RIVER VALLEY HIGH SCHOOL
YEAR 6
PRELIMINARY EXAMINATION II

CANDIDATE NAME												
CENTRE NUMBER	S					CLASS		INDEX NUMBER				

H2 BIOLOGY **9744/03**

Paper 3 Long Structured and Free-response Questions **20 Sep 2017**

2 hours

Additional Materials: Writing Paper

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

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

Section B
Answer any **one** question on the separate writing paper provided.

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

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

For Examiner's Use	
Section A	
1	**/19**
2	**/18**
3	**/ 13**
Section B	
4 or 5	**/25**
Total	**/ 75**

This document consists of **18** printed pages.

Section A

Answer **all** the questions in this section.

1 The Galapagos Islands is an archipelago approximately 1400 kilometers off the Western coast of Ecuador. It consists of more than 40 islands, including the small and isolated island Daphne Major. The map of the islands, and its location in relation to mainland Ecuador and Cocos Island, is shown in Fig. 1.1.

Fig. 1.1

There are now at least 13 species of finches on the Galapagos Islands, each filling a different niche on different islands. All of them evolved from one ancestral species, which colonised the islands only a few million years ago.

Molecular analysis was carried out on the nucleotide sequences of the Galapagos Islands finches and the Cocos finch, found on the island of Cocos, 830 km North-east of the Galapagos Islands. Fig. 1.2 shows the phylogeny of these finches as constructed from the molecular data obtained.

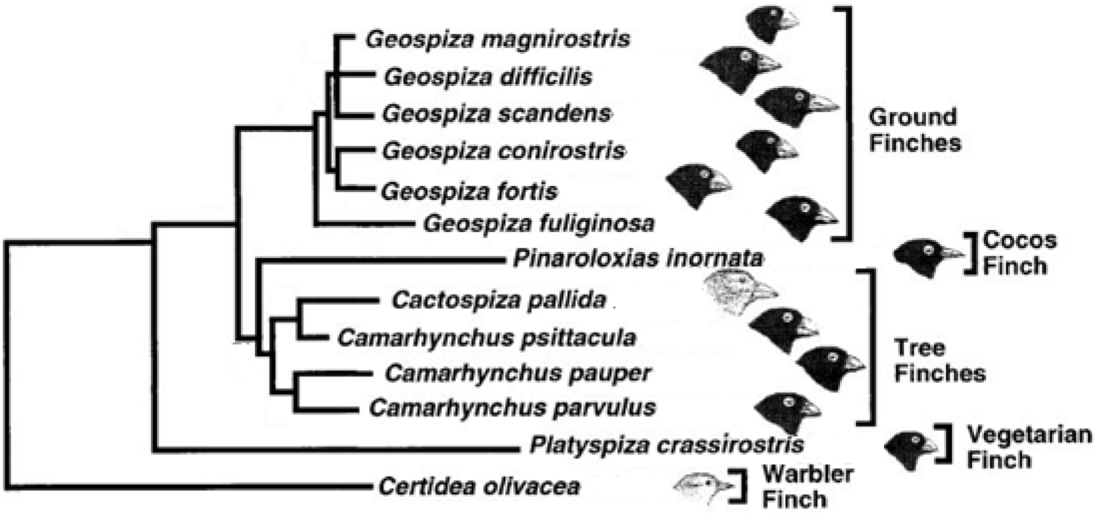


Fig. 1.2

(a)	Explain how DNA sequences can be used to determine evolutionary relatedness between species.	[2]
	1. Compare homologous DNA sequences/ same gene; **2. found in different species;** **3. The fewer the differences in the DNA sequences of homologous genes between species, the more closely related the species are (vice-versa);;**	
(b)	Suggest how the Cocos finch might be derived from the same common ancestor as the Galapagos finches, despite its lack of proximity to the Galapagos Islands.	[1]
	1. Last common ancestor to Galapagos and Cocos finch first dispersed to Cocos from Ecuador, then to the Galapagos islands;; **2. Last common ancestor to both finches was transported to Cocos islands due to human factors (by air/ship) from Ecuador / Galapagos Islands;;** **3. Last common ancestor to both finches was dispersed to Cocos island by an extreme weather event;;**	

A long-term study of the medium ground finch, *Geospiza fortis*, was carried out on the island of Daphne Major. Ground finches have bills particularly suited to eating seeds. Seeds eaten by the population of *G. fortis* are of a variety of sizes and are from a range of plants. Fig. 1.3 shows a male *G. fortis*.

Fig. 1.3

In 1977, a severe drought affected the Galapagos Islands. The number of different plant species producing seeds and total seed abundance was greatly reduced for the population of *G. fortis*.

