

Please check the examination details below before entering your candidate information

Candidate surname <i>StemUp Model Solution</i>		Other names
Centre Number	Candidate Number	

Pearson Edexcel Level 3 GCE

Wednesday 7 June 2023

Afternoon (Time: 2 hours)

Paper reference **9BN0/01**

Biology A (Salters Nuffield)

Advanced

PAPER 1: The Natural Environment and Species Survival

You must have:
Scientific calculator, HB pencil, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- **Show all your working out** in calculations and **include units** where appropriate.
- Answer the questions in the spaces provided
– *there may be more space than you need.*

Information

- The total mark for this paper is 100.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*
- You may use a scientific calculator.
- In questions marked with an **asterisk (*)**, marks will be awarded for your ability to structure your answer logically showing how the points that you make are related or follow on from each other where appropriate.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ►

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Answer ALL questions.

Some questions must be answered with a cross ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

- 1 *Homo sapiens* is the only living species of the genus *Homo*. Over 100 000 years ago, *Homo neanderthalensis*, a species closely related to modern humans, lived with other *Homo* species in the same habitat.

(a) Which of the following is the correct definition of the term habitat?

(1)

- ☐ A a group of organisms of different species living in the same area
- ☐ B a group of organisms of the same species living in the same area
- ☒ C a place where an organism lives
- ☐ D the role of an organism

(b) A fossil bone discovered in China is thought to be from a new species, *Homo longi*.

- (i) Samples of DNA from this bone and bones from other *Homo* species can be amplified using PCR.

Describe how these amplified samples of DNA can be prepared for analysis using gel electrophoresis.

(3)

The DNA is cut into fragments using restriction enzymes.

Fluorescent tags or radioactive tracers are attached to the DNA fragments (or a dye such as ethidium bromide is used to stain them).

The DNA fragments are loaded into wells in an agarose gel covered in buffer.

An electric current is passed through the gel, so the negatively charged DNA fragments move towards the positive electrode.



- (ii) Explain how the results of this analysis would show whether *Homo longi* is closely related to other *Homo* species.

(2)

Compare the size, thickness and position of the bands produced by Homo longi with the bands from the other Homo species.

If Homo longi is closely related to another species there will be more similarities in the pattern of bands, as their DNA base sequences are more similar.

(Total for Question 1 = 6 marks)

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2 Human activities are affecting many habitats.

These activities can change the biodiversity of communities and populations within a habitat.

(a) Which of the following describes biodiversity within a habitat?

(1)

- ☐ **A** the number of different alleles and the number of the same species
- ☒ **B** the number of different species and the number of different alleles
- ☐ **C** the number of different species and the number of the same alleles
- ☐ **D** the number of the same alleles and the number of the same species

(b) Brown Moss is a site of special scientific interest. It is an area containing shallow ponds, inhabited by birds and rare plants.

The biodiversity of plants growing in two ponds, A and B, at Brown Moss was studied. The table includes data collected from the two ponds.

Species	Number (n) in pond A	$n(n-1)$ for pond A	Number (n) in pond B	$n(n-1)$ for pond B
<i>Azolla filiculoides</i>	5	20	0	0
<i>Lemna minuta</i>	29	812	0	0
<i>Lemna trisulca</i>	50	2450	0	0
<i>Alisma plantago-aquatica</i>	2	2	0	0
<i>Alopecurus aequalis</i>	11	110	0	0
<i>Carex pseudocyperus</i>	2	2	0	0
<i>Equisetum fluviatile</i>	0	0	71	4970
<i>Juncus effusus</i>	0	0	60	3540
<i>Menyanthes trifoliata</i>	16	240	0	0
<i>Polygonum amphibium</i>	0	0	25	600
<i>Ranunculus circinatus</i>	13	156	0	0
<i>Sparganium erectum</i>	3	6	0	0
<i>Typha latifolia</i>	5	20	0	0
Total	136	3818	156	9110

(i) Complete the table for pond A giving the value for $n(n-1)$ for *Ranunculus circinatus* and give the totals.

(1)



(ii) Calculate the index of diversity for pond B using the formula

$$D = \frac{N(N-1)}{\sum n(n-1)}$$

(2)

$$D = (156 \times 155) \div 9110$$
$$= 24\,180 \div 9110 = 2.654$$

Answer 2.65

(iii) Pond B is close to a farm and some houses.

Chemicals and waste from the farm and houses have increased the levels of pollutants in pond B.

The biodiversity index for pond A is 4.81.

Comment on the effect of pollutants on the biodiversity of pond B.

(3)

Pond B has a much lower index of diversity (2.65) than pond A (4.81), so the pollutants have reduced biodiversity. Only 3 species are present in pond B compared with 10 in pond A, so species richness is lower.

