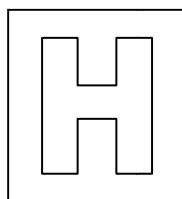


Candidate Name: \_\_\_\_\_

Class    Adm No

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## 2015 Preliminary Examination 2

### Pre-University 2

### H1 Biology

8875/02

Paper 2 Core Paper

18 September 2015

2 hours

Additional Materials:    Writing paper

#### READ THESE INSTRUCTIONS FIRST

**Do not open this booklet until you are told to do so.**

Write your Admission number and name on all the work you hand in.  
Write in dark blue or black pen on both sides of the paper.  
You may use a soft pencil for any diagrams, graphs or rough working.  
Do not use staples, paper clips, highlighters, glue or correction fluid.

#### Section A

Answer **all** questions.

#### Section B

Answer any **one** question.

At the end of the examination, fasten all your work securely together.  
The number of marks is given in brackets [ ] at the end of each question or part question. At the end of the examination, fasten all your work securely together.

For Examiner's Use	
Section A	
1	
2	
3	
4	
Section B	
Total	

This question paper consists of 18 printed pages including 1 blank page.

[Turn over

## Section A

Answer **all** questions in this section.

- The green algae are a large, informal grouping of algae consisting of the Chlorophyte and Charophyte algae, which are now placed in separate Divisions. The land plants are thought to have emerged from Charophyte algae

Charophyte algae have both chloroplasts and mitochondria. Exchanges between a mitochondrion, a chloroplast and the cytoplasm surrounding them in a Charophyte alga cell are shown in the Fig 1.1

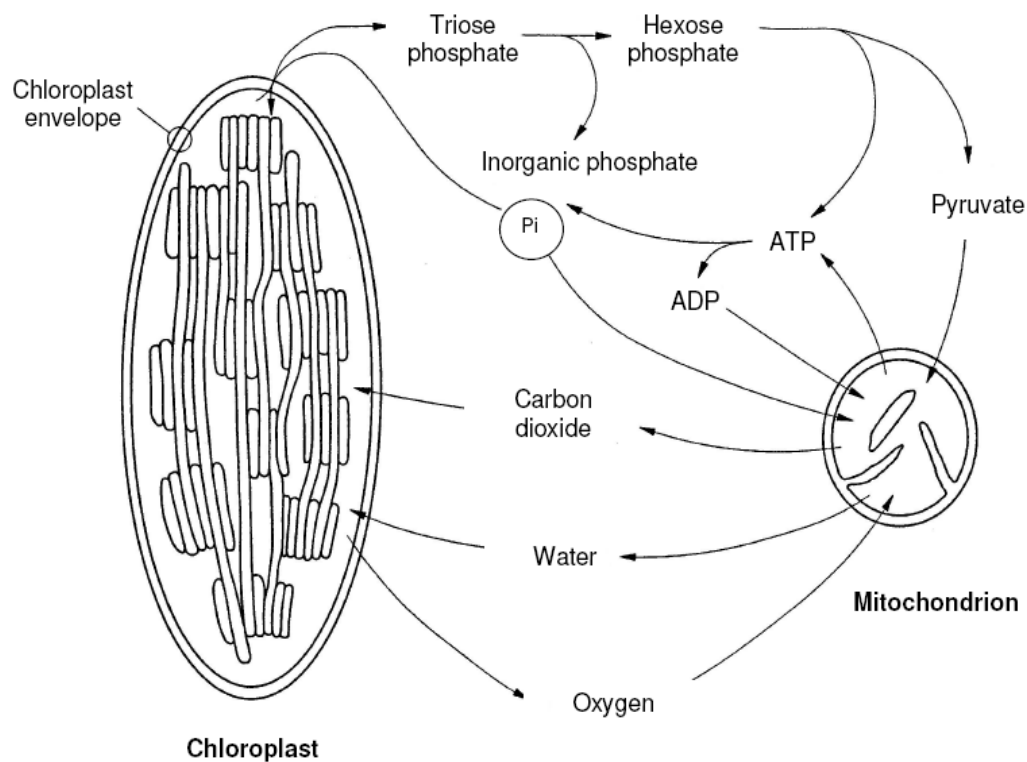


Fig. 1.1

- (a) Describe the role of oxygen in the mitochondrion and the chloroplast

Oxygen is a product of photosynthesis released by chloroplast;  
Formed during the photolysis of water;  
in the light dependent reaction;

Max 2 marks

Oxygen is utilized during aerobic respiration in the mitochondria;  
Final electron acceptor;  
During Oxidative phosphorylation;

Max 2 marks;

[4]

Mitochondria were isolated from Charophyte algae cells for further investigations. A study was carried out to find out the effect of three inhibitors, **X**, **Y** and **Z**, on the electron transport chain in the mitochondria. In each of three experiments, a different inhibitor was added. Table 1.1 below shows the state of the electron carriers, **P–S**, after the addition of inhibitor.

**Table. 1.1**

Inhibitor added	Electron carrier			
	P	Q	R	S
<b>X</b>	oxidised	reduced	reduced	oxidised
<b>Y</b>	oxidised	oxidised	reduced	oxidised
<b>Z</b>	reduced	reduced	reduced	oxidised

- (b) With reference to Table 1.1, give the order of the electron carriers in this electron transport chain.

Order: ..... **R – Q - P - S** .....

