2018 Collated Biomolecules and Enzymes (DNA, Gene Expression)

2018 / H2 / AJC PRELIM / P2 Q1

1 Fig. 1.1 shows the effect of pH on the activity of a protease enzyme at the optimal temperature of 37°C.

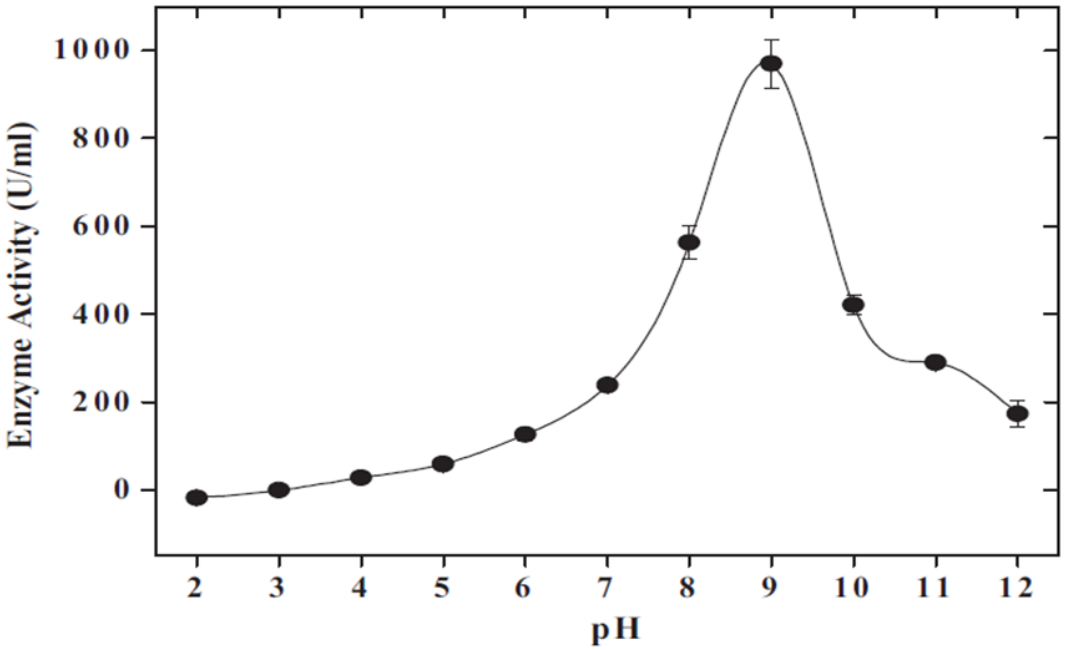

Fig. 1.1

(a) Draw, on Fig. 1.1, the approximate shape of the curve if the same experiment is conducted at 25°C.

Similar shape to Fig. 1.1 but lower than curve in Fig. 1.1; [1]

(b) Explain with reasons the shape of the curve you have drawn.

At lower temperature, lower kinetic energy of molecules;
Less effective collisions between enzyme and substrates, less enzyme-substrate complex formation per unit time / lower rate of enzyme-substrate complex formation; [2]

(c) Using information from the graph, explain why proteases stored in vesicles with pH 7.2 cannot break down vesicular membrane proteins and suggest how these proteases can be activated through increase in pH.

(At least one)
- With low activity of just 200 U/ml, enzyme is inactive at pH 7.2;
- Optimal enzyme activity of 900 U/ml (accept reasonable figure quoted, correct units quoted) is highest at pH 9;

At pH 9 (accept argument at pH 7.2):
- charges on acidic and basic R-groups altered;
- Contact and catalytic residues has the correct charge to catalyse the reaction at pH 9 (accept converse);
- R-group interactions such as ionic and hydrogen bonds are altered;
- Tertiary structure / 3D conformation / configuration of enzyme is that of an active enzyme;
- Active site shape is complementary to shape of substrate;
- Maximum rate of enzyme-substrate complex formation;

[max 4m]

(At least one)
- pH can be increased to optimum pH by pumping of H^+ ions out of the vesicles
- Vesicle membrane has proton pumps;

[6]

[Total: 9]

2018 / H2 / EJC PRELIM / P2 Q1 (Cancer Eukaryotic Cell Structure)

2 The synthesis of collagen is shown in Fig. 1.1.

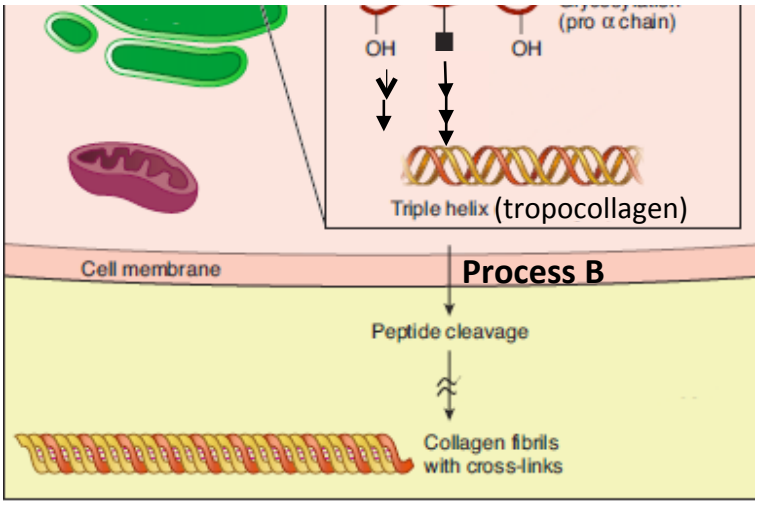

Fig. 1.1

(a) **(i)** Describe two important functions of structure **A** in the synthesis of collagen.

