Full Name:	Civics group: 21S	Index no.:	Date:

Core Idea 1: The Cell and Biomolecules of Life
Tutorial 2
Biomolecules - Carbohydrates

MCQ

1	2	3	4	5	6
B	B	C	A	D	A

9700 / 2010 / Nov - adapted

1 The equation shows a reversible reaction.

monosaccharides = simple sugars

$$\text{sucrose} + \text{water} \underset{2}{\overset{1}{\rightleftharpoons}} \text{glucose} + \text{fructose}$$

disaccharide

In this reaction, what enzyme catalyses reaction 1 and what types of reaction occur at **1** and **2**?

	enzyme	reaction at 1	reaction at 2
A	sucrase	condensation	hydrolysis
B	sucrase	hydrolysis	condensation
C	sucrose	condensation	hydrolysis
D	sucrose	hydrolysis	condensation

9700 / s2016 / QP12 / Q7

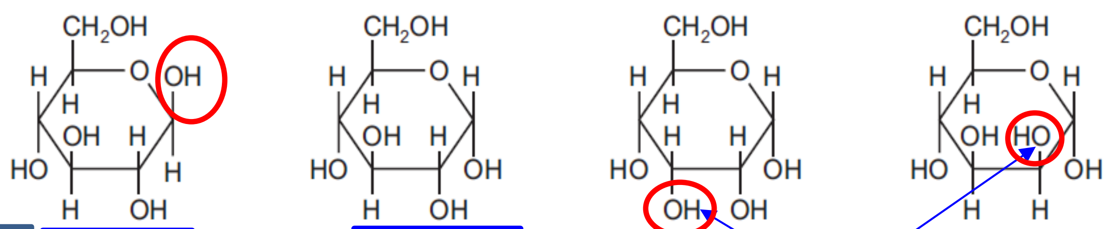
2 The diagrams show four monosaccharides with the formula $C_6H_{12}O_6$.

Which diagram shows α-glucose? ANS: **B**

For general info only: **(C)** α-allopyranose

For general info only: **(D)** α-mannose

A B C D



↑↓↑↓↑ β-glucose α -glucose

Note: Remember for α-glucose = ↓↓↑↓↑

-OH group at the plane different from the α-glucose and β-glucose

Thinking question:
What is the term that describe these 4 monosaccharides having the same formula $C_6H_{12}O_6$ *but different structural arrangements?*

ANS: ISOMERISM

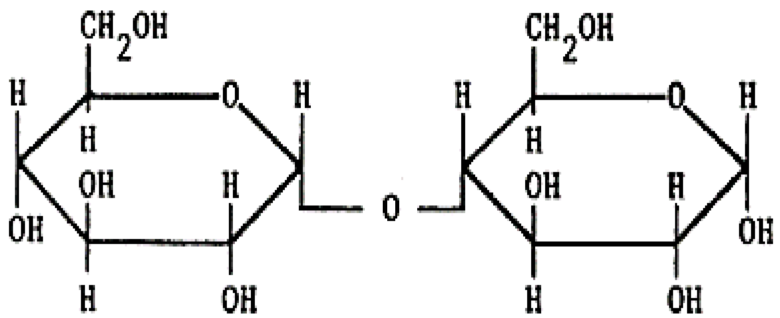
Class Activity:

Three monosaccharides condensed together to form a trisaccharide. How many glycosidic bonds does a trisaccharide have?

Ans:

Draw the condensation reaction of 2 α-glucose to self-check if you are able to understand and apply the concept of LO1(h)(i) ie the formation of glycosidic bonds. Note: Draw a disaccharide consisting of 2 β–glucose for a challenge.

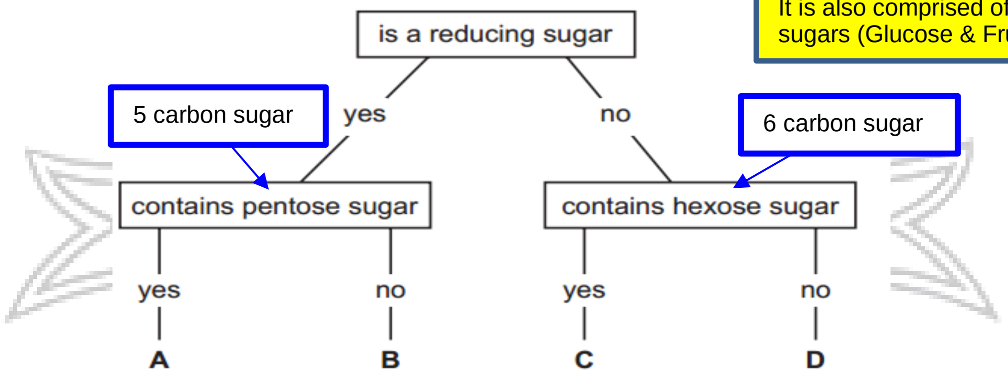
Ans:



9700 / 2005 / Nov

3 Which molecule in the key is sucrose? ANS: **C**

Note: Sucrose is a non-reducing sugar, that you must know.
It is also comprised of 2 hexose sugars (Glucose & Fructose).



4 Which statements about amylopectin and cellulose are correct?

1 Both contain 1-4 glycosidic bonds.
2 Amylopectin contains β-glucose while cellulose contains α–glucose.
3 Both have cross-linkages.
4 Both are branched molecules.

A 1 only
B 1 and 2 only
C 2 and 3 only
D 3 and 4 only

5 Which statement describes how the molecular structure of starch is suited to its function?

A Amylose has a branched structure and amylopectin is coiled to give a compact molecule for transport. ➔ amylose is coiled while amylopectin is coiled and branch. Further, amylose & amylopectin for storage, not for transport purpose

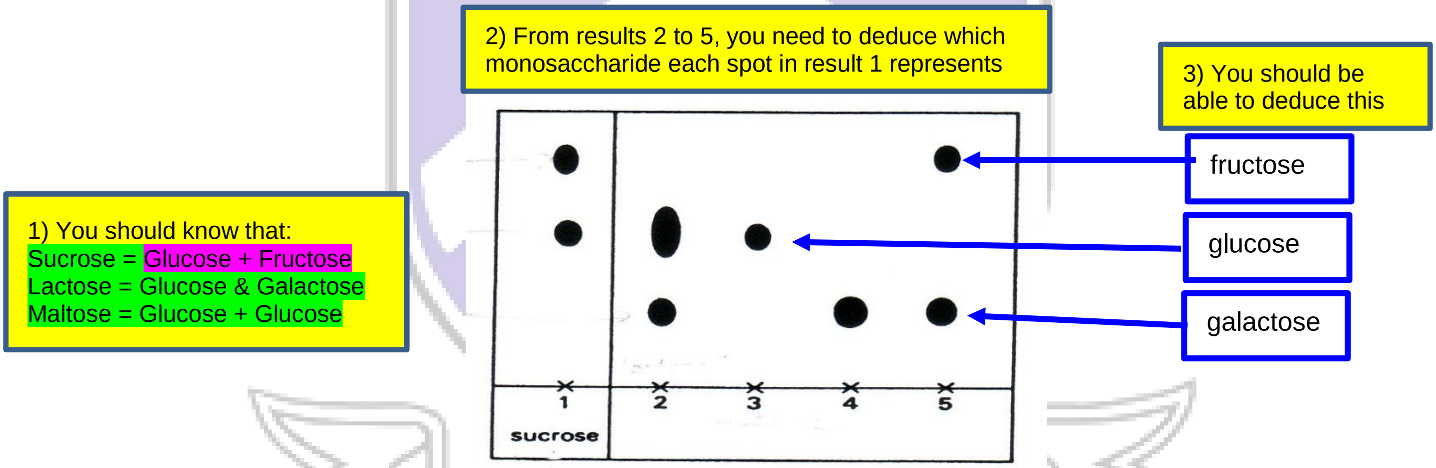
B In the breakdown of amylose and amylopectin, many condensation reactions release stored energy. ➔ breakdown is hydrolysis reaction

C The helical structure of amylose and amylopectin gives starch high tensile strength.

D The amylose-amylopectin complex is insoluble and does not affect the water potential of the cell. ➔Correct! Suited for storage function

N90/Q3

6 Five disaccharides were each hydrolysed with dilute acid, and the purified products were separated by one-dimensional chromatography. The final chromatogram is shown in the diagram below.



If spot 1 represents the products obtained from the hydrolysis of sucrose, which one of the following indicates the results obtained from the hydrolysis of lactose and maltose ?

	Lactose	Maltose
A	2	3
B	2	4
C	5	2
D	5	3

STQ
QUESTION 1

Starch grains in plant cells contain both amylose and amylopectin.