Scientists have postulated that the severity of the drought experienced may have been exacerbated by the rise in atmospheric CO_2 concentrations due to human activities.

(c) Explain how the emission of greenhouse gases such as CO_2 may be linked to the onset of drought. [2]

1. **Increased concentration of greenhouse gases in atmosphere;**
2. **traps heat and warms atmospheric temperature / leads to warming due to the greenhouse effect;**
3. **Increased evaporation as a result of rising global temperatures;**
4. **Lead to dryer environments / longer summers;**

The population size of *G. fortis* on Daphne Major fell by over 85% as a result of the 1977 drought.

In years with good rainfall there is an abundance of small, soft seeds that are favoured by *G. fortis*, especially those individuals with smaller bills. In years of drought, small seeds are scarce. Individuals of *G. fortis* with small bills are rarely successful in extracting seeds from the large, spiky, tough fruits of *Tribulus cistoides* (Fig. 1.4), which was the main source of seeds at the time.

Fig. 1.4

Table 1.1 shows results for mean mass and mean bill size of mature *G. fortis* before and after the drought. The individuals measured after the drought were a subset of the first sample, allowing a direct comparison of the changes that occurred.

Table 1.1

Date of sampling	**Sample size**	**Phenotypic feature measured**			
		Mass / g	**Bill length / mm**	**Bill depth / mm**	**Bill width / mm**
1976 (May)	642	15.79	10.68	9.42	8.68
1978 (March)	85	16.85	11.07	9.96	9.01
Percentage change		**+6.71**	+3.65	**+5.73**	+3.80

(d) **(i)** Complete Table 1.1 to show the percentage change in mass and bill depth from 1976 (May) to 1978 (March). [1]

(ii) After the drought, the population of *G. fortis* had significantly higher mean mass and larger mean bill size than the pre-drought population.

Name the type of natural selection that was occurring. [1]

Directional selection;;

(e) Explain how the changes in bill size that occurred in the population of *G. fortis* on Daphne Major provide support for Darwin's explanation of how natural selection operates. [3]

1. **Mutation leads to phenotypic variation in population;**
2. **Individuals have different bill size;**
3. **Lack of small seeds / larger, tougher seeds exerts selective pressure;**
4. **Birds with bigger bills can break open seeds;**
5. **Better able to survive and reproduce;**
6. **Pass on favourable alleles to offspring;**
7. **Over time, increased frequency of alleles for big bills in population;**

Current temperatures in the Galapagos archipelago rarely exceed 30°C, even in the summer months. However, climate scientists have warned that in light of global warming, temperatures in the archipelago may soon increase.

The Intergovernmental Panel on Climate Change has forecasted a rise in global average temperatures of up to 5°C over the next century.

(f) With reference to Fig. 1.1, suggest how global warming may affect the survival of the finches in the Galapagos Islands. [2]

1. **Finches will migrate polewards / to islands in the South as they seek cooler temperatures;;**
2. **If temperature increases too much, finches may not be capable of flying out of the archipelago and will perish / go extinct;;**
3. **Melting of glaciers leads to rising sea levels which will flood islands, reducing availability of habitats;;**
4. **If sea level rise excessively leading to islands being submerged, finches may not be capable of flying out of the archipelago and will perish / go extinct;;**

Scientists have also suggested that changes in carbon dioxide concentration in the atmosphere changes the stomatal density of plants.

43 different species of plants from a range of habitats were grown at normal atmospheric carbon dioxide concentration and at increased carbon dioxide concentration.

The mean stomatal density of each species was determined at both concentrations of carbon dioxide. The percentage change in stomatal density at the increased carbon dioxide concentration compared to the stomatal density at normal atmospheric carbon dioxide concentration was calculated for each species. Table 1.2 summarises the changes to mean stomatal density due to increased atmospheric carbon dioxide concentration for the species investigated.

