

New
Specification



Rewarding Learning

ADVANCED
General Certificate of Education
2018

Centre Number

--	--	--	--	--

Candidate Number

--	--	--	--	--

Biology

StemUp Model Solution

Assessment Unit A2 2

assessing

Biochemistry, Genetics and
Evolutionary Trends



[ABY21]

ABY21

MONDAY 11 JUNE, AFTERNOON

TIME

2 hours 15 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

You must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete in black ink only. **Do not write with a gel pen.**

Answer **all nine** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 100. Section A carries 82 marks. Section B carries 18 marks.

Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

You are reminded of the need for good English and clear presentation in your answers.

Use accurate scientific terminology in all answers.

You should spend approximately **25 minutes** on Section B.

You are expected to answer Section B in continuous prose.

Quality of written communication will be assessed in Section B.

Statistics Sheets are provided for use with this paper.

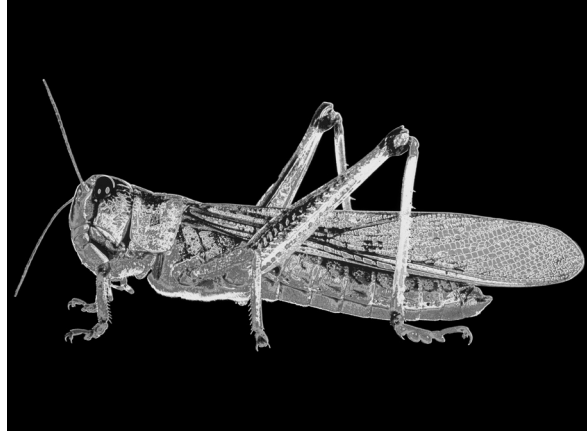
11590



36ABY2101 stemup.co.uk

Section A

- 1 The photograph below shows a locust.



© John Wells / Science Photo Library

- (a) Identify **two** features visible in the photograph that are characteristic of Phylum Arthropoda.

1. Jointed limbs (jointed legs and antennae).
2. Segmented body (fixed number of segments) with an exoskeleton. [2]



(b) Locusts are insects that show bilateral symmetry.

(i) Describe what is meant by bilateral symmetry.

The body can be divided into two identical (mirror-image) halves on either side of one central axis.

[1]

(ii) Suggest **two** advantages of bilateral symmetry.

1. *Allows a streamlined shape, for efficient movement in one direction.*

2. *Allows cephalisation: sensory receptors are grouped at the front (head), so the head tests the new environment first.*

[2]

(c) Insects are the most successful animal group in terms of the number of species.

Give **one** reason for this.

The basic body plan is easily modified, so insects evolve rapidly to occupy many niches, helped by fast reproduction.

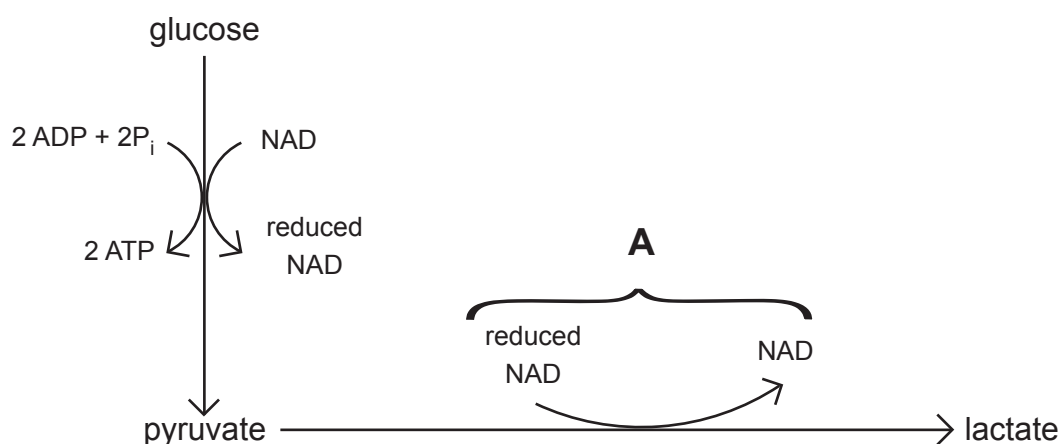
[1]

[Turn over]



2 Anaerobic respiration is not limited by the availability of oxygen.

- (a) The main stages of anaerobic respiration in mammals are summarised in the diagram below.



- (i) Name the part of the cell where anaerobic respiration takes place.

Cytoplasm

[1]

- (ii) Energy release in anaerobic respiration is a very rapid process. Using the diagram above and your knowledge, suggest an explanation for this.

Only glycolysis, a short part of the aerobic pathway, takes place, in
the cytoplasm, so no substances have to diffuse into the
mitochondrion.

[1]

- (iii) Explain the importance of A.

A regenerates NAD from reduced NAD, so NAD is available to pick
up hydrogen in glycolysis, allowing glycolysis (and ATP production) to
continue.