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.....

.....[2]

Structure A is the nuclear pore;

1. **Allows mature mRNA to leave nucleus and enter cytosol for translation into collagen by ribosom**
2. **Allows RNA polymerase/ ribonucleotides to enter nucleus to synthesise mRNA/tRNA dur transcription of collagen gene;**
3. **Allows exit of mRNA to ribosomes to be translated;**
4. **Allows tRNA to leave nucleus for amino acid activation/ amino acid attachment for use translation during collagen synthesis;**

(any 2)

(ii) Tropocollagen leaves the cell to be assembled to form collagen fibrils via **Process B**. Out **Process B**.

……

……

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……

……

……[3]

1. **Process B is exocytosis;**
2. **Secretory vesicle containing tropocollagen is transported to cell surface membrane a fuses with the cell surface membrane to release tropocollagen extracellularly;**
3. **This process requires ATP;**

(b) Suggest how chemical modification such as hydroxylation in organelle **C** results in collagen havin high tensile strength.

……

……

……

……[2]

1. **Hydroxylation is the process where hydroxyl groups are added/ attached/ joined to polypeptide chain;**
2. **To enable formation of numerous interchain hydrogen bonds during the formation tropocollagen triple helix, giving rise to high tensile strength;**

Fig. 1.2 shows two electron micrographs. One of the electron micrograph shows part of a normal cell while other electron micrograph shows part of a cancer cell. The white arrows point to an organelle within the c The appearance of this organelle in both cell types were visibly different. The cancer cell had a higher acti than the normal cell.

Organelle (indicated by white arrows) in a normal cell

Organelle (indicated by white arrows) in a cancer cell

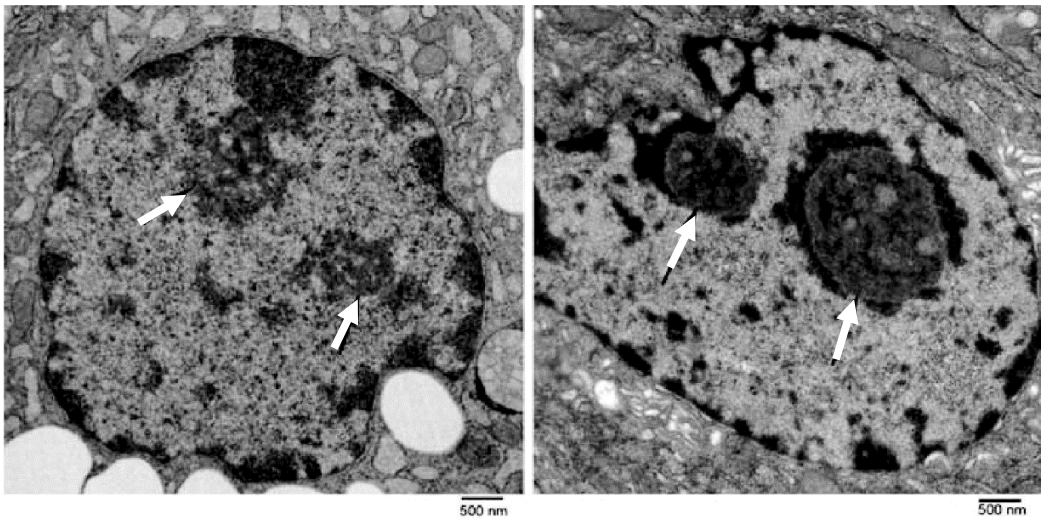

Fig. 1.2

(c) **(i)** Describe the visible difference between the organelle indicated by the white arrows in Fig. between the cancer cell and the normal cell.

……

……[1]

1. **Nucleoli in the cancer cell were denser/darker/more darkly stained and larger;**

(ii) Account for the higher activity of the cancer cell.

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……

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……[2]

1. **Nucleoli are the sites for rRNA synthesis which are key components of ribosomes requi for translation;**
2. **Larger and denser nucleoli in cancer cells due to increased rRNA enable cancer cell achieve higher rates of protein synthesis to enable excessive proliferation/growth;**

[Total:

2018 / H2 / EJC PRELIM / P2 Q2

3 The rate of glycolysis is regulated by the action of ATP on the enzyme phosphofructokinase (PFK), the third enzyme in the glycolysis pathway. PFK catalyzes the formation of fructose 1,6-bisphosphate from fructose-6-phosphate and ATP.

