APOLLO

# Biology
# HL Workbook

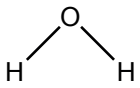
First assessment 2025
Whole questions arranged by syllabus topic.
Original question and scheme crops preserve source diagrams.

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# Water

6 questions

**1.** Which symbol indicates the polarity of the oxygen atom in the water molecule?




A. $\delta +$

B. $\delta -$

C. $+$

D. $-$

**1.** What property of water leads to aquatic environments having low fluctuations of temperature throughout the year?

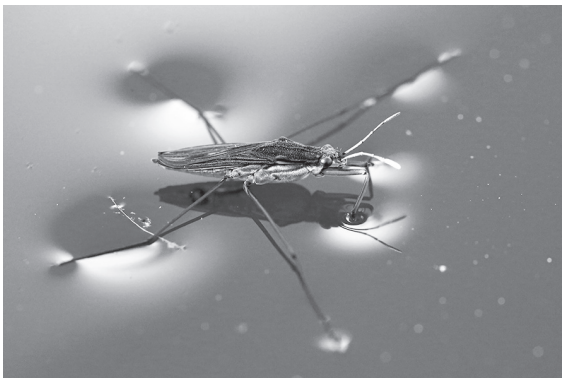
A. High specific heat capacity because covalent bonding restricts molecular motion

B. Low specific heat capacity because covalent bonding restricts molecular motion

C. Low specific heat capacity because hydrogen bonding restricts molecular motion

D. High specific heat capacity because hydrogen bonding restricts molecular motion

**1.** The photograph shows a pond skater.



Which property of water allows the insect to walk on water?

A. Adhesion

B. Capillarity

C. Surface tension

D. Transparency

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**2.** Water is the medium in which most processes of life occur.

(a) Distinguish between the physical properties of water and air. [2]

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The ringed seal (*Pusa hispida*) can be found in the Arctic and sub-Arctic regions of the Pacific, Atlantic and Arctic Oceans.



(b) Describe **two** physical adaptations of the ringed seal to live in water. [2]

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Ringed seals belong to more than one trophic level as they feed on zooplankton and fish. They are secondary consumers when they feed on zooplankton.

(c) State the trophic level of zooplankton. [1]

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Question 2 - working space

**2.** It has been hypothesized that asteroids were the primary source of Earth's water. What has caused the retention of water on Earth?

A. The gases of the early atmosphere absorbed water vapour.

B. High atmospheric pressure prevented water vapour from escaping.

C. Temperatures on Earth allowed condensation of water.

D. Water was trapped in the pores of newly formed rocks.

**1.** What allows the movement of water under tension in the xylem?

A. Adhesion of water molecules to dissolved mineral salts

B. Cohesion of water molecules due to hydrogen bonding

C. Adhesion between water molecules due to uneven sharing of charges

D. Cohesion between water molecules and other polar substances

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# Nucleic acids

8 questions

**2.** What is a nucleosome?

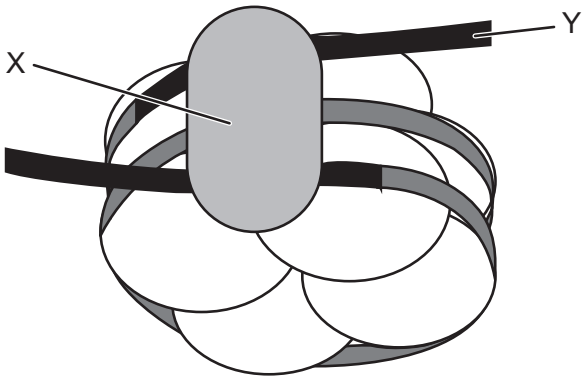
A. DNA wrapped around histone proteins in a eukaryotic cell

B. RNA bound to ribosomes in a eukaryotic cell

C. A region of the nucleus in a eukaryotic cell

D. Genetic material within a viral capsule

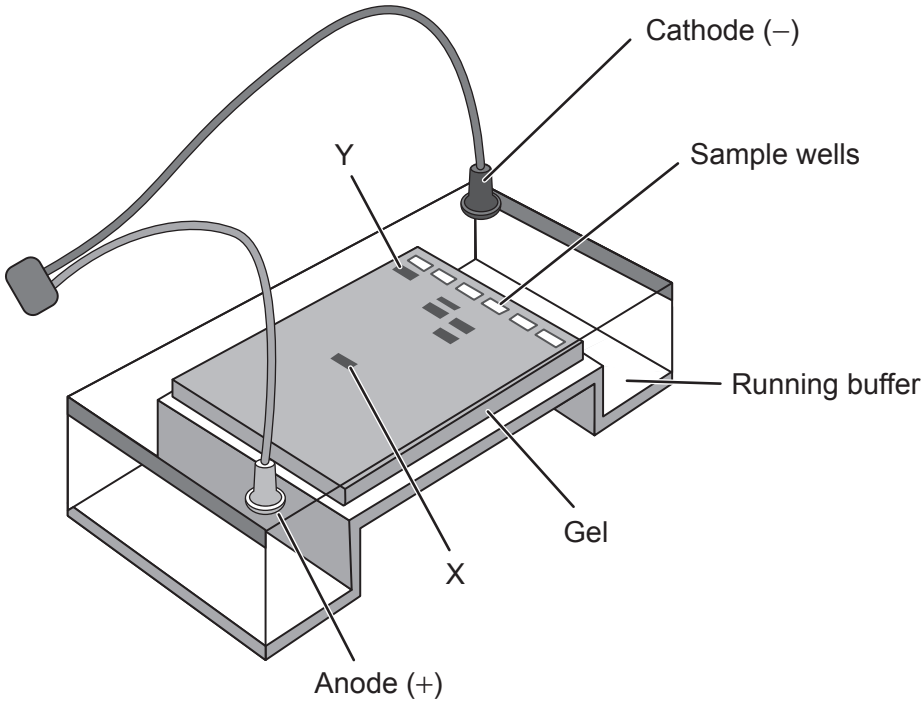
**2.** The diagram shows a structure found in a eukaryotic nucleus.




What is represented by X and Y?

| | X | Y |
|---|---|---|
| A. | Ribosome | mRNA |
| B. | Histone | Linker DNA |
| C. | Nucleosome | mRNA |
| D. | RNA polymerase | Linker DNA |

**9.** The diagram shows a gel electrophoresis apparatus.




What can be deduced from the diagram?

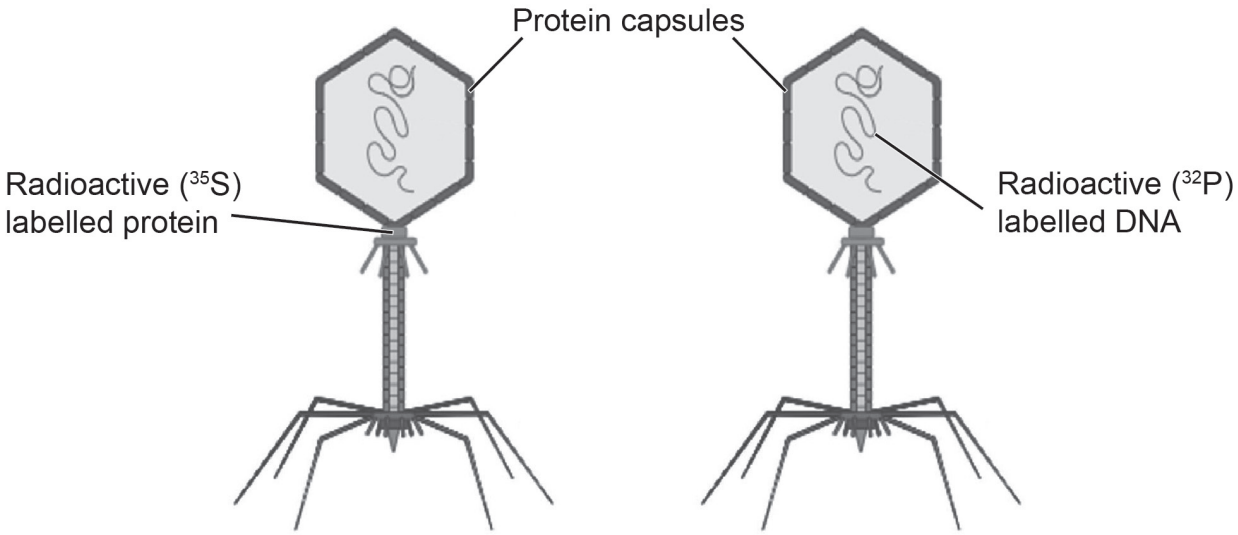
A. X is the smallest fragment.

B. Y is positively charged.

C. X is moving towards the cathode.

D. Y travels at the greatest rate.

**2.** Hershey and Chase used bacteriophages to investigate the chemical nature of genes. The phosphorus in the DNA and the sulphur in the protein of the bacteriophages were radioactively labelled.




The data obtained after the infection and then centrifugation of bacterial cells is shown in the table.

| Sample source | Supernatant | Pellet |
|---|---|---|
| **Concentration of radioactive sulphur** | high | low |
| **Concentration of radioactive phosphorus** | low | high |

What did Hershey and Chase conclude from their experiment?

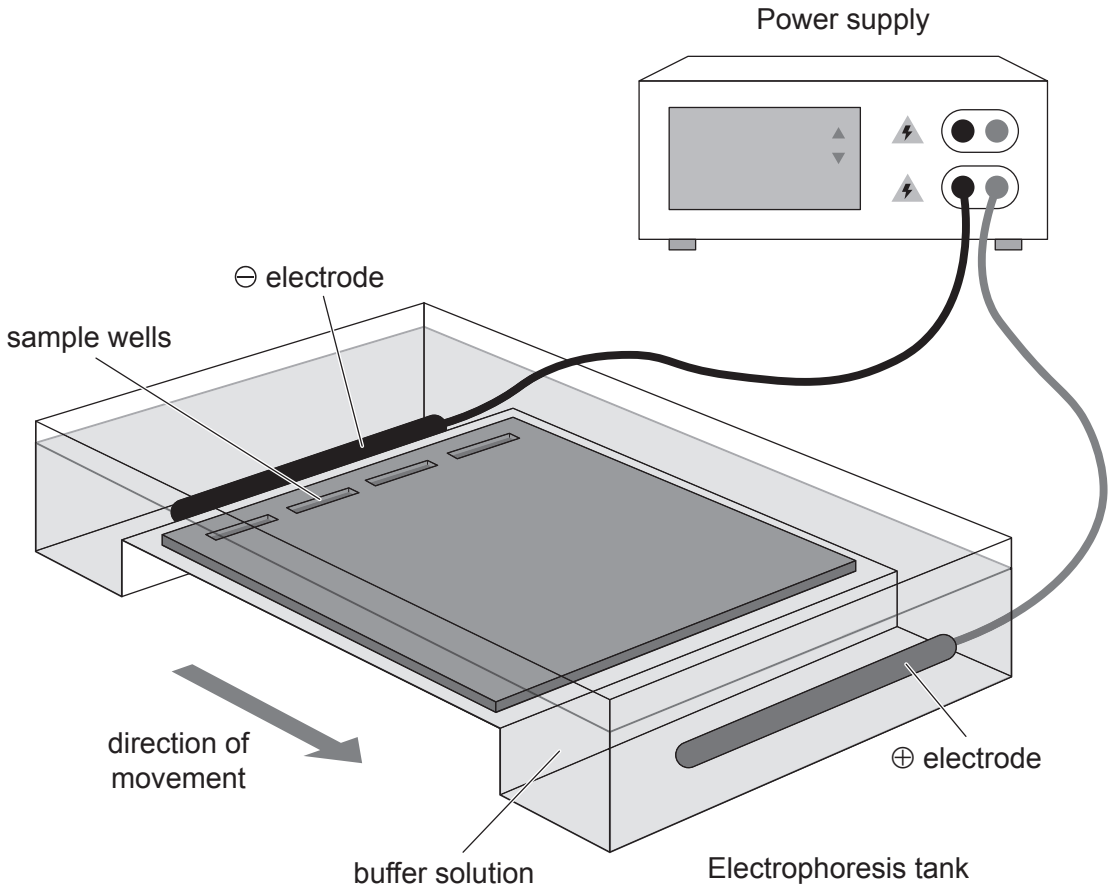
A. Viral DNA was found within the bacterial cells.

B. Viruses infect bacterial cells with proteins.

C. DNA was mainly outside the bacterial cells.

D. Neither protein nor DNA were chemicals making up genes in viruses.

**9.** Samples of DNA can be separated by gel electrophoresis.




Which fragments of DNA would travel the furthest on the gel?

| | Fragment size / kB | Fragment charge |
|---|---|---|
| A. | 4 | negative |
| B. | 10 | negative |
| C. | 10 | positive |
| D. | 2 | positive |

**1.** Which of the following describes the molecular structure of DNA?

I. Complementary base pairing occurs within the molecule
II. Contains deoxyribose
III. Contains thymine

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

**20.** What is a function of histones?

A. Supercoiling of DNA during binary fission in prokaryotes

B. Synthesis of proteins

C. Formation of microtubules during mitosis

D. Condensation of DNA

**4.** Before the structure of DNA was known, researchers analysed the ratios of the DNA bases found in cells of different species. The tetranucleotide hypothesis, formulated in 1910, proposed that DNA was made up of equal amounts of adenine, guanine, cytosine and thymine.