[1]

Inhibitors **X**, **Y** and **Z** were shown to also inhibit carbon dioxide production from mitochondria compared to control experiments. However the production of carbon dioxide can be detected when whole Charophyte algae cells is incubated with either one of these inhibitors.

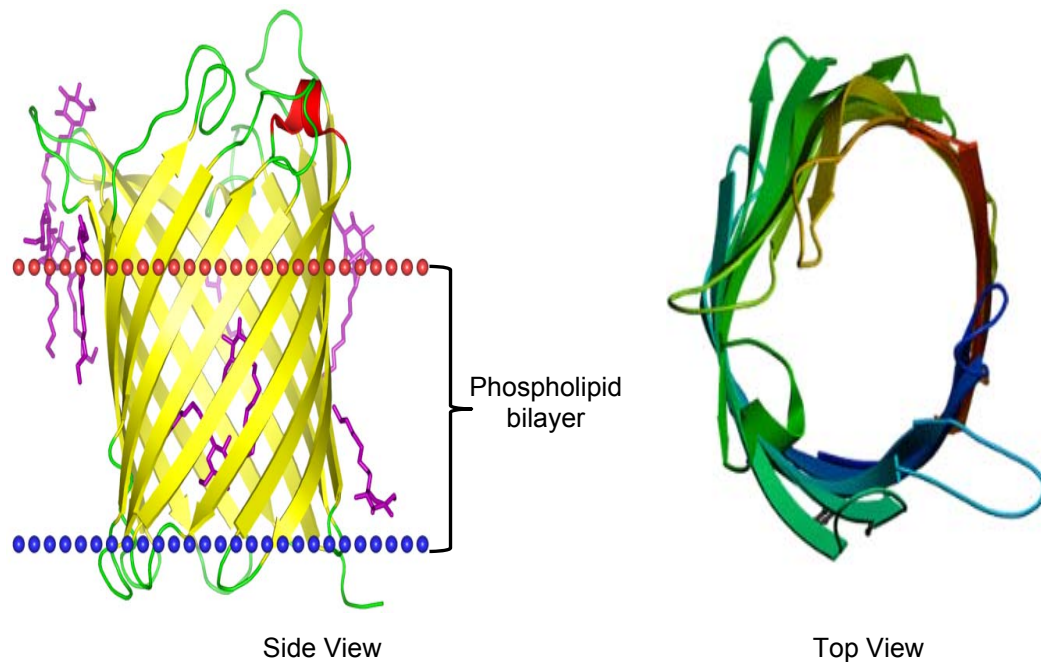
- (c) Explain how inhibitors **X**, **Y** or **Z** is able to inhibit carbon dioxide production from mitochondria.

Prevent Regeneration of NAD<sup>+</sup>/FAD;  
Link reaction/Krebs cycle responsible for carbon dioxide;  
NAD<sup>+</sup>/FAD needed for Krebs cycle /link reaction;

**Max 2 marks**

..... [2]

Porins are transmembrane proteins found on the outer membrane of the chloroplast in Charophyte algae and other eukaryotic cells. Their function is to transport ions across the membrane. Fig. 1.2 shows the side view and top view of the structure of a porin protein respectively.



**Fig 1.2**

(d) Explain why transmembrane proteins such as porins are needed to move ions

Ions are charged;  
Repelled/ will not be able to pass through hydrophobic core of membrane;  
Only non-polar molecules can directly diffuse across the phospholipid bilayer  
OR transmembrane proteins provide a hydrophilic channel for the passage of ions.

**Max 2 marks**

[Total: 9]

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2. An investigation was carried out to study the behaviour of chromosomes in early Cane toad (*Rhinella marina*) embryos. Using the radioactive-labelled DNA, a Cane toad embryonic stem cell with condensed chromosomes was carefully observed and the following measurements were taken:

1. Distance between the centromeres of the chromosomes and the poles of the spindle.
2. Distance between the centromeres of sister chromatids.
3. Distance between the poles of the spindle.

The results are enclosed in in Fig 2.1.