A graph of PFK against F6P concentration would exhibit the 'sigmoidal curve' typical of allosteric enzymes.

Fig. 2.1 shows the effect of substrate F6P (fructose 6-phosphate) concentration on the activity of PFK at different ATP concentrations. PFK is an allosteric enzyme with a quaternary structure that is inhibited by high levels of ATP. High levels of ADP and AMP will increase activity of the enzyme.

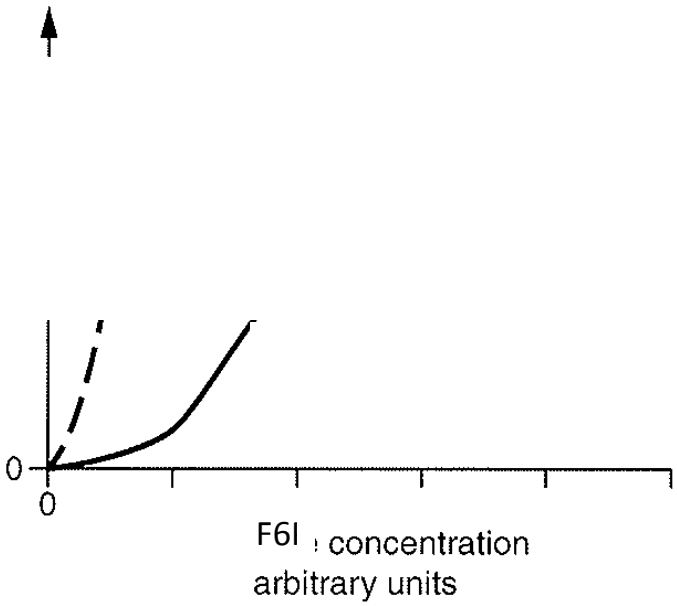

Fig. 2.1

(a) **(i)** With reference to PFK, explain the term '*allosteric enzyme*'.

.....

.....[1]

5. PFK is an enzyme that has more than 1 subunits/ multimeric/ 4 subunits
6. with the allosteric site where AMP/ADP/ATP can bind to;
Reject references to 'site other than active site'

(ii) On Fig. 2.1, label the graphs which reflect low ATP and high ATP concentrations respectively.
[1]

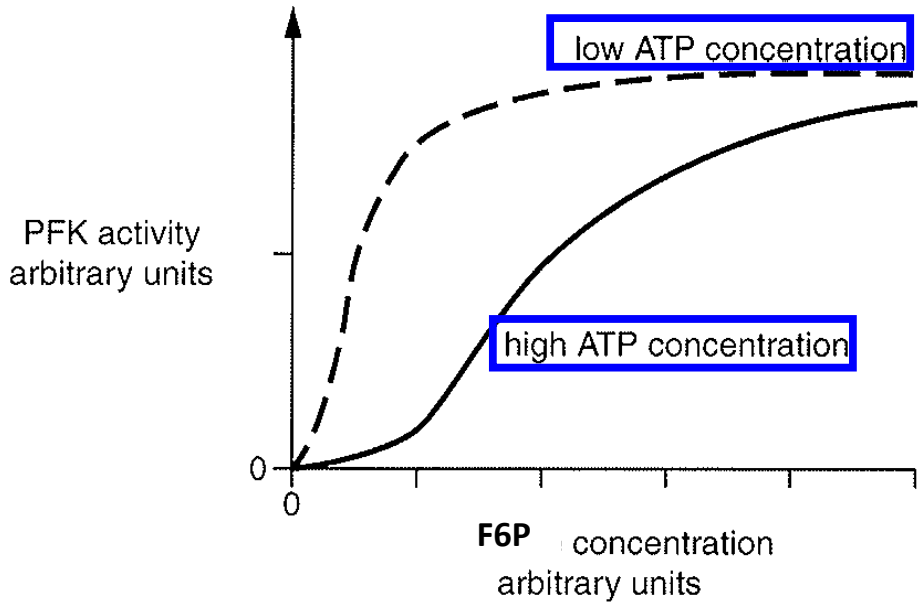

Fig.2.1

All or none;

(b) Enzyme researchers have used a model of allosteric enzyme mechanism called the 'symmetry model' to explain the action of PFK. F6P binds with great affinity only to the active state but not to the inactive state. Binding of one F6P molecule will progressively shift PFK structure from the inactive state to the active state.

A graph of PFK against F6P concentration would exhibit the 'sigmoidal curve' typical of allosteric enzymes.

(i) Explain how the binding of a molecule like AMP to PFK can increase the activity of PFK.

