Class Adm No

Candidate Name: _____

H

millennia institute

2018 Preliminary Exams
Pre-University 3

BIOLOGY **9744/01**

Paper 1 Multiple Choice **19 September 2018**

1 hour

Additional Materials: Optical Answer Sheet

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.
Write your name, Adm No. and class on all the papers you hand in.

There are **thirty** questions in this paper. Answer **all** questions. For each question, there are four possible answers, **A**, **B**, **C** and **D**.
Choose the one you consider correct and record your choice in soft pencil on the separate answer sheet.

Each correct answer will score one mark. A mark will not be deducted for wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

1. The first description of cell was attributed to microscopist, Robert Hooke, who was observing a slice of cork under the microscope. He termed his observation, *cella*, a latin word meaning 'a small room'. This observation later helped establish the cell theory.

Which of the following is correct about the cell theory?

A The theory suggests the cells are produced spontaneously.

B The theory agrees that virus follows the definition of cell.

C The theory was developed based on Robert Hooke's observation only.

D The theory could not be applied to all types of tissues.

2. The endosymbiotic theory states that mitochondria and chloroplasts originate from primitive bacterial cell. The symbiotic relationship is established when two different species benefit from each other. Further study suggests that mitochondria and chloroplast originate from aerobic and photosynthetic prokaryote respectively.

Which of the following biomolecule found in mitochondria and chloroplast best suggests that they once originate from prokaryote?

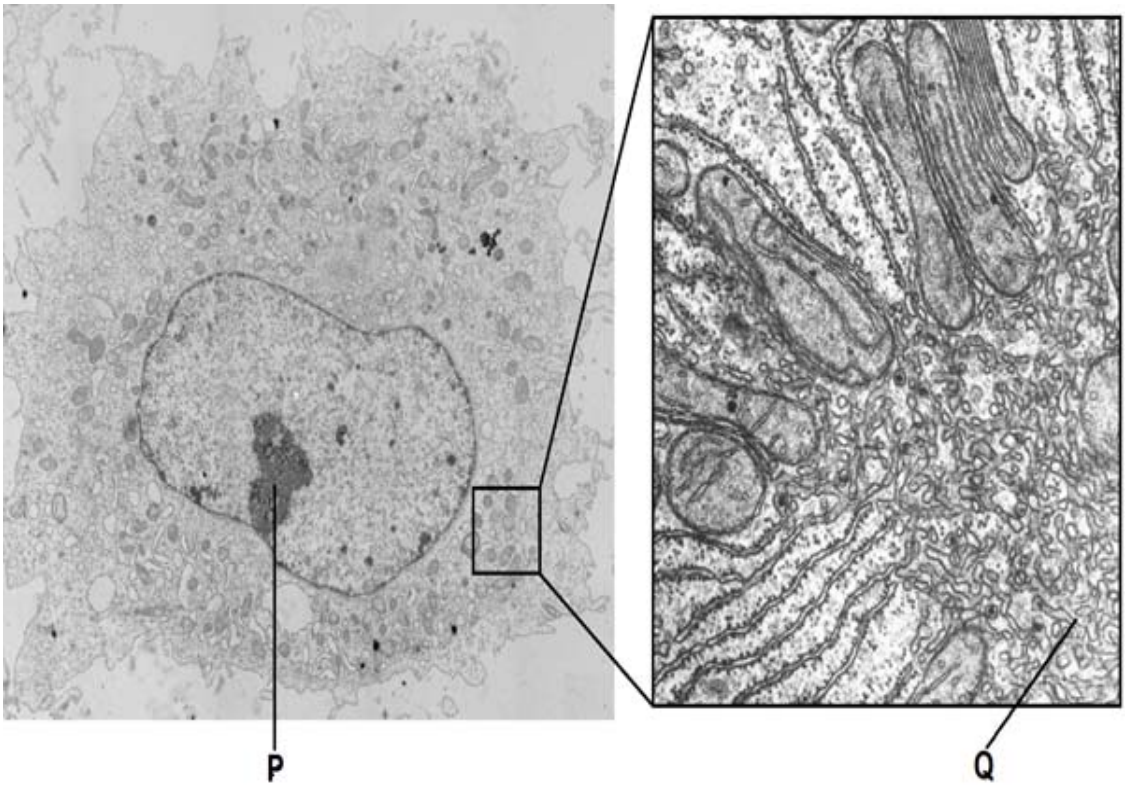
A Carbohydrate

B Lipid

C Protein

D Nucleic acid

3. The following diagram on the left shows the electro-micrograph of a cell found in a healthy individual. A region of the cell, indicated by the box, is magnified and shown in the diagram on the right.



Which of the following shows the correct identities and functions of **P** and **Q**?

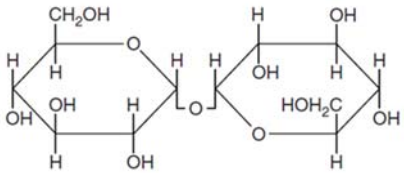
	Identity of P	**Function of P**	**Identity of Q**	**Function of Q**
A	Nucleosome	Transcription of rRNA	Smooth ER	Detoxification
B	Nucleosome	Assembly of ribosomes	Secretary vesicles	Storage of Ca^{2+}
C	Nucleolus	Assembly of ribosomes	Smooth ER	Synthesis of lipids
D	Nucleolus	Transcription of rRNA	Secretary vesicles	Modification of protein

4. Which row shows features of a typical prokaryotic cell?

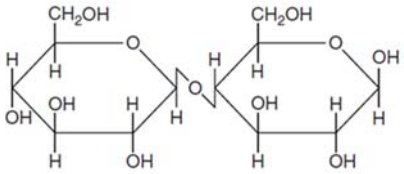
	Cell size	Nucleus	DNA	Ribosome size
A	>10 μm	Absent	Circular	70S
B	>10 μm	Present	Linear	80S
C	<10 μm	Absent	Circular	70S
D	<10 μm	present	linear	80S

5. Polysaccharide, disaccharide and monosaccharides are different forms of carbohydrates. Cellobiose, maltose, sucrose and trehalose are four different disaccharides. The following diagram shows the molecular structure of these disaccharides.

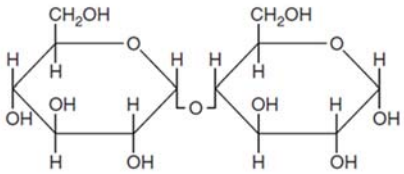
I



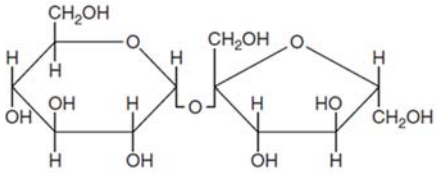
III



II



IV

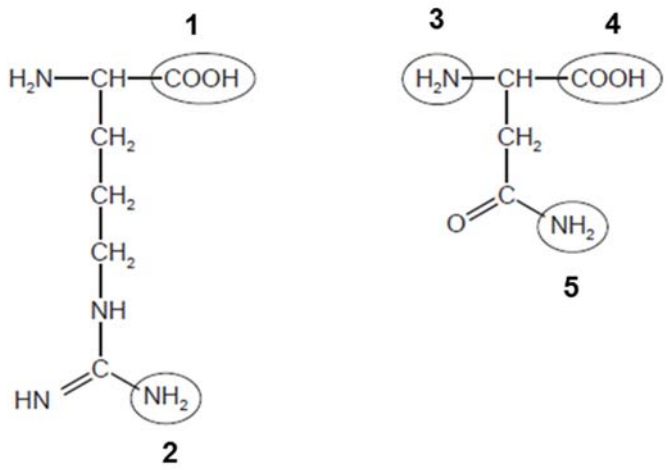


Using the information below, which option correctly identifies disaccharides **I** to **IV**?

- Cellobiose is formed from the hydrolysis of cellulose.
- Hydrolysis of cellobiose produces β-glucose.
- Trehalose is synthesised from two α–glucose.
- Maltose is formed from the hydrolysis of amylose.

	Cellobiose	Maltose	Sucrose	Trehalose
A	**III**	**I**	**IV**	**II**
B	**III**	**II**	**IV**	**I**
C	**IV**	**I**	**III**	**II**
D	**IV**	**II**	**III**	**I**

6. The diagram shows the structures of two amino acids, each of which has more than one amine ($-NH_2$) group.



Which of the two groups form the peptide bond that holds the two amino acids?

A **1** and **3**

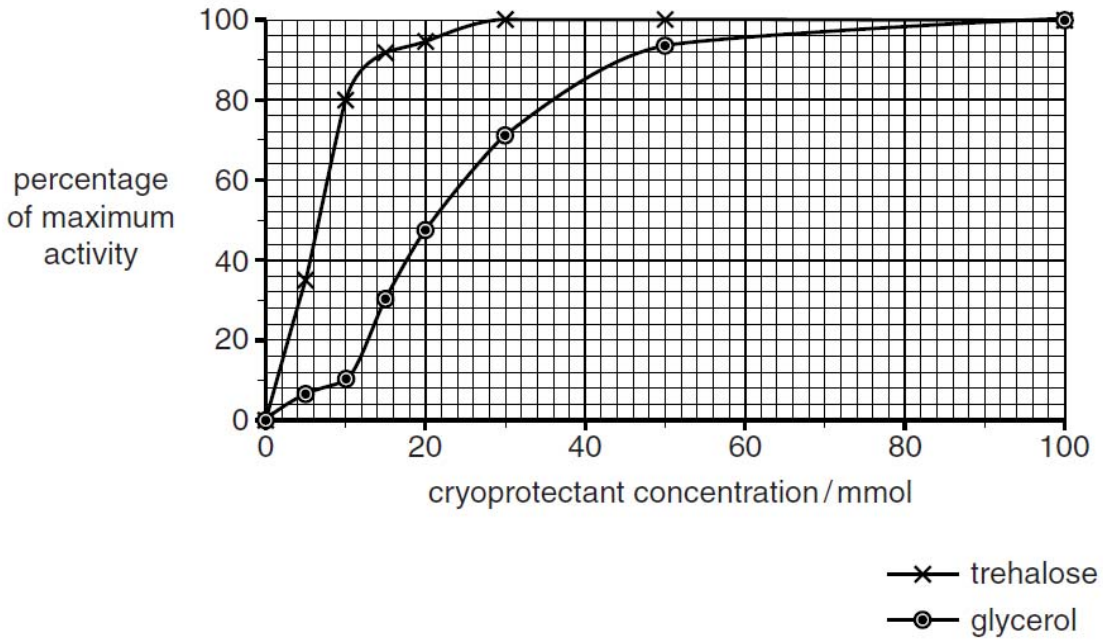
B **1** and **5**

C **2** and **4**

D **2** and **5**

7. An investigation was carried out to find out the protective effect of different concentrations of two cryoprotectants, trehalose and glycerol, on the activity of an enzyme. The enzyme was first incubated at freezing temperature, followed by incubating at its optimum temperature. The percentage of maximum activity of the enzyme was measured at its optimum temperature.

The following diagram shows the results of the investigation.



Which of the statement correctly describes the investigation?

A The enzymes were denatured after incubating at freezing temperature.

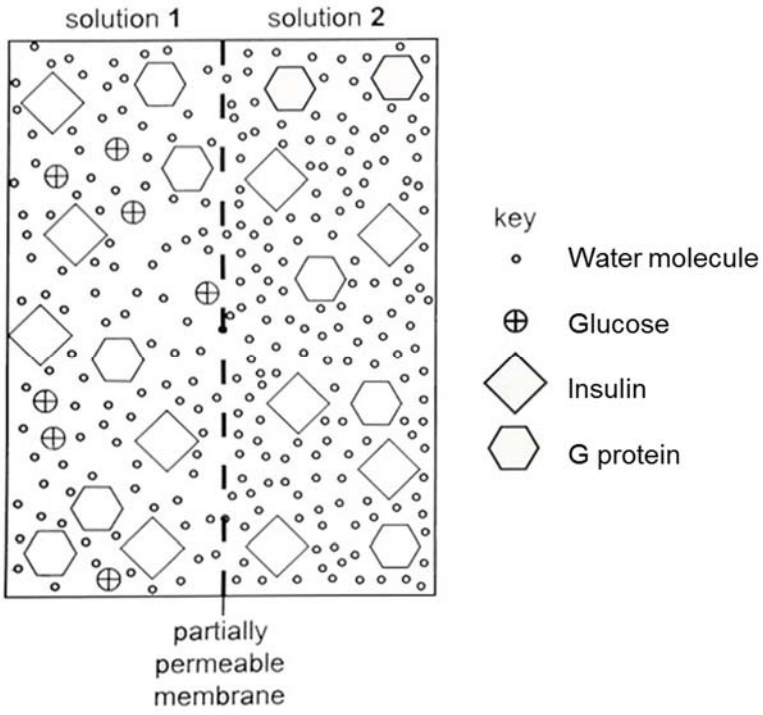
B Glycerol is a more effective cryoprotectant than trehalose.

C In the absence of cryoprotectant, the enzyme remains inactive.

D At all concentrations, trehalose results in a higher percentage of maximum enzyme activity.

8. The diagram represents an artificial partially permeable membrane separating two solutions, **1** and **2**.

The relative diameters and concentrations of the ions and molecules in the solutions and the pore diameter of the artificial partially permeable membrane are drawn proportionally in the diagram.



Which statement about the movement of the molecules between solution **1** and **2** is correct?

A The difference in water potential causes water to move by osmosis from solution **1** to solution **2**, a diffusion gradient causes net movement of glucose from solution **1** to solution **2**, and insulin and G protein to not move between the two solutions.

B Solution **1** has a lower water potential than solution **2**, causing net movement of water from solution **2** to solution **1** until the water potentials are the same; all the other molecules are too large to pass through the artificial partially permeable membrane.

C Insulin and G protein pass through the artificial partially permeable membrane equally in both directions because they are of the same concentration in solution **1** and solution **2**, but glucose and water diffuse in opposite directions until the concentrations of solution **1** and solution **2** are equal.

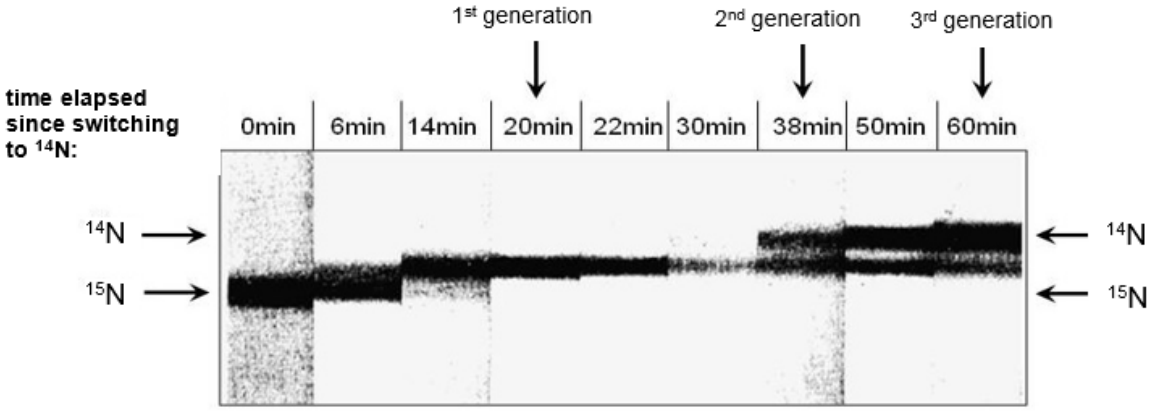
D Net movement of water occurs down a water potential gradient from solution **2** to solution **1**, net movement of glucose occurs down a diffusion gradient from solution **1** to solution **2**, and no movement of insulin and G protein occurs across the artificial partially permeable membrane.

9. In an investigation to study the mode of DNA replication, *Escherichia coli* (*E. coli*) cells were grown in a nutrient medium containing heavy isotope of nitrogen (^{15}N) for an extended period of time until all the DNA was labelled.

These *E. coli* cells were then transferred to a nutrient medium containing only light isotope of nitrogen (^{14}N) and were allowed to multiply over three generations. The DNA of the *E. coli* cells was then harvested at nine different time intervals.

Subsequently, density gradient centrifugation of these *E. coli* DNA using caesium chloride was performed.

The diagram shows the results obtained.



Which statements are consistent with the results observed?

I There was no evidence of semi-conservative DNA replication.
II In the 1st generation, only hybrid $^{14}N/^{15}N$ DNA was produced.
III In the second generation, 50% of $^{14}N/^{15}N$ DNA and 50% light $^{14}N/^{14}N$ DNA were produced.
IV In the 3rd generation, 75% hybrid $^{14}N/^{15}N$ DNA and 25% light $^{14}N/^{14}N$ DNA were produced.
V In the subsequent 4th generation, it is impossible to deduce the amount of DNA with ^{15}N.

A **I** and **II** only
B **II** and **III** only
C **III** and **IV** only
D **II**, **III** and **IV** only

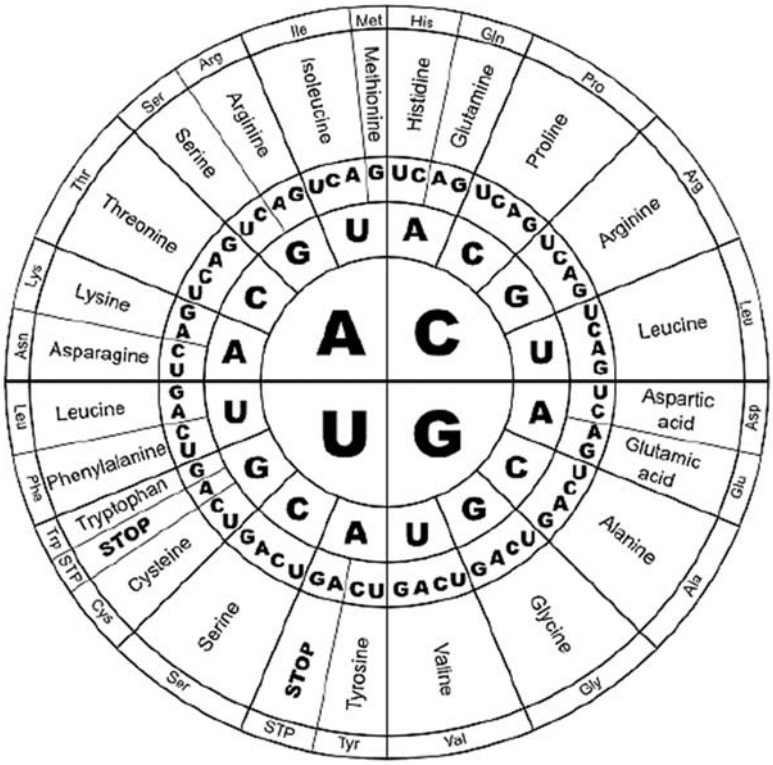
10. What is the minimum number of hydrogen bonds in a length of DNA containing 800 nucleotides?

A 800
B 1200
C 1600
D 2400

11. The first five DNA triplets that code for a particular protein is shown below:

3' CAC GGA AGC CCA GAA 5'

The genetic information in the sequence above is eventually converted into a specific amino acid sequence according to the figure below.

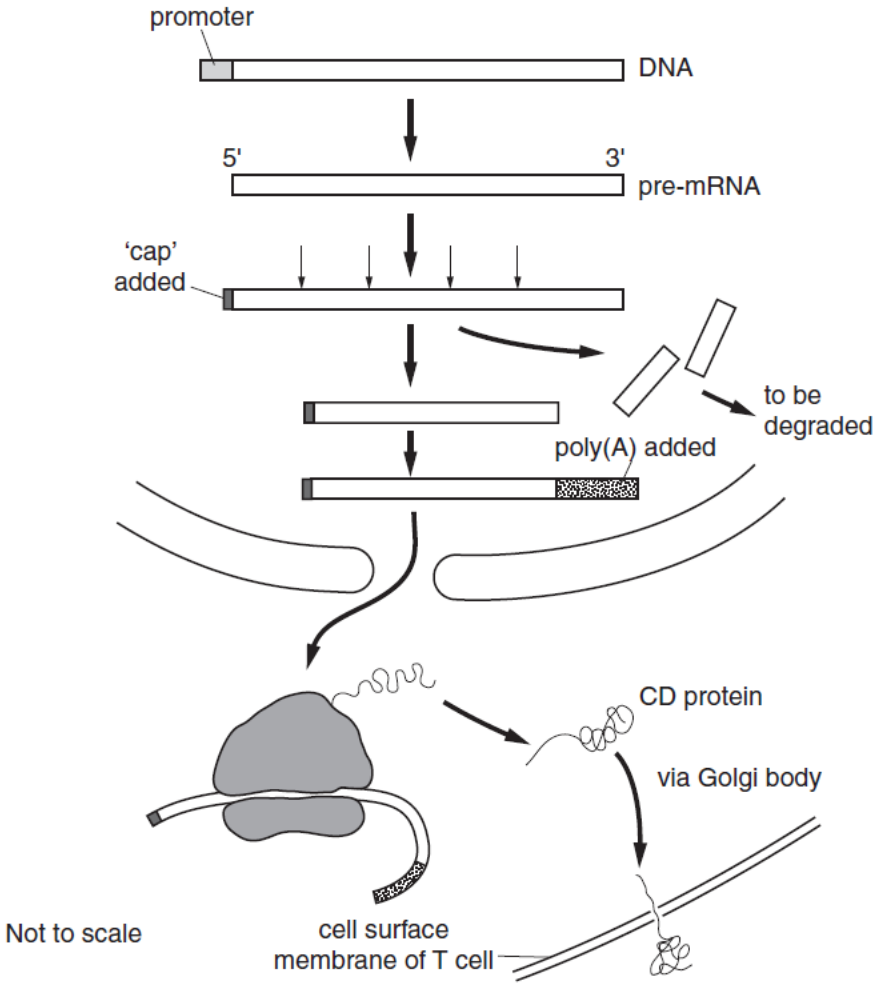


Using the given information, what is the sequence of the protein encoded by the DNA sequence above?

A His – Gly – Ser – Pro – Glu
B Val – Pro – Ser – Gly – Leu
C Lys – Thr – Arg – Arg – His
D Phe – Try – Ala – Ser – Val

[Turn over

12. The name of T lymphocytes is coined from the word 'thymus', the gland where the T lymphocyte matures. In the thymus, the T lymphocyte undergoes differentiation and maturation to form functional T lymphocytes. During differentiation, specific cell surface protein known as CD proteins are produced and inserted into the cell surface membrane.



Which of the statement is wrong about the production of CD protein?

A The ribosome synthesising the CD protein is attached to the rough endoplasmic reticulum.

B The promoter on the DNA is the start site of protein synthesis.

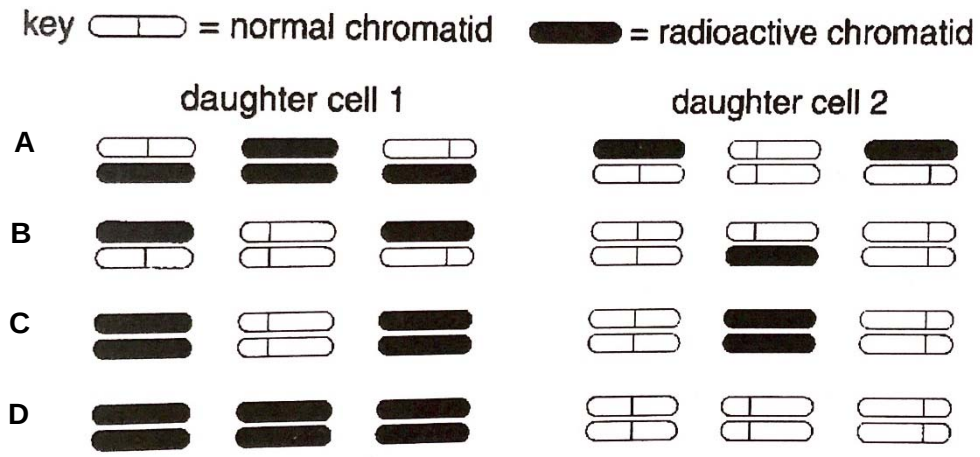
C CD protein must be processed in the Golgi body before insertion in the cell surface membrane.

D The type of CD protein inserted into the cell surface membrane determines the fate of the T lymphocyte.

13. The following experiment was carried out.

1 Haploid cells, containing three chromosomes each, were grown in a medium containing radioactive thymine, so that all the DNA was labelled.
2 Cells in early interphase were then transferred to a medium where the available thymine was not radioactive.
3 A single cell was immediately isolated and allowed to divide once. When the two daughter cells reached the next metaphase, they were fixed and their three chromosomes were inspected for radioactivity.

Which diagram represents the distribution of radioactivity at metaphase in the two daughter cells?



[Turn over

14. Which of the following statement(s) are true about the operon systems in prokaryote?

I Inducible operons can be switched on in the presence of regulatory protein that acts as repressor.

II Repressible operons are usually actively undergoing gene expression but are switched off in the presence of regulatory protein that acts as repressor.

III The co-repressor in trp operon is the trp repressor that binds to the operator of the trp operon.

IV The binding of trp repressors to the operators is reversible and the trp repressor is an allosteric protein.

V As the level of tryptophan increases, the repressors are able to bind to the operator to inhibit transcription of trp genes.

A **I, III** and **IV** only

B **II, III** and **V** only

C **I, IV** and **V** only

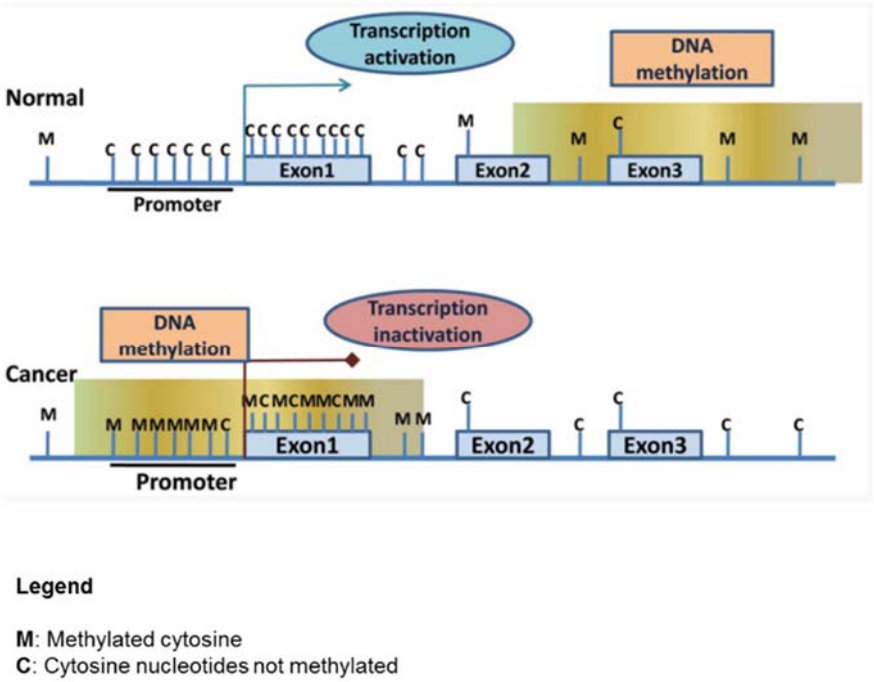
D **II, IV** and **V** only

15. Which option correctly compares the differences between gene expression in prokaryote and eukaryote?

	Transcriptional Control		Translational Control	
	Prokaryote	Eukaryote	Prokaryote	Eukaryote
A	RNA polymerase can only bind to promoter in the presence of transcription factors.	RNA polymerase can bind directly to promoter even without transcription factors.	Polycistronic mRNA directs the synthesis of several polypeptides.	Monocistronic mRNA directs synthesis of one polypeptide.
B	RNA polymerase can bind directly to promoter even without transcription factors.	RNA polymerase can only bind to promoter in the presence of transcription factors.	Polycistronic mRNA directs the synthesis of several polypeptides.	Monocistronic mRNA directs synthesis of one polypeptide.
C	RNA polymerase can only bind to promoter in the presence of transcription factors.	RNA polymerase can bind directly to promoter even without transcription factors.	Monocistronic mRNA directs synthesis of one polypeptide.	Polycistronic mRNA directs the synthesis of several polypeptides.
D	RNA polymerase can bind directly to promoter even without transcription factors.	RNA polymerase can only bind to promoter in the presence of transcription factors.	Monocistronic mRNA directs synthesis of one polypeptide.	Polycistronic mRNA directs the synthesis of several polypeptides.

