Candidate Name: _____

Class	Adm No

H

millennia institute

2023 End-of-Year Examination

Pre-University 3

H2 Biology **9744/02**

Paper 2 Structured Questions **12 September 2023**

2 hours

READ THESE INSTRUCTIONS FIRST

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

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

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

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

For Examiner's Use	
1	/10
2	/9
3	/10
4	/12
5	/10
6	/13
7	/11
8	/12
9	/5
10	/8
Total	/100

Answer **all** questions.

1. Biomolecules function as building blocks for macromolecules to be assembled. Carbohydrate is made up of many monosaccharides and can be found in both animals and plants.

(a) Name the bond formed between monomers in cellulose.

…… [1]

(b) Illustrate with a **labelled** diagram how two monomers form the bond in **(a)** in cellulose. **Circle** the bond formed between the two monomers.

Fig. 1.1 shows the partial structure of the monomer.

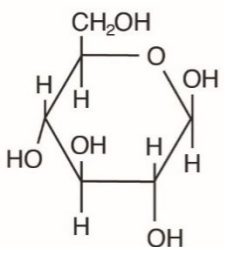

Fig. 1.1

[4]

(c) One of the defining features of all cells is the cell surface membrane. This membrane is composed of phospholipid bilayer, with other biomolecules dispersed throughout the bilayer.

(i) Describe the roles of carbohydrates in the cell surface membrane.

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…….. [2]

(ii) During the synthesis of phospholipid, the phospholipid sometimes needs to be moved between the layers. The movement is facilitated by a transmembrane protein called floppase.

Fig.1.2 shows floppase moving a phospholipid from the inner layer to the outer layer of the cell surface membrane.

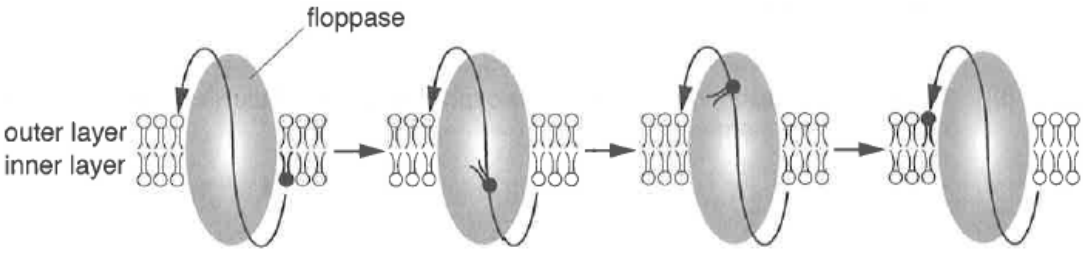

Fig. 1.2

Due to their hydrophilic heads, phospholipid molecules cannot cross the hydrophobic region of the membrane from the inner layer to the outer layer without floppase.

Using your knowledge of proteins, suggest how the structure of floppase allows phospholipids to cross the hydrophobic region of the membrane.

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…… [3]

[Total :10]

2. Catalase is an enzyme that catalyses the decomposition of hydrogen peroxide, which is a toxic product of metabolism.

A scientist investigated the activity of two forms of catalase, **P** and **Q**, extracted from *Anopheles gambiae*, an important vector of malaria. The scientists investigated the effect of increasing concentration of hydrogen peroxide on the activity of these two forms of catalase.

The results are shown in Fig. 2.1.

