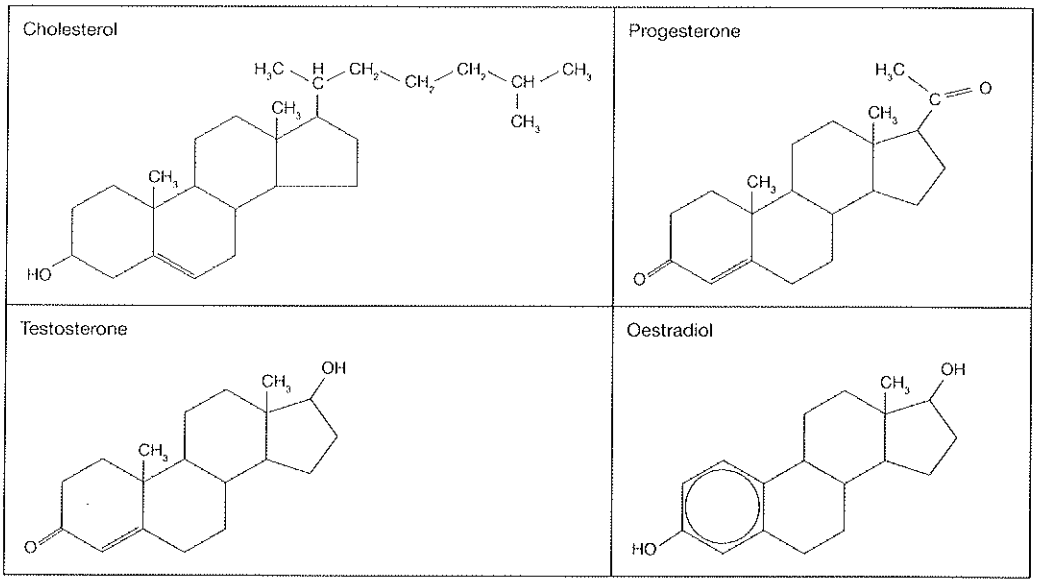


B.6.1.2

Hormone	Gland	Function of the hormone
Insulin	Pancreas	Reduces blood sugar levels.
Thyroxine	Thyroid gland	Regulates metabolic rate.
Adrenaline	Adrenal gland	Prepares the body for emergency (called the flight or fight response), e.g. increases heart rate, blood pressure, releases glucose into the blood.
Oestrogen	Ovaries	Female sex hormone. Plays a role in the development and maintenance of female secondary sexual characteristics and reproductive system.
Progesterone	Ovaries	Female sex hormone. Important in the menstrual cycle and pregnancy.
Testosterone	Testes	Male sex hormone. Important in the development and maintenance of male secondary sexual characteristics and reproductive system.
Aldosterone	Adrenal gland	Acts on the kidneys to regulate the concentration of sodium and potassium ions in the body, reabsorbing these ions when necessary. Plays a role in water balance.
Antidiuretic hormone (ADH)	Pituitary gland	Acts on the kidneys to reabsorb water back into the blood according to the body's needs.

B.6.1.3 Aldosterone and the sex hormones oestrogen, progesterone and testosterone.

B.6.2.1



B.6.2.2 Cholesterol and the sex hormones illustrated share a basic four-ring structure, but differ in the side-chains attached to the four fused rings and in the position of the double bond in the ring.

On C17, testosterone and oestradiol each have a hydroxyl (OH) group, whereas cholesterol and progesterone both have side-chains. Cholesterol has a longer chain than progesterone.

A double C=C bond occurs between C4 and C5 in testosterone and progesterone and between C5 and C6 in cholesterol.

Oestradiol shows variation in the structure of ring A, which is a benzene ring. There is no methyl group on C10 and there is an OH group on C3.