16. DNA methylation is a common modification in mammals, plants and even bacteria. It occurs during DNA replication and involves covalent bond formation. In mammals, DNA methylation occurs mainly in CpG islands, regions of nucleotides with high frequency of cytosine and guanine nucleotides. DNA methylation may affect cell differentiation and cell cycle progression. This implies that DNA methylation patterns are often tissue-specific, affecting certain cells under different situations.

The following diagram shows the difference in DNA methylation pattern in normal and cancer cells.



Chen, Q.W., Zhu, X.Y., Li, Y.Y., & Meng, Z.Q. (2014). Epigenetic regulation and cancer (Review). Oncology Reports, 31, 523-532. https://doi.org/10.3892/or.2013.2913

Which of the following statement is true about DNA methylation in normal and cancer cells?

A In normal cells, CpG islands in active promoters are not methylated and thus lead to transcriptional activation. However, in cancer cells, CpG islands in promoter are methylated and thus inhibit transcriptional activation.

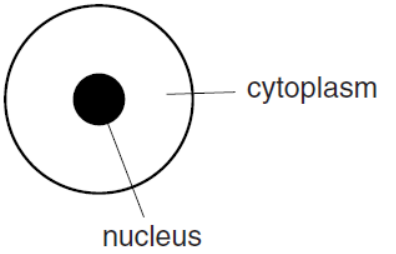
B In normal cells, CpG islands in active promoters are methylated and thus lead to transcriptional activation. However, in cancer cells, CpG islands in promoter are not methylated and thus inhibit transcriptional activation.

C In cancer cells, CpG islands in active promoters are methylated and this changes the heterochromatic structure to euchromatic structure.

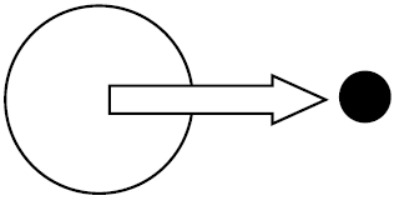
D In cancer cells, CpG islands in active promoters are methylated and this allows the expression of downstream genes coding for cell proliferation.

Use the following information to answer question **17** and **18**.

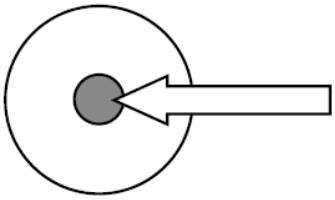
A cybrid is a cytoplasmic hybrid cell. The process of producing the cybrid cells is shown in the following diagram.



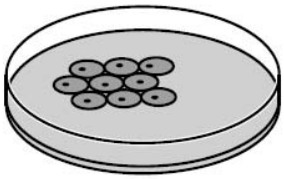
Ovum taken from a cow.



Remove intact nucleus and discard.

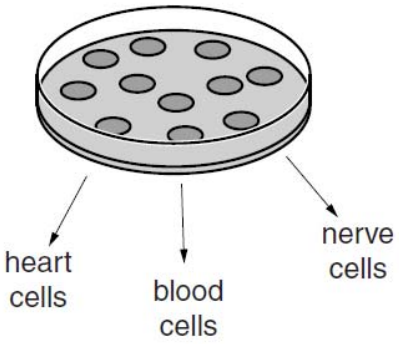


Insert intact nucleus of human cell to produce a cybrid.



The cybrid is then transferred to a Petri dish containing culture medium. The cell divides to the blastocyst stage. Under UK regulations the blastocysts may not be allowed to develop beyond 14 days.

Cybrids now grow and divide to produce stem cells.



Add different chemical substances to cause differentiation into different cell types for research, e.g. into Parkinson's disease.

17. Which of the following statements about the cybrid cell are true?

I Genes expressed in the blastocyst are of cow and human origin.
II The blastocysts formed from the cybrid cell contains genome from the cow.
III Chemical substances such as transcription factors are used to induce differentiation of stem cells.
IV The cybrid cells will not be rejected during implantation into human host.

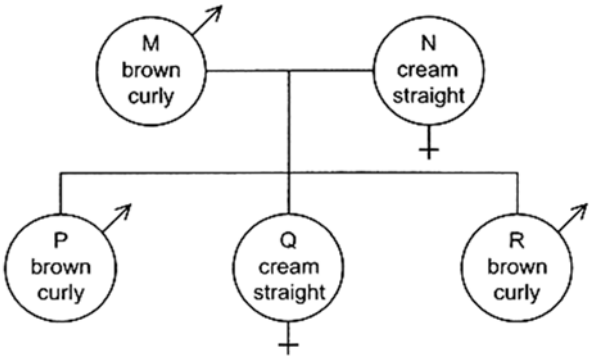
A **I** and **II** only
B **I** and **III** only
C **II** and **III** only
D **III** and **IV** only

18. Which of the following statement does not agree that the production of cybrid is an ethical procedure?

A The restriction of growing the blastocyst beyond 14 days because the brain and spinal cord are formed after 14 days.
B A human life is not destroyed during the production of cybrid cell.
C The presence of both human and animal genome implies that the resulting cell is not natural.
D Able to produce a higher number of stem cells as compared to the extraction of embryonic stem cells.

19. Assume that in goats a pair of alleles is responsible for the inheritance of hair colour and that another pair controls hair texture. These pairs are located on different autosomes. The allele for brown hair (B) is dominant to the allele for cream hair (b), and the allele for curly hair (C) is dominant to the allele for straight hair (c).

The diagram shows a cross between two goats.



If **P** is mated with a female goat of the same genotype as **M**, what are the chances of the first offspring being a male with cream coloured, straight hair?

A 0
B 1 in 4
C 1 in 16
D 1 in 32

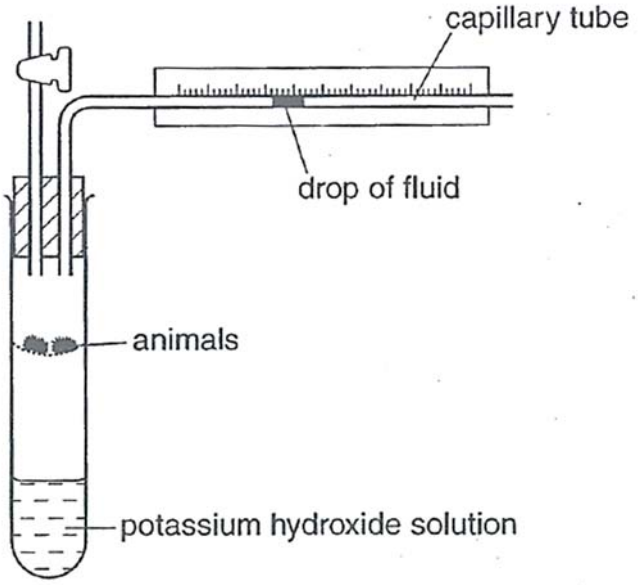
20. Possession of white or coloured feathers in poultry is controlled by two genes, A/a and B/b. Two birds that are heterozygous at both loci were crossed and the results are shown in the following table.

gametes	AB	Ab	aB	ab
AB	white feathers	white feathers	white feathers	white feathers
Ab	white feathers	white feathers	white feathers	white feathers
aB	white feathers	white feathers	coloured feathers	coloured feathers
ab	white feathers	white feathers	coloured feathers	white feathers

What best explains the inheritance of white and coloured feathers?

A recessive epistasis in which the epistatic allele is **A**
B recessive epistasis in which the epistatic allele is **B**
C dominant epistasis in which the epistatic allele is **A**
D dominant epistasis in which the epistatic allele is **B**

21. A respirometer was set up to investigate the rate of respiration of animals as shown below.

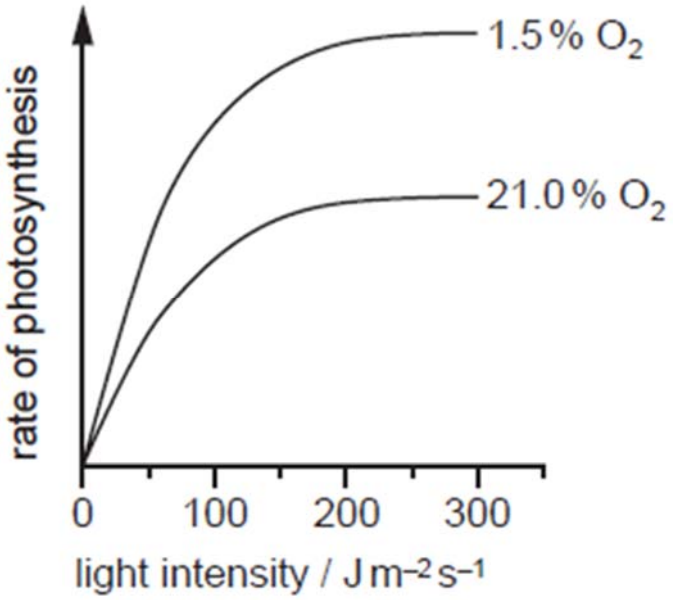


The results show that the drop of fluid moved to the left significantly more than expected. Mitochondria from the animals were isolated to investigate the cause.

Which of the following could best explain the results?

A ATP synthase is hyperactive.
B Higher than normal amount of grana observed.
C Proton pump is decoupled with the electron carriers.
D Cytochrome *b* in the electron transport chain was non-functional.

22. The following graph shows the effect of light intensity on the rate of photosynthesis of a plant at two different concentrations of oxygen. The investigation was made at atmospheric carbon dioxide concentrations.



Which of the following statement best describes the investigation?

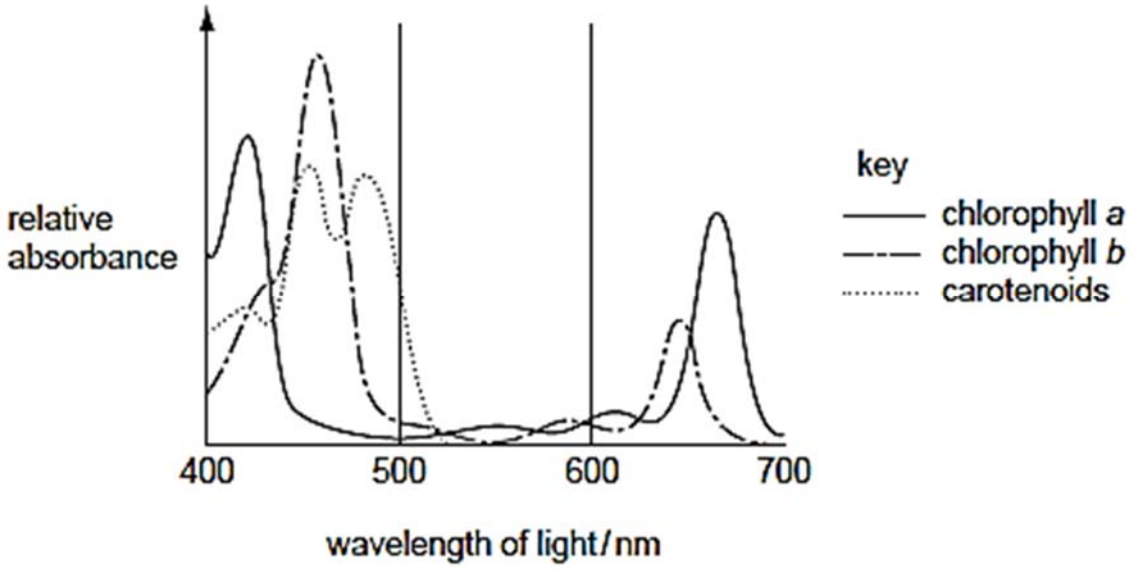
A The higher the light intensity, the higher the rate of photosynthesis.

B Level of oxygen produced is the only way to measure the rate of photosynthesis.

C The investigation should be performed at the optimal temperature to produce valid results.

D The concentration of oxygen must be 1.5% to produce maximum rate of photosynthesis.

23. The following graph shows the absorption spectra of photosynthetic pigments.



Which statements are correct?

I Having several pigments increase the efficiency of photosynthesis.

II Most leaves are green as chlorophyll absorbs light in the blue and red regions of the spectrum.

III Photosynthesis will be fastest in light at the red end of the spectrum as red light has higher energy than blue light.

IV Chlorophyll is broken down during leaf fall, leaving the leaves to appear yellow or red due to carotenoid.

A **I** and **II** only

B **I** and **III** only

C **I**, **II** and **IV** only

D **II** and **IV** only

24. Cystic fibrosis (CF) is a fatal genetic disease that affects the lung and causes a variety of symptoms such as persistent cough, bowel disturbance and infertility. There is currently no cure for the disease.

Approximately 1 in 25 people of Northern European descent carry the most common allele causing CF. The mutant allele expressed a protein with one missing amino acid as compared to the normal allele. To have CF, a child must inherit 1 copy of the CF gene mutation from each parent.

Gut cells with a single copy of this mutant allele took up 80% fewer *S. typhi* than normal cells. The bacterium causes the gut infection typhoid fever.

Which suggestion could provide an explanation for the number of people in Northern Europe carrying this mutant allele?

A The selective advantage of the heterozygotes prevents the selective pressure against individuals with CF from removing the recessive allele from the population.

B The selective disadvantage of the heterozygotes prevents the selective pressure against individuals with CF from removing the recessive allele from the population.

C The selective pressure against individuals with CF and the selective advantage of the heterozygotes are removing the dominant allele from the population.

D The selective pressure against individuals with CF and the selective disadvantage of the heterozygotes are removing the recessive allele from the population.

25. Speciation takes the form of either allopatric speciation or sympatric speciation.

Which sequence of events is considered most likely to lead to speciation?

A	adaptation of population	→	competition and predation leading to natural selection	→	behavioural isolation	→	allopatric speciation
B	adaptation of population	→	competition and predation leading to natural selection	→	behavioural isolation	→	sympatric speciation
C	competition and predation leading to natural selection	→	geographical isolation	→	adaptation of isolated populations	→	sympatric speciation
D	competition and predation leading to natural selection	→	geographical isolation	→	adaptation of isolated populations	→	allopatric speciation

26. Which of the following event occurs after glucagon binds to the specific receptor?

A Glucagon binds to the extracellular binding site of G-protein coupled receptor and leads to auto-phosphorylation of the cytoplasmic tail of the receptor.

B Glucagon binds to the extracellular binding site of receptor tyrosine kinase, recruiting the G protein and activates adenylate cyclase.

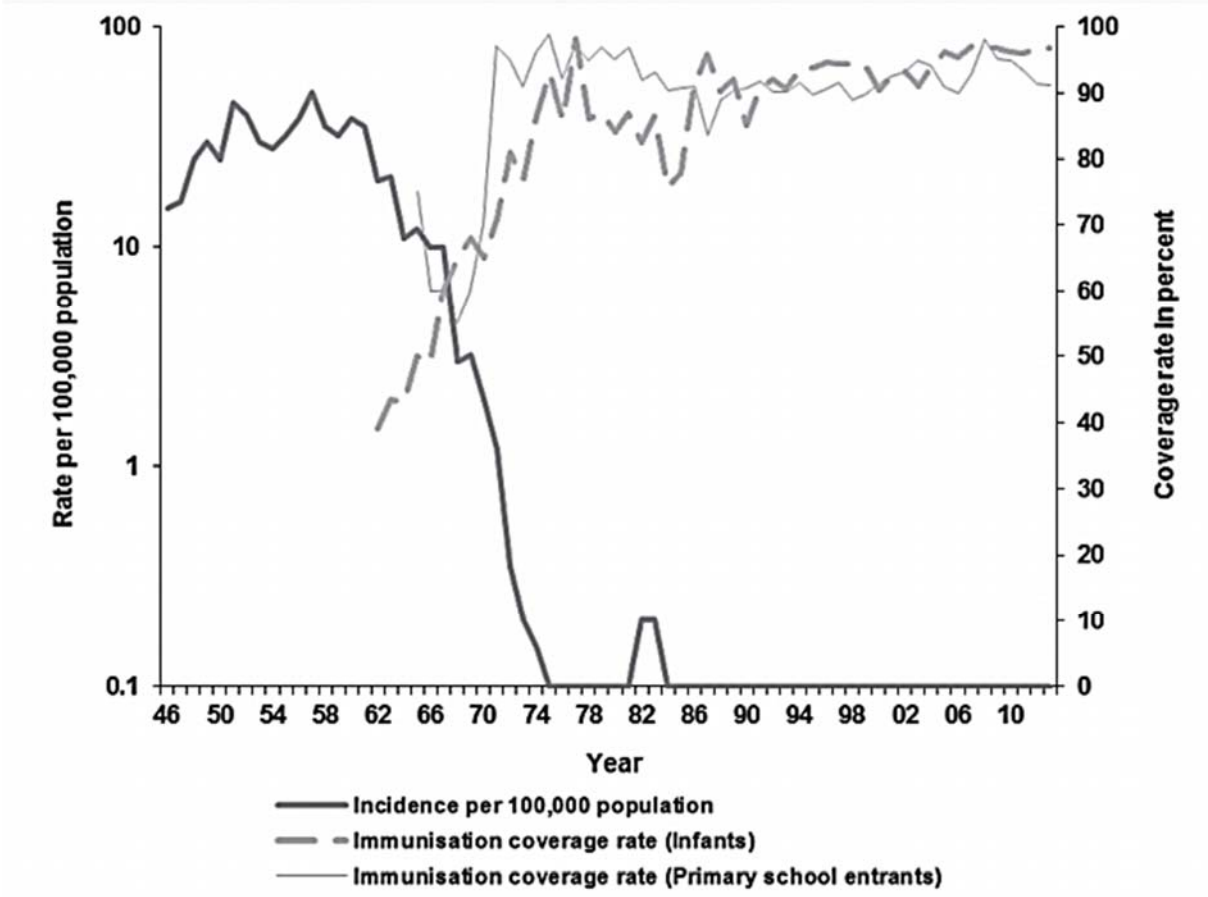
C Glucagon binds to the extracellular binding site of G-protein coupled receptor and changes the conformation of G-protein coupled receptor, activating the receptor.

D Glucagon binds to the extracellular binding site of receptor tyrosine kinase, causing the two kinases to form a dimer.

Use the following information to answer question **27** and **28**.

The following graph shows the incidence per 100 000 populations from diphtheria and immunisation coverage rate in Singapore from 1946 to 2013.

In Singapore, immunisation against diphtheria is compulsory by law. A child received the first dose at the age of 3 months, second dose at the age of 4 months and the third dose at the age of 5 months. The first booster dose is then given at the age of 18 months, followed by a second booster at the age of 11 years old.



27. Which statement best describes the changes in incidence rate and immunisation rate?

A The rate of diphtheria infection decreases as the immunisation coverage rates increase.

B The immunisation coverage rate in infants directly correlates with the immunisation coverage rate in primary school entrants.

C The incidence of diphtheria infection follows a seasonal trend.

D The immunisation coverage rate can never achieve 100%.

28. Which statement best describes the immunisation against diphtheria?

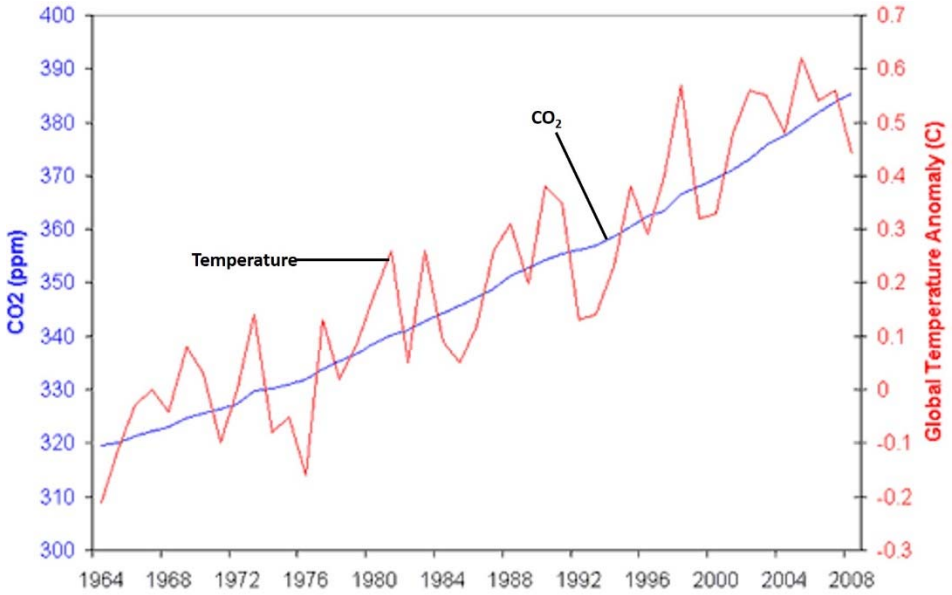
A Immunisation is a form of passive immunity.

B Herd immunity was established and this made the disease impossible to spread.

C Individual can still be protected from diphtheria without the booster shot.

D Booster shot is no longer necessary after 11 years ago as the antibody produced can last a lifetime after 11 years old.

29. The following graph shows the global CO_2 levels and global temperature anomaly from 1964 to 2008. Global temperature anomaly compares that year's average temperature to a long term average.



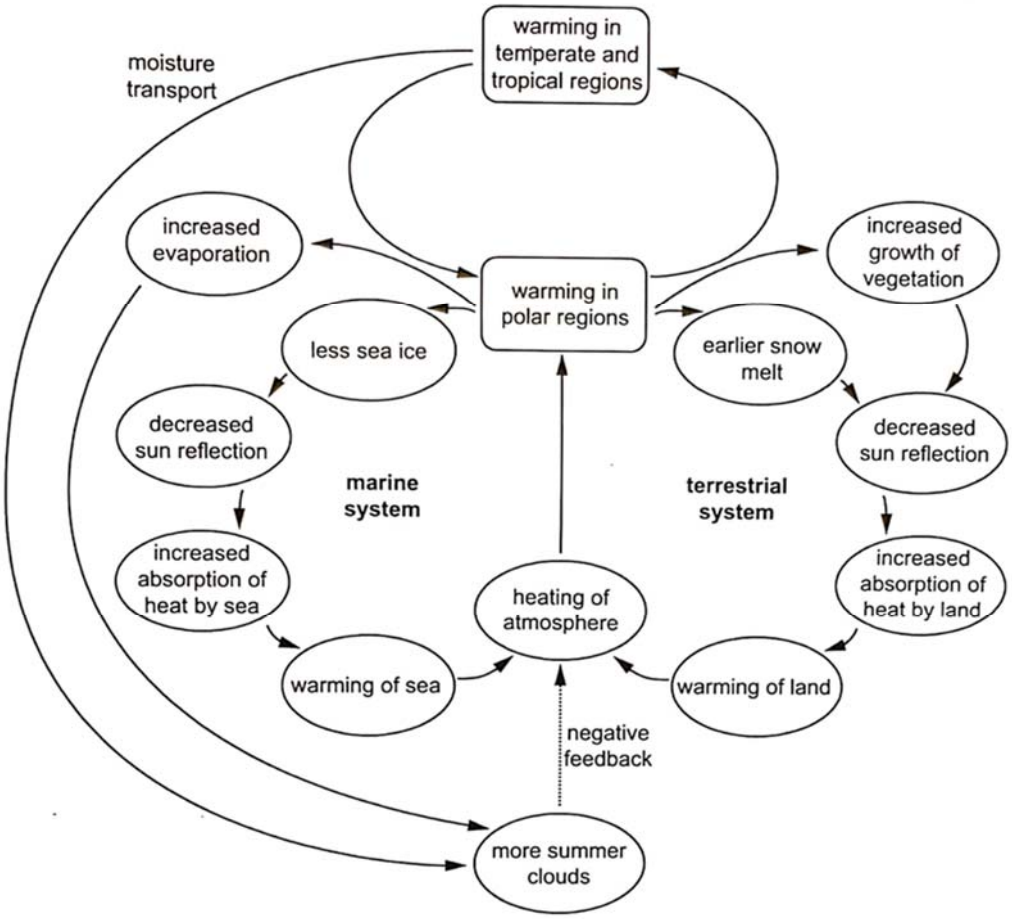
The following are some statements made by some students on the global CO_2 levels and global temperature anomaly.

Student **A**: Between 1964 to 2008, the highest temperature recorded must be in 2006.
Student **B**: Between 1964 to 2008, the global temperature fluctuates from -0.2^{o}C to 0.45^{o}C.
Student **C**: Between 1964 to 2008, the global CO_2 level increases from 320 ppm to 385 ppm.
Student **D**: Between 1964 to 2008, increase in temperature leads to the increase in global CO_2 level.

Which students made the correct deductions?

A Student **A** and **B**
B Student **B** and **C**
C Student **C** and **D**
D Student **B** and **D**

30. The diagram shows the effect of increasing temperatures on the ice and snow cover at the polar regions.



Which effect of higher temperatures in the polar regions could increase global warming?

A Increased evaporation leads to more rainfall, which absorbs heat from the land and sea.

B Melting of sea ice causes more cloud formation which increases absorption of heat in the atmosphere.

C Earlier melting of snow allows vegetation cover to increase faster, reducing loss of heat from the surface of the Earth.

D Melting of ice and snow results in less reflection of sunlight and more heat absorption by the earth.

End of Paper

Class Adm No

Candidate Name: _____

H

millennia institute

2018 Preliminary Exams
Pre-University 3

BIOLOGY **9744/01**

Paper 1 Multiple Choice **19 September 2018**

1 hour

Additional Materials: Optical Answer Sheet

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.
Write your name, Adm No. and class on all the papers you hand in.

There are **thirty** questions in this paper. Answer **all** questions. For each question, there are four possible answers, **A**, **B**, **C** and **D**.
Choose the one you consider correct and record your choice in soft pencil on the separate answer sheet.

Each correct answer will score one mark. A mark will not be deducted for wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

1. The first description of cell was attributed to microscopist, Robert Hooke, who was observing a slice of cork under the microscope. He termed his observation, *cella*, a latin word meaning 'a small room'. This observation later helped establish the cell theory.

Which of the following is correct about the cell theory?

Ans : D

A The theory suggests the cells are produced spontaneously.

B The theory agrees that virus follows the definition of cell.

C The theory was developed based on Robert Hooke's observation only.

D The theory could not be applied to all types of tissues.

2. The endosymbiotic theory states that mitochondria and chloroplasts originate from primitive bacterial cell. The symbiotic relationship is established when two different species benefit from each other. Further study suggests that mitochondria and chloroplast originate from aerobic and photosynthetic prokaryote respectively.

Which of the following biomolecule found in mitochondria and chloroplast best suggests that they once originate from prokaryote?