Table 1.2

Percentage change in stomatal density (to the nearest 10%)	Number of species
+40	2
+30	2
+20	4
+10	2
-10	7
-20	9
-30	9
-40	8

(g) Account for the results shown in Table 1.2. [5]

		1. 10 species show an increase in stomatal density;; **2. 33 species show a decrease in stomatal density;;** **Increased CO_2 concentration leads to** **3. Increase in global average temperature;** **4. Decreased in availability of rainwater;** **Effects of decreased stomata density** **5. Minimise water loss due to transpiration;** **6. Ensure sufficient water (in periods of drought);** **7. Plant still able to get sufficient CO_2 for photosynthesis;** **Plants increase stomatal density** **8. Allow for increased heat loss;** **9. Prevent enzymes from denaturing / ensure metabolic processes can continue;**	
	The experiment showed that plants are able to show significant changes in their phenotype in response to changes in the environment.		
	(h)	Suggest why plants need to be able to show changes in their phenotype within their lifetime.	[2]
		1. Plants are not mobile / cannot migrate;; **2. Changes in phenotype allow the plant to maximise their chance of survival;;**	
			[Total: 19]

2 Dengue fever is a mosquito-borne disease caused by the dengue virus. Fig. 2.1 shows the structure of a dengue virus.

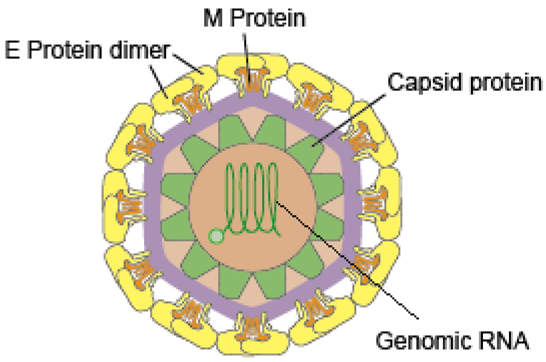


Fig. 2.1

(a) List **two** ways in which the structure of dengue virus is similar to the human immunodeficiency virus. [2]

1. **Genome made up of RNA;;**
2. **Viral genome enclosed in capsid;;**
3. **Glycoproteins found on envelope;;**

Dengue viruses consist of four serotypes, DENV-1 to DEV-4. The rapid identification of dengue virus serotypes isolated from patients' blood is important for clinical investigations. One of the methods used for identification of serotypes is DNA sequencing, which is a process of determining the precise order of nucleotides within a DNA molecule.

One of the DNA sequencing methods is based on the use of chain terminators, which are special nucleotides. Fig 2.2 shows the structure of a special nucleotide with a cytosine base.

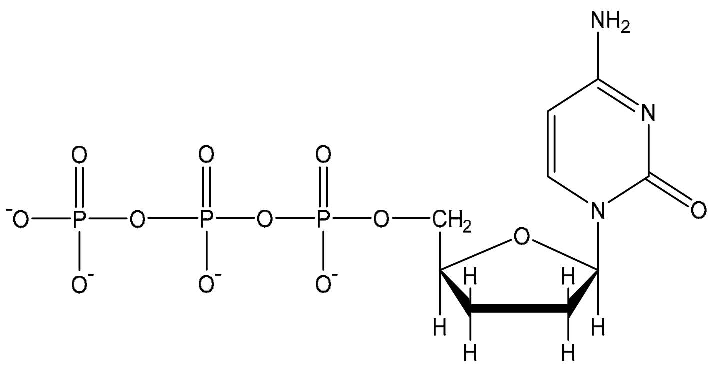


Fig 2.2

If a special nucleotide is added to a growing DNA strand, the chain is not extended any further. Each special nucleotide is labelled with a fluorescent dye, using a different colour for each of the four bases.

Fig 2.3 shows how a DNA chain ending with one of the special nucleotides is replicated.