This hypothesis was revised following the publication of Chargaff's paper in 1951, from which data is shown in the table.

| | Ratios | | | | |
|---|---|---|---|---|---|
| **Source** | **A:G** | **T:C** | **A:T** | **G:C** | **purines:pyrimidines** |
| **Ox** | 1.29 | 1.43 | 1.04 | 1.00 | 1.10 |
| **Human** | 1.56 | 1.75 | 1.00 | 1.00 | 1.00 |
| **Chicken** | 1.45 | 1.29 | 1.06 | 0.91 | 0.99 |
| **Salmon** | 1.43 | 1.43 | 1.02 | 1.02 | 1.02 |
| **Wheat** | 1.22 | 1.18 | 1.00 | 0.97 | 0.99 |
| **Yeast** | 1.67 | 1.92 | 1.03 | 1.20 | 1.00 |

(a) State **one** example of a purine. [1]

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(b) Explain how these results falsify the tetranucleotide hypothesis. [2]

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(c) Using these data, evaluate the hypothesis that the ratio of purines to pyrimidines in DNA in all organisms is 1.00. [1]

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**(This question continues on the following page)**

**(Question 4 continued)**

(d) Discuss how these results are consistent with the existence of a last universal common ancestor (LUCA). [2]

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(e) Discuss the evidence of the relationship between genome size and the complexity of organisms. [4]

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**References:**

**2.** Jamieson, J.D. and Palade, G.E., 1967. Intracellular transport of secretory proteins in the pancreatic exocrine cell. *Journal of Cell Biology*, 34, pp.597–615.

**3.** **image**
Ninjatacoshell, 2009. *Medicago italica root nodules 2.* [image online] Available at: <https://commons.wikimedia.org/wiki/File:Medicago_italica_root_nodules_2.JPG> [Accessed 16 July 2020].

**graph**
Fujikake, H., Yamazaki, A., Ohtake, N., Sueyoshi, K., Matsuhashi, S., Ito, T., Mizuniwa, C., Kume, T., Hashimoto, S., Ishioka, N.-S., Watanabe, S., Osa, A., Sekine, T., Uchida, H., Tsuji, A. and Ohyama, T., 2003. [Soybean root nodule growth]. *Journal of Experimental Botany*, 54(386), pp.1379–1388. REFERENCE REDACTED.

**4.** Chargaff, E., 1951. Structure and function of nucleic acids as cell constituents. *Federation proceedings*, 10(3), pp.654–659.

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Question 4 - working space

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# Origins of cells

3 questions

**2.** Which planet in the table falls within the “Goldilocks zone” and may be capable of sustaining extraterrestrial life?

| | **Planet** | **Temperature / °C** | **Atmosphere** | **Gravity / g** |
|---|---|---|---|---|
| A. | Kepler-22b | −11 to 16 | unknown | 2.4 |
| B. | WASP-39b | 750 | hydrogen, helium and other elements | 25.0 |
| C. | Gliese 876d | 50 to 80 | high levels of toxic gases | 20.0 |
| D. | Kepler-16b | −100 | unknown | 0.9 |

**12.** The Miller–Urey experiment carried out in 1952 tested the hypothesis of the chemical origin of life. What were the key findings?

A. Living cells could be produced from a mixture of chemicals.

B. Complex organic molecules could form under simulated primordial conditions.

C. Life could spontaneously emerge without external influence.

D. DNA and RNA could self-replicate in a prebiotic environment.

**13.** How does the Miller-Urey experiment contribute to an explanation of the origin of life?

A. It shows how phospholipids form protocells in specific laboratory conditions.

B. It explains how organic molecules arise from inorganic ones under certain environmental conditions.

C. It explains the synthesis of RNA, recreating deep sea vent conditions in the laboratory.

D. It shows how the last universal common ancestor (LUCA) evolved from vesicles.

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# Cell structure

4 questions

**12.** In 2020, Peplow and co-workers obtained an image showing a $GABA_A$ cell membrane protein receptor. The technique they used allowed them to take the image at a particular moment in time by treating the sample so that the protein molecules were firmer and more stable. What technique did they use to obtain this image?

A. Electrophoresis

B. Immunofluorescence

C. Cryogenic electron microscopy

D. Fluorescent dyes

**12.** What is a feature of immunofluorescence in light microscopy?

A. Can only be used on dead cells

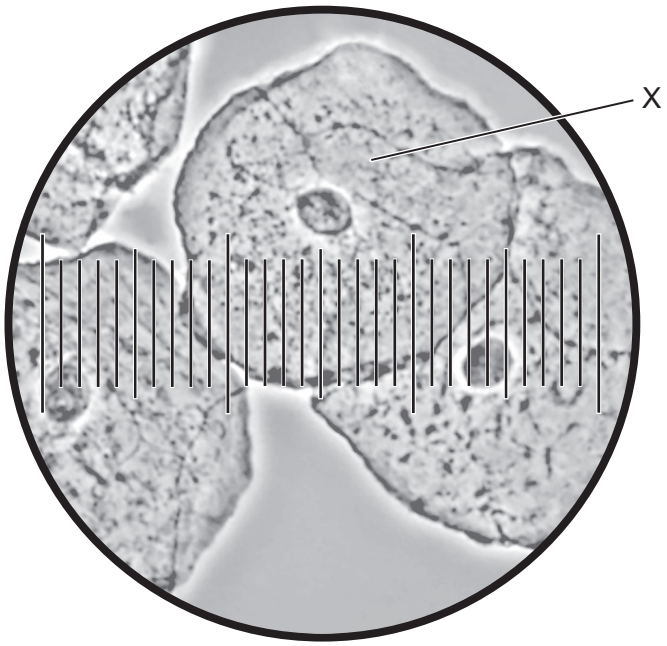
B. Enables higher resolution

C. Attaches a fluorescent stain to an antibody

D. Attaches a fluorescent stain to an antigen

**Turn over**

**1.** The micrograph is an image of human cheek cells viewed with a light microscope.




(a) Identify the piece of equipment that is used together with the microscope to measure the size of the cells. [1]

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(b) Each small division of the scale in the micrograph is equivalent to 2.5µm.

(i) Calculate the diameter of the cell labelled X. [1]

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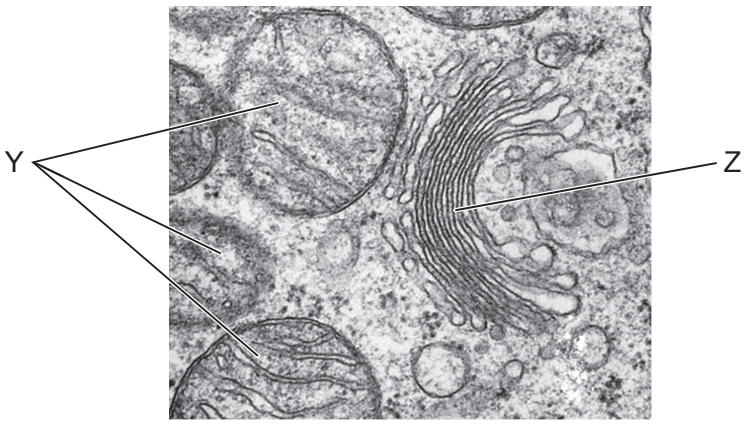
**(This question continues on the following page)**

**(Question 1 continued)**

(ii) Calculate the magnification of the image. [1]

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(c) The electron micrograph shows part of an animal cell.




Outline the functions of Y and Z in the cell. [2]

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**(Question 1 continued)**

(d) Viruses depend on living cells to reproduce. Compare and contrast the lysogenic and lytic cycles of the bacteriophage lambda. [3]

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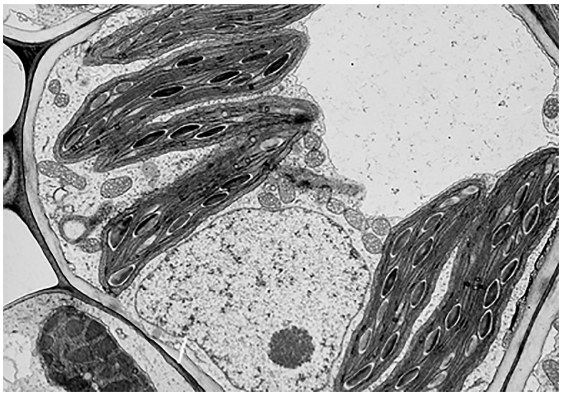
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Question 1 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**2.** The cytoplasm in eukaryotic cells is compartmentalized into membrane-bound organelles, as seen in this electron micrograph of a plant cell.



(a) State **two** membrane-bound organelles that are common to both plant and animal cells. [2]

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(b) (i) State **one** organelle that is found in a plant cell but not in an animal cell. [1]

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(ii) State **one** organelle that is common to prokaryotic and eukaryotic cells. [1]

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Question 2 - working space

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# Viruses

8 questions

**13.** What is a difference between the lytic and the lysogenic cycle of the bacteriophage lambda?

A. Only in the lytic cycle is lambda DNA inserted into the host DNA.

B. Only in the lysogenic cycle is the host metabolism used to replicate.

C. Only in the lytic cycle is the host metabolism used to replicate.

D. Only in the lysogenic cycle is lambda DNA inserted into the host DNA.

**13.** What is a difference between the lytic and the lysogenic cycle of the bacteriophage lambda?

A. Only in the lytic cycle is lambda DNA inserted into the host DNA.

B. Only in the lysogenic cycle is the host metabolism used to replicate.

C. Only in the lytic cycle is the host metabolism used to replicate.

D. Only in the lysogenic cycle is lambda DNA inserted into the host DNA.

**28.** What is a reason for the ineffectiveness of antibiotics against viruses?

A. Viruses have genes for antibiotic resistance.

B. Viruses do not have cell membranes.

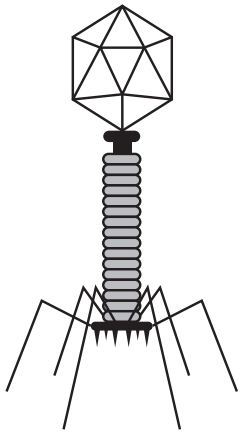
C. Antibiotics are only effective against archaea.

D. Antibiotics target metabolic processes.

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**4.** The diagram shows the structure of a bacteriophage lambda virus.



(a) On the image, label the capsid. [1]

(b) Describe **one** reason that viruses are not considered to be living. [1]

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(c) Explain how the bacteriophage lambda reproduces in the lysogenic cycle. [3]

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Question 4 - working space

**12.** What mode of existence do viruses exhibit?

A. Obligate parasite

B. Facultative parasite

C. Obligate heterotroph

D. Predator

**Turn over**

**13.** Which feature is common to all viruses?

A. Has a capsid

B. Contains RNA

C. Contains cytoplasm

D. Enveloped in host cell membrane

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**7.** At all levels of biological organization there is diversity.

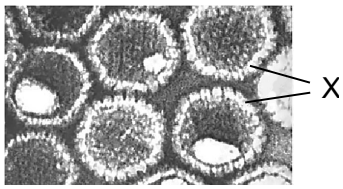
(a) Explain the diversity of possible base sequences in nucleic acids. [4]

(b) Describe, with examples, the diversity of structure in viruses. [7]

(c) Suggest how the diversity of chromosome number in animals and plants has evolved. [4]

Question 7 - working space

**14.** The image shows a group of enveloped viral particles.




What is the most likely composition of the structure labelled X?

A. Membrane derived from the host cell

B. Viral DNA

C. Viral cell walls

D. Viral enzymes

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# Diversity of organisms

3 questions

**13.** The table shows features of three types of cells (X, Y and Z).

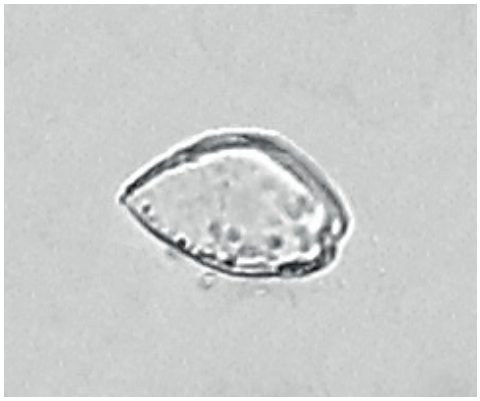
| Feature | Cell | | |
|---|---|---|---|
| | **X** | **Y** | **Z** |
| Cell wall | absent | present | present |
| Centrioles | present | absent | absent |
| Large vacuole | absent | present | present |
| Plastids | absent | present | absent |

To which kingdom do each of the cells belong?

| | **X** | **Y** | **Z** |
|---|---|---|---|
| A. | Animal | Fungi | Plant |
| B. | Fungi | Animal | Protist |
| C. | Animal | Plant | Fungi |
| D. | Protist | Animal | Plant |

**Turn over**

**34.** The image shows *Prorocentrum*, a coastal dinoflagellate that obtains energy from sunlight and from other organisms.



What best describes the mode of nutrition of *Prorocentrum*?