This is because most species cannot survive in the polluted conditions, as the pollutants are toxic and kill them.

Only species with adaptations to the polluted conditions can survive in pond B.

There is a lack of competition in pond B, so the few species present have very large numbers.

(Total for Question 2 = 7 marks)



P 7 1 9 0 6 A 0 5 3 2

3 The genetic information for a cell is stored in the DNA.

(a) Describe the structure of a DNA mononucleotide.

(2)

A DNA mononucleotide is made of a deoxyribose (pentose) sugar, a phosphate group and a nitrogenous base.

The base is one of adenine, guanine, cytosine or thymine, and it is joined to the deoxyribose sugar, as is the phosphate.

(b) Molecules of DNA are copied by semi-conservative replication.

(i) Which of the following is the result of semi-conservative replication?

(1)

- ☐ **A** both DNA molecules are a mixture of original DNA and RNA
- ☒ **B** both daughter DNA molecules contain one original DNA strand and one new DNA strand
- ☐ **C** one daughter DNA molecule has two original parent strands, the other daughter DNA molecule has two new strands
- ☐ **D** each strand of both daughter DNA molecules is a mixture of original and new DNA



(ii) Describe how DNA is replicated.

(4)

DNA helicase breaks the hydrogen bonds between the bases on the two strands, so the double helix unwinds and unzips.

Each original strand acts as a template. Free DNA nucleotides line up along each DNA strand.

They line up by complementary base pairing: A pairs with T and C pairs with G.

DNA polymerase joins adjacent nucleotides together by forming phosphodiester bonds, so each new molecule has one original and one new strand.

(Total for Question 3 = 7 marks)

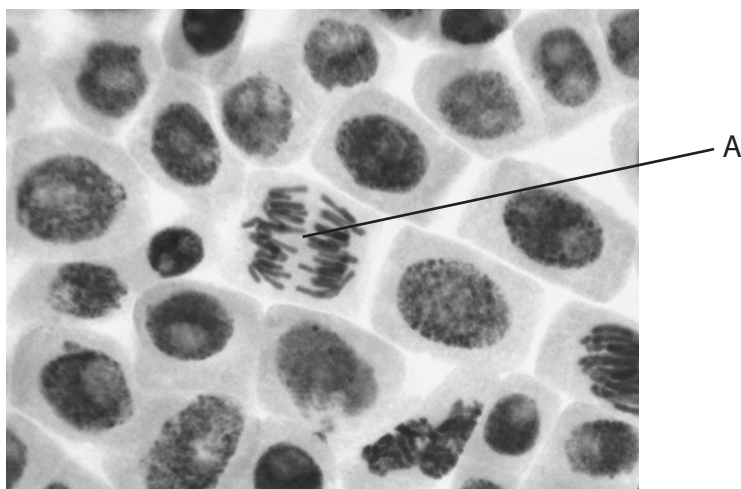
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- 4 Cell division can be observed using a microscope. The photograph shows cells from a root tip dividing.



(Source: © Dimarion/Shutterstock)

- (a) (i) Which of the following is the stage of mitosis shown in the cell labelled A?

(1)

- ☒ **A** anaphase
☐ **B** cytokinesis
☐ **C** metaphase
☐ **D** telophase

- (ii) Describe how other plant tissues can be prepared to find out if the cells are undergoing mitosis.

(3)

Cut a thin piece of tissue (e.g. a shoot tip) and treat it with hydrochloric acid.

Heat the tissue in the acid in a water bath (e.g. 60 °C) to break down the material holding the cells together.

Stain the tissue with toluidine blue or acetic orcein to show the chromosomes.

Macerate the tissue and squash it under a coverslip so the cells are spread into a single layer, then observe under the microscope.

(b) Describe what happens inside a cell during prophase of mitosis.

(4)

*The chromosomes condense, coiling up so they become shorter and thicker and visible;
each is seen as two sister chromatids joined at the centromere.*

The centrioles move to opposite poles of the cell.

The spindle forms as spindle fibres develop from the centrioles.

The nucleolus breaks down and the nuclear envelope breaks down.

(Total for Question 4 = 8 marks)



- 5 Many plants are known to have medicinal properties and are used in traditional medicines. These plants are often endangered.

A drug to treat breast cancer has been extracted from *Taxus brevifolia*, the Pacific yew tree.

(a) Seeds from endangered plants are placed in seed banks to conserve the species.

(i) Describe how the seeds are preserved for long periods of time in a seed bank.

(3)

The seeds are cleaned and their surfaces are sterilised to remove fungi and bacteria.