Ans : D

A Carbohydrate

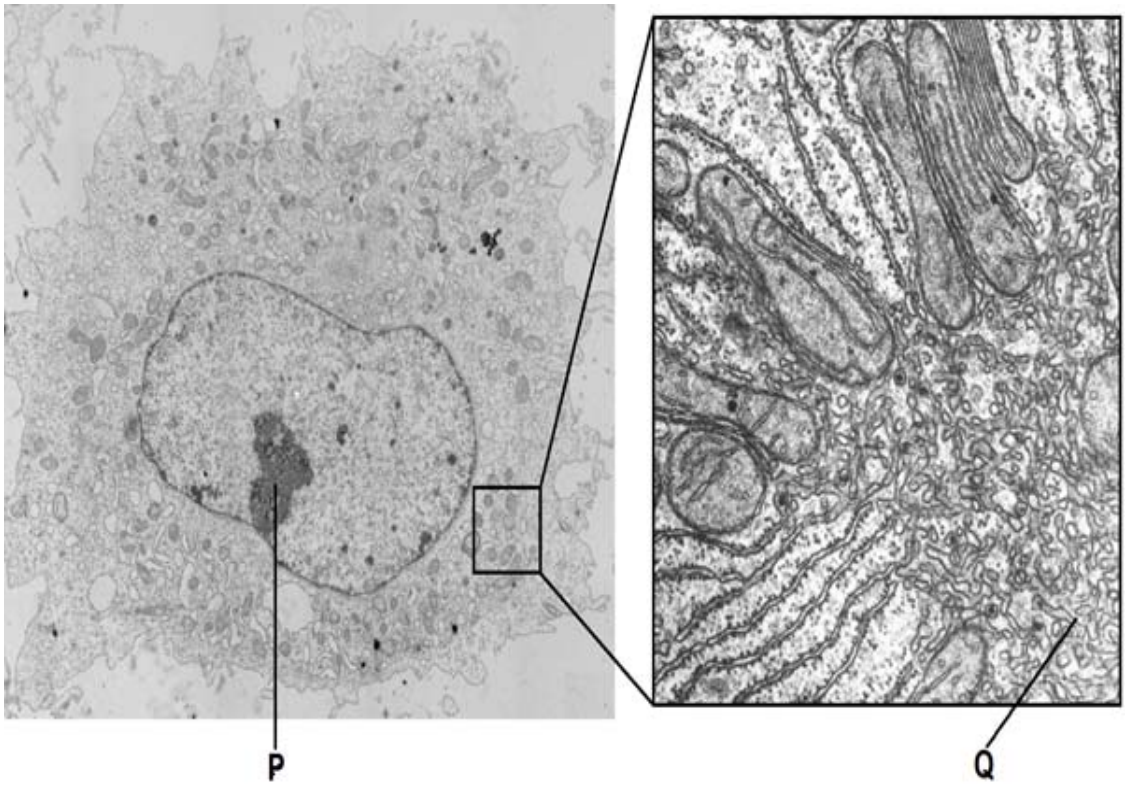
B Lipid

C Protein

D Nucleic acid

3. The following diagram on the left shows the electro-micrograph of a cell found in a healthy individual. A region of the cell, indicated by the box, is magnified and shown in the diagram on the right.

Ans : C



Which of the following shows the correct identities and functions of **P** and **Q**?

	Identity of P	**Function of P**	**Identity of Q**	**Function of Q**
A	Nucleosome	Transcription of rRNA	Smooth ER	Detoxification
B	Nucleosome	Assembly of ribosomes	Secretary vesicles	Storage of Ca^{2+}
C	Nucleolus	Assembly of ribosomes	Smooth ER	Synthesis of lipids
D	Nucleolus	Transcription of rRNA	Secretary vesicles	Modification of protein

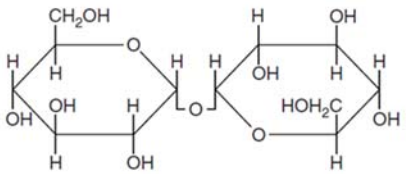
4. Which row shows features of a typical prokaryotic cell?

Ans : C

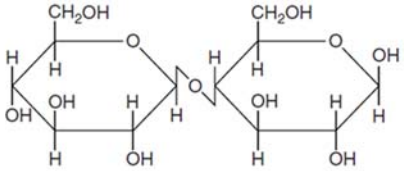
	Cell size	Nucleus	DNA	Ribosome size
A	>10 μm	Absent	Circular	70S
B	>10 μm	Present	Linear	80S
C	<10 μm	Absent	Circular	70S
D	<10 μm	present	linear	80S

5. Polysaccharide, disaccharide and monosaccharides are different forms of carbohydrates. Cellobiose, maltose, sucrose and trehalose are four different disaccharides. The following diagram shows the molecular structure of these disaccharides.

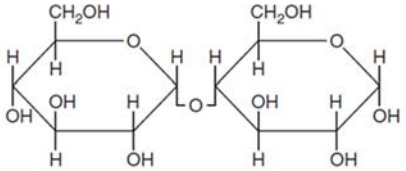
I



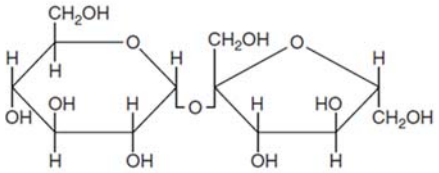
III



II



IV



Using the information below, which option correctly identifies disaccharides **I** to **IV**?

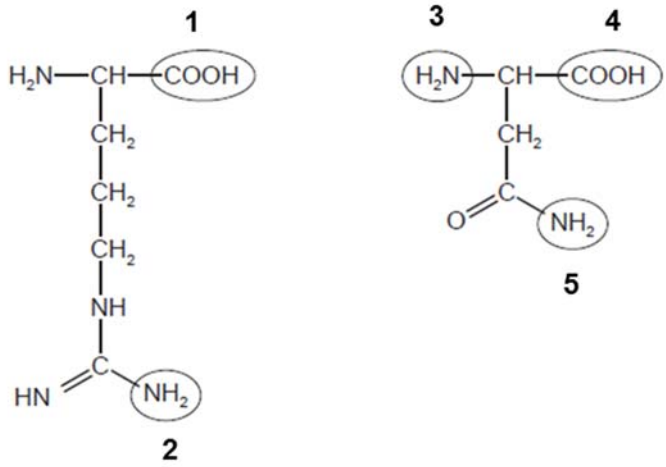
Ans : B

- Cellobiose is formed from the hydrolysis of cellulose.
- Hydrolysis of cellobiose produces β-glucose.
- Trehalose is synthesised from two α–glucose.
- Maltose is formed from the hydrolysis of amylose.

	Cellobiose	Maltose	Sucrose	Trehalose
A	**III**	**I**	**IV**	**II**
B	**III**	**II**	**IV**	**I**
C	**IV**	**I**	**III**	**II**
D	**IV**	**II**	**III**	**I**

6. The diagram shows the structures of two amino acids, each of which has more than one amine ($-NH_2$) group.

Ans : A



Which of the two groups form the peptide bond that holds the two amino acids?

A **1** and **3**

B **1** and **5**

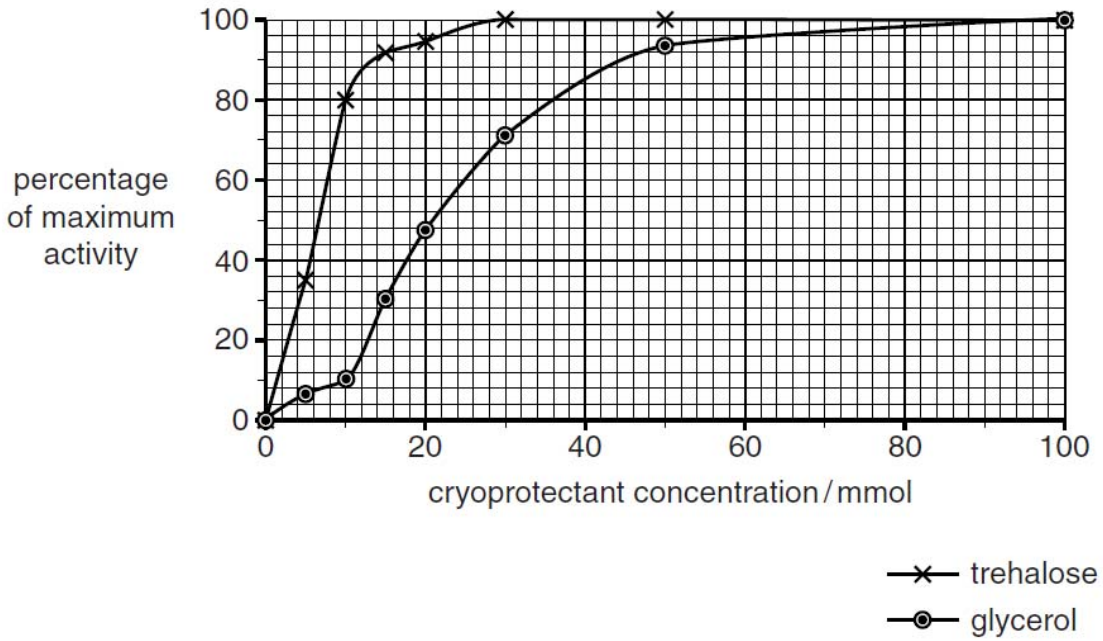
C **2** and **4**

D **2** and **5**

7. An investigation was carried out to find out the protective effect of different concentrations of two cryoprotectants, trehalose and glycerol, on the activity of an enzyme. The enzyme was first incubated at freezing temperature, followed by incubating at its optimum temperature. The percentage of maximum activity of the enzyme was measured at its optimum temperature.

Ans : D

The following diagram shows the results of the investigation.



Which of the statement correctly describes the investigation?

A The enzymes were denatured after incubating at freezing temperature.

B Glycerol is a more effective cryoprotectant than trehalose.

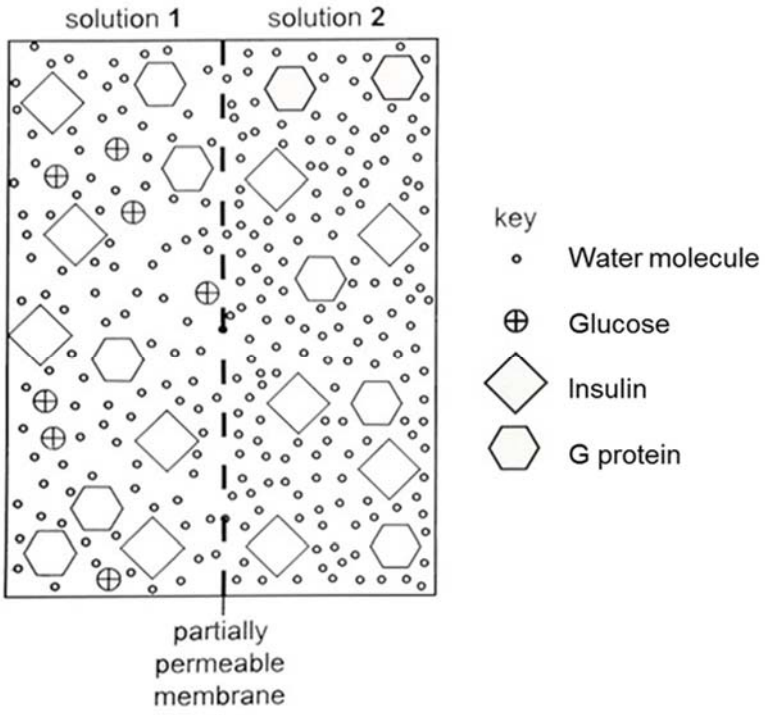
C In the absence of cryoprotectant, the enzyme remains inactive.

D At all concentrations, trehalose results in a higher percentage of maximum enzyme activity.

8. The diagram represents an artificial partially permeable membrane separating two solutions, **1** and **2**.

Ans : D

The relative diameters and concentrations of the ions and molecules in the solutions and the pore diameter of the artificial partially permeable membrane are drawn proportionally in the diagram.



Which statement about the movement of the molecules between solution **1** and **2** is correct?

A The difference in water potential causes water to move by osmosis from solution **1** to solution **2**, a diffusion gradient causes net movement of glucose from solution **1** to solution **2**, and insulin and G protein to not move between the two solutions.

B Solution **1** has a lower water potential than solution **2**, causing net movement of water from solution **2** to solution **1** until the water potentials are the same; all the other molecules are too large to pass through the artificial partially permeable membrane.

C Insulin and G protein pass through the artificial partially permeable membrane equally in both directions because they are of the same concentration in solution **1** and solution **2**, but glucose and water diffuse in opposite directions until the concentrations of solution **1** and solution **2** are equal.

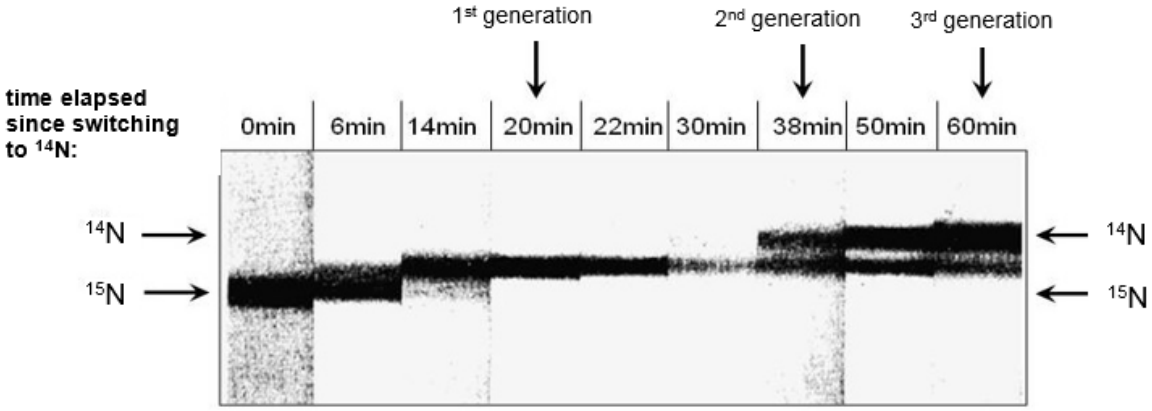
D Net movement of water occurs down a water potential gradient from solution **2** to solution **1**, net movement of glucose occurs down a diffusion gradient from solution **1** to solution **2**, and no movement of insulin and G protein occurs across the artificial partially permeable membrane.

9. In an investigation to study the mode of DNA replication, *Escherichia coli* (*E. coli*) cells were grown in a nutrient medium containing heavy isotope of nitrogen (^{15}N) for an extended period of time until all the DNA was labelled.

These *E. coli* cells were then transferred to a nutrient medium containing only light isotope of nitrogen (^{14}N) and were allowed to multiply over three generations. The DNA of the *E. coli* cells was then harvested at nine different time intervals.

Subsequently, density gradient centrifugation of these *E. coli* DNA using caesium chloride was performed.

The diagram shows the results obtained.



Ans : B

Which statements are consistent with the results observed?

I There was no evidence of semi-conservative DNA replication.
II In the 1st generation, only hybrid $^{14}N/^{15}N$ DNA was produced.
III In the second generation, 50% of $^{14}N/^{15}N$ DNA and 50% light $^{14}N/^{14}N$ DNA were produced.
IV In the 3rd generation, 75% hybrid $^{14}N/^{15}N$ DNA and 25% light $^{14}N/^{14}N$ DNA were produced.
V In the subsequent 4th generation, it is impossible to deduce the amount of DNA with ^{15}N.

A **I** and **II** only
B **II** and **III** only
C **III** and **IV** only
D **II**, **III** and **IV** only

10. What is the minimum number of hydrogen bonds in a length of DNA containing 800 nucleotides?

A 800
B 1200
C 1600
D 2400

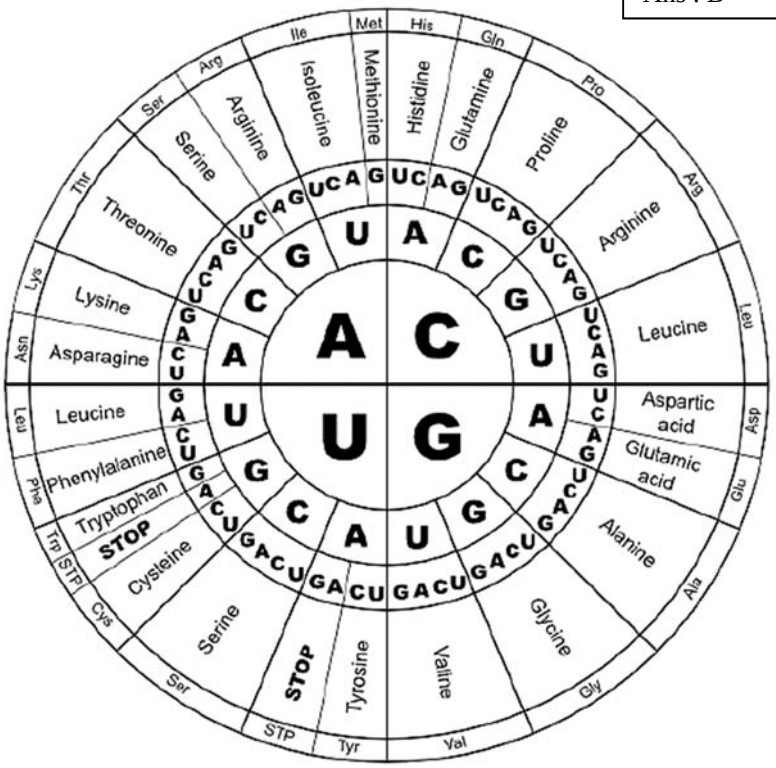
Ans : A

11. The first five DNA triplets that code for a particular protein is shown below:

3' CAC GGA AGC CCA GAA 5'

The genetic information in the sequence above is eventually converted into a specific amino acid sequence according to the figure below.

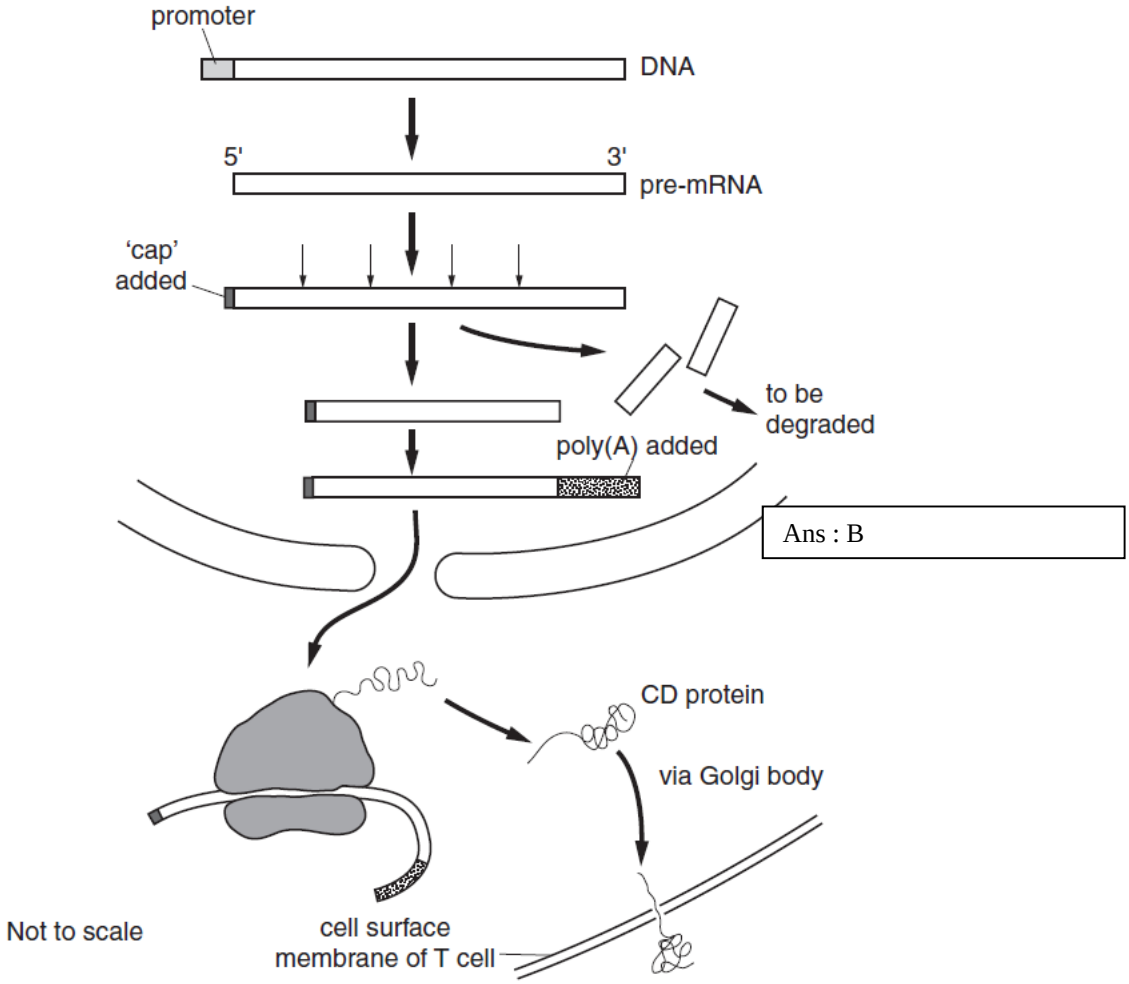
Ans : B



Using the given information, what is the sequence of the protein encoded by the DNA sequence above?

A His – Gly – Ser – Pro – Glu
B Val – Pro – Ser – Gly – Leu
C Lys – Thr – Arg – Arg – His
D Phe – Try – Ala – Ser – Val

12. The name of T lymphocytes is coined from the word 'thymus', the gland where the T lymphocyte matures. In the thymus, the T lymphocyte undergoes differentiation and maturation to form functional T lymphocytes. During differentiation, specific cell surface protein known as CD proteins are produced and inserted into the cell surface membrane.



Ans : B

Which of the statement is wrong about the production of CD protein?

A The ribosome synthesising the CD protein is attached to the rough endoplasmic reticulum.

B The promoter on the DNA is the start site of protein synthesis.

C CD protein must be processed in the Golgi body before insertion in the cell surface membrane.

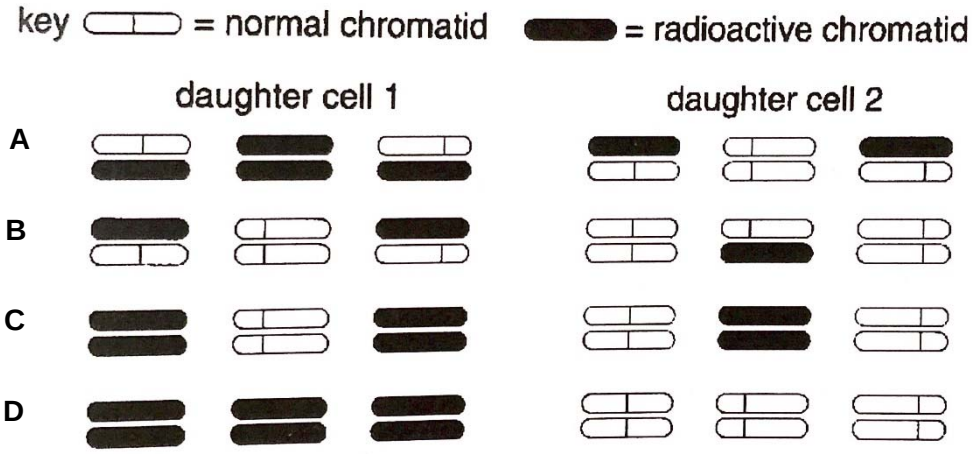
D The type of CD protein inserted into the cell surface membrane determines the fate of the T lymphocyte.

Ans : B

13. The following experiment was carried out.

1 Haploid cells, containing three chromosomes each, were grown in a medium containing radioactive thymine, so that all the DNA was labelled.
2 Cells in early interphase were then transferred to a medium where the available thymine was not radioactive.
3 A single cell was immediately isolated and allowed to divide once. When the two daughter cells reached the next metaphase, they were fixed and their three chromosomes were inspected for radioactivity.

Which diagram represents the distribution of radioactivity at metaphase in the two daughter cells?



[Turn over

14. Which of the following statement(s) are true about the operon systems in prokaryote?

Ans : D

I Inducible operons can be switched on in the presence of regulator acts as repressor.

II Repressible operons are usually actively undergoing gene expression but are switched off in the presence of regulatory protein that acts as repressor.

III The co-repressor in trp operon is the trp repressor that binds to the operator of the trp operon.

IV The binding of trp repressors to the operators is reversible and the trp repressor is an allosteric protein.

V As the level of tryptophan increases, the repressors are able to bind to the operator to inhibit transcription of trp genes.

A **I, III** and **IV** only

B **II, III** and **V** only

C **I, IV** and **V** only

D **II, IV** and **V** only

15. Which option correctly compares the differences between gene expression in prokaryote and eukaryote?

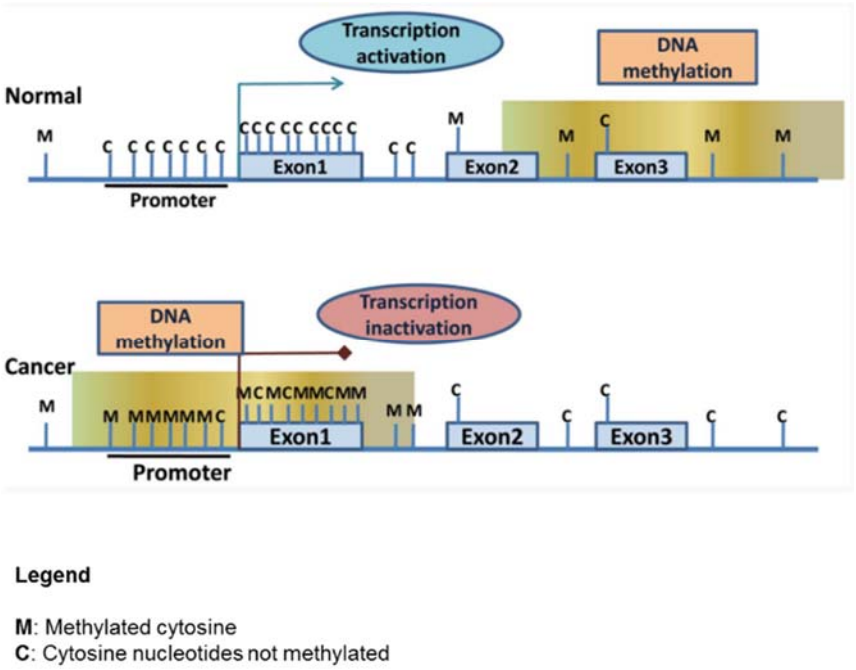
Ans : B

	Transcriptional Control		Translational Control	
	Prokaryote	Eukaryote	Prokaryote	Eukaryote
A	RNA polymerase can only bind to promoter in the presence of transcription factors.	RNA polymerase can bind directly to promoter even without transcription factors.	Polycistronic mRNA directs the synthesis of several polypeptides.	Monocistronic mRNA directs synthesis of one polypeptide.
B	RNA polymerase can bind directly to promoter even without transcription factors.	RNA polymerase can only bind to promoter in the presence of transcription factors.	Polycistronic mRNA directs the synthesis of several polypeptides.	Monocistronic mRNA directs synthesis of one polypeptide.
C	RNA polymerase can only bind to promoter in the presence of transcription factors.	RNA polymerase can bind directly to promoter even without transcription factors.	Monocistronic mRNA directs synthesis of one polypeptide.	Polycistronic mRNA directs the synthesis of several polypeptides.
D	RNA polymerase can bind directly to promoter even without transcription factors.	RNA polymerase can only bind to promoter in the presence of transcription factors.	Monocistronic mRNA directs synthesis of one polypeptide.	Polycistronic mRNA directs the synthesis of several polypeptides.