(a) Explain how **both** of these substances are formed from glucose in plant cells.
………………………………………………………………………………………………… [2]

1 Condensation reaction whereby α-glucose monomers are linked by α(1, 4) glycosidic bonds in both, with the release of 1 water molecule per condensation reaction to form linear chains in amylose and amylopectin

2 Amylopectin is branched with its branch points linked by α(1, 6) glycosidic bonds ;

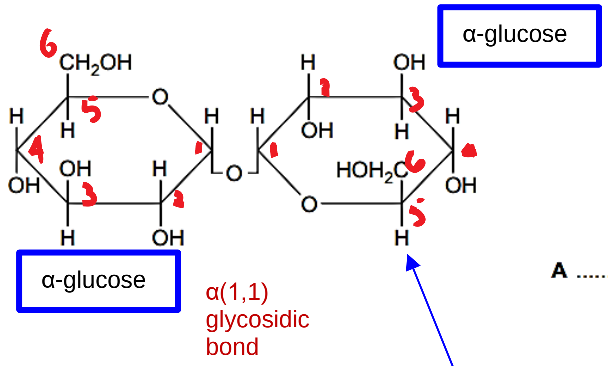
(b) Disaccharides are formed following synthesis from monosaccharides or as a result of polysaccharide hydrolysis.

Cellobiose, maltose, sucrose, and trehalose are four different disaccharides found in nature. Fig. 4.1 shows the molecular structure of these disaccharides.

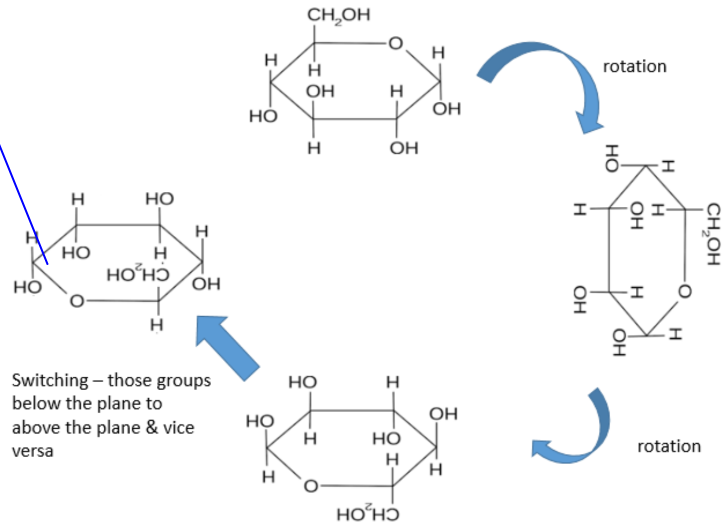
Identify the disaccharides, labelled **A** to **D**, using the information below.

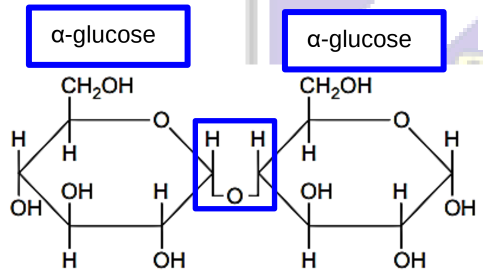
- Cellobiose is formed from the hydrolysis of the polysaccharide cellulose. You can inferred from the mentioned of hydrolysis of polysaccharide [which has only β(1,4) glycosidic bond] that cellobiose has β(1,4) glycosidic bond.
- When cellobiose is hydrolysed, two **β-glucose** molecules are produced.
- One of the disaccharides is sucrose. ➔ from content knowledge, sucrose is made up of glucose and fructose.
- Trehalose is synthesized from two **α-glucose** molecules.
- Maltose is formed from the hydrolysis of amylose, a component of starch. ➔ from content knowledge, maltose is made up of α-glucose and α-joined together to form α(1,4) glycosidic bond. You can inferred from the mentioned of hydrolysis of amylose [which has only α(1,4) glycosidic bond] that maltose has α(1,4) glycosidic bond.

Write the name of the disaccharides in the spaces provided on Fig. 4.1. **[4]**

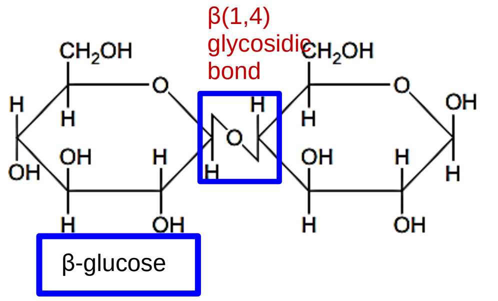


A .... trehalose

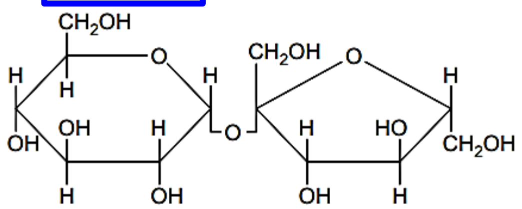




B .... maltose



C .... cellobiose



D .... sucrose

fructose is a 6C sugar but unique hexose which has pentagonal shape instead of hexagonal shape like glucose

Fig. 2.1

QUESTION 2 *(2020 JC1 Common Test)*

Agarose forms part of a more complex carbohydrate called agar, which is used as a growth medium for bacteria. Bacteria cannot use agarose in agar as a respiratory substrate.

Fig. 2.1 shows a representation of part of the carbohydrate molecule called agarose, which is made up of repeating units of galactose.

From the position of oxygen in the carbon ring, it can be seen that the adjacent units are inverted. Hence β glycosidic bonds are formed between subunits like in cellulose chains.

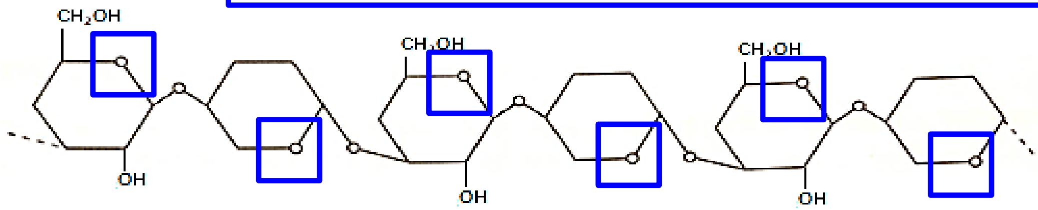


Fig. 2.1

(a) Identify the class of carbohydrate of which agarose is an example.

.... [1]

1. Polysaccharide;

(b) Plants contain a carbohydrate called amylose. Compare the structures of agarose and amylose.

Similarities & Differences

.... [4]

Similarities:

1. monosaccharides of both agarose and amylose are held together by glycosidic bonds**;**
2. both agarose and amylose are unbranched;

(R: large molecule unless mentioned linked by glycosidic bonds)

Differences:

1. agarose is made up of galactose but amylose is made up α glucose (R: glucose)**;**
2. **coiled/helical structures** in amylose but **linear/straight structures** in agarose**;**
3. alternate glucose is **not inverted 180° / same orientation** in amylose but **alternate galactose is inverted 180°** in agarose**;**
4. α(1,4) glycosidic bond is present in amylose but **different types of glycosidic bonds** are present in agarose;

Examiner's Comments

- Many students incorrectly stated the monomer of agarose is β-glucose despite the question stem stating it is made of repeating units of galactose. **(precision)**
- Students incorrectly numbered the carbons in each sugar molecule hence were not able to deduce the correct nature of the glycosidic bond. **(accuracy)**
- Students unable to identify the β glycosidic bond. As the –OH group of C1 of the sugar is point upwards, it is a β sugar molecule. **(precision)**

(c) Agarose serves an important role in maintaining the cell wall of algae, just like cellulose serves as the cell wall material of plants.

With reference to **Fig. 2.1** and your knowledge of cellulose, explain how the structure of agarose enables it to perform its function.

……………………………………………………………………………………..[2]

1. Due to ALTERNATE galactose being rotated 180° **in agarose**/ hydroxyl groups of galactose residues project outwards on both sides of the agarose chains**;**
2. numerous **hydrogen bonds/cross links** occur between parallel agarose chains**;**
3. This contributes to the high tensile strength of agarose, making it a suitable **structural polysaccharide** in algae cell walls;

Point 3 is compulsory

Examiner's Comments

- Students to take note of the phrasing of the first point. While other phrasing such as "alternate units are rotated 180° with respect to each other" is incorrect as alternate units have the same orientation. "Adjacent units are rotated 180° to each other" is a better expression of it.

Carbohydrates can also serve as energy storage in organisms. However, in many animals, the storage of lipids confers a greater advantage over the storage of carbohydrates.

(d) Explain two such advantages.

