

STUDENT NUMBER Letter

BIOLOGY

Written examination

Tuesday 23 May 2023

Reading time: 10.30 am to 10.45 am (15 minutes)

Writing time: 10.45 am to 1.15 pm (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

<i>Section</i>	<i>Number of questions</i>	<i>Number of questions to be answered</i>	<i>Number of marks</i>
A	40	40	40
B	11	11	80
			Total 120

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners and rulers.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.
- No calculator is allowed in this examination.

Materials supplied

- Question and answer book of 38 pages
- Answer sheet for multiple-choice questions
- Additional space is available at the end of the book if you need extra space to complete an answer.

Instructions

- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

At the end of the examination

- Place the answer sheet for multiple-choice questions inside the front cover of this book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

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SECTION A – Multiple-choice questions**Instructions for Section A**

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1

Prokaryotes regulate gene expression using the *trp* operon.

In the *trp* operon repression model, when the level of tryptophan is high in the cell

- A. the genes *trpE*, *trpD*, *trpC*, *trpB* and *trpA* are translated.
- B. RNA polymerase is blocked from transcribing the *trp* operon.
- C. the enzymes involved in tryptophan production are expressed.
- D. the repressor protein is bound to the *trp* operator, causing the operon to be expressed.

Question 2

Transformed bacterial cells can be used to produce large quantities of human insulin.

In the process of producing human insulin, scientists

- A. extract insulin from a human.
- B. insert the human insulin gene into the bacterial chromosome.
- C. use DNA ligase to isolate the insulin gene from human DNA.
- D. enable a transgenic bacterium to reproduce millions of identical transgenic bacterial cells.

Question 3

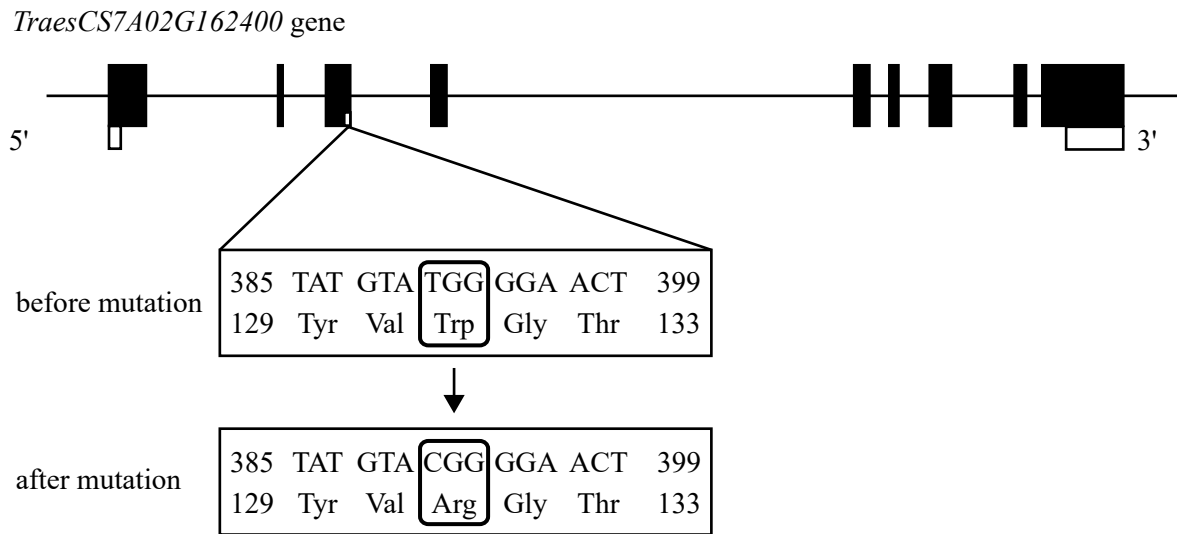
An experimental drug for the treatment of diabetes is given to a large group of people to confirm its effectiveness, monitor for side effects and collect information that will allow the drug to be used safely.

Which of the following is likely to improve the validity of this research?

- A. selecting trial subjects of diverse ages, genders and backgrounds
- B. having a single person measure all results
- C. removing a placebo or control group
- D. controlling fewer variables

The following information relates to Questions 4 and 5.

TraesCS7A02G162400 is a gene found in wheat plants. Below is a diagram that shows a mutation frequently found when the plant is in drought conditions.



Source: Y Pan et al., 'Genome-Wide Identification and Characterization of RNA/DNA Differences Associated with Drought Response in Wheat', *International Journal of Molecular Sciences*, vol. 23, no. 1405, January 2022, p. 8, <<https://doi.org/10.3390/ijms23031405>>

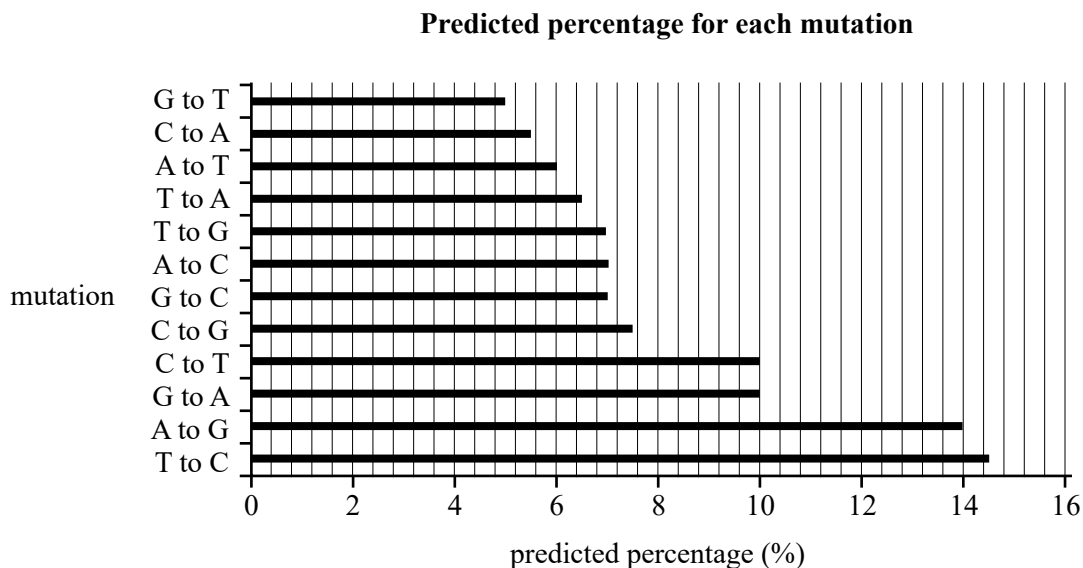
Question 4

This mutation

- A. will not change any codons produced during transcription for the protein.
- B. does not change the amino acid sequence of the protein.
- C. may alter the 3D structure of the protein produced.
- D. will stop translation of the protein.

Question 5

The data below shows the predicted percentage for several different point mutations occurring in this wheat species.



Source: adapted from Y Pan et al., 'Genome-Wide Identification and Characterization of RNA/DNA Differences Associated with Drought Response in Wheat', *International Journal of Molecular Sciences*, vol. 23, no. 1405, January 2022, p. 3, <<https://doi.org/10.3390/ijms23031405>>

From this data it can be concluded that the predicted percentage of a mutation of

- A. A to C is 6.5%.
- B. C to T is twice that of G to T.
- C. G to C and C to G is the same.
- D. A to G is the highest of all the mutations.