16. DNA methylation is a common modification in mammals, plants and even bacteria. It occurs during DNA replication and involves covalent bond formation. In mammals, DNA methylation occurs mainly in CpG islands, regions of nucleotides with high frequency of cytosine and guanine nucleotides. DNA methylation may affect cell differentiation and cell cycle progression. This implies that DNA methylation patterns are often tissue-specific, affecting certain cells under different situations.

Ans : A

The following diagram shows the difference in DNA methylation pattern in normal and cancer cells.



Chen, Q.W., Zhu, X.Y., Li, Y.Y., & Meng, Z.Q. (2014). Epigenetic regulation and cancer (Review). Oncology Reports, 31, 523-532. https://doi.org/10.3892/or.2013.2913

Which of the following statement is true about DNA methylation in normal and cancer cells?

A In normal cells, CpG islands in active promoters are not methylated and thus lead to transcriptional activation. However, in cancer cells, CpG islands in promoter are methylated and thus inhibit transcriptional activation.

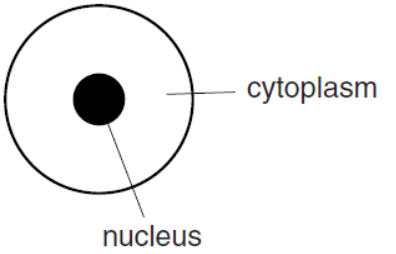
B In normal cells, CpG islands in active promoters are methylated and thus lead to transcriptional activation. However, in cancer cells, CpG islands in promoter are not methylated and thus inhibit transcriptional activation.

C In cancer cells, CpG islands in active promoters are methylated and this changes the heterochromatic structure to euchromatic structure.

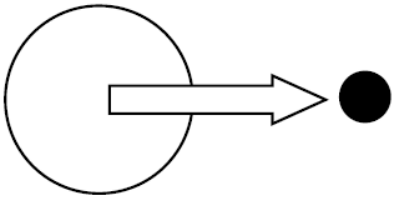
D In cancer cells, CpG islands in active promoters are methylated and this allows the expression of downstream genes coding for cell proliferation.

Use the following information to answer question **17** and **18**.

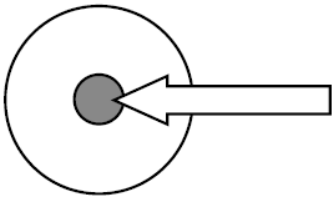
A cybrid is a cytoplasmic hybrid cell. The process of producing the cybrid cells is shown in the following diagram.



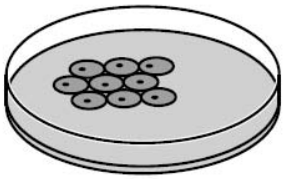
Ovum taken from a cow.



Remove intact nucleus and discard.

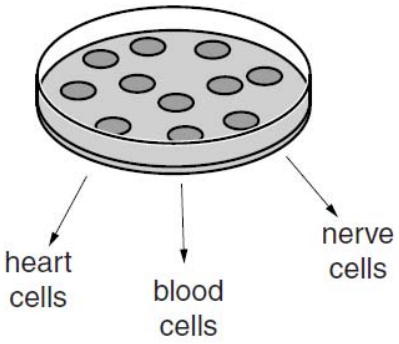


Insert intact nucleus of human cell to produce a cybrid.



The cybrid is then transferred to a Petri dish containing culture medium. The cell divides to the blastocyst stage. Under UK regulations the blastocysts may not be allowed to develop beyond 14 days.

Cybrids now grow and divide to produce stem cells.



Add different chemical substances to cause differentiation into different cell types for research, e.g. into Parkinson's disease.

17. Which of the following statements about the cybrid cell are true?

I Genes expressed in the blastocyst are both of cow and human origin.
II The blastocysts formed from the cybrid cell contains genome from the cow.
III Chemical substances such as transcription factors are used to induce differentiation of stem cells.
IV The cybrid cells will not be rejected during implantation into human host.

A **I** and **II** only
B **I** and **III** only
C **II** and **III** only
D **III** and **IV** only

Ans : B

18. Which of the following statement does not agree that the production of cybrid is an ethical procedure?

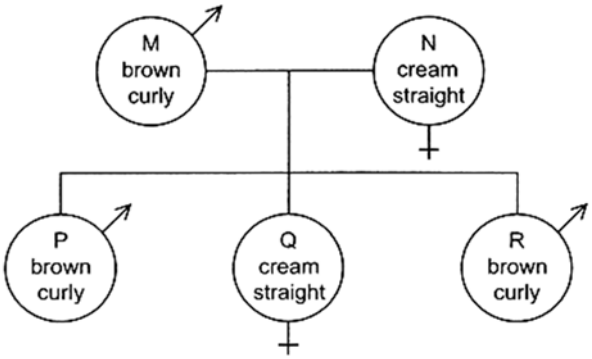
Ans : C

A The restriction of growing the blastocyst beyond 14 days because the brain and spinal cord are formed after 14 days.
B A human life is not destroyed during the production of cybrid cell.
C The presence of both human and animal genome implies that the resulting cell is not natural.
D Able to produce a higher number of stem cells as compared to the extraction of embryonic stem cells.

19. Assume that in goats a pair of alleles is responsible for the inheritance of hair colour and that another pair controls hair texture. These pairs are located on different autosomes. The allele for brown hair (B) is dominant to the allele for cream hair (b), and the allele for curly hair (C) is dominant to the allele for straight hair (c).

Ans : D

The diagram shows a cross between two goats.



If **P** is mated with a female goat of the same genotype as **M**, what are the chances of the first offspring being a male with cream coloured, straight hair?

A 0
B 1 in 4
C 1 in 16
D 1 in 32

20. Possession of white or coloured feathers in poultry is controlled by two genes, A/a and B/b. Two birds that are heterozygous at both loci were crossed and the results are shown in the following table.

Ans : C

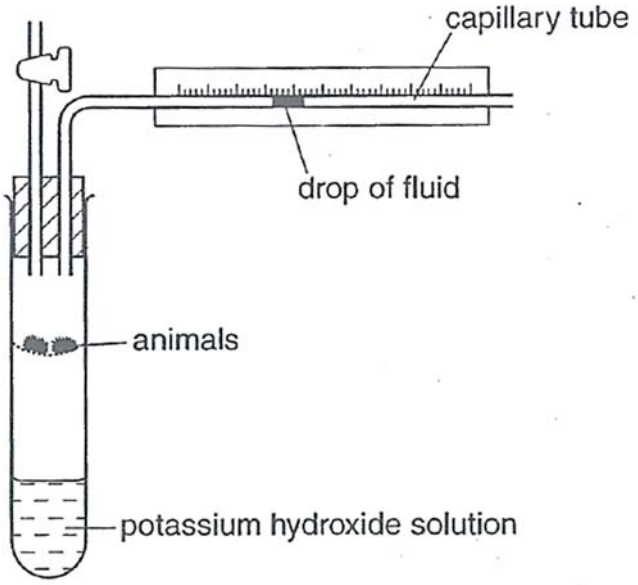
gametes	AB	Ab	aB	ab
AB	white feathers	white feathers	white feathers	white feathers
Ab	white feathers	white feathers	white feathers	white feathers
aB	white feathers	white feathers	coloured feathers	coloured feathers
ab	white feathers	white feathers	coloured feathers	white feathers

What best explains the inheritance of white and coloured feathers?

A recessive epistasis in which the epistatic allele is **A**
B recessive epistasis in which the epistatic allele is **B**
C dominant epistasis in which the epistatic allele is **A**
D dominant epistasis in which the epistatic allele is **B**

21. A respirometer was set up to investigate the rate of respiration of animals as shown below.

Ans : A



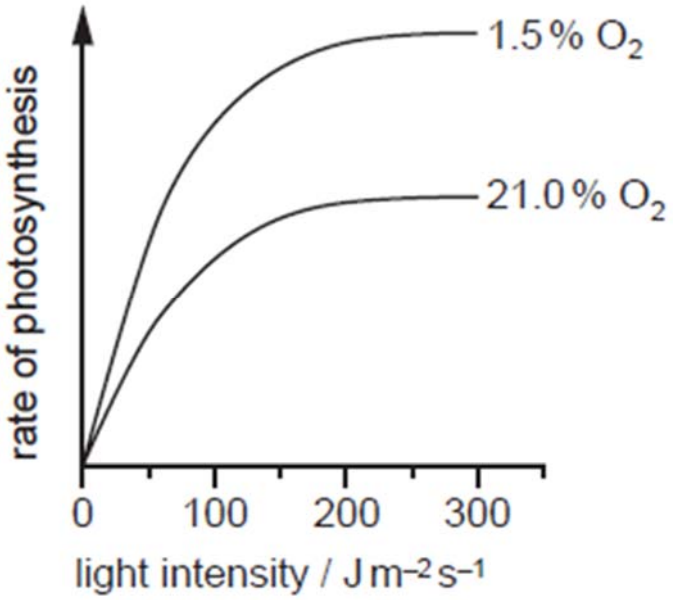
The results show that the drop of fluid moved to the left significantly more than expected. Mitochondria from the animals were isolated to investigate the cause.

Which of the following could best explain the results?

A ATP synthase is hyperactive.
B Higher than normal amount of grana observed.
C Proton pump is decoupled with the electron carriers.
D Cytochrome *b* in the electron transport chain was non-functional.

22. The following graph shows the effect of light intensity on the rate of photosynthesis of a plant at two different concentrations of oxygen. The investigation was made at atmospheric carbon dioxide concentrations.

Ans : C



Which of the following statement best describes the investigation?

A The higher the light intensity, the higher the rate of photosynthesis.

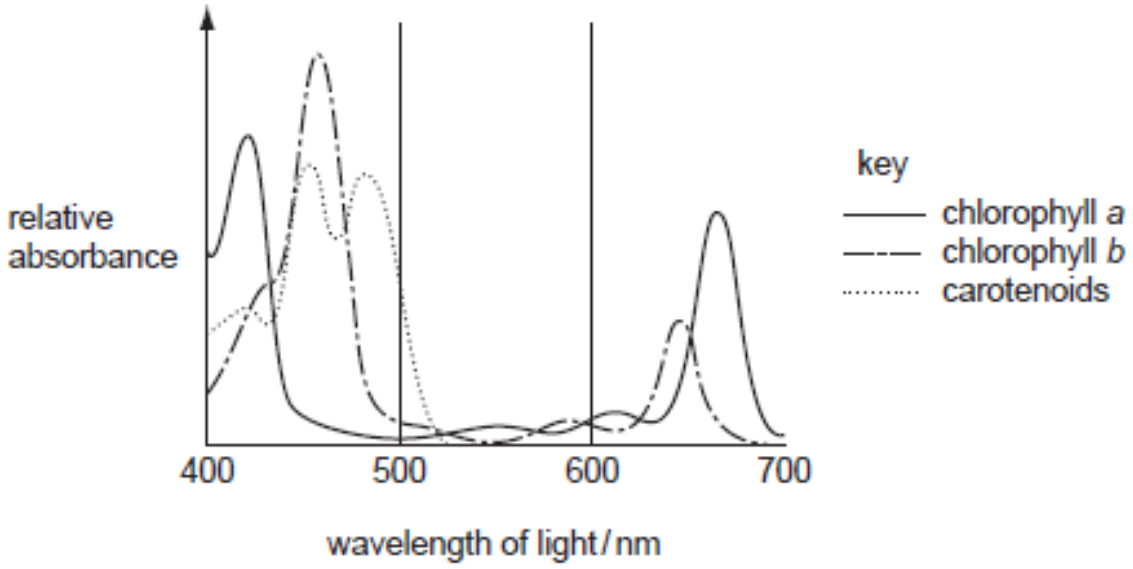
B Level of oxygen produced is the only way to measure the rate of photosynthesis.

C The investigation should be performed at the optimal temperature to produce valid results.

D The concentration of oxygen must be 1.5% to produce maximum rate of photosynthesis.

Ans : C

23. The following graph shows the absorption spectra of photosynthetic pigments.



Which statements are correct?

I Having several pigments increase the efficiency of photosynthesis.

II Most leaves are green as chlorophyll absorbs light in the blue and red regions of the spectrum.

III Photosynthesis will be fastest in light at the red end of the spectrum as red light has higher energy than blue light.

IV Chlorophyll is broken down during leaf fall, leaving the leaves to appear yellow or red due to carotenoid.

A **I** and **II** only

B **I** and **III** only

C **I**, **II** and **IV** only

D **II** and **IV** only

24. Cystic fibrosis (CF) is a fatal genetic disease that affects the lung and causes a variety of symptoms such as persistent cough, bowel disturbance and infertility. There is currently no cure for the disease.

Ans : A

Approximately 1 in 25 people of Northern European descent carry the most common allele causing CF. The mutant allele expressed a protein with one missing amino acid as compared to the normal allele. To have CF, a child must inherit 1 copy of the CF gene mutation from each parent.

Gut cells with a single copy of this mutant allele took up 80% fewer *S. typhi* than normal cells. The bacterium causes the gut infection typhoid fever.

Which suggestion could provide an explanation for the number of people in Northern Europe carrying this mutant allele?

A The selective advantage of the heterozygotes prevents the selective pressure against individuals with CF from removing the recessive allele from the population.

B The selective disadvantage of the heterozygotes prevents the selective pressure against individuals with CF from removing the recessive allele from the population.

C The selective pressure against individuals with CF and the selective advantage of the heterozygotes are removing the dominant allele from the population.

D The selective pressure against individuals with CF and the selective disadvantage of the heterozygotes are removing the recessive allele from the population.

Ans : D

25. Speciation takes the form of either allopatric speciation or sympatric speciation.

Which sequence of events is considered most likely to lead to speciation?

A	adaptation of population	→	competition and predation leading to natural selection	→	behavioural isolation	→	allopatric speciation
B	adaptation of population	→	competition and predation leading to natural selection	→	behavioural isolation	→	sympatric speciation
C	competition and predation leading to natural selection	→	geographical isolation	→	adaptation of isolated populations	→	sympatric speciation
D	competition and predation leading to natural selection	→	geographical isolation	→	adaptation of isolated populations	→	allopatric speciation

26. Which of the following event occurs after glucagon binds to the specific receptor?

Ans : C

A Glucagon binds to the extracellular binding site of G-protein coupled receptor and leads to auto-phosphorylation of the cytoplasmic tail of the receptor.

B Glucagon binds to the extracellular binding site of receptor tyrosine kinase, recruiting the G protein and activates adenylate cyclase.

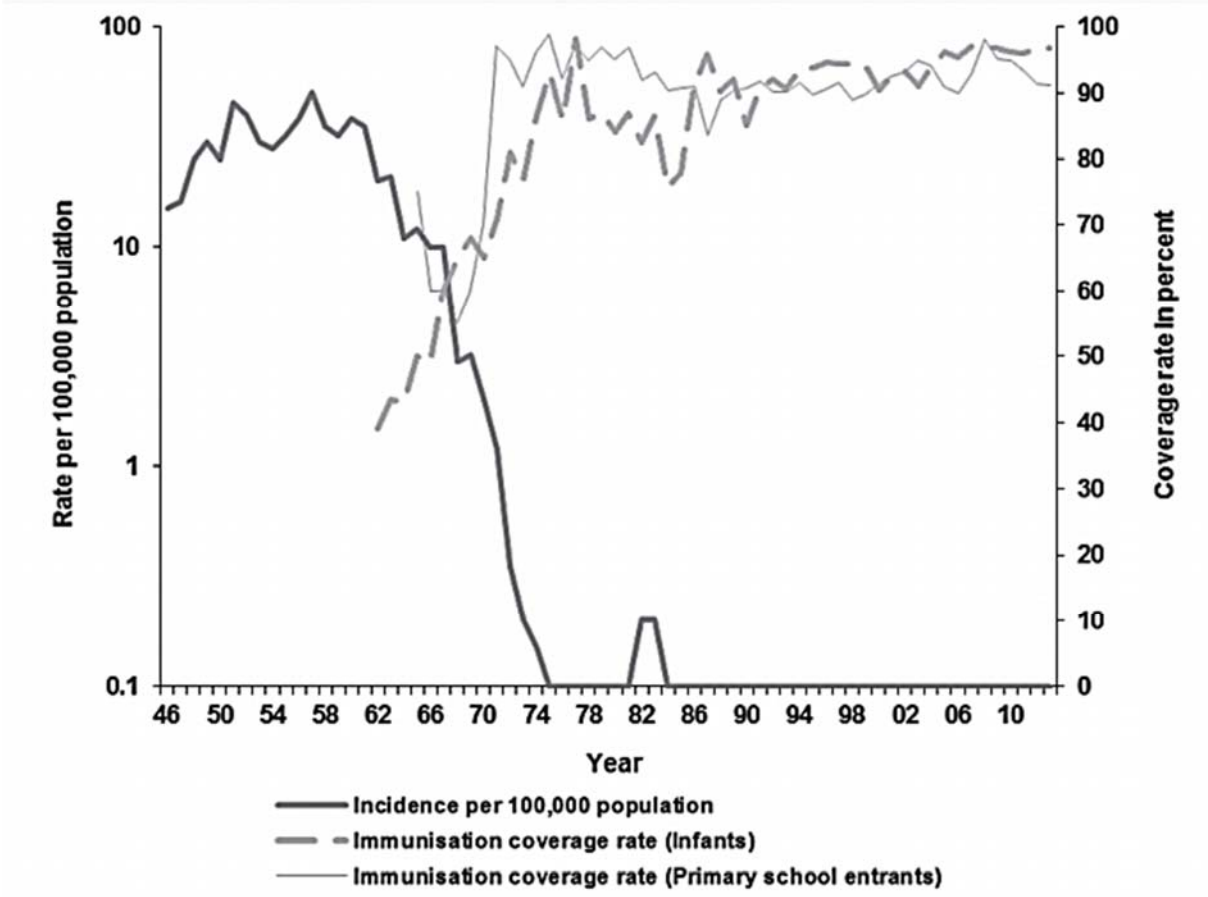
C Glucagon binds to the extracellular binding site of G-protein coupled receptor and changes the conformation of G-protein coupled receptor, activating the receptor.

D Glucagon binds to the extracellular binding site of receptor tyrosine kinase, causing the two kinases to form a dimer.

Use the following information to answer question **27** and **28**.

The following graph shows the incidence per 100 000 populations from diphtheria and immunisation coverage rate in Singapore from 1946 to 2013.

In Singapore, immunisation against diphtheria is compulsory by law. A child received the first dose at the age of 3 months, second dose at the age of 4 months and the third dose at the age of 5 months. The first booster dose is then given at the age of 18 months, followed by a second booster at the age of 11 years old.



Ans : A

27. Which statement best describes the changes in incidence rate and immunisation rate?

A The rate of diphtheria infection decreases as the immunisation coverage rates increase.

B The immunisation coverage rate in infants directly correlates with the immunisation coverage rate in primary school entrants.

C The incidence of diphtheria infection follows a seasonal trend.

D The immunisation coverage rate can never achieve 100%.

28. Which statement best describes the immunisation against diphtheria?

Ans : C

A Immunisation is a form of passive immunity.

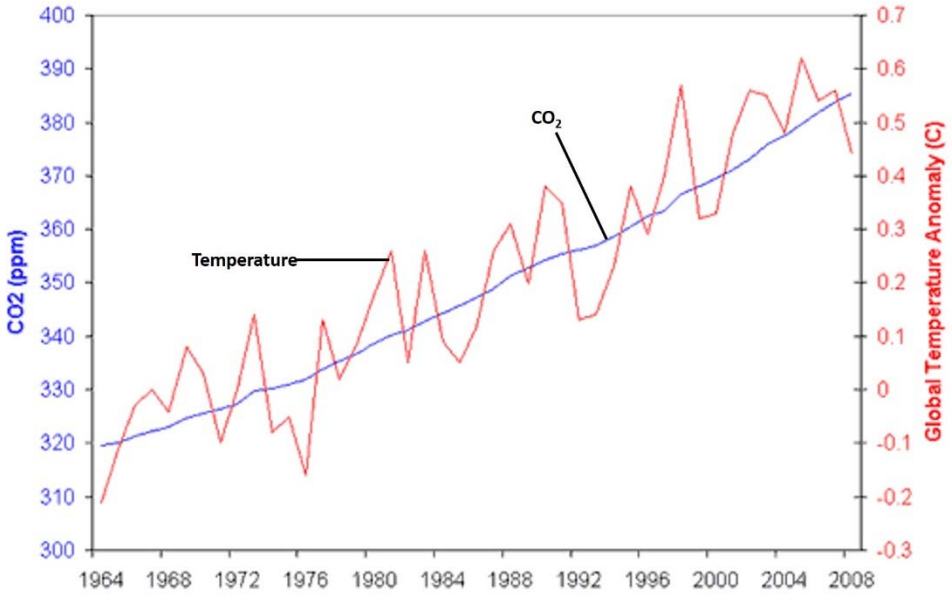
B Herd immunity was established and this made the disease impossible to spread.

C Individual can still be protected from diphtheria without the booster shot.

D Booster shot is no longer necessary after 11 years ago as the antibody produced can last a lifetime after 11 years old.

29. The following graph shows the global CO_2 levels and global temperature anomaly from 1964 to 2008. Global temperature anomaly compares that year's average temperature to a long term average.

Ans : C



The following are some statements made by some students on the global CO^2 levels and global temperature anomaly.

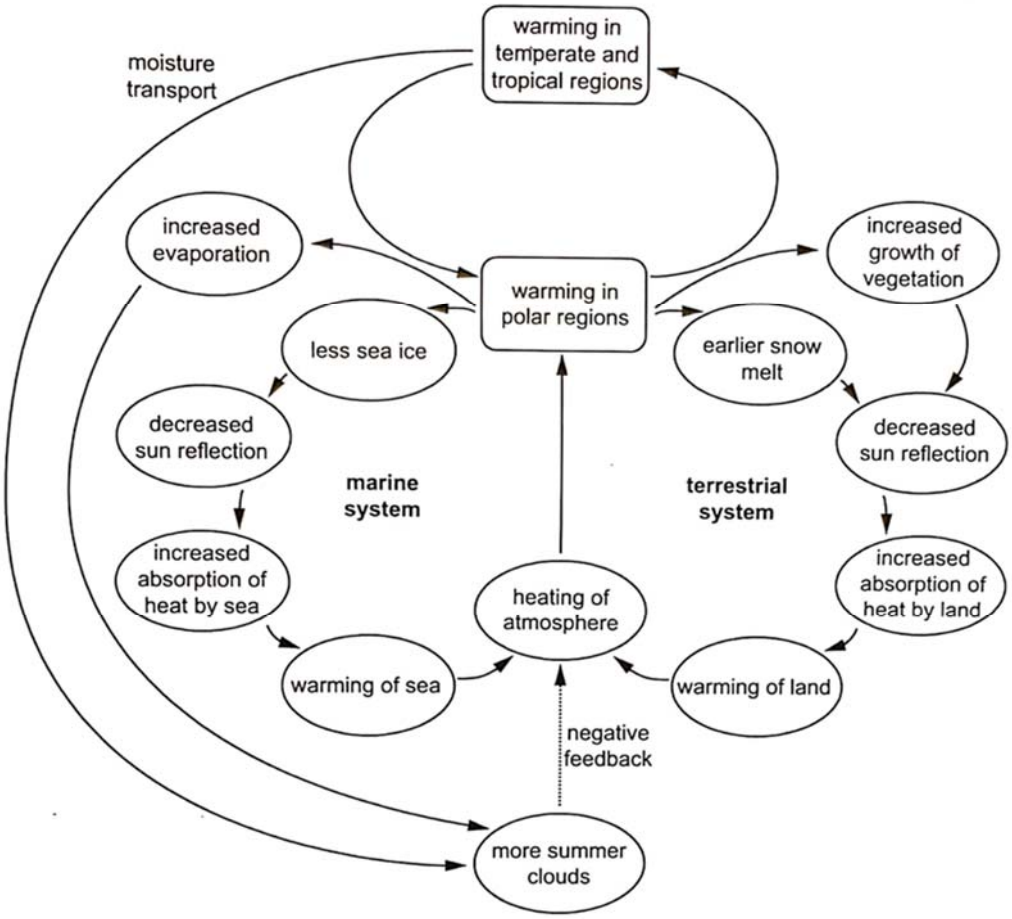
Student **A**: Between 1964 to 2008, the highest temperature recorded must be in 2006.
Student **B**: Between 1964 to 2008, the global temperature fluctuates from -0.2^{o}C to 0.45^{o}C.
Student **C**: Between 1964 to 2008, the global CO_2 level increases from 320 ppm to 385 ppm.
Student **D**: :Between 1964 to 2008, increase in temperature leads to the increase in global CO_2 level.

Which students made the correct deductions?

A Student **A** and **B**
B Student **B** and **C**
C Student **C** and **D**
D Student **B** and **D**

30. The diagram shows the effect of increasing temperatures on the ice and snow cover at the polar regions.

Ans : D



Which effect of higher temperatures in the polar regions could increase global warming?

A Increased evaporation leads to more rainfall, which absorbs heat from the land and sea.

B Melting of sea ice causes more cloud formation which increases absorption of heat in the atmosphere.

C Earlier melting of snow allows vegetation cover to increase faster, reducing loss of heat from the surface of the Earth.

D Melting of ice and snow results in less reflection of sunlight and more heat absorption by the earth.

End of Paper

Class Adm No

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2018 Preliminary Exams
Pre-University 3

BIOLOGY **9744/02**

Paper 2 Structured Questions **14 September 2018**

2 hours

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.
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You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in the question booklet.

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	
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Answer **all** questions in this section.

1. The survival and growth of living things are largely affected by the biotic and abiotic factors of the ecosystem. To investigate how temperature of the habitat affects growth of an animal, the relationship between mean mass of different mammalian species and the mean annual temperature of their habitat were investigated. Fig. 1.1 shows the result.

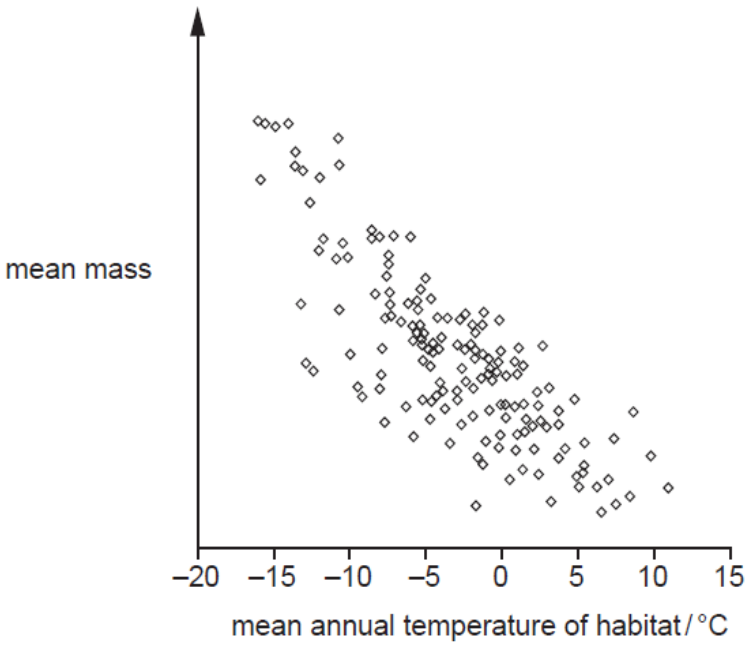

Fig. 1.1

(a) State what each plot point in the graph represents.