A. Mixotrophic

B. Autotrophic

C. Holozoic

D. Heterotrophic

**35.** What describes holozoic nutrition?

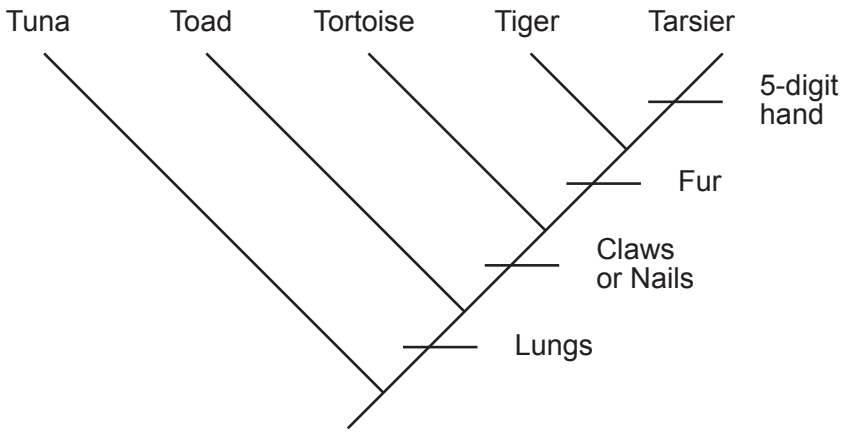
| | Nutrition type | Digestion |
|---|---|---|
| A. | chemoautotrophic | none |
| B. | photoautotrophic | none |
| C. | saprotrophic | external |
| D. | heterotrophic | internal |

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# Classification and cladistics

10 questions

**21.** What can be deduced from the cladogram?




A. Tortoises do not have lungs.

B. A tortoise and a tarsier are more closely related than a tiger and a tarsier.

C. A toad and a tuna are more closely related than a tiger and a tuna.

D. Tigers have fur and 5-digit hands.

**Turn over**

**22.** Classification systems can change based on new evidence. What evidence was used to produce the domains of organisms we now recognize?

A. mRNA sequence

B. rRNA sequence

C. Amino acid sequence

D. DNA sequence

**Turn over**

**22.** What is one application of DNA barcoding?

A. Selective breeding

B. Preserving an endangered species

C. Analysing environmental DNA

D. Sequencing a genome

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**9.** Evolution is the change in the heritable characteristics of a population.

(a) Describe the evidence for evolution from homologous structures. [4]

(b) Outline the conditions needed and the use of the Hardy–Weinberg equation to calculate allele frequencies in a population. [3]

(c) Explain how evolutionary relationships and cladograms can be used for classification. [8]

Question 9 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**7.** (a) Outline what is meant by the “root” and “node” with reference to a cladogram. [2]

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(b) Discuss the use of amino acid sequences of proteins as the basis for constructing cladograms. [3]

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(c) Identify a type of information, other than amino acid sequence, that could be used to construct a cladogram. [1]

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(d) Outline the use of parsimony analysis when choosing between different possible cladograms. [1]

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Question 7 - working space

**21.** The table shows the binomial naming of four species.

| Organism | Genus | Species |
|---|---|---|
| W | *Felis* | *catus* |
| X | *Conus* | *catus* |
| Y | *Ameiurus* | *catus* |
| Z | *Felis* | *silvestris* |

What can be concluded?

A. W, X and Y are the most closely related.

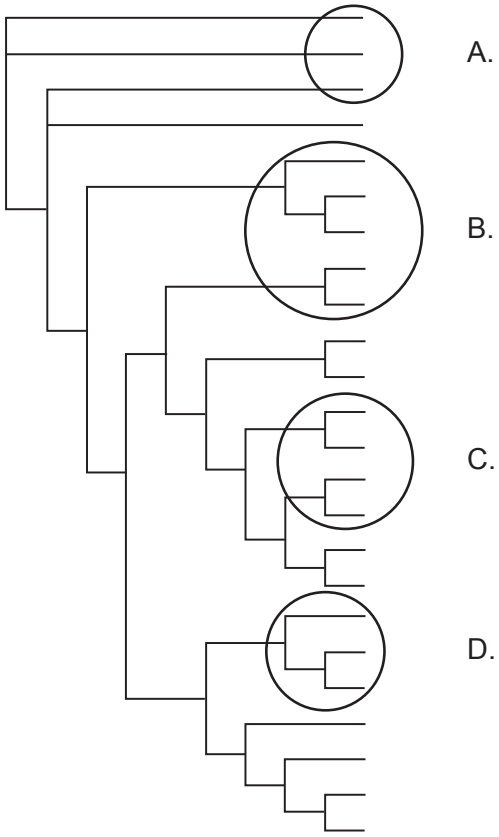
B. X and Y are the most closely related.

C. W and Z are the most closely related.

D. W is equally related to all the other species.

**Turn over**

**22.** Which encircled area shows a clade?



**21.** Domain is a taxonomic level above kingdom that has been used to classify living organisms into three groups.

What has provided the evidence for classification of organisms into domains?

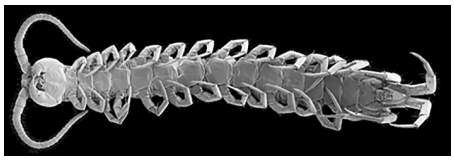
A. Ribosomal RNA (rRNA) base sequences

B. Mitochondrial DNA base sequences

C. Cell wall structure

D. Amino acid sequence of ATP synthase

**24.** The image shows an organism from the phylum Arthropoda.

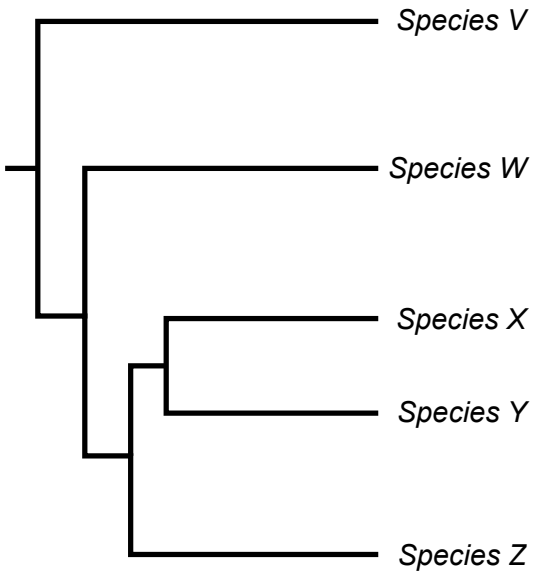


A dichotomous key was used to classify this arthropod. To which group does it belong?

Dichotomous key:

1. antennae pointing forwards . . . . . go to 2
   antennae pointing sideways . . . . . go to 3
2. branched antennae . . . . . A.
   unbranched antennae . . . . . B.
3. one pair of legs in each body segment . . . . . C.
   two pairs of legs in each body segment . . . . . D.

**25.** Scientists studied differences in the base sequences of a gene found in five animal species in order to determine their evolutionary relationships. A cladogram was constructed based on these differences.




What can be deduced from the cladogram?

A. There are only three clades shown.

B. Morphological differences between V and Z increase with time.

C. There is only one difference between the amino acid sequences of X and Y.

D. Y and Z have a more recent common ancestor than W and X.

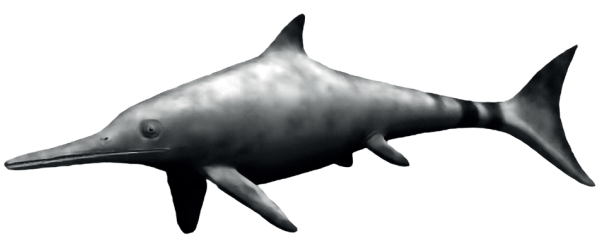
**Turn over**

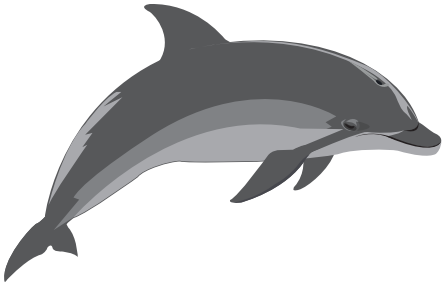
APOLLO

# Evolution and speciation

12 questions

**33.** The images show an ichthyosaurus and a dolphin. Ichthyosaurus is an extinct aquatic reptile, known only from fossil remains. Dolphins are mammals.





How have these species evolved?

A. Their streamlined bodies show divergent evolution.

B. Their streamlined bodies are analogous structures.

C. Their pentadactyl limbs are an example of convergent evolution.

D. Their pentadactyl limbs are analogous structures.

**21.** What applies to the process of speciation?

| | Mechanism | Change |
|---|---|---|
| A. | Reproductive isolation | Populations become more different in their traits |
| B. | Behavioural isolation | Allele frequency remains constant |
| C. | Interbreeding | Stabilizing selection occurs |
| D. | Temporal isolation | Hybrids produced |

**33.** What describes analogous structures?

A. They are formed from divergent evolution.

B. They share a common ancestor.

C. They came from different evolutionary origins.

D. They have the same structure but different functions.

**Turn over**

**34.** How are interspecific hybrids formed?

A. Cross-breeding members of different species

B. Selective breeding between individuals of the same species

C. Reproductive isolation between different species

D. Mutations within individuals of a given species

**21.** The salamander genus *Ensatina* from California, USA, has evolved several different forms, depending on location. Two such forms are shown.



What determines if these forms are members of the same species?

A. Have similar appearance

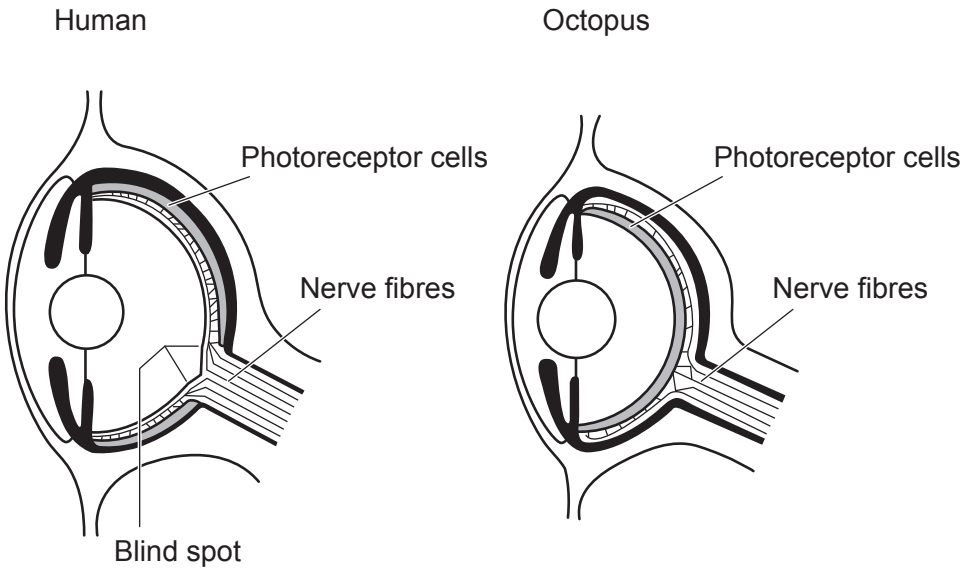
B. Populations mix freely

C. Produce fertile offspring

D. Can interbreed

**Turn over**

**33.** Human and octopus eyes have a similar structure and function but humans and octopuses have a different evolutionary origin.




What explains the similar structure of these eyes?

| | Type of evolution | Relationship of structures |
|---|---|---|
| A. | convergent | analogous |
| B. | convergent | homologous |
| C. | divergent | homologous |
| D. | divergent | analogous |

**Turn over**

**1.** The table shows the number of amino acids that are different in the sequences of the protein FOXP2 from a human compared with four other primate species.

| Primate species | Number of amino acid differences compared to human |
|---|---|
| *Pan paniscus* | 2 |
| *Pan troglodytes* | 2 |
| *Gorilla gorilla* | 2 |
| *Pongo pygmaeus* | 3 |

(a) Identify the total number of different genera named in the table. [1]

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(b) Deduce whether it is possible to conclude that *Pan paniscus* and *Gorilla gorilla* are more closely related to each other than to humans. [2]

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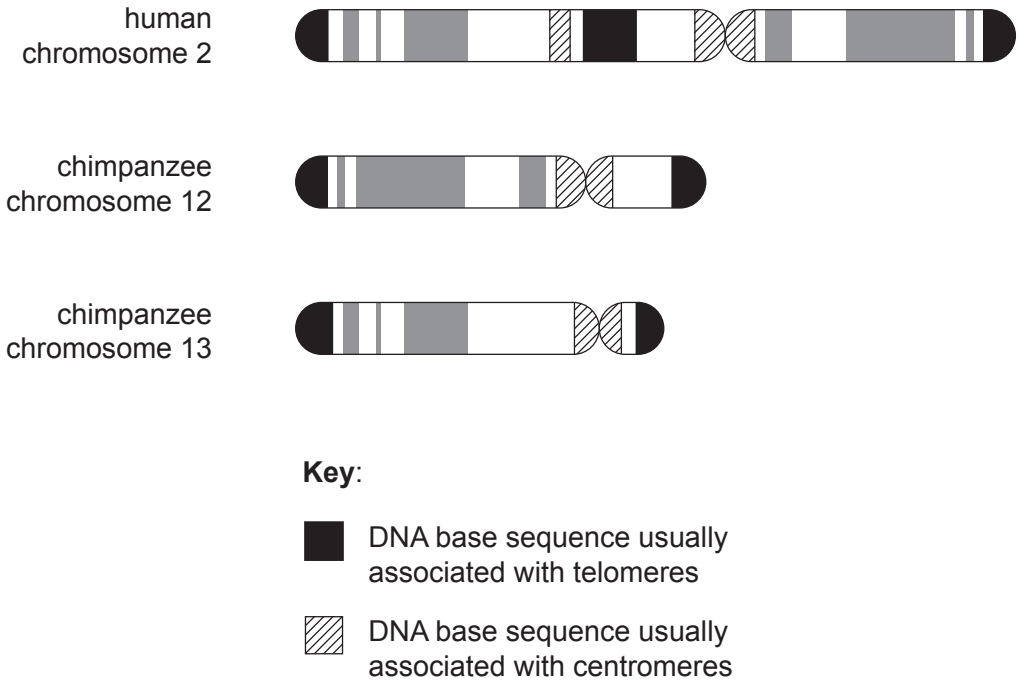
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**(This question continues on the following page)**

**(Question 1 continued)**

Humans have 46 chromosomes. However, each of the four other primates in the table have 48 chromosomes.