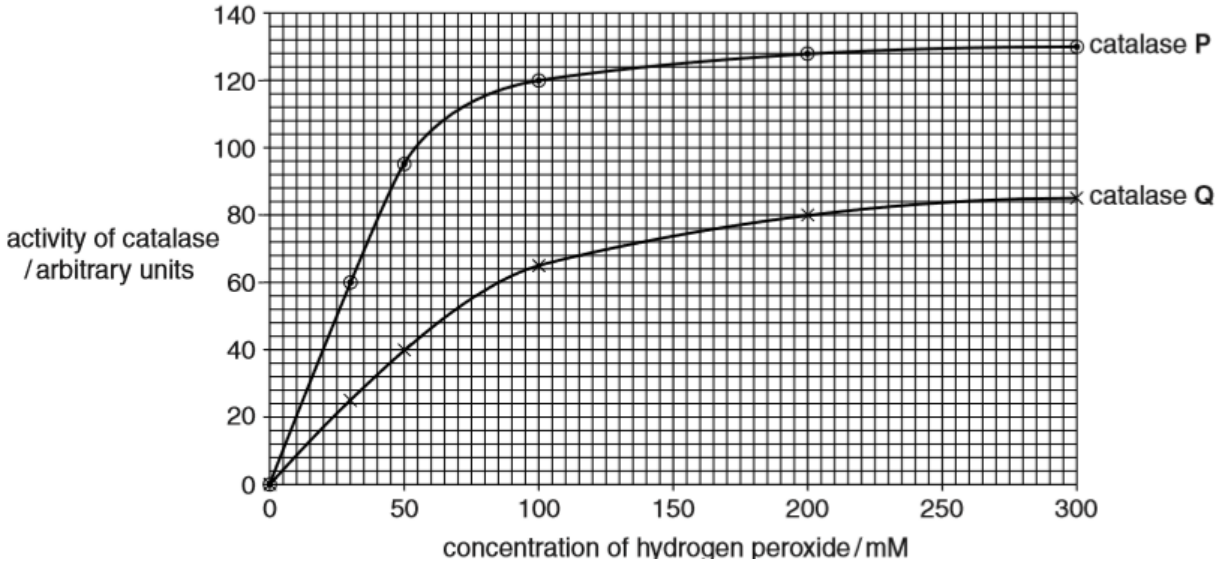

Fig. 2.1

(a) With reference to Fig. 2.1, describe and explain the effect of increasing concentration of hydrogen peroxide on the activity of catalase **P**.

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…… [4]

(b) Each molecule of catalase consists of four identical polypeptides. The two forms of catalase in *Anopheles gambiae* differ by only one amino acid at position 2 in the amino acid sequence.

Explain how the difference in one amino acid sequence is responsible for the lower activity of catalase **Q** compared with catalase **P**.

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…… [3]

(c) Female mosquitoes feed on blood in order to produce their eggs. After feeding, the metabolic rate increases for egg production.

The scientist allowed female mosquitoes to feed on blood. They found that female mosquitoes with only catalase **P** produced more eggs than those with only catalase **Q**.

Suggest why there is a difference in egg production between the two types of *Anopheles gambiae.*

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……...

…… [2]

[Total :9]

3.

(a) State the function of DNA and describe its property that allow it to perform this function.

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…… [2]

(b) In a somatic cell of a eukaryote, 20% of the nitrogenous base in the nuclear DNA is thymine.

Calculate the percentage of nitrogenous base in the nuclear DNA of this cell that is guanine and explain your answers.

Show your working clearly in the space below.

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…… [3]

(c) Fig. 3.1 shows the process of DNA replication.

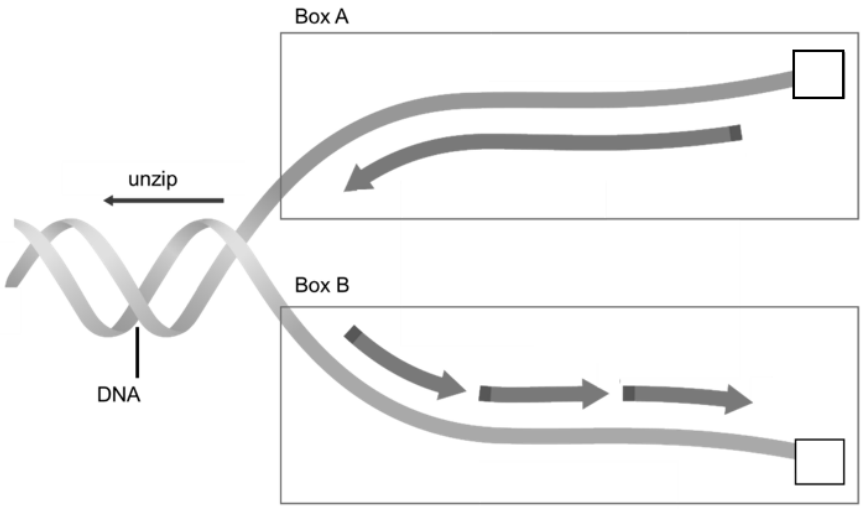

Fig. 3.1

(i) In the boxes provided in Fig. 3.1, label the end of DNA with either

- **3'** or
- **5'**.