B.6.3.1 (a) The level of oestrogen increases after menstruation, reaching a peak just before ovulation. The oestrogen surge about the 12th day reduces the level of the follicle stimulating hormone (FSH) and this in turn triggers the release of luteinising hormone (LH) from the pituitary gland. LH causes ovulation. Oestrogen levels drop at the end of the cycle. Oestrogen thickens the uterus lining and hence prepares the uterus for a possible pregnancy. The drop in oestrogen stimulates the pituitary to release FSH which then begins the maturation of an egg follicle at the beginning of the next cycle.

Progesterone levels rise to a maximum during the second half of the cycle. Progesterone prepares the body for pregnancy, especially by acting on the uterus. If fertilisation does not occur, progesterone levels fall rapidly at the end of the cycle. This drop triggers the breakdown of the lining and sends a message to the pituitary gland to start the next cycle.

(b) When fertilisation occurs, the ovaries continue to secrete oestrogen and progesterone. This halts the menstrual cycle and maintains the thick, blood-rich uterus lining so that it is ready for implantation of the embryo. (It does this by inhibiting the release of follicle stimulating hormone (FSH) and luteinising hormone (LH).)

B.6.3.2 (a) The combined pill contains both oestrogen and progesterone and it works by preventing ovulation. Levels of both hormones remain high during the cycle so as to inhibit the release of FSH and LH from the pituitary. Thus the ovaries are not stimulated, no new egg follicle matures, and ovulation does not occur. If no egg is produced the person cannot become pregnant. This is the most effective form of the pill.

(b) The minipill contains only progesterone, without oestrogen. It works by changing the composition of the cervical mucus so that it becomes more viscous and prevents the entry of sperm into the uterus and also by thinning the uterus lining so an egg cannot implant. This pill does not prevent maturation and release of an egg from the uterus; ovulation still occurs, but the egg is not fertilised.

B.6.4.1 Steroids are used in hormone replacement therapy (HRT) to treat hormone imbalances in the body, e.g.

- If there is a problem with aldosterone production, the hormone can be taken as medication.
- Female sex hormones are sometimes used by women to relieve the symptoms of menopause and to treat osteoporosis.
- Oestrogen and progesterone used for contraception.
- Older men may be treated with testosterone to maintain vitality.
- Testosterone is used to increase muscle mass in patients suffering muscle wasting during long-term illness.

B.6.4.2 Because anabolic steroids build muscle strength, they are illegally used by some athletes to increase their body mass and strength so as to give them an advantage in competition. However, the use of these steroids causes side effects such as the growth of facial hair, high blood pressure, increased risk of heart attack, aggressive behaviour and development of male secondary sexual characteristics in females. Sporting competitors are regularly urine tested for these drugs.

B.7.1.1 (a) Enzymes are catalysts because they increase the rate of chemical reactions in the body by lowering the activation energy for the reaction and they are not used up in the reaction. They are called biological catalysts because they are proteins in living things and they control the rate of chemical reactions in biological systems.

(b) An enzyme increases the rate of both the forward and reverse reactions so equilibrium is reached more quickly. The position of equilibrium is not altered.

B.7.1.2 (a) The substrate is the substance changed by the enzyme.

(b) Each enzyme acts on only one particular substrate or stereoisomer (or sometimes a group of very closely related substances). For example, amylase breaks down starch but not cellulose or glycogen, cellulase breaks down cellulose but not starch.

(c) An enzyme is a protein. Its functioning is determined by its three-dimensional shape and this is determined by its tertiary and quaternary structure. The substrate and enzyme bind together at a site on the enzyme surface called the active site. The structure of the active site and the structure of the substrate must 'fit' closely together for any reaction to occur. This is called the lock and key model of enzyme action. This close fit is responsible for enzyme activity and hence protein three-dimensional structure is responsible for specificity.

B.7.1.3 **Graph A:** The activity of an enzyme (and hence the rate of reaction) depends on the temperature. As temperature increases, the rate of reaction increases up to a maximum. Each enzyme has a characteristic optimum temperature. Enzyme P has maximum activity at 30°C and enzyme Q has maximum activity at 40°C.

At high temperatures the enzyme is denatured; there is a rapid loss of activity due to disruption of the bonds holding the protein in its unique shape.