[1]



(b) 'Facultative anaerobes' are organisms that are able to respire glucose anaerobically, but will respire aerobically when oxygen is available.

(i) Suggest why many organisms favour aerobic over anaerobic respiration.

Aerobic respiration produces much more ATP per glucose molecule:

about 38 ATP compared with only 2 ATP in anaerobic respiration.

This is because aerobic respiration results in the complete breakdown of glucose (to CO_2 and H_2O), whereas anaerobic respiration produces toxic waste products (lactate or ethanol).

[2]

(ii) Explain fully the advantage of anaerobic respiration to a mammal.

It allows the production of extra ATP, above and beyond that

produced by aerobic respiration, when the oxygen supply is limited,

so higher rates of muscular contraction are possible for short bursts,

e.g. important for predators chasing prey or for prey escaping

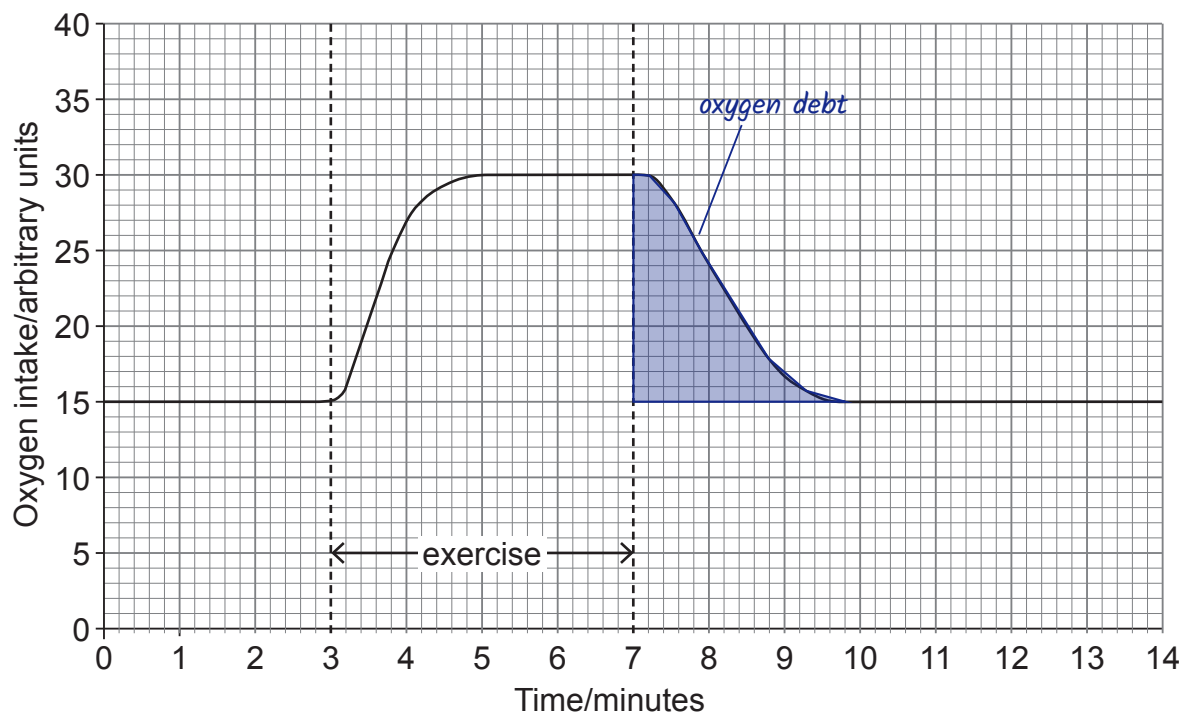
predators.

[2]

[Turn over]



- (c) The graph below shows how the intake of oxygen in an individual changes during and after exercise.



- (i) On the graph, shade the area which represents the oxygen debt. [1]

- (ii) State the function of the oxygen debt.

The extra oxygen is used to convert lactate back to pyruvate (in the liver) and to resynthesise reserves of ATP (and creatine phosphate).

[1]

- (d) Describe **two** differences between the process of anaerobic respiration in plants and animals.

1. Plants produce ethanol rather than lactate.

2. Carbon dioxide is produced in plants (not in animals), and the ethanol is not converted back to pyruvate.

[2]



- 3 Codeine is a painkilling drug. Once inside the body it is converted into its active ingredient, morphine, by the action of an enzyme. The enzyme is coded for by a single gene. The speed with which codeine is converted to morphine depends on an individual's genotype.

Individuals show one of three phenotypes:

1. 'ultra-rapid metabolisers' convert codeine rapidly to morphine
2. 'normal metabolisers' convert codeine to morphine at a rate appropriate to its use
3. 'poor metabolisers' convert codeine to morphine very slowly or not at all

Morphine can be fatal at high levels in the body.

- (a) Using the information provided, explain fully why it is recommended that ultra-rapid and poor metabolisers are **not** given codeine as a painkiller.

