YISHUN INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
**Higher 2**

CANDIDATE NAME ***ANSWERS***

CG _____ INDEX NO _____

# BIOLOGY

**9744/01**

Paper 1 Multiple Choice

**16 Sep 2022**

**1 hour**

Additional Materials: Multiple Choice Answer Sheet

**READ THESE INSTRUCTIONS FIRST**

Do not use staples, paper clips, glue or correction fluid/tape.
Write your name, index no. and CG on this cover page and OTAS provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

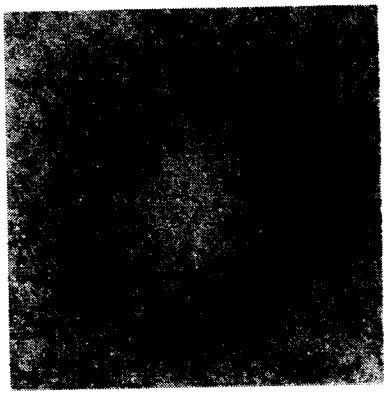
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

**Read the instructions on the Answer Sheet very carefully.**

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

This document consists of **21** printed pages and **1** blank page.

1 The electron micrograph shows a structure found in the cytoplasm of an animal cell.



What is this cell structure?

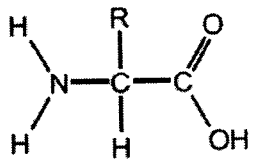
**A** centriole

**B** lysosome

**C** ribosome

**D** vesicle

2 The diagram represents an amino acid.




R represents a variable side chain.

Which of the following is **not** a possible side chain?

**A** $CH_3$

**B** $CH_2CH_2SCH_3$

**C** $CH_2CONH_2$

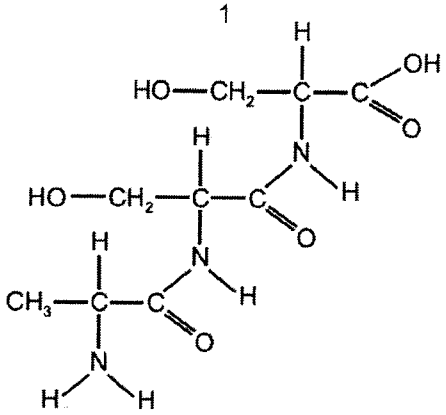
**D** $HOCH_2CH(OH)CH_2OH$

**3** A student carried out four tests for biological molecules on a solution. The results are shown in the table.

| test for biological molecule | observation |
|---|---|
| iodine solution | orange |
| biuret | blue |
| Benedict's | orange |
| emulsion | clear |

Which molecules are present in this solution?

1



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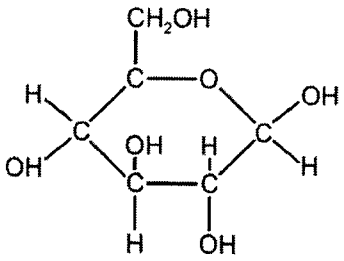

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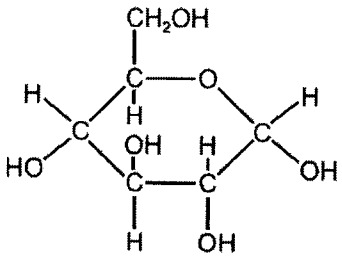
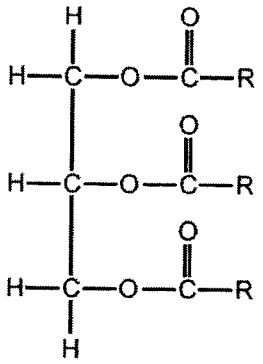


4



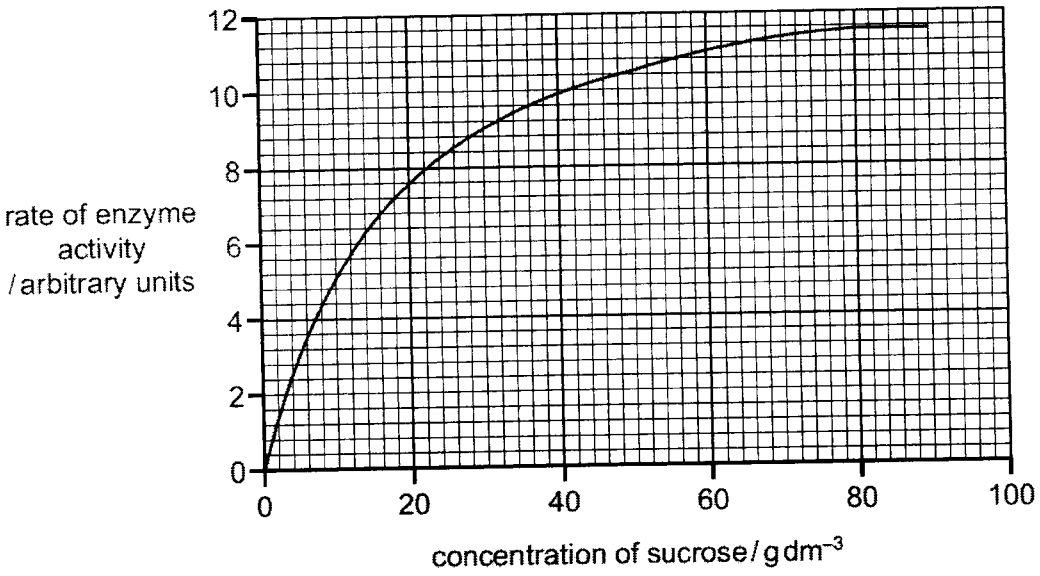
**A** 1 and 3

**B** 1 and 4

**C** 2 and 3

**D** 3 and 4

4 The graph shows the rate of activity of the enzyme sucrase plotted against the concentration of sucrose.




Why does the rate of enzyme activity remain constant from 80 – 90 g dm$^{-3}$.

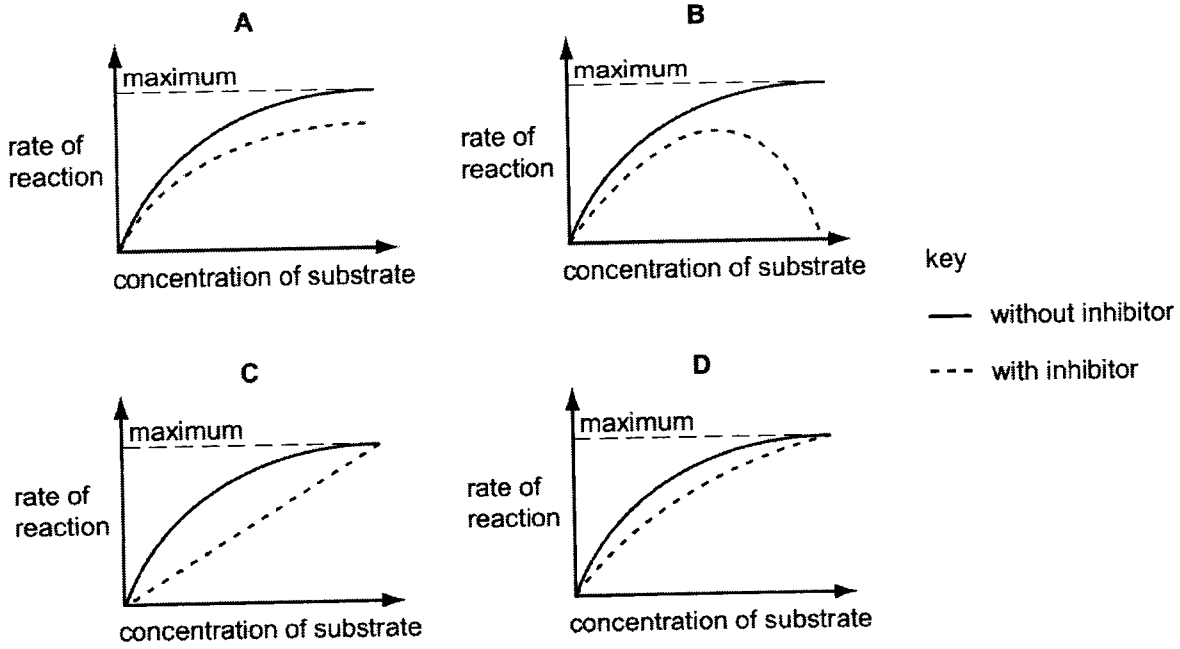
**A** All the enzyme has been inhibited.

**B** All the substrate has been used up.

**C** The concentration of the enzyme is limiting the rate.

**D** The concentration of the substrate is limiting the rate.

5 Which graph represents the action of a non-competitive inhibitor? **A**



6 The following are all observations about cell surface membranes.

1 Phospholipids labelled with radioactive phosphate groups change position over time.

2 Proteins labelled with fluorescent dyes change position over time.

3 Lectins are proteins that bind to polysaccharides. Lectins only attach to the outside of cell surface membranes.

4 Electron microscope images of membranes fractured by freezing shows a large number of regularly arranged particles interrupted by larger particles.

5 Some proteins can easily be removed from the membrane by changing the ionic balance.

6 Some proteins can only be separated from the membrane by disrupting the membrane with detergent.

Which observations provide evidence for the fluid mosaic model of cell surface membranes?

**A** 1, 2 and 4

**B** 1, 2 and 6

**C** 3, 4 and 5

**D** 3, 5 and 6

7 Some stem cells divide and give rise to phagocytes.

Where in the human body do these stem cells divide?

1 blood

2 bone marrow

3 lymph nodes

**A** 1, 2 and 3

**B** 1 and 3 only

**C** 2 only

**D** 3 only

8 Which statement(s) about RNA is / are correct?

1 It is less stable than DNA as it contains a ribose sugar that lacks a 2' OH group.

2 It is a single stranded polymer of purine and pyrimidine joined by phosphodiester bonds.

3 It is synthesised in the 5' to 3' direction where the 5'-phosphate group of the growing RNA strand is joined to the 3'-hydroxyl group of an incoming nucleotide.

4 The function of ribosomal RNA is to catalyse the formation of peptide bonds.

**A** 4 only

**B** 1 and 3 only

**C** 2 and 3 only

**D** 1, 3 and 4 only

9 The following statements list the processes that occur during translation.

1 The large subunit of the ribosome binds and forms the translation initiation complex.

2 The second amino acyl-tRNA complex now binds to mRNA at the "A" site of the ribosome.

3 The small ribosomal subunit, with initiator tRNA bound, binds to the 5' cap of the mRNA and scans for the first start codon.

4 Soluble protein called release factor recognises the stop codon and binds at the "A" site.

5 Formation of a peptide bond between the first and the second amino acids by peptidyl transferase.

6 The second amino acyl-tRNA complex moves from the "A" site to the "P" site.

Using the information provided above, deduce the order in which these processes occur.

**A** 1 → 3 → 2 → 5 → 6 → 4

**B** 1 → 3 → 2 → 6 → 5 → 4

**C** 3 → 1 → 2 → 5 → 6 → 4

**D** 3 → 1 → 2 → 6 → 5 → 4

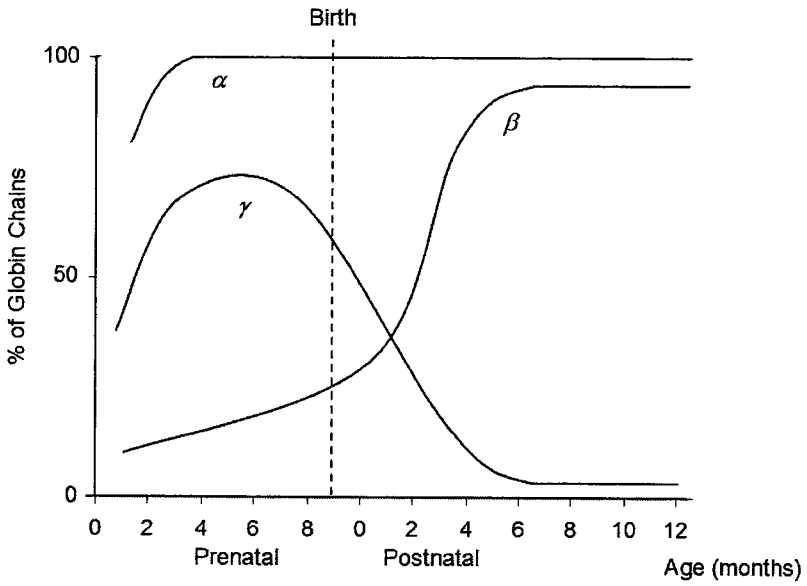
**10** The non-template strand of part of a DNA molecule has the sequence 5' GAATTA 3'.

Which row is correct for this part of the corresponding template and tRNA strands?

| | the sequence of the template strand | the anticodons of tRNA used in translation |
|---|---|---|
| **A** | 5' CTTAAT 3' | 5' CUU 3' and 5' AAU 3' |
| **B** | 5' CTTAAT 3' | 5' UAA 3' and 5' UUC 3' |
| **C** | 5' TAATTC 3' | 5' CUU 3' and 5' AAU 3' |
| **D** | 5' TAATTC 3' | 5' UAA 3' and 5' UUC 3' |

**11** The globin gene family in humans consists of α, β and γ genes. These genes code for the globin chains that make up haemoglobin and are expressed at different levels during different developmental stages.

The graph shows the expression of the various globin chains during the prenatal (fetal) and postnatal (after birth) periods.




Which statement **cannot** account for the differences in the levels of expression of globin chains?

**A** A growth factor triggers the expression of a transcription factor that increases the rate of β-globin gene expression during the postnatal period.

**B** Alternative splicing occurs in the mRNA of the α-globin and β-globin genes, resulting in differences in the rate of expression of globin chains during the prenatal period.

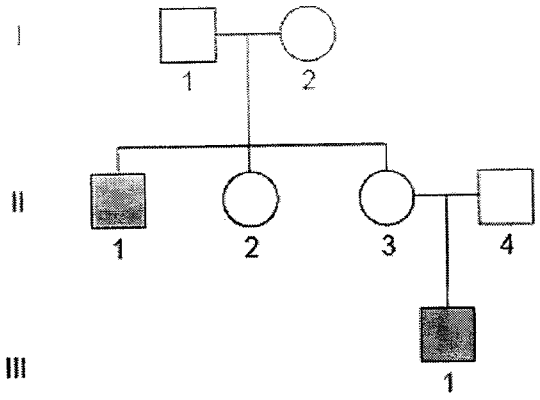
**C** Methyl groups are added to regulatory sequences of γ-globin genes during the prenatal period, allowing for some proteins to bind.

**D** The shortening of poly(A) tail in the mRNA of γ-globin genes reduces its stability, resulting in a decrease in the rate of expression of γ-globin chains during the prenatal period.

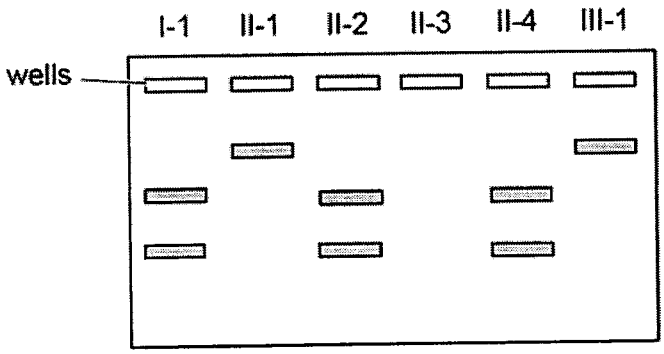
**12** Menkes' Disease in humans is characterised by sparse and wiry hair, growth failure and deterioration of the nervous system. Onset of the Menkes' syndrome usually occurs during infancy.

Restriction digestion was carried out on DNA samples taken from a family in which this X-linked disorder was present. The DNA fragments obtained were subjected to gel electrophoresis.

The family pedigree is shown below.

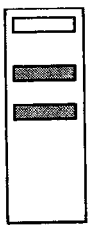



The figure below shows the results obtained after gel electrophoresis.

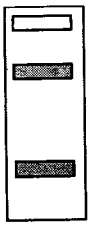



What would be the band pattern of individual II-3?

**A**

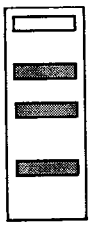


**B**

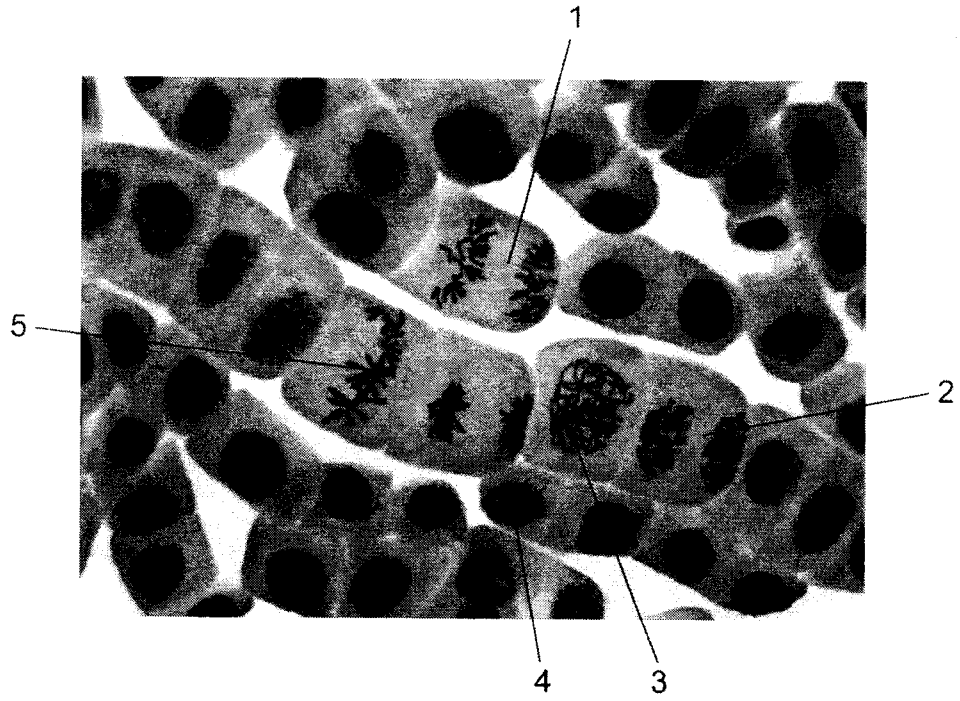


**C**

**D**



**13** The photomicrograph shows cells in different stages of mitosis.




In which order do these stages occur?