.....**[1]**

The mass of a mammal is commonly associated with the mass of fats. The fatty layer under the skin serves many important functions.

(b) Describe the formation of ester bond in triglyceride.

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.....**[2]**

(c) Discuss the relationship between the mean mass of mammalian species and the mean annual temperature of their habitat.

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…….[3]

The mean mass of the mammal is studied instead of the individual mass of the mammal, due to the variation in mass between mammals.

(d) Explain why this is important for survival of species.

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[Total:10]

2. Since the start of the epidemic, Human immunodeficiency virus (HIV) has caused 35 million deaths worldwide.

(a) Describe the structural components of virus.

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…….**[3]**

(b) Distinguish between the reproductive cycle of HIV and influenza virus.

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…….**[3]**

(c) Explain how HIV infection causes disease in humans.

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…….**[4]**

One common treatment method for HIV infected patients is the use of reverse transcriptase inhibitors. These inhibitors bind to the inhibitor binding site on the reverse transcriptase.

However, HIV often develops resistance against these inhibitors due to a single base substitution in the DNA sequence, resulting in a change of an amino acid in a subunit of reverse transcriptase. The mutant protein has the same number of amino acid sequence as the wild type protein and retains reverse transcriptase activity, but does not allow the binding of the inhibitors.

(d) Explain why the number of amino acid in mutated protein remains unchanged and retains reverse transcriptase activity, but does not allow the binding of the inhibitors.

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[Total:13]

3. Fig. 3.1 shows a plant cell undergoing gametogenesis.

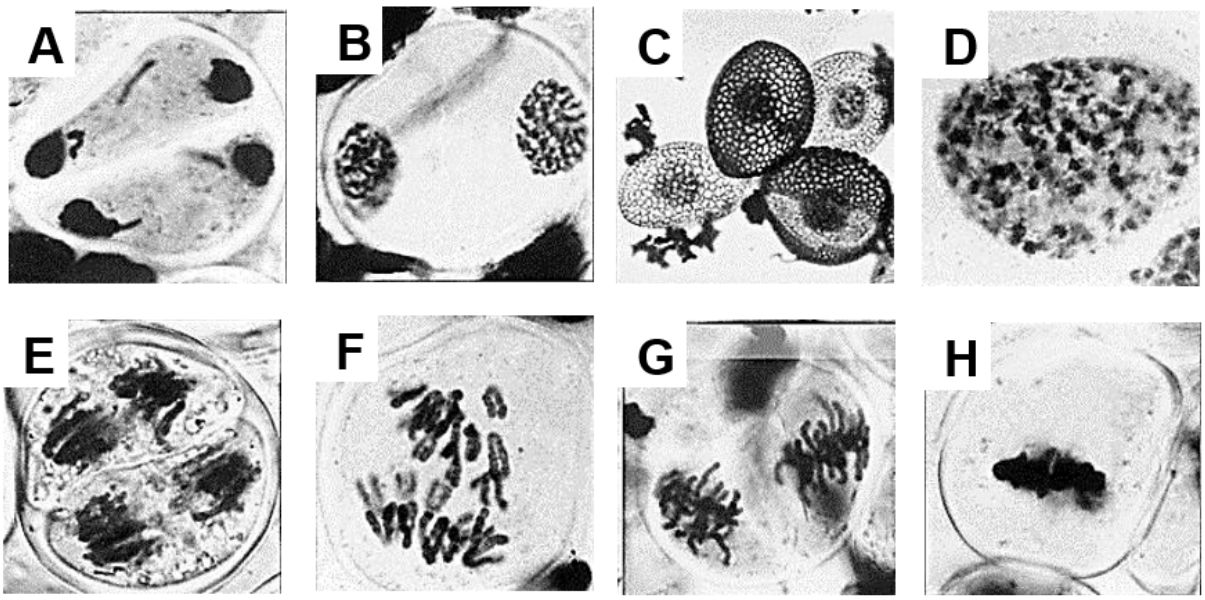

Fig. 3.1

(a) Arrange the letters **A** to **H** to show the correct sequence of events for this nuclear division.

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The cell was exposed to a toxin that causes spindle fibres to increase in length.

(b) Explain how the cell will be affected if the toxin was administered towards the end of stage **H**.

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(c) Explain how the toxin may lead to an absence of daughter cells or daughter cells with varied genetic content.

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(d) Explain the significance of this nuclear division during gametogenesis.

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…….**[3]**

[Total:10]

4. During an investigation, pollen grains from the anthers of a pure-bred plant with green leaves and hairy fruit were transferred by a student to the stigmas of a pure-bred plant with mottled (green and yellow) leaves and smooth-surfaced fruits. All the F_1 generation had green leaves and smooth fruit.

(a) Explain what is meant by pure-bred.

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.....[1]

(b) Explain how the genotype is linked to phenotype in tomato.

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.....[2]

A test cross was then made between the F1 plant and a plant with mottled leaves and hairy fruit. The phenotype of 100 offsprings of the test cross were recorded and shown in Table 4.1.

Table 4.1

Green leaves, smooth fruit	Green leaves, hairy fruit	Mottled leaves, smooth fruit	Mottled leaves, hairy fruit
8	46	40	6

(c) Using suitable symbols, draw a genetic diagram to explain the results of the test cross.

[5]

(d) Explain the difference between the observed test cross results from the expected test cross ratio.

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…….[2]

In a separate investigation, a test cross was performed between the same F1 plant and plant with mottled leaves and hairy fruit. Instead of recording the results for all four groups of phenotypes, the student recorded the number of the two more common groups of phenotype among the 100 offsprings. The results were shown in Table 4.2.

Table 4.2

Green leaves, smooth fruit	Green leaves, hairy fruit	Mottled leaves, smooth fruit	Mottled leaves, hairy fruit
Not recorded	52	44	*Not recorded*

The student claimed that the observed test cross ratio of offspring can be simplified to 1:1.

(e) Suggest why the student made this claim.

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…….[1]

(f) Perform the chi-squared test to verify this claim.

The formula and probability table is given as follow.

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Degrees of freedom	Probability		
	0.10	**0.05**	**0.01**
1	2.71	3.84	6.64
2	4.69	5.99	9.21
3	6.25	7.82	11.35
4	7.78	9.49	13.28

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…….[3]

[Total:14]

[Turn over

5. Fig. 5.1 shows an electron micrograph of an organelle.

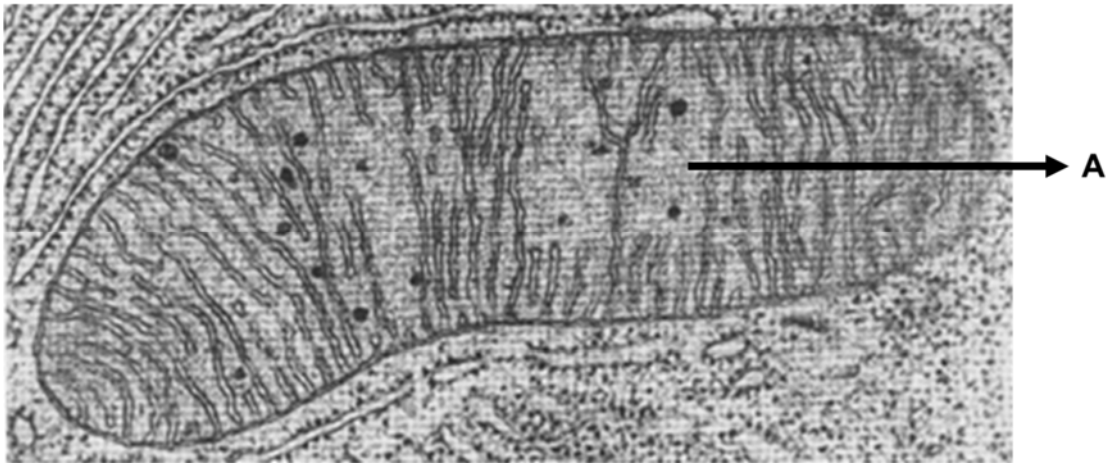

Fig. 5.1

(a) State the stage(s) of aerobic respiration that occur in **A**.

……**[1]**

(b) List down the end products of the stage(s) identified in **(a)**.

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……**[2]**

(c) Describe the importance of membrane during aerobic respiration.

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……**[3]**

Anaerobic respiration occurs in animals, plants, bacteria and archaea. It occurs when there is an absence of oxygen, releasing less amount of energy as compared to aerobic respiration.

(d) Explain how anaerobic respiration releases energy.

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(e) Many enzymes are involved in the different stages of aerobic and anaerobic respiration.

Fig. 5.2 shows the changes in energy during the progress of an uncatalyzed reaction.

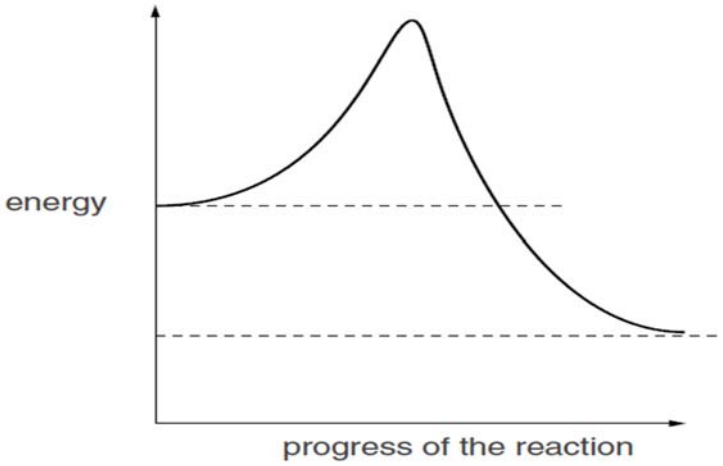

Fig. 5.2

(i) Draw on Fig. 5.2 the changes in energy during enzyme-catalysed reaction.

[1]

(ii) Label the following terms on your drawn diagram.

- Activation energy
- Overall energy released

[1]

[Total:12]

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6. Fig. 6.1 shows the effects of temperature and light intensity on the rate of photosynthesis of a plant.

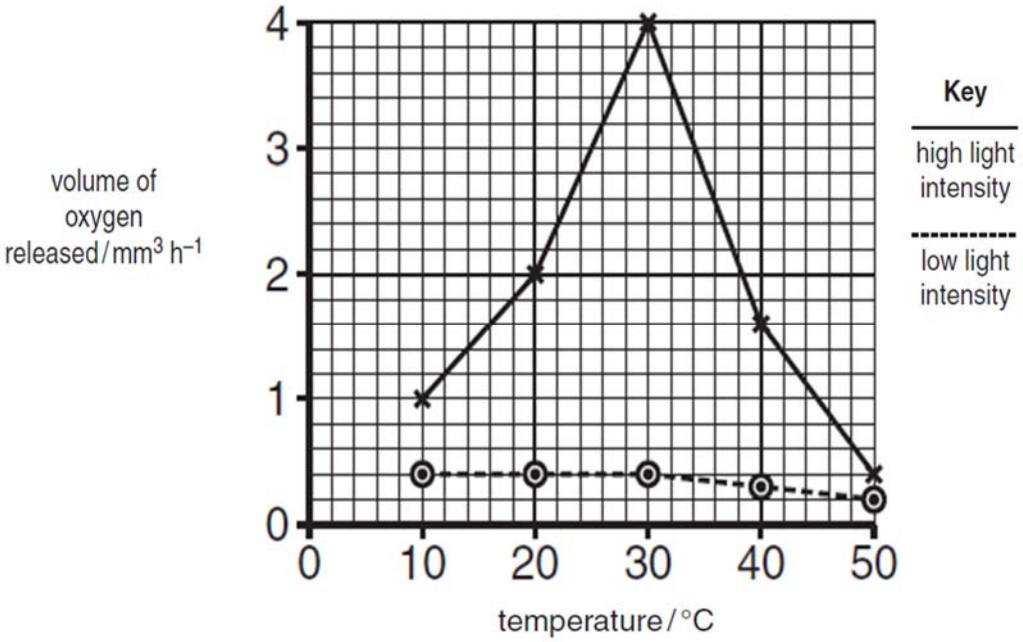

Fig. 6.1

(a) Compare the effect of temperature on the rate of photosynthesis between low and high light intensity.

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(b) Account for your answer in **(a)**.

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……**[5]**

[Total:8]

7. Recent research has revealed connection between the size of the nucleolus and the lifespan of the cell. Researchers believed that the nucleolus is an important organelle that coordinates many processes. This may imply that it is involved in many different signalling pathways.

(a) Suggest why the size of the nucleolus varies in different tissues.

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.....**[2]**

Reduced insulin signalling, dietary restriction and other signalling pathways increase the activity of a gene known as *NCL-1*, a nucleolar regulating gene. The increase in gene expression of *NCL-1* is associated with reduced size of nucleolus and increased lifespan.

(b) Describe how expression of *NCL-1* gene can be increased at the chromatin level in eukaryotes.

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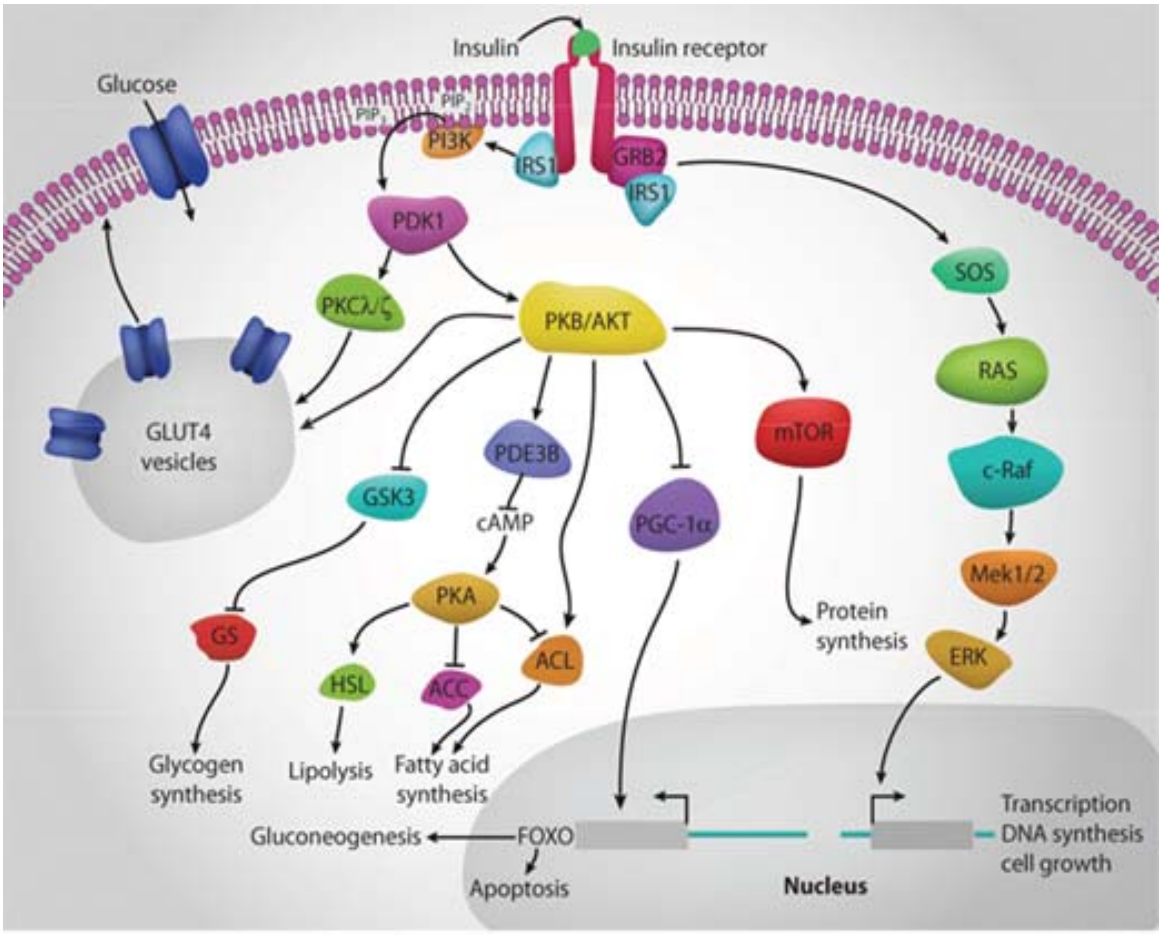
Insulin has several effects on cellular growth and metabolism. The actions of insulin are mediated by the insulin receptor, and the end results vary in different cells. Fig. 7.1 shows the signalling pathways activated when insulin binds to the receptor.



Michael W.King: Integrative Medical Biochemistry

Fig. 7.1

The association between insulin signalling and cancer risk is widely debated by scientists due to the release of contradicting studies.

(c) With reference to Fig. 7.1, suggest how dysregulation of the insulin signalling pathway may lead to cancer.

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…….**[3]**

(d) Suggest why dysfunctional insulin receptors is linked to many abnormalities.

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…….**[3]**

[Total:12]

8. Tuberculosis is an infectious disease caused by the intracellular pathogen, *Mycobacterium tuberculosis.* The disease affects the respiratory tract and caused an estimated 1.6 million deaths in 2016. Tuberculosis is treated with antibiotics such as rifampicin.

Increasingly, bacteria are developing resistance towards rifampicin. This is because bacteria contain an enzyme, rifampicin monooxygenase, which changes the structure of rifampicin from cyclic to linear, and thus inactivating the antibiotics.

(a) Define antibiotics.

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…….[2]

(b) Suggest how scientists should design a new drug to overcome the problem with rifampicin resistance.

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…….[1]

LRRK2 is a large protein encoding seven functional domains as shown in Fig. 8.1. LRRK2 has 2527 amino acids and a molecular weight of 286 kDa. It is a multi-domain protein comprising of a catalytic core domain, kinase domain and five protein-protein interaction domains. Mutations in the gene encoding for LRKK2 are associated with Parkinson's disease, cancer, Crohn's disease and bacterial infections.

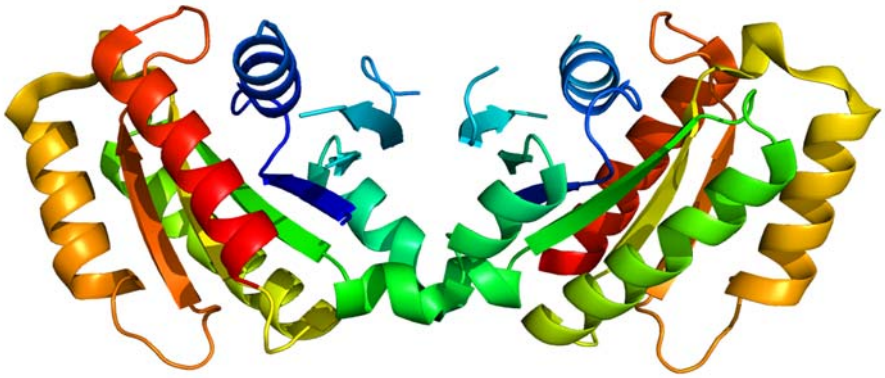

Fig. 8.1

(c) Using the information above, explain why there are more than one disease associated with mutations in the gene coding for LRRK2.

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.....**[4]**

Studies have shown that LRRK2 inhibits the maturation of phagosome in macrophages.

(d) Explain what will happen when an individual infected with *Mycobacterium tuberculosis* have functional LRRK2 protein.

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…[3]

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Fig. 8.2 shows the organisation of the DNA sequence which encode one of the domains of human LRRK2. The size of the exon and intron is stated within the brackets.

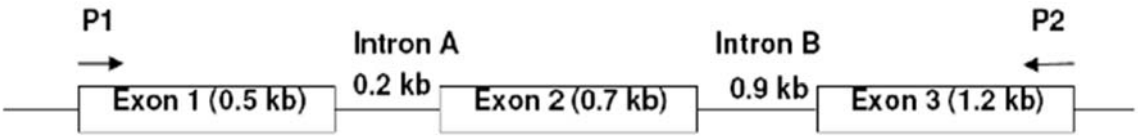

Fig. 8.2

The DNA sequences from three individuals, normal, mutant **A** and mutant **B** were obtained. The DNA sequences were subjected to transcription to form mRNA. The mRNA then underwent reverse transcription to form complementary DNA (cDNA). Polymerase chain reaction (PCR) was performed using primer **P1** and **P2**, which were specific to the exon regions shown in Fig. 8.2.

(e) Explain why cDNA sequences were used instead of DNA sequence.

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(f) Explain why two primers are needed for the polymerase chain reaction.

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.....**[2]**

The products of PCR were subjected to electrophoresis on an agarose gel and the results are shown in Fig. 8.3.

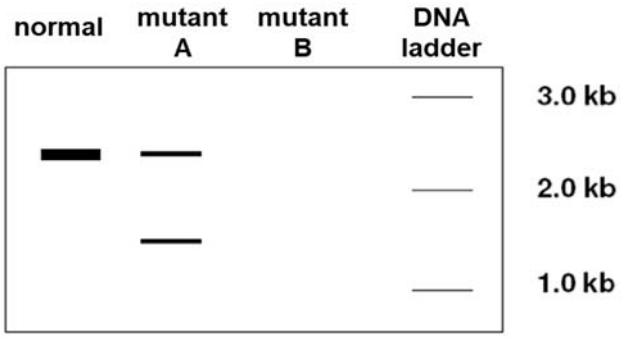

Fig. 8.3

(g) Deduce the size of the PCR product for the normal individual.

Show your working in the space below.

[1]

(h) Account for the band patterns observed for

(i) mutant **A**

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……**[2]**

(ii) mutant **B**

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……**[2]**

(i) Explain why there are more than one bands in the DNA ladder.

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…….[2]

[Total:21]

End of Paper

Class Adm No

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2018 Preliminary Exams
Pre-University 3

BIOLOGY **9744/02**

Paper 2 Structured Questions **14 September 2018**

2 hours

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Answer **all** questions in this section.

1. The survival and growth of living things are largely affected by the biotic and abiotic factors of the ecosystem. To investigate how temperature of the habitat affects growth of an animal, the relationship between mean mass of different mammalian species and the mean annual temperature of their habitat were investigated. Fig. 1.1 shows the result.

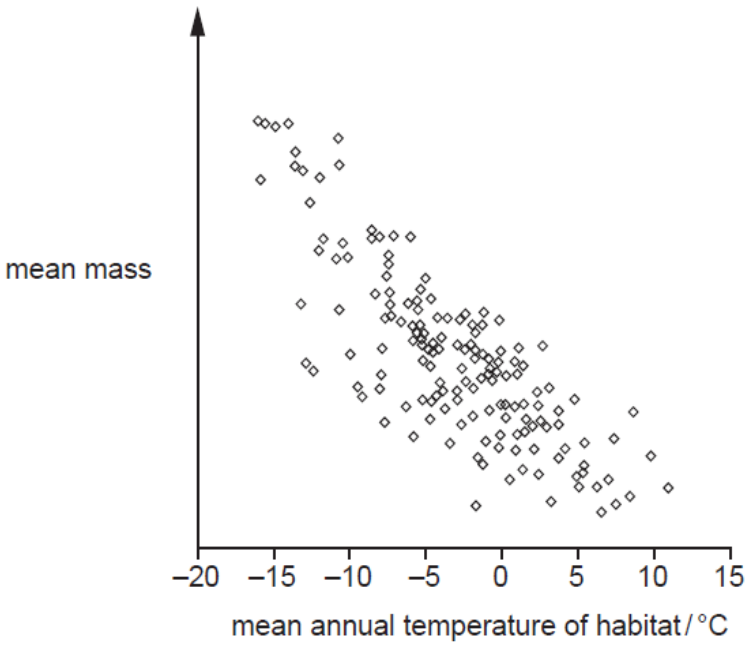

Fig. 1.1

(a) State what each plot point in the graph represents.

- Individual mammal species;

……[1]

The mass of a mammal is commonly associated with the mass of fats. The fatty layer under the skin serves many important functions.

(b) Describe the formation of ester bond in triglyceride.

- Each hydroxyl group (-OH) present in the glycerol molecule reacts with the carboxyl group (-COOH) of a fatty acid molecule;
- For each condensation reaction, a water molecule is removed;

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……[2]

(c) Discuss the relationship between the mean mass of mammalian species and the mean annual temperature of their habitat.

- The warmer the habitat, the lower mean mass of the mammal species/the colder the habitat, the higher the mean mass of the mamma species;
- Mammals <u>conserve heat</u> using stored <u>fats</u> which takes up mass;
- At each temperature, there is <u>variation/differences</u> in the <u>mean mass</u> among different species;
- Due to different behaviour/activity/diet/shape/amount of stored fat/fur thickness of the mammal;
- The lower the temperature, the greater the need to converse heat;

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……[3]

The mean mass of the mammal is studied instead of the individual mass of the mammal, due to the variation in mass between mammals.

(d) Explain why this is important for survival of species.

……

- <u>Variation in mass between mammal;</u>
- <u>Natural selection</u> depends on <u>existing variation</u> in a population;
- Genetic <u>variation</u> results in <u>phenotypic variation</u> among organisms within the same population;
- So that <u>under a selection pressure</u>, some phenotype confers <u>selective advantage</u> to certain individuals;
- while others phenotype confers <u>selective disadvantage</u> to other individuals;
- Variations helps to ensure <u>perpetuation/OWTTE of species</u>;
- and <u>safeguard/prevent/OWTTE</u> <u>species from extinction</u>;

2. Since the start of the epidemic, Human immunodeficiency virus (HIV) has caused 35 million deaths worldwide.

(a) Describe the structural components of virus.

- Viral genome contains either DNA or RNA, that can be single or double stranded;
- Genome can be circular or linear, can have more than one copy of the genome;
- All viruses have capsid protein that either surrounds the nucleic acid or encloses it;
- Made from identical protein subunits known as capsomere;
- Capsid protect the viral genome and determine the specific shape of the virus;
- Viral envelopes are phospholipid bilayer membrane derived from the host cell membrane;
- Embedded/OWTTE with glycoprotein and surround the capsid;
- Glycoproteins are essential for the attachment of virus to host cell receptor;
- Protein the virus from enzyme/chemical/harsh environment;

[3]

(b) Distinguish between the reproductive cycle of HIV and influenza virus.

Feature	HIV	Influenza
Entry	HIV enters host cell via fusion between membrane of influenza and cell surface membrane of host cell'	Influenza enters host cell via endocytosis
Target cell	CD4+ T helper cell/macrophage	Epithelial cell of respiratory tract
Genome	8 single stranded negative sense RNA	2 single-stranded positive sense RNA
Reverse transcriptase	Reverse transcription of RNA to dsDNA	No reverse transcription
Integration of viral genome	Integration of HIV dsDNA into host chromosome	No integration of viral genome
Proteolysis of viral protein	Proteolysis of viral polyprotein to form mature viral proteins**;**	No proteolysis**;**
Latency phase	Latency phase in HIV life cycle**;**	No latency period in influenza**;**

[3]

(c) Explain how HIV infection causes disease in humans.