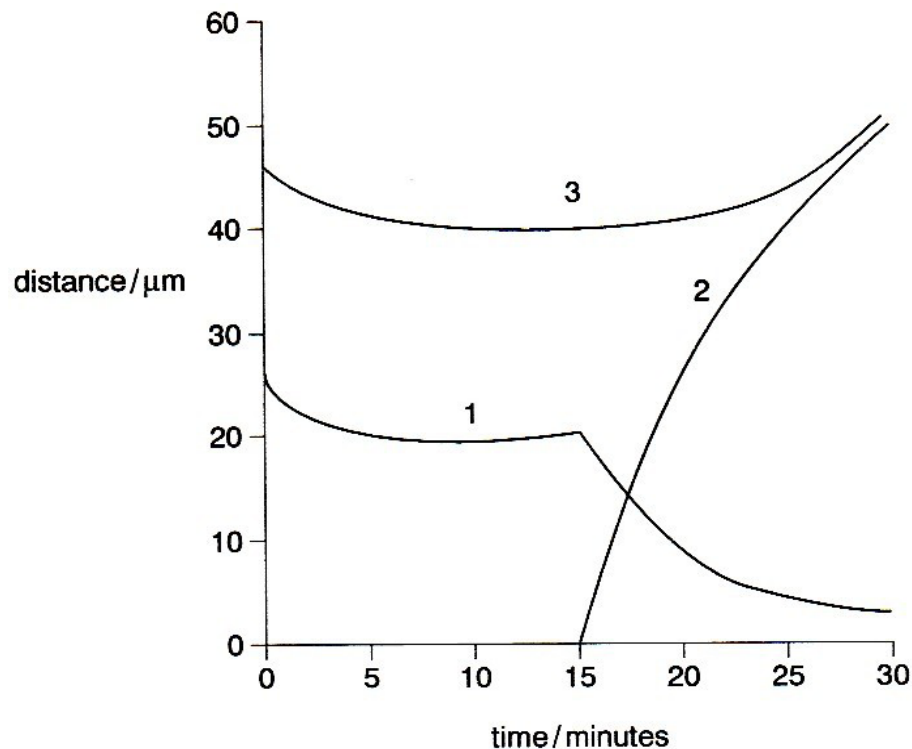


Fig 2.1

- (a) Distance between centromeres of sister chromatids increases from 0  $\mu\text{m}$  to about 50  $\mu\text{m}$  from 15 min to 30 min from time of experiment;
- Max 1**
- Anaphase taking place;  
Centromeres divide;  
Separation of sister chromatids as they move to opposite ends of the spindle poles;
- Max 2 marks.**

Docetaxel is a compound that is isolated from the bark of the Pacific Yew plant (*Taxus brevifolia*). Docetaxel has been shown to be cytotoxic based on its ability to inhibit microtubule disassembly.

A student repeated the previous investigation but introduced Docetaxel after 20 minutes to study the effect of this compound.

- (b) Sketch a graph on Fig. 2.2 to show the expected changes in distance between centromeres of the chromosomes and the poles of the spindle based on this experiment.

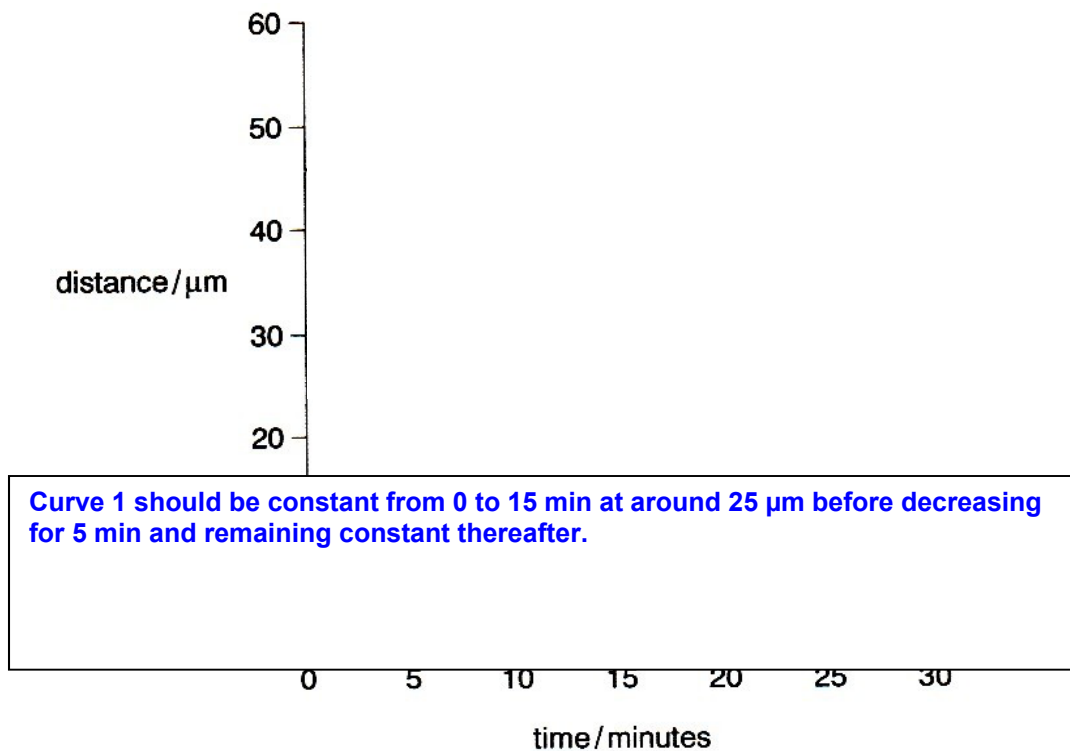


Fig 2.2

[1]

[Total: 4]

3. Tay–Sachs disease is an autosomal recessive disease which causes a progressive deterioration of nerve cells, mental and physical abilities in patients. This disease is caused by a mutation in the *hexA* gene found on chromosome 15, which codes for the alpha-subunit of hexosaminidase A, a lysosomal enzyme.

Anaemia is a condition that typically refers to a decrease in the amount of red blood cells in the blood. ABO haemolytic disease can result in anaemia. ABO haemolytic disease of the newborn (ABO HDN) refers to blood disorders that arise when the blood groups of the mother and newborn child do not match. It usually happens during a mother's second or subsequent pregnancy.

Antibodies from the mother can pass through the placenta and bind to the child's red blood cells. This leads to cell lysis, resulting in anaemia. While anaemia from ABO HDN is short lived, it can be fatal if severe. Table 3.1 shows the three different situations where blood group incompatibility can arise between a mother and her child

**Table 3.1**

	<b>Blood group</b>		
	<b>Situation 1</b>	<b>Situation 2</b>	<b>Situation 3</b>
<b>Mother</b>	O	A	B
<b>Child</b>	A or B	B	A

A man who is heterozygous at the locus for the blood type B antigen has a son with a woman with blood type O. Both parents are carriers for Tay-Sachs disease. The son was born with blood type B and does not suffer from Tay-Sachs disease. The couple decided to try for a second child and are worried about the risk of a disorder.