**A** 3 → 1 → 5 → 2 → 4

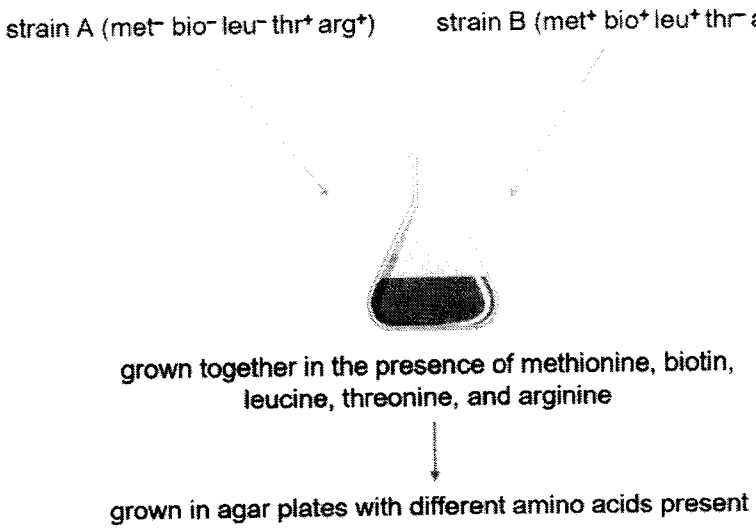
**B** 3 → 5 → 2 → 1 → 4

**C** 4 → 3 → 5 → 1 → 2

**D** 4 → 5 → 1 → 2 → 3

**14** Essential amino acids e.g. methionine (met), biotin (bio), leucine (leu), threonine (thr) and arginine (arg) are critical for the bacteria cells to survive and replicate. Some bacteria carried the genes required for the synthesis of the amino acid (indicated by "+") while others with the genes (indicated by "-") will take up these amino acids from the culture medium.

An experiment involving two strains of bacteria were conducted to investigate gene transfer.




The results of the investigation are summarised in the table below.

| flask | bacterial srain grown | amino acid present in agar plate | | | | | presence of bacteria colonies |
|---|---|---|---|---|---|---|---|
| | | met | bio | leu | thr | arg | |
| 1 | A | ✓ | ✗ | ✓ | ✗ | ✗ | no |
| 2 | B | ✗ | ✗ | ✗ | ✓ | ✓ | yes |
| 3 | A + B | ✗ | ✗ | ✗ | ✗ | ✗ | yes |

Which of the following process(es) could explain the results in flask 3?

1 Conjugation
2 Transduction
3 Transformation

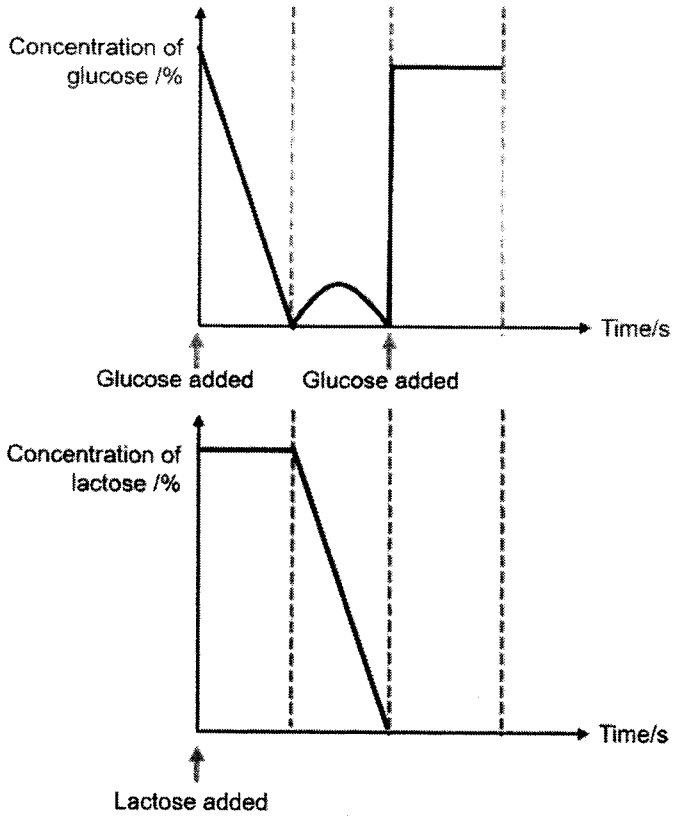
**A** 3 only

**B** 1 and 2

**C** 1 and 3

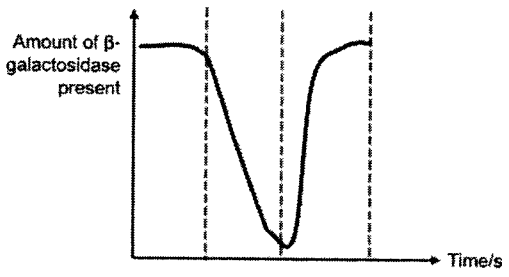
**D** 1, 2 and 3

**15** *Escherichia coli* are able to metabolise both glucose and lactose for their energy requirement. In an experiment, researchers added glucose and lactose into the *E. coli* culture at different time points and measured the amount of β-galactosidase, glucose and lactose levels at regular time intervals. The arrows in the diagram indicate the addition of the respective metabolite into the culture.

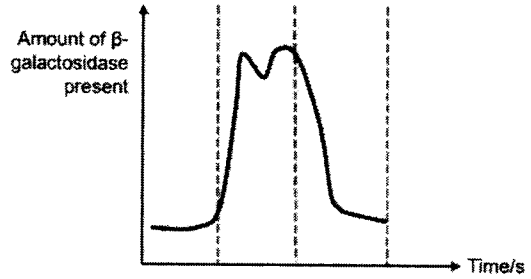



Which graph correctly shows the corresponding amount of β-galactosidase present in the culture?

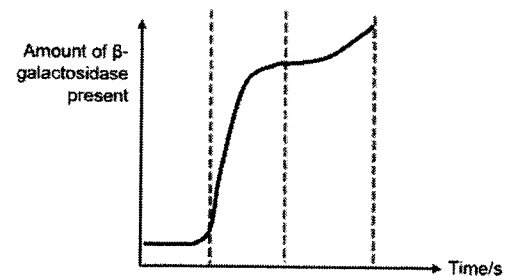
**A**



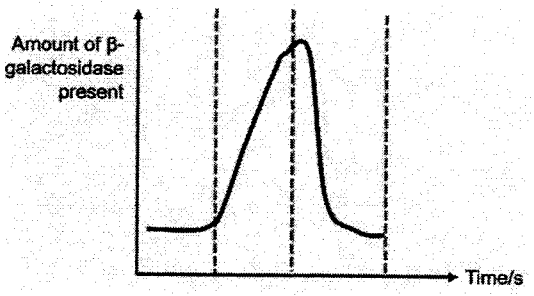

**B**




**C**




**D**



**16** Which of the following statement(s) concerning *trp* operon is / are true?

1 A mutation of the regulatory gene leads to constitutive production of tryptophan.

2 There is one start and one stop codon in the mRNA of *trp* operon.

3 The repressor is inactive in the presence of excess tryptophan.

4 The mRNA codes for multiple polypeptides involved in the synthesis of tryptophan.

**A** 1 only

**B** 1 and 4

**C** 2 and 3

**D** 1, 2 and 4

**17** A tall, green-stemmed plant with the genotype TTrr was crossed to a short, red-stemmed plant with the genotype ttRR. The F1 plants were allowed to self-fertilise. A $\chi^2$ test was carried out on the results obtained for the F2 generation.

Part of the table of values for $\chi^2$ is shown.

| degree of freedom | probability | | | | |
|---|---|---|---|---|---|
| | 0.5 | 0.1 | 0.05 | 0.01 | 0.001 |
| 1 | 0.46 | 2.71 | 3.84 | 6.64 | 10.83 |
| 2 | 1.39 | 4.6 | 5.99 | 9.21 | 13.82 |
| 3 | 2.37 | 6.25 | 7.82 | 11.34 | 16.27 |
| 4 | 3.36 | 7.78 | 9.49 | 13.28 | 18.46 |

The value of $\chi^2$ in this investigation was 7.6.

What is the probability of this value of $\chi^2$ value?

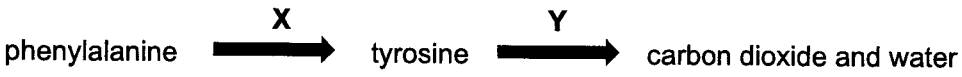
**A** between 0.001 and 0.01

**B** between 0.01 and 0.05

**C** between 0.05 and 0.1

**D** less than 0.05

**18** The following reaction sequence occurs in humans.




Genetic disease **P** is caused by an enzyme deficiency in step **X** and genetic disease **Q** is caused by an enzyme deficiency in step **Y.** Both conditions are rare and are caused by recessive alleles.

A person with genetic disease **P** marries a person with genetic disease **Q**.

Which phenotypes would be expected for their children?

**A** All have neither genetic disease

**B** All have genetic disease **P** only

**C** All have genetic disease **Q** only

**D** All have both genetic diseases

**19** A tall, pink-flowered plant is self-fertilised and produces the offspring shown.

| | flower colour | | |
|---|---|---|---|
| | red | pink | white |
| tall plants | 73 | 157 | 67 |
| dwarf plants | 21 | 53 | 25 |

When self-fertilised, which type of plant will only produce identical offspring?

**A** dwarf, pink-flowered

**B** dwarf, red-flowered

**C** tall, red-flowered

**D** tall, white-flowered

**20** Mammalian liver cells were homogenised, and the resulting homogenate centrifuged. Portions containing only mitochondria and cytosol (residual cytoplasm) were each isolated. Samples of each portion, and of the complete homogenate, were incubated in four ways:

1 with glucose

2 with pyruvate

3 with glucose plus cyanide

4 with pyruvate plus cyanide

Cyanide inhibits carriers in the electron transport chain. After incubation, the presence or absence of carbon dioxide and lactate in each sample was determined. The results are summarised in the table below.

| Tube | samples of homogenate | | | | | |
|---|---|---|---|---|---|---|
| | complete | | mitochondria only | | cytosol | |
| | carbon dioxide | lactate | carbon dioxide | lactate | carbon dioxide | lactate |
| 1 | ✓ | ✓ | ✗ | ✗ | ✗ | ✓ |
| 2 | ✓ | ✓ | ✓ | ✗ | ✗ | ✓ |
| 3 | ✗ | ✓ | ✗ | ✗ | ✗ | ✓ |
| 4 | ✗ | ✓ | ✗ | ✗ | ✗ | ✓ |

✗ = absent, ✓ = present

Which statement can be concluded from the table?

**A** Both aerobic and anaerobic respiration were occurring in tube 3.

**B** Carbon dioxide was not formed when mitochondria were incubated with glucose as there was no oxygen present.

**C** Lactate formation in mitochondria was inhibited by the presence of cyanide.

**D** The action of cyanide would be similar to that of a cell experiencing anaerobic respiration.

21 Which statement about respiration under anaerobic conditions in yeast and mammalian muscle tissue is correct?

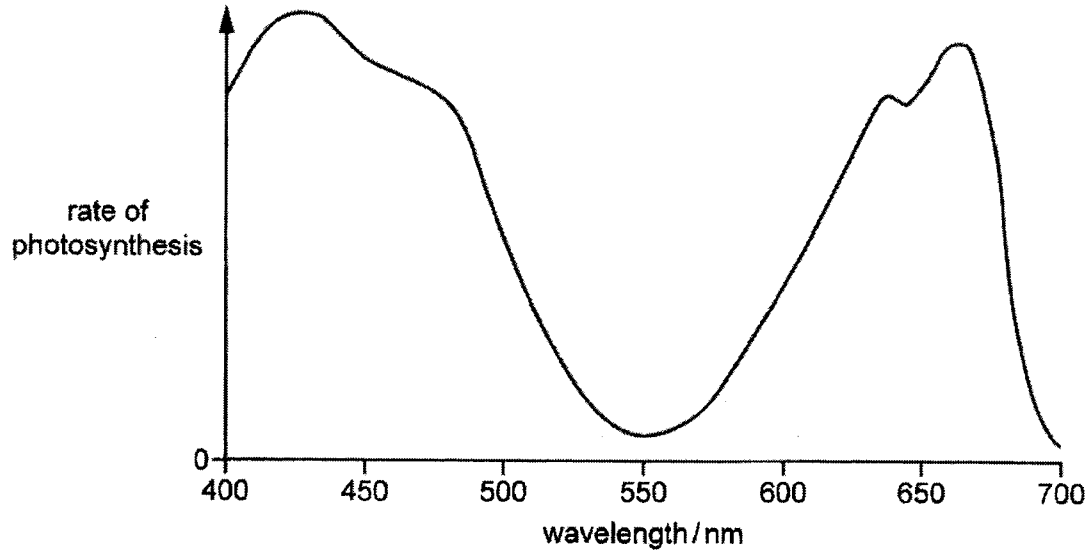
**A** During respiration under anaerobic conditions, only a small proportion of the energy in the initial reactants is used for ATP production.

**B** Under anaerobic conditions, ethanol production releases fewer carbon dioxide molecules than lactate production for the same yield of ATP.

**C** The amount of energy yielded from lactate production and ethanol production cannot be compared since the initial reactants are different.

**D** The continued production of ATP depends on respiration of ethanol in yeast and respiration of lactate in mammalian tissue.

22 The graph below shows the action spectrum for photosynthesis of a particular plant.




Which of the following explains the rate of photosynthesis for this plant at wavelengths of light between 525 nm and 575 nm?

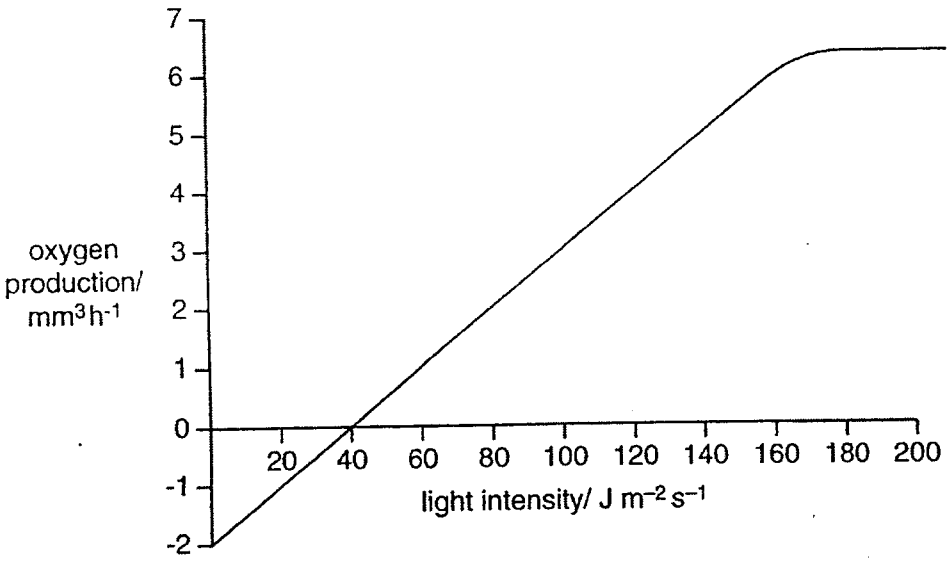
**A** Chlorophyll a is unable to undergo photoactivation between this wavelength.

**B** Energy level of light between this wavelength is low.

**C** The plant does not have pigments that absorb green light.

**D** The plant lacks carotenoid and xanthophyll pigments.

**23** The graph shows the relationship between oxygen production in photosynthesis and light intensity for a unicellular green organism in 0.02% sodium hydrogencarbonate solution.




The most likely explanation of the fact that the graph levels off at 180 J $m^2$ $s^{-1}$ is that the system is

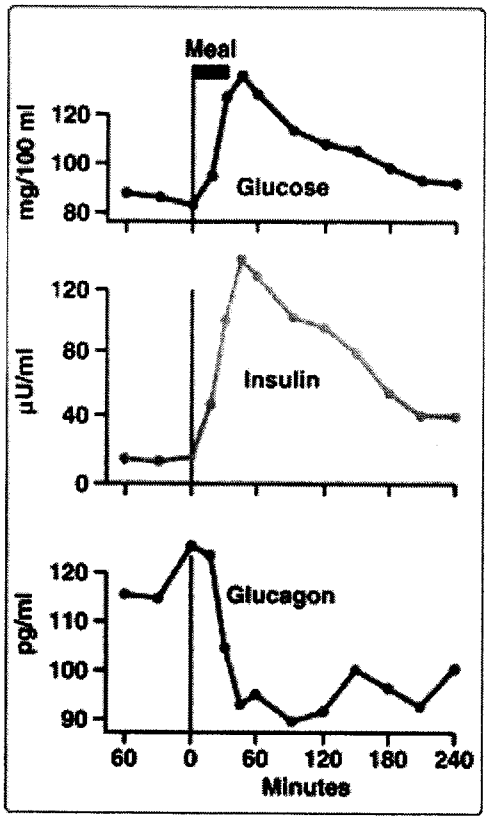
**A** light limited and carbon dioxide saturated.

**B** light limited and the temperature is below optimum.

**C** light saturated and carbon dioxide limited.

**D** light saturated and the temperature is above optimum.

**24** The figure shows the levels of glucose, insulin and glucagon found in blood, before and after a carbohydrate-containing meal was ingested.