The seeds are dried to a low water content and stored in dry, airtight conditions.

They are stored at a cold temperature of about -20°C (frozen), which slows metabolism so the seeds stay viable for many years.

(ii) Seed banks obtain seeds collected from a number of plants of each species.

Explain the advantages of this for the conservation of a plant species.

(2)

Seeds from many different plants ensure genetic diversity, with a large gene pool and many different alleles.

If the plants are reintroduced, conditions may have changed (e.g. a new disease), so there is a greater chance some can survive and adapt, reducing the risk of extinction.



- (b) The active ingredients in medicinal plants are identified and purified to make new drugs.

These drugs are tested extensively before use.

- (i) Which of the following methods are used before the three-phased testing of clinical trials?

(1)

- ☐ A testing on animals and humans
- ☒ B testing on animals, isolated cells and tissues
- ☐ C computer modelling and testing on humans
- ☐ D computer modelling and testing isolated cells with a placebo

- (ii) Describe the stages of a three-phased clinical trial.

(3)

Phase 1: the drug is tested on a small group of healthy volunteers to check for side effects and how it is metabolised in humans.

Phase 2: the drug is tested on small groups of patients with the condition to see if the drug is effective and to find the dose.

Phase 3: double-blind testing on a large group of patients; half are given the drug and half a placebo or existing drug.

(c) The gut has barriers to prevent pathogens entering the body.

Explain the role of conditions in the gut in preventing infection by microorganisms.

(2)

Acidic conditions in the stomach (hydrochloric acid, low pH) denature the enzymes of microorganisms, killing them.

Gut flora compete with other microorganisms for food and space, inhibiting the growth and reproduction of pathogens.

(Total for Question 5 = 11 marks)



6 Shrews, moles and hedgehogs are members of the same taxonomic group of mammals that eat insects.

(a) Members of this group of mammals occupy a variety of niches.

Which of the following describes a niche?

(1)

- ☐ A the environment of an organism
- ☐ B the habitat of an organism
- ☐ C the population of an organism
- ☒ D the role of an organism in its environment

(b) Shrews are very small mammals that maintain a body temperature of 40°C.

They require a good supply of oxygen as they lose heat rapidly.

(i) Explain how the structure of their lungs enables shrews to get oxygen into the body rapidly.

(4)

Shrew lungs contain many alveoli, which provide a large surface area for gas exchange by diffusion.

The alveoli have thin walls, one cell thick (squamous epithelium), giving a short diffusion distance.

Each alveolus is surrounded by a dense network of capillaries, which increases the surface area for diffusion.

Blood flow through the capillaries carries oxygen away, maintaining a steep concentration gradient so oxygen diffuses in rapidly.

- (ii) Some species of shrew have evolved to feed on insects found in cold water streams. They are semi-aquatic, spending part of their lives diving in water and part of the time living on land.

These shrews have large concentrations of the protein myoglobin in their muscles.

Myoglobin stores oxygen, which can be released for aerobic respiration during a dive.

The myoglobin in these shrews has a different, tertiary structure than in other species of shrew. This allows larger quantities of myoglobin to be stored in their muscles.

Describe how these species of semi-aquatic shrew may have evolved.

(4)

A gene mutation occurred, so some shrews had myoglobin with a different tertiary structure, allowing more myoglobin to be stored.

There was a selection pressure, such as competition for food on land, so feeding on insects in water was an advantage.

Shrews with the mutation could store more oxygen, so they could dive for longer and feed in water.

They were more likely to survive and reproduce, passing the advantageous allele on to their offspring.

Over many generations the frequency of the advantageous allele increased in the population.



- (iii) Explain why a change in the base sequence of the gene coding for myoglobin could change its tertiary structure.

(3)

A change in the base sequence of the DNA changes the triplet code, so the codons in the mRNA are changed.