- (a) Draw a genetic diagram to determine the probability of a second child not developing either Tay-Sachs disease or ABO HDN.

Let  $I^A$  represent the codominant allele for production of type A antigen.  
 Let  $I^B$  represent the codominant allele for production of type B antigen.  
 Let  $I^O$  represent the recessive allele for production of neither antigen.  
 Let T represent the dominant allele that codes for lysosomal enzyme hexosaminidase A  
 Let t represent the recessive allele that produces no lysosomal enzyme.

Parental phenotypes: Blood group B, Carrier for Tay Sachs X Blood group O, Carrier for Tay Sachs  
 Parental genotypes:  $I^B I^O Tt$  X  $I^O I^O Tt$   
 Gametes produced:  $I^B T$   $I^B t$   $I^O T$   $I^O t$  X  $I^O T$   $I^O t$

Genotype of offspring:

	$I^O T$	$I^O t$
$I^B T$	$I^B I^O TT$ Blood group B, Normal	$I^B I^O Tt$ Blood group B, Normal
$I^B t$	$I^B I^O Tt$ Blood group B, Normal	$I^B I^O tt$ Blood group B, Tay Sachs
$I^O T$	$I^O I^O TT$ Blood group O, Normal	$I^O I^O Tt$ Blood group O, Normal
$I^O t$	$I^O I^O Tt$ Blood group O, Normal	$I^O I^O tt$ Blood group O, Tay Sachs

Phenotype of offspring: Blood group B, Normal : Blood group B, Tay Sachs : Blood group O, Normal : Blood group O, Tay Sachs

Phenotypic ratio : 3 : 1 : 3 : 1

[4]

Sickle cell anaemia is another form of anaemia which is caused by defective haemoglobins resulting in fragile sickle shaped red blood cells.

In normal adults, the most common haemoglobin type is classified as haemoglobin A (HbA). HbA is a tetramer which consists of two  $\alpha$  and  $\beta$  globin chains each. The genes for these chains are found on two different chromosomes. These genes pass on information via mRNA transcripts to synthesize the polypeptide chains which then assemble to form the haemoglobin quaternary complex.

Haemoglobin S (HbS) is a variant of adult haemoglobin (HbA) that arises by a mutation in the  $\beta$  globin gene. Patients with two copies of HbS are susceptible to forming sickle shaped red blood cells and consequently may suffer from sickle cell anaemia.

(b) Describe how the information carried on mRNA allows the synthesis of a

5' UTR / cap allows recognition/binding by small ribosomal subunit;

Start codon signals the start of translation;

Three bases on the mRNA correspond to a codon;

Each codon on mRNA recognizes an anticodon to code for a specific amino acid;

The stop codon (UAG, UAA, UGA) instructs termination of translation;

Max 3m

[3]

A clinic sequenced the  $\beta$ -globin gene locus of three different patients with anaemia. The results are tabulated in Table 3.2.

**Table 3.2**

Genetic profile of the 6 <sup>th</sup> codon of patients' $\beta$ -globin gene		
Patient	DNA codon sequence*	Amino acid
1	GAG	Glutamic acid
2	GTG	Valine
3	GAC	Aspartic Acid

(c)

Hydrophilic/charged glutamic acid has been replaced with non-polar valine in amino acid sequence;

Decreases solubility of deoxygenated HbS;

When oxygen is low, HbS molecules precipitates out of solution;

HbS molecules aggregates/polymerize to form rigid fibres which cause red blood cells to become sickle shape;

**Max 3 mark**

..... [3]

(d)

Both glutamic acid and aspartic acid have the similar chemical property/ charged R groups / are acidic amino acids;

Hence, the change to the structure of the  $\beta$ -globin protein and eventually haemoglobin is insignificant

**OR**

Same type of interaction that maintains tertiary/ quaternary structure

**Max 1 mark**

4. A mammoth can be any species belonging to the extinct genus *Mammuthus*, *proboscideans* commonly equipped with long, curved tusks. They were members of the family Elephantidae which contains, along with mammoths, the two genera of modern elephants and their ancestors.

About three million years ago, the ancestors of mammoths migrated from Africa into Europe and Asia. There, about 1.7 million years ago, the steppe mammoth (*Mammuthus armeniacus*) evolved and became adapted to the cooler conditions. Then, about 700 000 years ago, as the climate changed and the Arctic became much colder, the woolly mammoth (*Mammuthus primigenius*) evolved. Woolly mammoths showed a number of characteristics that include thick fur, small ears and small tails.

(a)

**Genetic variations exist within the mammoth population);**

**Selection pressure - colder conditions;**

**Thick fur offers better insulation/ small ears and small tails offers smaller surface area to volume to reduce heat loss**

**Mammoth with small ears/small tails/ thick fur (2out of 3) had a selective advantage;**

**Mammoths with these traits were able to reproduce in greater numbers pass on their alleles for these traits to offspring;**

**Increase allele frequency for woolly mammoth traits in gene pool of population;**

**Max 4m**

A frozen, 43 000 year old woolly mammoth was found in Western Siberia. Its DNA was extracted and sequenced. The evolutionary relationship of the Woolly mammoth, Asian elephant (*Elephas maximus*) and African elephant (*Loxodonta africana*) was then investigated.