Graph B: The activity of enzymes varies with pH. Each enzyme is only active over a narrow pH range which is characteristic for that enzyme. Enzyme R is active in the acid range (with optimum activity at pH 3) whereas enzyme S is active in the neutral pH range (with optimum activity at pH 7).

B.7.2.1

Property	Inorganic catalyst	Biological catalyst (enzyme)
Organic or inorganic	Inorganic.	Organic.
Quantity needed for reaction	Small amounts only.	Small amounts only.
Is the catalyst changed chemically by reaction?	No change.	No change.
Specificity	Not specific, carries out many different reactions.	Highly specific (may only be able to react on one enantiomer of its substrate).
Effect of temperature on catalysis	Not temperature sensitive.	Temperature sensitive with a characteristic optimum. Denatured at high temperatures.
Effect of pH	Wide range unless chemically changed by pH.	Narrow optimum pH range and inactive outside that range.
Cofactors	Not needed.	Frequently need cofactors such as a specific vitamin or mineral.
State	Varies – may be solids with reaction occurring on surface, may be homogeneous.	Occur in aqueous solution (in living tissues).

B.7.3.1 The enzyme (E) combines reversibly with substrate (S) to form an enzyme-substrate complex (ES). This complex then forms the products (P) and regenerates the enzyme.

$E + S \rightleftharpoons ES \rightarrow E + P$

Where E = the enzyme

S = the substrate

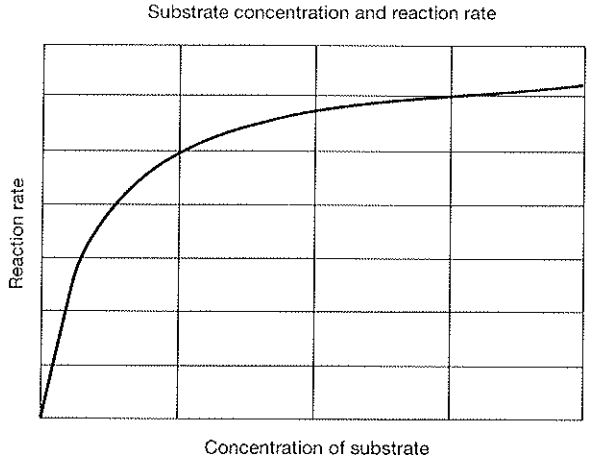
ES = an enzyme-substrate complex

P = the product

B.7.3.2 Since enzyme-catalysed reactions proceed through the formation of an ES complex, at low substrate concentration [S], the rate is proportional to the concentration of the substrate. This is because the formation of the complex ES depends on the substrate concentration, i.e. the reaction is first order with respect to substrate concentration [S].

However, at higher substrate concentration [S], all of the enzyme will be tied up in the form of the ES complex. Therefore the substrate can only be reacted when an ES complex breaks down to products, regenerating an enzyme to react again on a substrate molecule. This means that reaction rate will depend on how fast the complex ES is broken down to the enzyme (E) and the product (P). Therefore, at higher substrate concentrations, the reaction is zero order with respect to substrate concentration [S]. The enzyme is said to be saturated with substrate.

B.7.3.3



B.7.4.1 (a) The unit for the Michaelis constant is moles dm^{-3} (the same unit as substrate concentration).

(b) $V_{max}/2 = V_{max}\,[S]/(K_m + [S])$

$\frac{1}{2} = [S]/(K_m + [S])$

$K_m + [S] = 2[S]$

$K_m = [S]$

Therefore the Michaelis constant is equal to the substrate concentration when the reaction velocity is half the maximum velocity.

B.7.4.2 The initial reaction rate is determined experimentally at different substrate concentrations [S], while keeping the enzyme concentration, the temperature and the pH constant. The velocity can then be plotted against [S]. The velocity is the dependent variable, so it goes on the vertical axis. The V_{max} can be read from the graph and the Michaelis constant (K_m) is the substrate concentration [S] at half the maximum velocity (V_{max}).