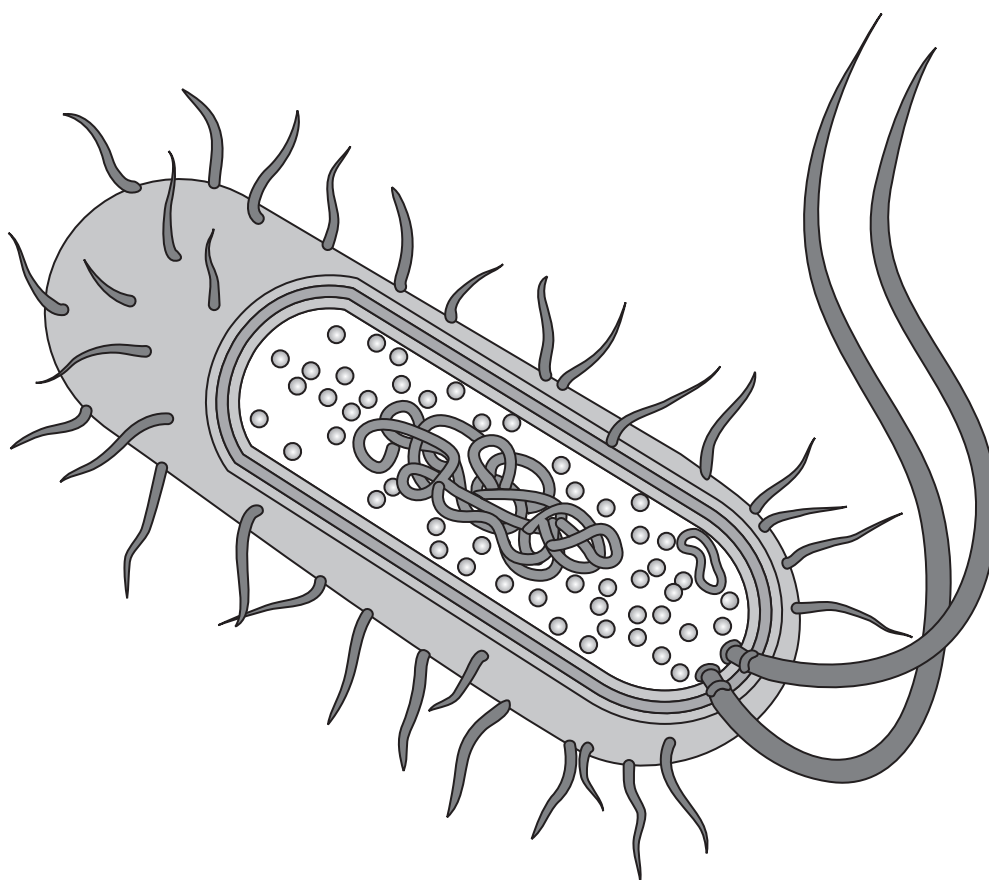
Therefore there will be a change in the sequence of amino acids (the primary structure) of the myoglobin, with different R groups.

This changes the bonding between R groups (hydrogen bonds, ionic bonds and disulfide bridges), so the polypeptide folds differently, changing the tertiary structure.

(Total for Question 6 = 12 marks)



- 7 The diagram shows the structure of a bacterium. Some bacteria are pathogenic to humans and can cause inflammation and fever.



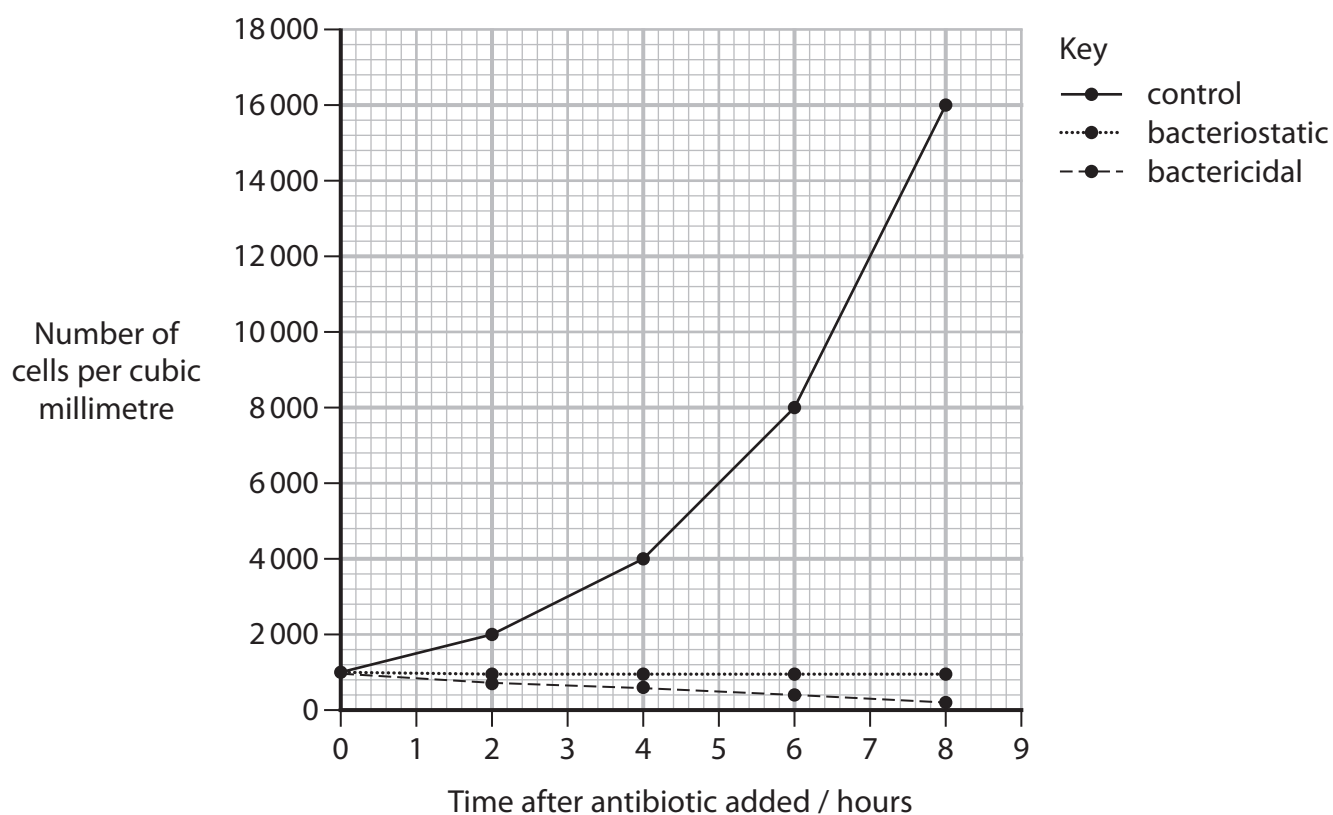
(a) Which of the following are found **only** in bacterial cells?