Scientists analysed chromosome 2 in humans and chromosomes 12 and 13 in chimpanzees (*Pan troglodytes*). The diagrams show a summary of their findings.




(c) Using evidence from the diagrams, justify the hypothesis that chromosome 2 in humans arose from the fusion of chromosomes 12 and 13 with a shared primate ancestor. [4]

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**(This question continues on page 5)**

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Answers written on this page
will not be marked.

**(Question 1 continued)**

(d) Some infectious diseases in humans are caused by viruses that originated in other primates.

(i) State **one** structural feature of a virus. [1]

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(ii) State the term used for an infectious disease that can transfer from other species to humans. [1]

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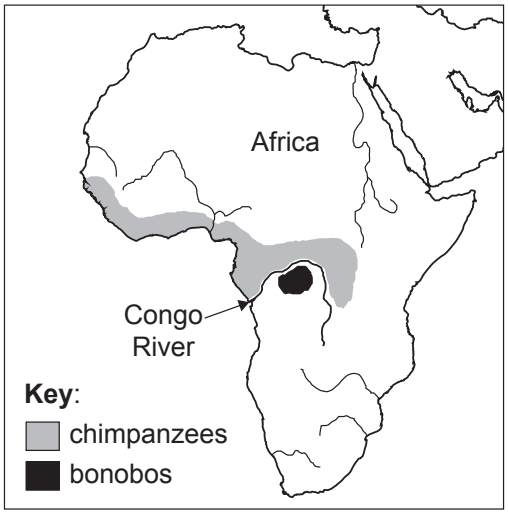
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Question 1 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**7.** The map shows the distribution of chimpanzees (*Pan troglodytes*) and bonobos (*Pan paniscus*) on either side of the Congo River as it flows towards the Atlantic Ocean in the Democratic Republic of Congo. Bonobos occupy the dense wet forest south of the Congo River, whereas chimpanzees occupy a forested habitat north of the river. Both species are descended from a common ancestor.




(a) State the type of speciation shown by the two species. [1]

. . . . . .
. . . . . .

(b) Describe how both species evolved from the common ancestor. [3]

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**(This question continues on the following page)**

**(Question 7 continued)**

(c) The bonobo is classified as an endangered species. Explain how deforestation could contribute to the decline in the population size of bonobos. [2]

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Question 7 - working space

**33.** What is evidence for evolution?

I. Homologous structures such as pentadactyl limbs
II. Domestication of dogs from wolves
III. Inheritance of acquired characteristics

A. I and II only

B. I and III only

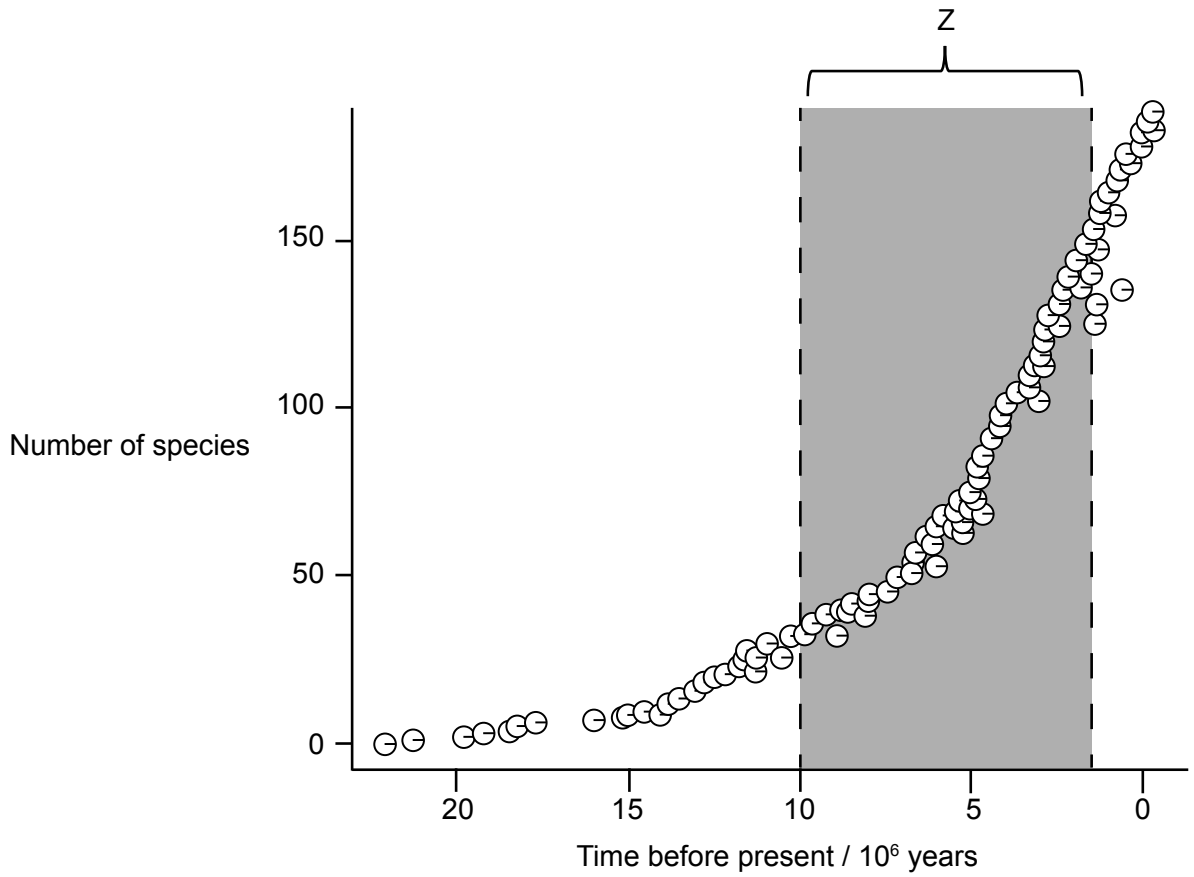
C. II and III only

D. I, II and III

**33.** What is the evolutionary origin and function of analogous structures in living organisms?

| | Evolutionary origin | Function |
|---|---|---|
| A. | different origin | similar function |
| B. | different origin | same or different function |
| C. | same or different origin | same function |
| D. | same origin | different function |

**32.** The number of hummingbird species in South America has increased continuously as shown in the graph.




What could be a reason for the increase in the number of hummingbird species during the period labelled Z?

A. Food and shelter are plentiful and there is little intraspecific competition.

B. Closely related species can coexist indefinitely in the same niche.

C. A wide range of unoccupied potential niches exists, leading to adaptive radiation.

D. There are few limiting factors on the population size of hummingbirds.

**33.** Polyploidy has been a cause of rapid speciation in some plant genera, such as *Helianthus*. Which observation is evidence that speciation has occurred?

A. A polyploid plant reproduces asexually.

B. A polyploid plant produces male and female gametes.

C. Fertile offspring are produced when a polyploid plant crosses with a diploid plant.

D. Fertilization can occur between polyploid individuals.

APOLLO

# Conservation of biodiversity

4 questions

**34.** The North Island giant moa (*Dinornis novaezealandiae*) went extinct some time between the arrival of humans in New Zealand and the 1800s.



What do scientists believe to be the cause of this extinction?

A. Deforestation

B. New diseases

C. Competition with other megafauna

D. Overhunting

**38.** Which action is part of the rewilding of ecosystems?

A. Applying fertilizer

B. Removal of apex predators

C. Reintroduction of keystone species

D. Restricting size for easier management

**Turn over**

**34.** What could minimize the loss of biodiversity?

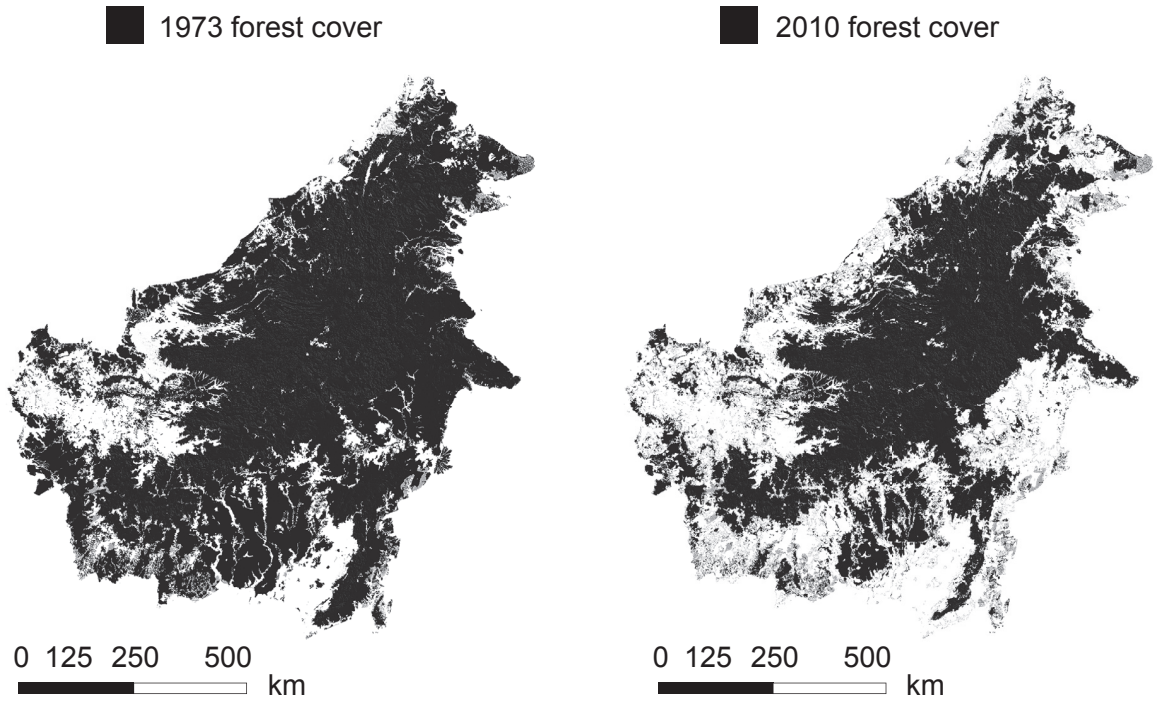
A. Increase the rate of deforestation

B. Introduce species into new environments to control predation

C. Reduce the use of renewable energy

D. Rewilding of degraded ecosystems

**34.** The satellite images show changes in the area covered by forest, much of which is mixed dipterocarp forest, on the island of Borneo in Southeast Asia.




Which human activities are most likely to have caused the changes shown in the map?