Alternatively, $1/V$ can be plotted against $1/[S]$. This is called the Lineweaver-Burke plot of enzyme activity, and the interval on the vertical axis is $1/V_{max}$ with the interval on the horizontal axis being $-1/K_m$.

B.7.4.3 (a) The higher the Michaelis constant (K_m), the higher the substrate concentration [S] needed to reach maximum velocity V_{max} and therefore the lower the enzyme activity. A low K_m means a more efficient enzyme.

(b) The K_m gives a measure of the activity of an enzyme and the level of substrate concentration [S] on which it will be effective. When K_m is known for a particular enzyme, the activity of the enzyme in tissues can be assessed. The same enzyme in different species may have a different K_m, leading to a different level of activity in the different species.

B.7.5.1 (a) Enzymes are proteins. They have a small area on their surface, usually a groove or space, which is called the active site. This is formed by the arrangement of some of the amino acid side-chain groups that make up the protein (enzyme). The groove or space matches the shape of the substrate molecule which interacts with it. The substrate fits into the space and binds reversibly to points on the enzyme, forming the enzyme-substrate complex.

(b) Intermolecular forces such as strong hydrogen bonds, and the weaker dipole-dipole forces and electrostatic interactions hold the ES complex together.

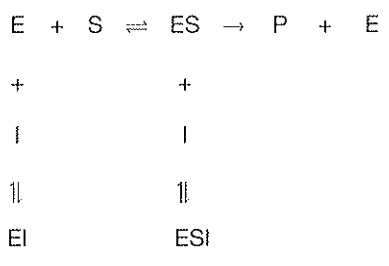
B.7.5.2 The induced fit model of enzyme activity is a modification of the lock and key model. In both models the enzyme and substrate fit together, but in the induced fit model both the enzyme and the substrate undergo a change when they interact. The active site changes shape slightly, either to bind the substrate or as a result of the substrate binding. This distorts the substrate and causes strain on the substrate bonds which increases the reaction rate. The induced fit model suggests less energy is needed due to strain on the substrate bonds.

In contrast, the earlier model of enzyme and substrate fitting together like a lock and key implies rigidity. It would take more energy to break bonds if they were not undergoing strain.

B.7.6.1 (a) Enzyme inhibition is the reduction of enzyme activity by small molecules and ions. It is an important aspect of cellular enzyme activity because it is a major control mechanism in biological systems, allowing chemical activity to be reduced when necessary. In some cases, the product of a reaction can act as an inhibitor (feedback). Some medications and toxic agents act by inhibiting specific enzymes.

(b) (i) In irreversible inhibition, the enzyme is permanently modified or destroyed. This may be due to a covalent bond forming with a side-chain group such as a serine –OH or a cysteine –SH. This may be at the active site or at another site resulting in a change in tertiary structure. Toxins such as nerve gas inhibit irreversibly.

(ii) With reversible inhibition, activity of the enzyme is temporarily reduced, but not lost. The bonding is usually non-covalent. The inhibitor binds reversibly to the enzyme. It may form an enzyme-inhibitor complex (EI) which can readily dissociate again, or the inhibitor may bind to the enzyme-substrate (ES) complex forming a reversible enzyme-substrate-inhibitor (ESI) complex.



(c) In competitive inhibition, the inhibitor competes with the substrate for access to the active site, reducing the availability of the active site. In non-competitive inhibition the inhibitor binds to the enzyme at a site away from the active site, reducing activity by changing the shape of the active site.

B.7.6.2 Both malonate and succinate are similar in structure, with negatively charged groups at the ends of both molecules. Both molecules compete for the same site, as both show electrostatic attraction to two positively charged amino acid side-chain groups in the active site. This reduces the number of active sites available to bind succinate, inhibiting the enzyme and reducing the rate of product formation. Inhibition by the malonate can be reduced by increasing the concentration of the succinate ion.