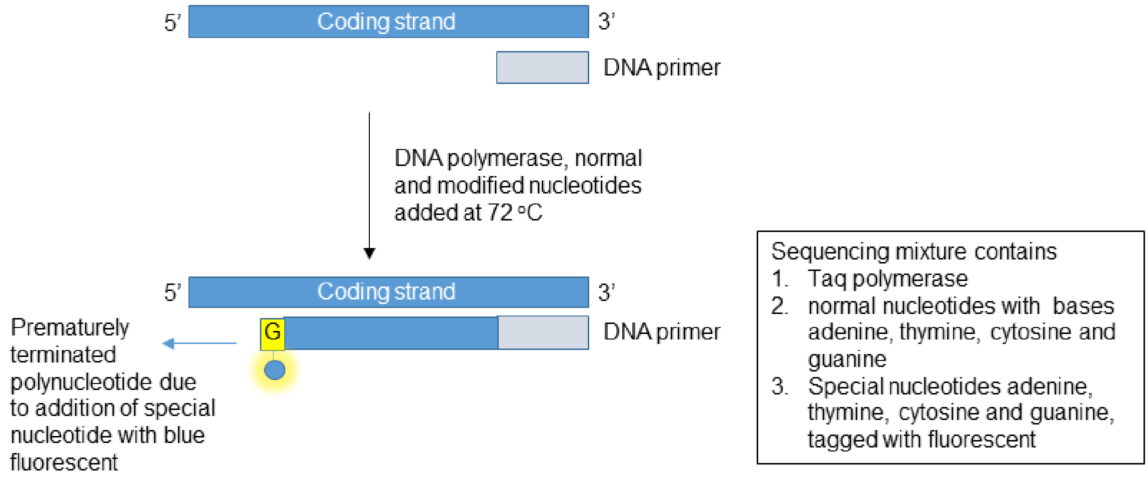


Fig. 2.3

	(b)	Suggest why the addition of special nucleotides would lead to the premature termination of replication.	[2]
		1. Since special nucleotide lacks hydroxyl group on 3' carbon of pentose;; **2. the incorporated special nucleotide cannot form phosphoester bond with incoming dNTP / nucleotide;;**	

This method of DNA sequencing described in Fig 2.3, can produce many DNA fragments terminated by a special nucleotide tagged with a florescent. Fig 2.4 shows a set of such fragments, where each fragment differs by 1 nucleotide.

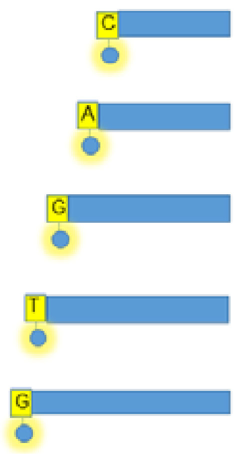


Fig. 2.4

These fragments are loaded onto an agarose gel, shown in Fig 2.5, and separated by a modified version of gel electrophoresis.

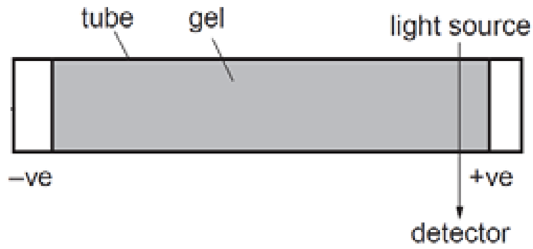


Fig 2.5

The order in which the fragments reach the light source and detector shown in Fig 2.5 is C, A, G, T.

(c) Explain why the DNA fragments will migrate and reach the detector in this order. [3]

1. **DNA is negatively charged;**
2. **Migrate towards (the detector at) positive electrode;**
3. **Separated on the basis of size of DNA fragments;**
4. **Shorter DNA fragment migrate through the pores of the agarose gel faster than longer DNA fragment/ vice versa;**
5. **Fragment ending with C is the shortest;**
6. **Migrate through the pores of the agarose gel fastest/ vice versa;**

Dengue virus is a major threat to health in tropical countries around the world, with 390 million people infected each year. To date, there are no vaccines for dengue virus.

(d) Suggest why there is no effective vaccine to protect against dengue. [2]

1. **there are four serotypes of dengue virus, each with slightly different viral proteins;;**
2. **not possible to stimulate the body to generate antibodies against all four types at once;;**

(e) Antibiotics are not used to treat viral infections.

Explain why antibiotics do not affect viruses. [2]

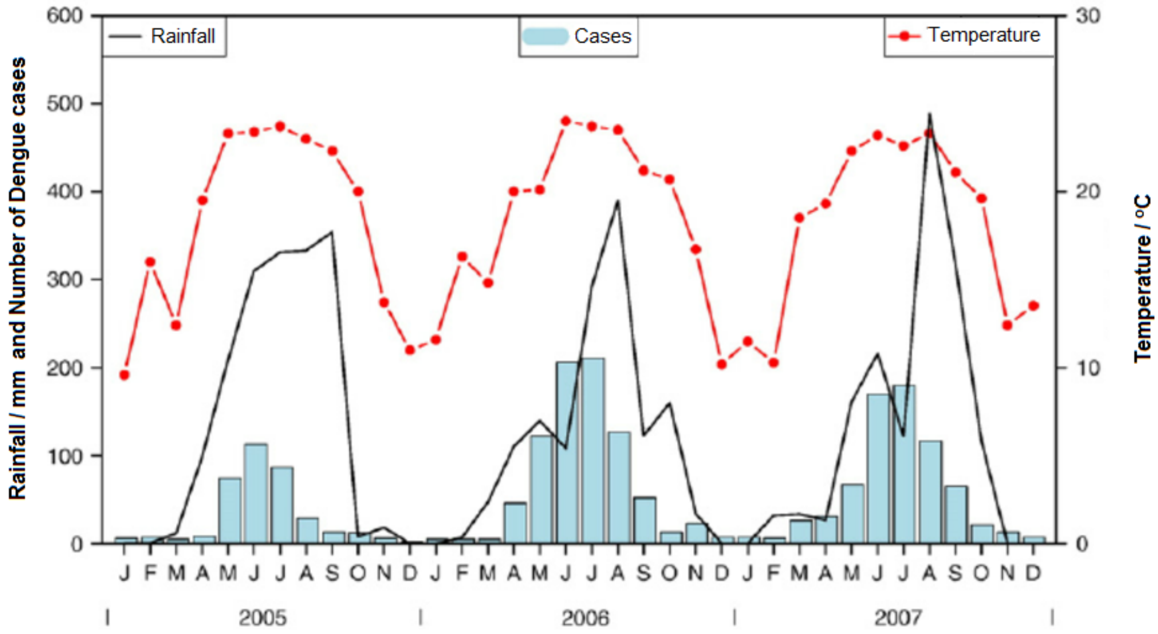
1. **antibiotics (only) used against bacteria (and some fungi);;**
2. **idea that antibiotics act on a cell structure not possessed by virus;;**