……………………………………………………………………………………..[2]

1. Triglycerides contain **more energy** per unit mass / lipids yield twice as much energy as carbohydrates per unit mass; (due to the greater number of carbon and hydrogen atoms per gram)
2. Oxidation of triglycerides produces metabolic water, which is useful for desert animals.
3. Triglyceride can act as **good thermal insulators** and prevent excessive loss of heat while carbohydrates cannot. Subcutaneous fats serve as heat insulator for **aquatic mammals (eg whale) / mammals living in cold climates (eg polar bear)**;
4. Triglycerides provide aquatic animals with **buoyancy** as it is less dense than water
5. Triglyceride store in fat tissue serve as a **protection against mechanical shock**;

Examiner's Comments

- Most students lost marks in the first point as they didn't compare the energy output **per unit mass** or **per gram. (accuracy)**
- **Reject**: Lipids are insoluble in water hence do not affect the water potential. As this is a comparison question with carbohydrates, please note that carbohydrates in storage form (glycogen and starch) also do not dissolve in water.

[Total: 8 m]

CLASS ACTIVITY

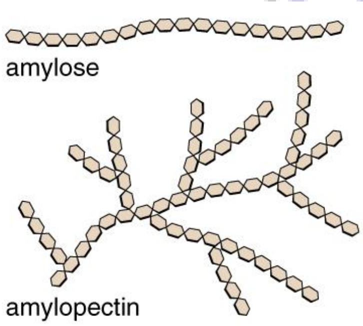
Using named examples, explain the importance of bonds contributing to the specific functions of polysaccharides. [10]

Guiding steps to writing this essay:

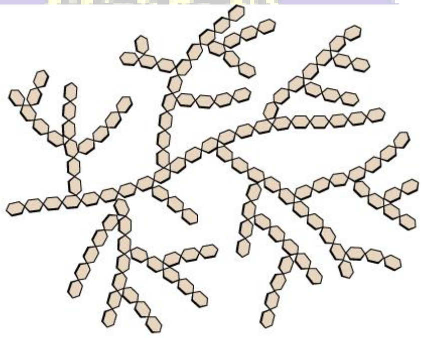
*__Name__ the 3 poly-sachharides and __classify__ them by their specific functions*** → *List the __bonds__ presents in the poly-sachharide* → *__Link the bonds__ listed to a specific __property__ of the poly-sachharide* → *__Link the property__ to a specific __function__ of the poly-sachharide* → *__Organise essay plan__ by bond-property-function in the named poly-sachharide* → *Write essay in __continuous pros__*

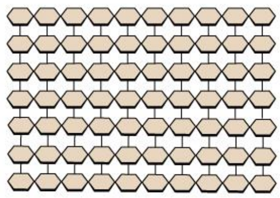
[Sample] In <u>starch</u>, many α-glucose monomers are joined by <u>glycosidic bonds</u>. This allows the formation of a <u>large molecule</u> which is <u>insoluble in water</u>, which makes starch a <u>good energy storage molecule</u> as it can be stored without affecting the osmotic potential of the cell.

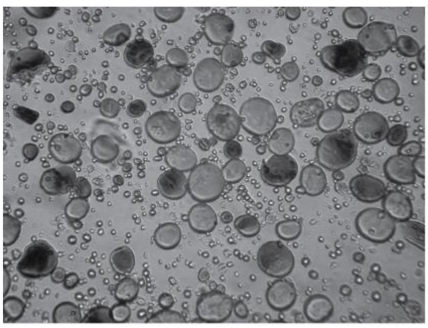
***The purpose of classifying the polysachharides is to avoid repetition of points. For eg. in storage polysachharides such as starch and glycogen, similar bonds are present that enable them to have similar properties and functions.*

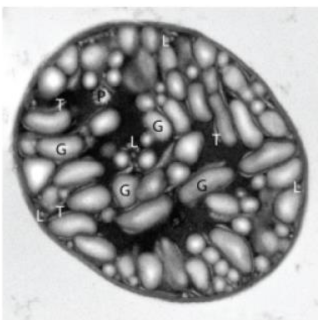


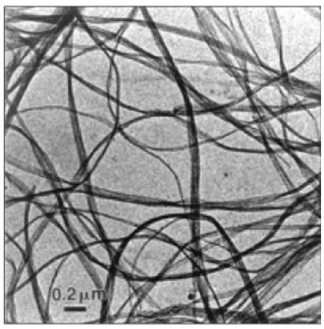
starch


glycogen

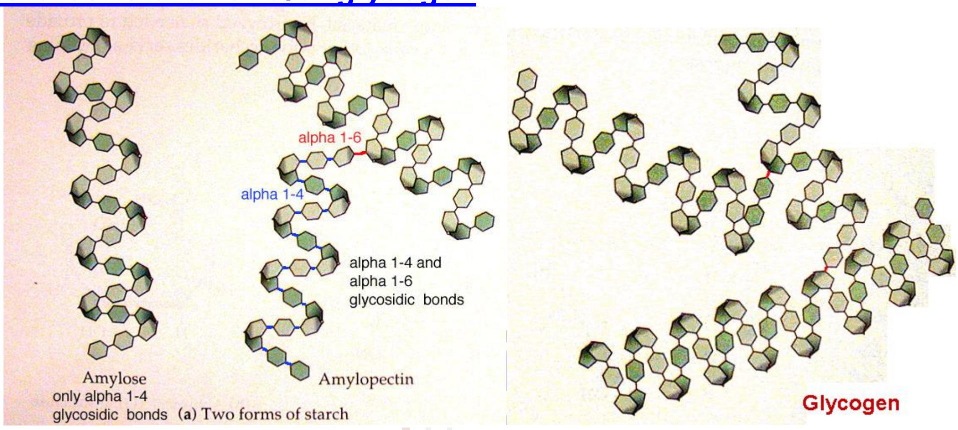

cellulose (fiber)

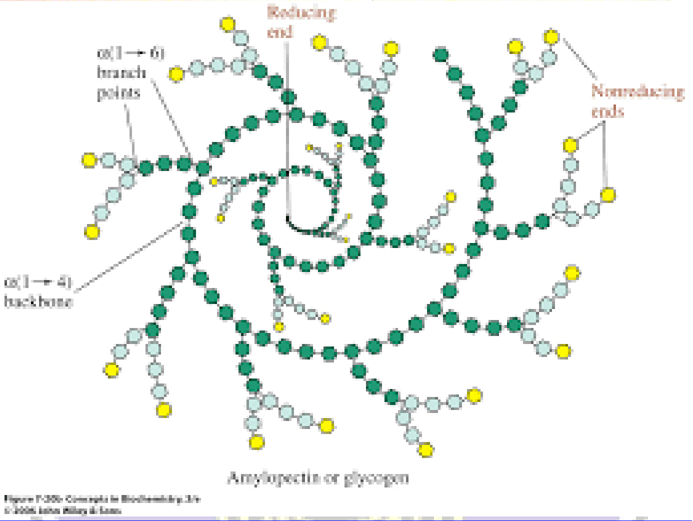






Carbohydrates: Starch and/or glycogen





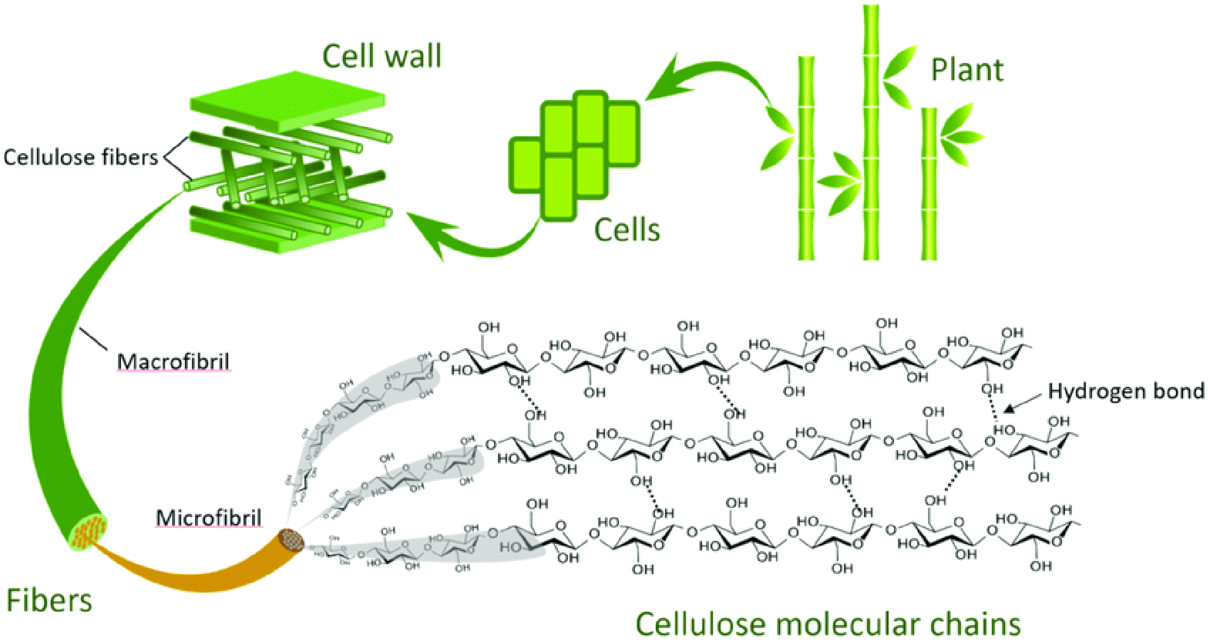
1 *[Bonds]* Glycosidic bonds (are strong covalent bonds that) join many α-glucose monomers together to form starch / glycogen;
2 *[Property & Function]* Which can be released upon hydrolysis of bonds as respiratory substrates;
3 *[Property & Function]* which also forms a large molecule so that the molecule is insoluble in water, for storage in large quanities without affect osmotic potential of cell.