Ultra-rapid metabolisers convert codeine to morphine very quickly, so they produce high levels of morphine in the body, which can cause harm (e.g. breathing difficulties) or even be fatal.

Poor metabolisers convert little or no codeine to morphine, so they produce little or no morphine, so codeine is ineffective as a painkiller for them (they get no pain relief).

[4]

[Turn over]



- (b) The table below shows the percentages of each of the metaboliser types in three different ethnic groups, **A**, **B** and **C**.

Type of metaboliser	Ethnic group		
	A	B	C
Ultra-rapid	2	8	3
Normal	91	78	90
Poor	7	14	7

- (i) Summarise the information shown in the table.

In each ethnic group most people are normal metabolisers (78 to 91%).

In each ethnic group the fewest people are ultra-rapid metabolisers (2 to 8%).

Ethnic group B has fewer normal metabolisers (78%) than the other groups, and more ultra-rapid (8%) and poor metabolisers (14%) than the other groups.

The proportions of each type of metaboliser are similar in groups A and C (2, 91, 7% and 3, 90, 7%).

[4]



- (ii) In order to compile the data in the table, blood tests were carried out on individuals from each ethnic group. The individuals were given codeine and blood morphine levels were then measured.

Suggest **two** variables that would have been controlled.

1. The dosage of codeine given (e.g. per kg of body mass).

2. The time between giving the codeine and measuring the blood morphine level. [2]

- (c) Poor metabolisers may be homozygous for an allele which codes for a non-functional enzyme.

Suggest an explanation for ultra-rapid metabolism.

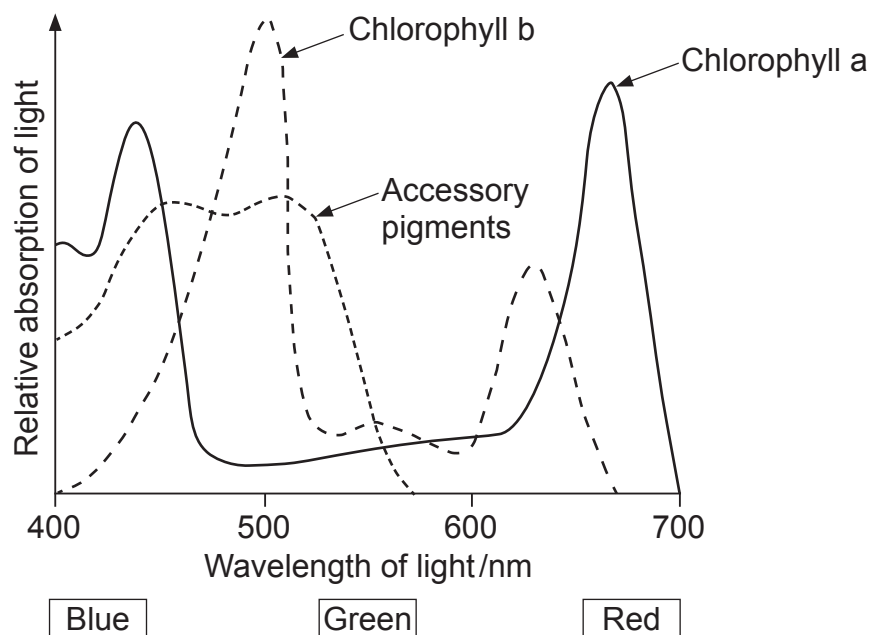
Ultra-rapid metabolisers may be homozygous for an allele producing a functional (highly active) enzyme;
since both alleles are expressed, a high level of functional enzyme is present, so codeine is converted to morphine rapidly.

[2]

[Turn over



- 4 (a) The graph below shows the absorption spectrum for the photosynthetic pigments in a typical plant.



- (i) Using the information provided, explain why plant leaves are normally green in colour.

Chlorophyll a, chlorophyll b and the accessory pigments absorb green light (500 to 600 nm) least; most blue and red light is absorbed. So the green light is reflected from the leaves, giving them their green colour.

[2]