Question 6

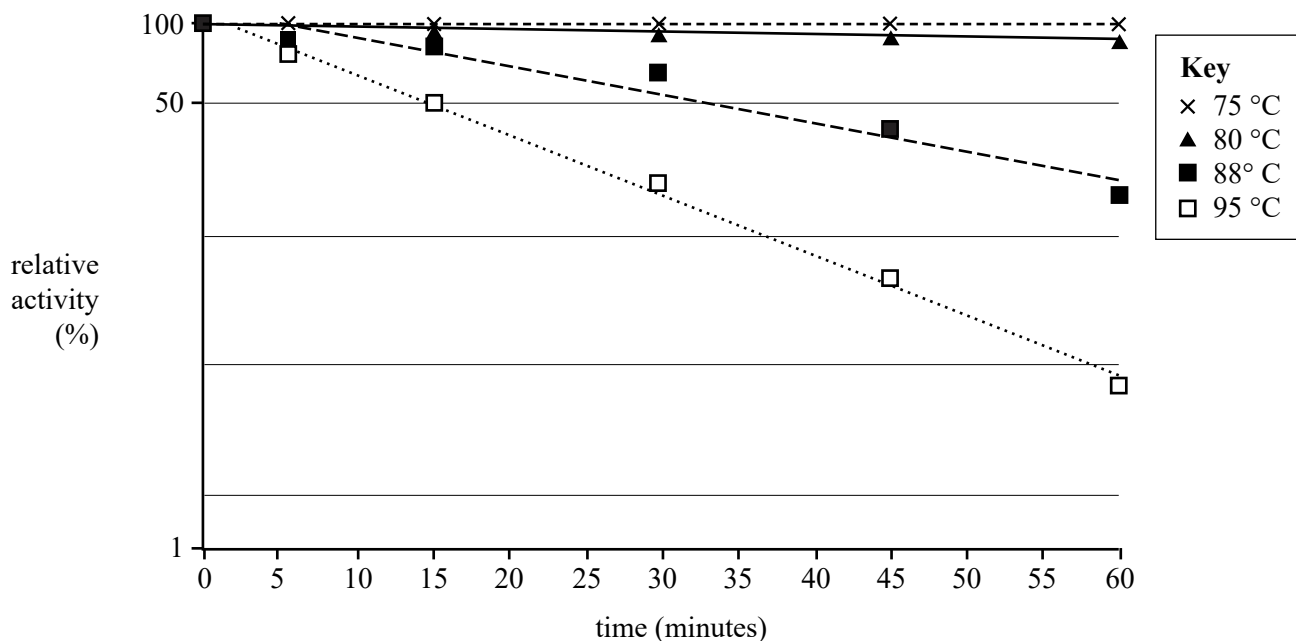
Papaya (*Carica papaya*) is one of the most economically important fruit crops in many tropical and subtropical countries. Papaya crops are affected by the papaya ringspot virus (PRSV). This virus can cause up to 100% losses of crops in some regions. PRSV disease management has been focused on developing tolerant or resistant varieties of papaya.

This could be achieved by

- A. releasing PRSV parasites on uninfected papaya populations.
- B. vaccinating all species of papaya plants.
- C. cloning papaya plants infected with PRSV.
- D. creating transgenic papaya plants.

Question 7

Thermus scotoductus strain K1 (*Tsk1*) DNA polymerase was incubated at different temperatures: 75 °C, 80 °C, 88 °C and 95 °C. The relative activity of the enzyme was measured over a period of 60 minutes. The results are shown in the graph below. Each point shown on the graph represents the average of three measured values at each time interval. Data for percentage relative activity is represented on a logarithmic scale.



Source: A Saghatelyan et al., 'Characteristics of DNA polymerase I from an extreme thermophile, *Thermus scotoductus* strain K1', *MicrobiologyOpen*, 2021, 10:e1149, <<https://doi.org/10.1002/mbo3.1149>>

It is reasonable to conclude that

- Tsk1* DNA polymerase is denatured at 95 °C and has an optimal temperature of 80 °C.
- at 88 °C after 35 minutes, *Tsk1* DNA polymerase would show increased relative activity.
- in order to synthesise complementary DNA strands from an existing template, *Tsk1* DNA polymerase is best incubated at 80 °C.
- after 15 minutes, *Tsk1* DNA polymerase incubated at 95 °C has half the activity of *Tsk1* DNA polymerase incubated at 75 °C.

Question 8

DNA profiling using autosomal short tandem repeats (STRs) can be used to link a person to a particular crime scene.

The following information was obtained after analysing DNA samples from people suspected of being linked to a crime scene and the evidence from that crime scene.

	Sample from evidence at crime scene	Sample from Suspect 1	Sample from Suspect 2	Sample from Suspect 3
STR locus	Number of repeats at each locus			
D8S1179	12, 12	12, 12	12, 12	12, 12
D21S11	28, 30	28, 30	28, 30	26, 30
D13S317	9, 15	9, 15	9, 15	8, 9
D7S820	10, 12	10, 10	10, 12	11, 12

Which of the following is a possible conclusion that can be made using the information from the table above?

- A. Results for the STR locus D8S1179 can be used to link only one suspect to the crime scene.
- B. Suspect 1 has two alleles of the same size for STR locus D13S317.
- C. Suspect 2 may be linked to the crime scene.
- D. More loci for Suspect 3 must be analysed before linking them to the crime scene.

Question 9

Scientists have been using molecular biology techniques to insert accessory pigment molecules into chloroplasts to enhance the efficiency of photosynthesis.

The main reason for doing this is to

- A. enhance the capture of light energy, especially visible green light.
- B. make the plant more drought-tolerant as it will consume less water.
- C. allow the plant to photosynthesise in the dark.
- D. increase the size of the leaves.

Question 10

What are the products formed in the light-independent reaction in photosynthesis?

- A. glucose, ADP and NADP⁺
- B. oxygen, ATP and NADPH
- C. oxygen, ADP and NADP⁺
- D. carbon dioxide, ATP and NADPH

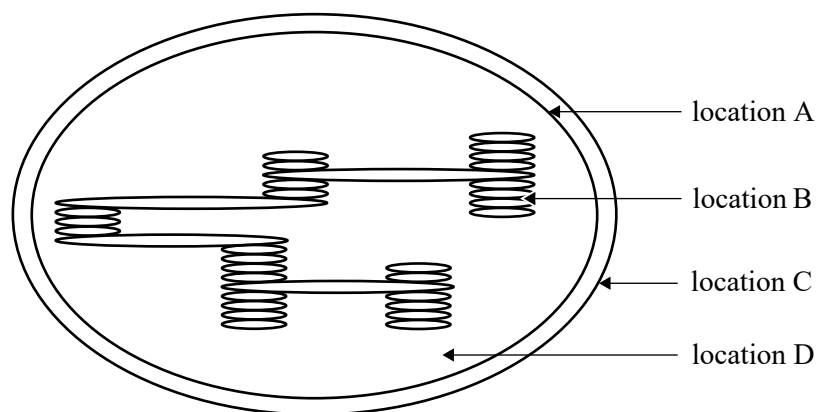
Question 11

Which of the following is a correct statement about photosynthesis?

- A. Protons generated in the light-dependent reaction move across the inner chloroplast membrane.
- B. The light-dependent reaction pathways are located on the thylakoid membranes.
- C. Oxygen is produced from the cleavage of carbon dioxide molecules.
- D. The end products of the light-dependent reaction are glucose and starch.

Question 12

Consider the diagram of the chloroplast below.



In which location of this chloroplast would you expect to find the enzyme Rubisco?

- A. location A
- B. location B
- C. location C
- D. location D

Question 13

Enzymes are required for the many different reactions in both cellular respiration and photosynthesis.

Which of the following is a correct statement?

- A. The presence of a coenzyme is necessary to enable some enzymes to function.
- B. The pH of the cytosol of the cell will not alter the activity of the enzymes.
- C. The concentration of the enzymes does not alter the rate of the reactions.
- D. The structure of both enzymes and coenzymes is unchanged by a reaction.

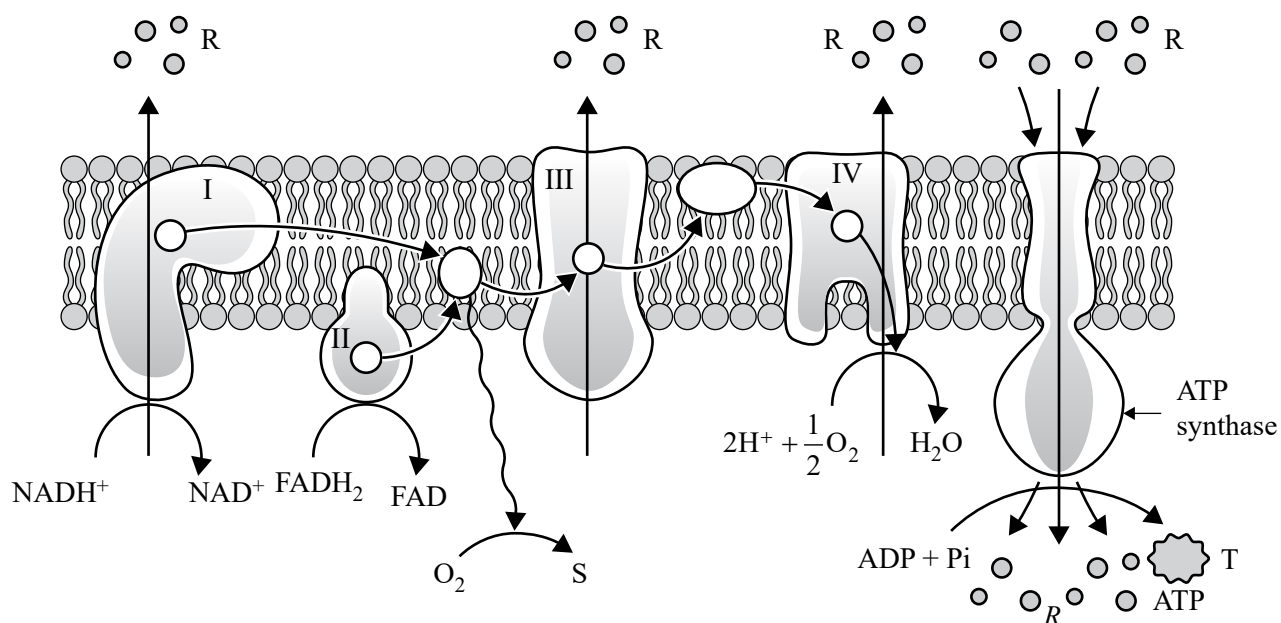
Question 14

Where in the cell are the enzymes involved in glycolysis located?