- HIV causes Acquired Immunodeficiency Syndrome (AIDS);
- Target cells include CD4+ T helper cells and macrophages;
- The window period/primary infection is the incubation period of HIV, where the infected individual display/exhibit no symptoms/physiological response;
- Followed by the **acute primary infection phase** where the infected individual display symptoms;
- Decrease number of CD4+ T helper cells and increase in free HIV particles;
- HIV particles decrease is followed by the **asymptomatic phase** where;
- Gradual drop/decline in the number of CD4+ T helper cell and symptoms disappear;
- Immune system can still manage the free viruses and infected cells;
- **Symptomatic phase** is characterised by immune suppression and onset of symptoms;
- Decrease in number of CD4+ T helper cells and increase in free HIV particles;
- Leading to AIDS where the immune system fails and opportunistic infections and cancer occur;

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..[4]

One common treatment method for HIV infected patients is the use of reverse transcriptase inhibitors. These inhibitors bind to the inhibitor binding site on the reverse transcriptase.

However, HIV often develops resistance against these inhibitors due to a single base substitution in the DNA sequence, resulting in a change of an amino acid in a subunit of reverse transcriptase. The mutant protein has the same number of amino acid sequence as the wild type protein and retains reverse transcriptase activity, but does not allow the binding of the inhibitors.

(d) Explain why the number of amino acid in mutated protein remains unchanged and retains reverse transcriptase activity, but does not allow the binding of the inhibitors.

Same number of amino acid
- DNA mutation result in a missense mutation, and not frame-shift mutation;

Retains reverse transcriptase function
- Active site of enzyme is not altered/OWTTE after mutation;

Does not allow binding of inhibitor
- Inhibitor binding site is no longer complementary to the 3D conformation/shape of the inhibitor;
- Change in amino acid sequence results in change in tertiary structure/3D conformation of protein;
- AVP;

……..
……..
……..
……..
……..
……..[3]

[Total:13]

[Turn over

3. Fig. 3.1 shows a plant cell undergoing gametogenesis.

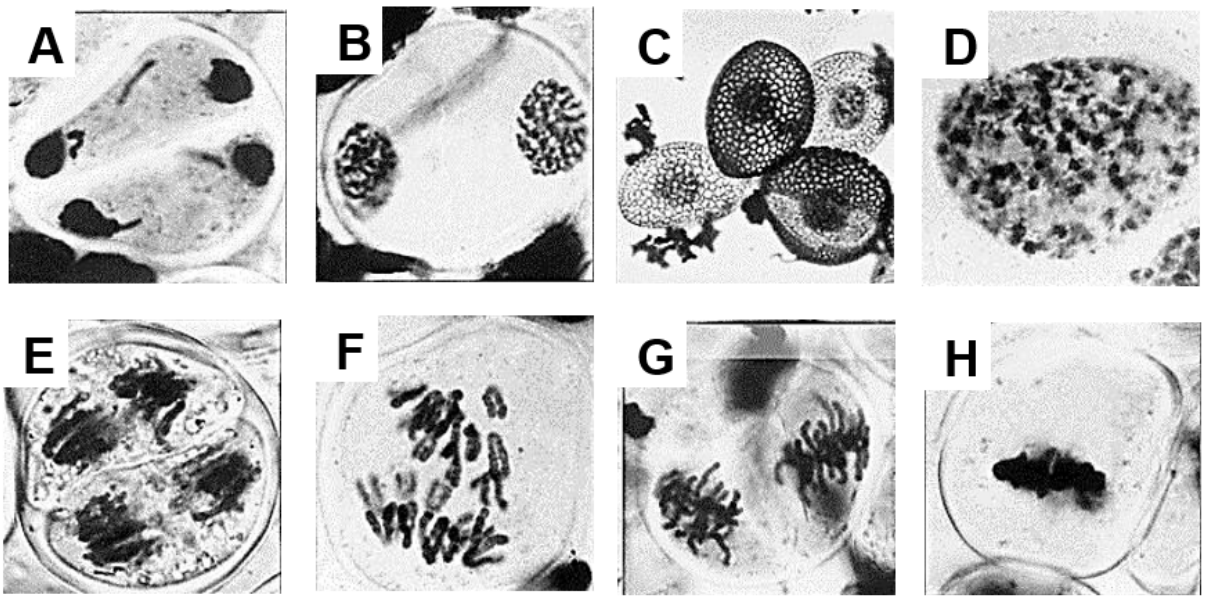


Fig. 3.1

(a) Arrange the letters **A** to **H** to show the correct sequence of events for this nuclear division.

- D H F **B G** E A C;

……[2]

The cell was exposed to a toxin that causes spindle fibres to increase in length.

(b) Explain how the cell will be affected if the toxin was administered towards the end of stage **H**.

- The interaction between centromere and spindle fibres will be disrupted;
- Metaphase plate may be disorganised/OWTTE;
- Anaphase I may not occur and homologous chromosome fail to separate;
- Length of cell may increase as pole to pole spindle fibre increases;
- AVP

[3]

(c) Explain how the toxin may lead to an absence of daughter cells or daughter cells with varied genetic content.

- M phase checkpoint may be triggered;
- to cause cell cycle arrest resulting in absence of daughter cells;
- failure of checkpoint resulting in daughter cells with unequal number of chromosome; due to non-disjunction;
- AVP;

[2]

(d) Explain the significance of this nuclear division during gametogenesis.

- Meiosis is a reduction division which is essential in producing haploid gametes that have half the number of chromosomes as an original somatic cell;
- In order to restore the original diploid / chromosome number in a zygote when gametes fuse;
- Meiosis creates genetic variation, essential for evolution;
- Ensures that species constantly change and adapt when environmental conditions change;
- AVP;

[3]

[Total:10]

4. During an investigation, pollen grains from the anthers of a pure-bred plant with green leaves and hairy fruit were transferred by a student to the stigmas of a pure-bred plant with mottled (green and yellow) leaves and smooth-surfaced fruits. All the F_1 generations had green leaves and smooth fruit.

(a) Explain what is meant by pure-bred

- Refers to alleles which are <u>homozygous</u>;

…….

…[1]

(b) Explain how the genotype is linked to phenotype in tomato.

- Genotype is the genetic make-up of an organism;
- <u>Expression of the gene</u> leads to the observable or measurable <u>trait</u>;
- Phenotype is influenced by both <u>genetic</u> and <u>environmental</u> factors;

……

…[2]

A test cross was then made between the F1 plant and a plant with mottled leaves and hairy fruit. The phenotype of 100 offsprings of the test cross were recorded and shown in Table 4.1.

Table 4.1

Green leaves, smooth fruit	Green leaves, hairy fruit	Mottled leaves, smooth fruit	Mottled leaves, hairy fruit
8	46	40	6

(c) Using suitable symbols, draw a genetic diagram to explain the results of the test cross.

Let **A** represent the **dominant allele** for **green leaves**, **a** represent the **recessive allele** for **mottled leaves.**
B represent the **dominant allele** for **smooth fruit**, **b** represent the **recessive allele** for **hairy fruit.**

F_1 test cross Green leaves, smooth fruit x Mottled leaves, hairy fruit

$\frac{\mathbf{A\ b}}{\mathbf{a\ B}}$ $\frac{\mathbf{a\ b}}{\mathbf{a\ b}}$

Gametes A b, a B, A B, a b | a b

Random Fertilization

		Female Gametes			
		A b	a B	A B	a b
Male Gametes	a b	$\frac{\mathbf{A\ b}}{\mathbf{a\ b}}$	$\frac{\mathbf{a\ B}}{\mathbf{a\ b}}$	$\frac{\mathbf{A\ B}}{\mathbf{a\ b}}$	$\frac{\mathbf{a\ b}}{\mathbf{a\ b}}$

Phenotypes	Green leaves, hairy fruit	Mottled leaves, smooth fruit	Green leaves, smooth fruit	Mottled leaves, hairy fruit
	46	40	8	6
	Parental		**Recombinants**	

- F1 genotype;
- Gametes;
- Results of punnett square;
- F2 gentoype;
- F2 phentoype and phenotypic ratio;

[5]

[Turn over

(d) Explain the difference between the observed test cross results from the expected test cross ratio.

- Expected test cross ratio is 1:1:1:1 while observed test cross results is not;
- Indicates that the 2 genes for leaves colour and fruit texture are linked/on the same chromosome;
- Therefore, there is crossing over between the 2 linked genes in some of the cells;
- And thus the observed offspring of test cross are predominantly/majority of parental combination/ORA;

[2]

In a separate investigation, a test cross was performed between the same F1 plant and plant with mottled leaves and hairy fruit. Instead of recording the results for all four groups of phenotypes, the student recorded the number of the two more common groups of phenotype among the 100 offsprings. The results were shown in Table 4.2.

Table 4.2

Green leaves, smooth fruit	Green leaves, hairy fruit	Mottled leaves, smooth fruit	Mottled leaves, hairy fruit
Not recorded	52	44	*Not recorded*

The student claimed that the observed test cross ratio of offspring can be simplified to 1:1.

(e) Suggest why the student made this claim.

- The 2 genes for leave colour and fruit texture are very closely linked;
- Crossing over between the 2 genes is very rare/low probability;
- The 2 genes are inherited as an unit/do not show independent assortment during meiosis;

[1]

(f) Perform the chi-squared test to verify this claim.

The formula and probability table is given as follow.

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Degrees of freedom	Probability		
	0.10	**0.05**	**0.01**
1	2.71	3.84	6.64
2	4.69	5.99	9.21
3	6.25	7.82	11.35
4	7.78	9.49	13.28

- $[(52-48)^2 + (44-48)^2]/48 = 0.67$;
- At p= 0.05, degree of freedom =1, critical x2 value is 3.84, since calculated chi-square value is less than critical chi-square value;
- There is no significant difference between the test cross and expected 1:1 ratio and hence student's claim is valid;

…….

…….

…….

…….[3]

[Total:14]

5. Fig. 5.1 shows an electron micrograph of an organelle.

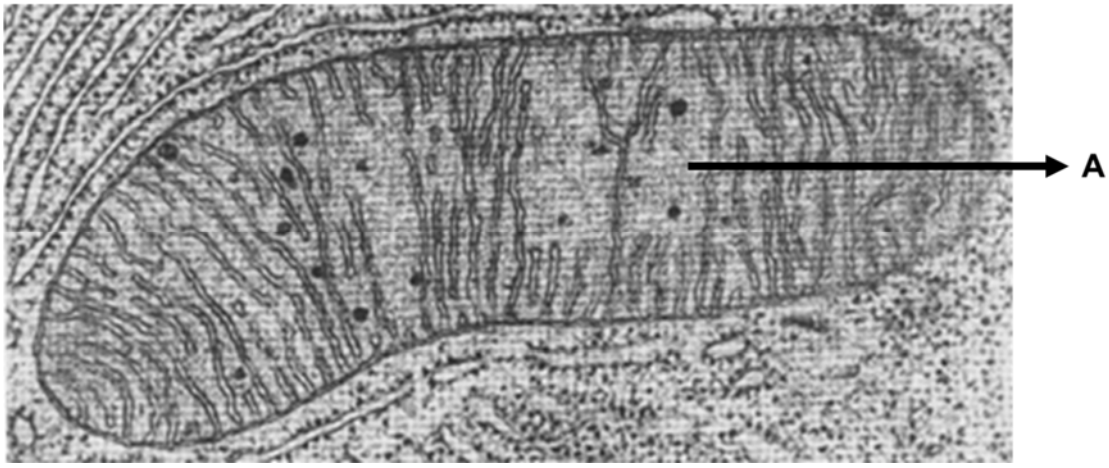


Fig. 5.1

(a) State the stage(s) of aerobic respiration that occur in **A**.

- Link reaction and Krebs cycle;

….[1]

(b) List down the end products of the stage(s) identified in **(a)**.

- Link reaction: acetyl coa, NADH and CO2;
- Krebs cycle: regeneration of oxaloacetate, NADH, FADH2, ATP and CO2;

……..
….[2]

(c) Describe the importance of membrane during aerobic respiration.

- The outer mitochondrial membrane compartmentalises/separate content of organelle from cytoplasm for aerobic respiration to occur;
- The inner mitochondrial membrane/cristae contains electron transport chain and ATP synthase to carry out oxidative phosphorylation;
- The inner mitochondrial membrane/cristae is highly folded and this increases the surface area to hold the enzymes;
- The inner mitochondrial membrane is impermeable to protons and thus act as barriers/OWTTE to the movement of protons;
- Maintains concentration gradient of protons between intermembrane space and matrix;
- Allowing generation of the proton motive force across the cristae for chemiosmosis to occur;

…….
…….
…….
…….
…….
…….
….[3]

Anaerobic respiration occurs in animals, plants, bacteria and archaea. It occurs when there is an absence of oxygen, releasing less amount of energy as compared to aerobic respiration.

(d) Explain how anaerobic respiration releases energy.

- Regenerating NAD+ for glycolysis;
- Glycolysis synthesise two net ATP molecule per glucose breakdown;
  [Compulsory]

- Lactate fermentation is the reduction;
- of pyruvate to lactate catalysed by lactate dehydrogenase.;
- Alcoholic fermentation is the decarboxylation;
- of pyruvate to ethanal catalysed by pyruvate decarboxylase;
- Ethanal is then reduced to ethanol, catalysed by alcohol dehydrogenase;

[4]

(e) Many enzymes are involved in the different stages of aerobic and anaerobic respiration.

Fig. 5.2 shows the changes in energy during the progress of an uncatalyzed reaction.

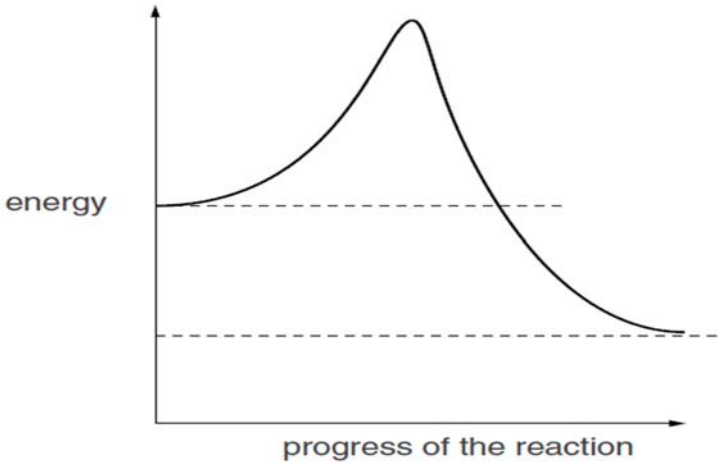


Fig. 5.2

(i) Draw on Fig. 5.2 the changes in energy during enzyme-catalysed reaction.

- Correct starting and ending level;
- Lower activation energy;

[1]

(ii) Label the following terms on your drawn diagram.

- Correct drawn label for activation energy;
- Correct drawn label for overall energy released;

[1]

[Total:12]

Blank Page

6. Fig. 6.1 shows the effects of temperature and light intensity on the rate of photosynthesis of a plant.

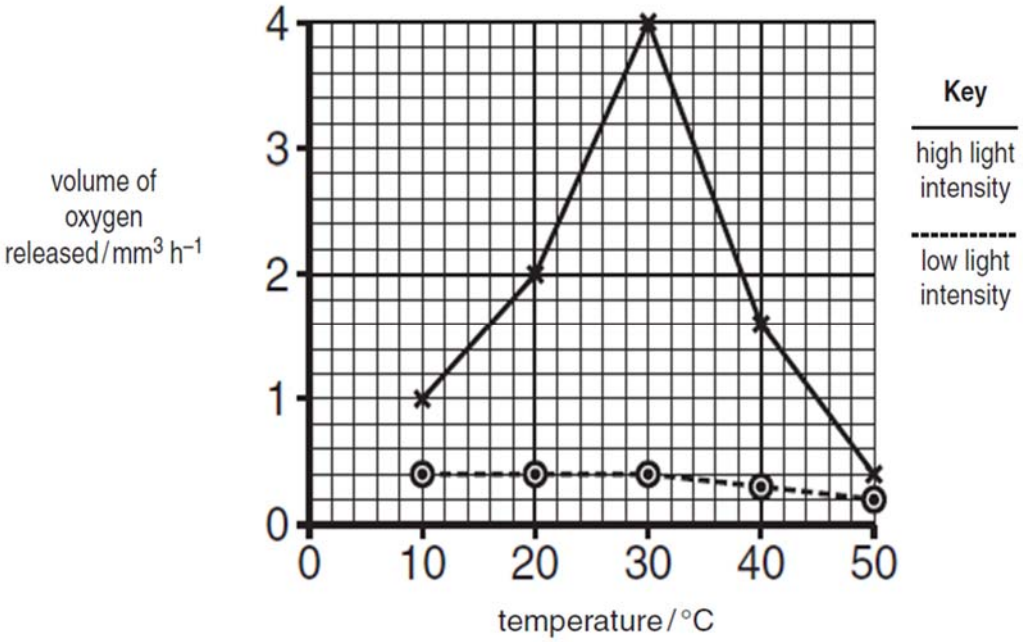


Fig. 6.1

(a) Compare the effect of temperature on the rate of photosynthesis between low and high light intensity.

- As temperature increases from 10^{o}C to 30 ^{o}C, the volume of oxygen released increases sharply/steeply/significantly from 1 mm^{3}h^{-1} to 4 mm^{3}h^{-1} at high light intensity but the volume of oxygen released remains constant at 0.2 mm^{3}h^{-1} at low light intensity;
- As temperature increases from 30 ^{o}C to 50 ^{o}C, the volume of oxygen released decreases sharply/steeply/significantly from 4 mm^{3}h^{-1} to 0.2 mm^{3}h^{-1} at high light intensity while the volume of oxygen released decreases slightly from 0.2 to 0.1 mm^{3}h^{-1} at low light intensity;
- The volume of oxygen released/rate of photosynthesis reaches the maximum/peak at 30 ^{o}C for high light intensity but the volume of oxygen released/rate of photosynthesis did not reach any maximum/peak at low light intensity;

[3]

(b) Account for your answer in **(a)**.

- At high light intensity, as temperature increase from 10^{o}C to 30 ^{o}C, the kinetic energy of molecules increases;
- Chances of effective collision between molecules is at higher frequency, leading to greater/higher rate of photosynthesis;
- At higher rate of photosynthesis, volume of oxygen released increases due to photolysis of water;

- At low light intensity, as temperature increase from 10^{o}C to 30 ^{o}C, the rate of photosynthesis is limit by the amount of light intensity/limiting factor is light intensity;
- At low and high light intensities, as temperature increase from 30^{o}C to 50 ^{o}C, the proteins are denatured and became non-functional;
- Lesser enzyme-substrate complexes formed per unit time;
- Lesser photolysis occurs and thus lesser oxygen released;

[5]

[Total:8]

7. Recent research has revealed connection between the size of the nucleolus and the lifespan of the cell. Researchers believed that the nucleolus is an important organelle that coordinates many processes. This may imply that it is involved in many different signalling pathways.

(a) Suggest why the size of the nucleolus varies in different tissues.

- The nucleolus is the site for transcription of rRNA;
- and the assembly of ribosomal subunits;
  Max 1

- Tissue such as muscle/skin/AVP with higher metabolic activity has bigger nucleolus/tissue with low metabolic activity such as neurones with smaller nucleolus;

[2]

Reduced insulin signalling, dietary restriction and other signalling pathways increase the activity of a gene known as *NCL-1*, a nucleolar regulating gene. The increase in gene expression of *NCL-1* is associated with reduced size of nucleolus and increased lifespan.

(b) Describe how expression of *NCL-1* gene can be increased at the chromatin level in eukaryotes.

- Chromatin remodelling complex alter the structure of nucleosome to be less tightly bound/OWTTE to histone;
- Allow RNA polymerase and transcription factor to access promoter easily;

- Demethylation/removal of methyl group from DNA;
  (Allow RNA polymerase and transcription factor to access promoter easily)

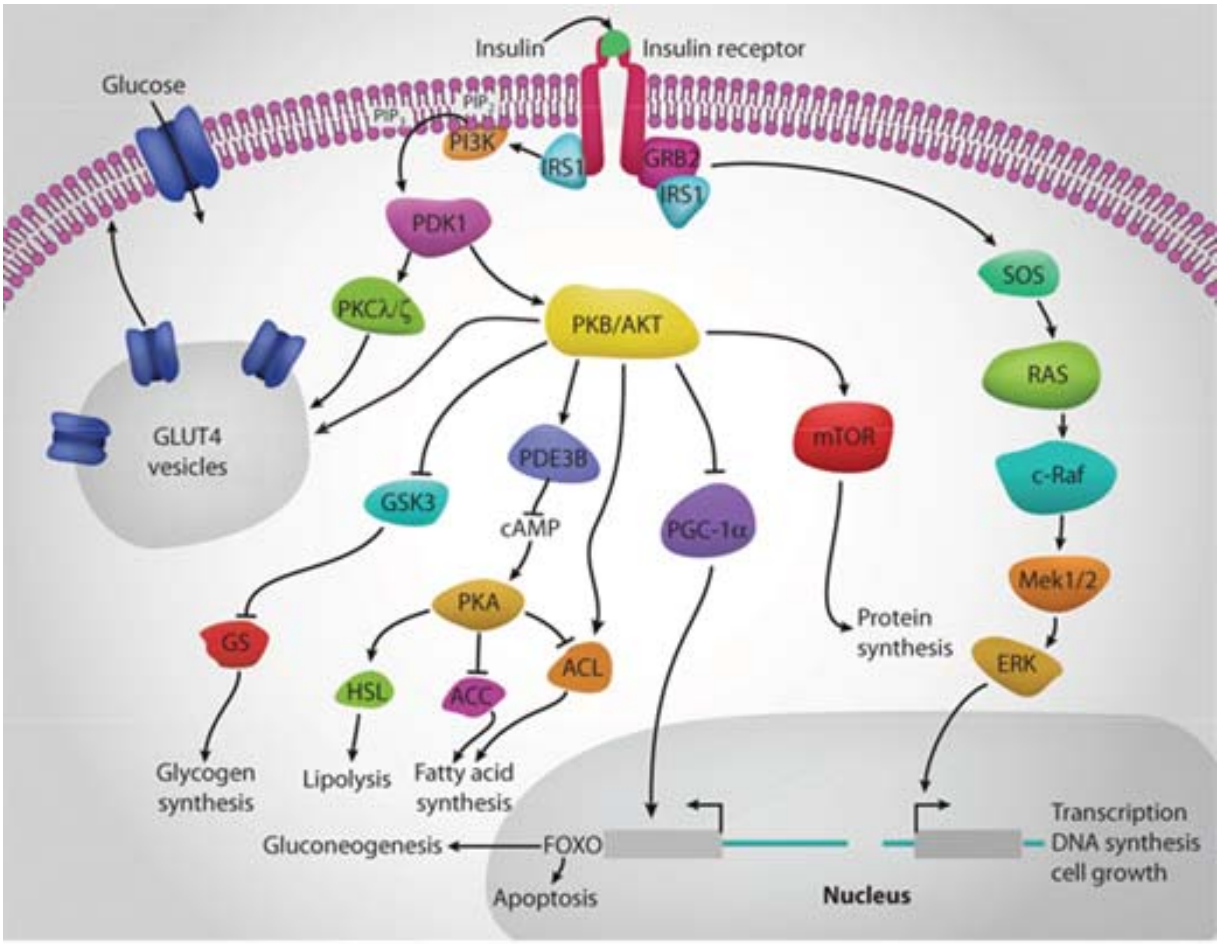
- Histone acetylation will loosen/OWTTE the ionic bond between DNA and histone;
- Addition of acetyl group to positively charged lysine in histone tails;
- Catalysed by histone acetyl transferase;
- Acetylated lysine acts as binding sites for chromatin remodelling complexes;

- Demethylation/removal of methyl group from histone;

[4]

Blank Page

Insulin has several effects on cellular growth and metabolism. The actions of insulin are mediated by the insulin receptor, and the end results vary in different cells. Fig. 7.1 shows the signalling pathways activated when insulin binds to the receptor.



Michael W.King: Integrative Medical Biochemistry

Fig. 7.1

The association between insulin signalling and cancer risk is widely debated by scientists due to the release of contradicting studies.

(c) With reference to Fig. 7.1, suggest how dysregulation of the insulin signalling pathway may lead to cancer.

- Increased synthesis/activation of SOS/RAS/c-RAF/Mek1/2/ERK leads to increased expression of gene involved in DNA synthesis and cell growth;
- Increased synthesis/activation of PGC/FOXO leads to increase rate of gluconeogenesis, providing the cell with more glucose to cope with the increase metabolism rate during cancer;
- Decreased synthesis/activation of PKB/AKT leads to increase rate of gluconeogenesis, providing the cell with more glucose to cope with the increase metabolism rate during cancer;
- Decrease synthesis/activation of PGC/FOXO leads to decrease rate of apoptosis, inhibiting the death of cancerous cell;
- Increase synthesis/activation of PKB/AKT leads to decrease rate of apoptosis, inhibiting the death of cancerous cell;
- Mutation of RAS;
- AVP;

[3]

(d) Suggest why dysfunctional insulin receptors is linked to many abnormalities.

- Activated <u>second messengers</u> recruit and activate many other downstream relay protein and <u>protein kinase</u>;
- Each activated protein kinase will initiate a sequential phosphorylation and activation of other kinases/<u>phosphorylation cascade</u>;
- At each phosphorylation step, <u>each activated kinase</u> is able to activate a <u>large number of the next kinase</u>;
- <u>Signal amplification</u> result in activation of <u>large</u> number of different effector protein;
- Large number of effector proteins serving different cellular functions;

[3]

12]

[Turn over

8. Tuberculosis is an infectious disease caused by the intracellular pathogen, *Mycobacterium tuberculosis.* The disease affects the respiratory tract and caused an estimated 1.6 million deaths in 2016. Tuberculosis is treated with antibiotics such as rifampicin.

Increasingly, bacteria are developing resistance towards rifampicin. This is because bacteria contain an enzyme, rifampicin monooxygenase, which changes the structure of rifampicin from cyclic to linear, and thus inactivating the antibiotics.

(a) Define antibiotics.

- Antibiotics are natural substances derived from microorganism/bacteria/fungi;
- that inhibit or kill bacteria by disrupting/OWTTE the structure and metabolism of bacterial cell;
- Bacteriostatic antibiotics inhibit the growth and cell division of bacteria;
- Bactericidal antibiotics kill bacteria when the bacteria are in the process of undergoing cell division;

[2]

(b) Suggest how scientists should design a new drug to overcome the problem with rifampicin resistance.

- Design new rifampicin analogs that are not susceptible to the enzyme inactivation;
- Design drugs that inhibit the enzyme;
- AVP;

[1]

LRRK2 is a large protein encoding seven functional domains as shown in Fig. 8.1. LRRK2 has 2527 amino acids and a molecular weight of 286 kDa. It is a multi-domain protein comprising of a catalytic core domain, kinase domain and five protein-protein interaction domains. Mutations in the gene encoding for LRKK2 are associated with Parkinson's disease, cancer, Crohn's disease and bacterial infections.