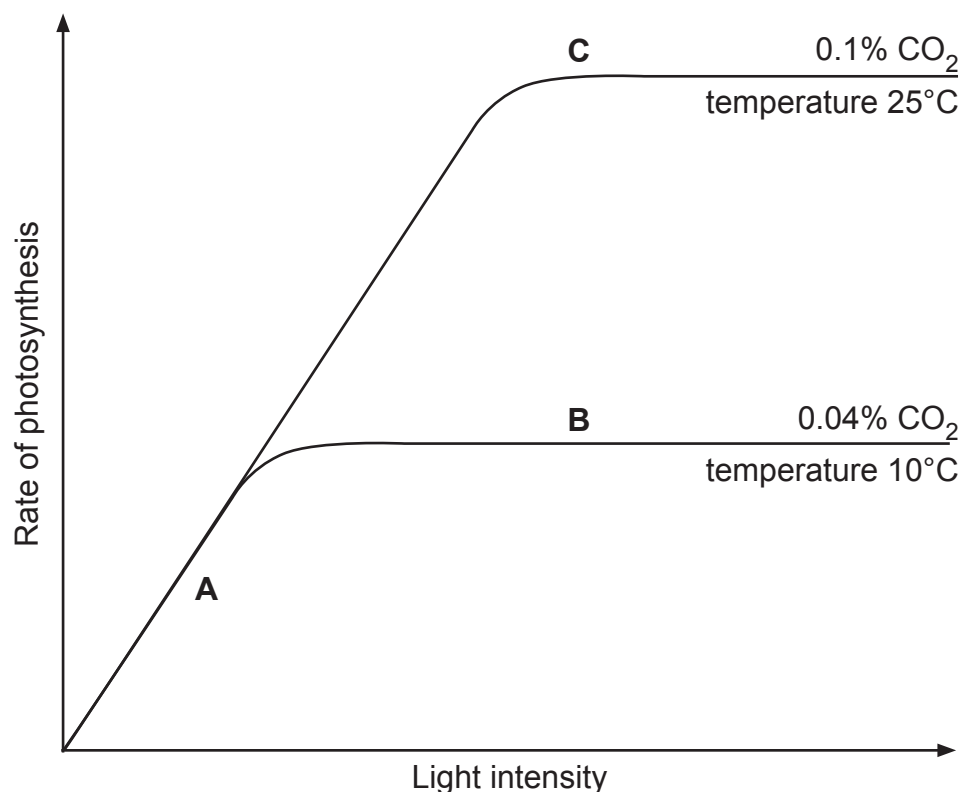
- (ii) An action spectrum may also be plotted. Describe what is meant by the term 'action spectrum'.

A graph showing how effective photosynthesis is (the rate of photosynthesis) at different wavelengths of light.

[1]



- (b) The graph below summarises the relationship between light intensity and rate of photosynthesis in different conditions of temperature and CO₂ availability.



- (i) Suggest how scientists investigating this relationship would have accurately measured the **rate** of photosynthesis.

Use a water plant (e.g. Elodea) in a photosynthometer, or an oxygen probe in a closed container, and measure the volume of oxygen produced (collected) over a set time at each light intensity in the different conditions of temperature and CO₂, keeping other variables constant.

[2]

[Turn over]



- (ii) Using your knowledge of the light-dependent reaction, explain why the rate of photosynthesis is higher at **B** than at **A**.

At B the light intensity is higher, so there is more photoactivation of chlorophyll and more electrons are emitted from the photosystems, so more ATP and more reduced NADP (NADPH) are produced for the light-independent reaction.

[2]

- (iii) Using your knowledge of the light-independent reaction, explain why the rate of photosynthesis is higher at **C** than at **B**.

At C the carbon dioxide concentration is higher (0.1% rather than 0.04%), which increases the rate of carbon fixation: the reaction of carbon dioxide with ribulose biphosphate (RuBP), to produce more glycerate phosphate (GP), which is reduced to triose phosphate.

The temperature is also higher (25 °C rather than 10 °C), which increases enzyme activity (more kinetic energy, more collisions), of rubisco and the other enzymes of the light-independent reaction (Calvin cycle), since the light-independent reaction is enzyme controlled.

[4]



- (c) Many British plant species grow fastest at a temperature of approximately 25°C. Temperatures greater than this can cause a very high rate of transpiration. The plants' response to this can result in a reduction of growth rate.

With reference to the response of plants to high transpiration rates, explain why growth is faster at 25°C than at 30°C.

At 30 °C the high transpiration rate causes water stress, so the stomata close to reduce water loss, giving less carbon dioxide uptake for photosynthesis, so less glucose (carbohydrate), and so less amino acid and protein, is produced for growth. At 25 °C the stomata stay open, so growth is faster.

[2]

[Turn over]



- 5 Bacteria are prokaryotes and their chromosomal DNA is found as a single large loop within the cell. A number of smaller rings of DNA called plasmids are also present. Genes for antibiotic resistance are often present in plasmids.

The genomes of some bacteria can be more prone to change than the genomes of eukaryotes. For example, plasmids can be exchanged between bacterial cells when they are in close contact, even if the bacteria are different species. In addition, the DNA repair process in plasmids is less effective than in chromosomal DNA, contributing to a high mutation rate.

Antibiotic resistance genes work in a variety of ways. For example, some code for membrane carriers which are able to remove antibiotics from inside bacterial cells. Globally, the number of antibiotic-resistant populations of bacteria is increasing.

A bacterial population can grow very rapidly; in optimum conditions bacteria can reproduce every 20 minutes by division, during which a fully grown cell splits into two daughter cells.

- (a) Apart from organisation of DNA, state **one** difference between prokaryotic and eukaryotic cells.

No membrane-bound organelles (e.g. no mitochondria). [1]

- (b) (i) As with plant and animal populations, bacterial populations show genetic variation which can arise from various sources. Using the information provided, describe **one** feature of bacteria which increases genetic variation and **one** feature which decreases genetic variation in populations.