Which row correctly identifies the events occurring at the respective timings?

| | Timing | Events |
|---|---|---|
| **A** | 60 minutes before meal | Glucagon results in the activation of glycogen phosphorylase, leading to increased rates of glycogenolysis in liver cells and an increase in blood glucose levels. |
| **B** | 30 minutes before meal | Glucagon binds to G protein-linked receptors, leading to the activation of G proteins due to the phosphorylation of GDP molecules. Cellular responses lead to the maintenance of blood glucose levels. |
| **C** | At the start of meal (0 minutes) | Insulin binds to tyrosine kinase receptors, resulting in the cross-phosphorylation of tyrosine residues. Cellular responses lead to a decrease in blood glucose levels. |
| **D** | 60 minutes after meal | Insulin results in the translocation of glucose transporters to the cell surface, leading to increased rates of glucose uptake in muscle cells and a decrease in blood glucose levels. |

**25** Which statements are correct interpretations of Darwinian evolutionary theory?

1 Advantageous behaviour acquired during the lifetime of an individual is likely to be inherited.

2 In competition for survival, the more aggressive animals are more likely to survive.

3 Species living in a stable environment will not evolve any further.

4 Variation between individuals of a species is essential for evolutionary change.

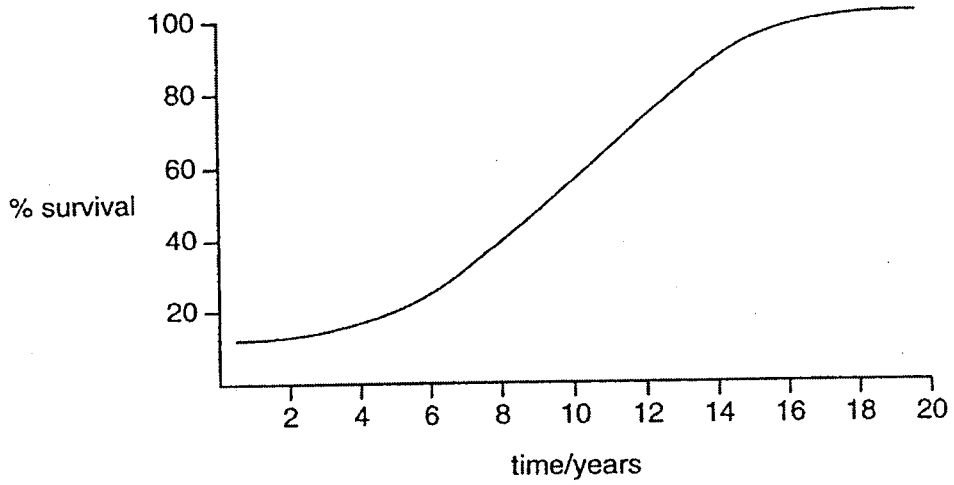
**A** 1, 2 and 4 only

**B** 2 and 3 only

**C** 3 and 4 only

**D** 4 only

**26** The graph shows the effect of pesticide treatment on houseflies over a number of years. A standard amount of pesticide was used each year in summer.




How is the effect of the pesticide best explained?

**A** A few resistant flies reproduced more successfully, and the resistance allele increased in frequency.

**B** At every generation an increasing proportion of flies mutated to become resistant.

**C** Repeated exposure to the pesticide caused the flies to become more resistant.

**D** The allele for resistance mutated from the recessive form to the dominant form.

27 Reproduction in seahorses, *Hippocampus* , is unusual as it is the male rather than the female that becomes pregnant. The male has a brood pouch located on its tail. The larger the male the larger the pouch. The female transfers unfertilised eggs into the pouch. The larger the female the more eggs are produced that can be transferred to the brood pouch. The male releases sperm onto the eggs and they are fertilised. The male carries the developing brood for a period of several weeks until he finally gives birth.

Research into seahorse populations has revealed the following.

- They are monogamous. A male and female remain together for the whole mating season.
- Within a population, mates are selected by size. Large females mate with large males and small females mate with small males.
- Few intermediate sized individuals are produced and they have a low survival rate.

Which of the following conclusions **cannot** be drawn from the above information?

**A** Disruptive selection has occurred.

**B** Intermediate sized individuals are selected against.

**C** There is phenotypic variation in tail size in males.

**D** Monogamy results in lower selection pressure as males and females remain together the whole mating season.

28 An antibody is a protein complex secreted by plasma B cells. Which of the following statements regarding the mechanisms of generating antibody diversity is true?

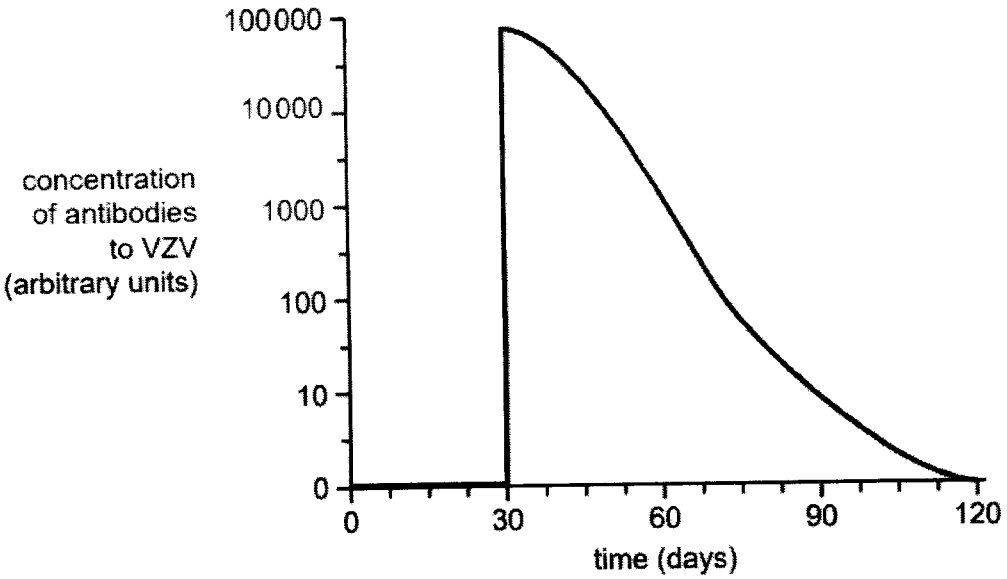
**A** An antibody changes its affinity upon binding to the antigen through a process known as somatic hypermutation.

**B** Class switching occurs to produce antibodies with different constant regions in B cells undergoing differentiation in the bone marrow.

**C** DNA rearrangement during somatic recombination generates a wide repertoire of B cells with different B cell receptors.

**D** During clonal expansion, rearrangement of the V, D and J segments give rise to antibodies with different variable regions.

**29** Chickenpox (varicella) is a highly contagious viral disease caused by the varicella-zoster virus (VZV). A laboratory technician measured the concentration of antibodies to VZV in a person's blood over a 120-day period. An event occurred on day 30 that significantly altered the concentration of antibodies. The concentration of antibodies over the 120 days is displayed in the graph below.




Which one of the following events could have occurred on day 30?

**A** a booster vaccination against VZV for the person

**B** an exposure of the person to VZV

**C** an injection of antibodies to VZV into the person

**D** an oral dose of antibiotics was given to the person

**30** Investigations into the possible current and future impacts of climate change need to be put into the context of the well-documented and on-going impacts of other drivers of change, such as population growth. The statements below are effects of climate change and population growth.

1 More intensive land use results in degradation of soils and more rainfall run-off

2 Food and feed shortages

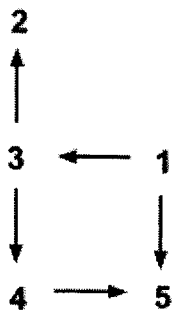
3 Greater frequency of water deficit in soil for crops and pasture growth

4 More frequent dry years experienced

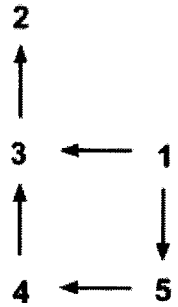
5 Increase food demand and competition for pastures

Which of the following diagram correctly illustrates the relationship between climate change and population growth?

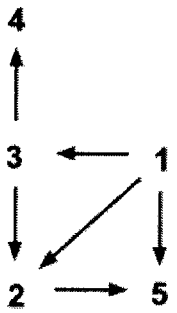
**A**



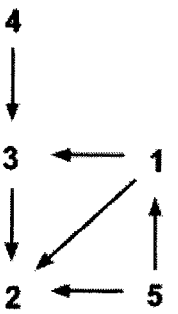

**B**




**C**




**D**



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YISHUN INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAM
**Higher 2**

NAME **ANSWERS**

INDEX NO _____ CG _____

# BIOLOGY

**9744/02**

Paper 2 Structured Questions

**31 Aug 2022**

Candidates answer on the Question Paper.

**2 hours**

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your name, index no. and CG on this cover page.
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.

Answer all questions 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.

The number of marks is given in brackets [ ] at the end of each question or part question

At the end of the examination, **submit booklets A, B and C separately** to the invigilator.

| For Examiner's Use | |
|---|---|
| **Section A** | |
| 1 | /12 |
| 2 | /9 |
| 3 | /10 |
| 4 | /7 |
| 5 | /9 |
| 6 | /9 |
| 7 | /9 |
| 8 | /11 |
| 9 | /12 |
| 10 | /7 |
| 11 | /5 |
| Total | /100 |

This document consists of **29** printed pages and **1** blank page.

Answer **all** questions

1 Collagen is a major component of the cartilage found in some of the structures of the human gas exchange system. Cells that synthesise and secrete the components of cartilage are known as chondrocytes.

Fig. 1.1 is a transmission electron micrograph of a chondrocyte.

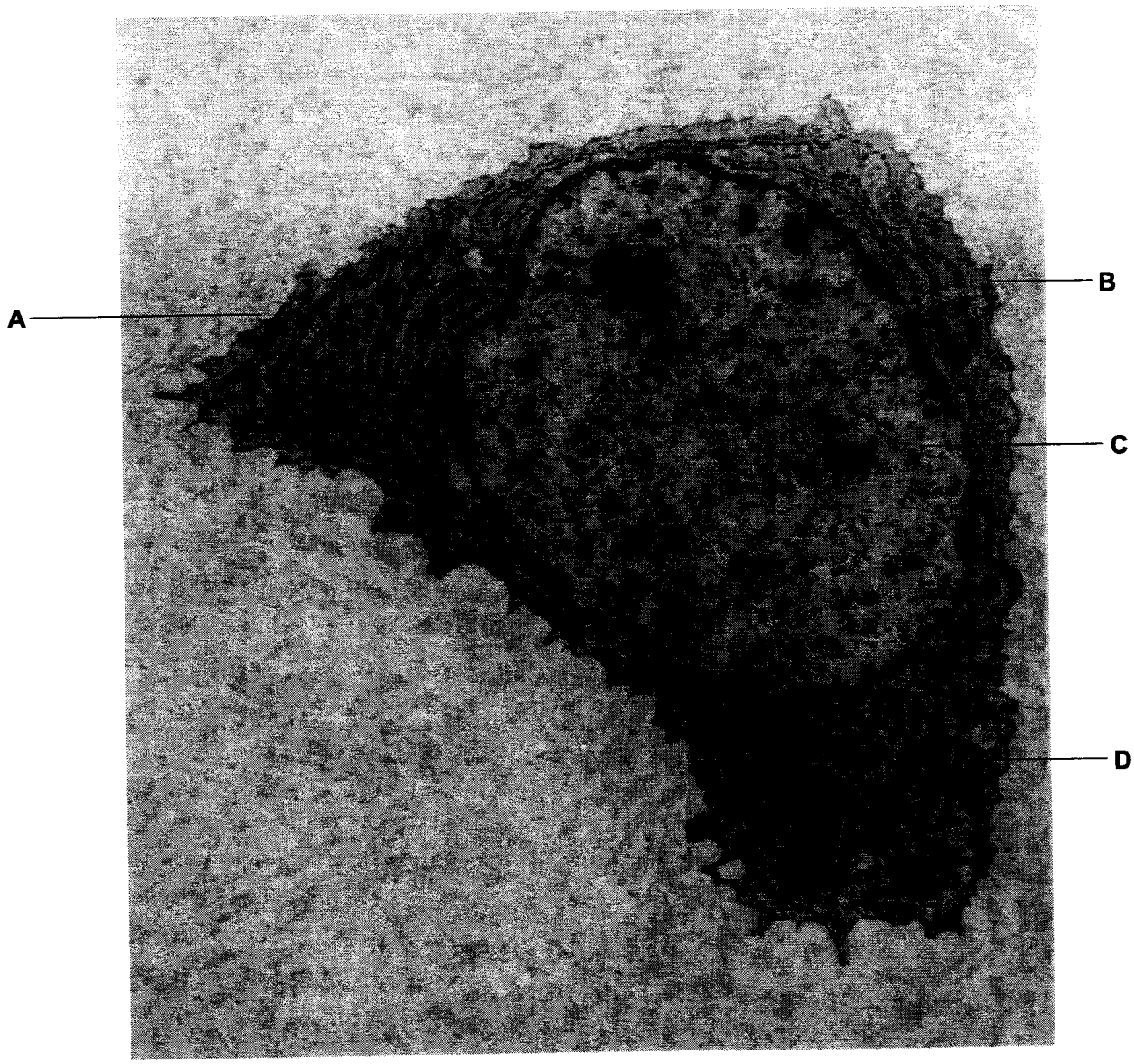



**Fig. 1.1**

**(a)** Identify structures **A - D**.

**A rough endoplasmic reticulum;**
**® *rER***
**Ⓐ ribosomes**

**B cell surface membrane;**

**C nucleus / nucleoplasm / euchromatin;**
**® *nucleolus***

**D Mitochondrion;**
**® *mitochondria*** [2]

**(b)** With reference to Fig. 1.1, explain **two** features of the chondrocyte that show how the cell is adapted to its function.

**1. extensive rough endoplasmic reticulum**

**with bound ribosomes for synthesis of collagen / components of cartilage**

**® *protein synthesis (too vague)*;**

**2. many mitochondria to produce ATP**

**needed for transcription / translation / collagen synthesis / cartilage component;**

**3. large nucleus**

**active transcription of genes coding for collagen;** [2]

***any 2 marking points***

**(c)** Collagen forms tropocollagen which is transported to the Golgi apparatus before being secreted out of the chondrocyte.

Describe the role of Golgi apparatus in collagen formation.

**1. receive tropocollagen in vesicle at cis face**

**tropocollagen undergo sorting, packaging and modification / glycosylation / cleavage of terminal ends;**

**2. to form molecular identification tag**

**pinch off in secretory vesicle at trans face;** [2]

**(d)** Fig. 1.2 shows part of the primary structure of a collagen polypeptide.

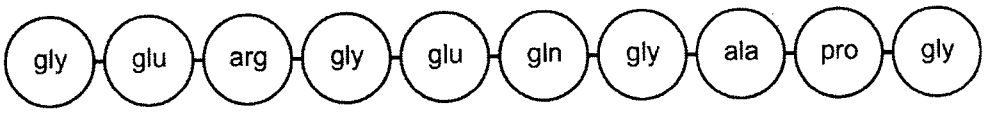



**Fig. 1.2**

With reference to Fig. 1.2, name the

**(i)** type of covalent bond formed between the amino acids;

**peptide bond;** [1]

**(ii)** enzyme that catalyses the formation of bond between the amino acids;

**peptidyl transferase;** [1]

**(iii)** reaction that forms the covalent bond between the amino acids.

**condensation;** [1]

**(iv)** Fig. 1.3 shows the molecular structure of the amino acid glycine (gly).

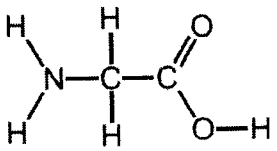


**Fig. 1.3**

With reference to Fig. 1.2 and Fig. 1.3 and the function of collagen, explain how the structure of a collagen polypeptide makes it suitable to form a collagen molecule.

1. **collagen polypeptide has gly-x-y motif /**

   **every 3rd amino acid being gly / 1 in 3 amino acid is gly;**

2. **gly is smallest amino acid / has H as R-group**

   **fit into tight center of triple helix / tropocollagen allowing it to coil tightly;**

3. **ref. to NH of peptide bond of gly can form hydrogen bond**

   **with C=O of peptide bond of amino acid in adjacent polypeptide chain;**

4. **linking any structural feature to conferring higher tensile strength;** [3]

**any 3 Marking points**

[Total: 12]

2 (a) The content of lysosomes in animal cells has a pH of 5.0. The cytosol has a pH of 7.2. The lysosomal membrane enclosing the lysosomal content, controls the passage of hydrogen ions from the cytosol into the lysosome. The low pH created by the entry of hydrogen ions is optimum for the action of acid hydrolase enzymes in the lysosome.

(i) State and explain the transport mechanism used to move hydrogen ions from the cytosol of an animal cell into the lysosome.

Transport mechanism **1. Active transport;**

Explanation **2. Lysosome has a higher concentration of hydrogen ions compared to the cytosol;**

**3. ATP is needed to transport hydrogen ions against a concentration gradient from cytosol into lysosome;** [3]

(ii) Suggest how the structure of the lysosomal membrane allows hydrogen ions to be transported into the lysosome but does not allow the ions to leave the lysosome.

**Any 2 below:**

**1. Hydrogen ions are charged, ∴ will be repelled by the fatty acid tails in the hydrophobic core of the lysosomal membrane (∴unable to leave the lysosome);**

**2. Movement of hydrogen ions into the lysosome require a transmembrane protein embedded in the lysosomal membrane;**

**3. Transport protein for hydrogen ions is unidirectional, only transports ions into the lysosome;**

**4. Binding site for hydrogen ions located on cytosol side of transmembrane protein in lysosomal membrane;** [2]

(iii) The acid hydrolases in the lysosome cannot function in neutral conditions (pH 7.0) or alkaline conditions.

Explain the advantage to the animal cell of having acid hydrolases that cannot function in neutral, near neutral or alkaline conditions.