(1)

- ☐ A cellulose cell wall, plasmid, 70S ribosome
- ☐ B flagellum, plasma membrane, mitochondria
- ☐ C plasma membrane, cellulose cell wall, plasmid
- ☒ D plasmid, 70S ribosome, circular DNA

- (b) Some bacteria are pathogenic. Bacteriostatic and bactericidal antibiotics are drugs used to treat diseases caused by bacteria.

The graph shows the effects of two types of antibiotic on the growth of bacteria. The control line shows the growth of bacteria with no antibiotic present.



- (i) State what is meant by the term **bactericidal** antibiotic.

(1)

A bactericidal antibiotic is a substance that kills bacteria.

- (ii) Calculate the mean rate of increase in the number of bacteria in the control from 6 to 8 hours.

Give your answer in **standard form**.

(2)

$$\text{Increase from 6 to 8 hours} = 16\,000 - 8000 = 8000 \text{ cells mm}^{-3}$$

$$\text{Rate} = 8000 \div 2 = 4000 \text{ cells mm}^{-3} \text{ per hour}$$

Answer $4.0 \times 10^3 \text{ hour}^{-1}$

- (iii) Symptoms of bacterial infection include fever and inflammation.

Explain the role of the inflammatory response in protecting the body from bacterial infection.

(4)

Damaged cells and mast cells release histamine at the site of infection.

Histamine causes vasodilation (dilation of the arterioles), which increases blood flow to the infected area, causing redness and heat.

Histamine also makes the capillaries more permeable, so fluid, plasma proteins and white blood cells leave the blood.

Therefore more white blood cells (phagocytes such as neutrophils and macrophages) reach the infected area and engulf and destroy the bacteria by phagocytosis.



*(c) Antibiotics can be used to prevent death from bacterial infections.

They act in a number of ways, but all affect a target site in the bacteria.

Many bacteria are developing resistance to antibiotics.

Antibiotic resistance is likely to cause 300 million premature deaths by 2050.

The table gives examples of some antibiotics and the development of resistance.

Mechanism of resistance	Example of antibiotic	How bacteria develop resistance to antibiotic	Example of resistant bacteria
Destruction of the antibiotic	penicillin	Produces enzymes that destroy the drug	<i>Staphylococcus</i>
Decrease in antibiotic uptake	vancomycin	Changes in the permeability of the cell membrane prevent the drug entering the bacterial cell	<i>Pseudomonas</i>
Activation of a transport mechanism	tetracycline	Pumps develop in the cell membrane to remove toxic substances from the cell	<i>Escherichia coli</i>
Modification of target site	linezolid	Mutations in the bacterial DNA causes a change in the target site so the antibiotic can no longer bind to it	<i>Escherichia coli</i>



Discuss the mechanisms bacteria have developed to become resistant to antibiotics and the codes of practice used to overcome this resistance.

(6)

The use of antibiotics acts as a selection pressure. Antibiotics kill or stop the growth of all non-resistant bacteria, so only bacteria that have a mechanism of resistance survive and reproduce, passing on the resistance allele. Over time the resistant bacteria become more common, so antibiotic resistance evolves by natural selection.