4 *[Bonds]* α-1,4-glycosidic bonds forms a helical structure;
5 *[Property & Function]* which causes the molecule to be compacted for storage in large amounts in cell;

6 *[Bonds]* Hydroxyl groups of glucose residues project into the interior of the helices, leading to absence of hydrogen bonds with water
7 *[Property & Function]* causing starch / glycogen to be insoluble in water for storage in large quantities without affecting the osmotic potential of cells;

8 *[Bonds]* α-1,6-glycosidic bonds allows for amylopectin / glycogen to be highly branched;
9 *[Property & Function]* thus allowing many enzymes to act on it at the same time, enabling quick release of glucose (for an increased rate of respiration);

Carbohydrates – Cellulose



10 *[Bonds]* β-1,4 Glycosidic bonds (are strong covalent bonds) join many β-glucose monomers together to form long chains of celluolose;

11 *[Property & Function]* This also forms a macromolecule/polymer/large molecule so that it is insoluble in water;

12 Ideal as a building material for plant cell wall

[Bonds]

13 *Hydrogen bonds / cross links between hydroxyl groups of adjacent chains

14 prevent the hydroxyl groups from forming hydrogen bonds with water

[Property & Function]

15 Allows for formation of microfibrils

16 ref. cellulose having high tensile strength / insoluble in water;

17 To help prevent cells from bursting / maintain shape of cell / allows for cell turgidity in solutions with higher water potential.

[Total: 10 m]

Core Idea 1: The Cell and Biomolecules of Life

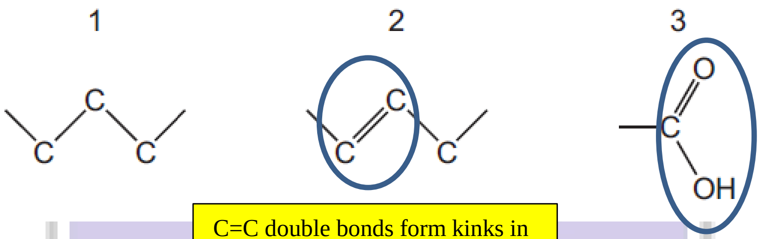
Biomolecules - Lipids

MCQ
ANSWERS

1	**2**	**3**	**4**
A	**A**	**A**	**D**

1 The diagrams show some of the type of bonds in fatty acids.

General formula of fatty acid is RCOOH where R is the hydrocarbon chain



Carboxyl group found at one end in the structural formula of fatty acids.

C=C double bonds form kinks in unsaturated fatty acids

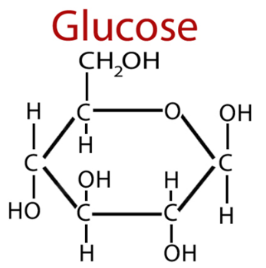
Which row shows the bonds found in each type of molecule?

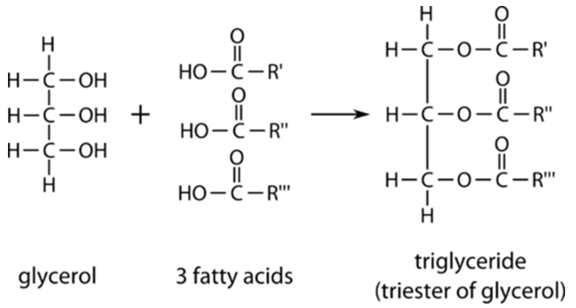
	unsaturated fatty acid	saturated fatty acid
A	1, 2 and 3	1 and 3 only
B	1, 2 and 3	2 and 3 only
C	1 and 3 only	1, 2 and 3
D	2 and 3 only	1, 2 and 3

2 The table shows some differences between glucose and a triglyceride. Which difference explains the fact that glucose is soluble in water, while the triglyceride is insoluble in water?

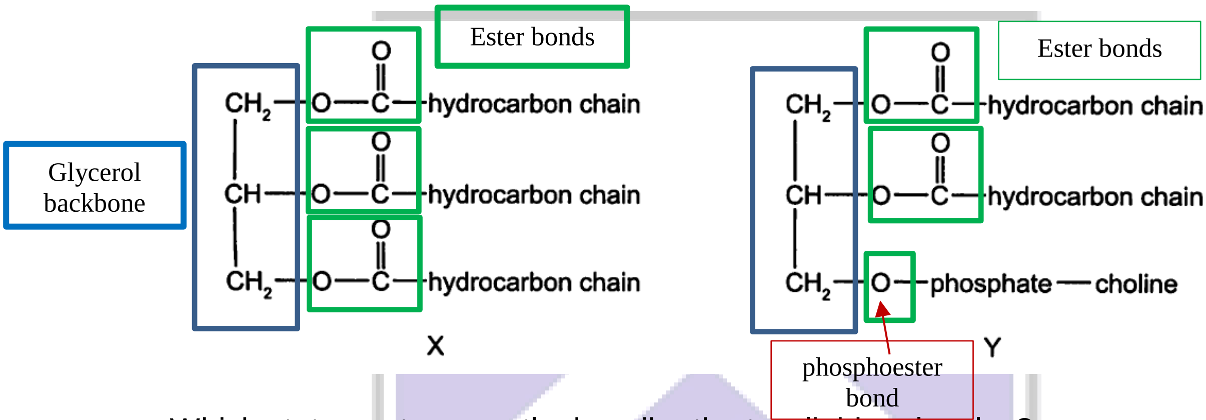
Has to contain polar groups

Difference	Glucose	Triglyceride
A	Contains polar groups (due to presence of many –OH groups)	Does not contains polar groups
B	Does not contains double bonds (having double bonds or not do not explain solubility in water)	contains double bonds
C	Higher ratio of carbon: hydrogen (this ratio whether high or low do not explain solubility in water)	Lower ratio of carbon: hydrogen
D	Occurs in a ring form (this merely state the structural arrangement, does not explain solubility in water)	Does not occurs in a ring form





3 The diagram shows the structure of two lipid molecules.



Which statements correctly describe the two lipid molecules?

1 Both molecules are esters of glycerol. (True, ester is a compound produced by the reaction between an acid and an alcohol)

2 Both the molecules are made by condensation reactions. (True, X is condensation of one glycerol molecule and three fatty acids while Y is condensation reaction of one glycerol molecule, two fatty acids and one phosphoric acid -phosphate-containing group)

3 The hydrocarbon chains of both molecules are always from saturated fatty acids. (False, can be either saturated or unsaturated fatty acids)

4 Both molecules are able to form hydrogen bonds with water. (False, only Y can form hydrogen bonds with water, due to the presence of the phosphate group which is polar and hydrophilic)

5 The hydrocarbon chains of both molecules are always the same length. (False, can be of differing lengths)

A 1 and 2
B 1, 2 and 4
C 2, 3, and 4
D 3, 4, and 5

4 Cows and whales are mammals that produce milk to feed their babies. Newborn whales grow faster than newborn cows. The milk of both cows and whales contains saturated fatty acids with different chain lengths.

Implied newborn whales need more energy to grow

The table shows the percentage of saturated fatty acids of different lengths in cow and whale milk.

When given a table, try to understand and interpret the data to deduce conclusion.

chain length of saturated fatty acid / number of carbon atoms	percentage of saturated fatty acids in milk	
	cow	whale
4 – 12	22.2	0
14	10.6	13.8
16	25.5	27.9
18	40.1	29.4
>18	1.6	28.9

Cows have saturated fatty acid of between 4 -12 C atoms in its hydrocarbon chain but whales have none.

Whale has higher percentage of saturated fatty acids of more than 18 C atoms in its hydrocarbon chain compared to cow

Ratio in cows
= (22.2+10.6+25.5) / (40.1+1.6)
= 1.40
Implies that cow has higher percentage of fatty acids with short hydrocarbon chains

Ratio in whales
= (0+13.8+27.9) / (29.4+28.9)
= 0.715
Implies that whale has lower percentage of fatty acids with short hydrogen carbon chains

Which statement about the ratio of short fatty acids (4–16 carbons) to long fatty acids (18 or more carbons) in the milk of cows and whales is correct?