- A. in the cytosol
- B. in the nucleus
- C. in the mitochondria
- D. on the plasma membrane

Question 15

Consider the diagram below, which illustrates the electron transport system across a membrane.



Source: adapted from VectorMine/Shutterstock.com

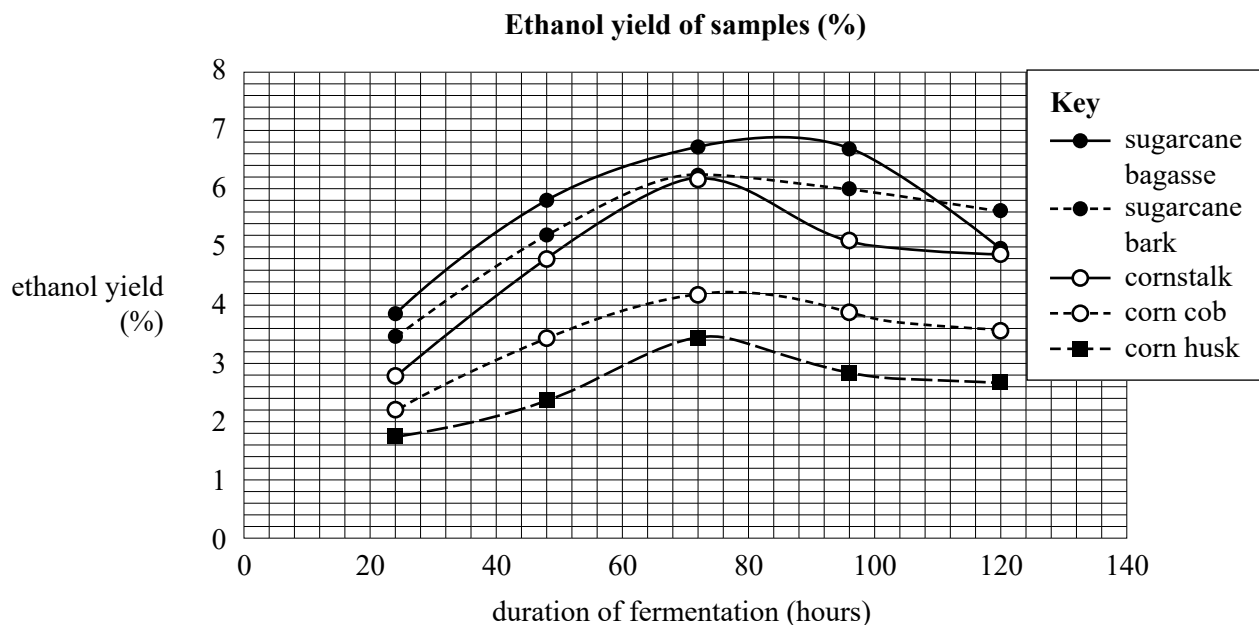
Which of the following is correct?

- A. The particles labelled R are oxygen ions.
- B. The product labelled S is a water molecule.
- C. The membrane would be part of the outer mitochondrial membrane.
- D. 26 or 28 ATP molecules would be produced at position T for each glucose molecule entering the aerobic respiration pathway.

Use the following information to answer Questions 16 to 19.

Biomass can be used in the production of liquid fuels such as bioethanol. Examples of five different biomass materials are sugarcane bagasse, sugarcane bark, cornstalk, corn cob and corn husk.

Scientists investigated the yield of ethanol that could be obtained over 120 hours from the same mass of each of these different biomass materials. The ethanol yield for each material was recorded every 24 hours. The results are shown in the graph below.



Data: W Braide, et al., 'Production of bioethanol from agricultural waste', *Journal of Fundamental and Applied Sciences*, vol. 8, no. 2, 2016, p. 378

Question 16

The following conclusion can be drawn from the investigation.

- At 90 hours of fermentation, the ethanol yield from corn husks was higher than the ethanol yield from corn cobs.
- The ethanol yield for sugarcane bark was always lower than the ethanol yield for sugarcane bagasse.
- During the fermentation process from 24 to 48 hours, the rate of production of ethanol was higher for cornstalk than for sugarcane bark.
- The ethanol yield was independent of the duration of fermentation.

Question 17

The scientists identify the biomass that will produce the most ethanol at 120 hours of fermentation.

This biomass is

- sugarcane bagasse.
- sugarcane bark.
- cornstalk.
- corn cob.

Question 18

The scientists wanted to check whether their results were reproducible.

To do this, they repeated the experiment and changed the

- A. type of investigation.
- B. variable being measured.
- C. method of the experiment.
- D. person recording the observations.

Question 19

Which of the following is a correct statement about the production of bioethanol from biomass?

- A. The temperature of the biomass would not affect the production of ethanol.
- B. A microorganism that respire anaerobically must be present in the biomass.
- C. The biomass must contain a source of protein.
- D. Oxygen is a product of the process.

Question 20

Plants are exposed to pathogens regularly.

A chemical barrier produced by some plants to prevent pathogens from entering the plant are

- A. antibodies.
- B. antimicrobial proteins.
- C. keratinised epidermal cells.
- D. microorganisms on the surface of plant tissue.

Question 21

Complement proteins and interferons are involved in a human immune response.

Which of the following is a correct statement about their role in a response?

- A. Antibodies are produced in response to the release of both complement protein and interferons.
- B. Both complement proteins and interferons can be part of the innate immune response.
- C. Interferons are released in response to the presence of phagocytic cells.
- D. Complement proteins are released from activated mast cells.

Question 22

When human skin tissue is damaged by a sharp object, an inflammatory response is initiated.

Which of the following is a correct statement about this inflammatory response?

- A. Antibodies are released by macrophages that attach to pathogens in the area around the damaged skin tissue.
- B. Blood flow to the damaged area would decrease as blood vessels in the area vasoconstrict.
- C. Swelling around the damaged area is caused by an increase in the number of immune cells.
- D. Cytokines released by damaged cells attract neutrophils to the damaged area.

Question 23

A student has previously had an allergic reaction to an unknown substance. To investigate possible causes of the allergic reaction, solutions containing ten known substances were applied to the student's forearm. The skin was then lightly scratched in each area to allow the substance in each solution to enter the skin.

The photograph below shows the positioning of the ten solutions on the skin of the student's forearm.



Source: Microgen/Shutterstock.com

The student was found to be allergic to one of the substances applied to their forearm.

Which of the following is a correct statement?

- A. If the student has had prior exposure to the substance, and the substance is an allergen, a local inflammatory response will be observed in the skin around the substance.
- B. Mast cells coated with IgE antibodies will release antigens in response to an allergen present in the solution.
- C. Antihistamines should be taken by the student before any sample is applied.
- D. The skin region around each sample would become cold and pale after a sample is applied.

Question 24

T lymphocytes that activate B lymphocytes are known as

- A. naïve T cells.
- B. helper T cells.
- C. memory T cells.
- D. cytotoxic T cells.

Question 25

The table below compares features of two methods of transmission of the influenza A virus.

Features	Aerosol transmission	Droplet transmission
Definition	Exposure to pathogen-containing aerosols (tiny droplets) found in the air	Exposure to pathogen-containing droplets found on surfaces sprayed by coughing or sneezing
Mean particle size (micrometres)	$<5 \mu\text{m}$	$>10 \mu\text{m}$
Particle suspension behaviour	Can remain suspended in the air for several minutes or more	Rapidly settle out of air onto surfaces
Distance virus can spread	Can move on air currents throughout building	Can travel less than three metres
Infection site	Lower respiratory tract	Mucous membranes
Dose of virus required to induce infection	Low dose	Higher dose

Source: adapted from NCJ Brienen et al., 'The Effect of Mask Use on the Spread of Influenza During a Pandemic', *Society for Risk Analysis*, vol. 30, no. 8, 2010, p. 1213, <<https://doi.org/10.1111/j.1539-6924.2010.01428>>

Based on the data from the table, which of the following would be best for reducing the infection rate from the influenza A virus?