Resistance arises from mutations. Bacteria have a single circular DNA molecule, so any mutation is expressed. Resistance genes can also spread quickly between bacteria by conjugation, when plasmids are exchanged.

Several mechanisms are shown in the table. Staphylococcus produces enzymes that destroy penicillin. Pseudomonas has a cell membrane with changed permeability, so less vancomycin enters the cell. E. coli develops pumps in the cell membrane that remove tetracycline from the cell. A mutation in E. coli DNA changes the target site, so linezolid can no longer bind to it. Each antibiotic has a specific target, so each mechanism is specific to that antibiotic.

Hospitals use codes of practice to reduce resistance. Doctors avoid prescribing antibiotics unnecessarily (e.g. not for viral infections) and patients must complete the full course, so no resistant bacteria are left to multiply. Staff wash hands and use alcohol gels between patients to stop the spread of resistant bacteria. Patients are screened on admission and infected patients are isolated, so resistant strains cannot pass to others.

(Total for Question 7 = 14 marks)



- 8 The species of seagrass, *Posidonia oceanica*, is endemic to the Mediterranean Sea.

The photograph shows part of an underwater seagrass meadow.



(Source: © Alberto Romeo)

- (a) Which of the following describes an endemic species?

(1)

- ☐ A found in many geographical areas
- ☒ B found in only one geographical area
- ☐ C a hybrid between two species
- ☐ D threatened with extinction

- (b) Seagrass is a very slow growing species that lives for a long time.

Seagrass absorbs large amounts of carbon dioxide. It stores 15 times more carbon dioxide per year than a similar area of rainforest.

Rainforests store approximately 5 tonnes of carbon per hectare per year.

In the sea near Spain, seagrass covers an area of 1.2 million hectares

Which of the following describes the mass of carbon stored by this area of seagrass each year?

(1)

- ☐ A 7.5×10^6 tonnes year⁻¹
- ☐ B 75 tonnes per year
- ☐ C 9.0×10^6 tonnes year⁻¹
- ☒ D 9.0×10^7 tonnes year⁻¹

- (c) Seagrass cannot survive if the water becomes warmer or more acidic.

Seagrass in the Mediterranean Sea has declined by 34% in the last 50 years.

- (i) Explain why the increase in greenhouse gases is leading to a decrease in the growth of seagrass.

(3)

More carbon dioxide dissolves in the sea water, forming carbonic acid, so the acidity of the water increases (pH falls).

Greenhouse gases increase global warming, so the water temperature increases.

The change in temperature and pH means they are no longer optimum, so the enzymes of the seagrass are denatured and less seagrass survives and grows.

- (ii) Discuss the possible effects of a reduction in seagrass on animals living in the Mediterranean Sea.

(4)

Less seagrass means less photosynthesis, so there is less food for primary consumers (herbivores) and less oxygen released into the water.

Less oxygen is available for respiration by aquatic animals.

This has an impact on food chains and food webs, as less energy is transferred to secondary consumers, and there is more competition for food and more predation, as there is less shelter.

Therefore the number of aquatic animals would decrease and biodiversity would fall.



- (iii) Seagrass is long-living and more resistant to breakdown by microorganisms than plants living in the rainforest.

Explain why maintaining a healthy population of seagrass reduces the release of carbon dioxide into the atmosphere.

(3)

Seagrass takes up carbon dioxide from the water by photosynthesis, fixing it in the Calvin cycle (light-independent reactions) into organic compounds.

As seagrass lives a long time and is resistant to breakdown, there is less decomposition by microorganisms, so less carbon dioxide is released by their respiration.

Therefore the carbon remains locked in the plant, so seagrass acts as a carbon sink and sequesters carbon.

(Total for Question 8 = 12 marks)

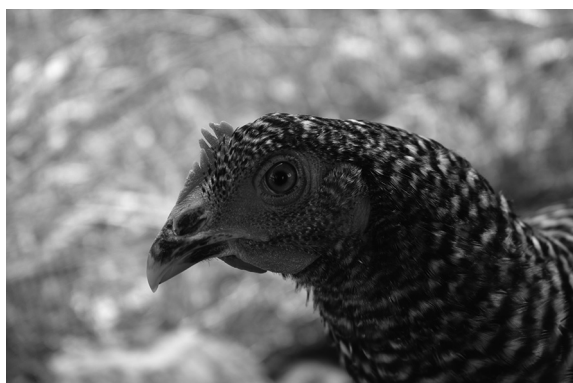


- 9 It is difficult to tell the sex of young chickens. This can be overcome by breeding programmes that allow the sex of the chicken to determine the visible features.