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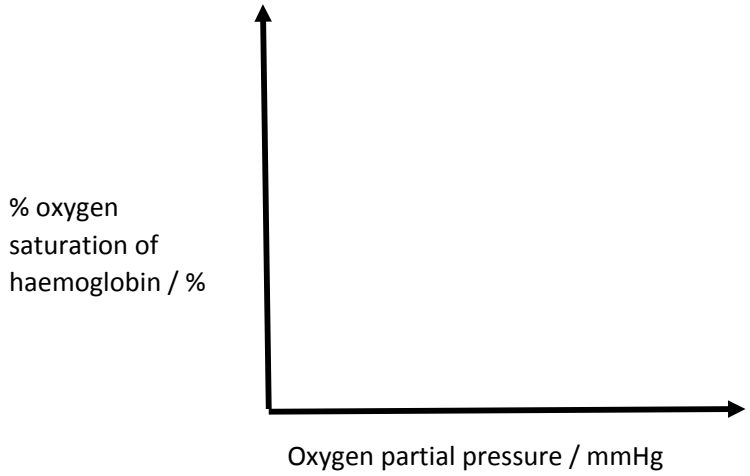
.....

.....[2]

1. **Binding of AMP to allosteric site of PFK will induce conformation change in PFK from inactive to active state;**
2. **Conformation change will help to stabilize the active state of PFK / and will lead to the active site being made more complementary to F6P;**

(ii) The enzymatic mechanism in PFK is similar to that of the oxygen-binding mechanism of the transport protein, haemoglobin. Sketch the shape of the oxygen binding graph for haemoglobin at increasing concentrations of oxygen in the space below. [1]



S-shaped curve starting from origin (gentle slope followed by steep curve, followed by gentle slope)

(iii) Using your knowledge of the structure of haemoglobin, explain the shape of the graph you drew in **(b) (ii)**.

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……..

……..[3]

1. **Cooperative binding of oxygen - Binding of one oxygen molecule to one haemoglobin subunit induces a structural / conformational change in the other 3 subunits;**

2. **This leads to an increase in their affinity for oxygen, thus lead to rapid loading of the other 3 oxygen molecules / steep increase in % oxygen saturation of haemoglobin;**

3. **Gentle slope/plateau of graph at the end reflects saturation of the haemoglobin binding sites in the haemoglobin molecules present;**

(c) Explain the significance of regulation of PFK by ATP to AMP ratios.

……...

……...

……...

……..[2]

1. **High glycolysis rates lead to high respiratory rates, producing high levels of ATP, therefore high ATP:AMP can inhibit PFK to slow glycolysis because there is sufficient levels of ATP in the cell;**
2. **till these ATP are depleted to low ATP:AMP levels where PFK is activated to increase glycolysis/respiration rate to increase levels of ATP;**
3. **This reduces the need for glycolysis to be at constantly high rates, leading to efficient use of resources in the cell (e.g. ADP, ATP, glucose and pyruvate etc).;**

(Any 2)

2018 / H2 / JJC PRELIM / P2 Q2

4 Fig. 2.1 shows a triglyceride molecule.

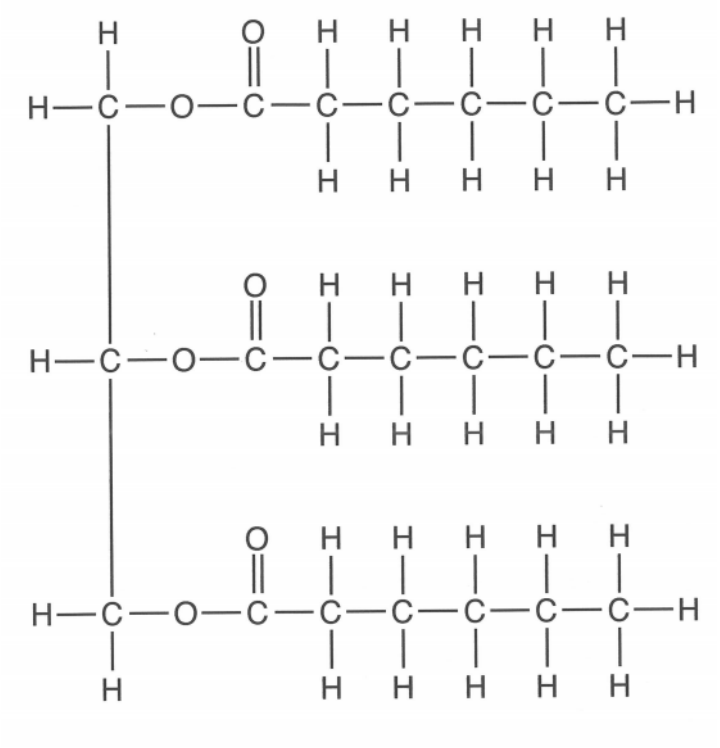


Fig. 2.1

(a) (i) State the names of the two types of molecules that undergo condensation reactions to form a triglyceride. [2]

1. **glycerol ;**
2. **fatty acid ;**

(ii) Describe what is meant by a condensation reaction. [2]

1. **A condensation reaction takes place between the –OH group and –COOH group ;**
2. **involves the removal of (one) water molecule ;**
   A: Three condensation reaction and removal of three water molecules

(iii) The triglyceride in Fig. 2.1 is saturated.