- A. Mandate mask wearing in all enclosed areas and disinfect surfaces frequently.
- B. Disinfect all surfaces frequently and introduce hand sanitation stations.
- C. Wear a mask that excludes particles greater than $8 \mu\text{m}$ in size.
- D. Close windows in buildings to reduce air currents.

Question 26

It is recommended that people who are at risk of severe complications from influenza be vaccinated.

Which of the cells of the adaptive immune system are most likely to increase in number following an injection of an antigen-based vaccine?

- A. cytotoxic T cells
- B. natural killer cells
- C. plasma cells
- D. mast cells

Question 27

It is recommended that pregnant women and babies older than six months receive an influenza vaccination every year.

It is likely that before six months of age, an unvaccinated baby could be protected from influenza by

- A. active natural immunity.
- B. passive natural immunity.
- C. active artificial immunity.
- D. passive artificial immunity.

Question 28

It is recommended that people be vaccinated against influenza viruses each year from mid-April onwards. The influenza season in Australia is typically between June and September.

Why is it recommended that influenza vaccinations be administered months before influenza cases increase?

- A. Authorities want to wait to see if there will be an influenza outbreak.
- B. The number of vaccinations available is greatest in April.
- C. Immunity develops 2–4 months after vaccination.
- D. Influenza is at its peak in April.

Question 29

The composition of influenza vaccines can change from year to year as new strains of influenza virus appear. New strains of influenza virus appear because of

- A. viral resistance to antibiotics.
- B. more people being vaccinated against influenza.
- C. overuse of disinfectant solutions on household surfaces.
- D. gene mutations that lead to changes in the surface proteins of the virus.

Question 30

The lymphatic system plays an important role in a human immune response.

Which of the following is a correct statement?

- A. Lymph vessels act as a transport system for cells of the immune system.
- B. Lymph nodes are found evenly distributed throughout the human body.
- C. Lymph nodes are the main site of a passive immune response.
- D. The site of clonal expansion occurs within the thymus.

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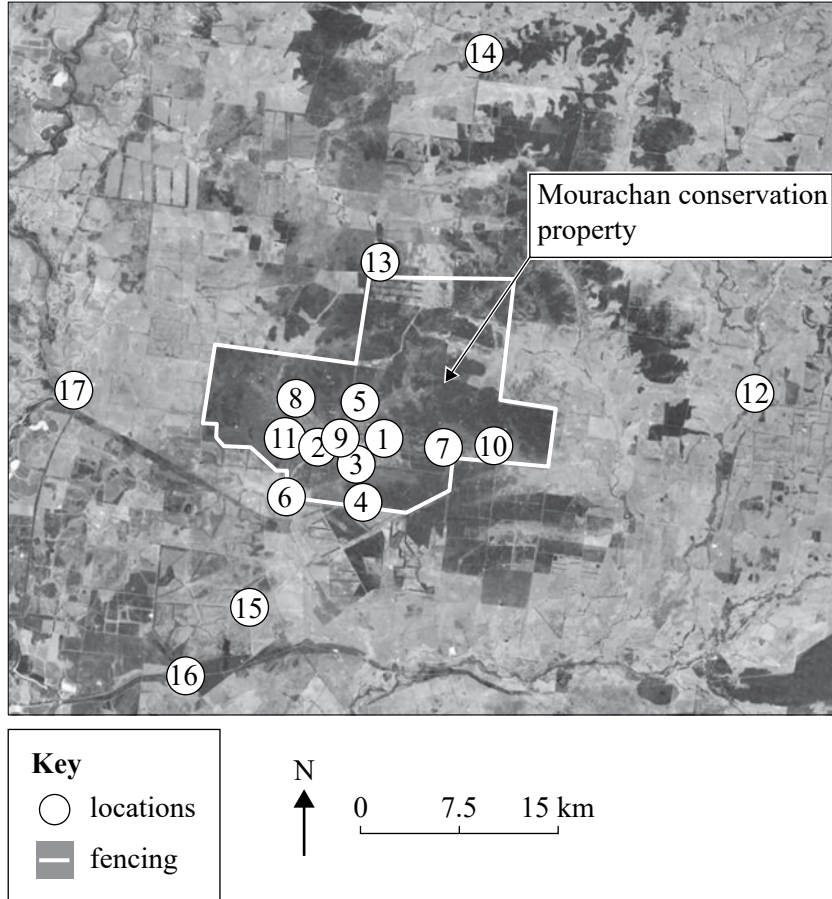
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**SECTION A – continued
TURN OVER**

Use the following information to answer Questions 31 and 32.

The eastern grey kangaroo (*Macropus giganteus*) is found in the eastern states of Australia.

Populations of eastern grey kangaroos are found living within and outside the Mourachan conservation property, Queensland. Scientists investigated the genetic diversity of the kangaroos living in this region. The scientists collected and analysed scat (faecal matter) from 17 different locations. The position of each of the locations is shown on the map below.



Source: adapted from MA Zemanova, D Ramp, 'Genetic Structure and Gene Flow in Eastern Grey Kangaroos in an Isolated Conservation Reserve', *Diversity*, vol. 13, no. 570, 2021, p. 2, <<https://doi.org/10.3390/d13110570>>

Question 31

Scientists looked for evidence of past population bottlenecks occurring in the eastern grey kangaroos living within the region.

Evidence of past population bottlenecks may be indicated by

- A. low genetic diversity within the population.
- B. high numbers of kangaroos in the population.
- C. individual kangaroos previously found outside the property relocating to inside the property.
- D. constant environmental conditions both within and outside the conservation property.

Question 32

A high fence (shown on the map on page 16) is to be built along the boundary of the conservation property. Scientists have concerns about the effect this fence will have on both the kangaroos living within the conservation property and those living outside it.

The scientists predict that after this fence is built there will be

- A. an increase in the rate of gene mutations in kangaroos.
- B. no change to the environmental selection pressures acting on the kangaroos.
- C. a decrease in gene flow between kangaroos living within and kangaroos living outside the conservation property.
- D. greater genetic variation in kangaroos within the conservation property compared to kangaroos outside the conservation property.

Question 33

In order to determine the age of a fossil, scientists can use relative or absolute dating methods.

Which of the following statements about relative or absolute dating is correct?

- A. Relative dating compares DNA sequences of fossils to determine how recently they diverged from a common ancestor.
- B. Radiometric techniques used in absolute dating enable scientists to determine the exact day on which a fossil was formed.
- C. Carbon-14 dating is a type of absolute dating that calculates the age of the surrounding rock strata in which fossils are found.
- D. Relative dating gives the approximate age of a fossil, or the rock layers in which a fossil is found, by comparing it to similar fossils and rock layers of known ages.

Question 34

Index fossils may be used to compare the age of rock layers in different locations. Ammonites, similar to the one illustrated below, are often used as index fossils.



Source: SciePro/Shutterstock.com

For a particular species of ammonite to be a good index fossil, it is likely that the ammonite species

- A. was a rare marine species.
- B. became extinct due to human impact.
- C. had a widespread geographical distribution.
- D. consisted of individuals that contained few hard parts.

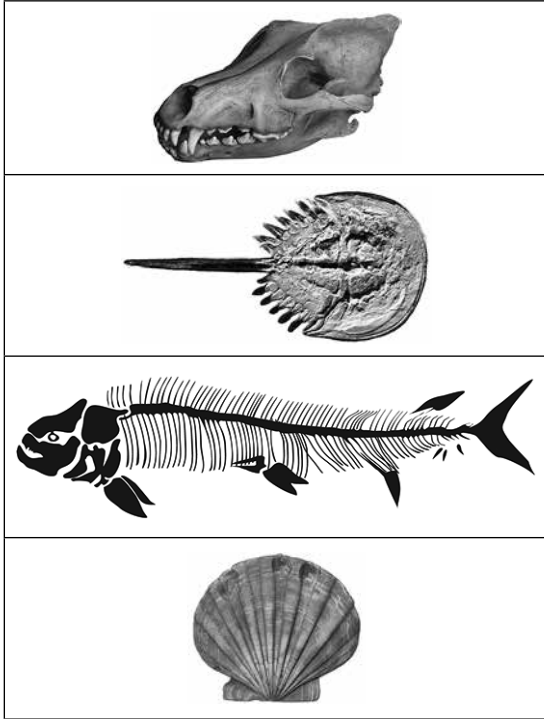
Question 35

The layers in the following diagrams represent rock strata from an exposed rock face that contains fossils. The uppermost stratum is closest to the ground surface. The order of strata has not been altered over time by earth movements.