A The ratio in cow milk is $\boxed{\text{higher}}$ because young cows need more energy than young whales. ➔ not true, question stem says whales grow faster, hence should need more energy than cows

B The ratio in cow milk is $\boxed{\text{lower}}$ because young cows need less energy than young whales. ➔ not true as ratio in cow milk is higher

C The ratio in whale milk is $\boxed{\text{higher}}$ because young whales need less energy than young cows. ➔ not true that young whales need less energy based on clues in question stem.

D The ratio in whale milk is $\boxed{\text{lower}}$ because young whales need more energy than young cows. ➔ ratio of 0 to 28.9 in whale milk compared to ratio of 22.2 to 1.6 in cow milk (based on info from table) is lower in whale milk and because young whales grow faster than young cows (as given in question stem), young whales need more energy for faster growth.

For compare, contrast or difference- type of questions, answer must have point by point comparison.

STQ
QUESTION 1

(a) Describe how a saturated fatty acid differs in structure from an unsaturated fatty acid.
…………………………………………………………………………………………………....[2]

3 absence of a C=C double bond in the hydrocarbon chain of fatty acid in saturated fatty acid but presence of a C=C double bond (in the hydrocarbon chain of fatty acid) in unsaturated fatty acid.

4 saturated fatty acid has more hydrogen / is saturated with hydrogen while unsaturated fatty acid has less hydrogen

(b) Explain why triglycerides are not considered to be polymers.
……………………………………………………………………………………………........[1]

1 not made of many repeating monomers/units.

(c) Explain the differences in solubility in water between triglycerides and the products of their hydrolysis.
……………………………………………………………………………………………….[3]

1 [State the Difference] Triglycerides are insoluble in water; (products of triglyceride's hydrolysis yield glycerol and fatty acids), glycerol is soluble in water while fatty acids are insoluble in water.

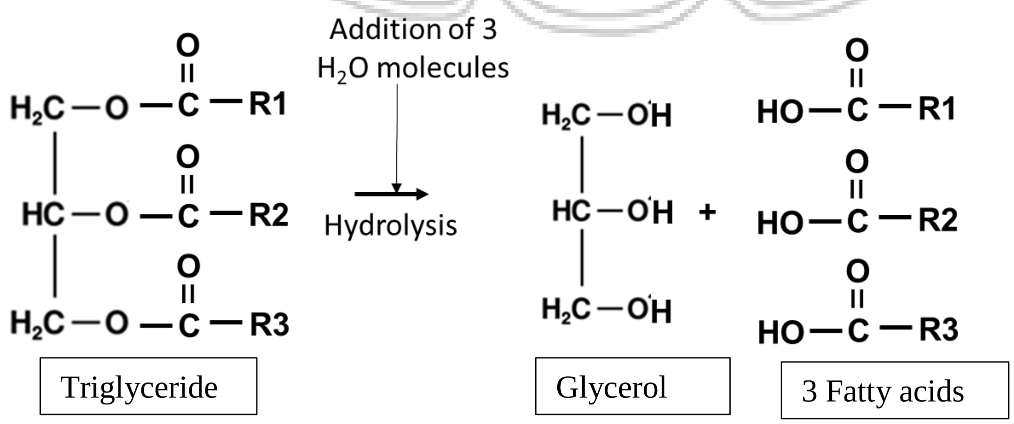
[Explain]

2 Triglycerides consist mostly of non-polar hydrocarbons, which are unable to interact with water (polar solvent) via hydrogen bonds. They are thus insoluble in water.

(The products of triglyceride hydrolysis are glycerol and fatty acids)

3 Glycerol is soluble in water as its polar –OH groups can interact with water (polar solvent) via hydrogen bonds;
Fatty acids are insoluble in water as their long hydrocarbon chains are unable to interact with water (polar solvent) via hydrogen bonds.

(d) Draw an annotated diagram to show the hydrolysis of a triglyceride. ➔ need to include the addition of water and the products formed
………………………………………………………………………………………………….[3]



[Total: 9]

QUESTION 2

Fig. 2.1 shows the structure of a type of phospholipid known as phosphatidylcholine.

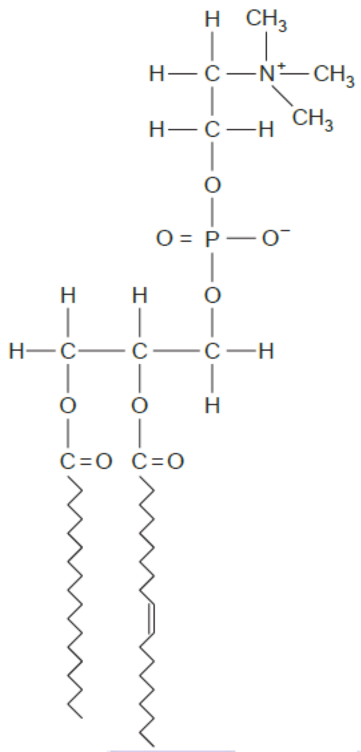


Fig. 2.1

(a) Contrast the structure of the phosphatidylcholine in Fig. 2.1 with the structure of a triglyceride molecule.

…………………………………………………………………………………………………[2]

1 Apart from the hydrocarbon tails, phosphatidylcholine has phosphate group/phosphate and choline attached to glycerol, while triglyceride does not have any other group attached to glycerol;

2 Phosphatidylcholine has 2 hydrocarbon tails while triglyceride has 3;

3 Phosphatidylcholine has 2 ester bonds and 1 phosphoester bond while triglyceride has 3 ester bonds.

(b) Plants use both lipids and carbohydrates for energy storage. Explain how the structure of triglycerides make them more suitable for energy storage than starch.

…………………………………………………………………………………………………[2]

1 Long hydrocarbon tails has many C-H bonds / more H than O per gram compared to carbohydrates;

2 ref. compact energy store, as more/twice as much energy released per unit mass;

(c) Phospholipase is an enzyme that can break down phospholipids, and it is found in bee venom. Suggest how bee venom destroys cells.

…………………………………………………………………………………………………[2]

1 Phospholipid bilayer makes up the cell surface membrane of cells;

2 Phospholipase catalyses the hydrolysis of ester linkages in phospholipids;

3 Breaking down of phospholipids disrupt the bilayer, hence cells rupture/lyse;

[Total: 6]

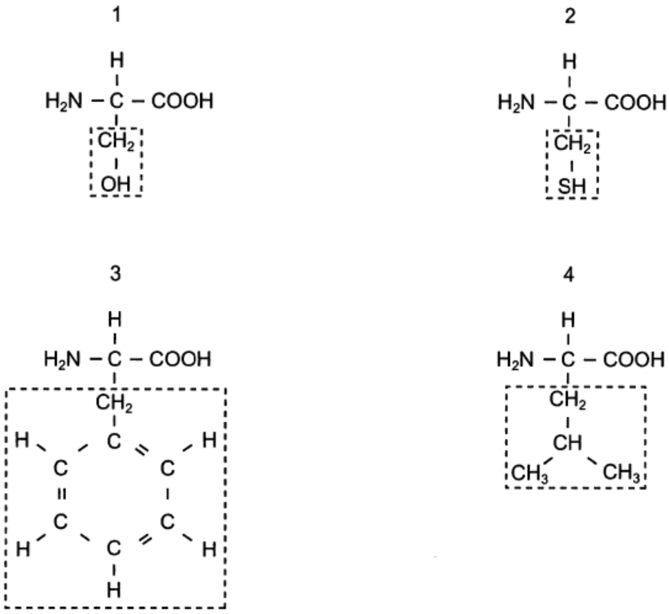
Core Idea 1: The Cell and Biomolecules of Life
Biomolecules
Proteins

MCQ

ANSWERS

1	2	3	4	5	6
D	C	B	B	B	D

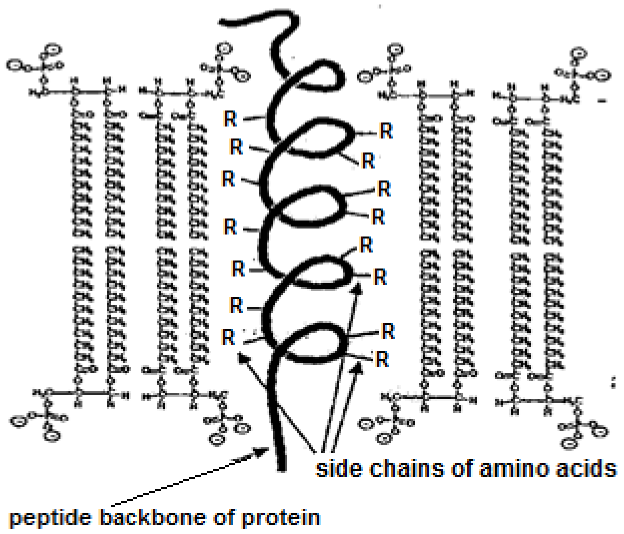
1 The diagram shows four different amino acids, each with a different R group (side chain).