**1. Acid hydrolases break down / hydrolyse named macromolecule e.g. proteins, nucleic acids, lipids, and carbohydrates;**

**2. Acid hydrolases will be denatured at pH of cytosol;**

**OR**

**3. Hence inability to function at neutral / alkaline conditions ensures that**

**damage / break down of cell contents / organelles / molecules in the cytosol is avoided;** [2]

**(b)** An analysis of a membrane protein located on the lysosomal membrane is carried out. The amino acid sequence that makes up the **transmembrane** segment of the protein is shown below.

***...Ile – Thr – Leu – Ile – Tyr – Phe – Gly – Val – Met – Ala – Gly – Val – Ile – Gly – Thr – Ile – Leu – Leu – Ile – Ser-...***

Suggest why such an amino acid sequence would enable the protein to span the lysosomal membrane.

***1.*** **R groups of amino acids making up transmembrane segment of protein are largely non-polar / hydrophobic;**

***2.*** **Amino acid sequence / polypeptide is folded such that transmembrane region embedded in membrane contains amino acids with hydrophobic R groups facing protein exterior**

**will interact with non-polar fatty acid tails of phospholipids via hydrophobic interaction;** [2]

[Total: 9]

3 Cyclooxygenase (COX) is an enzyme that catalyses the conversion of arachidonic acid (AA), into prostaglandins which are then involved in promoting inflammation, pain and fever.

There are two isoforms of the enzyme, COX-1 and COX-2 and they differ in the shape of their active sites.

Fig. 3.1 shows a simplified diagram of the active sites in COX-1 and COX-2.

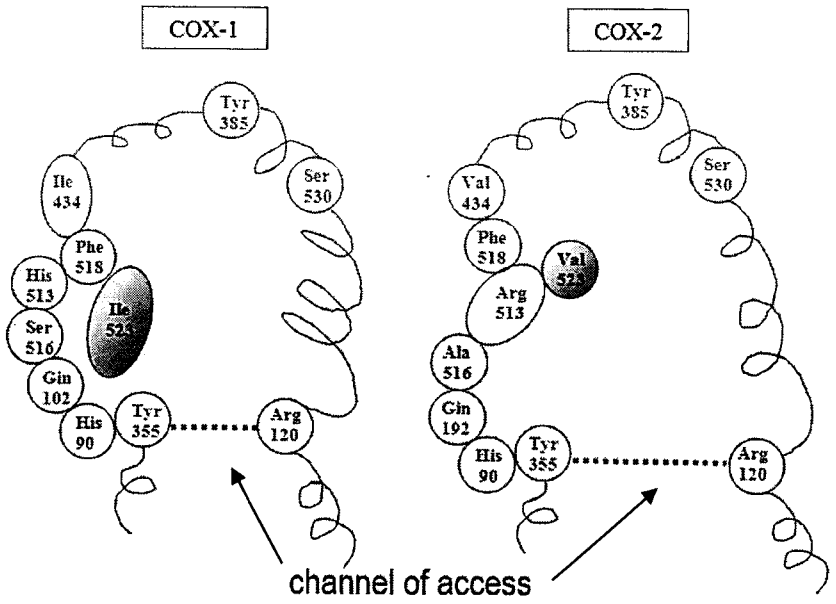



**Fig. 3.1**

**(a)** With reference to Fig. 3.1, describe how the differences in amino acids result in a change in the configuration of the active site in COX-1 and COX-2.

**1. QV any differences in amino acids with positions / QV any 2 differences in amino acids without positions**

**e.g. Gln in COX-1, at position 102 while in COX-2, at position 192 / His is a smaller amino acids in position 513 in COX-1 while arg is a bigger amino acid in same position in COX-2 etc;**

**2. Different amino acids,**

**different R groups;**

**3. Changes in the types of R group interaction between amino acids**

**Affected folding of polypeptide into its tertiary structure;**

**4. Resulted in a larger channel of access in COX-2**

**and a smaller channel of access in COX-1;** [4]

COX enzymes are targets of nonsteroidal anti-inflammatory drugs (NSAIDs) e.g., Ibuprofen, to reduce the inflammatory symptoms.

Fig. 3.2 shows COX-1 when bound to AA and when ibuprofen is present.

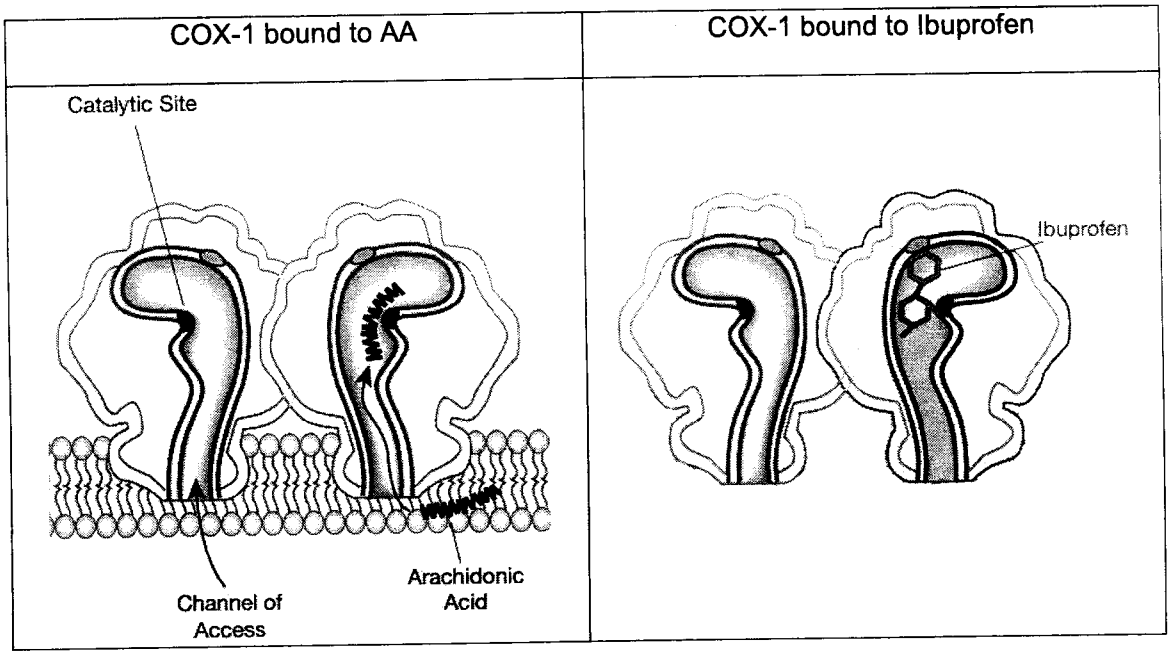



**Fig. 3.2**

**(b)** With reference to Fig. 3.2,

**(i)** explain how ibuprofen reduces the effects of inflammation.

**1. Ibuprofen is a (competitive) inhibitor**

**has a shape that can fit into the / enter the channel of access / 3D configuration complementary to active site;**

**2. Bind to the catalytic site, (form EI complex)**

**blocks AA from binding;**

**3. Prevent COX from converting AA**

**To prostaglandins;** [3]

**(ii)** explain how ibuprofen can bind to the same active site.

**1. Ibuprofen may possess <u>similar</u> charges as AA**

**Form <u>similar</u> interactions as AA;**

**2. Can fold into the <u>similar</u> configuration as AA**

**To fit into the active site;** [2]

© Inhibition of COX-1 by NSAIDs has been strongly implicated in gastric ulceration and bleeding. Newer drugs have been developed to selectively inhibit only COX-2.

Using information from Fig. 3.1 and 3.2, suggest how selective inhibition could occur.

**Size of the drug to be bigger than the access channel for COX-1;** [1]

[Total: 10]

4 To investigate the mode of DNA replication in a unicellular organism, 3 separate cultures of the cells were grown. The first was grown in a medium containing $^{14}N$, the common isotope of nitrogen and the second was grown in a medium containing $^{15}N$, the heavy isotope of nitrogen.

The cells of the third culture were grown in a medium containing $^{15}N$ for many generations first. Cells in early interphase were then transferred to a medium containing the common nitrogen form, $^{14}N$. The cells were allowed to grow for one generation and then they were fixed at the next metaphase.

DNA was isolated from cells of all three cultures and separated into single strands by mild chemical treatment. The density of this single-stranded DNA was measured using density gradient centrifugation. The results of Tubes **A**, **B** and **C** are shown in Fig 3.1 below.

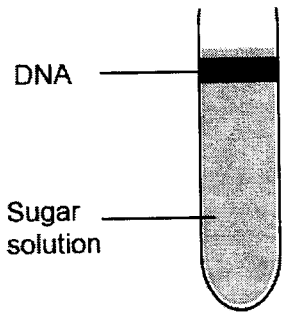
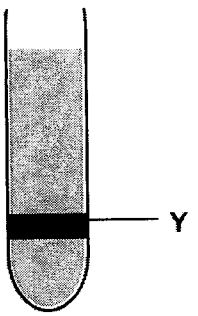
| Tube A | Tube B | Tube C |
|---|---|---|
|  |  |  |
| DNA from cells cultured on $^{14}N$. | DNA from cells cultured on $^{15}N$. | DNA from cells grown originally on $^{15}N$, then transferred for one generation to a medium in $^{14}N$ but fixed at the next metaphase. |

**Fig. 4.1**

**(a) (i)** Assuming that DNA replication in the unicellular organism occurred through a similar mechanism to humans, what is the expected relative amount of each type of DNA in **Tube C**?

**$^{14}N$: $^{15}N$ = 3:1 ratio / 75% : 25%** [1]

(ii) Explain your answer to (a)(i).

1. **DNA replication is a <u>semi-conservative</u> process,**

**each of the original / parental strand acts as a template for the complementary daughter strand / newly synthesized strand;**

2. **at the end of first generation, the ratio of 1 $^{14}N$: 1 $^{15}N$ DNA strands,**

**and after 2nd replication, ratio of 3 light: 1 heavy strand DNA <u>or</u> 3 $^{14}N$: 1 $^{15}N$ DNA strands;;**

**OR**

3. **at the end of first generation, $^{15}N$ strands as template, to synthesize new complementary $^{14}N$ strand, resulting in ratio of 1 $^{14}N$ DNA: 1 $^{15}N$ DNA,**

**and after 2nd replication, both $^{15}N$ and $^{14}N$ strands are template for synthesis of new complementary $^{14}N$ strand,**

**there will be 3 light: 1 heavy strand DNA <u>or</u> 3 $^{14}N$: 1 $^{15}N$ DNA strands;** [2]

**Either 1 and 2 OR 1 and 3**

Studies were then carried out to determine the nitrogenous base composition of the band of DNA marked **Y** in Tube B. This involved finding values for each individual (+ or -) DNA strand. Table 4.1 below shows the results obtained.

**Table 4.1**

| DNA sample | Percentage of base present in DNA sample / % | | | | Ratio of (A+G) to (C+T) |
|---|---|---|---|---|---|
| | A | G | C | T | |
| + strand | 28 | 15 | **25** | **32** | 0.75 |
| - strand | 32 | 25 | **15** | 28 | 1.33 |

(b) (i) Fill in the missing values in Table 4.1. [1]

**Correct values for C and T in all columns;**

(ii) State the ratio of (A+G) to (C+T) in the band of DNA marked "**Y**" in Tube B in Fig. 4.1. Explain your answer.

1. **Ratio of (A+G): (C+T) is 1:1;**

2. **Adenine and guanine are purines which will base pair respectively**

**with thymine and cytosine, which are pyrimidines;**

[2]

(iii) State why the ratios of (A+G) to (C+T) in the + and – strands of DNA do not follow the ratio stated in **(b)(ii)**.

**The + and – strands of DNA are single-stranded,**

**% of A, G, T and C is dependent on nucleotide sequence on the strand;** [1]

[Total: 7]

5 Occasionally during meiosis, homologous chromosomes fail to separate at anaphase. This is known as non-disjunction.

Turner's syndrome is the most common chromosome mutation in human females that occurs during gamete formation. Errors during meiosis led to some resulting gametes missing an X chromosome or when one of the pair of X chromosomes is damaged.

Fig. 5.1 is a diagram of a normal X chromosome and two variants of 'damaged' X chromosomes, $X_1$ and $X_2$.

- In $X_1$, a section of the 'p' arm of the chromosome is missing.
- In $X_2$, a section of the 'q' arm of the chromosome is missing.

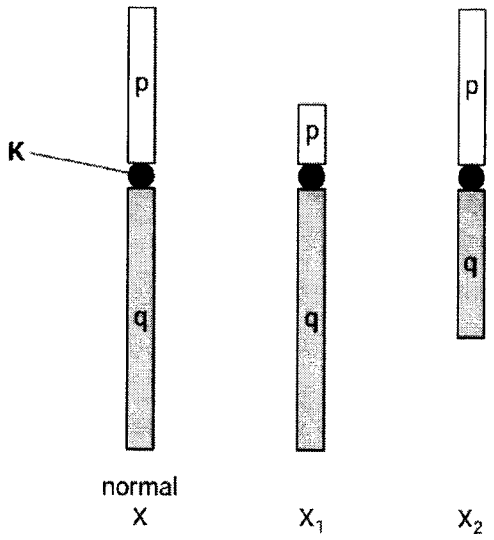



**Fig. 5.1**

**(a)** State the function of structure **K**.

**1. site of attachment of sister chromatids;**

**2. attachment site for kinetochore proteins;** [1]

***any 1 MP***

**(b)** Suggest how variants $X_1$ and $X_2$ can be produced.

**1. Cause of variant**

**e.g. spontaneous mutation / exposure to mutagen;**

**2. Impact on chromosome**

**e.g. translocation / breakage of chromosomes / deletion of chromosomal segments;** [2]

**(c)** Explain how spindle fibres play an important role in ensuring a gamete with normal number of chromosomes is produced.

1. **Kinetochore spindle fibres bind to all chromosomes**

**Allow spindle checkpoint to complete;**

2. **Ensure alignment of chromosomes**

**at metaphase plates during Metaphase (I and II);**

3. **Shorten to pull all chromosomes**

**To respective poles during Anaphase (I and II) for equal separation of chromosomes into daughter cells / gametes;**

4. **Non-kinetochore spindle fibres**

**Interact with each other to lengthen the cell;** [3]

***any 3 marking points***

**(d)** The genes on the X chromosomes are involved in the development of the female reproductive organs.

Suggest why females with Turner's syndrome are sterile.

1. **Inability to develop eggs, due to underdeveloped ovaries;**

**Inability to produce female hormones for development of womb lining / under-developed ovaries / uterus / inability to ovulate;** [1]

***any 1 marking point***

Unlike meiosis which occurs in the cells within reproductive organs, mitosis occurs in somatic cells found throughout the body.

At various points during the mitotic cell cycle, there are checkpoints to ensure that only genetically identical daughter cells to each other and to the parent cell are produced. Other cells which did not pass the checkpoints undergo apoptosis to prevent uncontrolled cell division.

Vincristine and 5-fluorouracil are drugs which have been developed to cause cellular apoptosis.

- Vincristine binds to spindle microtubules and prevents the spindle apparatus from carrying out its function.
- 5-fluorouracil prevents the synthesis of thymine nucleotides

**(e)** Complete Table 5.1 to show which event in the cell cycle will occur when Vincristine or 5-fluorouracil are added to healthy dividing cells at the start of the interphase stage of the cell cycle.

Place a tick (✓) if the event will occur or a cross (×) if the event will not occur. All boxes in the table should be completed.

**Table 5.1**

| Cell cycle event / Drug | Interphase | Prophase | Metaphase | Anaphase |
|---|---|---|---|---|
| Vincristine | ✓ | ✓ | × | × |
| 5-fluorouracil | × | × | × | × |

[2]
[Total: 9]

6 Fig. 6.1 shows the unpacking of bacterial circular chromosome.

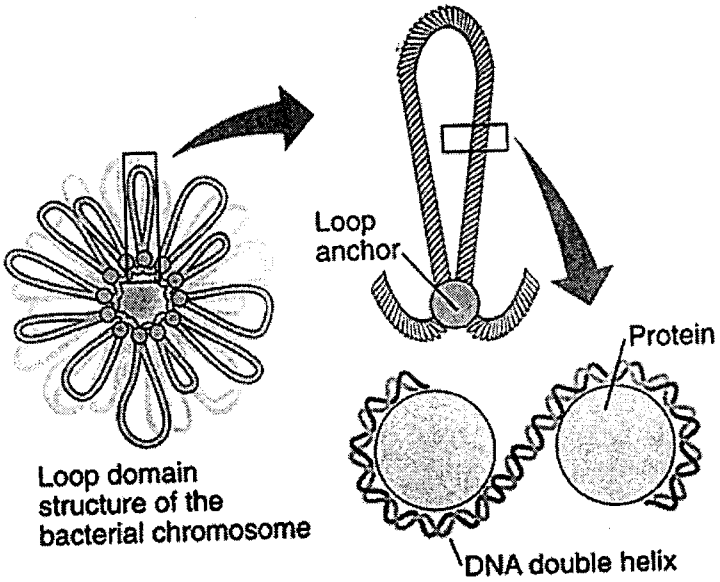



**Fig. 6.1**

**(a)** Using the information from Fig 6.1 and your own knowledge, describe how the bacterial chromosome is packed in a bacterial cell.

1. **single molecule of circular DNA**

   **With a double helix structure;**

2. **Associated / coil around (DNA binding) proteins**

   **® *DNA coils around loop anchor***

   **to result in the DNA bending / looping;**

3. **Further coiling results / DNA held by loop anchor**

   **in the formation of loop domains;**

4. **Supercoiling**

   **Formed highly condensed chromosomes;** [4]

Fig. 6.2 shows the production of defective phages during bacteriophage replication that results in gene transfer between bacteria.