Which of the following diagrams illustrates the correct order of faunal succession?

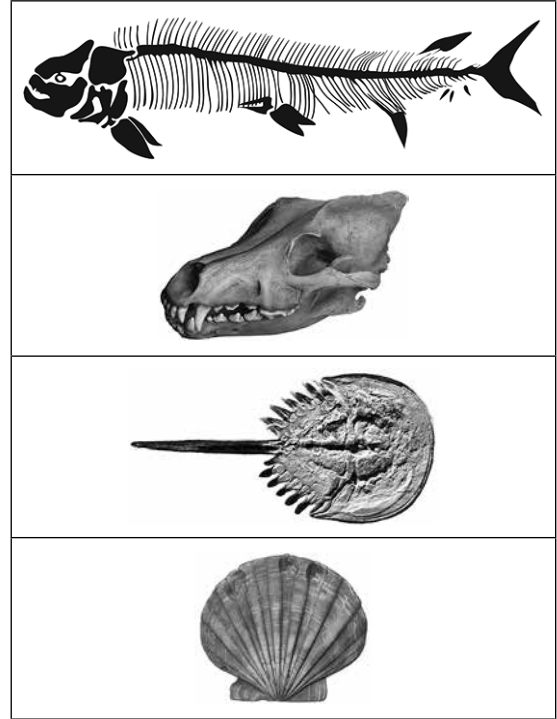
Ground surface

A.



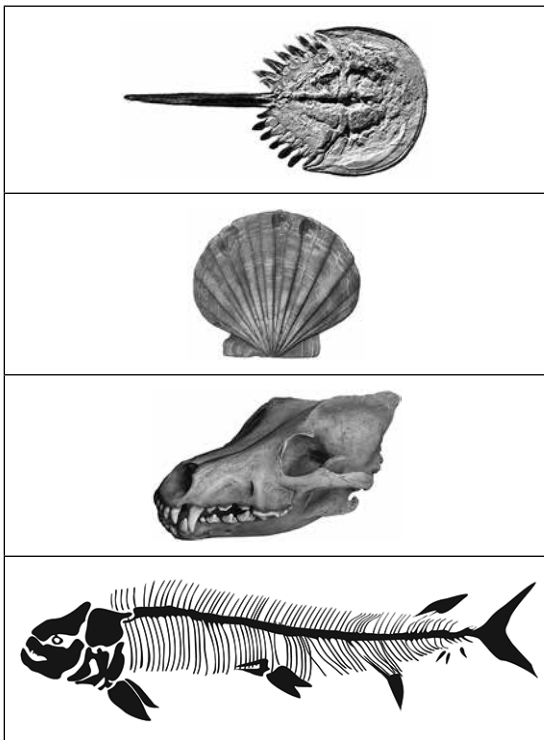
Ground surface

B.



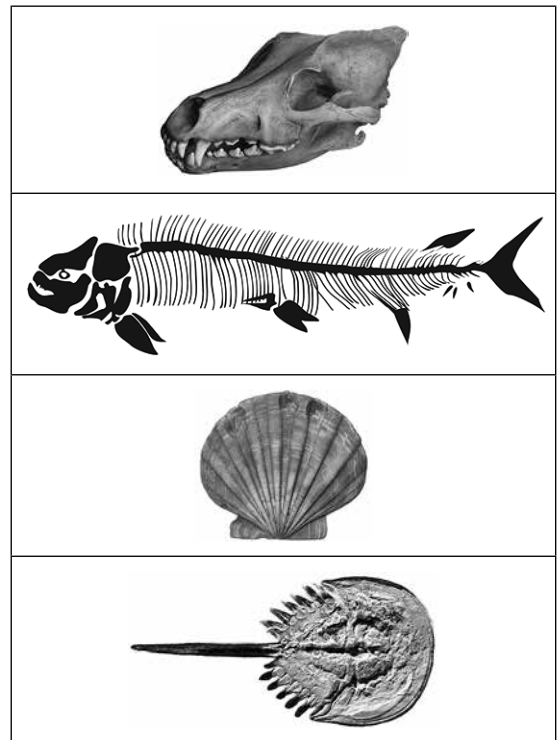
Ground surface

C.



Ground surface

D.



Sources: (according to option A layout, from top) Eowyn_photos/Shutterstock.com; koi88/Shutterstock.com; Vertata/Shutterstock.com; LorraineHudgins/Shutterstock.com

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Question 36

The blind cave fish (*Astyanax mexicanus*) lives in dark, underwater caves. The eyes of *A. mexicanus* develop initially in the embryo with lens and retinal cells which then undergo apoptosis. The eyes degenerate into small, non-functional structures covered by skin and connective tissue.

The most appropriate term for the non-functional eyes in the blind *A. mexicanus* is

- A. adaptive.
- B. vestigial.
- C. analogous.
- D. homologous.

Question 37

Cytochrome *c* is a highly conserved protein found in all eukaryotes. It consists of a single 104 amino acid peptide. Cytochrome *c* is an electron-carrying protein involved in cellular respiration. The following table shows the amino acid (aa) sequences for the first 100 amino acids in the cytochrome *c* peptides of a horse and a human. Each letter represents a particular amino acid.

Position of aa in sequence		10		20		30		40		50
Horse	GDVEK	GKKIF	VQKCA	QCHTV	EKGGK	HKTGP	NLHGL	FGRKT	GQAPG	FTYTD
Human	GDVEK	GKKIF	IMKCS	QCHTV	EKGGK	HKTGP	NLHGL	FGRKT	GQAPG	YSYTA

Position of aa in sequence		60		70		80		90		100
Horse	ANKNK	GITWK	EETLM	EYLEN	PKKYI	PGTKM	IFAGI	KKKTE	REDLI	AYLKK
Human	ANKNK	GIIWG	EDTLM	EYLEN	PKKYI	PGTKM	IFVGI	KKKEE	RADLI	AYLKK

Source: 'Cytochrome C in Molecular Evolution', Merck, <<https://www.sigmaaldrich.com/AU/en/technical-documents/technical-article/research-and-disease-areas/metabolismresearch/cytochrome-c>>

From this information it can be concluded that

- A. the DNA sequence coding for the cytochrome *c* of a human carries more mutations than the DNA sequence coding for the cytochrome *c* of a horse.
- B. horses and humans utilise different enzymes to catalyse the same steps in the biochemical pathway for cellular respiration.
- C. there are 11 differences between the amino acid sequences for cytochrome *c* in a horse and those in a human.
- D. cytochrome *c* of horses and humans is more highly conserved between positions 1 and 10 than between positions 51 and 60.

Question 38

Characteristics of all mammals include

- A. a larger cranium than jaw.
- B. hair or fur.
- C. opposable thumbs.
- D. a prehensile tail.

Use the following information to answer Questions 39 and 40.

In the 1970s, a fossil, a jawbone and teeth from a primitive kangaroo were found in Papua New Guinea (PNG). The fossil was first classified in the extinct genus *Protemnodon* (giant wallabies). It was re-classified in 2022 into a new genus, *Nombe*, based on 3D scanning data. Measurements of the fossil's teeth and jaw were compared with data from extinct and existing species of kangaroo-like animals. *Nombe nombe* ate rainforest leaves and weighed 40–50 kg. *N. nombe* migrated to PNG from Australia between 5–8 million years ago.