A. Logging and palm oil plantation

B. Logging and rewilding

C. Mining and afforestation

D. Afforestation and palm oil plantation

**Turn over**

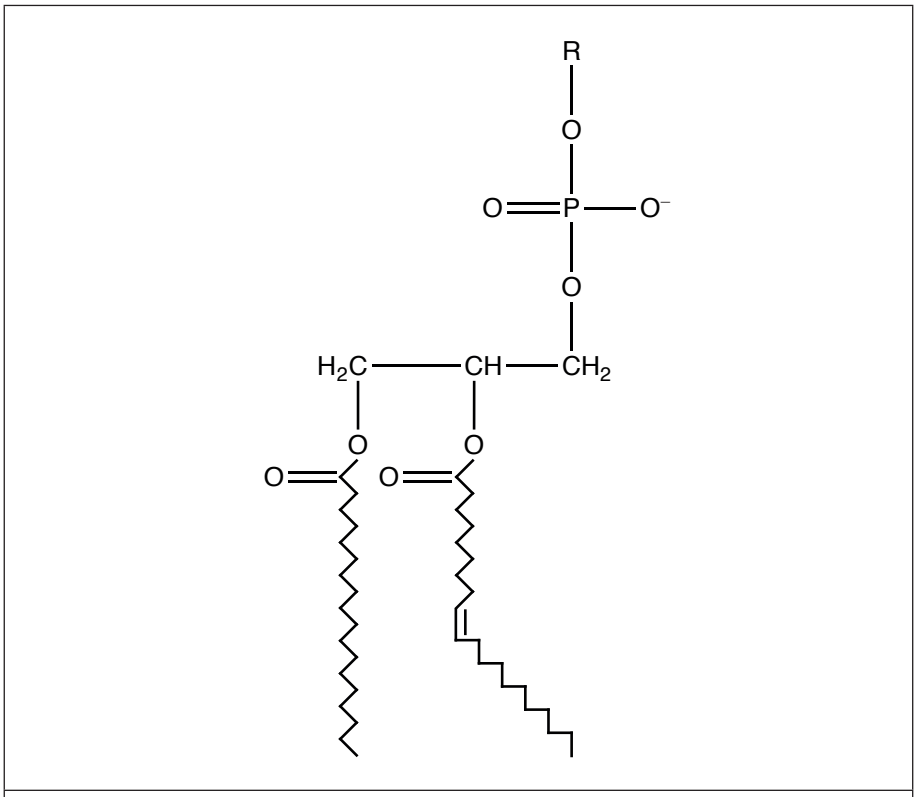
APOLLO

# Carbohydrates and lipids

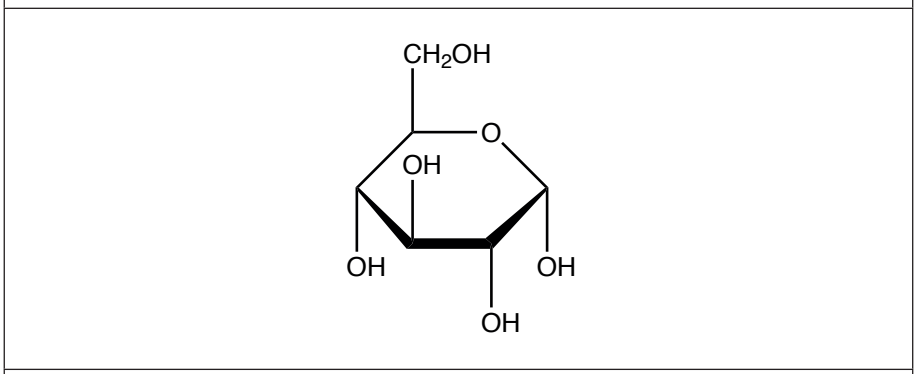
7 questions

**3.** Which of these molecules is amphipathic?

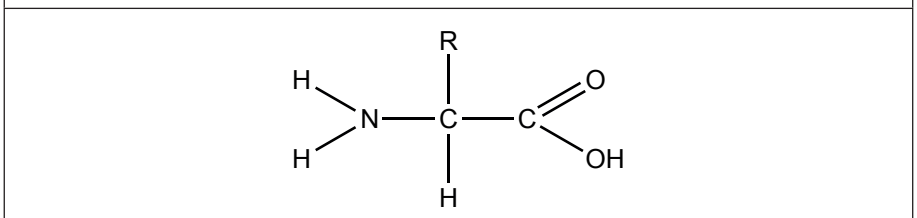
A.



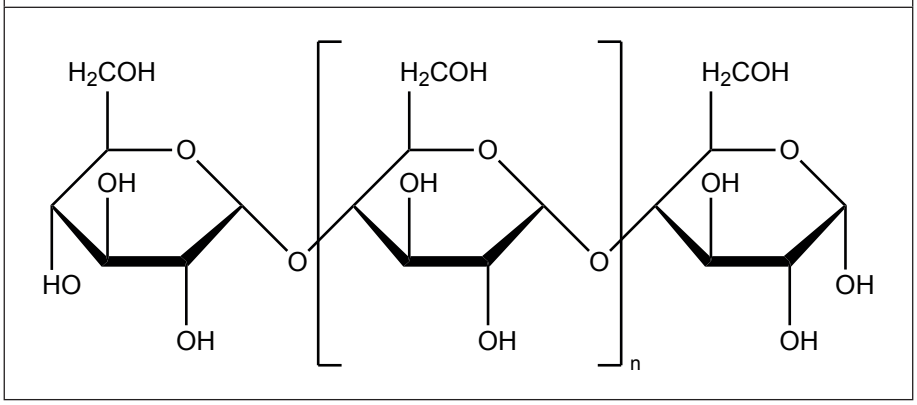

B.




C.




D.




**Turn over**

**3.** What is the function of cellulose in plant cells?

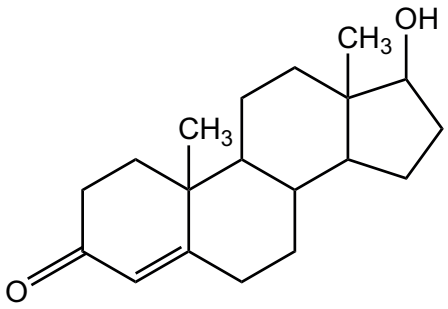
A. It increases the strength of cell walls.

B. It is a source of energy for plants.

C. It maintains the structure of the vacuole.

D. It increases the permeability of the cell membranes.

**3.** A simplified diagram of molecule X is shown.




What describes molecule X?

A. Lipid able to pass through the bilayer of membranes

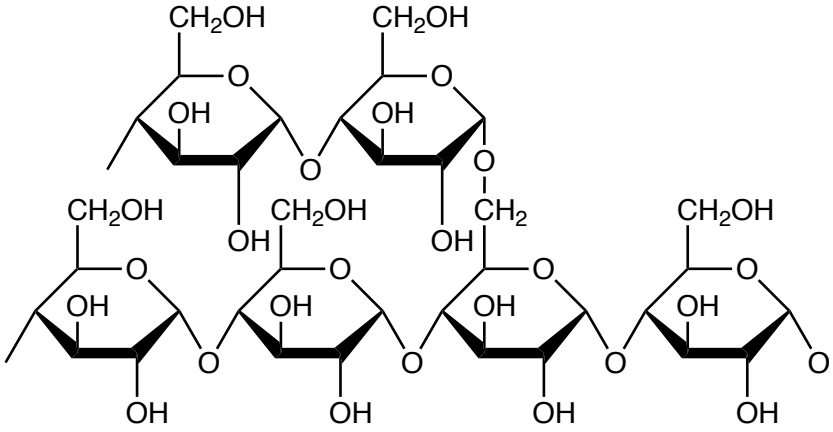
B. Lipid used for energy storage in mammals

C. Carbohydrate transported in the blood

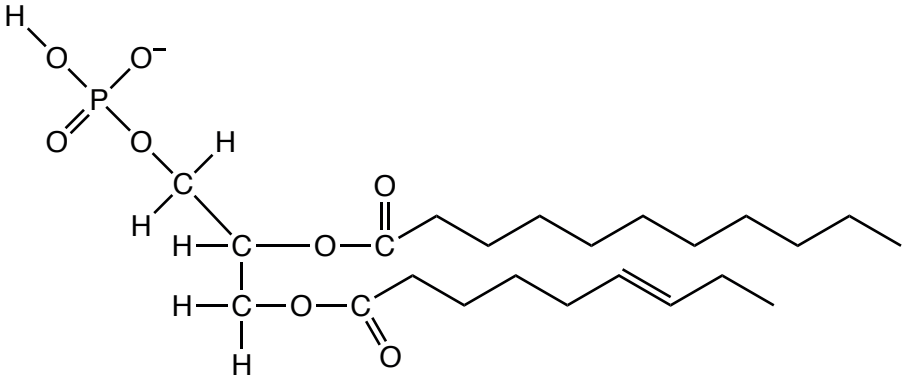
D. Carbohydrate used for energy storage in plants

**3.** Which molecular diagram shows a phospholipid molecule?

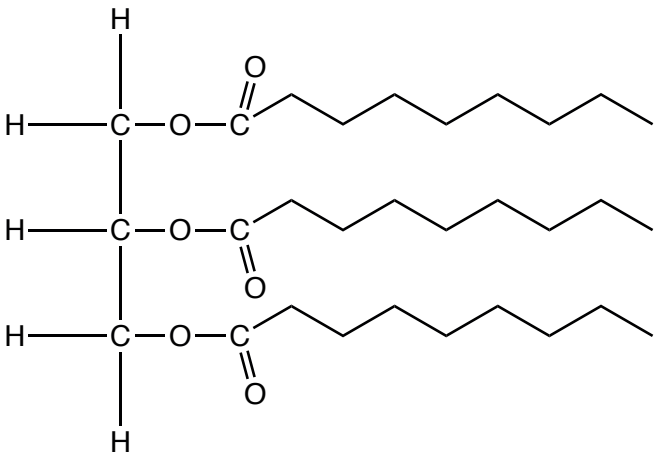
A.



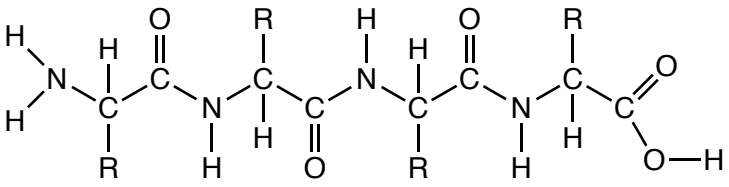
B.



C.



D.



**Turn over**

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**8.** Monosaccharides can be used to make polysaccharides, and can also be combined with other types of carbon compound to form molecules such as nucleotides.

(a) Using named examples, explain the relationships between the structure of carbohydrates and their properties and functions in cells. [7]

(b) Outline, with examples, the wide range of uses of adenosine triphosphate (ATP) in cells. [5]

(c) Distinguish between the roles and locations of reduced hydrogen carriers in aerobic respiration and photosynthesis. [3]

Question 8 - working space

**4.** Which molecules are produced during the hydrolysis of a triglyceride molecule?

A. Water and glycerol

B. Fatty acids and glycerol

C. Water and fatty acids

D. Water and lipids

**5.** The structure of monomers affects the structure and function of the polymers they form. Which row describes the structural features of polysaccharides made from alpha-glucose and beta-glucose?

| | Monomer | Polymer | Shape of polymer |
|---|---|---|---|
| A. | alpha-glucose<br>beta-glucose | starch<br>cellulose | unbranched, straight<br>branched, helical |
| B. | alpha-glucose<br>beta-glucose | starch<br>cellulose | branched, helical<br>unbranched, straight |
| C. | alpha-glucose<br>beta-glucose | cellulose<br>starch | branched, helical<br>unbranched, straight |
| D. | alpha-glucose<br>beta-glucose | cellulose<br>starch | unbranched, straight<br>branched, helical |

**Turn over**

APOLLO

# Proteins

6 questions

**4.** Which row correctly matches the level of structure of a protein molecule with the bonds that stabilize it?

| | **Level of structure** | **Bonds** |
|---|---|---|
| A. | primary | peptide and hydrogen bonds between amine and carboxyl groups |
| B. | secondary | hydrogen bonds between R-groups of amino acids |
| C. | tertiary | disulfide, hydrogen and ionic bonds between R-groups of amino acids |
| D. | quaternary | covalent bonds between hydrophobic and hydrophilic regions on the polypeptide subunits |

**4.** Myoglobin is a globular protein in which nearly all the non-polar R-groups point towards the inside of the molecule. The outside surface contains all the polar R-groups. What can be deduced from this?

A. Disulfide bonds occur on the inside.

B. Hydrogen bonds form with water on the outside.

C. Ionic bonds form with water on the outside.

D. Covalent bonds occur on the inside.

**4.** Diagrams of three different proteins, X, Y and Z, are shown.

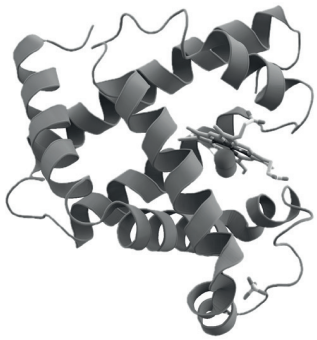
X



Y



Z



Which row describes the structure of each protein shown?

| | X | Y | Z |
|---|---|---|---|
| A. | quaternary | globular | secondary |
| B. | conjugated | fibrous | globular |
| C. | tertiary | quaternary | primary |
| D. | globular | secondary | fibrous |

**Turn over**

**3.** The table shows some essential and non-essential amino acids.

| Essential amino acids | Non-essential amino acids |
|---|---|
| valine | alanine |
| lysine | glycine |

What is a valid conclusion for an amino acid in the table?

A. Lysine is synthesized by the human body.

B. Alanine can only be obtained from food.

C. Glycine is not used in the human body.

D. Valine must be supplied in the diet.

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**2.** (a) Some of the twenty amino acids that are linked together to make polypeptides in human cells are essential in the diet and others are not. Distinguish between essential and non-essential amino acids. [2]

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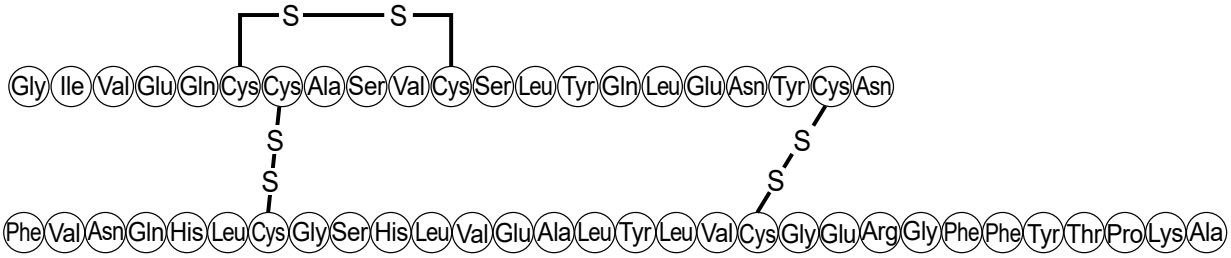
(b) The molecules of all amino acids include an amine group, a carboxyl group and an R-group. Draw a diagram to show the structure of an amino acid molecule. [3]

(c) The R-groups of amino acids are very diverse chemically. Interaction between R-groups in different parts of a polypeptide helps to determine the tertiary structure of a protein. List **two** types of interaction between R-groups. [2]

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Question 2 - working space

**6.** The diagram shows the structure of insulin.




From the diagram, what can be concluded about the structure of insulin?