In birds the sex chromosomes are Z and W. Males are ZZ and females are ZW.

Head colour in chickens is a sex-linked characteristic carried only on the Z chromosome.

The dominant allele gives bar-headed chickens and the recessive allele gives black-headed chickens.



(Source: © Dimarion/Shutterstock)

Bar-headed chicken



(Source: © Muskoka Stock Photos/Shutterstock)

Black-headed chicken

- (a) (i) Which of the following is the genotype of a black-headed female chicken?

(1)

- ☐ A $Z^B Z^b$
☐ B $Z^b Z^b$
☒ C $Z^b W$
☐ D $Z^B W^b$

- (ii) A bar-headed female chicken was crossed with a black-headed male chicken.

Draw a genetic diagram to show the genotypes and phenotypes of the offspring produced by this cross.

(3)

Parental phenotypes: *bar-headed female* × *black-headed male*

Parental genotypes: $Z^B W$ × $Z^b Z^b$

Gametes: Z^B and W Z^b and Z^b

gametes	Z^B	W
Z^b	$Z^B Z^b$	$Z^b W$
Z^b	$Z^B Z^b$	$Z^b W$

Offspring:

$Z^B Z^b$ = bar-headed males

$Z^b W$ = black-headed females

Ratio 1 : 1

- (iii) Male chickens produced by this cross were crossed with a bar-headed female chicken.

Deduce why this cross will produce both bar-headed and black-headed females.

(3)

The males from the first cross are all heterozygous, $Z^B Z^b$, so they produce gametes carrying either the B (bar-headed) allele or the b (black-headed) allele.

Females receive their Z chromosome from the male, so a female will inherit either the B or the b allele from him ($Z^B W$ or $Z^b W$).

Females only have one allele for head colour, as W carries no allele, so $Z^B W$ females are bar-headed and $Z^b W$ females are black-headed.

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(b) Gene expression leads to the synthesis of proteins that give rise to the phenotype.

Describe how one gene can give rise to more than one protein.

(3)

The gene is transcribed into pre-mRNA, which contains introns and exons. The introns are removed.

The exons can then be joined together in several different ways, or some exons can be removed (alternative splicing).

This produces different mRNA molecules from the same gene.

Translation of the different mRNA gives different amino acid sequences, so different polypeptides and proteins are made.

(Total for Question 9 = 10 marks)

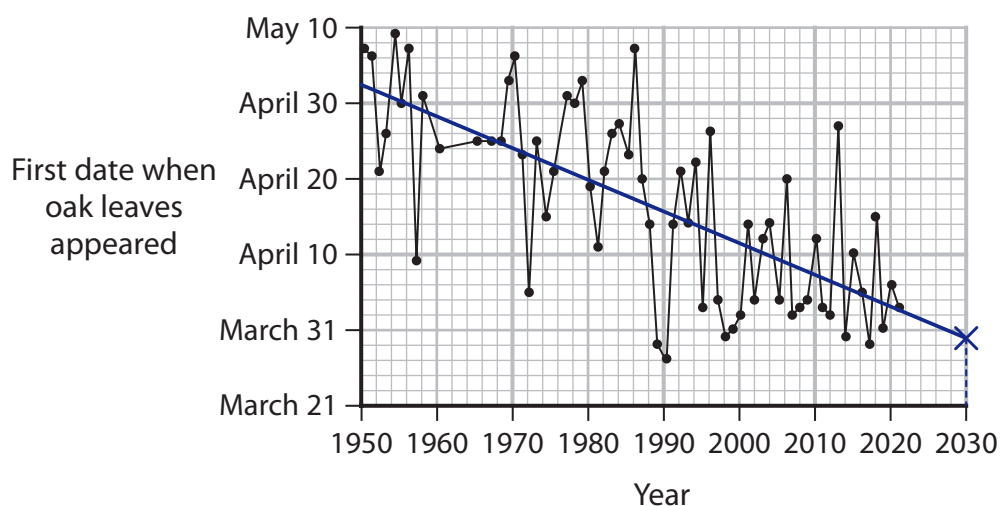


- 10 The average spring temperature in the UK has increased by 0.5°C from 1995 to 2014. This is due to climate change.

This has affected plants and the insects that feed on them.

- (a) Many butterfly species depend on oak trees.
The larvae feed on the young leaves in spring.

The graph shows the date when oak leaves first appeared on one tree between the years 1950 and 2021.