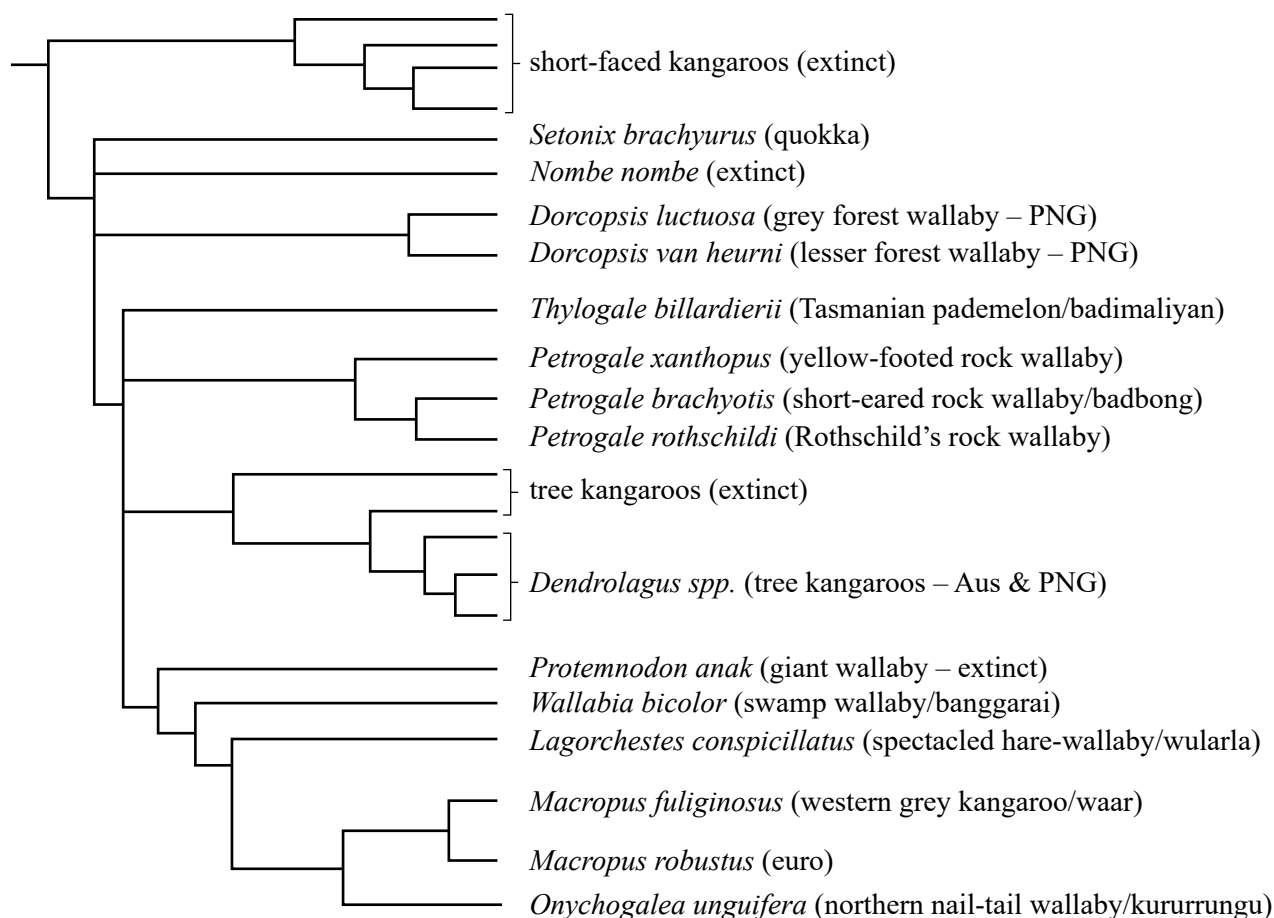
Question 39

The most likely reason for the recent re-classification of the fossil teeth and jawbone from *Protemnodon* genus to *Nombe* genus is that

- A. sophisticated 3D scanning technology was not available in the 1970s.
- B. *Nombe* at 40–50 kg was too small to be the giant wallaby *Protemnodon*.
- C. the first study of data to classify the fossil was found to contain random errors.
- D. a transitional fossil with features of *Protemnodon* and *Nombe* was found in an Australian rainforest.

Question 40

The phylogenetic tree below summarises the evolutionary relationships of *Nombe nombe* to kangaroos and wallabies. Indigenous language names (where available) are shown alongside common names.



Source: adapted from IR Kerr and GJ Prideaux, 'A New Genus of Kangaroo (Marsupialia, Macropodidae) from the Late Pleistocene of Papua New Guinea', *Transactions of the Royal Society of South Australia*, <146:2, 295–318, DOI: 10.1080/103721426.2022.2086518>

According to the phylogenetic tree, which of the following statements is correct?

- Nombe nombe* was most closely related to the extinct short-faced kangaroos.
- Protemnodon anak* diverged earlier than *Nombe nombe* from a common ancestor.
- Setonix brachyurus* and *Dorcopsids* (forest wallabies from PNG) are equally closely related to *Nombe nombe*.
- Wallabia bicolor* (swamp wallaby) is more closely related to *Nombe nombe* than to *Petrogales* (rock wallabies) and tree kangaroos.

SECTION B**Instructions for Section B**

Answer **all** questions in the spaces provided.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1 (8 marks)

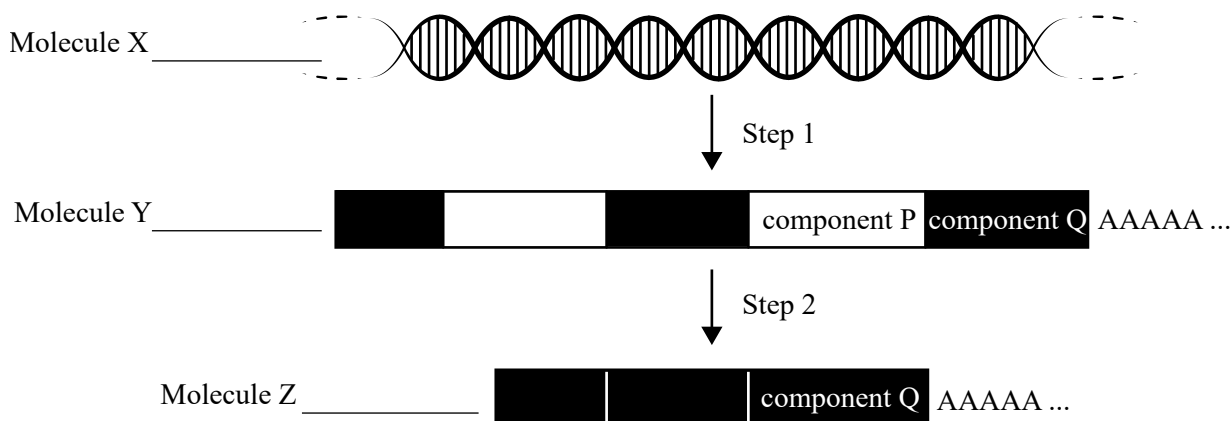
The nucleic acids, DNA and RNA, are both found inside animal cells.

- a. Compare where you would find each type of nucleic acid inside a typical animal cell. 2 marks

- b. Using your knowledge of the DNA and RNA found in cells, complete the following table. 3 marks

Nucleic acid	DNA	RNA
Number of nucleotide strands		
Type of pentose sugar present		
Full names of bases present		

c. The diagram below shows RNA processing in eukaryotic cells. 3 marks



Source: adapted from Mariia Arsonova/dreamstime.com

- i. In the diagram above, label the molecules X, Y and Z.
- ii. Compare the roles of components P and Q in molecule Y.

Question 2 (4 marks)

In a functioning cell, polypeptides such as enzymes are synthesised and delivered to specific cellular organelles.

a. State the role of the Golgi apparatus in this process. 1 mark

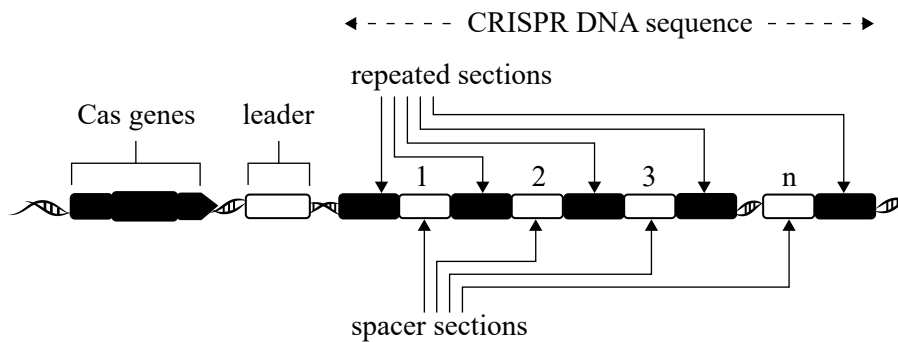
b. During synthesis of a protein, a sequence of amino acids is joined together. After this primary structure has been created, further changes to the primary structure will produce a functional protein. Consider the protein RNA polymerase.

Describe all the other structural hierarchical levels that are required to form a functional RNA polymerase molecule. 3 marks

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Question 3 (9 marks)

Prokaryotes contain a CRISPR DNA sequence, which consists of nucleotide repeated sections and spacer sections. The diagram below illustrates the positioning of these sections in part of the prokaryote circular chromosome.



Source: J Zhang et al., ‘The CRISPR-Cas9 system: a promising tool for discovering potential approaches to overcome drug resistance in cancer’, *RSC Advances*, 8, 2018, p. 33464, <<https://pubs.rsc.org/en/content/articlehtml/2018/ra/c8ra04509g>>

- a. Outline the function of the CRISPR DNA sequence in prokaryotes. In your answer, state the origin of the spacers.