[1]

(ii) Explain why DNA is replicated differently in Box **A** and Box **B**.

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……
…… [2]

(d) During protein synthesis, DNA is used as a template to form mRNA and the resulting mRNA is used as a template to form polypeptide chain.

Describe 2 other differences between the enzyme used to form mRNA and the enzyme used to form polypeptide chain.

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……...

…… [2]

[Total :10]

4. Sickle cell anaemia is most commonly caused by the haemoglobin variant HbS, a result of a point mutation.

(a) Describe the effect of the point mutation to haemoglobin.

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…… [4]

(b) Sickle cell anaemia can be treated with a drug called hydroxyurea which induces the formation of fetal haemoglobin (HbF). HbF is normally found in fetus and newborn. When present in individuals with sickle cell anaemia, HbF prevents sickling of red blood cells.

(i) Suggest how formation of HbF would be induced.

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…… [2]

(ii) Suggest how elevated levels of HbF may reduce the symptoms of sickle cell anaemia.

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…… [2]

(c) Sickle cell anaemia is caused by a somatic mutation as it affects the somatic cell. On the other hand, germline mutation affects the gametes.

Explain why somatic mutation may have milder consequence than germline mutation.

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…… [2]

(d) Mitochondrial complex I deficiency is the most common mitochondrial disorder present in childhood. It can be caused by mutation in mitochondrial DNA (mtDNA) or mutation in nuclear DNA.

The characteristics of the deficiency caused by mutations in mtDNA are:

- a cell in an ovary produces gametes with different proportion of normal mitochondria and mitochondria that contains the mtDNA mutation
- a person has disease symptoms when the proportion of mutant mitochondria in their cells exceed a certain threshold
- the severity of disease symptoms, and the age at which they appear, can vary greatly in the children of one woman.

In a family with history of mitochondrial complex I deficiency that is caused by mutation in a nuclear DNA, the probability of a child inheriting the mutation can be predicted.

Suggest why, in families where mitochondrial complex I deficiency is caused by mtDNA mutation, it is not possible to predict the probability of a child inheriting the mutation.

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…… [2]

[Total :12]

5. Polymerase chain reaction (PCR) is a molecular technique commonly used in molecular biology.

(a) Describe the aim of PCR.

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…….. [1]

(b) Describe what occurs in the

(i) first stage,

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…….. [2]

(ii) second stage,

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…….. [2]

(iii) third stage of PCR.

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…….. [2]

(c) State the number of DNA molecules formed after 100 cycles of PCR.

…… [1]

In the set-up of PCR, all the required components are placed in a machine called thermocycler. The enzyme responsible for PCR has a half-life of around 40 minutes at 95^{o}C.

(d) With reference to your knowledge of PCR, explain why a half-life of 40 minutes at 95^{o}C allow many cycles of PCR before the enzyme needs to be replaced.

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…… [2]

[Total :10]

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6. Prokaryote reproduces via asexual process, producing clones of daughter cells.

Despite this, prokaryotes exhibit a wide range of adaptations, suggesting the presence of genetic variation in prokaryotes. Genetic recombination and random mutation can lead to the variation in prokaryotic genome. However, the probability of random mutation occurring in the population is relatively low.

(a) State why random mutation may still lead to genetic variation in prokaryote despite its low rate.

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…… [1]

Genetic recombination is the combination of DNA from two sources into the genome of an individual. In prokaryotes, transformation is one such processes.

(b) Describe how transformation leads to genetic variation in prokaryotic genome.

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…… [2]

Transformation is exploited in the laboratory to make copies of eukaryotic genes in large amount. Fig. 6.1 shows how insulin gene is inserted into bacterial plasmid.