Feature which **increases** genetic variation

Transfer of plasmids between bacteria (even of different species),
and high mutation rates in plasmids.

Feature which **decreases** genetic variation

Absence of sexual reproduction: bacteria reproduce by division, so
daughter cells are genetically identical. [2]



- (ii) Explain fully why the number of antibiotic-resistant populations of bacteria is increasing.

Overuse of antibiotics means antibiotic resistance is a selective advantage: resistant bacteria survive and reproduce while non-resistant bacteria are killed.

Antibiotic-resistance genes are on plasmids, so they can spread easily between bacteria (even of different species) and between populations.

There are rapid mutation rates in plasmids, which is where the antibiotic-resistance genes are located.

Bacteria reproduce rapidly (every 20 minutes), increasing the numbers of antibiotic-resistant bacteria populations.

[3]

Organisms may be classified according to characteristics including morphology, cell structure and genetic makeup.

- (iii) Suggest **two** reasons why scientists can find it difficult to classify many types of bacteria.

1. *Bacteria are microscopic, and most have a similar morphology.*

2. *They have very variable genomes, and breeding investigations are difficult to carry out.*

[2]

[Turn over]

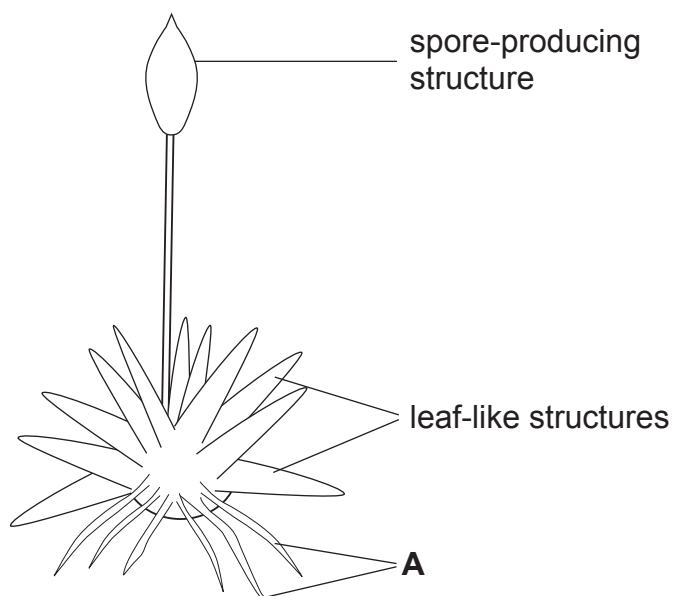


BLANK PAGE
DO NOT WRITE ON THIS PAGE

11590



- 6 (a) In terms of evolutionary development, mosses (bryophytes) are the least evolved group in the plant kingdom. The typical moss structure is represented in the diagram below.



© Chief Examiner

- (i) Identify the structures labelled **A**.

Rhizoids

[1]

- (ii) State **two** ways in which the leaf-like structures are different from true leaves.

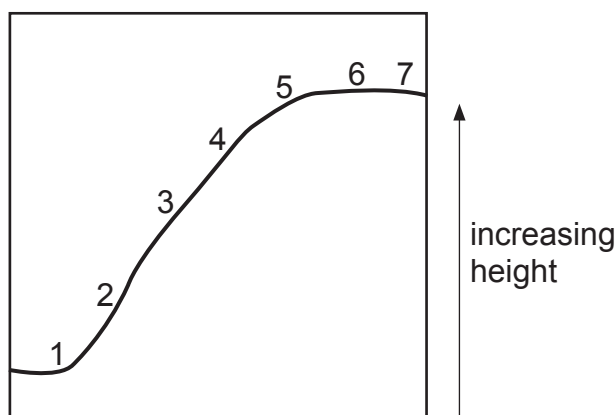
1. They do not possess a waterproof cuticle.