- (b) Explain how analysis of rRNA genes can be used to compare evolutionary relationships between the three members of the family Elephantidae.

**DNA-DNA hybridization can be used to examine the evolutionary relationships between members.**

**The more complementary the nucleotide sequences, the more closely related they are. [A: reverse argument]**

**OR**

**DNA analysis / Compare sequence of rRNA genes**

**The greater the differences in nucleotide sequence, the more distantly related the species are. [A: reverse argument]**

**Max 2m**

The Asian elephant is presently classified as an endangered species. Current populations are threatened by poaching, ecological challenges, urbanization as well as health problems. A scientist embarked on a study which involved the production of functional recombinant elephant growth hormone (*eGH*) protein in *Escherichia coli* bacteria to better understand dwarfism in Asian elephants.

The initial steps in the procedure to produce recombinant eGH proteins are summarized as follows.

- Step 1 Reverse transcriptase is used to make *eGH* from the elephant's mRNA from endocrine cells
- Step 2 *eGH* cDNA is amplified by PCR to increase the quantify of cDNA
- Step 3 *eGH* cDNA is cloned into an expression vector using BamH1 restriction enzyme

- (c) Explain why elephant cDNA prepared from mRNA was used for producing functional eGH proteins in *E.coli* instead of elephant genomic DNA

**cDNA does not have intron sequences/ genomic DNA have intron sequences ;**

**mRNA from endocrine cells will have gone through post-transcriptional processing/splicing to remove introns;**

**E. coli will not be able to carry out post-transcriptional processing/splicing;**

**Introns from genomic DNA will affect folding of eGH which may result in non-functional proteins;**

**Max 2 mark**

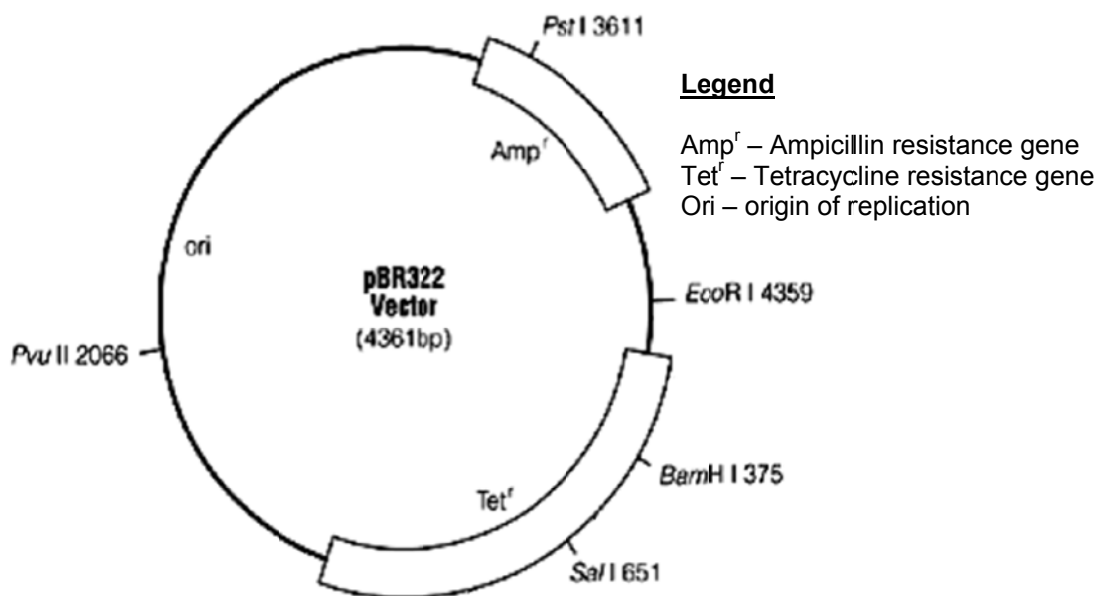
During Polymerase chain reaction (PCR), the primers used to amplify eGH cDNA were extended sequences that included recognition sites for *Bam*H1 restriction enzyme. The recognition site for *Bam*H1 is enclosed in Table 4.1.

**Table 4.1**

Restriction enzyme	Specific recognition site
<i>Bam</i> HI	5'-G <sup>^</sup> A T C C-3' 3'-C C T A G <sup>^</sup> -5'

^ indicates where the restriction enzyme cuts

Fig 4.1 shows the plasmid pBR322 which was used as the expression vector to produce eGH proteins. *Bam*H1 restriction enzyme was used to clone amplified eGH cDNA into pBR322.