Explain how the structure would be different for an unsaturated triglyceride. [3]

1. **contains the lesser number of hydrogen atoms ;**
2. **presence of carbon-carbon double covalent bond (C = C) ;**
3. **presence of kinks in the hydrocarbon chain ;**

(b) The eukaryotic cell surface membrane contains phospholipids, cholesterol and proteins.

(i) Describe how a phospholipid molecule differs from a triglyceride molecule. [2]

	Phospholipids	Triglycerides	
1	**1 glycerol, 2 fatty acids and 1 (-vely charged) phosphate group**	**1 glycerol and 3 fatty acids**	**;**
2	**2 ester bonds and a phosphoester bond**	**3 ester bonds**	**;**
3	**Phospholipid diversity is based on differences in the two fatty acids and in the groups attached to the phosphate group of the head.**	**Triglyceride diversity is based on differences in the three fatty acids.**	**;**
4	**Phospholipids are amphipathic in nature.**	**Triglycerides are non-polar in nature.**	**;**
5	**Phospholipids may associate covalently with carbohydrates to form glycolipids.**	**Triglycerides do not associate covalently with carbohydrates.**	**;**

*** A: fatty acid tails / hydrocarbon chains.**

(ii) Describe the roles of cholesterol in eukaryotic cell surface membranes. [2]

1. **increases the stability of membranes/decrease membrane fluidity, by restraining the movement of phospholipids, at (relatively) warm temperatures ;**
   or
2. **increases the flexibility of membranes/increase membrane fluidity, by hindering the close packing of phospholipids, at low temperatures ;**
   I: helps to reduce the tendency of membrane to 'freeze'/solidfy/breaking up (consequence)
3. **acts like a plug, reducing the escape / entry of charged ions/small polar molecules through the membrane ;**

(c) The respiratory quotient, RQ, is used to show which substrate is being metabolised by cells. It can be determined using the equation below.

$$RQ = \frac{\text{molecules of carbon dioxide released}}{\text{molecules of oxygen taken in}}$$

Lauric acid is a saturated fatty acid found in coconuts and has a chain of 12 carbon atoms.

(i) Complete the equation below which outlines the aerobic respiration of lauric acid. [1]

$C_{12}H_{24}O_2$ + ……. O_2 ➔ $12CO_2 + 12H_2O$

17 ;

(ii) Calculate the RQ value for lauric acid.

Give your answer to 2 decimal places.

allow ecf from (i) for one mark

RQ value = **0.71** [1]

[Total: 13]

2018 / H2 / PJC PRELIM / P2 Q1

5 Collagen is the main structural protein in the human body. It strengthens the tendons and supports the skin and internal organs. Fig.1.1 shows the organization of collagen fibres.

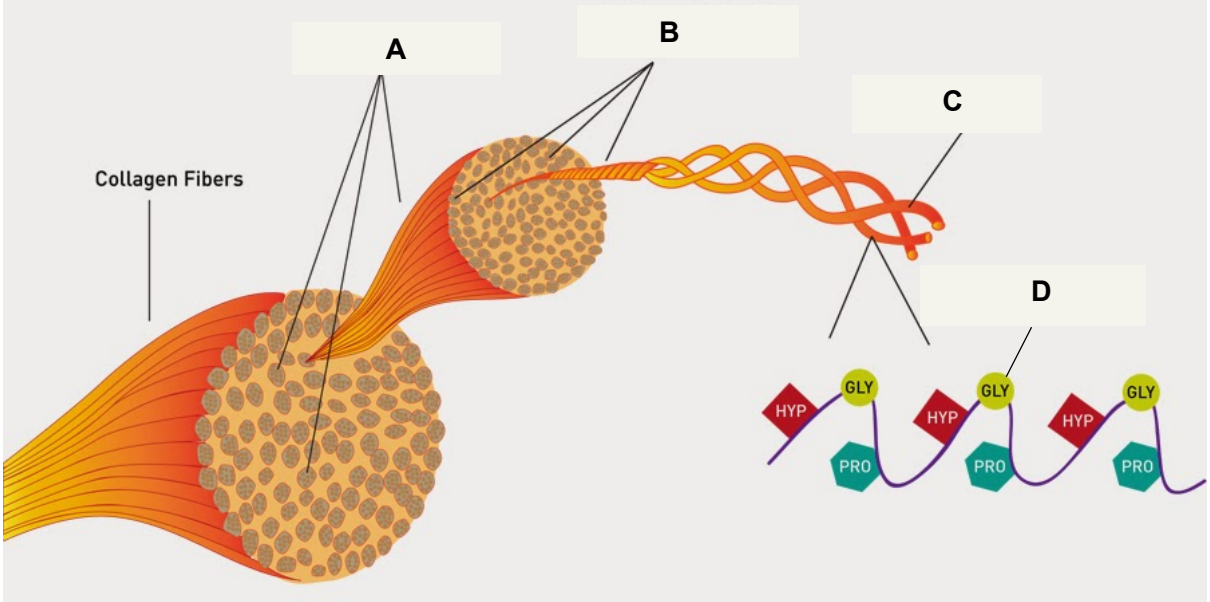


Fig. 1.1

(a) Label structures **A**, **B**, **C** and **D** in Fig. 1.1. [2]