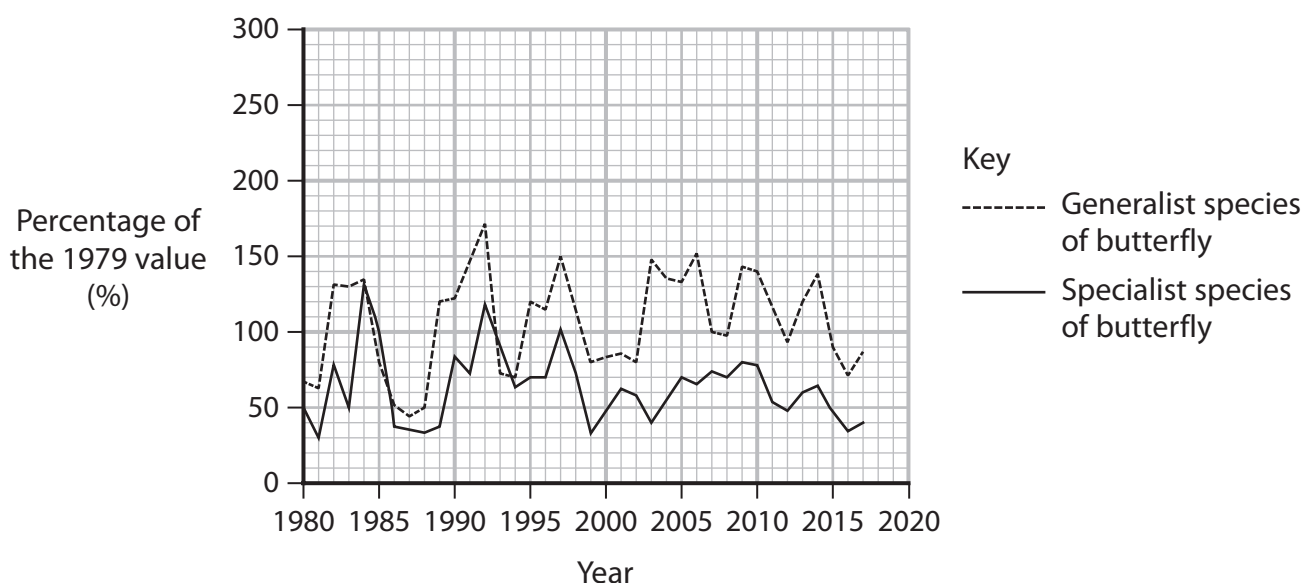
Draw a trend line to predict when oak leaves will first appear in the year 2030.

(2)

Date 30 March

- (b) Specialist butterfly species feed on only one plant species. Generalist butterfly species feed on a range of plant species.

The graph shows the changes in the population sizes of the two types of butterfly from 1980 to 2017.



Explain why specialist butterfly species may find it more difficult to adapt to the changes in spring temperatures.

(3)

Specialist species feed on only one type of plant, so if that plant is affected they have nothing else to feed on.

Due to climate change the food plant may not be available at the right time, e.g. the young leaves appear earlier, before the larvae hatch.

Other species may be competing with the specialist species for the same food plant.

Generalist species are more likely to find alternative food plants, so they can survive.

- (c) The effect of the rise in spring temperature on the life cycle of butterflies was studied.

These insects have a typical life cycle of four stages:

egg, larva, pupa and adult.

The photograph shows a butterfly larva (caterpillar) feeding on a leaf.



(Source: © dossyl/Shutterstock)

- (i) Explain why an increase in environmental temperature may lead to a shorter life cycle.

(2)

The life cycle depends on metabolic reactions (e.g. respiration and protein synthesis) controlled by enzymes.

A higher temperature increases the kinetic energy of enzymes and substrates, so there are more frequent collisions and a faster rate of formation of enzyme-substrate complexes, so development is faster.

- *(ii) Devise a laboratory investigation to study the effect of temperature on the duration of the larval stage in a specialist butterfly species.

(6)

Independent variable: temperature. Set up incubators or water baths at five or more temperatures, e.g. 10, 15, 20, 25 and 30 °C, and check each with a thermometer.

Dependent variable: the duration of the larval stage, measured as the time from the egg hatching to the larva pupating.

Control variables: use the same specialist species, with eggs of the same age from the same source. Give each larva the same food plant (its only food), with the same mass of fresh leaves replaced regularly. Keep humidity and light intensity the same, e.g. in a controlled-environment cabinet.

Place several eggs (e.g. 10) in separate containers at each temperature as repeats.

Monitor the larvae at regular intervals, e.g. every 12 hours, and record the time since hatching when each one pupates.

Calculate the mean duration of the larval stage at each temperature and the standard deviation. Plot a graph of mean duration against temperature and use Spearman's rank correlation to test whether there is a significant correlation between temperature and the duration of the larval stage.

(Total for Question 10 = 13 marks)

TOTAL FOR PAPER = 100 MARKS



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