**Fig 4.1**

(d) **BamH1 is used to cleave/digest/cut the DNA at BamH1 restriction sites in both eGH cDNA and pBR322;**

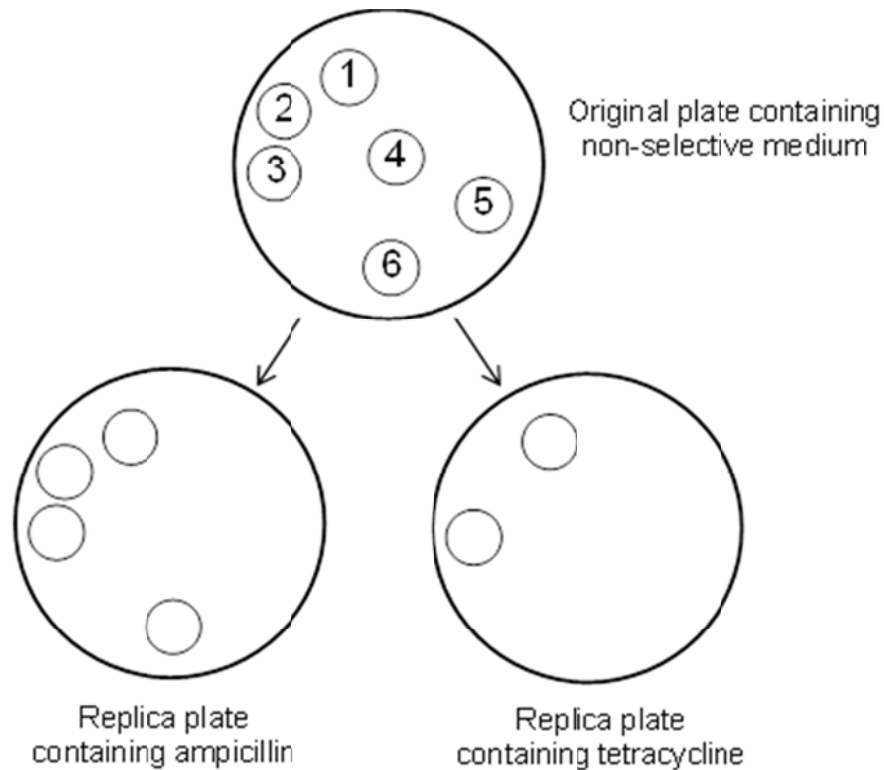
**BamH1 restriction digest produces sticky ends in in both eGH cDNA and pBR322 that are complementary to each other;**

**DNA ligase** added to catalyse formation of phosphodiester bonds between eGH and pBR322 fragments to produce recombinant plasmid;

**Formation of hydrogen bonds between overhangs of complementary sticky ends**;

**Max 2 mark**

After BamH1 restriction enzyme was used to clone eGH cDNA into pBR322, the mixture containing recombinant DNA was used to transform *E.coli* bacteria. Replica plating was used to identify the bacteria with the gene coding for eGH. Fig. 4.2 shows the bacterial colonies that grew on two replica plates.



**Fig 4.2**

- (e) With reference to Fig 4.1 and Fig 4.2, explain which colonies the student may propagate to produce large quantities of eGH proteins.

**Colonies 2 and 6 ;**  
**Max 1**

Only recombinant Bacteria with eGH will be able to grow in plates containing ampicillin but not in plates containing tetracycline;

Bacteria without pBR322 will not survive in plate containing ampicillin;

Bacteria that grow in plates with tetracycline contain re-annealed pBR322 plasmids;

Due to insertional activation of tetracycline gene on pBR322;

**Max 2 marks**

More than two thirds of an Asian elephant's day may be spent feeding. Bananas are a staple food for this elephant species. However this fruit is commonly infected by fungal pathogen *Fusarium oxysporum*. In recent times, a particularly infectious strain of this fungus, classified as the TR4 strain, is threatening to depress banana populations which may further affect the Asian elephant's survival.

A team of students conducted an experiment to study the TR4 resistance by genetically modified bananas

The following two groups of banana plants, growing next to each other, in identical conditions, were infected with TR4:

<u>Plant Group</u>	<u>Specimen</u>
Non-transgenic banana plants	Plant <b>P</b> And Plant <b>Q</b>
Banana plants genetically engineered to express TR4 resistant gene (BRF gene)	Plant <b>R</b>

The number of fungal colonies was tracked each day for 4 days after infection. The results are shown in Fig. 4.4.