2. They have no stomata, and no vascular tissue.

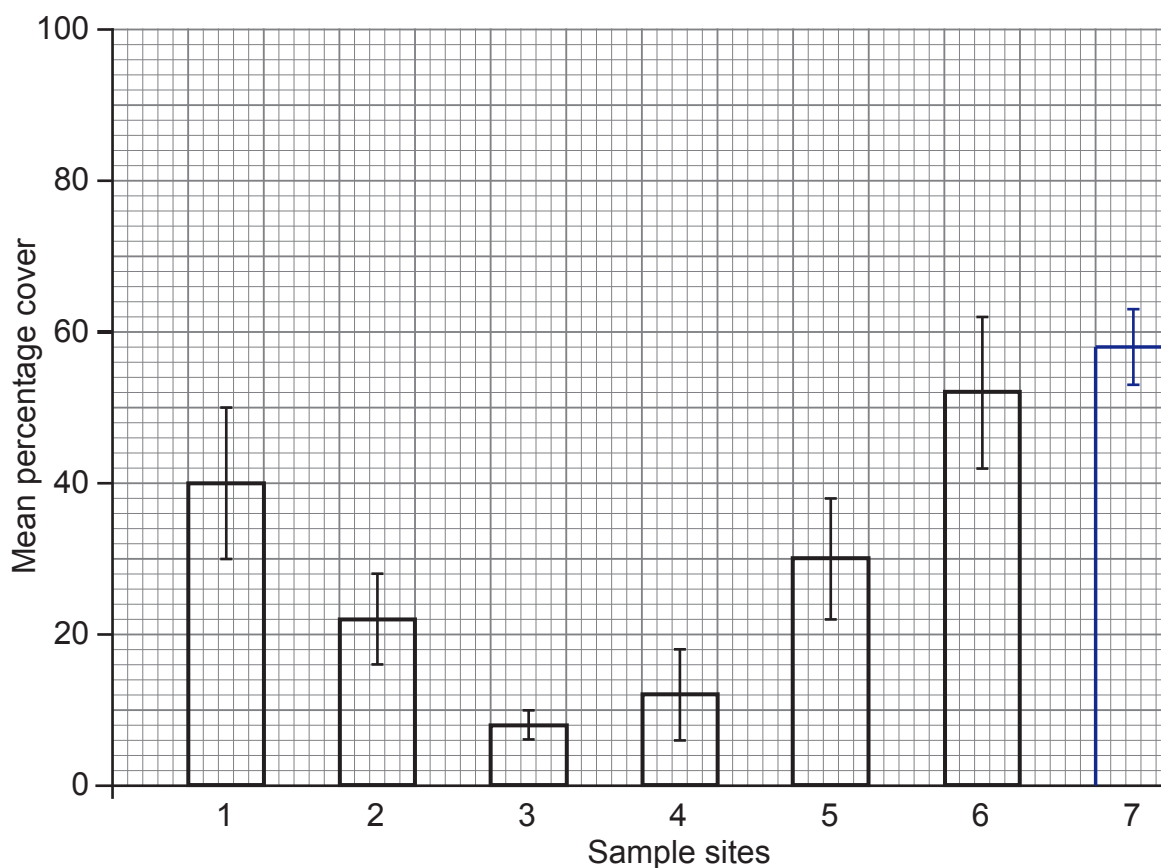
[2]



- (b) Mosses of the genus *Sphagnum* are typically found in wet habitats with high levels of rainfall and poor drainage. The mean percentage cover of *Sphagnum* was investigated at a number of sites on a mountain. The position of the sample sites is shown in the diagram below.



The mean percentage cover of *Sphagnum* for sample sites 1–6 is shown in the graph below. Associated 95% confidence limits are included.



- (i) The mean percentage cover of *Sphagnum* in site 7 was 58% and the standard deviation of the mean (standard error) ($\hat{\sigma}_{\bar{x}}$) was 2.422 (n=25).

Using the information given and the Statistics Sheets provided, calculate 95% confidence limits for site 7.

(Show your working.)

$$d.f. = n - 1 = 25 - 1 = 24$$

Tabulated t value at $p = 0.05$ and $d.f. = 24$ is 2.064

95% confidence limits = mean $\pm$ ($t \times$ standard error)

$$= 58 \pm (2.064 \times 2.422) = 58 \pm 5.0$$

upper limit 63%

lower limit 53% [3]

- (ii) Complete the graph by plotting mean percentage cover and 95% confidence limits for site 7. [1]

- (iii) Describe the trend shown by the results and suggest an explanation for the distribution of *Sphagnum* on this mountain.

Sphagnum cover is highest at the base of the mountain (site 1) and
on the flat mountain top (sites 6 and 7), and lowest on the steep
mountain side (sites 3 and 4).

Flatter areas drain poorly, so there is more standing water (*Sphagnum*
needs wet habitats); the steep sides drain quickly, so there is less
standing water. [2]

[Turn over]



Ferns (pteridophytes) are more highly adapted than mosses for terrestrial life. Ferns are common in hedgerows and woodland and are easily recognised by their finely-divided leaves and the presence of spore-producing sporangia on the lower surface of leaves. Mature plants of some fern species can grow to heights of one metre or more.

- (c) Using the information provided, explain fully **one** advantage of ferns reaching heights of one metre or more.

Spores released from sporangia on the underside of leaves held a metre or more high are more likely to be blown longer distances by the wind, giving more effective dispersal, so new areas are colonised and there is less competition between the new plants and the parent.

[2]





BLANK PAGE

DO NOT WRITE ON THIS PAGE

(Questions continue overleaf)

11590

[Turn over



- 7 (a) Mendel's second law of inheritance is known as 'the law of independent assortment'. Explain the meaning of this law with respect to dihybrid inheritance.

The segregation of the two alleles of one gene is independent of the segregation of the two alleles of the second gene during gamete formation (meiosis).