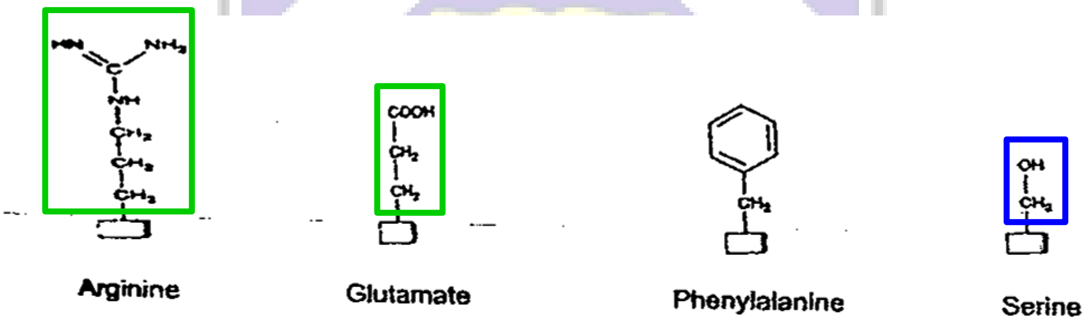
Which amino acids could form a hydrophobic interaction between their R groups?
Amino acids 3 and 4 have non-polar R groups, hence they will form hydrophobic interactions with each other. R groups of 1 and 2 are polar (due to –OH and –SH), and will form hydrogen bonds.

A 1 and 2
B 1 and 3
C 2 and 4
D 3 and 4

2



With reference to the figure above, which one of the following amino acids, with only the side chains indicated, is likely to be found at any of the positions protruding from the peptide backbone of the protein?

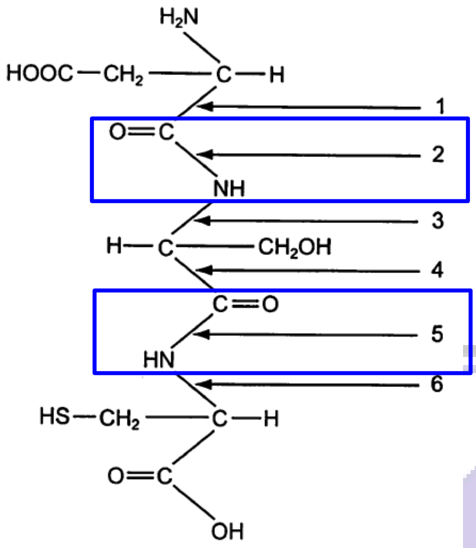


A Arginine
B Glutamate
C Phenylalanine
D Serine

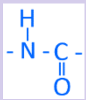
The positions protruding from the peptide backbone (R groups of amino acids) of the protein are in contact with the hydrophobic fatty acid tail/chain of phospholipid molecules in the phospholipid bilayer. Only a non-polar amino acid on the surface of the protein will be able to interact with the hydrophobic fatty acid tail/chain of phospholipid molecules in the bilayer via hydrophobic interactions.

Arginine and glutamate are charged amino acids (green) while serine is a polar amino acid (blue). The hydrophilic R groups of these amino acids are unable to interact with the hydrophobic core of the phospholipid bilayer.

3 The diagram represents a tripeptide.

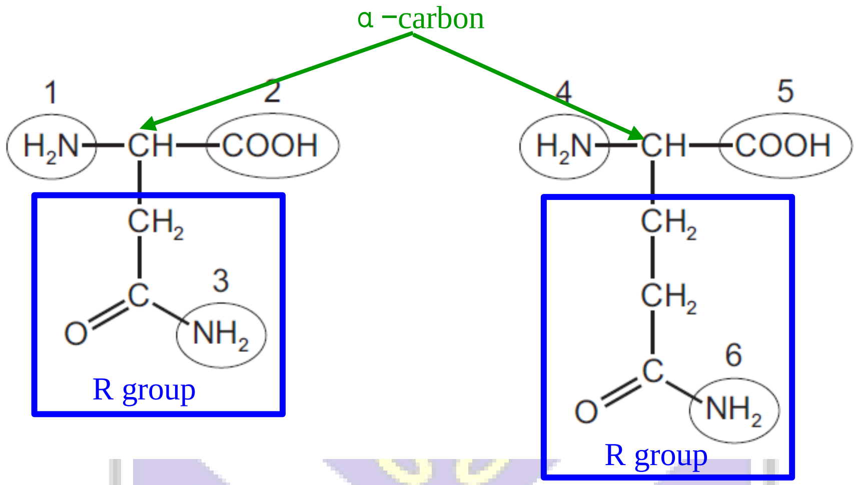


At which bonds does hydrolysis occur to release the amino acids from the tripeptide?

The peptide  bond is

A 1 and 4
B 2 and 5
C 2 and 6
D 3 and 6

4 The diagrams show the structures of two amino acids, each of which has two amino (–NH_2) groups.



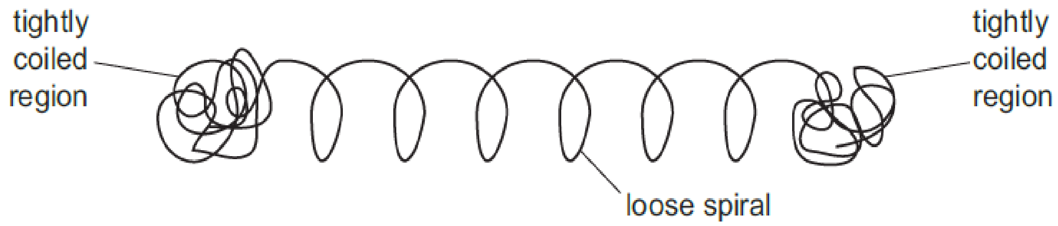
A peptide bond is formed between the two amino acids.

Which groups form the peptide bond?

Peptide bond is formed between the –NH_2 group of one amino acid and the –COOH group of another amino acid (neither can be a part of the R group). 3 and 6 are part of an R group, hence they cannot form peptide bonds. Therefore, only 1 and 5 OR 2 and 4 can form peptide bonds with each other.

A 1 and 4
B 1 and 5
C 2 and 6
D 3 and 5

5 The protein glutenin gives bread dough its elasticity. The diagram represents a polypeptide of glutenin.



What describes the structure of glutenin?

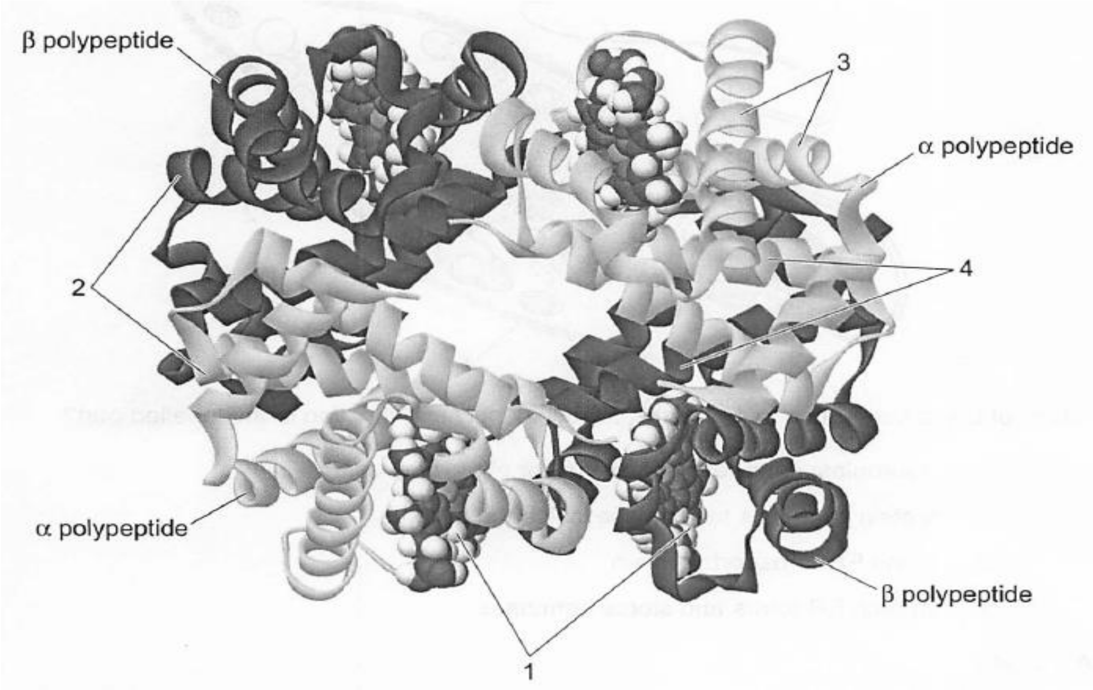
A secondary structure because the loose spiral is an α-helix (This answer ignored the tightly coiled region, which is tertiary structure.)