A. It is composed of two polypeptide chains stabilized by disulfide bonds.

B. It is a simple protein composed of one continuous polypeptide chain.

C. It is a fibrous protein.

D. Its molecules do not display quaternary structure.

APOLLO

# Membranes and membrane transport

10 questions

**14.** The table shows concentrations of potassium ions and sodium ions maintained inside and outside human cells.

| | Concentration of ions / $10^{-3}$ mol dm$^{-3}$ | |
|---|---|---|
| **Ions** | **Intracellular** | **Extracellular** |
| Potassium | 135 | 4 |
| Sodium | 10 | 145 |

What explains these concentrations?

A. Active transport using a protein pump

B. Facilitated diffusion using a vesicle

C. Simple diffusion using a protein channel

D. Osmosis using an aquaporin

**15.** What is the role of clathrin molecules in the formation of vesicles?

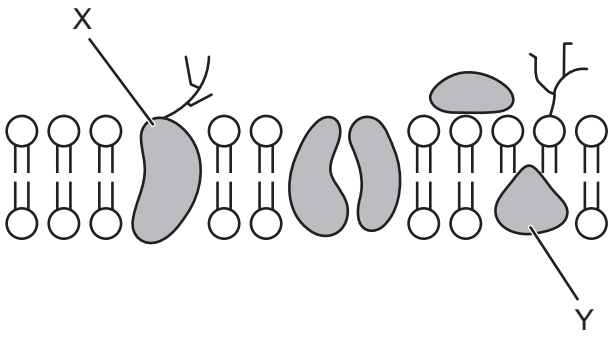
A. Facilitate transport of sodium and potassium ions

B. Bind together to help the membrane become indented

C. Adhere to the phospholipid bilayer to increase fluidity

D. Create a concentration gradient for uptake of substances into vesicles

**14.** The diagram shows a portion of fluid mosaic membrane.




What are the membrane structures X and Y?

| | X | Y |
|---|---|---|
| A. | glycoprotein | integral protein |
| B. | integral protein | peripheral protein |
| C. | channel protein | integral protein |
| D. | glycoprotein | peripheral protein |

## Section B

Answer **two** questions. Up to one additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**9.** The structure of membranes allows them to carry out many functions in cells.

(a) Discuss the use of membranes for compartmentalization in eukaryotic cells. [4]

(b) Describe the methods that are used to move substances into and out of cells. [7]

(c) Explain the role of membranes in the depolarization and repolarization of axons. [4]

Question 9 - working space

**4.** Which molecule is paired with the component of the cell membrane that allows it to pass through the membrane?

| | Molecule | Component of the cell membrane |
|---|---|---|
| A. | insulin | aquaporin |
| B. | glycogen | channel protein |
| C. | oestradiol | phospholipid bilayer |
| D. | carbon dioxide | pump protein |

**14.** Which type of protein uses energy from ATP to transfer particles across membranes against a concentration gradient?

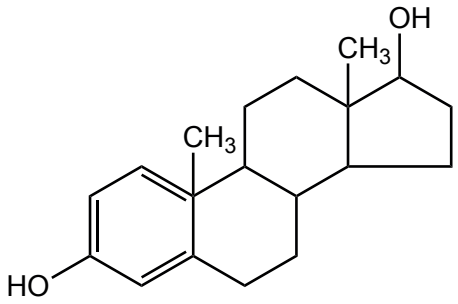
A. Glycoprotein

B. Pump protein

C. Aquaporin

D. Channel protein

**4.** Oestradiol is a steroid hormone.




How does oestradiol cross plasma membranes?

A. It can move between phospholipids because it is non-polar.

B. It can pass either between phospholipids or through channel proteins because it is amphipathic.

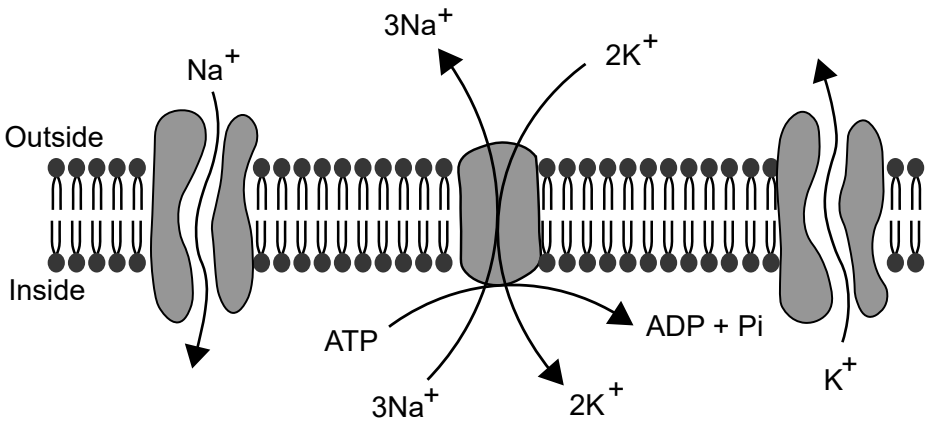
C. It can only pass through hydrophilic pores as its polar ends can form H bonds.

D. It must pass through channel proteins due to its large size.

**15.** Which changes would take place in the plasma membrane composition to maintain fluidity at very low temperatures?

| | Unsaturated fatty acids | Saturated fatty acids | Proteins |
|---|---|---|---|
| A. | increase | increase | decrease |
| B. | no change | increase | decrease |
| C. | increase | decrease | no change |
| D. | decrease | no change | increase |

**15.** The diagram shows the movement of ions that can occur across the membrane of a neuron.




From the diagram, what can be deduced about the movement of sodium ions?

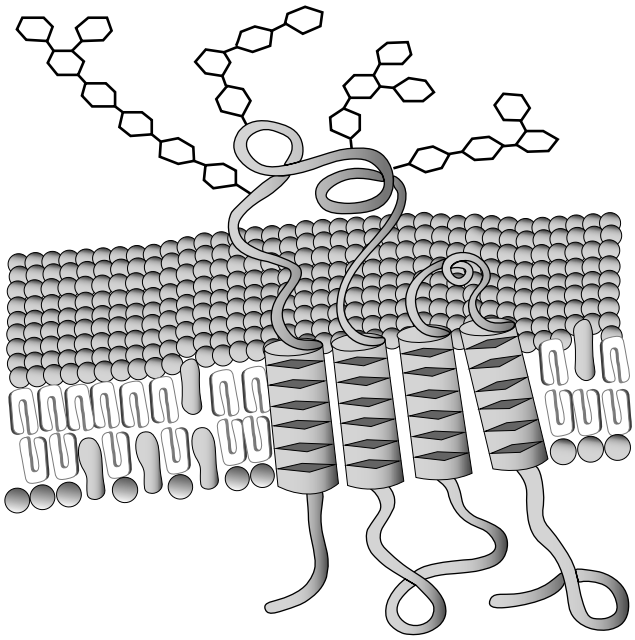
A. They are actively pumped out and some re-enter by facilitated diffusion.

B. They are actively pumped out and some re-enter by simple diffusion.

C. They diffuse out of the cell along with potassium ions.

D. There is a net movement of sodium ions into the cell.

**17.** The image shows a glycoprotein embedded in the phospholipid bilayer of a cell membrane.



Which feature of this glycoprotein can be deduced from the image?

A. It is a peripheral protein that allows attachment to neighbouring cells.

B. It is a channel protein that provides hydrophilic channels for carbohydrate transport.

C. It is an integral protein that may be involved in cell recognition.

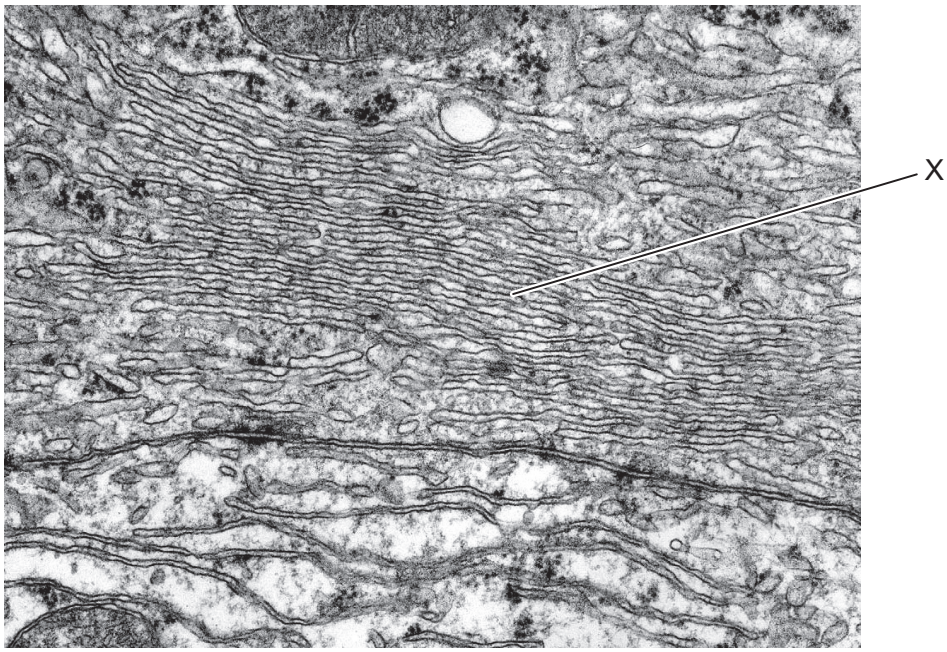
D. It is a transport protein that increases the permeability of the membrane to glucose.

APOLLO

# Organelles and compartmentalization

4 questions

**13.** The electron micrograph shows part of a eukaryotic cell.




What is the organelle labelled X?

A. Mitochondrion

B. Smooth endoplasmic reticulum

C. Lysosome

D. Nucleus

**16.** Eukaryotic cells have membrane-bound organelles. What is a property of one of these organelles?

A. The rough endoplasmic reticulum synthesises lipids for use outside the cell.

B. The nucleus has a double membrane to allow vesicle formation for intracellular transport.

C. The mitochondrion has enzymes and substrates of the Krebs cycle compartmentalized in the matrix.

D. The Golgi apparatus uses ribosomes to synthesise proteins for export from the cell.

**16.** What is a benefit of double membranes surrounding the nuclei of eukaryotic cells?

A. They reduce the surface area of the nucleus.

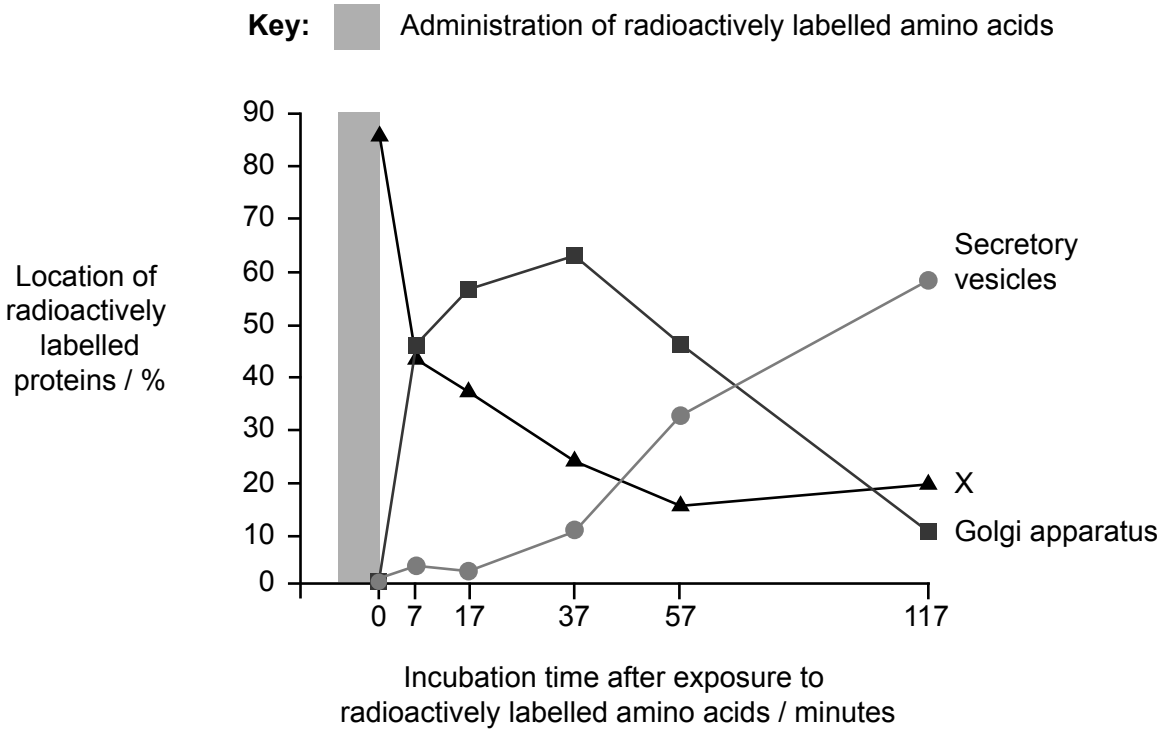
B. They can easily break down into vesicles during mitosis.