[1]

- (b) Coat colour in Doberman dogs is determined by the interaction between two genes. One gene determines the overall colour and has the alleles **B/b**. The second gene dilutes the colour and has the alleles **D/d**.

Black coat colour occurs when the dog possesses at least one **B** allele. Dark red coats are found in dogs which lack the dominant **B** allele.

These colours can be diluted by the presence of two recessive **d** alleles to produce a faded colour. The effect of this in the presence of a **B** allele is blue coat (faded black) while the double homozygous recessive genotype results in a fawn coat (faded red).

- (i) State all the genotypes that produce:

• dark red coat colour *bbDD and bbDd*

• blue coat colour *BBdd and Bbdd*

[2]



- (ii) Complete a genetic diagram to show the ratio of genotypes and phenotypes produced from the following cross:

BbDd × Bbdd

Parental phenotypes: *black* × *blue*

Parental genotypes: *BbDd* × *Bbdd*

Gametes: *BD Bd bD bd* × *Bd bd*

	<i>BD</i>	<i>Bd</i>	<i>bD</i>	<i>bd</i>
<i>Bd</i>	<i>BBDd</i>	<i>BBdd</i>	<i>BbDd</i>	<i>Bbdd</i>
<i>bd</i>	<i>BbDd</i>	<i>Bbdd</i>	<i>bbDd</i>	<i>bbdd</i>

Offspring genotypes and phenotypes:

1 BBdD *black*
2 BbDd *black*
1 BBdd *blue*
2 Bbdd *blue*
1 bbDd *dark red*
1 bbdd *fawn*

Genotype ratio:

1 BBdD : 2 BbDd : 1 BBdd : 2 Bbdd : 1 bbDd : 1 bbdd

Phenotype ratio:

3 black : 3 blue : 1 dark red : 1 fawn

[5]

[Turn over



- (c) The Xolo is a breed of dog native to Mexico. A dominant allele **H** gives rise to a hairless variety of the dog, while the recessive allele for the gene, **h**, produces a normal hairy coat.

Breeding two hairless dogs together produces both hairless and hairy offspring, in the ratio of 2 hairless : 1 hairy. This ratio can be best explained by a combination of alleles that is lethal.

Draw a genetic diagram to explain this ratio.

Parental phenotypes: hairless × hairless

Parental genotypes: Hh × Hh

Gametes: H h × H h

	H	h
H	HH	Hh
h	Hh	hh

HH = lethal (dies before birth)

Hh = hairless, hh = hairy

Surviving offspring: 2 Hh hairless : 1 hh hairy

[3]

- (d) In terms of dog populations in general, suggest **one** reason why it would not be appropriate to use the Hardy-Weinberg equation to calculate allele and genotype frequencies.

Mating is not random: breeders choose which dogs mate (artificial selection), and breeding populations may not be large.

[1]



- 8 (a) Gene technology has many applications, one of which is the manufacture of substances of medical importance such as insulin. Before the application of genetic engineering, the insulin required for the treatment of diabetes had to be extracted from pigs and cows in abattoirs.

- (i) Name the group of organisms that is used to produce insulin in genetic engineering.

Bacteria (prokaryotes)

[1]

- (ii) Suggest **one medical** advantage of making insulin for the treatment of diabetes by genetic engineering, rather than obtaining insulin from dead livestock.

Human insulin is made, which is more effective than animal insulin,
with less risk of transfer of pathogens from livestock.

[1]

- (b) Gene therapy is another application of gene technology. Cystic fibrosis is caused by the presence of two recessive alleles for a particular gene. Impaired lung function is one symptom of this condition and part of a treatment programme can involve the use of liposomes or viruses to insert functioning genes into the cells of the lung.

However, the use of gene therapy to treat cystic fibrosis has not been very successful for a number of reasons. One of these is the difficulty of getting functional genes into a high enough proportion of lung cells.

Suggest **one** reason why only a small number of lung cells gain the functional gene in gene therapy.

The functional genes in the liposomes or viruses may not reach all parts
of the lungs (e.g. blocked by mucus), or may not enter cells due to an
immune response.

[1]

[Turn over]



- (c) Gene technology has recently been trialled in a new treatment for the genetic disease sickle cell anaemia. This disease is caused by a mutation in one of the genes which codes for haemoglobin. As a result, red blood cells have a distorted shape and may block narrow capillaries.

Bone marrow transplants can be used to treat sickle cell anaemia, since red blood cells are produced from stem cells in bone marrow. However, these transplants are often unsuccessful.

- (i) Using your knowledge of the immune system, suggest why a bone marrow transplant may be unsuccessful.

The tissue types do not match, so the transplanted cells are recognised as foreign and attacked by T-killer cells (cell-mediated response).

[1]



It is hoped that the new treatment involving gene technology will prove more successful in treating sickle cell anaemia.

Scientists have been able to 'edit' the genes in the stem cells in the bone marrow of the patient. This involved removing the mutated sequence and replacing it with a functional version.