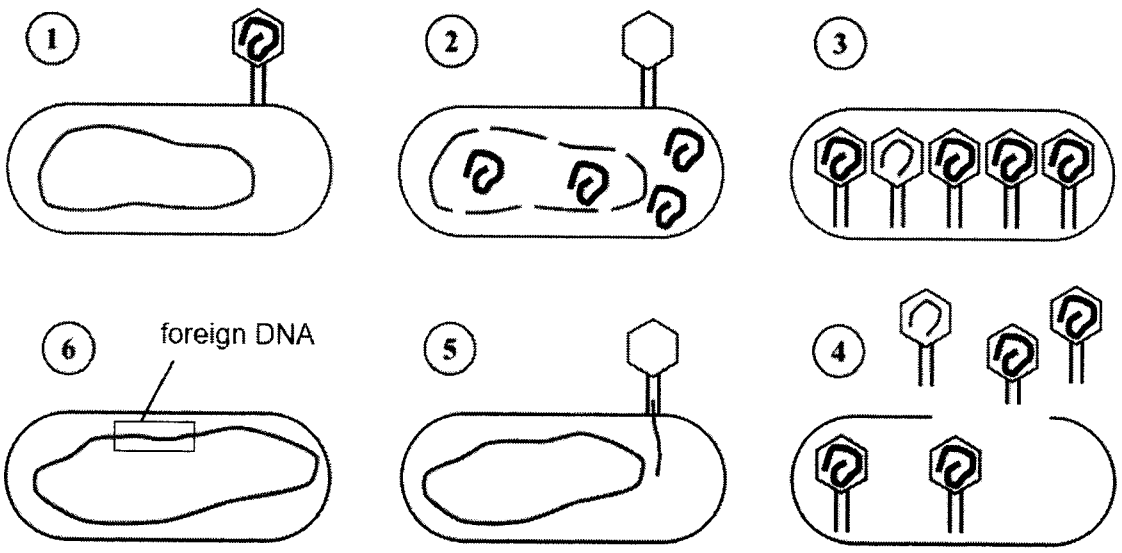



**Fig. 6.2**

**(b)** With reference to Fig. 6.2,

**(i)** suggest why Stage **2** occurs.

**1. Prevent expression of bacteria genes**

**Coding for enzymes *(@ phage-encoded nuclease) (®: lysosome, lysozyme)* that degrade bacteriophage DNA;**

**2. Frees up dNTPs**

***@ frees up DNA nucleotides***

**For replication of phage genome;** [2]

**(ii)** describe how the bacteria cells obtain new genetic material.

**1. <u>Random</u> segments of bacteria DNA**

**packed into capsid head of bacteriophage;**

**2. Defective phage attaches to new host cell**

**with receptors on cell surface that are specific/ complementary to the tail fibres;**

**3. <u>Bacterial</u> DNA injected into new host cell,**

**homologous recombination occurred to result in integration of foreign DNA;** [3]

[Total: 9]

7 The interpupillary distance (IPD) is the distance in millimetres between the centres of the pupils of the eyes. Fig. 7.1 shows how IPD is measured.

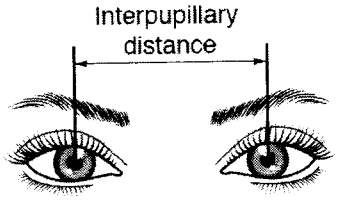



**Fig. 7.1**

IPD is one example of a characteristic of human facial structure that shows variation. Fig. 7.2 shows the pattern of variation in IPD in a large sample of adults.

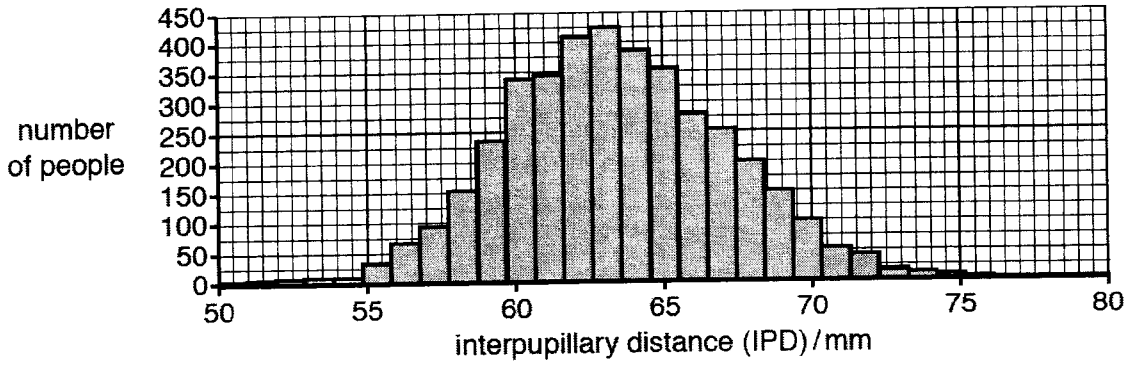



**Fig. 7.2**

**(a)** **(i)** Name the type of variation shown in Fig. 7.2.

**continuous variation;** [1]

**(ii)** Explain how genes and the environment contribute to variation in IPD in humans.

1. **IPD is controlled by several / many genes / polygenic trait;**
2. **additive effect of genes;**
3. **each gene has small influence / impact;**
4. **environmental factors affect gene expression;**

**named e.g. diet / age;** [3]

***Max. 2m from marking points 1 to 3***

An investigation was carried out on the difference in IPD of males and females. Table 7.1 shows the results of the investigation.

**Table 7.1**

| individual | IPD / mm | |
|---|---|---|
| | male | female |
| 1 | 70 | 65 |
| 2 | 72 | 62 |
| 3 | 68 | 59 |
| 4 | 73 | 69 |
| 5 | 72 | 66 |
| 6 | 65 | 63 |
| 7 | 66 | 67 |
| 8 | 62 | 58 |
| 9 | 67 | 62 |
| 10 | 68 | 68 |
| mean ($\bar{x}$) | 68 | 64 |
| standard deviation ($s$) | 3.50 | 3.73 |
| variance ($s^2$) | **12.25** | **13.91** |

***(A) 3 sig. fig***

**(b)** **(i)** Complete Table 7.1 by calculating the variance ($s^2$) for the IPD for each gender. [1]

**(ii)** A t-test can be used to determine whether there is any significant difference between the IPD in males and females.

Calculate the value of t and the number of degrees of freedom, using these formulae:

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}} \qquad v = n_1 + n_2 - 2$$

**key to symbols**

$s$ = standard deviation
$\bar{x}$ = mean
$n$ = sample size (number of observations)
$v$ = degrees of freedom

Show your working.

$$t = \frac{|68 - 64|}{\sqrt{\left(\frac{12.25}{10} + \frac{13.9}{10}\right)}}$$

$$= 2.47$$

value of t = **2.47;** .....
**@ 2 dp / 3 sf**
**@ variation from rounding off**

degree of freedom = **18;** ..... [2]

**(iii)** For this t-test, the proposed null hypothesis is:

there is no difference between the IPD between males and females.

Table 7.2 shows the critical values for several different probabilities and degrees of freedom.

**Table 7.2**

| degrees of freedom | probability, $p$ | | | | |
|---|---|---|---|---|---|
| | 0.5 | 0.1 | 0.05 | 0.01 | 0.001 |
| 1 | 1.00 | 6.31 | 12.71 | 63.66 | 636.62 |
| 2 | 0.82 | 2.92 | 4.30 | 9.92 | 31.60 |
| 3 | 0.76 | 2.35 | 3.18 | 5.84 | 12.92 |
| 4 | 0.74 | 2.13 | 2.78 | 4.60 | 8.61 |
| 5 | 0.73 | 2.02 | 2.57 | 4.03 | 6.87 |
| 6 | 0.72 | 1.94 | 2.45 | 3.71 | 5.96 |
| 7 | 0.71 | 1.89 | 2.36 | 3.50 | 5.41 |
| 8 | 0.71 | 1.86 | 2.31 | 3.36 | 5.04 |
| 9 | 0.70 | 1.83 | 2.26 | 3.25 | 4.78 |
| 10 | 0.70 | 1.81 | 2.23 | 3.17 | 4.59 |
| 11 | 0.70 | 1.80 | 2.20 | 3.11 | 4.44 |
| 12 | 0.70 | 1.78 | 2.18 | 3.05 | 4.32 |
| 13 | 0.69 | 1.77 | 2.16 | 3.01 | 4.22 |
| 14 | 0.69 | 1.76 | 2.14 | 2.98 | 4.14 |
| 15 | 0.69 | 1.75 | 2.13 | 2.95 | 4.07 |
| 16 | 0.69 | 1.75 | 2.12 | 2.92 | 4.01 |
| 17 | 0.69 | 1.74 | 2.11 | 2.90 | 3.97 |
| 18 | 0.69 | 1.73 | 2.10 | 2.88 | 3.92 |
| 19 | 0.69 | 1.73 | 2.09 | 2.86 | 3.88 |
| 20 | 0.69 | 1.72 | 2.09 | 2.85 | 3.85 |

Use Table 7.2 and your answers to **(b)(ii)** to decide whether the null hypothesis should be accepted or rejected.

Explain your answer.

accept or reject null hypothesis **Reject;**

explanation 1. **calculated t value of 2.47 is more than critical t value of 2.10 (at v = 18, p = 0.05);**

2. **difference in IPD between male and female IPD is statistically significant**

**difference is not due to chance;** [2]

[Total: 9]

8 Photosynthesis is a complex process involving a light-dependent stage and a light-independent stage.

(a) (i) Name the products of the light-dependent stage that are needed in the light-independent stage.

**ATP, NADPH / reduced NADP;** [1]

(ii) Describe the role of chlorophyll b in photosynthesis.

**act as accessory pigment (in light harvesting complex)**

**absorbs light to pass on to reaction centre / chlorophyll a molecule (via inductive resonance);** [1]

A student carried out an experiment to investigate the effect of light intensity and light wavelength on the rate of photosynthesis.

An aquatic plant, *Elodea canadensis,* was put into a beaker containing sodium hydrogencarbonate solution as a source of carbon dioxide. A lamp was placed at different distances from the beaker to change light intensity. The number of bubbles released by the aquatic plant in 1 minute was counted as a measure of the rate of photosynthesis. All other variables were controlled.

At each distance from the lamp, the experiment was repeated using a red filter in front of the lamp to give a different wavelength of light. The experiment was repeated using a blue filter and then using a green filter. Each filter transmitted the same light intensity.

Fig. 8.1 shows a graph of the results.

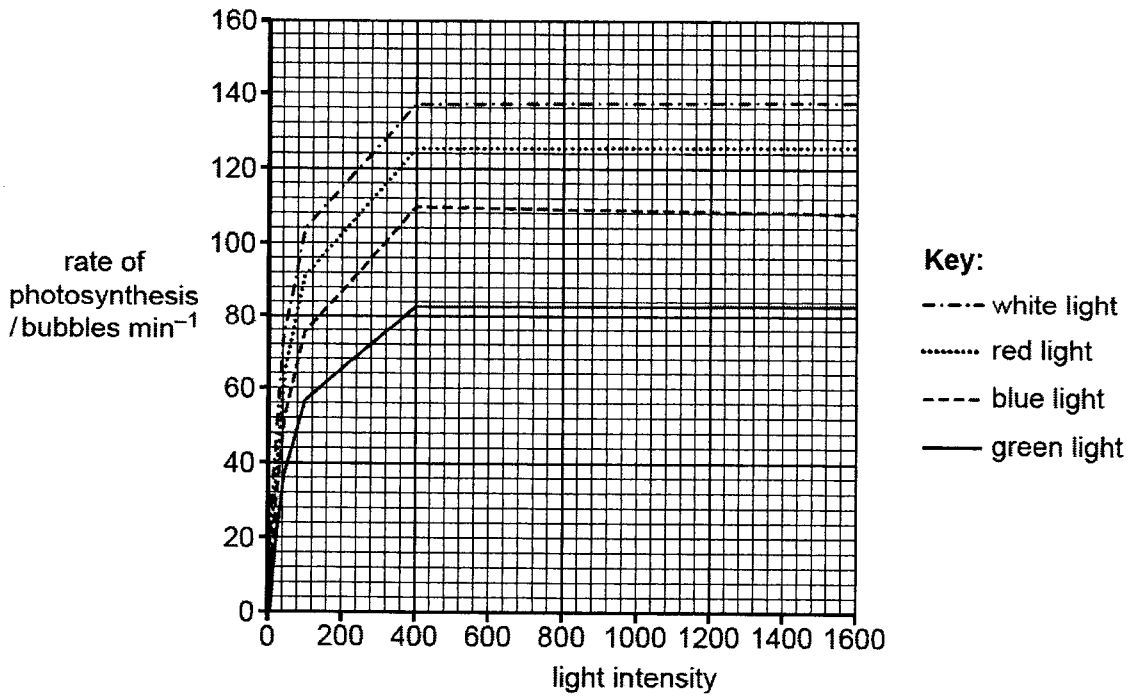



**Fig. 8.1**

**(b)** With reference to Fig. 8.1,

**(i)** state the range over which light intensity is the limiting factor;

**0 – 400;** [1]

**(ii)** explain what factor may be limiting the rate of photosynthesis above the range of light intensity stated in **(c)(i)**.

1. **temperature;**
2. **less kinetic energy**

**result in lower rate of (named enzyme-controlled reaction) e.g. effective collisions between $H_2O$ and water-splitting complex;**

3. **concentration of $CO_2$**
4. **results in less frequent effective collision between $CO_2$ and rubisco thus less $CO_2$ fixation in Calvin cycle;** [2]

***Marking points 1+2 or 3+4***

**(iii)** At a light intensity of 1600, explain why different colour filters result in different rates of photosynthesis.

1. **rate of photosynthesis is highest for red light at 125 bubbles $min^{-1}$**

**lowest for green light at 83/84 bubbles $min^{-1}$;**

2. **different wavelengths of light**

**is absorbed by different pigments (in photosystem);**

3. **red light is absorbed the most**

**leading to faster rate of light dependent reaction / photophosphorylation / photoactivation (of chlorophyll a) / ORA;** [3]

**(iv)** Predict and explain the effect on the number of bubbles produced if a rubisco inhibitor was added.

1. **number of bubbles produced would decrease;**
2. **inhibitor lowers rate of $CO_2$ fixation by rubisco**

**thus lower rate of Calvin cycle;**

3. **lower regeneration of ADP and NADP**

**leading to lower rate of light dependent reactions thus less $O_2$ released from photolysis;** [3]

[Total: 11]

**9** The aye-aye, *Daubentonia madagascariensis*, is a primate native to Madagascar. Aye-ayes are nocturnal (active at night) and make their nests high up in trees. They feed on insect larvae in the trunks of trees.

Fig. 9.1 shows an aye-aye.

**Fig. 9.1**

The International Union for Conservation of Nature (IUCN) is the world's largest global environmental organisation. The IUCN Red List of Threatened Species™ evaluates the conservation status of plant and animal species.

The aye-aye is categorised as endangered on the IUCN Red List, which means that it faces a very high risk of becoming extinct in the wild.

**(a)** **(i)** Table 9.1 shows the taxonomic classification of aye-aye.

**Table 9.1**

| | |
|---|---|
| **Domain** | Eukarya |
| **Kingdom** | Animalia |
| Phylum | Chordata |
| **Class** | Mammalia |
| Order | Primates |
| **Family** | Daubentoniidae |
| Genus | ***Daubentonia*** |
| Species | ***Daubentonia madagascariensis*** |

Complete Table 9.1. [3]

**Marking points:**
1. **Taxonomy: all correct for credit;**
2. **Correct Genus name;**
3. **Correct species name, underlined;**

(ii) Suggest **one** reason why aye-ayes have become endangered.

**habitat destruction / hunting / AVP with brief elaboration;** [1]

There are two main aye-aye populations on the island of Madagascar, one in the west and one in the east.

Fig. 9.2 is a map of Madagascar showing the location of the two main populations.

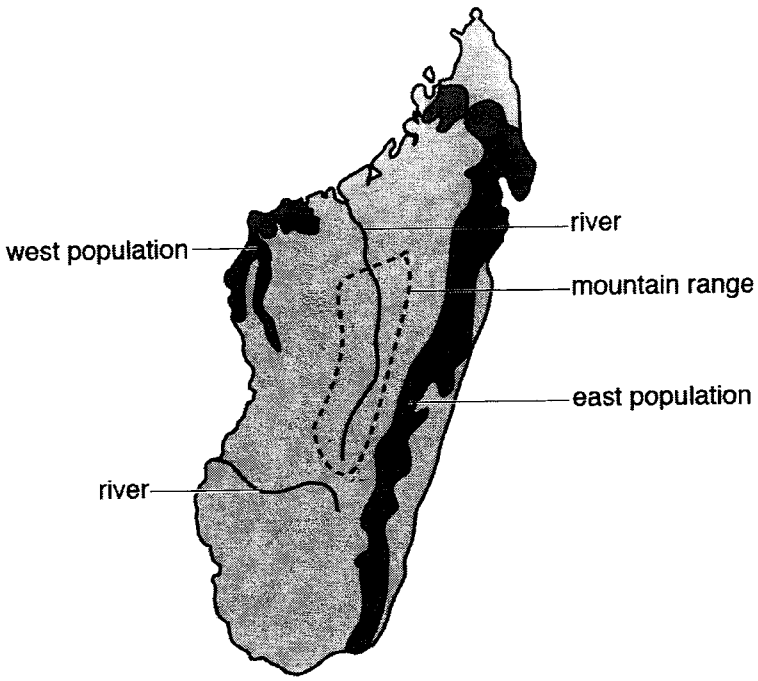



**Fig. 9.2**

A study into the variation in the DNA nucleotide sequence of aye-ayes showed that there is a large genetic difference between the west and east populations. The two populations of aye-ayes may be evolving into separate species.

**(b)** (i) State one advantage of using DNA nucleotide sequence in this study.

**unambiguous / objective / quantifiable / AVP;** [1]

(ii) With reference to Fig. 9.2, suggest why there is a large genetic difference between the two populations.