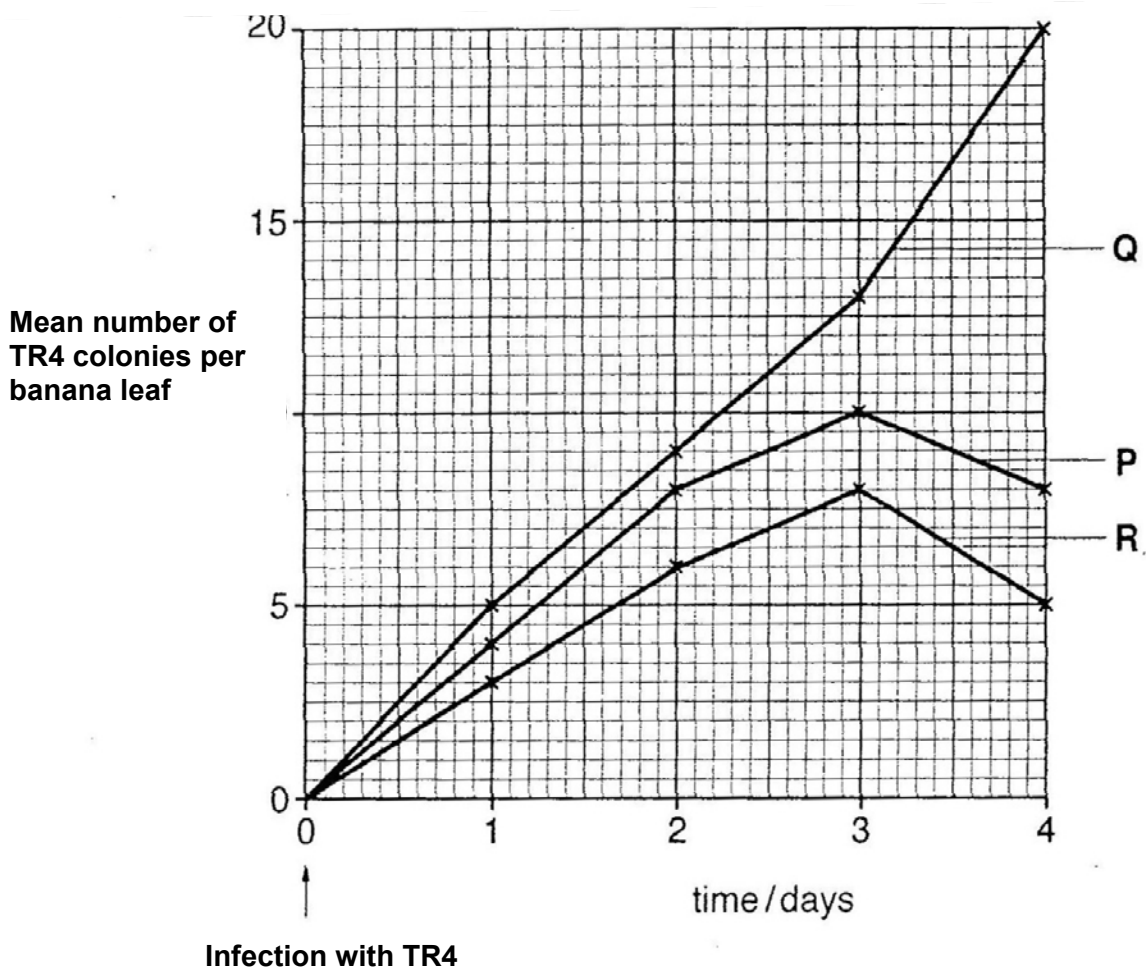


Fig. 4.3



- (f) **Plant R is more resilient;**  
**Max 1m**  
**In Q, the mean number of viruses per leaf increases sharply from 0 to about 13 while In R, the mean number increases less sharply from 0 to about 8 over 3 days after infection. (OWTTE with ref to data)**  
**In R, the mean number of viruses per leaf decreases from about 8 on day 3 to about 5 on day 4 while in R, the mean number continues to increase from 13 to 20. (OWTTE with ref to data);**
- (g) **Max 1m**

.....

**Spread/Transfer of TR resistance gene from Plant R;  
AVP**

**Reject mutation**

**Section B**

Answer **one** question.

Write your answers on the separate answer paper provided.  
Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.  
Your answers must be in continuous prose, where appropriate.  
Your answers must be set out in sections **(a)**, **(b)** etc., as indicated in the question.

**5.**

- (a)** Explain how pH may affect the activity of mammalian catalase [8]
- (b)** Compare and contrast DNA replication with transcription [7]
- (c)** Using the example of honey bees, explain how the phenotype of organisms can be affected by the environment. [5]

[Total: 20]

**6.**

- (a)** Describe the structure and function of the endoplasmic reticulum. [7]
- (b)** Describe the role of membranes in photosynthesis. [7]
- (c)** Discuss the ethical and social concerns that arise from increasing reliance on genetically modified organisms [6]

[Total: 20]

**End Of Paper**

(a) Explain how pH may affect the activity of mammalian catalase

[8]

Optimum pH

At optimal pH, conformation of active site is most ideal for substrate binding;

resulting in most effective collisions between substrate and enzyme resulting in maximum rate of reaction;

resulting in the highest rate of formation of enzyme-substrate complex per unit time

resulting in maximum rate of hydrogen peroxide decomposition;

Max 3m

Deviation from optimum pH

At pH higher or lower than optimal, there is change in  $H^+$  concentration;

There is change/alteration/neutralization in ionization of R groups of amino acids;

That are acidic/basic;

Disrupts ionic; and hydrogen bonds;

Change in 3d shape/globular shape of enzyme;

active site changes shape;

less effective formation of enzyme-substrate complexes and lower enzymatic activity;

Reduce rate of hydrogen peroxide decomposition;

Max 5m

(b) Compare and contrast DNA replication with transcription

[7]

	DNA replication	DNA transcription
Nucleotide bases involved	Deoxyribonucleotides; newly synthesised strand complementary to the template strand where A pairs with T and C pairs with G;	Ribonucleotides; newly synthesised mRNA strand, complementary to template strand, where A pairs with U and C to G;
End-product	2 double stranded DNA molecules, formed by semi-conservative method: two molecules of DNA formed: each consist of one newly synthesized daughter strand and one parental strand	1 single stranded mRNA molecule is complementary to the template DNA strand
Number of strands required for synthesis of complementary strand(s)	Both DNA strands of double helix DNA molecule are required to act as template strand for synthesis of complementary strands	Only one strand of DNA molecule is required to act as template strand for the synthesis of mRNA
Where enzymes bind for start of process	Origin of replication where helicase binds to: unwind and unzip the double stranded DNA	Promoter region, near 3' end of gene where RNA polymerase binds to: unwind and unzip the DNA
Enzymes used in producing the complementary strand	DNA polymerase III is used in synthesising the complementary strand by adding DNA nucleotides to the 3' end of the existing strand (primer)	RNA polymerase II is used in transcribing the pre-mRNA strand, by adding nucleotides to 3' end of strand
Primers requirement	Need primers for the 3' end (from existing strand) as DNA Pol is unable to initiate polynucleotide synthesis	Do not require primers as RNA pol is able to initiate polynucleotide synthesis

Max 4m

AVP

Similarities between transcription and replication:

Both occur in the nucleus;

Both processes involves the synthesis of polymers from monomers;

Both need template to initiate the synthesis of product;

Both processes involves complementary base pairing.