B.7.6.3

Property	Competitive inhibition	Non-competitive inhibition
Reversibility	Reversible.	Reversible.
Complex formed with enzyme	EI (enzyme-inhibitor) only.	EI or ESI (enzyme-substrate inhibitor).
Position of binding to enzyme	Active site.	Not active site, binding site elsewhere on enzyme.
Effect of increasing substrate concentration [S]	Inhibition overcome by increasing the [S]. The greater the concentration of substrate present, the less the effect of the inhibitor.	No effect. Increasing [S] does not decrease inhibition.
Effect on V_{max}	Not altered.	V_{max} is decreased.
Effect on K_m	K_m increased.	Not altered.

B.7.6.4 Diagram A is competitive inhibition – the inhibitor fits in the active site, preventing the substrate attaching there.

Diagram B is non-competitive inhibition – the inhibitor does not attack the active site, but it attaches elsewhere and alters the shape of the molecule so the substrate no longer fits.

Diagram C shows no inhibition; the enzyme and substrate lock together.

B.7.7.1 (a) Various, e.g. mercury, cadmium, lead, arsenic, silver and copper.

(b) When compounds containing the heavy metals are ingested, they affect enzyme activity because they are irreversible enzyme inhibitors. They can form covalent bonds with amino acid side-chains that are important at the active site or for tertiary structure. An example is the effect of silver ions (Ag^+) on the $-CH_2-SH$ side-chain of cysteine. The silver ion replaces the hydrogen on the –SH group forming $-CH_2-S-Ag$ and releasing a hydrogen ion (H^+). Disulfide bonds essential for tertiary structure can also be disrupted by heavy metal ions. They compete with metal cofactors such as zinc, magnesium and calcium.

B.7.7.2 Enzyme activity increases as temperature increases due to greater particle kinetic energy and hence more collisions between enzyme and substrate molecules. However, the greater the thermal agitation within the protein molecule, the more the disruption of bonds necessary for tertiary and quaternary structure. Hence high temperatures cause protein denaturation. The optimum temperature for enzyme activity is when collisions are occurring at a fast rate, but not fast enough to cause denaturation of the enzyme.

B.7.7.3 Enzymes are active over a narrow pH range, and each enzyme has a particular pH at which it has optimal activity. For example, the enzyme pepsin in the stomach is active in acidic conditions, with an optimum pH of 2. Hydrochloric acid is produced in the stomach and this allows pepsin to function there, digesting proteins. Most cellular enzymes are active around a neutral pH, e.g. succinate dehydrogenase. The effect of pH on enzymes is due to the electrostatic nature of the enzyme to substrate (ES) binding and pH is also important in tertiary protein structure. Charges on groups such as $-NH_2$, –COOH and –OH in proteins are susceptible to changes in pH, e.g. –COOH is present as the uncharged form in acid, whereas at a neutral or basic pH it occurs as $-COO^-$. Changing the charge on amino acids affects the bonds between them, disrupting their tertiary structure and making them ineffective as catalysts.

B.8.1.1 (a) Each nucleotide consists of a pentose sugar (ribose or deoxyribose), a phosphate group and an organic nitrogenous base (a ring structure which contains nitrogen).