   e.g. viruses, do not have, a cell wall / ribosomes
3. **suggestion that viruses are, inside host cells not within reach of antibiotic;;**

any two

The *Aedes aegypti* mosquito is the main vector that transmits the viruses that cause dengue. The viruses are passed on to humans through the bites of an infective female *A. aegypti* mosquito, which mainly acquires the virus while feeding on the blood of an infected person.

Fig. 2.6 shows the monthly number of dengue cases in Sakon Nakhon Province, Thailand, from January 2005 to December 2007.

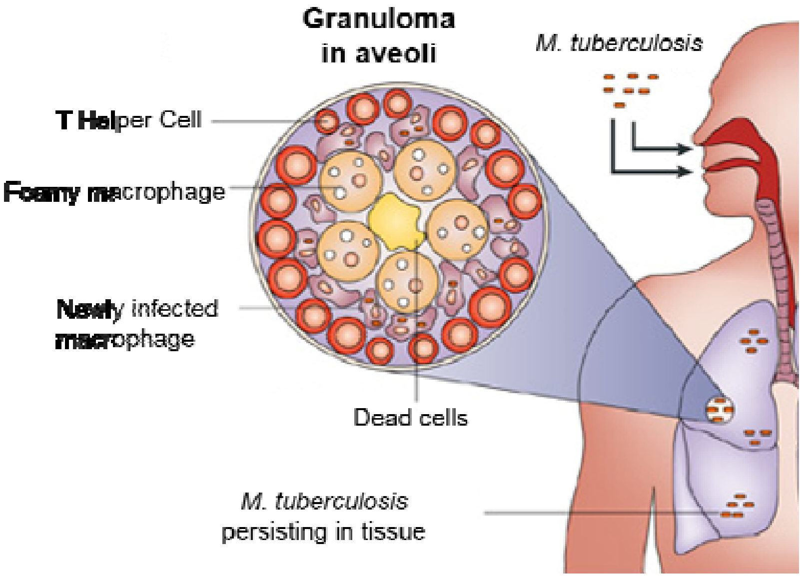


Source: Monthly district level risk of dengue occurrences in Sakon Nakhon Province, Thailand. The Science of the total environment. 408 (2010). 5521-8.

Fig. 2.6

	(f)	Explain how temperature affects the number of dengue cases in Thailand.	[3]
		1. Increased temperature, increased dengue occurrences; **2. accelerates emergence of mosquitoes / life cycle shorten;** **3. increasing mosquito population;** **4. reduce extrinsic incubation period of virus in insect;** **5. increasing the number of infective vector;** **6. female mosquitoes digest blood faster and feed more frequently;**	
	(g)	Other than climate change, state and explain how **two** other factors can contribute to the increase in the number of dengue cases.	[2]
		1. Increased rainfall; more breeding sites for mosquitoes; **2. lack of effective mosquito control; increase in mosquito populations;** **3. increased movement of people; increase spread of virus;** **4. increased population density; increase transmission between**	

		humans; 5. AVP;;	
	The primary preventative measure to reduce dengue infections is the control of mosquito populations. Traditional methods of mosquito control using insecticides are not viable in the long term, as new and stronger versions of insecticides must continually be developed. Biological approaches are now being used as an alternative to control mosquito populations. Researchers are experimenting with release of *Wolbachia*-infected mosquitoes as a means of suppressing *Aedes* mosquito populations. When male mosquitoes with *Wolbachia* mate with wild female mosquitoes without *Wolbachia*, eggs laid by these female mosquitoes will be sterile. The technique requires the release of a large number of male mosquitoes to reduce the overall mosquito population.		
	(h)	State the **one** advantage and **one** disadvantage of using the biological method.	[2]
		Advantage 1. **Prevent development of resistance to insecticide;;** **Disadvantage** 1. **need to be reapplied over time as the population of mosquitoes gradually returns;;** 2. **need to continually cultivate large number of male mosquitoes;;**	
		[Total: 18]	