- (ii) With reference to the limitations of traditional gene therapy, explain fully the advantages of this technique.

In traditional gene therapy functional DNA has to gain entry to cells using vectors; this problem is bypassed, as there is no need for vectors.

There is no issue over expression, as the functional sequence is incorporated fully into the DNA (chromosomes).

The treatment is long term, with no need for reapplication, and the functional DNA will be in all blood cells made by the stem cells.

There is no risk of infection or allergic response from vector viruses, and no risk of rejection as the patient's own cells are used.

[4]

- (iii) Suggest **one** possible disadvantage of this technique.

It may affect the genome in unexpected ways (e.g. causing harmful mutations); the mutated allele can still be passed on to offspring.

[1]

[Turn over]



Section B

Quality of written communication will be assessed in this section.

- 9 Protein synthesis is the process by which polypeptide and protein molecules are made in the cell. This is based on the genetic code carried by DNA in the nucleus.

(a) Describe and explain the roles of DNA, RNA and ribosomes in protein synthesis. [12]

(b) In humans, almost all cells in the body contain the same 21 000 (approx.) genes but do not all produce the same proteins. Explain what is meant by 'epigenetics' and, in relation to this, explain why enzymes associated with liver function are only produced in liver cells. [6]

(a) Describe and explain the roles of DNA, RNA and ribosomes in protein synthesis.

DNA carries the genetic code for protein synthesis in its base sequence:

the sequence of bases in a gene determines the sequence of amino acids

in a polypeptide, with each base triplet coding for one amino acid.

Transcription takes place in the nucleus. DNA helicase breaks the

hydrogen bonds between complementary bases, separating the two DNA

strands of the gene, and one strand acts as the template.

Free RNA nucleotides line up by complementary base pairing with the

exposed bases of the template strand (with uracil pairing with adenine),

so the bases in the messenger RNA (mRNA) are complementary to the

DNA strand being read. RNA polymerase catalyses the joining of the

RNA nucleotides by phosphodiester bonds, forming pre-mRNA.

Introns (non-coding sequences) are then removed from the pre-mRNA by

splicing and the exons are joined together, forming mature mRNA.



The mRNA moves out of the nucleus to the ribosomes in the cytoplasm via the nuclear pores.

Ribosomes consist of ribosomal RNA (rRNA) and protein, in a large and a small subunit. Translation begins when both subunits link together at the first three bases at one end of the mRNA (the start codon), forming a functioning ribosome.

Each set of three bases (base triplet) on the mRNA is known as a codon, and each codon codes for a specific amino acid.

Transfer RNA (tRNA) molecules have three exposed bases, the anticodon, which is complementary to a codon. Each tRNA carries a specific amino acid (attached using ATP) and brings it to the correct position on the mRNA, due to the complementary base pairing between codon and anticodon.

This occurs at the aminoacyl (A) site of the ribosome. A second site, the peptidyl (P) site, holds the tRNA carrying the growing chain, and here adjacent amino acids are linked together by a condensation reaction, forming a peptide bond.

The ribosome then moves along the mRNA by three bases (one codon), the empty tRNA is released to collect another amino acid, and the process repeats, so the polypeptide grows until a stop codon is reached.

The polypeptide is then released and folds to form the protein. Several ribosomes (a polysome) can translate the same mRNA at the same time,

[Turn over



so many copies of the protein are made quickly.



- Epigenetics refers to changes (variation) in gene expression, that is, whether genes are switched on or off, which do not involve changes in the DNA base sequence.

It can occur by methylation of DNA and by histone modification (e.g. acetylation). Methylation is the addition of a methyl group (CH_3) to cytosine in CG sequences, usually in the promoter region of a gene. This prevents transcription factors and RNA polymerase binding, so the gene is

11590



not transcribed and is switched off (silenced). Histone modification alters how tightly the DNA is wound around the histones, which affects whether genes can be transcribed.

Almost all cells contain the genes coding for the liver enzymes. In liver tissue the genes coding for these enzymes are unmethylated and so switched on: they are transcribed and translated, and the enzymes are produced.

In other tissues these genes are switched off by methylation, as this is a long-term (stable) way of silencing genes.

The methylation pattern is passed on from cell to cell by mitosis, so all the daughter cells of a liver cell continue to produce liver enzymes, while other cell types never produce them.





THIS IS THE END OF THE QUESTION PAPER

BLANK PAGE

DO NOT WRITE ON THIS PAGE

11590



BLANK PAGE
DO NOT WRITE ON THIS PAGE

11590





BLANK PAGE

DO NOT WRITE ON THIS PAGE

11590



DO NOT WRITE ON THIS PAGE

For Examiner's use only	
Question Number	Marks
1	
2	
3	
4	
5	
6	
7	
8	
9	

Total Marks	
-------------	--

Examiner Number

Permission to reproduce all copyright material has been applied for.
In some cases, efforts to contact copyright holders may have been unsuccessful and CCEA
will be happy to rectify any omissions of acknowledgement in future if notified.