(b) (i) Adenine

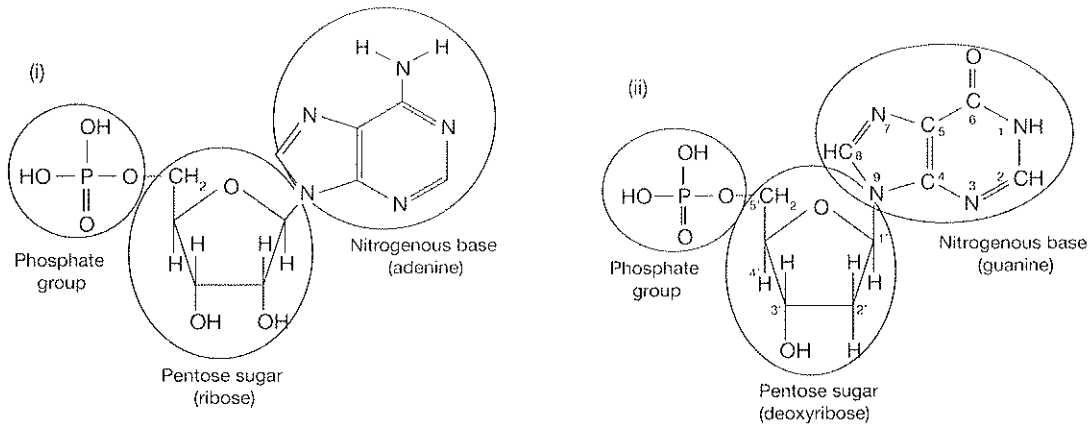
(ii) Guanine

(iii) Thymine

(iv) Uracil

(v) Cytosine

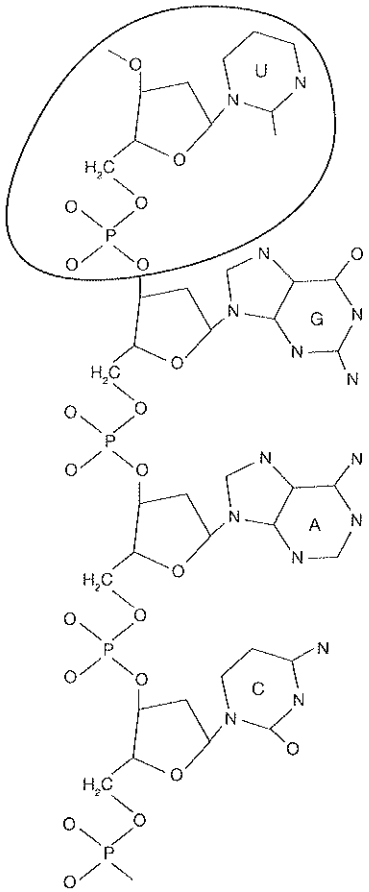
(c)



B.8.1.2 A nucleic acid (polynucleotide) is a condensation polymer made of a series of nucleotides joined together. Nucleotides are the monomers that make up a nucleic acid.

B.8.1.3 Nucleic acids contain a chain of nucleotides forming a backbone in which the sugar of one nucleotide is joined, by covalent bonding, to the phosphate of the next nucleotide. The nitrogenous bases are attached to the first carbon atom of the sugar which forms part of the backbone. The sequence of bases varies.

B.8.1.4 Various, e.g.

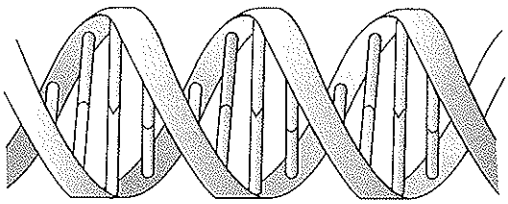


B.8.2.1

Factor	RNA	DNA
Name	Ribosenucleic acid.	Deoxyribosenucleic acid.
Found	Cytoplasm and nucleus of cells.	Nucleus of all human cells except red blood cells.
Single or double strands	A single-strand nucleic acid.	A double strand nucleic acid.
Pentose sugar present in molecule	Ribose.	Deoxyribose (lacks an O atom on C2).
Nitrogen bases present in molecule	Adenine, guanine, cytosine, thymine.	Adenine, guanine, cytosine, uracil.
Functions in the body	Carries information from the nucleus to the cytoplasm of the cell and directs protein synthesis.	Forms genes along chromosomes in the nuclei of cells. Contains the genetic blueprint.

B.8.3.1 A DNA molecule consists of two strands (chains) lying side by side. Hydrogen bonds form between the bases of adjacent chains. The four bases always connect in the same way: thymine is always opposite adenine, and guanine is always opposite cytosine. The molecule looks like a ladder with the bonded bases forming the rungs of the ladder.

B.8.3.2 A helix is a twisted structure. In DNA the two strands making up the ladder-like chain twist, spiralling around an axis, to form a double helix shape.