3	Tuberculosis (TB) is a disease caused by the bacterium *Mycobacterium tuberculosis*, and accounts for more than 1 million deaths annually. Some of the symptoms of infection include shortness of breath, fever, chest pains and coughing up blood. Fig. 3.1. shows the transmission and infection of *M. tuberculosis*.  **Fig. 3.1** The immune response to TB results in the formation of granulomas. These cellular aggregates restrict the spread of the infection, but fail to kill all of the bacteria. This results in a tight interplay between *M. tuberculosis* and the host cells within the granulomas during the latent stage of infection. Foamy macrophages are granuloma-specific cells that are characterised by the accumulation of large amounts of lipids contained within numerous lipid vacuoles. These macrophages are formed as a result of prolonged interaction with *M. tuberculosis.*			
	(a)	Describe how TB is transmitted.		[2]
		1. *M. tuberculosis;* **2. in airborne particles / droplet nuclei;** **3. enters the upper respiratory tract;** **4. and reaches the alveoli of lungs;**		
	(b)	With reference to Fig. 3.1 and your own knowledge, describe the formation of granulomas in *M. tuberculosis* infections.		[3]
		1. *M. tuberculosis* ingested by alveolar macrophages; **2. Replicate intracellularly;** **3. Destroy alveolar macrophages;** **4. Infect more macrophages;**		

5. **Leads to activation of T lymphocytes;**
6. **Which surround infected macrophages;**
7. **Forming a barrier shell;**

M. tuberculosis have mycobacterial cell walls that are different from other bacterial cell walls due to their thick lipid coating. The cell walls consist of arabinogalactan, a biopolymer of two monosaccharides, complexed with mycolic fatty acids. Fig. 3.2 shows the structure of a *M. tuberculosis* mycobacterial cell wall, compared with that of a common bacteria.

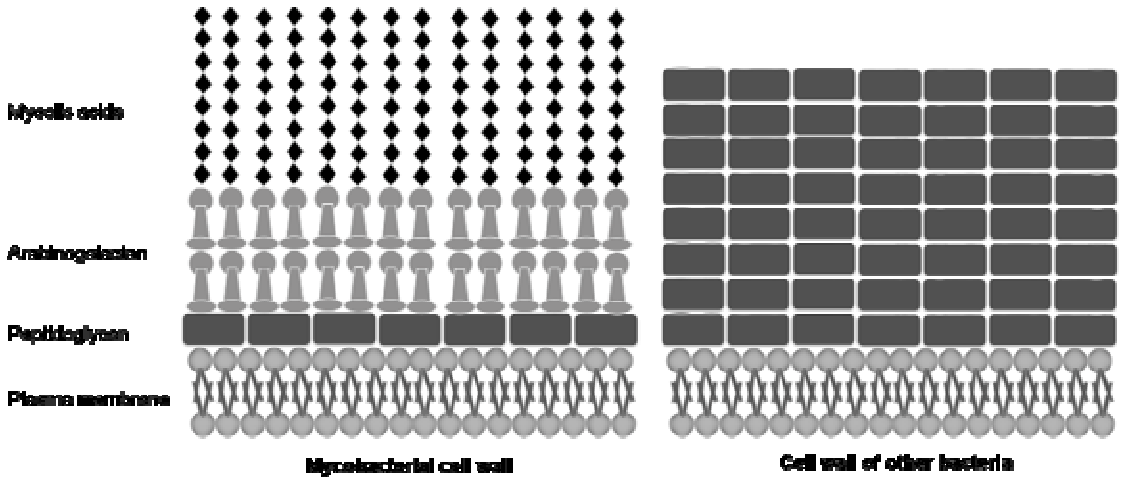


Fig. 3.2

(c) With reference to Fig. 3.1 and 3.2, suggest how the persistence of *M. tuberculosis* within the granulomas allows it to replicate intracellularly. [2]

1. **Foamy macrophages provide lipids;;**
2. **For the formation of new mycolic acids;;**

Treatment of TB uses antibiotics to kill the bacteria. Effective treatment with traditional bacteriacidal antibiotics such as penicillin are ineffective. Antibiotics such as isoniazid and rifampicin are used instead for a prolonged period of time in order to ensure successful treatment of TB.