In Fig. 6.2, the resulting plasmid is added to bacteria cell that is treated with calcium chloride ($CaCl_2$). Usually, the bacterial cell is also subjected to heat shock to facilitate the uptake of plasmid DNA. Bacteria cells that have successfully taken up the plasmid DNA is known as transformed bacterial cells. The transformed bacterial cells are plated on agar plate with suitable growth medium, allowing scientists to identify cells that express the insulin gene.

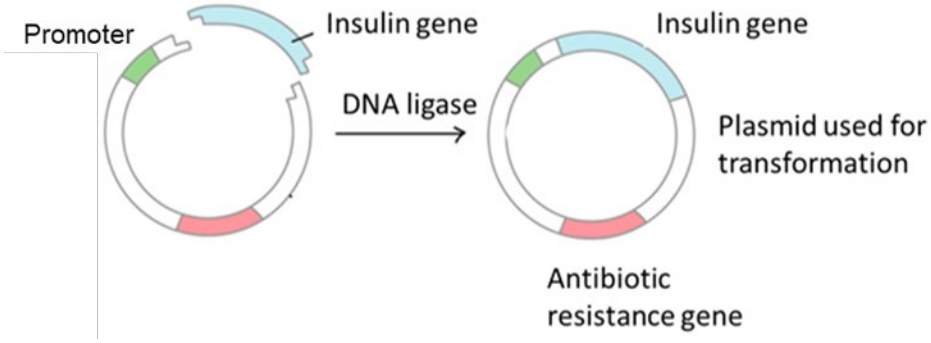

Fig. 6.1

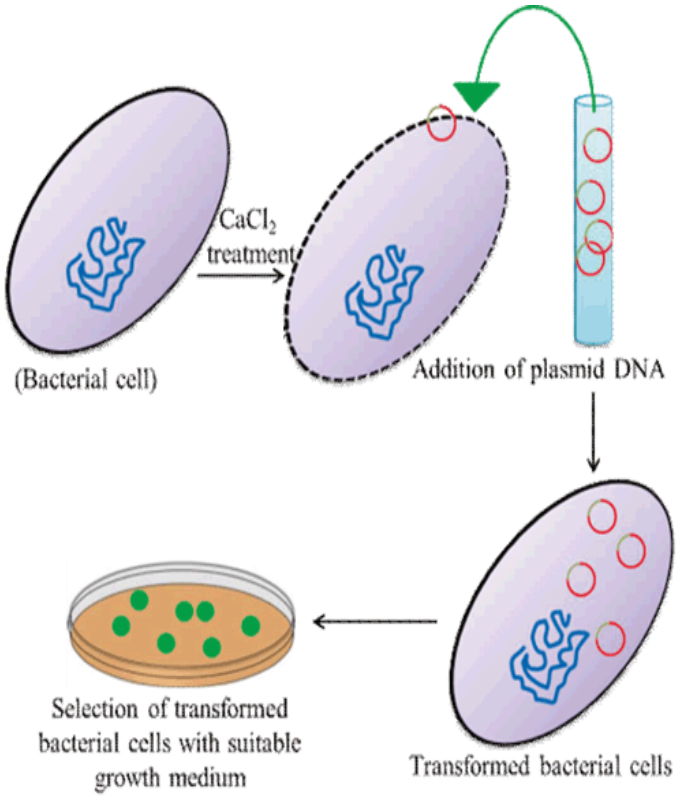

Fig. 6.2

(c) With reference to all the information provided and your knowledge of molecular biology,

(i) explain why insulin gene obtained from eukaryote can be added into plasmid DNA.

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…… [2]

(ii) explain the importance of growing bacterial cells on agar plate with suitable growth medium.

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…… [2]

(iii) suggest how calcium chloride and heat shock can facilitate the uptake of plasmid DNA into the bacterial cell.

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…… [2]

After selection of transformed bacterial cell, DNA analysis is conducted to check if plasmid in bacteria contains the insulin gene.

(d) Outline how Southern Blot is used to detect the presence of insulin gene.

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…… [4]

[Total :13]

7. *Thermus thermophilus* is a bacterium found in hot springs. The bacterium respires aerobically, even though the high temperature of hot spring leads to low solubility of oxygen in water.