B tertiary structure because the different regions form a 3D shape

C quaternary structure because there are both globular and fibrous regions (diagram shows only one polypeptide, hence glutenin is not quaternary structure as quaternary structure requires more than one polypeptide chain to be associated together to form a protein. 'Globular' and 'fibrous' just refers to two different types of proteins.)

D quaternary structure because there are both spiral and tightly coiled regions ('spiral' is secondary structure while 'tightly coiled regions' is tertiary structure.)

6 The diagram shows a haemoglobin molecule.



Which identifies the different parts of the molecule?

	1	2	3	4
A	alpha helix	beta pleated sheet	binding site	hydrophobic amino acids
B	hydrophobic amino acids	beta pleated sheet	prosthetic group	binding site
C	prosthetic group	hydrophobic amino acids	alpha helix	hydrophilic amino acids
D	prosthetic group	hydrophilic amino acids	alpha helix	hydrophobic amino acids

2 is facing the aqueous medium, hence comprises of amino acids with polar/hydrophilic R groups. 4 is buried in the interior of the protein, and comprises of amino acids with non-polar hydrophobic R groups.

Note: 'α-polypeptide' (also called 'α-chain' in lecture notes, refers to the name of the polypeptide) is not the same as 'α-helix' (refers to a type of secondary structure)

Recall: haemoglobin consists of four polypeptide chains: two α-chains (light grey) and two β–chains (dark grey)

STQ

QUESTION 1

[SAJC/2010/JC1/MSA1] Pancreatic lipase is an enzyme produced by the pancreas which hydrolyzes fats. It consists of one polypeptide made up of 469 amino acids. The polypeptide has α-helices and β-pleated sheets. The active site of this enzyme consists of three non-polar amino acids. Fig. 1.1 shows the structure of pancreatic lipase.

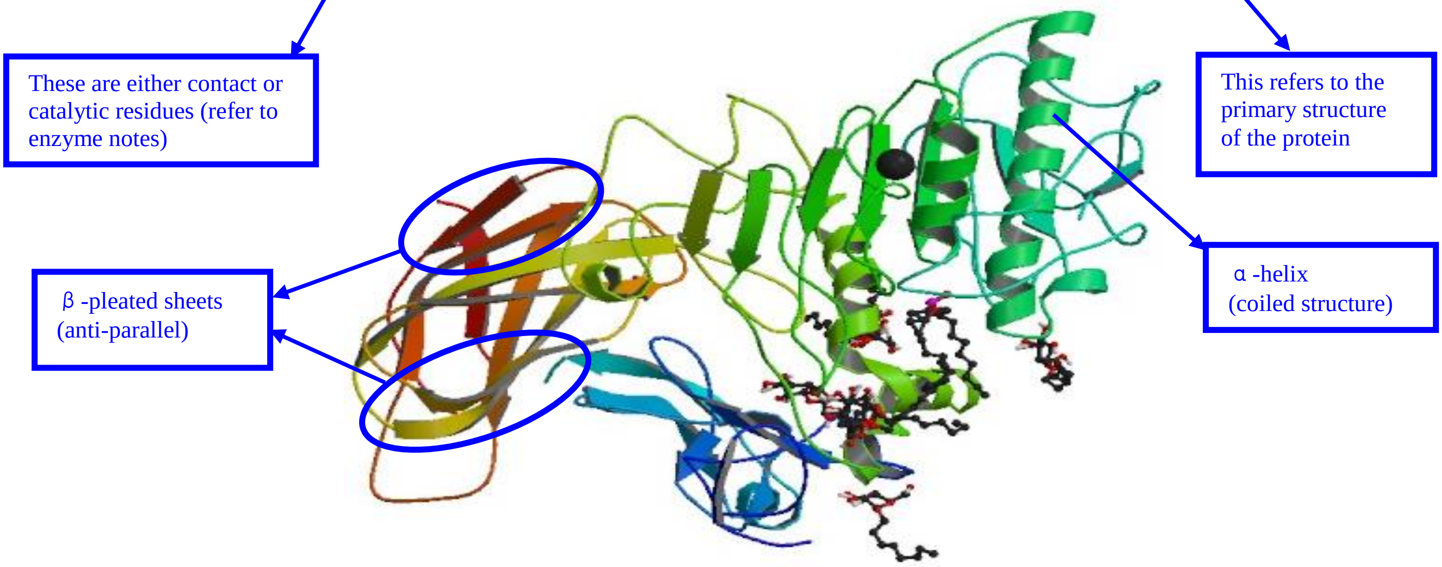


Fig. 1.1

(a) Explain the molecular structure of pancreatic lipase with respect to the different levels of protein folding**.**

……………………………………………………………………………………………[5]

Different levels of protein folding refers to primary, secondary, tertiary and quaternary (not applicable for this question) structure of a protein.

Primary structure

1 Refers to the number, type and sequence of amino acids in a linear polypeptide chain;
The **469 amino acid residues** are linked by peptide bonds ;

Secondary structure

2 Refers to the folding of the polypeptide chain into regular structures such as **α helices and β pleated sheets** ;
Stabilized by hydrogen bonds formed between peptide bonds in the same chain (between –CO group of one amino acid and –NH group of another amino acid);

Tertiary structure

3 Refers to the folding of the polypeptide chain into its unique 3-dimensional (globular) conformation
Maintained by hydrophobic interactions, hydrogen bonds, ionic bonds and disulfide bonds between R groups of amino acid residues in the same polypeptide chain ;

4 Non-polar / hydrophobic amino acids are buried in the interior AND polar and charged amino acids are on the surface on the protein ; OWTTE

5 The 3 non-polar amino acids far apart from each other in the linear sequence are **brought into close proximity at the active site** ;

REJECT references to quaternary structure as pancreatic lipase is a monomeric protein.

(b) Analysis shows that the two protein samples of pancreatic lipase, one isolated from mice and the other from rabbits, have identical amino acid composition. Explain whether this is sufficient to conclude that the two protein samples are identical.

……………………………………………………………………………………………………[2]

'Identical amino acid composition' just means that the two proteins have the same number of the different types of amino acid residues (e.g. both have 30 glycines, 20 alanines, 15 glutamates etc.)

Illustration: The two polypeptide sequences below have the same amino acid composition, but the amino acid sequence is different.

Sequence 1: Gly-Ala-Trp-Gly-Phe
Sequence 2: Ala-Trp-Gly-Phe-Gly

Hence, they are different proteins (and most likely have different functions).

1 Insufficient;

2 Sequence of amino acids in the linear polypeptide chain may be different / different primary structure ;
Resulting in different secondary, tertiary (and quaternary structures) of the protein ;

Teachers' comments

The primary sequence of a polypeptide chain determines the secondary and thus tertiary structures of the protein.

However, it is possible for enzymes with different primary, secondary, tertiary and quaternary structures to have the same biological function (i.e. to catalyse the breakdown of lipids) if both enzymes have the same 3D arrangement of contact and catalytic amino acid residues at their respective active sites. (It is, however, unlikely in nature that these two enzymes will have identical amino acid compositions. i.e. the scenario described in 2(b) is theoretical only.)

[Total : 7]

Class Activity 2 – Error Editing

Correct errors (if any) in the following statements:

1. The base substitution in the enzyme haemoglobin cause a change in the active site so that oxygen could no longer be carried.

   The base substitution in the protein haemoglobin cause a change in the **binding site** so that oxygen could no longer be carried.

2. Haemoglobin is soluble in blood hence it can transport oxygen to all parts of the body.

   Haemoglobin is soluble in **aqueous medium (cytoplasm of red blood cell)** hence it can transport oxygen to all parts of the body.

3. Haemoglobin's α and β subunits consists of both α-helix and β-pleated sheet.

   Haemoglobin's α and β subunits consists of **only** α-helix and **no** β-pleated sheet.

QUESTION 2

First paragraph is quite irrelevant to the question

Transglutaminase (TGase) secreted by *Streptomyces mobaraense* is a valuable enzyme for the food industry. TGase, better known to chefs as "meat glue", has the ability to bond protein-containing foods together. Some of its uses include the production of restructured meat and the hardening of fish protein paste.

TGase consists of 331 amino acids, including only one cysteine residue. The three amino acid residues at the catalytic site are cysteine 64, aspartate 255 and histidine 274, where the numbers denote the positions of the amino acids in the amino acid sequence of TGase. Fig. 2.1 shows the structure of TGase.