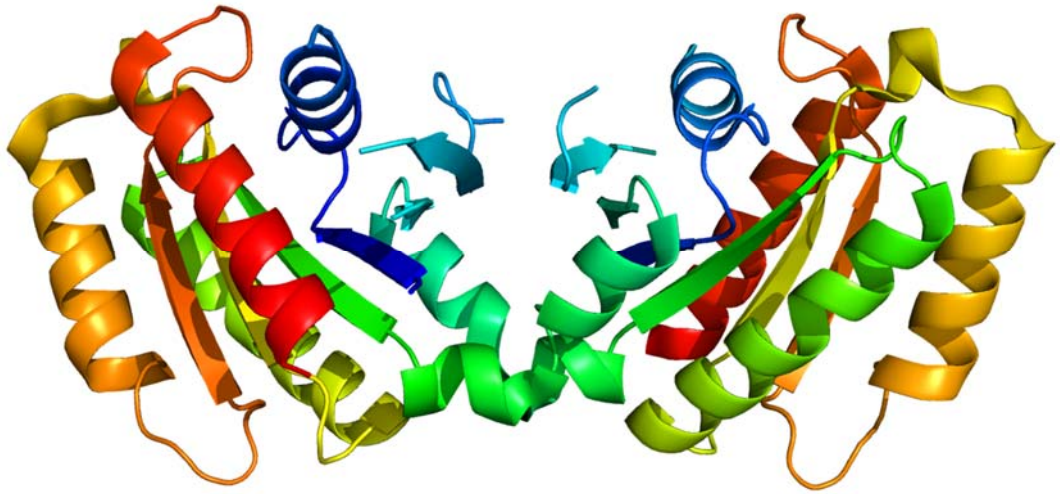


Fig. 8.1

(c) Using the information above, explain why there are more than one disease associated with mutations in the gene coding for LRRK2.

- Mutation result in the change in sequence of base of any of the domain may lead to change in sequence of mRNA; …
- Leading to a change in sequence of amino acid in polypeptide; …
- Eventually leading to change in property and function of the protein;
  Max 2 …

- Mutation in the protein-protein interaction domains may alter the interaction between LRRK2 and target protein; …
- affecting the 3-dimensional conformation and function of the target protein; …
- Mutations in the catalytic core domain may alter the catalysis of target substrate;
- Mutations in the kinase domains may alter the phosphorylation of target protein;

[4]

Studies have shown that LRRK2 inhibits the maturation of phagosome in macrophages.

(d) Suggest what will happen when an individual infected with *Mycobacterium tuberculosis* have functional LRRK2 protein.

- As *M. tuberculosis* enters the lungs, alveolar macrophages phagocytose the mycobacteria;
- And attempts to form a phagosome containing the bacteria/ *M. tuberculosis*;
- The mycobacterium will fail/OWTTE to inhibit the fusion of phagosome with lysosome;
- Phagolysosoome is formed and lysosomal enzyme will kill the bacteria/ *M. tuberculosis;*
- *M. tuberculosis* fails to survive /die and infection will stop/OWTTE;

[3]

Fig. 8.2 shows the organisation of the DNA sequence which encodes one of the domains of human LRRK2. The size of the exon and intron is stated within the brackets.

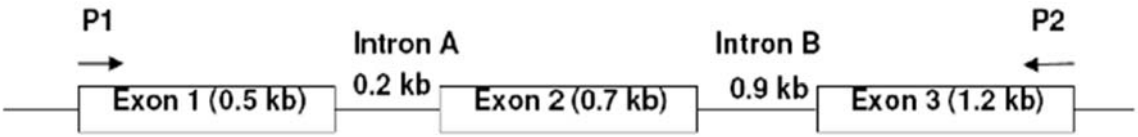


Fig. 8.2

The DNA sequences from three individuals, normal, mutant **A** and mutant **B** were obtained. The DNA sequences were subjected to transcription to form mRNA. The mRNA then underwent reverse transcription to form complementary DNA (cDNA). Polymerase chain reaction (PCR) was performed using primer **P1** and **P2**, which were specific to the exon regions shown in Fig.8.2.

(e) Explain why cDNA sequences were used instead of DNA sequence.

- cDNA sequences are <u>complementary</u> to the <u>mRNA</u> sequence/exact copies of DNA sequence without the introns;
- the mRNA went through <u>pre-mRNA splicing</u> to <u>remove/splice the introns</u>;

[2]

(f) Explain why two primers are needed for the polymerase chain reaction.

- Serve as the <u>forward</u> and <u>reverse</u> primers;
- Each primer is <u>complementary</u> and <u>binds to the 3' end</u> of each <u>template</u> strand of the double helix;

[2]

[Turn over

The products of PCR were subjected to electrophoresis on an agarose gel and the results are shown in Fig. 8.3.

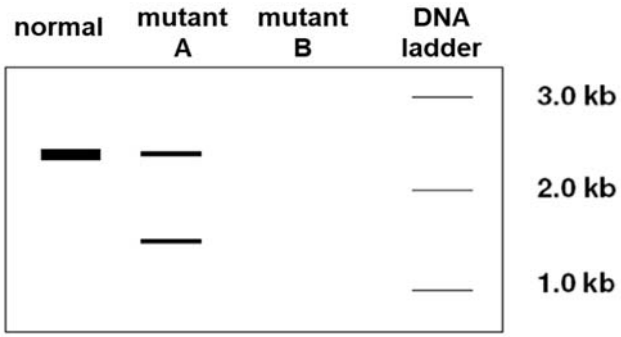


Fig. 8.3

(g) Deduce the size of the PCR product for the normal individual. Show your working in the space below.

0.5 + 0.7 +1.2 = 2.4kb;

[1]

(h) Account for the band patterns observed for

(i) mutant **A**

- mutant A has one band pattern same as normal individual/2.4km and another band pattern of 1.7kb ;
- implying that this person is heterozygote with one normal allele and one mutant allele;
- mutant allele is a result of deletion of exon 2, intron A and intron B;

[2]

(ii) mutant **B**

- <u>No bands</u> because there is <u>no PCR product</u>;
- Due to mutation in the binding site of primer P1 and/or P2;
- When primer P1 and/or P2 cannot bind, initiation of DNA replication cannot occur;
  OR
- No bands because transcription/reverse transcription did not occur;
- Due to mutation in the promoter/ general transcription factor/reverse transcription start site;
- AVP;

[2]

(i) Explain why there are more than one bands in the DNA ladder.

- DNA ladder is a <u>mixture of DNA fragments</u> of various <u>sizes</u>;
- Used to <u>estimate</u> the size of DNA fragments in <u>sample</u>;
- Gel electrophoresis separates DNA fragment by <u>size/molecular weights</u> where smaller fragments move faster and further from the starting point/ bigger fragments move slower and closer to the starting point;

…….
…….
…….
….[2]

[Total:21]

End of Paper

Candidate Name: _____

Class	Adm No

H

millennia institute

2018 Preliminary Exams
Pre-University 3

BIOLOGY **9744/03**

Paper 3 Long Structured and Free-response Questions **17 September 2018**

2 hours

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 in the space provided on the Question Paper.

Section B
Answer any **one** question in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

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.

For Examiner's Use	
1	
2	
Section B	
Total	

Section A

Answer **all** questions in this section.

1. Monoclonal antibodies are antibodies derived from a single unique parent cell. In the industry, monoclonal antibodies are produced from hybridoma. The procedures are illustrated in Fig. 1.1.

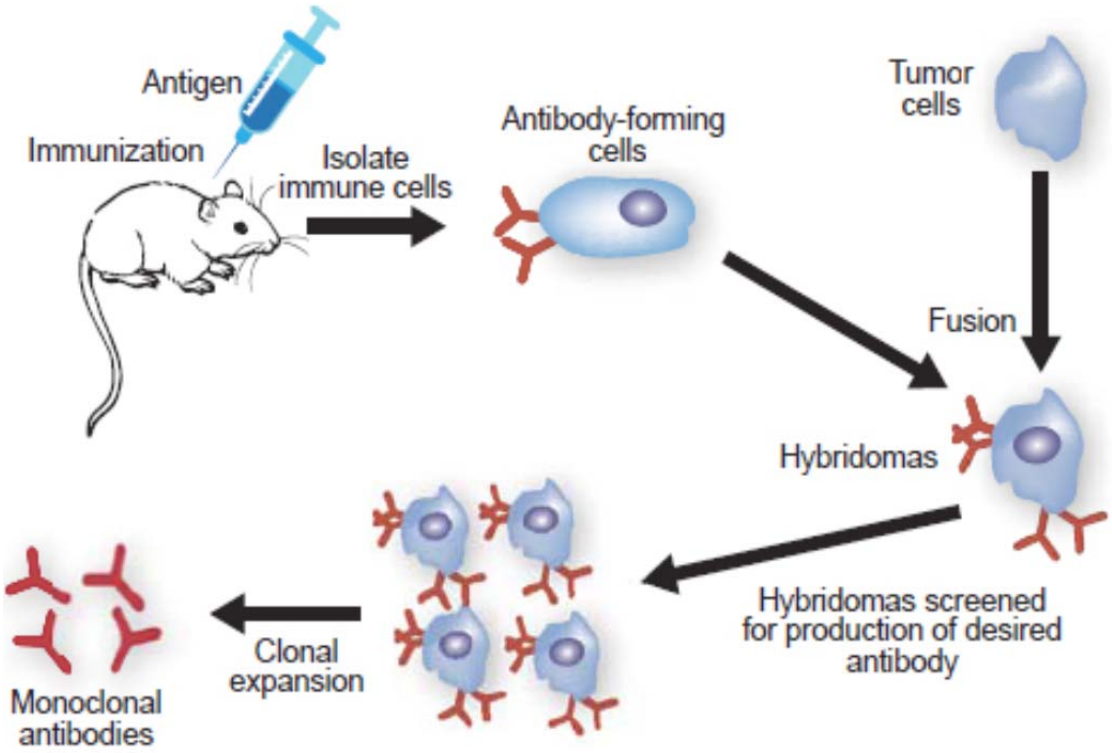


Fig. 1.1

The steps to produce monoclonal antibodies using hybridoma technique are as follow:

Step 1: A mouse is injected with a specific antigen.
Step 2: The mouse is left for a few weeks to allow immune response to occur.
Step 3: Immune cells are isolated and plasma cells are extracted from the mouse's spleen.
Step 4: Plasma cells are fused with tumour cells to form hybridoma.
Step 5: Hybridomas are screened to select the ones that are producing the desired antibody.
Step 6: Selected hybridomas are isolated to grow and divide during clonal expansion.

(a) State the type of immunity involved in the production of monoclonal antibody.

…….[1]

(b) In the space below, draw a labelled diagram of an antibody such as immunoglobulin G (IgG).

[3]

(c) Describe the events that occur in step 2 during the immune response in the hybridoma technique.

…….

…….

…….

…….

…….

…….

…….

…….[4]

Hybridoma is a hybrid cell consisting of both tumour and plasma cells.

(d) Explain how mutations result in cancer.

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……

……**[4]**

Besides genetic mutation, cancer can be caused by other causative factors.

(e) Identify two such factors.

…….

……**[1]**

The tumour cells were genetically modified such that an enzyme known as hypoxanthine-guanine-phosphoribosyltransferase (HGPRT) is absent. HGPRT enzyme is involved in the synthesis of purine. On the other hand, the plasma cells have the HGPRT enzyme. Therefore, the fused plasma cell in the hybridoma supplies the HGPRT enzyme for the survival of the hybridomas.

(f) Explain the roles of purine in living organisms.

…….

…….

…….

…….[2]

(g) Explain why unfused tumour cells and unfused plasma cells are unable to grow for a long period of time.

…….

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…….[2]

The HGPRT enzyme consists of four polypeptide chains, as shown in Fig. 1.2.

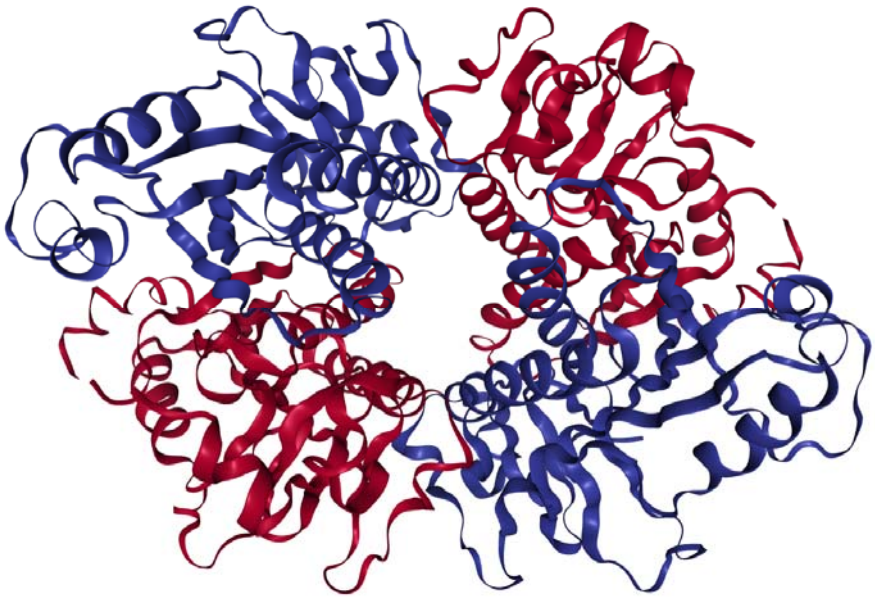

Fig. 1.2

(h) Explain the importance of the shape of HGPRT enzyme to its function.

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.....**[2]**

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Rheumatoid arthritis (RA) is an autoimmune disease in which T lymphocytes attack the cartilage of joints by secreting a protein, TNFα. RA can be treated using either the anti-inflammatory drug, MTX, or monoclonal antibody, infliximab.

Five groups of people with RA received the following treatments for one year:

- group **P** – MTX only
- group **Q** – MTX plus low dosage of infliximab at intervals of eight weeks
- group **R** – MTX plus low dosage of infliximab at intervals of four weeks
- group **S** – MTX plus high dosage of infliximab at intervals of eight weeks
- group **T** – MTX plus high dosage of infliximab at intervals of four weeks.

At the end of the year's treatment, the proportion of people in each group with increased joint damage was determined.

The experimental results are shown in Fig. 1.3. The number of people in each group is shown in brackets. All bar graphs display means ± standard error mean (S.E.M) (sample size ⩾ 3). Comparisons between infliximab treatments and untreated controls were made using a Student's t-test (*p < 0.5, **p < 0.01, ***p < 0.001).

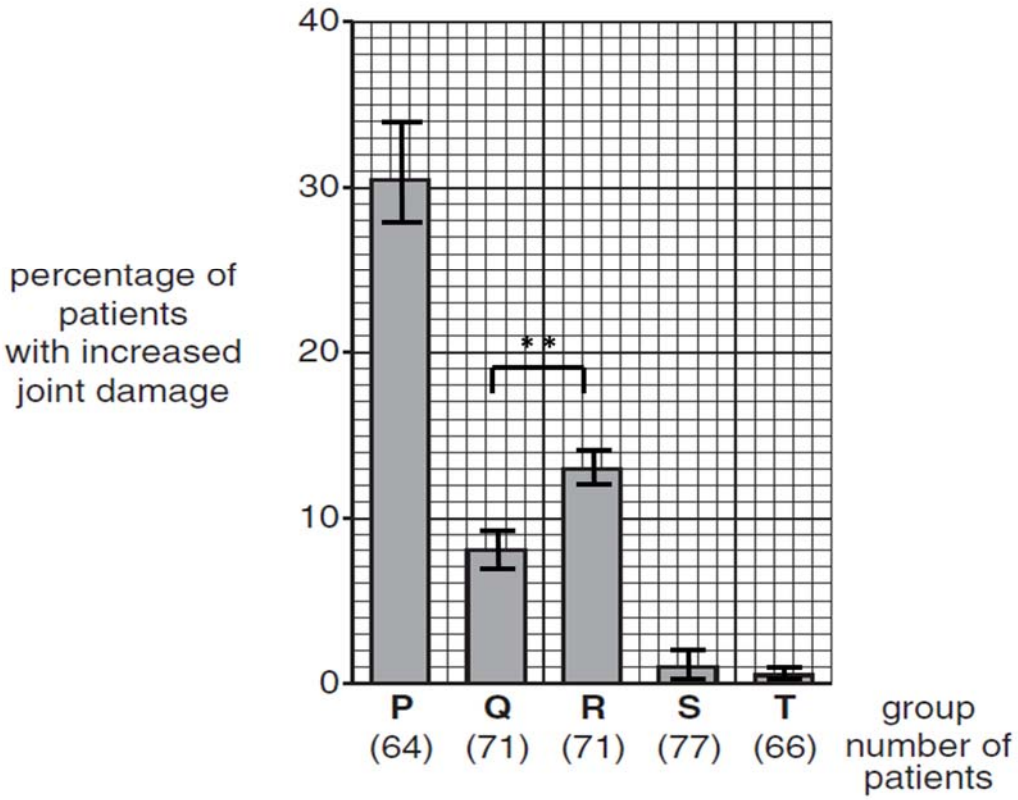

Fig. 1.3

(i) Discuss the effectiveness of infliximab treatment on these patients.

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.....

.....**[4]**

(j) With reference to the S.E.M and the t-test results, assess the validity of the experimental results.

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.....

.....**[2]**

[Total:25]

2. The middle of the Nevada desert seems an unlikely spot to find a fish. But an underground fissure in scorching-hot Death Valley is the only natural habitat for the endangered Devils Hole pupfish, a silvery blue creature about the size of a pet goldfish.

The water inside Devils Hole is consistently a toasty 32°C, hot enough to kill most other fish. For two months of the year, the cavern—which opens into a deep subterranean lake—receives no direct sunlight. And yet scientists believe a small population of pupfish has lived there for 10,000 to 20,000 years.

Now, evidence is growing that these fish might be far younger than previously assumed: A new study suggests that the Devils Hole pupfish actually colonised its watery cavern somewhere between 105 and 830 years ago, making scientists rethink how it got there in the first place. “Our new estimate of the younger age in a way makes this species even more fascinating because it has so many of these unique traits relative to other pupfish,” says Christopher Martin, a biologist at the University of North Carolina, Chapel Hill, who led the study.

Pupfish first arrived in Death Valley during a wet period, probably when water joined the area to lakes or rivers elsewhere. But as the water dried up and the area turned to desert, the pupfish became isolated in a smattering of springs.

Devils Hole is especially isolated, and the pupfish population there is particularly small, ranging from 35 to 548 fish in the remote cavern since official recordkeeping began in the 1970s. Their survival has been heralded as an evolutionary anomaly, as such populations usually become severely inbred and die out. “All we know about conservation genetics suggests that these populations of very small size should not be able to survive in the long term,” Martin says.

To figure out just when the Devils Hole pupfish diverged from its kin, the researchers sequenced 13,000 different stretches of DNA from 56 pupfish from around Death Valley and the world. Those data allowed them to reconstruct the area's pupfish family tree and calculate when the different species emerged. Although scientists previously believed the first pupfish species came to Death Valley several million years ago, these analyses suggest they arrived around the time of the valley’s most recent flood, just 10,000 years ago. The analysis also suggests the Devils Hole pupfish became isolated from other pupfish in Death Valley fewer than a thousand years ago, much more recently than expected.

http://www.sciencemag.org/news/2016/01/bizarre-desert-dwelling-fish-may-have-evolved-just-couple-hundred-years-ago. Extracted on 10th June 2018.

(a) Suggest why there is discrepancy to the age of the early ancestor of pupfish.

.....

.....**[1]**

Scientists believed that the change from an extensive lake system to a few pools drives the evolution of five species of the pupfish.

(b) Explain how this may happen.

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.....**[5]**

During autumn in 2017, there were only 115 of the fishes in the Death Valley.

(c) Suggest why the pupfish becomes endangered when their population falls to very low numbers.

.....

.....

.....

.....**[2]**

In the study, the scientists used biochemical data to establish the evolutionary relationship of the pupfish.

(d) Describe two other methods that the scientists could use to understand the homology between different fish species.

.....

.....

.....

.....**[2]**

The pupfish survives in water with high temperature of 32^{o}C, minimal food, and receive no sunlight two months of the year.

(e) Describe the effect of temperature on protein structure and function.

.....

.....

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.....

.....

.....**[3]**

(f) Explain how the biomolecules of organisms adapt to the harsh living condition of Death Valley.

.....

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.....

.....**[3]**

The Death Valley receives less than two inches of rain every year. In comparison, the average rainfall in the United States is 32 inches in 2017.

(g) Predict what may happen to the pupfish if water level rises to form an extensive lake system.

.....

.....

.....

.....**[2]**

Rising sea level may be caused by the addition of extra water from ice sheet or the thermal expansion of sea water. Thermal expansion of sea water refers to the increase in volume of sea water due to the increased sea temperature.

(h) Describe three other effects of increased sea temperature.

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.....

.....

.....**[3]**

Besides the increase in sea temperature, another effect of global warming is the increase in surface temperature. Fig. 2.1 shows the annual mean surface temperature in Singapore from 1948 to 2011.

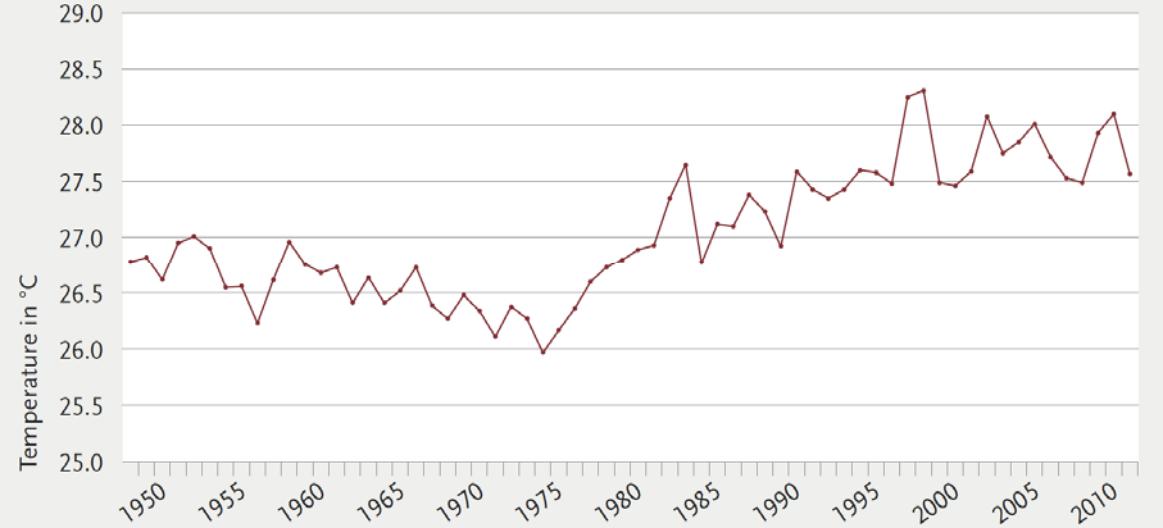

Fig. 2.1

(i) Describe the changes in annual mean surface temperature from 1948 to 2011.

.....

.....

.....

.....

.....

.....

.....**[3]**

(j) Suggest the event that may take place in 1975.

.....

.....**[1]**

[Total:25]

Section B

Answer **one** question in this section.

Write your answers on the lined paper provided at the end of this Question Paper.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous pose, where appropriate.

Your answers must be set out in parts **(a)** and **(b)**, as indicated in the question.

3 **(a)** With reference to a named virus and its reproductive cycle, describe how the virus can transfer genes between bacteria. **[10]**

(b) 'Without genetic variations, antibody is completely useless in the immune system.'

Discuss the validity of this statement. **[15]**

[Total: 25]

4 **(a)** Plants and other photosynthetic organisms convert light energy into chemical energy in the form of ATP and NADPH. Photosynthesis comprises both light and dark reactions, which are catalysed and regulated by proteins.

Describe the importance of proteins in photosynthesis. **[10]**

(b) Discuss the extent to which increased temperature can lead to the increase in dengue transmission. **[15]**

[Total: 25]

[Turn over

[Turn over

End of Paper

Candidate Name: _____

Class	Adm No

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millennia institute

2018 Preliminary Exams
Pre-University 3

BIOLOGY **9744/03**

Paper 3 Long Structured and Free-response Questions **17 September 2018**

2 hours

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 in the space provided on the Question Paper.

Section B
Answer any **one** question in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

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.

For Examiner's Use	
1	
2	
Section B	
Total	

Section A

Answer **all** questions in this section.

1. Monoclonal antibodies are antibodies derived from a single unique parent cell. In the industry, monoclonal antibodies are produced from hybridoma. The procedures are illustrated in Fig. 1.1.

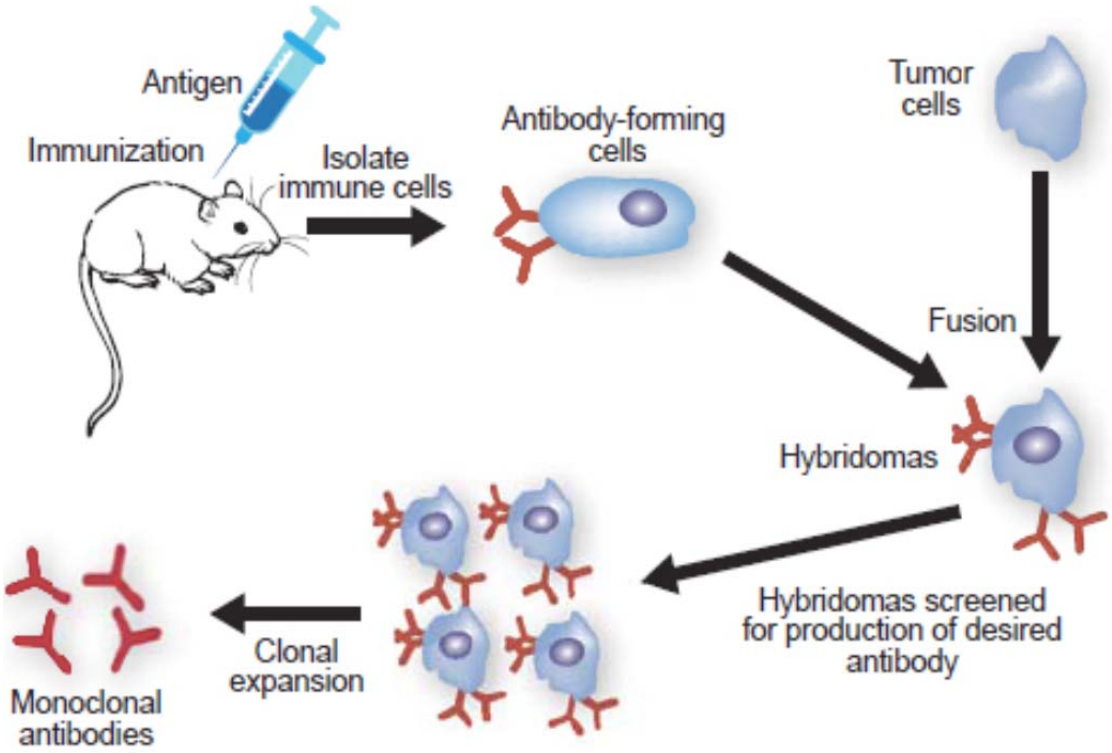


Fig. 1.1

The steps to produce monoclonal antibodies using hybridoma technique are as follow:

Step 1: A mouse is injected with a specific antigen.
Step 2: The mouse is left for a few weeks to allow immune response to occur.
Step 3: Immune cells are isolated and plasma cells are extracted from the mouse's spleen.
Step 4: Plasma cells are fused with tumour cells to form hybridoma.
Step 5: Hybridomas are screened to select the ones that are producing the desired antibody.
Step 6: Selected hybridomas are isolated to grow and divide during clonal expansion.