One strain of *Thermus thermophilus,* HB8, expresses the enzyme, nitrate reductase, which allows nitrate to be used as final electron acceptor in the electron transport chain.

(a) Name the cellular location(s) where ATP is formed during aerobic respiration.

…… [1]

(b) Explain the advantage that HB8 has in hot springs.

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…… [2]

A mutant strain of HB8, known as HB8 mutant, was artificially created by introducing mutation to the gene that codes for nitrate reductase.

An investigation was carried out to find out the population growth of HB8 and HB8 mutant in aerobic and anaerobic conditions. In each experiment, a flask containing bacterial culture medium was incubated. Table 7.1 shows how the flasks were set up.

Table 7.1

flask	bacteria	conditions
1	HB8	aerobic
2	HB8 mutant	
3	HB8 and HB8 mutant	
4	HB8	anaerobic
5	HB8 mutant	
6	HB8 and HB8 mutant	

The number of bacteria in each flask was calculated after 20 hours and the results are shown in Fig. 7.1.

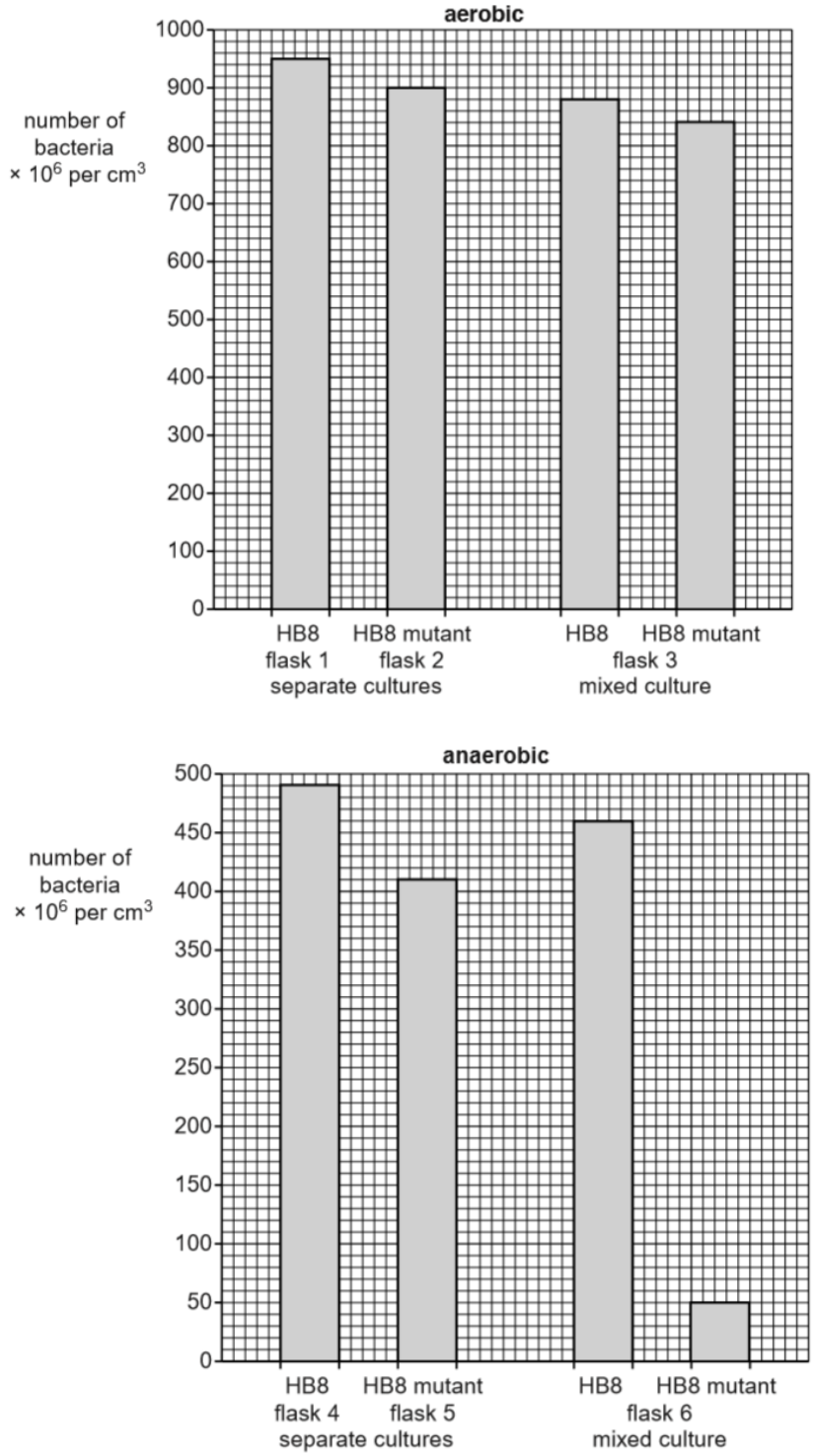

Fig. 7.1

(c) With reference to the information given, describe the growth of

(i) the two strains of bacteria in **aerobic and anaerobic** conditions in **separate** cultures,

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…… [2]

(ii) **all** the bacteria strains in **anaerobic** conditions.

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…… [3]

(d) Describe how anaerobic respiration in yeast cells differs from anaerobic respiration in bacterial cells.

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…… [3]

[Total :11]

8. In the sweet pea plant, one gene codes for flower colour and one gene codes for pollen grain shape.

Flower colour is either purple or red, and the allele **F** coding for purple flowers is dominant over the allele **f** coding for red flowers.

Pollen grain shape is either long or round, and the allele **G** coding for long pollen grains is dominant over allele **g** coding for round pollen grains.

(a) A dihybrid cross was carried out between homozygous dominant and homozygous recessive sweet pea plant parents to produce the F1 generation.

The offspring from the F1 generation were crossed to produce the F2 generations. Table 8.1 shows the actual results of the cross.

Table 8.1

Phenotypes of F2 offspring	Number of individuals