(d) With reference to Fig. 3.2, explain why administering penicillin will not effectively treat TB. [2]

1. **Penicillin only interferes with the interpeptide linking of peptidoglycan;**
2. **But does not prevent formation of arabinogalactan;**
3. **Newly synthesised still has protective cell wall;**
4. **Will not die from osmotic instability / autolysis;**

Isoniazid is administered as a prodrug, and must be activated by a bacterial enzyme known as KatG. Upon activation, isoniazid inhibits the action of fatty acid synthase, inhibiting the synthesis of mycolic acids and thus preventing the synthesis of the mycobacterial cell wall.

Alarmingly, strains of *M. tuberculosis* that display resistance to isoniazid have been increasingly common. Scientists studied the genome of a resistant strain K131, and noted that there were numerous mutations identified in the 2.0-2.5Mb region. Fig. 3.3 shows the complete genome of K131.

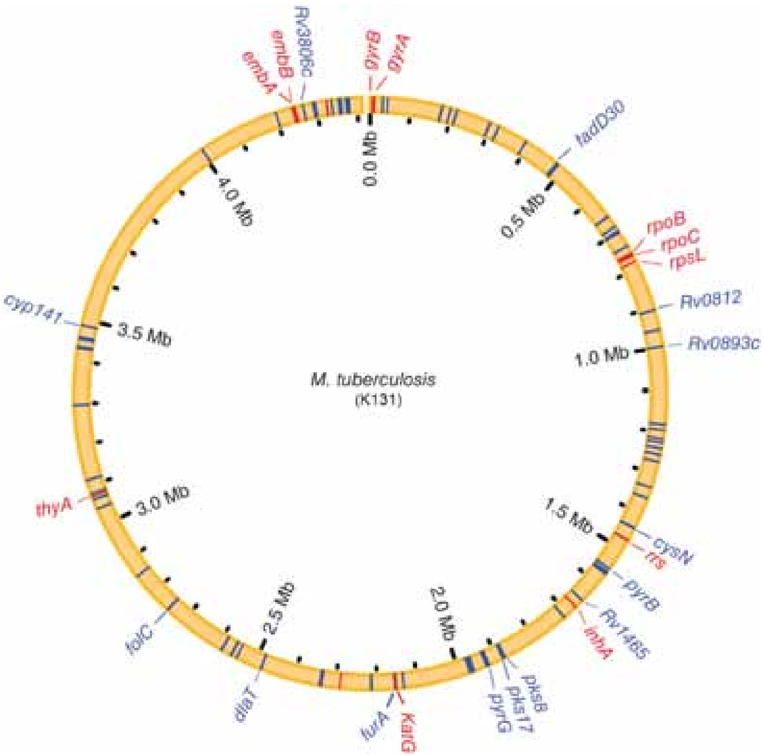


Fig. 3.3

	(e)	Explain how strain K131 is resistant to isoniazid.	[4]

1. ***KatG* is located in the 2.0-2.5Mb region;**
2. **Mutation to the gene would alter the mRNA encoded;**
3. **Amino acid sequence of KatG altered;**
4. **Affect folding of KatG;**
5. **Change in conformation of active site;**
6. **Unable to bind to isoniazid to activate it;**
7. **Fatty acid synthase function not inhibited;**
8. **Mycolic acids still synthesised;**

[Total: 13]

Section B

Answer **one** question in this section.

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

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

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in parts

4	**(a)**	Discuss the role of complementarity in cellular mechanisms.	[12]
		1. Complementary shape;; **2. Complementary base pairing;;** **3. Complementary interaction;;** **4. allows for <u>specificity</u> of reaction;;** **<u>Complementary shape</u>** **5. Substrate(s) fit into the active site of enzyme;** **6. via lock and key hypothesis;** **7. And induced fit hypothesis;** **8. To form enzyme-substrate complex;** **9. DNA to fit into binding site of proteins** **10. To regulate replication;** **11. And gene expression;** **12. Ligand/ signaling molecule to fit into binding site of receptors;** **13. Allows for cell signaling;** **14. Binding of substances to transport proteins;** **15. Allows for movement of substances across cell membrane;** **16. and viral entry;** **<u>Complementary interaction</u>** **17. H bonds between polar groups;** **18. Hydrophobic interaction between non-polar groups;** **19. Ionic bonds between oppositely charged groups;** **20. Allows for folding of polypeptide into 3D shape;** **21. Stability of biomolecules;**	