1. **east and west populations of aye-ayes have phenotypic variation**

**due to presence of genotypic variation;**

2. **east and west of Madagascar have different environmental conditions thus different selection pressures**

**resulting in aye-ayes with different favourable phenotypes being selected for;**

3. **different favourable alleles are passed down to offspring**

leading to different allelic frequencies in the gene pools;

4. different mutations occur in the east and west populations;

5. geographical isolation / barrier e.g. rivers / mountains between the 2 populations

prevent interbreeding / gene flow resulting in genetic divergence; [4]

*Any 4 marking points*

**(iii)** Name the type of speciation that may be occurring.

allopatric speciation; [1]

**(iv)** Suggest **and** explain a pre-zygotic isolating mechanism that could prevent successful reproduction between aye-ayes of the two populations.

1. physical / morphological / mechanical;

2. reproductive features do not match / unable to mate;

3. behavioural;

4. different mating calls / courtship rituals;

5. gametic;

6. incompatible gametes causing fertilisation to be unsuccessful;

7. temporal;

8. different breeding seasons; [2]

**Marking points 1+2 / 3+4 / 5+6 / 7+8**

[Total: 12]

10 Tuberculosis (TB) is a major cause of ill health worldwide.

(a) The World Health Organization (WHO) Global Tuberculosis Report for 2019 published data on the estimated number of deaths from TB and HIV/AIDS in 2018. All deaths of HIV-infected people from TB were also counted as deaths of people with HIV/AIDS.

Fig. 10.1 shows these data. The dark grey boxes show the estimated number of deaths of people from TB who were also counted as deaths of people with HIV/AIDS.

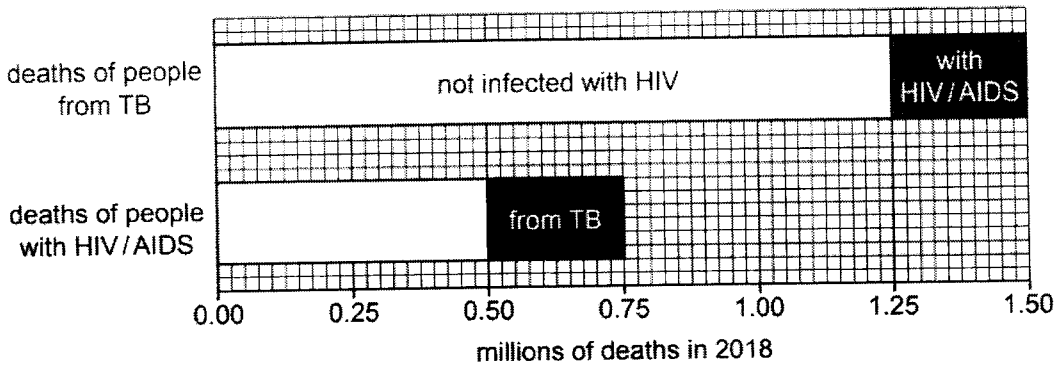



**Fig. 10.1**

A student used the data in Fig. 10.1 to predict that measures to control the spread of HIV will decrease the number of deaths from TB.

Discuss whether the data in Fig. 10.1 support this prediction.

**[Does not support]**

**1. much larger proportion of individuals dying from TB do not have HIV/AIDS;**

**2. [QV] deaths of people from TB with HIV/AIDS is 0.25 million out of 1.5 million**

**OR 1.25 million people dying from TB does not have HIV/AIDS;**

**3. the 0.25 million people may still die from TB even if they do not have HIV/AIDS;**

**[Support]**

**4. significant proportion of deaths of people from with HIV/AIDS are caused by TB;**

**5. [QV] 0.25 million deaths of people with HIV / AIDS caused by TB out of 0.75 million;**

**6. fewer people will be immunocompromised thus less susceptible to TB;**

**7. AVP;** [3]

**(b)** In healthy people, the number of T-helper cells ranges from 500 to 1200 cells per $cm^3$ of blood. In untreated people infected with HIV, the number of T-helper cells can decrease to below 200 cells per $cm^3$ of blood.

Explain how a low number of T-helper cells makes it more likely that untreated people infected with HIV will die if they are also infected with TB.

1. **lesser activation of B cells**

   **to undergo clonal expansion and differentiation (to form effector B cells);**

2. **fewer plasma cells to produce / secrete antibodies;**

3. **fewer memory B cells to fight future infections;**

4. **lesser activation of CD8+ cells**

   **to undergo clonal expansion and differentiation (to form effector T cells);**

5. **fewer cytotoxic T cells to kill infected cells;**

6. **fewer memory T cells to fight future infections;**

7. **people infected with HIV is immunocompromised**

   **increased risk of developing active TB / succumb to opportunistic infections;** [4]

[Total: 7]

11 Frogs are ectothermic animals. This means that their body temperature will vary as the environmental temperature varies.

Several species of the frog genus, *Rana*, can be found in North America. Many of these species inhabit areas within a range of latitudes from the colder north to the warmer south.

Table 11.1 shows data for four of these species, *R. clamitans*, *R. palustris*, *R. pipens* and *R. sylvatica*.

**Table 11.1**

| Species | Body temperature of frog / °C | | | |
|---|---|---|---|---|
| | lower lethal, below which frog dies | minimum to start development | maximum to complete development | upper lethal, above which frog dies |
| *R. clamitans* | 10.0 | 11.0 | 35.0 | 37.0 |
| *R. palustris* | 5.0 | 7.0 | 30.0 | 31.0 |
| *R. pipens* | 3.0 | 6.0 | 28.0 | 30.0 |
| *R. sylvatica* | 0.0 | 2.0 | 24.0 | 25.0 |

**(a)** Using the information in Table 11.1, suggest why global warming will result in a decrease in species diversity in frogs in the current habitats.

**1. frogs are ectotherms / body temperature varies with environmental temperature**

**global warming will increase frogs' body temperature;**

**2. different frog species have different upper lethal range**

**25°C in R. sylvatica to 37°C in R. clamitans;**

**3. species from habitats at lower latitude (e.g. R. clamitans) may migrate to higher latitudes / towards the north**

**as habitat temperatures exceeds upper lethal temperature;**

**4. species already from habitats at higher latitudes (e.g. R. sylvatica) are not able to migrate further north**

**thus die when environmental temperature increases above upper lethal temperature;** [3]

***any 3 Marking points***

**(b)** Explain how human activities could have contributed to an increase in greenhouse gases that resulted in the rise of global temperatures.

**1. state any one anthropogenic effect that contributed to $CO_2$**

**e.g. burning of fossil fuel due to transportation, powering of buildings, etc.;**

**2. state any one anthropogenic effect that contributed to $CH_4$**

**e.g. cattle rearing due to increased consumption of meat;** [2]

[Total: 5]

YISHUN INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAM
**Higher 2**

NAME **ANSWERS**

INDEX NO _____ CG _____

# BIOLOGY

**9744/03**

Paper 3 Long Structured and Free-Response Questions

**13 Sep 2022**

**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your name and class in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

**Section A**
Answer **all** questions in the spaces provided on the Question Paper.

**Section B**
Answer any **one** question in the spaces provided on the Question Paper.
Indicate the question you have attempted at the top of page **18**.

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.

The number of marks is given in brackets [ ] at the end of each question or part question.

| For Examiner's Use | |
|---|---|
| **Section A** | |
| 1 | /30 |
| 2 | /10 |
| 3 | /10 |
| **Section B** | |
| 4 or 5 | /25 |
| Total | /75 |

This document consists of **25** printed pages and **1** blank page.

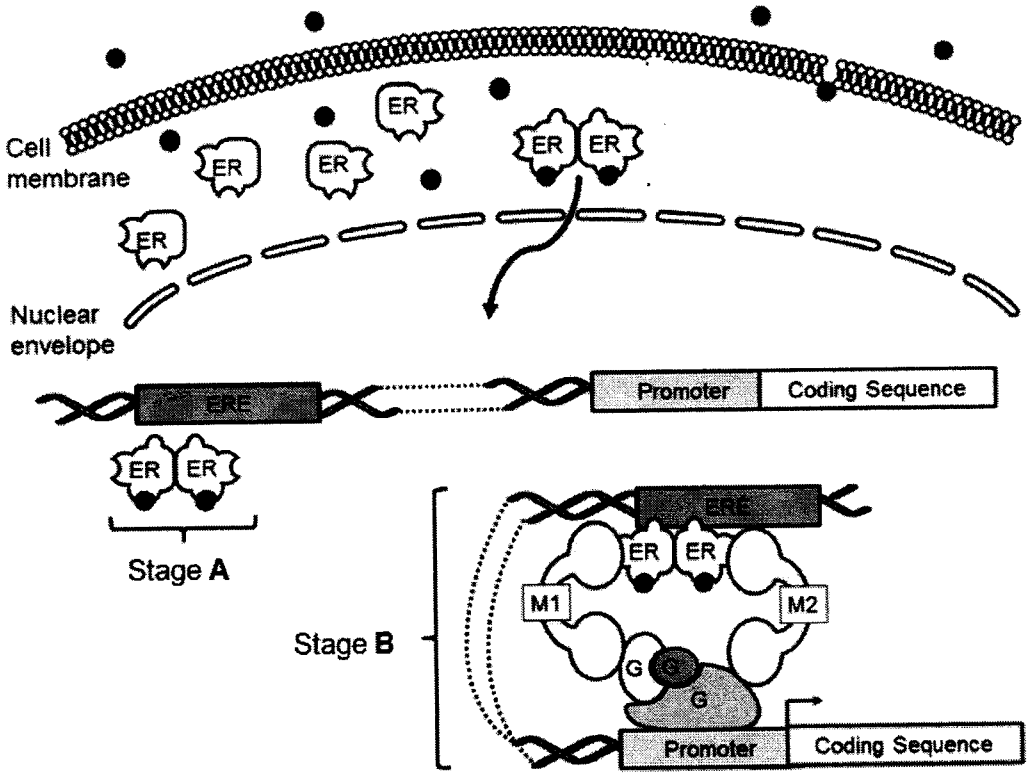
## Section A

Answer **all** questions in this section.

1 Estrogen receptors (ER) are expressed in mammary cells. Fig. 1.1 shows how an ER serves its functions at target cells:

- as an intracellular receptor activated by the steroid hormone estrogen (E), when E binds to complementary ligand binding site on ER,
- and as a transcriptional activator, after two ER bound with E dimerised and enters the nucleus.

Estrogens induce transcription of genes in their target cells. Such genes have estrogen response elements (ERE) as enhancers.




**Legend:**

| | |
|---|---|
| ● | : estrogen |
| ..... | : long stretch of DNA |
| M1 and M2 | : mediators |
| G | : general transcription factor |

* RNA polymerase is not shown *

**Fig. 1.1**

**(a)** With reference to Fig. 1.1, describe stages **A** to **B**.

***Stage A:*** **1. dimerized ER bound to E binds via complementary fit to ERE**

**acts as transcriptional activator;**

***Stage B:*** **2. E-ER dimer recruits DNA bending proteins resulting in DNA looping,**

**E-ER dimer brought closer to the promoter;**

**3. recruit mediators (M1 and M2)**

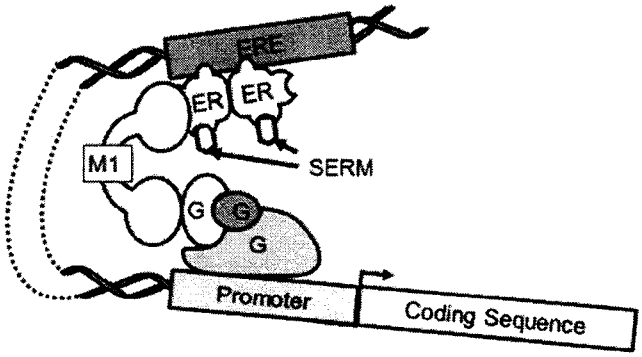
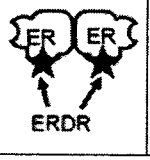
**and general transcription factors (G);**

**4. RNA polymerase binds (more stably) to promoter**

**forming transcription initiation complex leading to increased rate of transcription;** [4]

Estrogen receptors are over-expressed in around 70% of breast cancer cases. Research into the treatment of metastatic breast cancer focused on the use of drugs such as selective estrogen-receptor modulator (SERM) and estrogen receptor downregulator (ERDR) as shown in Table 1.1.

**Table 1.1**

| drug | function of drug | presence of drug-receptor complex in the nucleus | effect of drug on the target gene |
|---|---|---|---|
| SERM ○ |   | ✓ |   |
| ERDR ★ |   | ✗ | Basal rate of transcription |

**(b)** With reference to Table 1.1,

**(i)** explain how SERMs can be used in the treatment of breast cancer.

**1. SERMs are structurally similar to estrogen / E**

***(®: similar to ER / same shape as ER)***

**compete with E for binding with ER / binds to ER, blocking E from binding;**
***(®: binds to active site of ER)***

**2. SERMs recruit M1 but not M2 / does not recruit M2 / prevent complete recruitment / assembly of mediators / prevent complete DNA bending**

**formation of stable transcription initiation complex is reduced / prevented;**

**3. This reduces rate of oncogene / cancer critical gene expression OR**

**reduce rate of transcription of gene that result in excessive cell division / rate of cell division exceeding rate of cell death;** [3]

**(ii)** suggest <u>why</u> ERDRs might be more effective than SERMs.

**1. ERDRs prevent movement of ERDR-ER complexes to the nucleus**

**/ ER degraded in the cytoplasm,**

**preventing increased oncogene expression / transcription;**

**2. SERMs still allows movement of ER into the nucleus / enables recruitment of M1 and general transcription factors /**

**transcription initiation complex to be formed for transcription / gene expression;** [2]

(c) Cancer is described as a multi-step process. Explain how mutations may lead to uncontrolled proliferation in cells lining the milk ducts, leading to breast cancer.

1. loss of function mutation of tumour suppressor gene / mutations must affect both alleles of tumour suppressor gene,

non-functional tumour suppressor protein formed upon gene expression;

2. loss of arrest of cell division, loss of ability for DNA repair and loss of apoptosis;

3. gain of function mutation of proto-oncogene

/ only need one mutated allele;

hyperactive protein upon gene expression;

OR

3a. gain of function mutation in promoter of proto-oncogene,

excessive amount of proteins formed upon gene expression;

4. leads to excessive stimulation of the cell cycle / cell keeps dividing;

5. accumulation of other mutations in a single cell

resulting in uncontrolled proliferation of cells lining the milk ducts;

AVP e.g.:

6. activation of telomerase gene, enabling the maintenance / replacement of telomeres,

cells are able to overcome the Hayflick limit / continue dividing (despite presence of mutations);

7. activation of genes involved in angiogenesis,

blood vessels formed supply nutrients and oxygen to tumour cells (and remove waste);

8. Activation of genes involved in metastasis,

enabling cells to travel from primary tumour site to establish themselves in a different location in the body / migrate into neighbouring tissues;

OR

9. Increased expression of genes coding for extracellular proteases to degrade cytoskeleton,

promoting metastasis into nearby blood vessels / tissues; [4]

*Any 4 marking points*

Fig. 1.2 shows that in breast cancer cells, there is an overexpression of human epidermal growth factor receptor 2 (HER2) proteins. HER2 functions as a receptor protein on the cell surface membrane to send a signal to the nucleus for the cell to undergo cell division.

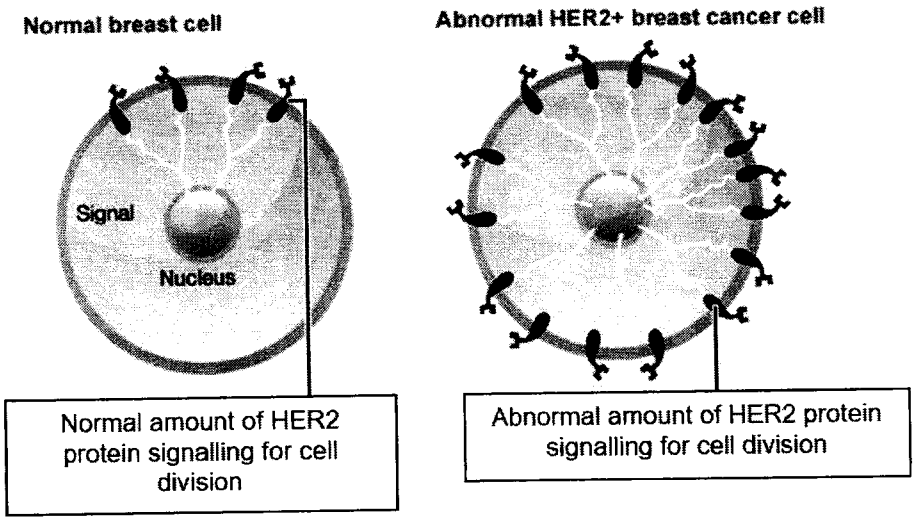



**Fig. 1.2**

Trastuzumab, an antibody specific to HER2, is an effective treatment for early-stage HER2+ breast cancer. However, advanced-stage HER2+ breast cancer patients tend to develop resistance to the treatment.

HER2+ breast cancer cells also overexpress CD47, a surface protein that helps cancer cells evade macrophage phagocytosis. Research has shown that blockage of CD47 using an antibody specific to CD47 (α-CD47 mAb) is also an effective treatment for HER2+ breast cancer.

An investigation was conducted to determine the effectiveness of treating HER2+ breast cancer cells with both trastuzumab and α-CD47 mAb.

Groups of genetically identical breast cancer cells were subjected to 3 different treatments:

1. incubation with α-CD47 mAb
2. incubation with trastuzumab
3. incubation with both trastuzumab and α-CD47 mAb

The investigation was done twice, with 3 replicates for each treatment.

The percentage of phagocytosis by macrophages was assessed and shown in Fig. 1.3.

Data are presented as mean ± S.D. (standard deviation).

Statistical differences between the two groups of cells are marked by asterisk ($P \leq 0.0001$).