B.8.3.3 Various, e.g. you could use anything from toothpicks to strips of plastic to represent the sides of the ladder and attach coloured objects, e.g. jellybeans to represent the bases (use 4 different colours to represent the 4 different bases). Take a photograph of your model.

B.8.4.1 DNA is the genetic material that is inherited from parents. This genetic material is stored on 23 pairs of chromosomes (long thread-like structures) in the nucleus of each cell. Each chromosome consists of a very long, coiled up molecule of DNA. Sections of the DNA which contain complete messages are called genes. The DNA contains the information that controls how an individual will develop, including instructions on how to make each type of protein in the body. This is sometimes called the genetic blueprint. Each time a cell splits to produce two new cells, the information in the original cell must be copied exactly so that each new cell has identical information to the original cell.

B.8.4.2 (a) DNA controls the synthesis of proteins and thus it controls the growth and functioning of organisms. The DNA contains a 'protein code' that determines which amino acids join together to make each protein in the body. Each sequence of three nucleotides (a triplet) in the DNA determines an amino acid, e.g. guanine-thymine-adenine is the code for the amino acid histidine, adenine-adenine-adenine is code for phenylalanine, cytosine-cytosine-adenine is code for glycine. The DNA is found in the nucleus, but protein is synthesised in the cytoplasm. So information in the DNA is transferred accurately to the cytoplasm as mRNA.

(b) The DNA double strand 'unzips'.

A copy of the DNA information is made in the form of mRNA.

Messenger RNA (mRNA) moves through the nuclear membrane into the cytoplasm.

Amino acid molecules present in the cytoplasm join together in an order based on the triplet sequence on the RNA molecule. This sequence of amino acids forms the protein.

(c) Transcription is the process of transferring the DNA information to messenger RNA (mRNA) – genetic information is transcribed from DNA to mRNA.

Translation is the process in which mRNA is decoded so that a chain of amino acids can join together in a particular sequence to form a particular protein.

B.8.4.3 Glycine-valine-alanine-glycine-proline-alanine-glycine-histidine-histidine-serine-arginine.

B.8.5.1 (a) DNA profiling is useful for:

- Identification of people.
- Criminal identification, determining if a suspect in a crime was present at a crime scene based on tissue samples found at the crime scene.
- Establishing paternity, determining the parents of a child when this is in dispute.

DNA evidence is useful for these purposes because:

- Every cell (except red blood cells) in the body of a person contains identical DNA, so obtaining a very small sample from body tissues will allow the DNA to be analysed and a DNA fingerprint to be obtained. For example, DNA can be obtained from white blood cells, skin fragments, hair root follicles or saliva.
- The DNA fingerprint is unique to the person from whom the sample was obtained (except in the case of identical twins or triplets.

(b) DNA fingerprinting is still a relatively new technique. It is considered very reliable when carried out carefully. However, there is concern about:

- DNA fingerprints cannot actually identify a person. They can only determine the probability that a sample is from a particular person. This varies with the accuracy of data collection and testing. To be used in criminal investigations the probability must be very high.
- Accuracy of results when performed in private laboratories as they vary in security, testing standards and quality control.
- The possibility of human error while creating a big enough sample for analysis from very small samples and in interpreting the results.
- The destruction of very small samples during testing, so that results cannot be replicated.
- Cost of testing which tends to be high, so there is concern that some people may be unable to use such techniques in self-defence.

You might like to research the use of DNA testing in court cases.

(c) The person A.

B.8.5.2 DNA profiling involves the following steps:

- Collection of a sample.
- Chemicals are added to disrupt the nuclear membranes and release the DNA from the nucleus. If there is not enough material to analyse, a method called polymerase chain reaction is used to increase the size of the sample. The enzyme DNA polymerase is used to duplicate small sections of the DNA.
- Different-sized sections of DNA are obtained by techniques such as RFLP (restriction fragment length polymorphism). Restriction enzymes are used to cut the DNA molecule into shorter fragments, each enzyme always cutting at a certain sequence of base pairs. The probability that any two people will have the same pattern of fragments when their DNA is cut by two or more restriction enzymes is very small.
- Gel electrophoresis is used to separate the cut segments using an electric field. The negatively charged phosphate groups are attracted to the positive end of a charged plate. The shorter fragments move faster through the gel than longer fragments. A dye is used to make the fragments visible so they can be photographed.