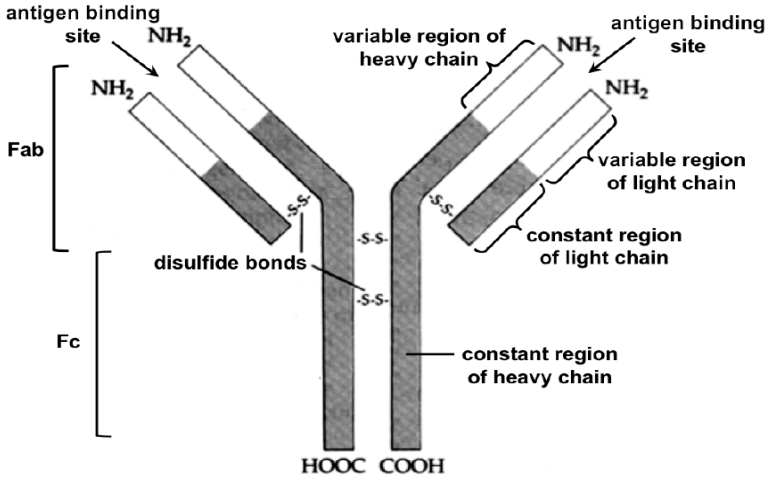
(a) State the type of immunity involved in the production of monoclonal antibody.

- Active artificial immunity

[1]

(b) In the space below, draw a labelled diagram of an antibody such as immunoglobulin G (IgG).

- Correct shape;
- Correctly label and number of light and heavy chains;
- Correctly label and number of variable and constant regions;
- Fab and Fc;



[3]

(c) Describe the events that occur in step 2 during the immune response in the hybridoma technique.

- Antigen is recognised as non-self/foreign by B cell/lymphocyte/APC;
- B cell with specific antigen receptor complementary to the antigen;
- B cell phagocytose the pathogen with the antigen;
- And displays class II MHC:peptide complex on the cell surface membrane of B cell;
- Activated CD4+ T helper cells with the same specific receptor will bind to the complex;
- And activate B cells which will then undergo clonal expansion to form more plasma and memory B cells/lymphocytes;

[4]

[Turn over

Hybridoma is a hybrid cell consisting of both tumour and plasma cells.

(d) Explain how mutations result in cancer.

- Gain-of-function mutation of proto-oncogene gene result in mutated oncogene;
  OR
- Gain-of-function mutation of ras gene result in mutated hyperactive/OWTTE Ras protein;
  OR
- Gain-of-function mutation of *c-myc* gene result in mutated hyperactive/OWTTE c-myc protein;
- Gain-of-function mutation is dominant where only one mutated allele is needed;
- Leads to over-stimulation of cell cycle through constitutive active protein/protein binding to substrate with increased affinity/protein being resistant to degradation;

Max 2

- Loss-of-function mutation of tumour suppressive gene;
  OR
- Loss-of-function mutation of p53 gene result in mutated inactivated p53 protein;
- Loss-of-function mutation is recessive where two copies of the alleles need to be mutated to produce non-functional tumour suppressive protein;
- Leads to loss of cell cycle arrest through loss of ability for DNA repair/loss of apoptosis during DNA damage/loss of cell cycle control/inappropriate cell cycle progression;

- Accumulation of mutations results in uncontrolled cell division;

Max 2

[4]

(e) Identify two such factors.

- Carcinogenic chemicals such as tar, ethidium bromide and tetrachloromethane
- Ionizing radidation such as ultraviolet radiation from sunlight
- Loss of immunity/immunosuppression that may weakens the immune system, thus increased chance of developing cancer
- Integration of viral DNA and disrupting proto-oncogene/tumor suppressor gene
- Genetic disposition/inherited in the family

Two factors to score one mark;

[1]

The tumour cells were genetically modified such that an enzyme known as hypoxanthine-guanine-phosphoribosyltransferase (HGPRT) is absent. HGPRT enzyme is involved in the synthesis of purine. On the other hand, the plasma cells have the HGPRT enzyme. Therefore, the fused plasma cell in the hybridoma supplies the HGPRT enzyme for the survival of the hybridomas.

(f) Explain the roles of purine in living organisms.

- Purine is a type of nitrogenous base that form part of the structure of nucleotide;
- Adenine and guanine are examples of purines;
- Forms deoxyadenosine 5'-monophosphate and deoxyguanosine 5-monophosphate in DNA;
- Forms riboadenosine 5-monophosphate and riboguanosine 5-monophosphate in RNA;
- Form the energy currency ATP and GTP;
- Important biomolecules/cofactor/reducing agent such as NADPH / NADH;

[2]

(g) Explain why unfused tumour cells and unfused plasma cells are unable to grow for a long period of time.

- Unfused tumor cells do not have the HGPRT enzyme to synthsise purine, which is essential for metabolism/survival/DNA replication/gene expression of cell/AVP;
- Unfused plasma cells are unable to grow indefinitely due to end-replication problem/absence of telomerase;

[2]

The HGPRT enzyme consists of four polypeptide chains, as shown in Fig. 1.2.

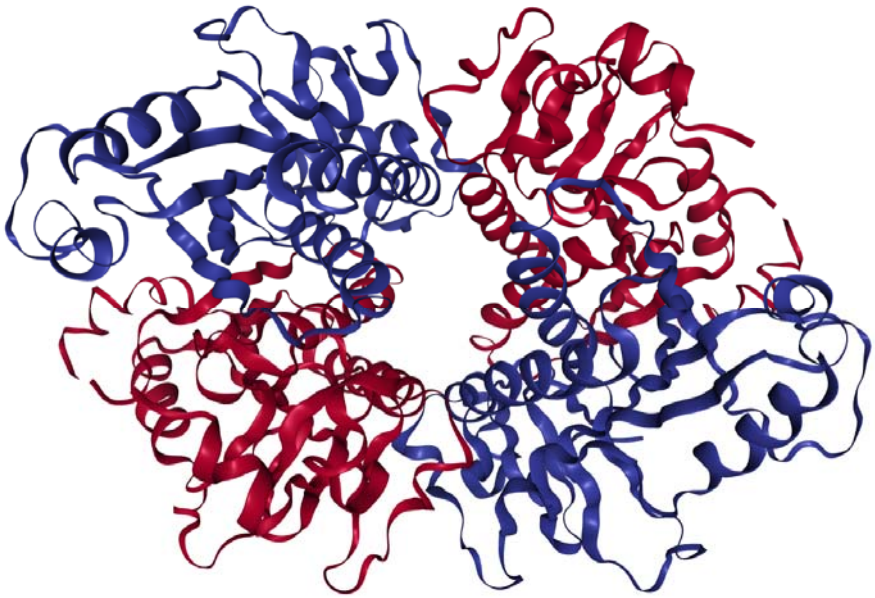


Fig. 1.2

(h) Explain the importance of the shape of HGPRT enzyme to its function.

- Globular;

Any 1 of the following

- All HGPRT enzymes/proteins expressed have the same amino acid sequence and thus have the same 3-dimensional conformation, giving the same binding site;
- Soluble in water and thus able to perform its function in the cell's aqueous environment;
- Amino acid with polar and charged R groups are found on the exterior surface of protein/enzyme;
- Amino acid with hydrophobic R groups are found on the interior surface of protein/enzyme;
- AVP;

[2]

Rheumatoid arthritis (RA) is an autoimmune disease in which T lymphocytes attack the cartilage of joints by secreting a protein, TNFα. RA can be treated using either the anti-inflammatory drug, MTX, or monoclonal antibody, infliximab.

Five groups of people with RA received the following treatments for one year:

- group **P** – MTX only
- group **Q** – MTX plus low dosage of infliximab at intervals of eight weeks
- group **R** – MTX plus low dosage of infliximab at intervals of four weeks
- group **S** – MTX plus high dosage of infliximab at intervals of eight weeks
- group **T** – MTX plus high dosage of infliximab at intervals of four weeks.

At the end of the year's treatment, the proportion of people in each group with increased joint damage was determined.

The experimental results are shown in Fig. 1.3. The number of people in each group is shown in brackets. All bar graphs display means ± standard error mean (S.E.M) (sample size ⩾ 3). Comparisons between infliximab treatments and untreated controls were made using a Student's t-test (*p < 0.5, **p < 0.01, ***p < 0.001).

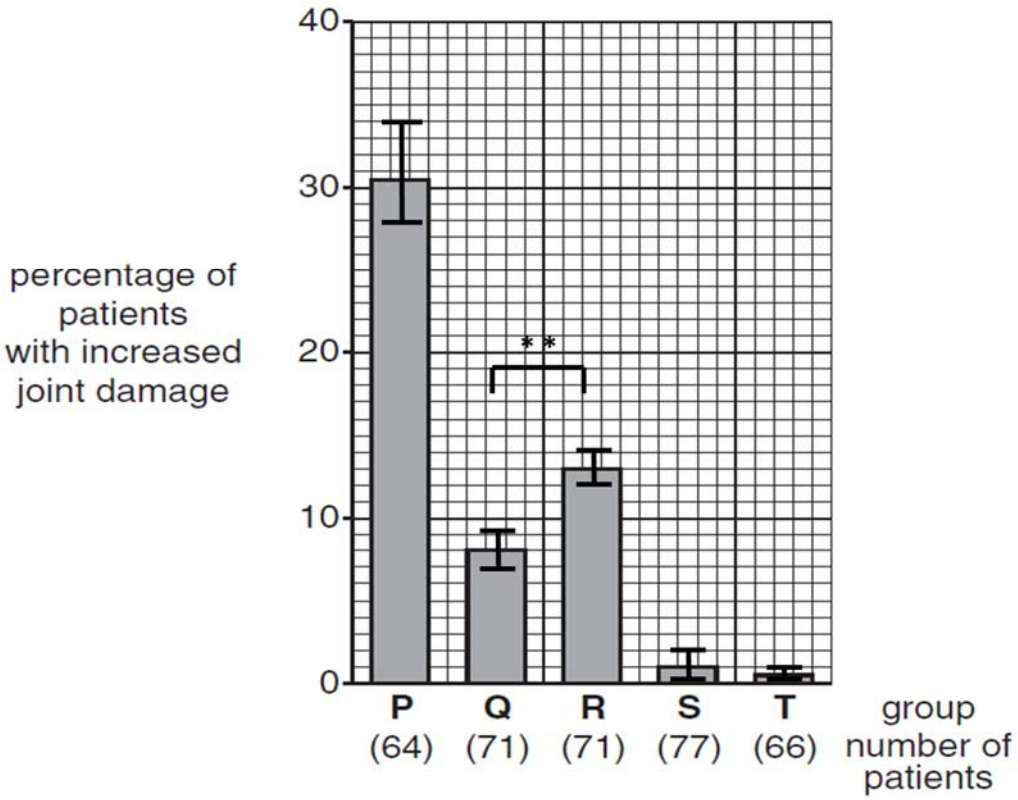


Fig. 1.3

(i) Discuss the effectiveness of infliximab treatment on these patients.

- in group P patients without infliximab treatment serving as control, the percentage of patients with increased join damage is highest at 30%;
- The percentages of patients with increased joint damage after given low dosage of infliximab are 8% and 13% for doses given at eight weeks interval and four weeks intervals respectively;
- The percentages of patients with increased joint damage after given high dosage of infliximab are 1% and 0.5% for doses given at eight weeks interval and four weeks intervals respectively;

Max 2

- There was higher percentage of patients with increased joint damage in patients given low dosage of infliximab than patients given high dosage of infliximab;
  OR
- At high dosage of infliximab treatment, there are lesser patients with increased joint damage as compared to low dosage of infliximab treatment;

- In the presence of infliximab, there are lesser patients with increased joint damage;
- High dosage given at either four or eight weeks interval is (most) effective;

[4]

(j) With reference to the S.E.M and t-test results, assess the validity of the experimental results.

- There is no significant difference between group S and group T;
- since the standard error bar of S and T overlap;
- Imply that the effect of high dosage is the same at intervals of eight weeks and at four weeks;
- Group Q should have higher percentage of patients with increased joint damage since it is administered at a lower frequency than R;
- There is significant difference between group Q and group R;
- since the standard error bar of S and T overlap;
- AVP;

[2]

al:25]

2. The middle of the Nevada desert seems an unlikely spot to find a fish. But an underground fissure in scorching-hot Death Valley is the only natural habitat for the endangered Devils Hole pupfish, a silvery blue creature about the size of a pet goldfish.

The water inside Devils Hole is consistently a toasty 32°C, hot enough to kill most other fish. For 2 months of the year, the cavern—which opens into a deep subterranean lake—receives no direct sunlight. And yet scientists believe a small population of pupfish has lived there for 10,000 to 20,000 years.

Now, evidence is growing that these fish might be far younger than previously assumed: A new study suggests that the Devils Hole pupfish actually colonised its watery cavern somewhere between 105 and 830 years ago, making scientists rethink how it got there in the first place. “Our new estimate of the younger age in a way makes this species even more fascinating because it has so many of these unique traits relative to other pupfish,” says Christopher Martin, a biologist at the University of North Carolina, Chapel Hill, who led the study.

Pupfish first arrived in Death Valley during a wet period, probably when water joined the area to lakes or rivers elsewhere. But as the water dried up and the area turned to desert, the pupfish became isolated in a smattering of springs.

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To figure out just when the Devils Hole pupfish diverged from its kin, the researchers sequenced 13,000 different stretches of DNA from 56 pupfish from around Death Valley and the world. Those data allowed them to reconstruct the area's pupfish family tree and calculate when the different species emerged. Although scientists previously believed the first pupfish species came to Death Valley several million years ago, these analyses suggest they arrived around the time of the valley’s most recent flood, just 10,000 years ago. The analysis also suggests the Devils Hole pupfish became isolated from other pupfish in Death Valley fewer than a thousand years ago, much more recently than expected.

http://www.sciencemag.org/news/2016/01/bizarre-desert-dwelling-fish-may-have-evolved-just-couple-hundred-years-ago. Extracted on 10th June 2018.

(a) Suggest why there is discrepancy to the age of the early ancestor of pupfish.

- Tentative nature of knowledge due to lack of knowledge in the past ; ……..
- Using recent technology deepens knowledge;
- AVP; …..**[1]**

Scientists believed that the change from an extensive lake system to a few pools drives the evolution of five species of the pupfish.

(b) Explain how this may happen.

- Existing variation exists within the ancestral/OWTTE population due to random mutations; …..
- Different selection pressures in each area where each population resides; ….
- Fish with alleles that confer selective advantage survive to reproductive age, and pass on these alleles to offspring (viable and fertile); ….
- Results in change in allele frequency / gene pool, leading to allopatric speciation …..
- Reproductive isolation resulting in absence of gene flow; ….
- The isolated population begins to evolve independently (idea) via genetic drift, mutation); ….
- Accumulation of sufficient genetic differences/mutation, hence unable to interbreed to produce viable and fertile offspring; …..
- Thus, altering the allele frequencies in each isolated population; ….

….

…..…….……..……..……[5]

During autumn in 2017, there were only 115 of the fishes in the Death Valley.

(c) Suggest why the pupfish becomes endangered when their population falls to very low numbers.

- There will be difficulty in finding a mate and reproduce; ……..
- Smaller gene pool/loss in genetic diversity and thus more vulnerable to changes in environment; ……..
- The rarity of species may attract poachers; ……..
- Difficult/slower for population number to increase significantly;
- AVP; ……**[2]**

In the study, the scientists used biochemical data to establish the evolutionary relationship of the pupfish.

(d) Describe two other methods that the scientists could use to understand the homology between different fish species.

- Embryological homology comparing structure of early development;
- Fossil record of fishes preserved in sedimentary rocks;
- Biogeography to study the geographical distribution of species;
- Anatomical homology to study homologous or analogous body structures between species;

[2]

The pupfish survives in water with high temperature of 32^{o}C, minimal food, and receive no sunlight two months of the year.

(e) Describe the effect of temperature on protein structure and function.

- Heat increases the kinetic energy of the molecules, breaking weak bonds;
- such as ionic bond, hydrogen bond and hydrophobic interaction(any two) that maintain the specific 3-dimesional shape of the protein;
- resulting in denaturation and loss of protein function;
- Aggregation of unfolded protein may take place;

[3]

(f) Explain how the biomolecules of organisms adapt to the harsh living condition of Death Valley.

- Proteins contain strong disulphide bonds between the;
- R groups of amino acids holding the tertiary and quaternary structure;
- Carbohydrates such as cellulose contain many cross linkages;
- Triglycerides contain fatty acid with saturated carbon-carbon bond;
- Nucleic acids contain more G=C hydrogen bonds than A=T hydrogen bonds;
- AVP;

[3]

The Death Valley receives less than two inches of rain every year. In comparison, the average rainfall in the United States is 32 inches in 2017.

(g) Predict what may happen to the pupfish if water level rises to form an extensive lake system.

- Number of fishes of all species may increase initially;
- Due to increased breeding space/food;
- Eventually, there may be competition between the five species of pupfish;
- Possibly reducing the number of fishes in long term;
- The different species of fishes experience different selection pressure;
- Thus, not all fishes may survive/ORA;
- Interbreeding between species with compatible genetics/chromosome number;
- Different species may occupy different niches within the lake system;

[2]

Rising sea level may be caused by the addition of extra water from ice sheet or the thermal expansion of sea water. Thermal expansion of sea water refers to the increase in volume of sea water due to the increased sea temperature.

(h) Describe three other effects of increased sea temperature.

- Increase in temperature in the ocean water may stress the coral and zooxanthellae symbiotic relationship, leading to coral bleaching;
- Increased evaporation may lead to increased precipitation/heavy rain;
- Leads to rising sea level may results in flooding;
- Flooding may stress the fresh water supplies;
- Migration of marine life where temperature is cooler and more optimal for their survival/ORA;

[3]

Besides the increase in sea temperature, another effect of global warming is the increase in surface temperature. Fig. 2.1 shows the annual mean surface temperature in Singapore from 1948 to 2011.

Fig. 2.1

(i) Describe the changes in annual mean surface temperature from 1948 to 2011.

- The annual mean surface temperature decreases in fluctuating manner from 26.8°C in 1948 to 26.0 °C in 1975/decrease by 8 °C from 1948 to 1975;
- The annual mean surface temperature increases from 26.0 °C in 1975 to 26.9 °C in 1981/1982;
- Further increase in fluctuating manner to 27.6 °C in 2011;

[3]

(j) Suggest the event that may take place in 1975.

- Urbanisation/increase number of building;
- Increase emission of greenhouse gases/carbon dioxide/methane;
- AVP;

[1]

[Total:25]

Section B

Answer **one** question in this section.

Write your answers on the lined paper provided at the end of this Question Paper.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous pose, where appropriate.

Your answers must be set out in parts **(a)** and **(b)**, as indicated in the question.

3 **(a)** With reference to a named virus and its reproductive cycle, describe how the virus can transfer genes between bacteria. **[10]**

(b) 'Without genetic variations, antibody is completely useless in the immune system.'

Discuss on the validity of this statement. **[15]**

[Total: 25]

4 **(a)** Plants and other photosynthetic organisms convert light energy into chemical energy in the form of ATP and NADPH. Photosynthesis comprises both light and dark reactions, which are catalysed and regulated by proteins.

Describe the importance of proteins in photosynthesis. **[10]**

(b) Discuss the extent to which increased temperature lead to the increase in dengue transmission. **[15]**

[Total: 25]

3a) With reference to a named virus and its reproductive cycle, describe how the virus can transfer genes between bacteria. **[10]**

1 Lambda phage can undergo specialized transduction;
2 when it switches from a lysogenic to a lytic cycle;.
3 The single tail fibres of the Lambda phage attach to specific receptor sites on the surface of a bacterial host cell;
4 The tail sheath contracts, piercing through the bacterial cell wall and cell membrane and the phage DNA is injected into the bacterial cell;
5 Lambda genome is integrated into specific site on the bacterial chromosome/prophage insertion site via integrase;
6 Once integrated, the phage DNA in a bacterium is called a prophage.
7 A prophage gene could code for a repressor protein that prevents transcription of most of the other prophage genes.
8 When the bacteria cell divides by binary fission, it also replicates the prophage DNA along with its own bacterial chromosome, passing on the prophage to daughter cells;
9 Switch from lysogenic to lytic cycle due to environmental signals, such as radiation, availability of nutrients or the presence of certain chemical (any 2);
10 The repressor proteins that were repressing lambda gene replication are no longer made;
11 allowing the Lambda phage genome to be excised from the bacterial chromosome;
12 The viral genome may not be excised properly at this stage and hence viral DNA may contain bacterial genes which are adjacent to the virus DNA during integration;
13 The virus DNA, containing some of the host bacterial gene, is packed into a new viral particle and released;
14 The viral particle may infect another bacteria and inject its DNA along with the host bacterial DNA;
15 The bacterial DNA may undergo crossing over with the homologous DNA region in the recipient cell, resulting in new combination of alleles/gene in the recipient;

QWC: Good spread of knowledge communicated without ambiguity to include at least 3 marking points from each paragraph

3b) 'Without genetic variations, antibody is completely useless in the immune system.'

Discuss the validity of this statement. **[15]**

Stand [compulsory]

1 Antibody useless to a large extent without genetic recombination;
2 AVP;

Antibody and why antibody is useless

3 Antibody is the soluble form of B cell receptor secreted from activated plasma cells;
4 Genetic variation occurs to generate the wide diversity of antibody;
5 Without these genetic variation, immune system is only useful to a limited amount of antigen and effector function;
6 Foreign antigen will not be recognized as non-self and no immune response can be launched;
7 May lead to uncontrolled infection by pathogen;
8 Moreover, the antigen on pathogen may be mutated, thus it is important to have wide repertoire of antibody;

Max 3

V(D)J recombination and its importance

9 During V(D)J recombination/somatic recombination, the heavy and light chains at the variable region;
10 Undergo gene recombination during the differentiation of B cells;
11 There are multiple copies of the V, D and J gene segments, thus many different variable/V regions can be made by selecting different combinations of these segments;
12 For instance, In the **κ/**kappa light chain, the 40 V_k and 5 J_k gene segments can recombine to generate 200 possible V_K regions;
13 The choice of light chain and random pairing of the different variable regions of light and heavy chains during formation of the receptors;
14 Results in the highly diverse repertoire/OWTTE antigen binding sites of antibody;

Max 3

Somatic hypermutation and its importance

15 Somatic hypermutation refers to random point mutation;
16 in the rearranged VDJ region of heavy chain gene locus and the rearranged VJ region of light chain locus;
17 of the activated B cells in the adaptive immune response during clonal expansion;
18 Each clone with a mutation acquires an altered amino acid sequence within the variable region of the Ig chains;
19 This leads to affinity maturation, the average increase in affinity of the antibody to the antigen;

Max 3

Class switching and its importance

20 *Class/isotype switching is the process of B cell switching its isotype classes;*

21 regulated by cytokines released by $CD4^+$ T helper cells;

22 *occurs at the constant region of the heavy chain gene locus;*

23 Enables the same VH/variable heavy exon to be associate with different CH/constant heavy exon in the course of an immune response.

24 *Provide antibody with same antigen specificity but distinct/different effector functions;*
Max 2

How antibody can still be useful

25 Without genetic variation, antibody is still able to recognize limited number of epitope through the antibody's antigen binding site;

26 Without genetic variation, the antigen binding site of the antibody can still bind to the limited number of epitope but at lower affinity;

27 The antigen may not be able to bind to the antigen binding site firmly/OWTTE OR The antigen may fall off from the antigen binding site;

28 Without genetic variation, the antibody can still function with the limited type of effector functions;
Max 2

QWC: Good spread of knowledge communicated without ambiguity to include both sides of discussion and reference to the three types of genetic variation;

4a) Plants and other photosynthetic organisms convert light energy into chemical energy in the form of ATP and NADPH. Photosynthesis comprises of both light and dark reactions, catalysed and regulated by proteins.

Describe the importance of proteins in photosynthesis. **[10]**

Light reaction

1 Photosystem is a light–capturing unit located in the thylakoid membrane of the chloroplast;
2 consisting of a reaction centre surrounded by numerous light harvesting complexes.
3 The photosystems are made up of chlorophyll/pigment and protein;
4 The light harvesting complex enables the photosystem to absorb light energy and transfer to the reaction centre;
5 The energy is received by special chlorophyll a in the reaction centre, and thus transferred to the electron acceptor, a protein;
6 During the light dependent reaction, proteins/electron carriers such as cytochrome complex are involved in the electron transport chain;
7 Transfer of electron along protein carriers of ETC releases energy;
8 to pump proton from the stroma to the thylakoid space;
9 the enzyme NADP+ reductase transfers electrons from the protein to NADP+;
10 In chemiosmosis, ATP synthase is a transport protein;
11 Enables the diffusion of hydrogen ions from the thylakoid space into the stroma;
12 This provides energy for the synthesis of ATP from ADP;

Dark reaction

13 The ATP and NADPH are used in the dark reaction/Calvin cycle to synthesis sugar;
14 In the dark rection/calvin cycle, an enzyme Rubisco/rubulose bishosphate catalyse carbon fixation/incorporation of carbon dioxide with ribulose bisphosphate;
15 Many other enzymes are involved in the catalysis of other steps in Calvin cycle;

QWC: Include example and respective roles of proteins involve in light and dark reactions.

Discuss the extent of how increased temperature can lead to the increase in dengue transmission. **[15]**

1 *Aedes aegypti* is the primary vector of dengue virus;
2 Mosquitoes are cold blooded animals where their body temperature is affected by the environment;
3 Embryonic development is usually completed in 48 hours in a warm and humid environment, but may take weeks in cooler environment;
4 Increased temperature leads to shorter hatching time;
5 Larval development occurs in four stages and is dependent on temperature, availability and density;

Max 3

6 Temperature greatly influence its behaviour, development, reproduction and survival;
7 At temperature higher than 30^{o}C, the survival rate of larvae and pupae drop/OWTTE;
8 Increased temperature increases the rate of enzymae catalysed reactions which lead to higher metabolic rates;
9 As metabolic rates increase, the development rates/life cycle of egg, larva and pupa shortens/hasten;
10 At higher temperature, insects will mature, mate and reproduce in a shorter span of time than normal and consequently there is a greater capacity to produce more offspring during the transmission period;
11 At higher temperature, female mosquitoes digest blood faster and feed more frequently, thus increasing transmission intensity;
12 Increased temperature leads to increase water temperature, larvae take shorter time to mature and consequently there is greater capacity to produce more offspring.
13 Shorten developmental time of mosquito increases its survival rate as egg, larvae and pupae are less susceptible to predators, diseases and parasitism.

Max 5

14 Increased temperature encourages mosquitoes to migrate to higher latitudes with colder temperature;
15 Increased temperature may lead to warmer and shorter winters, allowing more mosquitoes to survive during and through winter as they can be active for a longer period of time;
16 In warmer climate, dengue virus complete extrinsic incubation within the female mosquito faster, thereby increasing the proportion of infectious vector;
17 Increased temperature leading to increased precipitation/rainfall increases the number and quality of breeding sites for mosquitoes;

Max 3

How increased temperature does not lead to increased transmission rate

18 At temperature beyond 35^{o}C, the survival rate of mosquito at all stages of life cycle decreases, thus decreasing transmission rate;
19 Due to decrease activity of enzyme at higher temperature, decreasing the rate of enzyme-catalysed reaction;

Max 1

Other factors

20 Economy of country/region will affect the extent of vector control;
21 Drug resistance of dengue virus strain;

22 Dense human population can lead to increase transmission;
23 Migration of people/increasing people movement;
Max 1

Stand [compulsory]
24 Increased temperature can lead to an increase in dengue transmission to a large extent, but can be managed with vector control management;
25 AVP;

QWC: Stand/Conclusion of discussion and coherent link between temperature, life cycle, mosquito and transmission;