A: Collagen fibrils;
B: Tropocollagen / Collagen triple helix;
C: Loose helical polypeptide chain;
D: Glycine;

(b) With reference to Fig. 1.1, describe the bonds involved in the formation of collagen which contribute to its high tensile strength. [2]

a. **Within 1 tropocollagen molecule numerous *hydrogen bonds** form between amino acids of adjacent polypeptide chains;;**
b. **covalent *cross-links** form between *lysine** residues at C and N ends of adjacent/parallel tropocollagen molecules;;**

Ignore if mention staggered arrangement

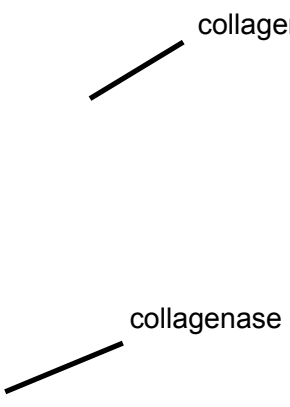
(c) Suggest why the assembly of collagen takes place outside the cell. [2]

a. **Cleaving of the ends of the tropocollagen before assembly into collagen fibres is performed by enzymes found only outside of the cell ;;**
b. **Collagen molecule is too large to pass through the cell surface membrane and has to be assembled outside the cell ;;**
c. **Assembly of collagen outside the cell allows alignment of microfibrils / formation of bonds between the microfibrils ;;**

Max 2

(d) Certain pathogenic bacteria such as *Clostridium histolyticum*, have collagenases which digests collagen tissue of their hosts, causing a form of tissue death known as gangrene.

The action of collagenase can be seen in Fig.1.2, illustrating the specificity of the active site in binding to a segment of collagen and eventually cleaving it into 2 segments.



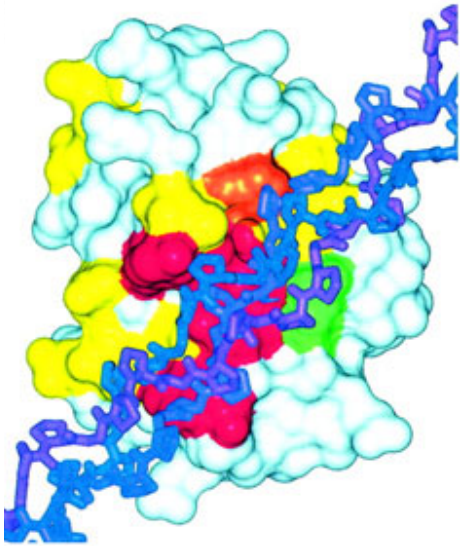


Fig. 1.2

(i) Explain the function of amino acid residues situated at the active site of collagenase. [2]

1. **Catalytic residues act on bonds in substrate and help to catalyse conversion of substrate to product;;**
2. **Amino acids in collagenase have specific *R groups** which facilitates cleaving of peptide bonds e.g. acid-base catalysis;;**
3. **Contact residues help to hold substrate at correct orientation/position;;**
4. **via weak interactions such as hydrogen bonds, ionic bonds & hydrophobic interactions;;**

Max 2

(ii) A scar is an area of fibrous tissue that replaces normal skin after an injury. All scarring is composed of the same collagen as the tissue it has replaced, but the composition of the scar tissue, compared to the normal tissue, has slightly different arrangement. Scar tissue also lacks elasticity unlike normal tissue which distributes fiber elasticity. The extend of scarring depends on the amounts of collagen expressed at the injury site.

Santyl® Ointment is an enzymatic ointment which contains collagenase. The enzyme collagenase is derived from *Clostridium histolyticum*.

Suggest a therapeutic use of collagenase. [1]

a. **Collagenase can be applied to remove callouses/scar/warts;;**

[Total: 9]

2018 / H2 / PJC PRELIM / P2 Q2

6 Fig. 2.1 shows an incomplete diagram of the fluid mosaic model of membrane structure. The diagram shows the cell surface membrane of a eukaryotic cell.