		<u>Complementary base pair</u> **22. A-T (A-U) and C-G;** **23. Allows for stability of DNA double helix;** **24. Allows for replication of DNA;** **25. Allows for the synthesis of mRNA/transcription;** **26. allows for the binding of (anticodon on) tRNA to (codon on) mRNA;**	
	(b)	Explain how genetic recombination occurs in B lymphocytes and the advantages of each process.	[13]
		1. Somatic recombination; **2. occurs during development of B lymphocytes;** **3. via removal of intervening (DNA) sequences;** **4. followed by joining of gene segments;** **5. by enzymes;** **6. At <u>variable regions</u> of immunoglobulin <u>heavy chain</u> <u>gene</u> locus;** **7. <u>Rearrangement</u> of D and J gene segments;** **8. followed by <u>rearrangement</u> of V gene segment;** **9. VDJ exon joined to the constant segments;** **10. during RNA splicing;** **11. At <u>variable regions</u> of immunoglobulin <u>light chain</u> <u>gene</u> locus;** **12. Rearrangement of V and J gene segments;** **13. VJ exon joined to the C segments;** **14. during RNA splicing;** **15. Hypermutation;** **16. occurs during clonal expansion of B lymphocytes;** **17. in <u>variable region</u> of immunoglobulin chains;** **18. These point mutations;** **19. in (rearranged) VDJ gene segments;** **20. occurs at higher rate <u>than normal mutations</u>;** **21. Class switching;** **22. occurs during clonal expansion of B lymphocytes;** **23. in <u>constant region</u> of immunoglobulin chains;**	

		24. where one constant region is replaced by another constant region; **Advantages:** 25. Somatic recombination gives rise to antibody diversity; 26. to respond to large diversity of (molecular structures associated with) pathogens; 27. Hypermutation allows for formation of immunoglobulin with higher affinity for antigens / affinity maturation;; 28. Class switching results in different classes of antibodies; 29. with the same antigen specificity; 30. allowing for variable effector functions; **QWC:** Scientific argumentation exemplified by citing one advantage for each of the three processes;;	
			[Total: 25]

5	(a)	Explain what is meant by mutation, and outline its advantages and disadvantages to animals.	[13]
		Explain what is meant by mutation 1. Inherited change in nucleotide sequence;; 2. Base-pair insertion, deletion and substitution;; 3. Changes to chromosome structure and number;; Single Gene Disorder 4. Sickle cell anaemia; 5. Base-pair substitution; 6. In β-globin gene; 7. Reduced ability to carry oxygen; Multi Gene Disorder 8. Accumulation of mutations; 9. Lead to the development of cancer; 10. Gain of function of proto-oncogenes; 11. Loss of function mutation in tumour-suppresor genes;	

12. Loss of cell cycle checkpoints / uncontrolled cell division;

Chromosomal Mutations

13. Non-disjunction of chromosomes;
14. During meiosis;
15. Leads to aneuploidy / polyploidy;
16. gives rise to a named genetic disease (Turner / Klinefetler / Down syndrome);

Evolutionary significance

17. Raw material for evolution;
18. Gives rise to phenotypic variation;
19. Allows natural selection to take place (select for different phenotypes);
20. increase chance of survival of species;
21. lead to microevolution / speciation;

Increased affinity of antibodies

22. Mutations in VDJ / VJ regions;
23. B lymphocytes produce antibodies with higher affinity;
24. Leading to affinity maturation;
25. More effective immune response;

QWC:

Implications of mutations clearly communicated to include at least 1 advantage and 2 disadvantages;;

	(b)	Describe the role of proteins in the transformation of energy from the environment to plant cells for their survival.	[12]

1. Light energy is converted to chemical energy;
2. via photosynthesis;
3. for cells to respire / carry out metabolic processes;

4. Proteins bind photosynthetic pigments;
5. to form photosystems;
6. for capturing of photons;

7. Electron transport chain; consists of proteins like
8. cytochromes;

		9. ferredoxin; 10. arranged in progressively lower energy levels; 11. Energy released powers (intermembrane) protein pumps; 12. to generate proton gradient; 13. NADP+ reductase protein; 14. catalyses formation of NADPH; 15. ATP synthase protein; 16. utilises energy from chemiosmosis / proton gradient; 17. to catalyses formation of ATP 18. Peptide enzyme catalyses the photolysis of water; 19. to replace electrons on PSII 20. that contributes to proton gradient; 21. RUBP carboxylase protein; 22. catalyses fixation of carbon dioxide; 23. to ribulose bisphosphate; 24. Peptide enzymes catalyses formation of glycosidic bonds; 25. to synthesis glucose molecules; 26. for energy storage;	
		[Total: 25]	