C. Hydrophilic phospholipid tails can be kept away from the cytoplasm.

D. Pores are formed to allow movement of DNA from the nucleus to the cytoplasm.

**2.** In an experiment investigating the secretion of proteins by gland cells, researchers supplied radioactively labelled amino acids to a sample of pancreas cells that secrete digestive enzymes.

The graph shows the relative abundance of radioactively labelled proteins in three different organelles during the period after the cells were exposed to the radioactively labelled amino acids.




(a) Suggest a reason for using amino acids that were radioactively labelled. [1]

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(b) (i) X is a membrane-bound organelle. Identify X. [1]

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**(This question continues on the following page)**

**(Question 2 continued)**

(ii) Explain the role of ribosomes located on X. [2]

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(iii) Outline the evidence provided by the data that molecules containing radioactively labelled amino acids move from X to the Golgi apparatus. [1]

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(c) Gland cells that secrete large volumes of fluid typically have many aquaporins in their plasma membranes. Suggest a reason for this. [1]

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(d) After synthesis, globular proteins assume their final tertiary structure. Explain the relationship between the sequence of amino acids and the tertiary structure of globular proteins. [4]

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Question 2 - working space

APOLLO

# Cell specialization

6 questions

**16.** Which term describes very early-stage embryonic stem cells in a mouse?

A. Totipotent

B. Pluripotent

C. Multipotent

D. Unipotent

**16.** What results from an unspecialized cell experiencing gradients of signalling chemicals?

A. Cell differentiation

B. Meiosis

C. Saltatory conduction

D. DNA replication

**16.** Which is a description of stem cells?

A. Hair follicle stem cells are pluripotent.

B. Stem cells in bone marrow are multipotent.

C. Very early embryo stem cells are pluripotent.

D. Late embryo stem cells are totipotent.

**12.** What is a reason that both phloem sieve tube elements and human red blood cells are considered atypical?

A. They have no cytoplasm

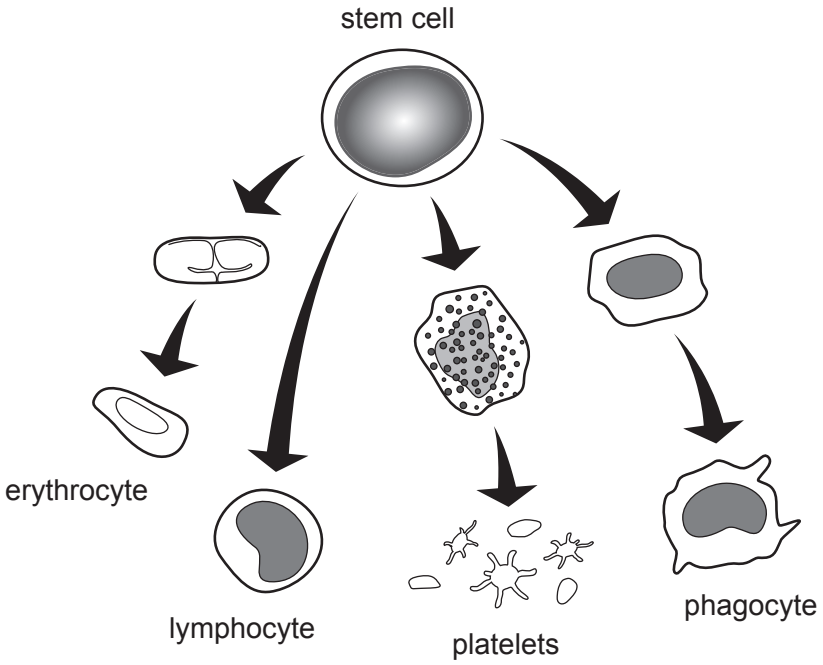
B. Their DNA is free in the cytoplasm

C. They do not have a nucleus

D. All membrane-bound organelles are missing

**Turn over**

**14.** Stem cells can differentiate to produce a variety of cell types in the adult human body.




Which description corresponds to the stem cell in the diagram?

| | Type | Location |
|---|---|---|
| A. | totipotent | bone marrow |
| B. | multipotent | bone marrow |
| C. | totipotent | blood |
| D. | multipotent | blood |

**16.** In multicellular animals, embryonic stem cells have the ability to differentiate into a range of cells with different functions. What is the term used to describe cells with this property?

A. Pluripotent

B. Multipotent

C. Totipotent

D. Specialized

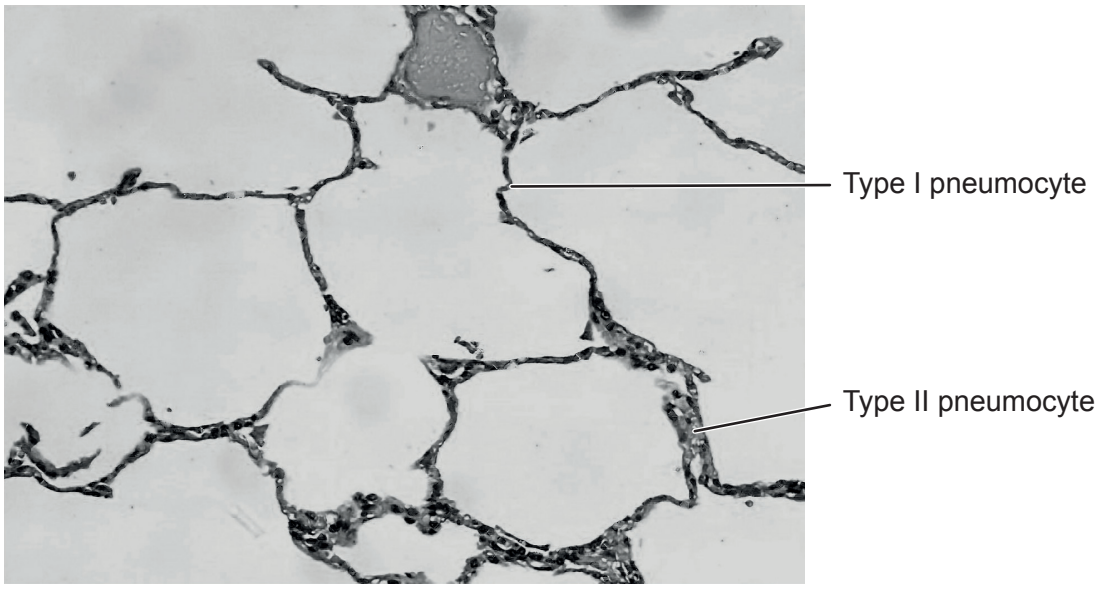
**Turn over**

APOLLO

# Gas exchange

9 questions

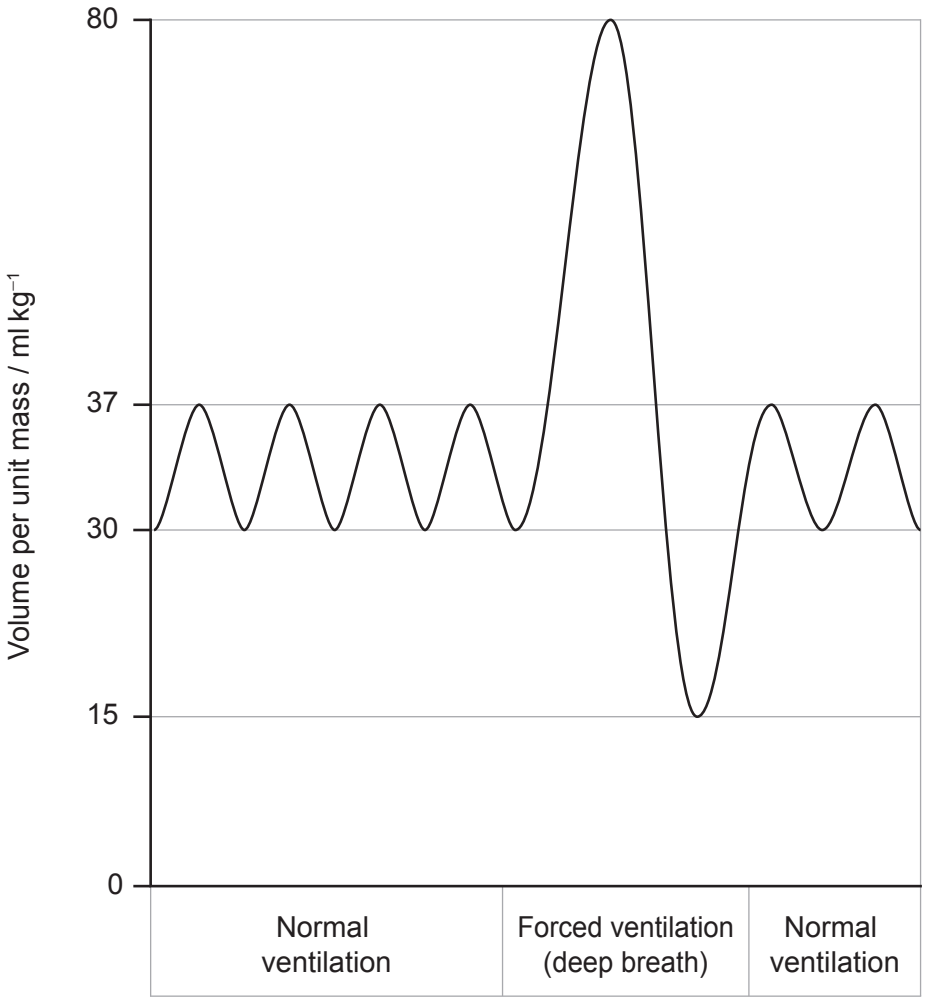
**15.** The micrograph shows alveoli in a human lung.




How are the pneumocytes adapted to their function?

| | **Type I pneumocytes** | **Type II pneumocytes** |
|---|---|---|
| A. | many secretory vesicles (lamellar bodies) | many secretory vesicles (lamellar bodies) |
| B. | many secretory vesicles (lamellar bodies) | large number of mitochondria |
| C. | large number of mitochondria | extreme thinness |
| D. | extreme thinness | many secretory vesicles (lamellar bodies) |

**23.** The graph shows changes in lung volume during normal ventilation and forced ventilation (taking a deep breath).




What is the vital capacity?

A. $7\,ml\,kg^{-1}$

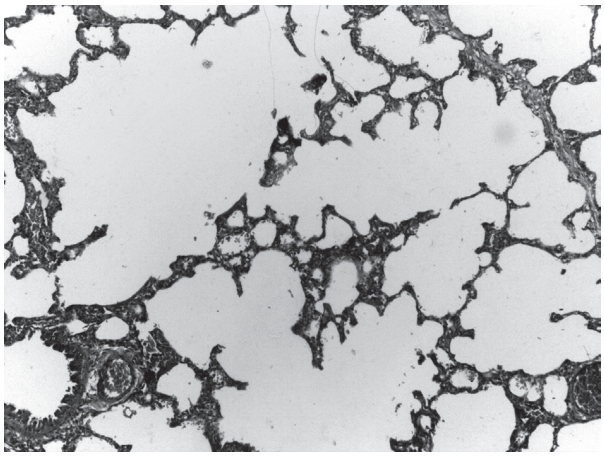
B. $37\,ml\,kg^{-1}$

C. $65\,ml\,kg^{-1}$

D. $80\,ml\,kg^{-1}$

**Turn over**

**23.** Emphysema is a condition where the alveoli of the lungs are destroyed, resulting in patients feeling out of breath. The micrograph shows air pockets resulting from emphysema.



What is a direct consequence of the destruction of alveoli?