purple flowers, long pollen grains	294
purple flowers, round pollen grains	24
red flowers, long pollen grains	25
red flowers, round pollen grains	57

(i) Explain how the results support the fact that this is a non-mendelian inheritance.

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…… [2]

(ii) Draw a genetic diagram to show the actual cross between the two offspring from the F1 generation.

[4]

(b) A test cross was carried out with sweet pea plants known to be heterozygous for both flower colour and pollen grain shape.

The results of the test cross are shown in Table 8.2.

Table 8.2

Phenotypes of F2 offspring	Observed number of individuals (O)	Expected number of individuals (E)	(O-E)	$(O-E)^2$	$\frac{(O-E)^2}{E}$
purple flowers, long pollen grains	105				
purple flowers, round pollen grains	15				
red flowers, long pollen grains	16				
red flowers, round pollen grains	64				

(i) Chi-squared test was carried out to investigate if the results in Table 8.2 were significantly different from those expected.

The formula for chi-squared test is shown in Fig. 8.1.

$$X^2 = \Sigma \left\{ \frac{(O-E)^2}{E} \right\}$$

Fig. 8.1

Complete Table 8.2 and calculate the value of χ^2. Show your working clearly in the space below.

Value of χ^2 : …… [4]

(ii) The results of a test cross can be used to determine a crossover value (COV). A crossover value is the percentage of the total number of offspring showing recombination.

The COV can be calculated using the formula below.

$$\text{COV} = \frac{\text{number of recombinants}}{\text{total number of individuals}} \; x \; 100$$

Calculate the COV from the **observed results** shown in Table 8.2. Show your working clearly in the space below.

COV : ……% [2]

[Total :12]

9. The greenish warbler, *Phylloscopus trochiloides*, is a species of small bird that originated in India. Thousands of years ago, populations of the greenish warbler spread around the world to establish themselves in north-eastern Europe and Siberia (Fig. 9.1).

The following describes the changes:

- A gradual change in characteristics occurred in these populations, leading to different forms of the greenish warbler.
- One example of gradual change is in the song of the male warbler, which is very distinctive and used in mating behaviour.
- When greenish warblers from north-eastern Europe meet those from Siberia, no mating takes place.