Not present in haemoglobin

Primary structure. Hints that TGase consists of only one polypeptide chain ➔ no quaternary structure

Far apart in linear structure, but brought into close proximity at active site due to folding of polypeptide into tertiary structure

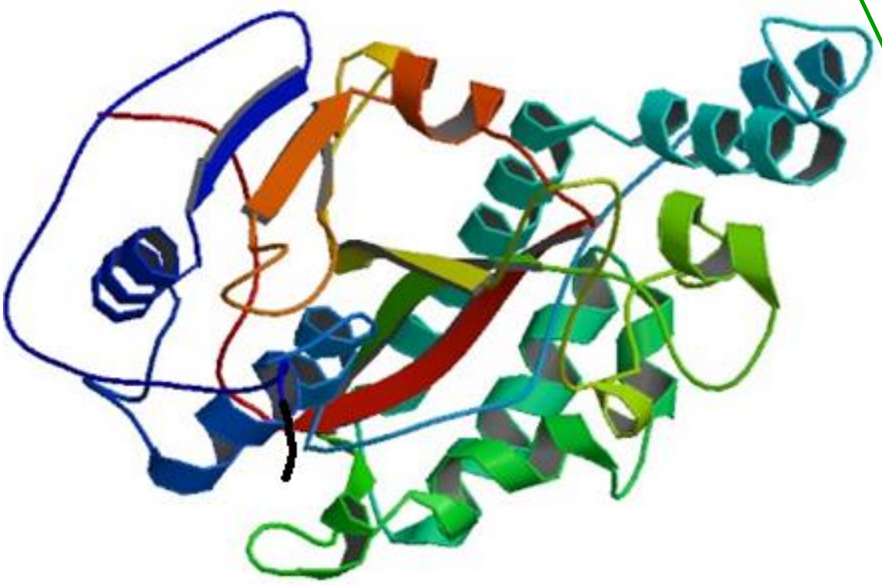


Fig. 2.1

(a) With reference to Fig. 2.1 and your knowledge of haemoglobin, state **three** structural differences between TGase and haemoglobin.

………………………………………………………………………………………………[3]

Need to (1) extract important information in question stem and (2) examine the structure of TGase (Fig. 2.1) carefully to identify structural differences between TGase and haemoglobin.

Feature	TGase	Haemoglobin
1. type of secondary structure presnt	1. Consist of α-helices and β-pleated sheets	Consist of only α-helices;
2. Levels of protein structure	2. Consists of primary, secondary and tertiary structure/ No quaternary structure	Consists of primary, secondary, tertiary and quaternary structure/ quaternary structure is present;
3. No. of polypeptide chain	3. Consists of only one polypeptide chain/ No dimer	Consists of four polypeptide chains/ 2 identical dimers;
4. Presence of haem group	4. Does not carry a prosthetic/ haem group	Carries a prosthetic/ haem group containing Fe^{2+} ;

5. Presence of catalytic site	5. Consists of a catalytic site	Does not consist of catalytic site;
6. Presence of cysteine residue	6. Contains one cysteine residue	Does not contain any cysteine residues

[Any 3 pairs]

Haemoglobin and hemocyanins are hemeproteins whose physiological importance is principally related to their ability to bind molecular oxygen.

Hemocyanins is a hexameric metalloprotein (i.e. 6 protein subunits), with each subunit containing two copper atoms. Hemocyanins has the ability to bind to oxygen and is found in horseshoe crab.

(b) State the level(s) of protein organization that hemocyanins has.

……………………………………………………………………………………………………[1]

1 Primary structure, secondary structure, tertiary structure **AND** quaternary structure

(c) With reference to the above information and your knowledge of haemoglobin, relate the structure of hemocyanins to its functions.

……………………………………………………………………………………………………[4]

1 Consists of **6 subunits**, each capable of binding to one oxygen molecule ;
Maximises the transport of oxygen within each hemocyanin molecule ;

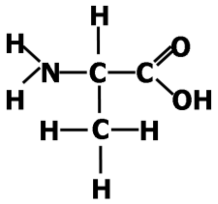
2 Hydrophobic amino acid residues are buried in the interior of the globular structure while the hydrophilic amino acid residues are on the exterior surface of the hemocyanin molecule ;
Soluble in an aqueous medium, aids in its transport of oxygen in blood ;

3 **Non-covalent (interchain) interactions** such as ionic bonds, hydrogen bonds and hydrophobic interactions are involved in the association of hexameric subunits ;
Cooperative binding of O_2 whereby slight changes in oxygen concentration can allow greater ease of loading / unloading oxygen ;

4 Presence of Cu^{2+} ions ;
Combines **reversibly** with oxygen and hence enhances the release of oxygen in metabolically active tissues.

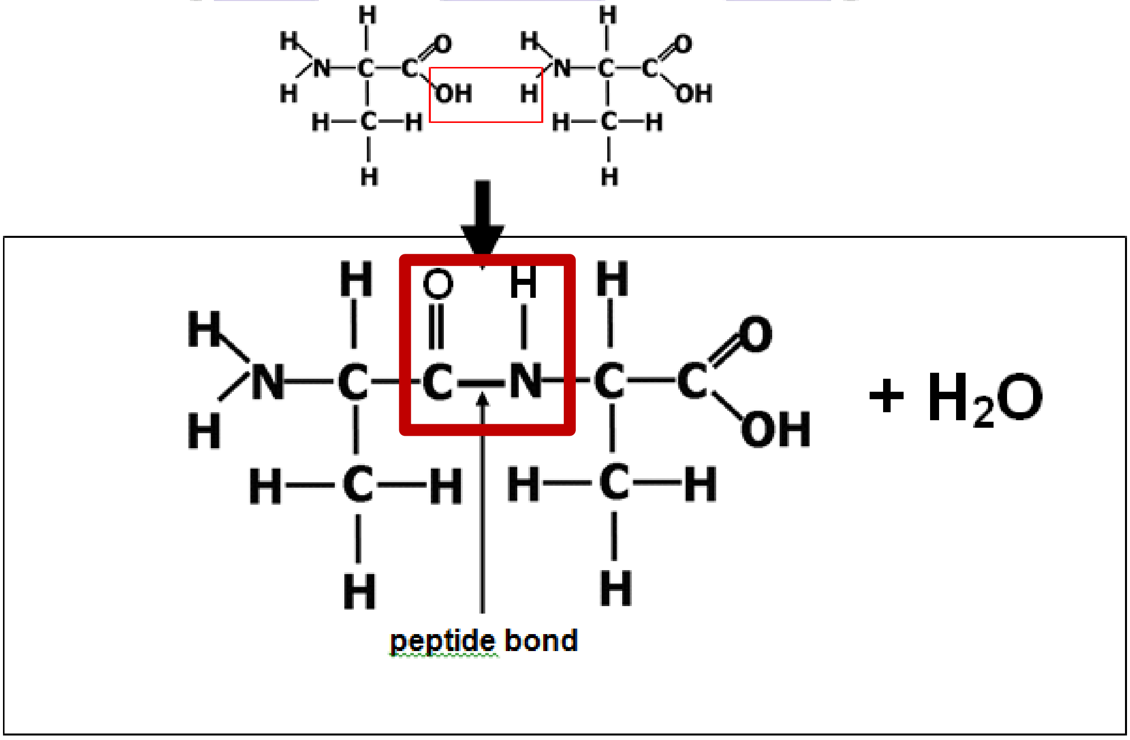
Marked Assignment

The diagram below shows the molecular structure of the amino acid alanine.



(a) Draw a ring around the group that distinguishes alanine from other amino acid.
……………………………………………………………………………………………………[1]

(b) Show how a dipeptide is formed from two alanine molecules.
……………………………………………………………………………………………………[2]



2 Correct drawing of two alanine molecules (all atoms are clearly shown) ;
Correct drawing of the dipeptide ;
3 Clear labelling of the peptide bond ;
Removal of a water molecule ;

(c) Describe the chemical reaction involved in the formation of dipeptide.
……………………………………………………………………………………………………[2]

1 **Condensation** reaction between two adjacent amino acids ;
Release of 1 H_2O molecule in each condensation reaction ;

2 Covalent/peptide bond is formed between the –CO group of first amino acid and –NH group of adjacent amino acid ;;

(d) Explain the significance of the R groups of different amino acids to protein structure ………………………………………………………………..…………………...……..…[5]

About R-groups:

1 Different types of amino acids have different chemical properties of R groups ; e.g. polar, non-polar, charged / basic or acidic [**STATE** all] ;

About protein structure:

2 Sequence of the different amino acid residues in the primary structure ; Determines how the polypeptide chain coils and folds ;

3 Due to chemical **interactions between the different R groups** of the amino acids (to form higher levels of protein structure)

4 Allows the formation e.g. hydrogen bonds, ionic bonds, disulfide bonds and hydrophobic interactions [name any 2 types of bonds]

OR

- **hydrogen bonds** between polar R groups (of amino acid residues),
- **ionic bonds** between charged (acidic and basic) R groups (of amino acid residues),
- **disulfide bonds** between sulfhydryl (R) groups of cysteine residues and
- **hydrophobic interactions** between non-polar R groups (of amino acid residues).

Significance:

5 This determines the **specific 3D conformation** of the protein at the tertiary and quaternary levels ;

[Total : 10]