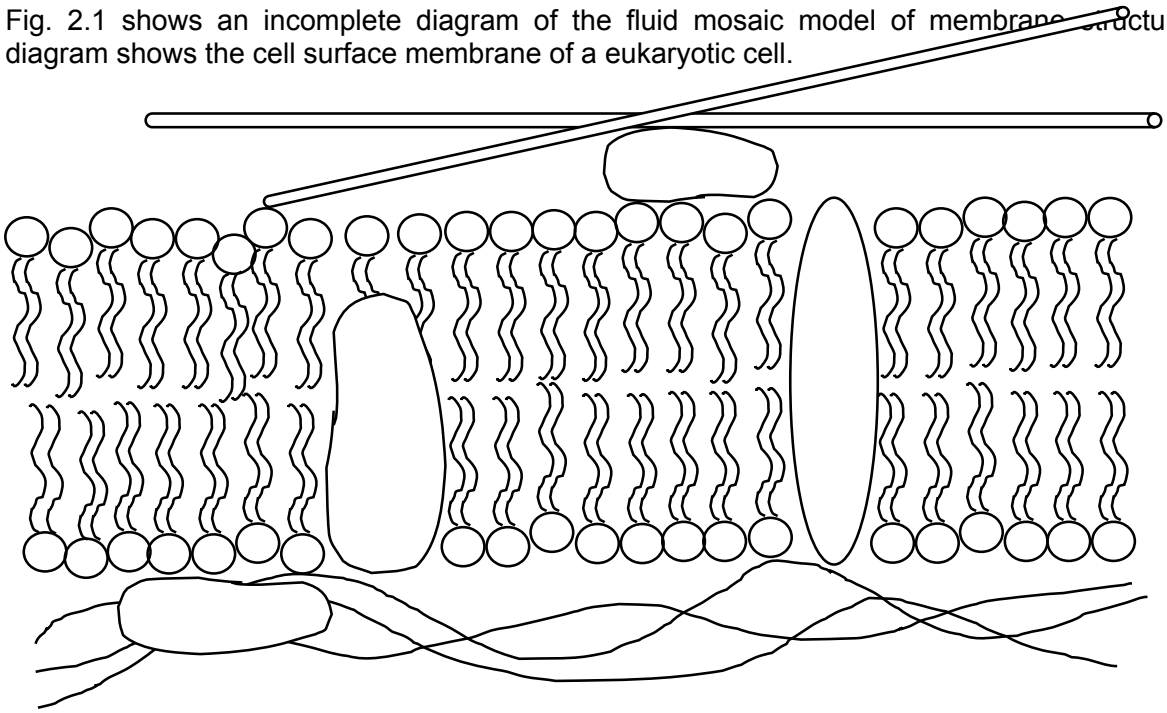


Fig. 2.1

(a) State what is meant by fluid mosaic model. [2]

fluid

a. refers to phospholipids (and proteins), move / constant motion / diffuse laterally and rotate on their axis, due to weak hydrophobic interactions between them;;

mosaic

b. refers to proteins / glycoproteins embedded in the phospholipid bilayer / AW in a random and scattered arrangement;;

(b) Phospholipids are a type of lipid. Lipids, in general, are made up of glycerol and fatty acids monomers covalently bonded together. Name the covalent bond and describe the breakage of this bond. [2]

a. ester bond;; R! ester

b. **Addition of 1 water molecule across ester bond via hydrolysis, products of hydrolysis are the hydroxyl group (-OH) in the glycerol molecule and the carboxyl group (-COOH) of a fatty acid;;**

[Turn Over

(c) List four features of cell surface membranes of eukaryotic cells that are **not** visible in Fig. 2.1. and outline their roles in the cell surface membrane. [4]

Feature	Role
a) cholesterol;	✓ Regulate fluidity / OR ✓ increase flexibility and stability of membrane;
b) unsaturated fatty acids; Accept phospholipid tails for fatty acids	✓ Forms kinks which prevents close packing of phospholipids, allowing membranes to remain fluid at low temperatures; (prevents freezing of membranes)
c) carbohydrate chains added to protein(s) / glycoproteins; A! oligosaccharides for carbohydrate chains	✓ cell-to-cell recognition in defense recognition by immune system OR ✓ cell-to-cell adhesion to form tissues OR ✓ receptor sites for chemical signals (e.g. hormones) ;
d) carbohydrate chains added to lipids / glycolipids;	
e) channel protein; A! aquaporin	✓ Confer selective permeability, allow specific polar molecules or ions to pass through the membrane;
f) carrier protein;	
g) AVP;;	

Any 4
R! peripheral / extrinsic / integral / intrinsic / transmembrane, proteins
R! attachment to, cytoskeleton / microfilaments

(d) The inner and outer membrane of the mitochondrion differ in the detail of their membrane components. The inner membrane is also much less permeable than the outer membrane.

Suggest **two** ways in which the structure of the inner membrane is different from that of the outer membrane to produce a **less permeable** inner membrane. [2]

a. **reduced gaps between membrane molecules;;**

b. higher proportion of phospholipids with saturated fatty acids / ora;;
c. fewer unsaturated fatty acids so, fewer 'kinks' in tails / closer packing;;
d. higher proportion of cholesterol molecules;;
e. fewer, channel / carrier / transport, proteins;;
f. smaller diameter of channels in non-specific channel proteins;;
g. fewer types of (specific), transport / carrier, proteins;;
h. AVP;; e.g. fewer, aquaporins / channels for water;;

Any 2

[Total: 10]

2018 / H2 / RI PRELIM / P2 Q1

7 **Fig. 1.1** shows the effect of low ATP on Phosphofructokinase (PFK) activity.