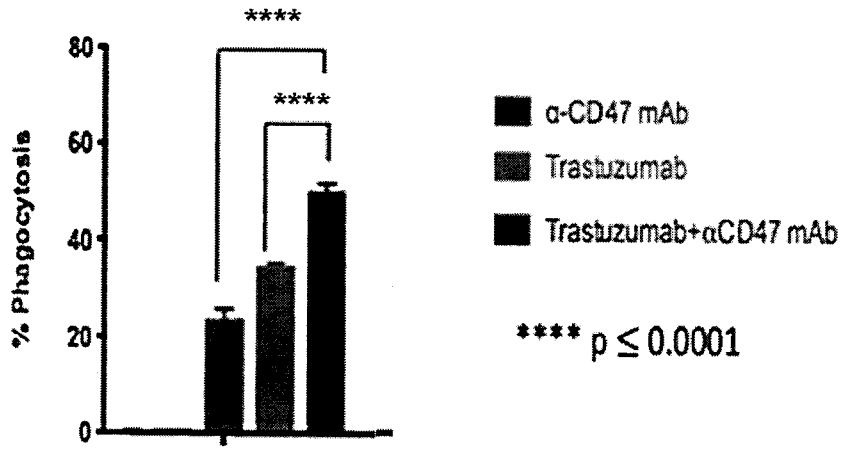



**Fig. 1.3**

**(d)** Using Fig. 1.3 and the information provided, comment on the effectiveness of the combined treatment versus a treatment using either trastuzumab, or α-CD47 mAb alone in humans. Discuss on the confidence of the presented data.

**1. Combined treatment with trastuzumab and α-CD47 mAb is more effective as shown by the higher % of phagocytosis**

**compared to trastuzumab / α-CD47 mAb alone;**

**2. [QV] e.g. % phagocytosis for trastuzumab and α-CD47 mAb treatment is higher at 50% (accept 48 - 52%) vs. 25% (accept 22 - 26%) for α-CD47 mAb alone;**

**OR**

**% phagocytosis for trastuzumab and α-CD47 mAb treatment is higher at 50% (accept 48 - 52%) vs. 37% (accept 35 - 38%) for trastuzumab alone;**

**There is confidence in the data due to:**

**3. High reproducibility / reliability from performing of a repeat experiment / 3 replicates done per experiment;**

**4. Ref. statistical test analyses revealed a very significant difference between treatment with α-CD47 mAb alone / with trastuzumab alone**

**vs combined treatment, hence results not due to chance alone;**

**5. Ref. relatively small standard deviation for all groups, suggesting consistency in results with respect to the mean;**

**There is lack of confidence in the efficacy of treatment due to:**

**6. Experiment performed on breast cancer cell line *in vitro*, need more clinical studies on humans;**

**7. Lack of a control group / untreated cells for better comparison and conclusions;**

**8. AVP;** [4]

***Marking points 1 & 2 + AND 2 marking points from 3 to 8 for full credit***

An early diagnosis of many types of cancer can result in successful treatment.

The BRCA2 protein is involved in suppressing the development of tumours.

Several different dominant alleles of the gene, *BRCA2*, code for faulty versions of the BRCA2 protein. The presence of any one of these faulty alleles leads to an increased chance of developing several types of cancer, including breast and lung cancers. Not everyone with one of these alleles develops cancer. This is because environmental factors, including lifestyle, are also involved.

Fig. 1.4 is a pedigree (family tree) showing the occurrence of cancers in four generations of a family. The presence of a faulty *BRCA2* allele was confirmed in person 15. The other individuals with cancer were not tested for the presence of the allele.

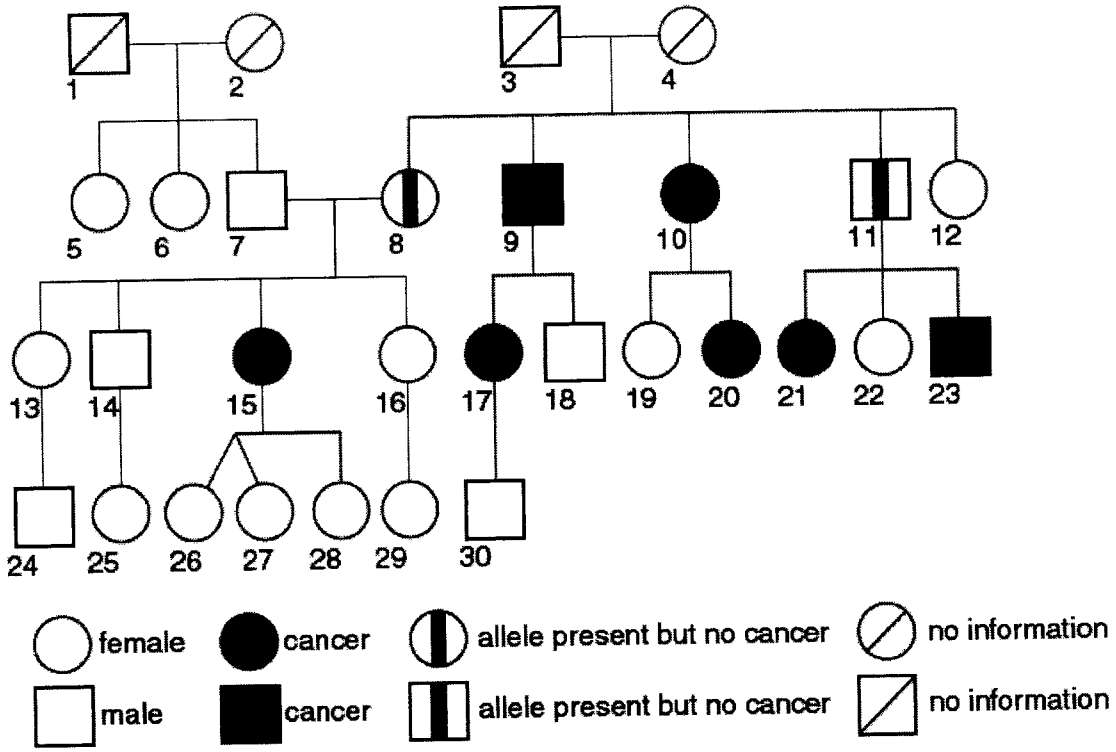



**Fig. 1.4**

(e) Discuss the extent to which Fig. 1.4 provides evidence that a faulty *BRCA2* allele increases the risk of a person developing cancer.

***Any 3 marking points below:***

1. **individual 8 or 11 has *BRCA2* allele, but <u>does not</u> have cancer;**
2. **no evidence / unknown, that individuals, apart from 15, with cancer have, *BRCA2* allele**

**OR**

3. **individuals with cancer, apart from 15, may have a different mutation;**
4. **no children of individual 15, are known to have the *BRCA2* allele / have cancer;**
5. **individuals in fourth generation / children of individual 15, may develop cancer later in life;**
6. **individual 15 has cancer <u>and</u> *BRCA2* allele;**
7. **(some) individuals with cancer in third generation had a parent with cancer but unknown to have *BRCA2* allele;**

**OR**

8. **some) individuals with cancer in third generation had a parent with *BRCA2* allele;**
9. **individual 3 or 4 may have had the *BRCA2* allele;**

**OR**

10. **any individual from 8 to 11 may have inherited the *BRCA2* allele, from individuals 3 or 4;**
11. **overall data is inconclusive;** [3]

(f) Traditionally, stem cells from bone marrow have been used to treat patients with leukaemia, a cancer of the blood or bone marrow.

Recent studies have shown that stem cells taken from umbilical cord blood may be more effective in treating leukaemia than stem cells taken from bone marrow.

Table 1.2 shows the results from patients with leukaemia after treatment with stem cells from unrelated sources over a two-year period.

**Table 1.2**

| source of stem cells | probability / % | |
|---|---|---|
| | leukaemia-free survival | death from immune rejection of transplant |
| cord blood | 34 | 12 |
| bone marrow | 33 | 31 |

Using information from Table 1.2 and your knowledge on stem cells, suggest why stem cells from the cord blood may be more preferred in the treatment of leukaemia.

**1. <u>similar</u> probability for survival**

**cord blood 34% vs bone marrow 33%;**

**2. lower probability of death from immune rejection**

**cord blood 12% vs bone marrow 31%;**

**3. idea of ease of obtaining e.g. easier to obtain cord blood from discarded umbilical cord / no need for invasive surgery**

**compared to invasive procedures to obtain bone marrow;**

**OR**

**4. idea of storage e.g. easy to store**

**long storage time;** [3]

**(g)** Embryonic stem cells have been known to express a specific set of genes that enable them to behave like stem cells, but these genes are turned off in normal somatic cells. Researchers have discovered that they can convert human fibroblast cells into embryonic stem cells by switching on the specific set of genes. These cells have been cultured in labs all over the world, and they are termed induced pluripotent stem cells (iPSCs).

**(i)** Describe the characteristics of an induced pluripotent stem cell (iPSC).

1. **An iPSC cell is an undifferentiated / unspecialised cell**

**capable of undergoing proliferation / mitotic division / cell division / self-renewal;**

**OR**

**An iPSC is an undifferentiated / unspecialised cell lacking tissue-specific structures;**

2. **Can differentiate into all cell types in an organism except extraembryonic tissue**

**(hence cannot form an entire organism / foetus on its own);**

3. **An iPSC can differentiate to produce specialised cells**

**as a result of differential switching on of genes / differential gene expression upon receiving molecular signals;**

4. **An iPSC has long term self-renewal capacity due to presence of telomerase,**

**ensures maintenance of telomere length / replacement of telomeres, enabling cells to overcome the Hayflick limit (and continue cell division / mitotic division / proliferation);** [3]

***Max 3 marking points***

**(ii)** Suggest an ethical concern regarding the use of embryonic stem cells which is no longer relevant with the development of iPSCs.

1. **No destruction of embryos with use of iPSC**

**hence not regarded as killing a life due to some views that embryos are living organisms;**

2. **Some object to extracting stem cells from an embryo to make replacement body cells**

**is treating embryo as just a source of spare parts;** [1]

***Any 1 marking point above***

The histone tails of different regions of chromatin are covalently modified during the formation of the human fibroblast cell. These modifications are added and removed by enzymes. The main effect of modifying histone tails is to attract specific proteins to a stretch of chromatin.

Fig. 1.5 shows the action of one of these enzymes, histone methyl transferase.

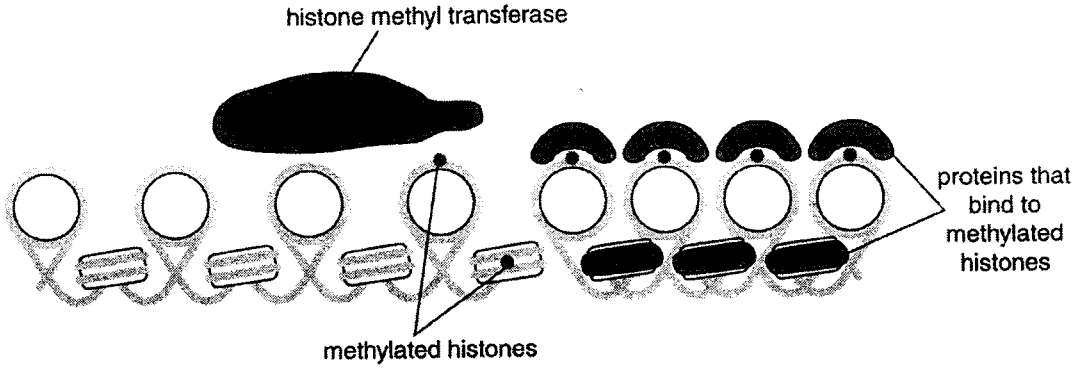



**Fig. 1.5**

**(iii)** Suggest why histone methylation occurs over large areas of chromatin during the formation of the human fibroblast cell.

1. **only specific group of genes are transcribed during formation of human fibroblast cell to produce specific proteins / enzymes to perform specific function;**

2. **of the specific group, only a few genes are expressed each time to respond to changes in external environment / needs of cell;**

3. **regions with genes that are not expressed will be tightly coiled through histone methylation,**

**many regions on chromatin are non-coding sequence thus are not transcribed & will be tightly coiled;** [3]

[Total: 30]

2 Today, viruses are considered an exception to the cell theory which states that the simplest units of life are cells. Viruses have also been referred to as "organisms at the edge of life".

**(a)** State **one** characteristic of viruses that may classify them as being

**(i)** living,

**1. able to reproduce / replicate with the aid of a host cell**

**2. possess nucleic acids containing genetic information for reproduction**

**3. able to obtain and use energy**

**4. able to respond to environment e.g. by switching replication cycles**

**5. able to evolve and mutate** [1]

***Any 1 marking point***

**(ii)** non-living.

**1. are acellular**

**2. lack cytoplasm and metabolic machinery / organelles**

**e.g. nucleus, mitochondria, ribosomes**

**3. cannot undergo metabolism**

**e.g. cellular respiration / synthesis of organic compounds**

**4. cannot replicate independently**

**are obligate parasites / dependent on host cell for metabolic machinery to replicate and synthesise new viral components**

**5. unable to generate or store energy**

**derive ATP from host cell**

**6. contains only 1 type of nucleic acid**

**either DNA or RNA but not both** [1]

***Any 1 marking point***

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by a novel coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).

Fig. 2.1 shows the mechanism used by SARS-CoV-2 to infect the cells in the airways of human hosts.

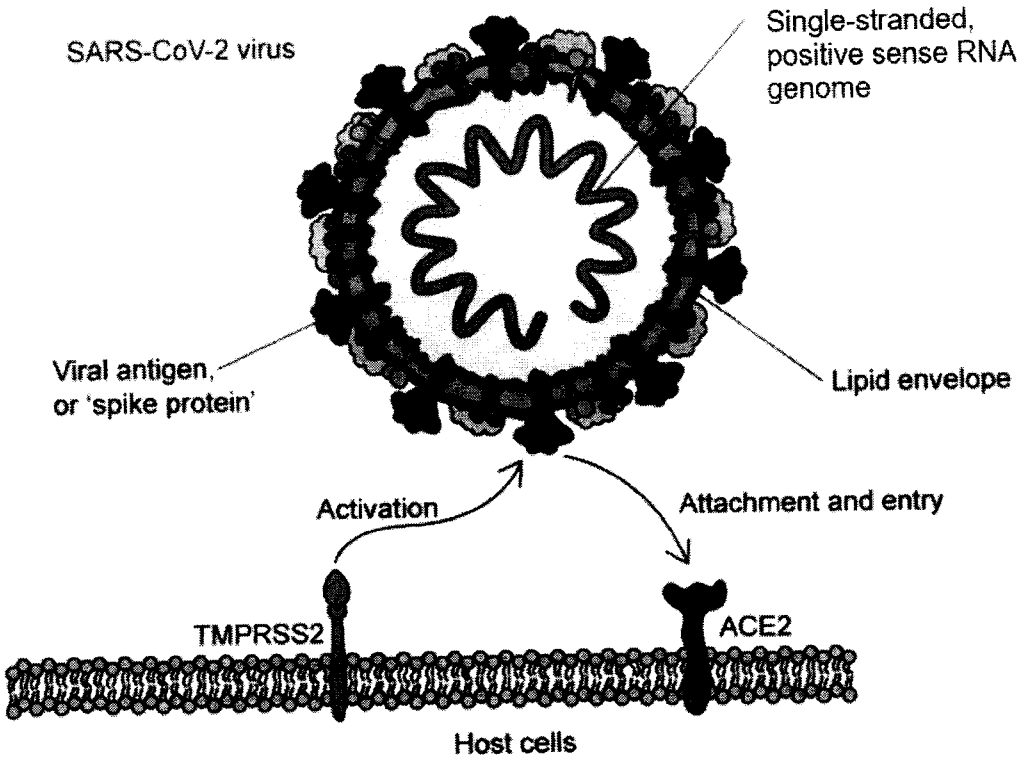



**Fig. 2.1**

**(b)** With reference to Fig. 2.1, suggests how SARS-CoV-2 infects human cells.

**1. viral antigen / spike protein binds TMPRSS2 (on host cell membrane)**

**via complementary fit;**

**2. resulting in a conformational change to viral antigen**

**activating it;**

**3. activated viral antigen is now complementary to ACE2;**

**4. allowing binding of viral antigen to result in virus entering by receptor mediated endocytosis;** [3]

A drug currently being trialled for the treatment of COVID-19 is Nafamostat, a drug that is currently licensed for the treatment of other conditions.

During one trial, scientists investigated the effect of Nafamostat on the activity of TMPRSS2, and the results are shown in Fig. 2.2 below.

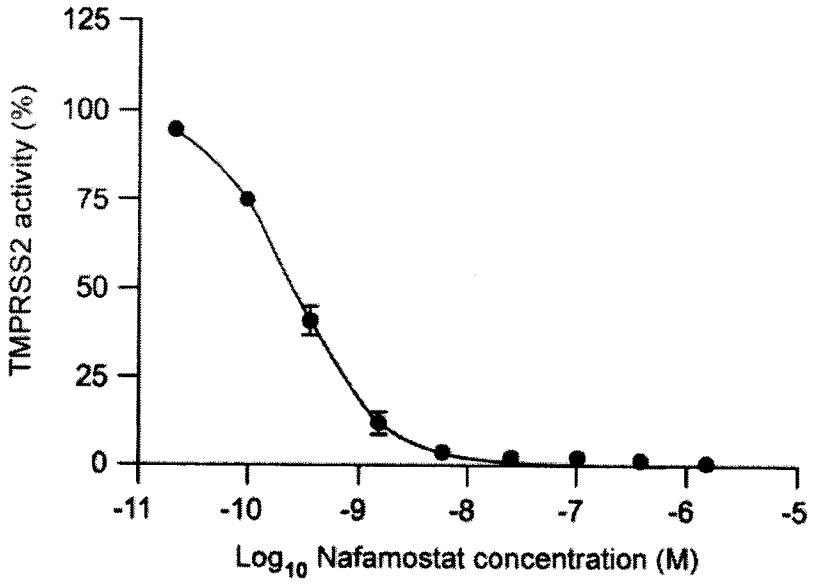



**Fig. 2.2**

**(c)** With reference to Fig. 2.1 and and Fig. 2.2, suggest how Nafamostat might function as a treatment for COVID-19.

1. **as Nafamostat concentration increases from $10^{-10.5}$ to $10^{-7}$ M, ® *$10^{-11}$***

**TMPRSS2 activity decreases (steeply) from 95% to 0%; ® *100%***

2. **Nafamostat is (structurally similar to viral antigen / complementary in shape to the TMPRSS2)**

**able to bind and block / inhibit TMPRSS2 from binding to viral antigen;**

3. **virus antigen is not activated**

**hence cannot bind ACE2 to enter host cell;** [3]

Fig. 2.3 shows the reproductive cycle of the coronavirus SARS-CoV-2.