Fig. 9.1

Explain why the greenish warblers from north-eastern Europe and Siberia are considered different species.

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[Total:5]

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[Turn Over]

10. The green sea turtle, *Chelonia mydas*, are found in coastal areas and can live for at least 70 years. The sex of green sea turtle is determined by the temperature at which their eggs develop in the nest. The sex of green sea turtles can therefore be affected by climate change.

Green sea turtles mate near the beach where they nest. The female lay about 100 eggs and the eggs hatch after about 55 days.

The Great Barrier Reef in the Coral Sea off the coast of Australia has two populations of green sea turtles.

- Population **N** breeds and nest at the northern end of the Great Barrier Reef
- Population **S** breeds and nest at the southern end of the Great Barrier Reef

In 2014, scientists studied the relative proportions of male and female green sea turtles in three age groups within population **N** and population **S**. The results of this study are shown in Table 10.1.

Table 10.1

Age/years	Percentage within each age group of population **N**		Percentage within each age group of population **S**	
	male	female	male	female
25 – 70	13	87	31	69
15 – 25	1	99	35	65
5 - 14	1	99	32	68

(a) For each population, describe the age-related trends in the percentage of males and females.

population **N** …….

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population **S** …….

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…… [2]

Fig. 10.1 shows how the temperature at which the eggs of green turtles develop determines the sex of offspring.

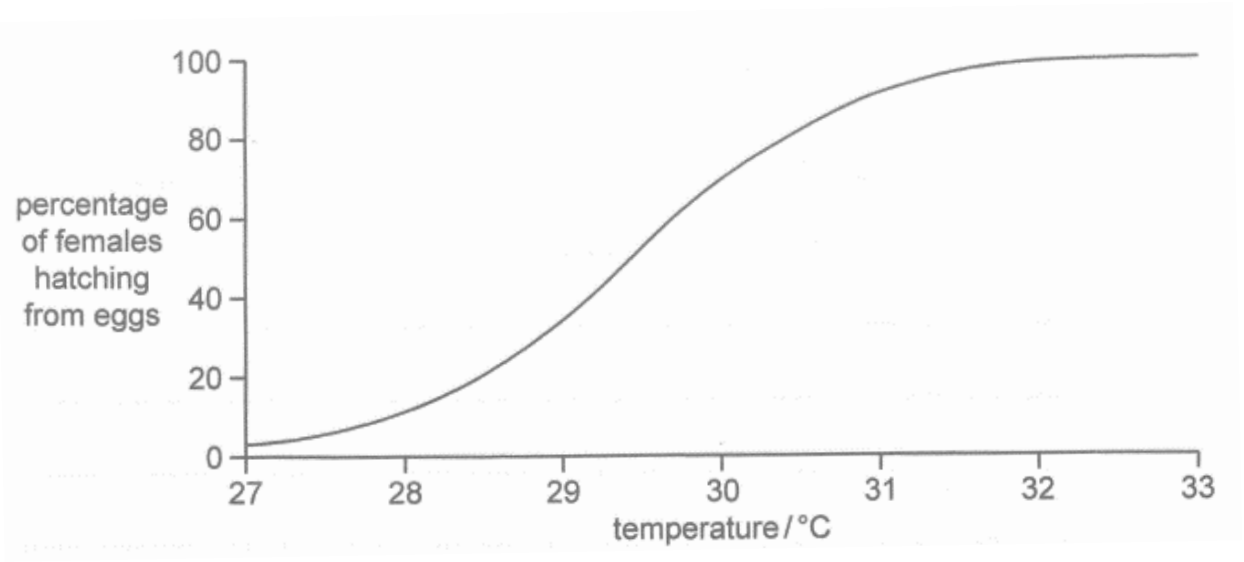

Fig. 10.1

(b) Use the information to suggest an explanation for the age-related trends in the percentage of males and females in each of the two populations, as shown in Table 10.1.

population **N** …….

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……...

……...

population **S** …….

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……. [4]

(c) Explain why population **N** could become extinct if the age-related trend in the percentage of males and females continues for another 50 years.

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…… [2]

[Total:8]

End of Paper