4 marks

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Sickle-cell disease and β -thalassemia are two human blood disorders. Both diseases are the result of mutations in the haemoglobin β gene. In both diseases, the ability of the red blood cells to carry oxygen is reduced. Scientists are developing a treatment that involves turning off a gene in stem cells. This will increase the oxygen-carrying capacity of the blood in people with these disorders. The scientists are using the CRISPR-Cas9 gene-editing technique to locate and edit the gene in stem cells. The gene is called BCL11A.

The scientists designed a single guide RNA (sgRNA) to locate a sequence of nucleotides within the BCL11A gene, as shown below.

sgRNA target sequence	PAM
TAGTCTAGTGCAAGCTAACAGTTGCTTTTATCACAGGCTCCAGGAAG ATCAGATCACGTTTCGATTGTCAACGAAAATAGTGTCCGAGGTCCTTC	

Source: H Frangoul et al., 'CRISPR-Cas9 Gene Editing for Sickle Cell Disease and β -Thalassemia',
The New England Journal of Medicine, vol. 384, no. 3, 2021, p. 254,
www.nejm.org/doi/full/doi/10.1056/NEJMoa2031054

- b. i. Write the nucleotide sequence that must be used on the sgRNA to locate the targeted sequence within the BCL11A gene. 1 mark

- ii. Describe the function of the PAM sequence adjacent to the sgRNA target sequence. 2 marks

- c. Scientists have successfully edited the BCL11A gene. Initially, two patients were treated. Some of each patient's stem cells were extracted and then genetically modified. Each patient then had their own cells returned to them. Both responded well, with significant and sustained increases recorded in their haemoglobin levels. The two patients no longer needed blood transfusions to survive. However, both patients had some adverse reactions. The scientists have since treated another 75 patients.

Identify an ethical concept that the scientists would have needed to consider before proceeding with the treatment of the additional 75 patients. How would they justify the continuation of the treatment in new patients? 2 marks

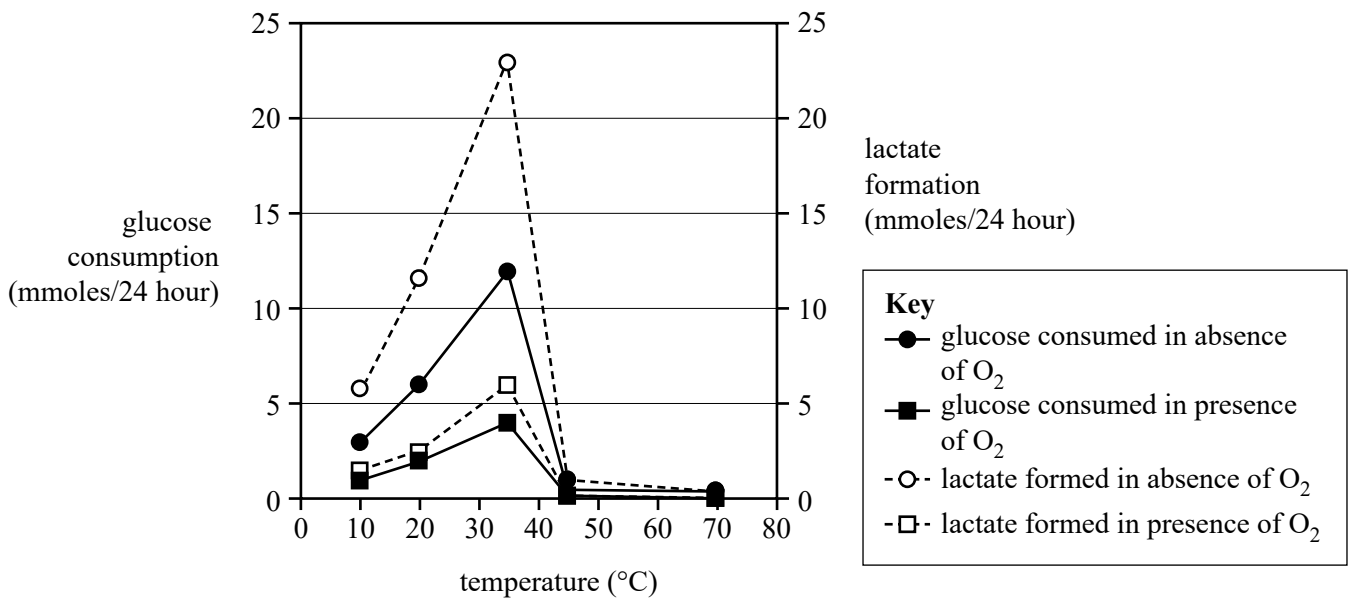
Question 4 (12 marks)

- a. Metabolic pathways possess a number of key regulatory enzymes. If one of these enzymes were inhibited using a non-competitive inhibitor, explain how this inhibitor would affect the activity of this enzyme.

2 marks

A student was conducting an experiment using cultured human kidney cells. The student added the same number of cells suspended in the same volume of nutrient solution to 10 identical containers. Each container was then placed into its own incubator.

Ten incubators were set at one of five temperatures, 10 °C, 20 °C, 35 °C, 45 °C or 70 °C. At each temperature setting there were two incubators. One incubator at each temperature setting was supplied with oxygen while the other was not. After 24 hours, the student measured the amount of glucose consumed and the amount of lactate produced in each cell population. The results they obtained were plotted below.



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- b. i. What were the values for glucose consumption and lactate production at 35 °C for the cells grown in the presence of oxygen? 2 marks

glucose consumption: _____

lactate production: _____

- ii. Explain why the consumption of glucose and the production of lactate by these cells at 35 °C was different if they were grown in the presence or absence of oxygen. 5 marks

- c. Explain why both glucose consumption and lactate production in the cells grown at 45 °C were lower than those grown at 35 °C. 3 marks

Question 5 (3 marks)

A group of scientists conducted experiments investigating the photosynthetic output of a newly discovered plant species. The plants were exposed to differing environmental conditions in an enclosed greenhouse. Light and water availability were kept the same. The amount of glucose produced was measured and recorded in the table below. Plants of the same size were used in each of these experiments.

Air temperature (°C)	Carbon dioxide in surrounding air (%)	Relative humidity of surrounding air (%)	Quantity of glucose produced (mg/day)
25	5	75	75
25	2	75	40
25	5	25	50
40	5	75	45
40	2	75	20
40	5	25	25

Plants can be placed into three main groups, C3, C4 or CAM plants, based on their photosynthetic adaptations.

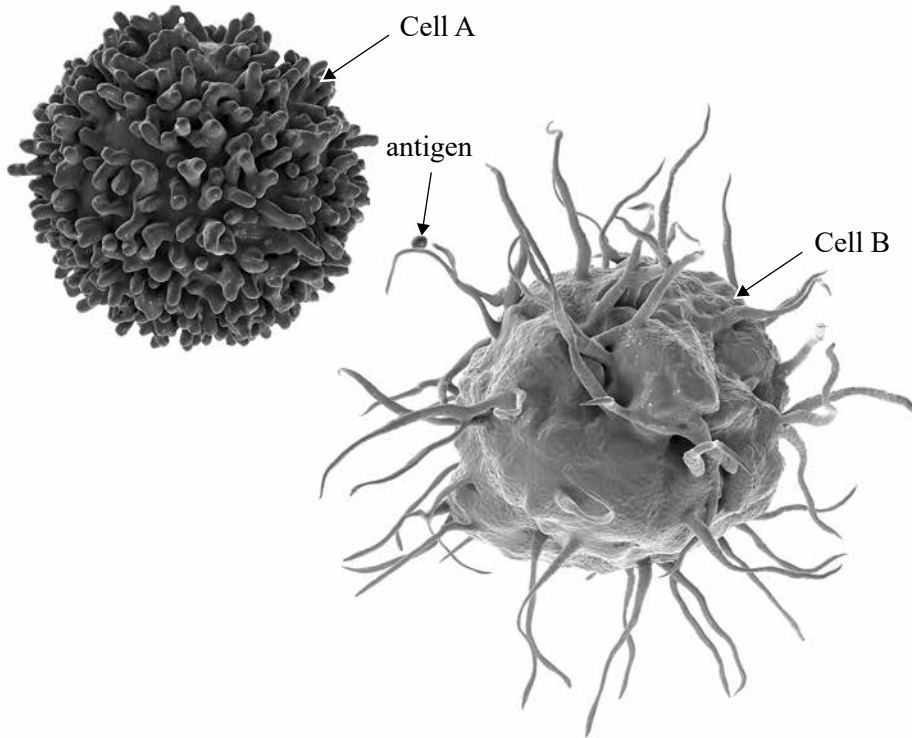
To which of these groups would this newly discovered plant species most likely belong? Justify your answer.