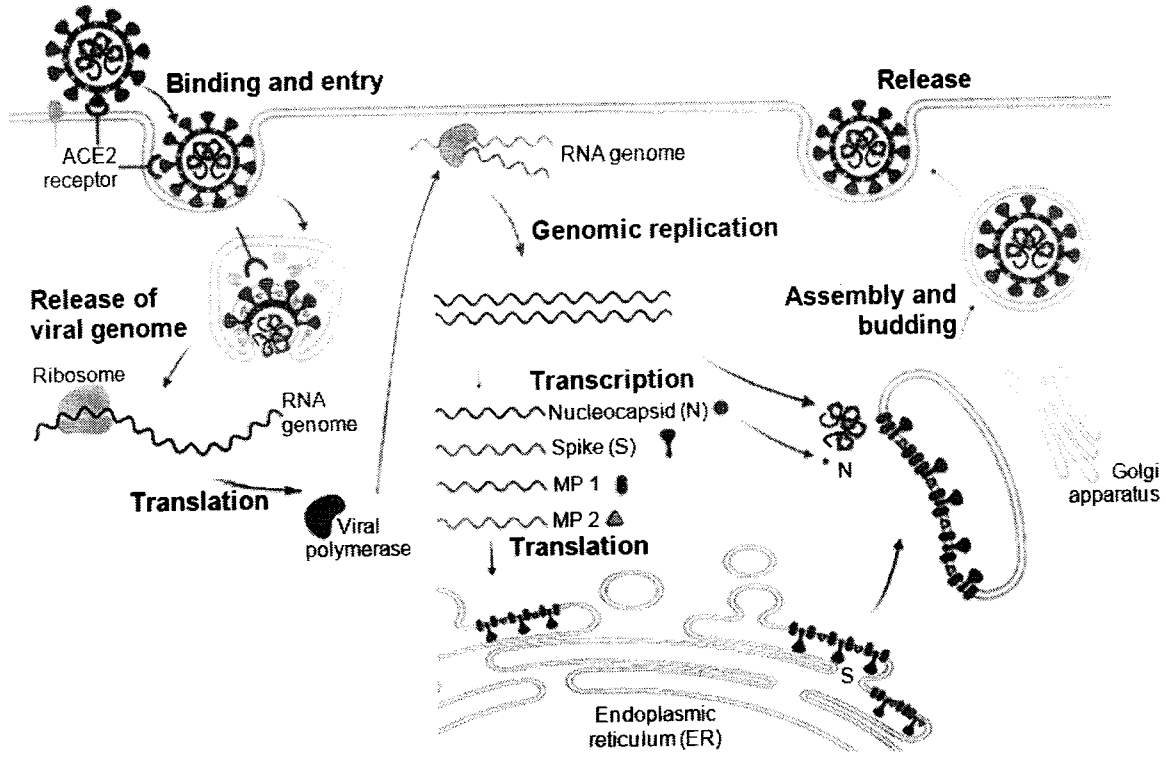



**Fig. 2.3**

**(d)** Compare between the reproductive cycles of SARS-CoV-2 and the influenza virus.

1. **SARS-CoV-2: spike protein binds to ACE2 receptor**

   **Influenza virus: haemagglutinin binds to sialic acid containing receptor;**

2. **SARS-CoV-2: exit by exocytosis**

   **Influenza virus: exit by budding;**

3. **SARS-CoV-2: positive sense RNA genome**

   **Influenza virus: negative sense RNA genome;**

4. **both require viral polymerase / RNA dependent RNA polymerase for genome replication**

5. **both enter host cell by receptor mediated endocytosis;** [2]

***max. 1 similarity***
***max. 1 difference***

***® SARS-CoV-2 assemble viral proteins in rER while influenza assemble at sell surface membrane, as HA and NA are inserted into rER membrane before being transported to cell surface membrane.***

[Total: 10]

3 Table 3.1 shows dengue incidences and precipitation pattern in a tropical country from 2013 to 2017.

**Table 3.1**

| Year | Average annual rainfall/mm | Number of cases of Dengue Fever | Average Maximum Temperature/°C | Average Minimum Temperature /°C |
|---|---|---|---|---|
| 2013 | 665 | 20270 | 32.3 | 23.2 |
| 2014 | 585 | 19902 | 33.9 | 23.2 |
| 2015 | 578 | 18910 | 33.8 | 24.2 |
| 2016 | 695 | 4260 | 34.8 | 24.5 |
| 2017 | 564 | 2145 | 36.2 | 25.0 |

**(a)** With reference to Table. 3.1, comment on the relationship between dengue fever prevalence and climate factors.

**1. QV Number of cases from highest to lowest in relation to decreased rainfall**

**e.g. 20270 in 2013 to 2145 in 2017, 665mm to 564mm;**

**2. QV Number of cases from highest to lowest in relation to increased maximum and minimum temperature**

**e.g. 20270 in 2013 to 2145 in 2017, 32.3 °C to 36.2 °C with 23.2 °C to 25.0 °C;**

**3. High annual rainfall increases number of breeding sites / stagnant water**

**for A. egypti to lay eggs;**

**4. High maximum and minimum temperature exceeded the temperature range for A. egypti**

**Decreased development and reproduction rate;** [4]

To reduce the transmission of dengue fever through decreasing vector numbers, scientists used high doses of radiation on male *A. aegypti* before releasing large numbers into the wild.

**(b)** Suggest how releasing the treated male mosquitoes may reduce transmission of dengue fever.

**1. Radiation destroyed reproductive cells of male mosquitoes**

**leading to sterility;**

**2. Mating do not result in fertilization**

**no production of offspring;** [2]

Recently a new method was developed to control *A. aegypti*. Scientists produced transgenic males carrying a 'lethal gene' which kills their offspring before they can reproduce.

The scientists released transgenic males every week in one area of a city in Brazil. At regular intervals they determined the number of *A. aegypti* per $km^2$ in the area where transgenic males were released and in a control area where no transgenic males were released.

Fig. 3.1 shows their results.

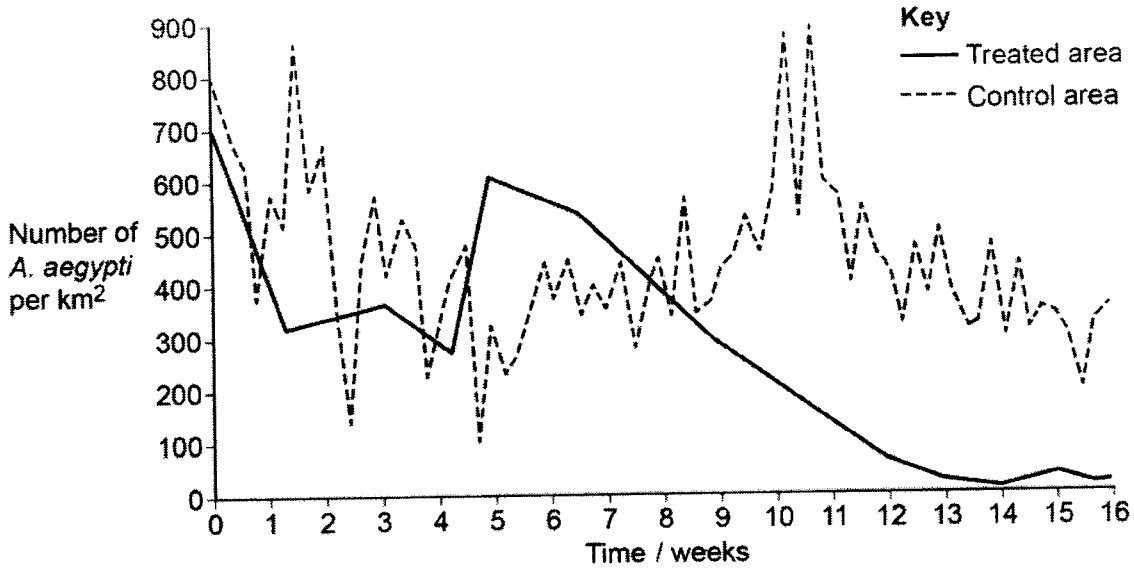



**Fig. 3.1**

**(c) (i)** With reference to Fig. 3.1, conclude whether the release of transgenic males successfully reduced the vector population.

**1. successful from Week 0 to 4.5**

**Numbers of mosquitos decrease from 700 and lowest at 280 per $km^2$;**

**2. not successful from Week 4.5 to Week 8.5**

**Number of mosquitoes increased to 600 per $km^2$, higher than control area;**

**3. Successful from Week 9 onwards**

**Number of mosquitoes in treated area consistently lower at 280 compared to 380 per $km^2$ in control area;**

**OR**

**4. Successful, decreased from Week 0 to 16**

**Number of mosquitoes from 700per $km^2$ to less than 50 per $km^2$;** [3]

***Marking points 1 +2 AND 3 / 4 for full credit***

(ii) Suggest why the scientists released more transgenic males every week.

**Short life span / ensure sufficient transgenic male mosquitoes to ensure reproductive competitiveness;**

*AVP* [1]

[Total: 10]

## 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, were appropriate.

Your answers must be in continuous prose, where appropriate.

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

**4 (a)** DNA can be replicated *in vivo* (in cells) or *in vitro* (outside cells) by processes like the polymerase chain reaction (PCR).

Compare the process of DNA replication in cells with PCR. [10]

| Feature | DNA replication in cells | PCR |
|---|---|---|
| 1. end replication problem | occurs in cells resulting in 3' overhang in template strand / shortening of daughter strand | does not occur, 3' end of template strand is completely replicated |
| 2. nature of primers | RNA primers synthesised by primase | DNA primers artificially synthesised and added to reaction mixture |
| 3. number of types of primers | many types, each leading and lagging strand with own primer complementary to different sections of the template strand | 2 types, forward and reverse, complementary to sequences flanking the target sequence |
| 4. fate of primers | removed by DNA polymerase and replaced with DNA nucleotides | not removed, forms part of the replicated DNA |
| 5. DNA polymerases | more than 1 type, 1 to elongate daughter strand, 1 to remove primer and fill up the gap | 1 type, Taq polymerase |
| 6. template | entire parental strand is replicated | only target sequence (segment of template strand) is replicated |
| 7. starting point of replication | multiple origins of replication | flanking sequence that primers are complementary to |
| 8. separation of template strand | hydrogen bonds between complementary bases broken by helicase | hydrogen bonds between complementary bases broken by increase in kinetic energy due to increase in temperature |

| Feature | DNA replication in cells | PCR |
|---|---|---|
| 9. product | shorter than parent strand at 5' end (by 1 primer length) | mostly length of target sequence with those daughter strands using original DNA as template being longer |
| 10. product | leading strand synthesised continuously, lagging strand synthesised discontinuously in Okazaki fragments | all daughter strands synthesised continuously |
| 11. product | Double stranded DNA molecule | |
| 12. mode of replication | Semi-conservative from 5' to 3' | |
| 13. Nature of DNA polymerase | Require primer to provide a free 3'OH end for elongation to synthesize the new DNA strand | |
| 14. Original Template | Requires DNA as the template | |
| 15. Enzymes involved in formation of phosphodiester bonds | Requires DNA polymerase | |

**16. AVP – Differences**
**17. AVP – Similarities**

***QWC: include at least 1 similarity and differences***

**(b)** Both DNA replication in cells and PCR may harbour mutations resulting in changes to DNA base sequences.

Discuss the impact of mutations to organisms. [15]

1. **results in creation of new alleles**
2. **increase genetic diversity in gene pool for natural selection**
3. **if new allele code for favourable phenotype, individual is selected for**
4. **e.g. antibiotic resistance in bacteria / melanism in moth during industrialisation**
5. **if new allele code for detrimental / unfavourable phenotype, individual is selected against**
6. **e.g. CFTR / gain of function mutation in protooncogene / loss in function mutation in tumour suppressor gene resulting in cancer**
7. **imprecise joining of V(D)J segments (in hypervariable region) during somatic recombination in B (and T) cells maturation**
8. **results in wide repertoire of B (and T) cell receptors that can bind to wide variety of antigens**

9. somatic hypermutation during clonal expansion / differentiation in plasma cells
10. results in variety of immunoglobulin with different affinity to specific antigen
11. allowing for affinity maturation which selects plasma cells that can produce antibodies that binds well to specific antigen
12. increasing efficiency of immune response in secondary responses
13. may result in B cells that produce antibodies with self-reactivity resulting in auto-immunity
14. antigenic drift in virus results in changes to antigenic epitope allowing virus to evade detection by memory B cells
15. antigenic shift in virus results in recombination of genetic material from different strains giving rise to ability to infect new host type (cross species barrier)
16. Chromosomal mutations leading to changes in structure or numbers of chromosomes to result in speciation or disease
17. E.g. of polyploidy in maize leading to sympatric speciation
18. Gene mutations leading to changes in protein structure resulting in disease
19. E.g. sickle cell anaemia due to change of amino acid from glutamate to valine to result in hydrophobic protrusion which fits into hydrophobic pocket during low partial pressure of oxygen resulting in sickle shaped red blood cells
20. E.g. Down syndrome, aneuploidy of the 21$^{st}$ chromosome where there are 3 chromosome 21 resulting in a trisomy 21 leading to intellectual/ physical disabilities
21. Isolated populations accumulate mutations independently to result in reproductive barriers, resulting in genetic divergence to result in speciation
22. AVP

*QWC: at least 2 mutations linked to relevant impact in 2 different areas*

**Examiner's Report:**

**Many candidates incorrectly went on to describe in a detailed manner the different types of mutations without relating to the impact of the organism. Answers which were awarded credit were frequently in the area of mutations to proto-oncogene, tumour suppressor genes and β-globin gene. Candidates who mentioned natural selection failed to identify correctly the impact of the selection pressure on the organisms and vaguely mentioned that favourable alleles are inherited by the offspring without relating to changes in gene pool.**

[Total: 25]

5 (a) Both eukaryotic cells and bacterial cells are able to divide to give daughter cells. Eukaryotic cells can divide by mitosis to produce cells for growth and repair or meiosis to produce gametes. Bacterial cells, however, can only divide by binary fission to result in clones.

Compare the process of mitosis in eukaryotic cells and binary fission in bacterial cells. [10]

| Feature | Eukaryotic cell | Bacterial cell |
|---|---|---|
| 1. Location of chromosome | each chromosome is free floating in cytosol | each DNA strand of bacterial chromosome attaches to cell surface membrane |
| 2. occurrence of chromosome after replication | replicated DNA are joined at centromere forming 2 sister chromatids after replication | chromosomes exist as 2 separate chromosomes after replication |
| 3. arrangement of chromosomes | chromosomes are lined up in single row at metaphase plate during metaphase | chromosomes are attached to cell surface membrane adjacent to each other |
| 4. separation of chromosomes | sister chromatids are pulled apart to opposite poles of the cell by kinetochore spindle fibres during anaphase | daughter chromosomes are separated as cell wall material is deposited between the points of attachment |
| 5. location of chromosomes at the end of division | nuclear envelope forms around daughter chromosomes at each pole forming new nuclei | daughter chromosomes are in nucleoid region in cytoplasm |
| 6. division of cell | cleavage furrow (for animal cells) or cell plate (for plant cells) forms at equator to separate the parent cell occurs concurrently with telophase (in mitosis) | formation of septum between 2 daughter chromosome separates the parent cell into 2 daughter cells |
| 7. Duration of cellular division | Longer due to larger genome and presence of organelles | Shorter with a smaller genome and no organelles |
| 8. Ploidy of parent cell | Diploid with 2 sets of homologous chromosomes | Haploid with 1 circular chromosome |
| 9. DNA replication | Both require chromosomes to be replicated <u>before</u> separation of DNA into new daughter cells. | |
| 10. Daughter cells | Have the same number of chromosomes and genetic material as the parent cell / genetically identical to each other (and to parent cell) | |

***Max: 9 marking points for comparative statements***
**QWC: awarded for at least 1 similarity AND 1 difference**

(b) Discuss how genetically varied cells can arise despite binary fission being the only mode of cell division for bacterial cells. [15]

1. **mutation resulting in change in nucleotide sequence in DNA**
2. **can be spontaneous during DNA replication**
3. **or induced due to exposure to mutagens / ionising radiation**
4. **resulting in changes in base structure or pairing properties of the bases**
5. **error in DNA replication where wrong bases are paired**
6. **due to error in proof reading by DNA polymerase**
7. **transformation – competent bacteria cells take up naked DNA from the environment**
8. **and undergo successful homologous recombination**
9. **conjugation between F+ and F- cells**
10. **where F plasmid from F+ cell is transferred to F- cell via conjugation bridge**
11. **transduction where bacteriophages transfers genetic material from 1 host to the next**
12. **generalised transduction involving lytic phages which package and transfer random fragments of lysed bacterial host chromosome to next host**
13. **specialised transduction involving temperate phages which package and transfer specific fragments of lysed bacterial host chromosome adjacent to prophage to next host**
14. **successful gene transfer between bacteria result in acquisition of new alleles**
15. **State e.g. of genes acquired from gene transfer processes e.g. genes coding for antibiotic resistance / enzymes to use new metabolites / etc.**

**QWC: at least 2 different modes**

[Total: 25]