Both processes require energy from ATP

Max 3m

- (c) Using the example of honey bees, explain how the phenotype of organisms can be affected by the environment [5]

Worker bees are phenotypically different from queen bees;

even though genetically similar;

Worker bees are smaller and have larger mouthparts and modified legs as compared to the queen bee;

The development of the female larvae to a queen bee or worker bee depends on the diet;

Once a particular female larva is selected to become the sexually mature queen bee, it is fed exclusively with royal jelly;

High protein level in the royal jelly;

Royal jelly stimulates the development of the female reproductive system;

Larvae which are fed with a diet of honey and pollen grow to be worker bees;

-

7.

(a) Describe the structure and function of the endoplasmic reticulum.

[7]

Intro (Max 2 marks)

The endoplasmic reticulum is a complex system of flattened, membrane bound sacs called cisternae;

made up of rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER);

RER structure (Max 1 marks)

The membrane of RER is continuous with the nucleus membrane;

Sheet-like and

covered with ribosomes on its surface;

RER function (Max 2 marks)

Proteins which are made by the ribosomes are extensively modified by enzymes within the cisternae

polypeptides enter the RER is folded into its tertiary/quaternary structure;

Transport the proteins to the Golgi Apparatus via transport vesicles;

SER structure (Max 1 marks)

SER is system of interconnected tubules with the RER;

ribosomes are absent from the surface of the SER membrane;

SER function (Max 1 marks)

Involved in the synthesis of lipids and steroids/cholesterol/reproductive hormones with the help of enzymes found within the SER;

Gives rise to the Golgi Apparatus when membrane of the SER buds off as a transport vesicle and fuses with the cis-end of the Golgi Apparatus;

(b) Describe the role of membranes in photosynthesis.

[7]

The membrane envelope of chloroplast allows for compartmentalisation as the chloroplast enzymes require different / specific conditions from the rest of the cell to function;

Thylakoid membrane holds the photosynthetic pigments that absorb light energy during photosynthesis;

Thylakoid membrane provide large surface area to volume ratio to increase rate of light dependent reactions;

Holds electron carriers of the electron transport chain;

The transport of electrons down ETC releases energy to pump H<sup>+</sup> into thylakoid space enclosed by thylakoid membrane;

Proton pump in thylakoid membrane actively transports H<sup>+</sup> against a concentration gradient;

Thylakoid membrane being impermeable to protons, allows build up of proton gradient across thylakoid membrane;

Stalked particle / ATP synthase embedded in thylakoid membrane allow harnessing of proton motive force to synthesise ATP from ADP and phosphate groups;

Inner membrane of the chloroplast contains transport proteins to allow transport of metabolites e.g. triose phosphate;

Max 7m

- (c) Discuss the ethical and social concerns that arise from increasing reliance on genetically modified organisms [6]

Ethical implications [max 2]:

Concern over tampering of nature via mixing of genes among species.h named (E.g. Bt corn/ Golden rice);

Violation of natural organism's intrinsic values and rights ( Pain and suffering through genetic engineering procedures or outcomes);

May not be accommodating towards religious groups (Vegetarians faced with strawberries bearing antifreeze proteins from a winter fish);

May not be accommodating towards groups with dietary restrictions; (Muslims faced with plants/animal/pharmaceutical products carrying genes/genetic products from pigs;

Currently, in the United States, food labeling of GM food is optional / voluntary, so consumers do not know they are consuming GM foods;

Social implications:

-Threat to human safety (max 2)

Transgenic food can cause allergies (e.g. Bt toxin in Bt corn/genes in Golden rice coming from several organisms);

There may be long term unexpected/negative effect of transgenic food on human health;

When transgenic food is produced with using vectors containing antibiotic resistance genes, there are concerns that these genes may spread during consumption;

The first concern would be transforming normally harmless bacteria in the gut to become pathogenic;

The greater concern would be the spread of these genes to other potentially harmful bacteria in the body or the environment

-Threat to safety of the environment (max 2)

Cross-pollination/unintended transfer of transgenes from GM crops (e.g. oilseed rape with herbicide-resistance);

GM crops may establish themselves as 'super weeds' and thus become invasive to reduce biodiversity or disrupt ecological balance;

GM crops may be toxic to non-target organisms (e.g. Bt toxin affecting larvae of monarch butterflies);



- Issues pertaining to Access and Intellectual Property (max 1)

Research companies typically seek patents to make profits/protect results of research);

These patents increase in price of seeds/ domination of world food production by few companies;

Patent rights can lead to developed countries exploiting the resources of developing countries;

Intellectual property costs may encourage bio-piracy;

Bio-piracy may lead developed countries exploit the resources of developing countries;

-other social implications (max 1)

Advances in genetic engineering technology and outcomes would be more skewed in developed countries;

May lead to dominance of world food production by developed countries / increasing dependence of developing countries on industrialized nations;

Impact on international trade with named example (e.g. Europe being more hesitant in accepting GM products compared to US);