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Question 6 (4 marks)

The human immune system has many different types of cells.

The diagram below illustrates two of these cell types and their interaction with each other. Cell A is a component of the adaptive immune system. Cell B is a component of the innate immune system. Cell B has an antigen attached to its plasma membrane.



Source: Kateryna Kon/Shutterstock.com

Outline the events in an immune response, which will occur after the interaction between these two cells.

Question 7 (5 marks)

Mpox is a disease that is endemic to West and Central Africa. It is caused by a virus that was first discovered in monkeys. Symptoms of mpox include fever and blisters on the skin. The virus is transmitted from one person to another by direct skin contact with an infected person, or through contaminated materials such as bedding. In early 2022, cases of mpox were identified in countries where the virus is not endemic.

- a. Mpox is classified as endemic to West and Central Africa.

What does this mean about the disease?

1 mark

- b. The incubation period for mpox is 5–21 days.

Considering this, what would be two of the most effective methods to control the spread of mpox from Africa to other continents? Justify your answer.

2 marks

- c. In May 2022, there were two approved vaccines for mpox in the United States of America. ACAM2000 is a very effective vaccine, but it can have serious side effects on a person's health. It takes 4 weeks to develop a maximum immune response. The JYNNEOS vaccine has few side effects and takes 10 weeks for immunity to be established. Data regarding its effectiveness is limited. In the United States, the JYNNEOS vaccine was recommended for use for individuals who were known or presumed contacts.

Vaccination would be recommended if mpox were becoming a widespread disease in the United States. Suggest which of the above vaccines should be used. Justify your answer.

2 marks

Question 8 (5 marks)

Many cancer cells have high amounts of the protein-programmed death-ligand 1 (PD-L1) on their membrane. The presence of high amounts of PD-L1 prevents immune cells from detecting cancer cells. Monoclonal antibody (mAb) therapy against PD-L1 can be used to treat certain cancers.

- a. Explain how mAbs could work to treat cancers that have high membrane levels of PD-L1. 3 marks

- b. Some mAbs, called antibody-drug conjugates, are mAbs linked to a chemotherapy drug. Traditional chemotherapy often affects all dividing cells in the body. What would be the advantage of using antibody-drug conjugate mAb treatment? 2 marks

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Question 9 (10 marks)

- a. Scientists have been investigating the ancient migration of human populations using DNA samples obtained from present-day humans. Both mtDNA (mitochondrial DNA) and whole genome (nuclear DNA) analyses have been used.

Identify a key difference between the information gained from mtDNA analysis and whole genome analysis. State an advantage of using each method.

3 marks

- b. It is believed that the first hominins to arrive in Australia were *Homo sapiens*. Evidence from various sites suggests these first *H. sapiens* migrated from northern Australia, via the east and west coastlines, to southern Australia and Tasmania. Evidence from the Warraty rock shelter in the Flinders Ranges in South Australia shows that humans occupied this area 49 000 years ago.

State two types of evidence, apart from fossilised human skeletons, that may have been found at the Warraty rock shelter and that would support the theory of its occupation by early *H. sapiens* populations.

2 marks

- c. Fossil evidence shows that the first hominin species that left Africa was *Homo erectus*, about 2 million years ago. The last known *H. erectus* population existed in Indonesia about 108 000 years ago. *H. erectus* individuals were similar in height to modern humans (146–185 cm).

Describe two differences and one similarity (other than height) that would be observed between the skeletons of *H. erectus* and *H. sapiens*.

3 marks

Difference 1 _____

Difference 2 _____

Similarity _____

- d. DNA evidence from present-day humans shows that *Homo neanderthalensis* interbred with *H. sapiens* while the two species coexisted in Europe. Fossil discoveries show that *H. erectus* and *H. sapiens* coexisted in Indonesia about 143 000 years ago.

Explain whether you would expect scientists to find DNA evidence to support the view that *H. erectus* and *H. sapiens* interbred?

2 marks

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Question 10 (8 marks)

The following examples illustrate aspects of speciation.

Example 1

The Isthmus of Panama is a land bridge separating the Atlantic and Pacific Oceans. The bridge began forming 10 million years ago and closed about 3 million years ago. There are 15 species of snapping shrimp *Alpheus* in the waters on the Atlantic side of the isthmus and 15 other *Alpheus* species on the Pacific side. Each of the 15 species has a ‘sister’ species, which is its closest living relative according to DNA studies and morphological comparisons, on the opposite side of the isthmus. Genetic data shows that the 30 species diverged 3–9 million years ago.

Example 2

Two species of Japanese land snail *Euhadra* possess a single-locus gene that controls the direction of the spiral of the snail’s shell. The shell of *E. quaesita* spirals to the left, while the shell of *E. aomiorensis* spirals to the right. In other ways the species are identical. If two snails from the different species attempt to mate, their genital openings do not align because of the directions of their shells, resulting in an unsuccessful mating.

Example 3

Populations of the mosquito fish *Gambusia hubbsi* live in ponds that were once connected. Some ponds have predatory fish that feed on mosquito fish. *G. hubbsi* in these ponds have a streamlined head and a powerful tail, which enables them to swim with rapid bursts of speed. Other ponds have no predatory fish. *G. hubbsi* in these ponds have a rounder body, favouring slow swimming for sustained periods. When scientists bring together *G. hubbsi* from different ponds, they find that females prefer to mate with males whose body shapes are similar to their own.

Example 4

In North America, apple maggot flies, *Rhagoletis pomonella*, feed and mate on the fruits of the native hawthorn tree, as well as on apple trees planted by European settlers in the last 200 years. Apples grow faster than hawthorn fruits. *R. pomonella* populations that feed and mate on apples reach sexual maturity quicker than those that feed and mate on hawthorn fruits. The apple-feeding flies no longer mate with hawthorn-feeding flies. Furthermore, researchers have found alleles in apple-feeding flies that benefit them but are harmful to hawthorn-feeding flies.

- a. Discuss the types of evidence that scientists use to determine whether speciation is occurring, or has occurred. Refer to examples from the article above to support your response.

4 marks

- b. Complete the table below, stating whether each example in the article shows allopatric or sympatric speciation. Justify each of your choices, using evidence drawn from the article. 4 marks

Example	Type of speciation shown in example	Justification/reason(s) for choosing this type of speciation
Snapping shrimp		
Japanese land snail		
Mosquito fish		
Apple maggot fly		

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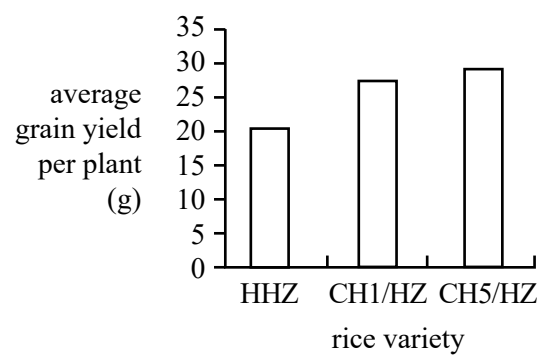
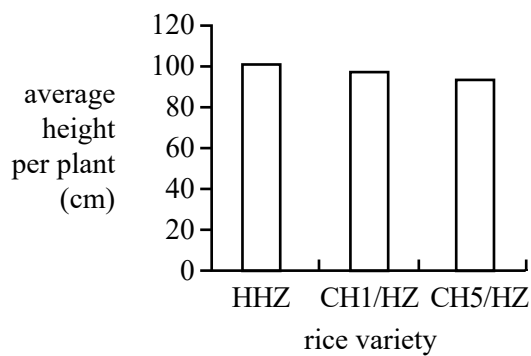
Question 11 (12 marks)

Rice (*Oryza sativa*) is an important food crop. CRISPR-Cas 9 technologies are being used to develop high-yielding rice varieties that have a high photosynthetic efficiency.

In one experiment, scientists knocked out the hexokinase gene *OsHXX1* using the CRISPR-Cas9 gene-editing method in the rice variety Huanghuazhan (HHZ) and obtained two different genetically modified varieties, which they called CH1 Huanghuazhan (CH1/HZ) and CH5 Huanghuazhan (CH5/HZ).

These genetically edited rice varieties were then grown in a field alongside the non-modified varieties. The rice from all varieties was harvested at the end of the growing period and the scientists obtained the following results.

Rice varieties HHZ, CH1/HZ and CH5/HZ



Source: adapted from S Zheng et al., 'Improving the Rice Photosynthetic Efficiency and Yield by Editing *OsHXX1* via CRISPR/Cas9 System', *International Journal of Molecular Sciences*, vol. 22, no. 17, 2021, p. 554, <<https://doi.org/10.3390/ijms22179554>>