B.8.5.3 A DNA data bank would contain DNA fingerprints of the whole population. Some criminologists would like to see such data banks set up, with people being tested at birth to obtain their fingerprints. This could help to solve many crimes which are presently unable to be solved. However, the cost would be considerable and there are concerns about the possibilities of misuse of such information if it became available to the public, such as the existence of genetic defects, vulnerability to cancer or other life-threatening diseases. For example, a person could experience difficulty obtaining health insurance if a genetic code is present which suggests they could develop cancer; this would be unfair as this gene may never be 'turned on'. Some countries are setting up DNA banks of people who have been involved in crimes. In other countries this is illegal. What is the status in your country?

B.9.1.1 (a) Glycolysis: Glucose is converted via a number of steps into two molecules of pyruvic acid (CH_3–CO–COOH). At physiological pH, pyruvic acid exists as the pyruvate ion (CH_3COCOO^-). The carbon in glucose is oxidised. NADH (nicotinamide adenine dinucleotide) removes the hydrogen atoms and is reduced.

$C_6H_{12}O_6 + 2NAD^+ \rightarrow 2CH_3COCOO^- + 2NADH + 4H^+ + \text{energy}$

(b) $2CH_3COCOO^- + 2NADH + 4H^+ + 6O_2 \rightarrow 6CO_2 + 6H_2O + 2NAD^+$

(c) $CH_3COCOO^- + NADH + H^+ \rightarrow CH_3CHOHCOO^- + NAD^+$

The reduction of pyruvate to lactate regenerates the NAD^+ for further glycolysis to continue. Thus the production of energy for the cell can continue as glycolysis releases energy in the form of the high energy compound ATP.

B.9.1.2

Factor	Aerobic respiration	Anaerobic respiration
Air/oxygen present	Yes.	Not needed. Only occurs when oxygen is limited.
Oxidation/reduction of pyruvate	Oxidation.	Reduction.
End products	Carbon dioxide and water. Energy – a greater amount of energy is released for use in the cell.	Lactate ion. Energy – not as much as in the aerobic stage.

B.9.1.3 $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

B.9.1.4 Oxidation: $C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^-$

Reduction: $6O_2 + 24H^+ + 24e^- \rightarrow 12H_2O$

B.9.2.1 (a) Useful properties include:

- The ability to form complex ions in organic compounds, e.g. cytochromes and haemoglobin.
- Redox properties which are useful in catalysis.
- Their charge densities.

(b) The process of electron transport is the last step in the aerobic stage of respiration. It involves a system in which hydrogen atoms removed from the carbon compounds during the oxidation reactions are separated into H^+ ions and electrons, the electrons then passed along a chain. The electron acceptors in the chain are the cytochromes. The cytochromes contain a protein, a porphyrin ring and an iron (Fe^{2+}) ion. Some also contain a Cu^{2+} ion. The metal ion cofactors change oxidation state as the electrons are transferred along the chain to oxygen. Energy is released as the electrons move along the chain. This energy is trapped in the high-energy ATP molecule.

$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ and $Cu^{2+} + e^- \rightleftharpoons Cu^+$

(c) Haemoglobin is the respiratory pigment which carries oxygen in the red blood cells to the body cells. Haemoglobin contains a haem group (porphyrin) which has an iron atom in its centre. This iron is in the 2+ oxidation state. Oxygen binds to this iron forming a complex and making the haemoglobin oxygenated. However, the oxidation state of the iron is not altered when oxygen combines with haemoglobin. This is in contrast to the functioning of iron and copper in electron transfer.

Notes