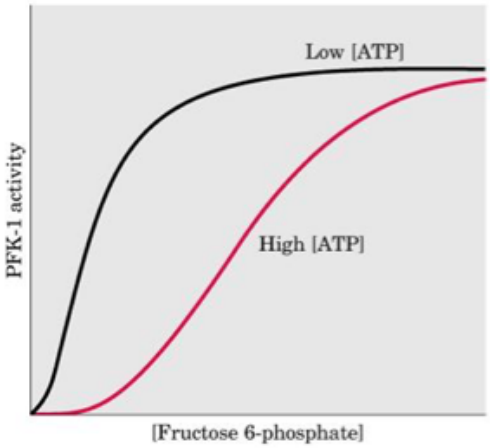


Fig. 1.1

(a) **(i)** On **Fig. 1.1**, draw a graph to show the effect of high ATP on PFK activity [1]

(ii) Explain the graph you have drawn. [3]

1) High levels of ATP inhibits PFK activity by lowering its affinity for fructose 6-phosphate.
2) ***ATP**** acts as an allosteric inhibitor which binds to an allosteric site which inhibits the PFK activity
3) [V_{max}]: inhibition can be overcome by high substrate concentrations;
4) [idea of cooperativity] binding of substrate to 1 subunit changes conformation of other subunits such that it becomes easier for substrate to bind;

(iii) Name 1 molecule that will act as allosteric activator of PFK activity.[1]

AMP/ADP
R: fructose-6-phosphate

(b) **Fig. 1.2** shows a PFK molecule.
(i) Describe the structure of PFK. [4]

1) PFK has a ***quaternary**** structure made up of 4 polypeptide chains.
2) Each of which has primary structure which is unique number and sequence of amino acid in a polypeptide linked by peptide bonds.
3) Secondary, tertiary and quaternary structures are hence direct consequences of primary structure.
4) Secondary structure refers to regular coiling and folding/pleating of polypeptide held by hydrogen bonds between CO and NH groups of polypeptide backbone.
5) Tertiary structure refers to a single polypeptide chain which is further folded into specific 3D conformation, held by bonds between R-groups within same polypeptide.
6) Tertiary structure is maintained by hydrophobic interaction, hydrogen bonds, ionic bonds.
7) Overall conformation of PFK is maintained by its primary, secondary and tertiary structure in addition to interaction among the 4 polypeptide chains.
8) Presence of ***active sites**** complementary in shape and charge to substrate.
9) Presence of ***allosteric sites**** complementary in shape and charge to activator/inhibitor.
10) PFK is globular/water-soluble, arranged so that most of its hydrophilic amino acid side chains are o external surface of the protein while hydrophobic amino acid side chains are buried in interior.

(ii) Explain how a change in pH affect the PFK activity.[3]

1) Affects ionisation of ***R groups**** of aa;
2) A change in pH will disrupt the ***ionic and hydrogen bond**** that maintain the 3D conformation of active site of PFK;
(A: mention of either one of the bonds)
3) which will result in a change in 3D conformation of ***active sites**** (R: catalytic sites), no longer complementary in shape and charge to substrate / substrate cannot fit, hence;
4) less ***enzyme-substrate complex**** formed hence reducing the PFK activity;

[Total : 12]

2018 / H2 / RVHS PRELIM / P2 Q2

8 **(a)** Explain how the structure of fatty acids allow triglycerides to be a good store of energy. [2]

Fatty acids makes triglycerides

1. **(S) non-polar/uncharged/large/long hydrocarbon chain**
2. **(F) can be stored (in large amounts) without having any significant effect on the water potential of a cell**
3. **(S) have large number of hydrogen atoms**
4. **(F) store large amounts of energy**

Fig. 2.1 shows the structure of a lipoprotein. Lipoproteins transport fats from the liver to other tissues via the bloodstream. The proteins of lipoproteins play an important role in the deposition of fats to the correct tissue.

Fig. 2.1

(b) Describe how lipoproteins allow for the transport of fats from the liver to a specific tissue via blood. [4]

1. **Phospholipid molecules form a single layer**
2. **Non polar / hydrophobic hydrocarbon tail interact with (non polar / hydrophobic) fats**
3. **Polar / hydrophilic phosphate head interact with the (aqueous) blood**
4. **Membrane protein binds to cell of target tissue**
5. **via complementary shape**

Fig. 2.2 shows a protein embedded in a phospholipid bilayer.

Fig. 2.2

Source: Adapted from RCSB Protein Data Bank

(c) With reference to Fig. 2.2,

(i) name the secondary structure and describe the bonding involved, and [3]

1. **β-pleated sheet**
2. **held in place by hydrogen bonds**
3. **between (O atom of) C=O and (H atom of) N-H groups**
4. **at regular intervals**
5. **of polypeptide chain parallel to each other**

(ii) describe how the structure of haemoglobin differs from that of the protein in Fig. 2.2. [2]

	Haemoglobin	Protein in Fig 2.2
Level of protein structure	Quaternary	Tertiary
Secondary structure	Largely α-helices	Largely β-pleated
Amino acids arrangement	Hydrophilic amino acids on the surface of protein.	Both hydrophobic and hydrophilic amino acids on the surface of protein
Haem group	Presence of haem group	No haem group

[Total: 11]