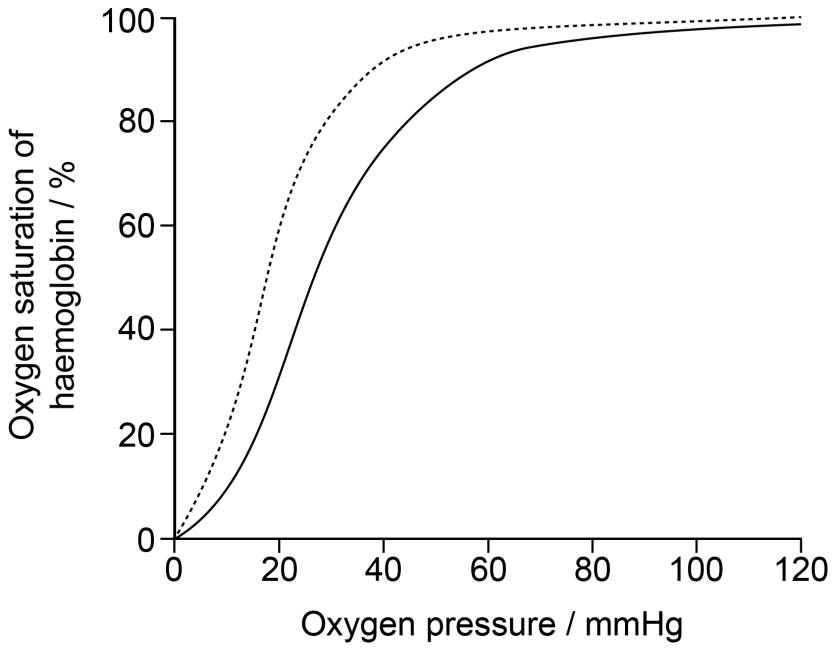
A. Decrease in surface area for gas exchange

B. Increased blood flow to the lungs

C. Increase in pulmonary surfactant production

D. Decrease in ventilation rate

**25.** Two oxygen dissociation curves in an adult human are shown.

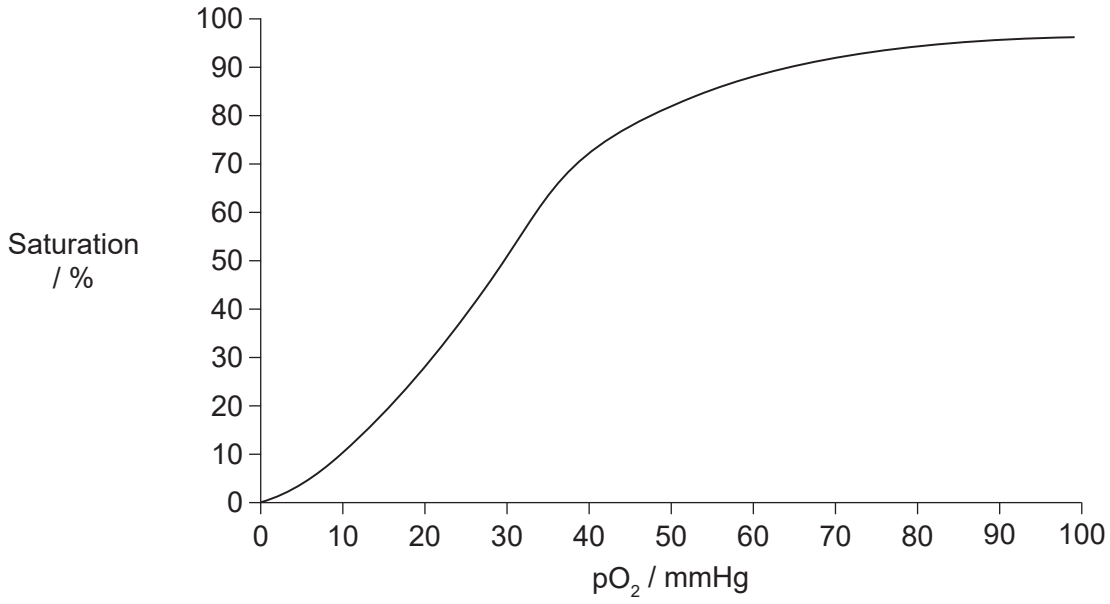



What is the explanation for the shift of the dissociation curve to the right-hand curve?

| | Carbon dioxide | Affinity of haemoglobin for oxygen |
|---|---|---|
| A. | dissociates from haemoglobin | increases |
| B. | dissociates from haemoglobin | decreases |
| C. | associates with haemoglobin | increases |
| D. | associates with haemoglobin | decreases |

**Turn over**

**1.** Oxygen dissociation curves show the percentage of oxygen saturation of adult haemoglobin (Hb) at different oxygen concentrations, as measured in partial pressure of oxygen ($pO_2$).




(a) Identify the percentage of oxygen saturation of haemoglobin at a partial pressure of 40 mmHg. [1]

. . . . . .

(b) Describe the relationship between partial pressure of oxygen ($pO_2$) and percent saturation of haemoglobin. [2]

. . . . . .

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(c) On the graph, sketch an oxygen dissociation curve for foetal haemoglobin. [1]

**(This question continues on the following page)**

**(Question 1 continued)**

(d) Describe an adaptation of haemoglobin for the transport of oxygen. [1]

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(e) Describe how tidal volume can be measured in a human. [3]

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Question 1 - working space

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**10.** There is a relationship between form and function in the diversity of molecules and of systems.

(a) Describe the relationship between codons and polypeptide structure. [4]

(b) Outline the relationship between structure and function in photosystems. [3]

(c) Explain the causes of a decreased blood pH and its effects on the ventilation rate in humans. [8]

**Disclaimer:**

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**References:**

**1.** Images and graphs: Bridges, A.D., MaBouDi, H., Procenko, O., Lockwood, C., Mohammed, Y., Kowalewska, A., et al., 2023. *PLoS Biol* 21(3), e3002019. https://doi.org/10.1371/journal.pbio.3002019. Reference redacted. Source adapted.

**2.** NOAA Fisheries Plans Western Alaska Meetings on Ringed Seal "Critical Habitat", 2015. *Pusa hispida hispida*. [image online] Available at: https://commons.wikimedia.org/wiki/File:Pusa_hispida_hispida_NOAA_2.jpg [Accessed 13 March 2024]. Source adapted.

**3.** Bezanilla, F., 2005. Voltage-gated ion channels. *IEEE Transactions On Nanobioscience* 4(1). https://doi.org/10.1109/tnb.2004.842463. Source adapted. Reprinted with permission from IEEE.

**4.** tonaquatic, 2021. *Dicot plants stem show plant vascular tissue under light microscope view for botany education.* [image online] Available at: https://www.gettyimages.co.uk/detail/photo/dicot-plants-stem-show-plant-vascular-tissue-under-royalty-free-image/1326289492?phrase=xylem&adppopup=true [Accessed 5 April 2024]. Source adapted.

**5.** Data from Jennifer L. Hope, Linda M. Bradley, Lessons in antiviral immunity. *Science* 371, 464–465 (2021). DOI: 10.1126/science.abf6446.

**6.** WWF. 2013. *Ecosystems in the Greater Mekong: Past trends, current status, possible futures*.

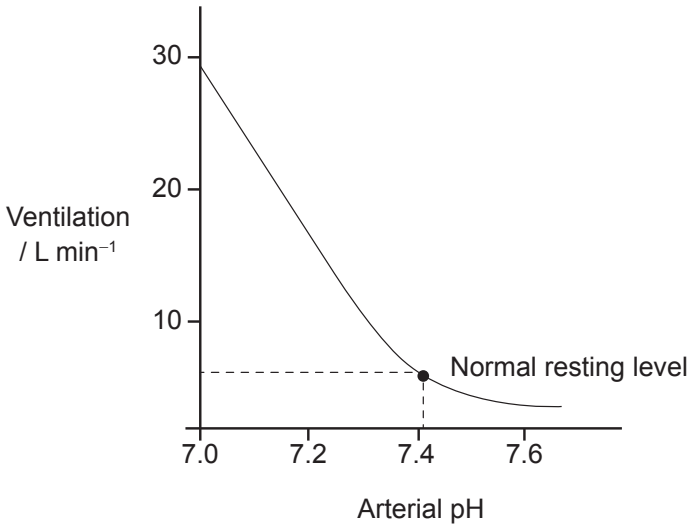
**7.** Reprinted with permission of AAAS from Fig 2a from Long et al *Science Advances*, 31 Jan 2018, Vol 4, Issue 1 DOI: 10.1126/sciadv.aap9004. © The Authors, some rights reserved; exclusive licensee AAAS. Distributed under a CC BY-NC 4.0 License (http://creativecommons.org/licenses/by-nc/4.0/).

Question 10 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**4.** The graph shows the relationship between blood pH in the arteries and volume of air inhaled and exhaled per minute.




(a) State the effect of decreases in arterial pH on ventilation. [1]

. . . . . .

. . . . . .

(b) Outline how the pH of arterial blood is monitored by the human body. [1]

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**(This question continues on the following page)**

**(Question 4 continued)**

(c) Explain the main cause of pH changes in the blood. [2]

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(d) State which muscles would contract more vigorously, or more frequently, to increase the volume of air inhaled per minute. [2]

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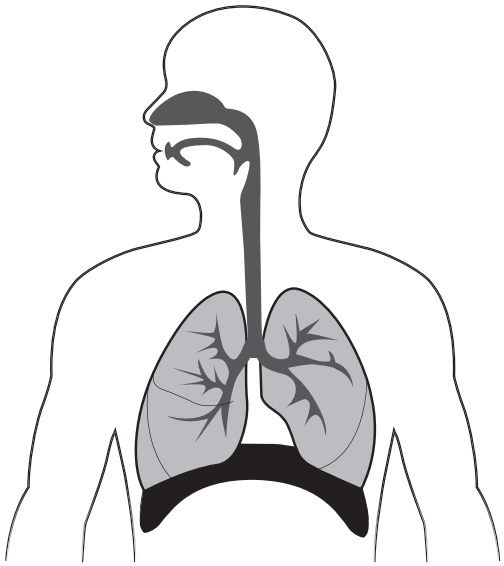
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Question 4 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**5.** The image shows the location of the lungs and diaphragm in a human.



(a) Explain how contraction of the diaphragm causes air to enter the lungs. [2]

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. . . . . .
. . . . . .

(b) State another muscle group that causes inspiration when it contracts. [1]

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(c) Outline the role of surfactant in the mammalian lung. [2]

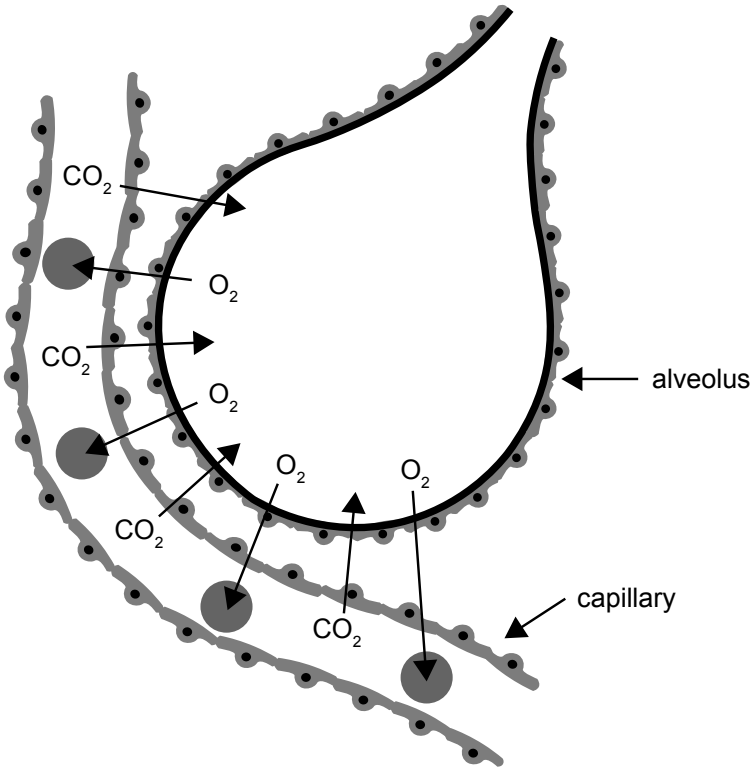
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Question 5 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**4.** Multicellular organisms need efficient exchange surfaces where molecules can move between tissues and their surroundings. In mammals, gas exchange takes place in the alveoli of the lungs.




(a) Describe how the exchange of gases is brought about between the alveoli and the blood. [3]

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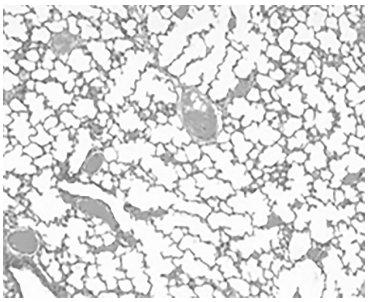
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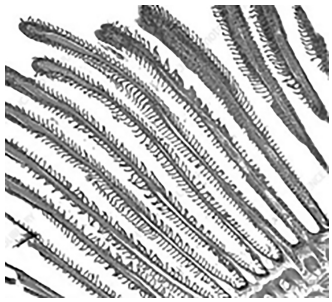
**(This question continues on the following page)**

**(Question 4 continued)**

The images show the lungs of a human and the gills of a fish taken with a light microscope.



Alveoli in the lungs of a human



Gills from a fish

(b) Describe **two** features common to the exchange surfaces of alveoli and gills. [2]

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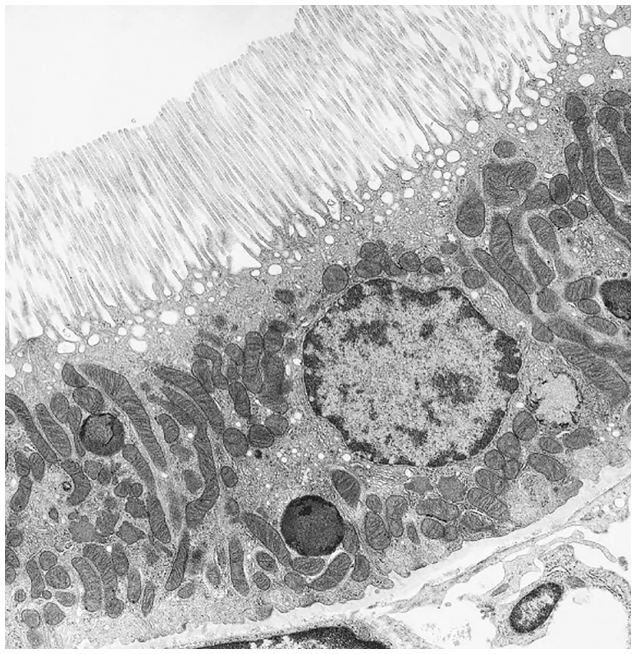
**(This question continues on page 13)**

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Answers written on this page
will not be marked.

**(Question 4 continued)**

The image shows cells from the wall of a proximal convoluted tubule of a rat kidney.



(c) Outline the visible features of these cells that adapt them for reabsorption of materials from the glomerular filtrate. [2]

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Question 4 - working space

APOLLO

# Transport

13 questions

**24.** What increases the rate of transpiration?

A. Increasing the humidity

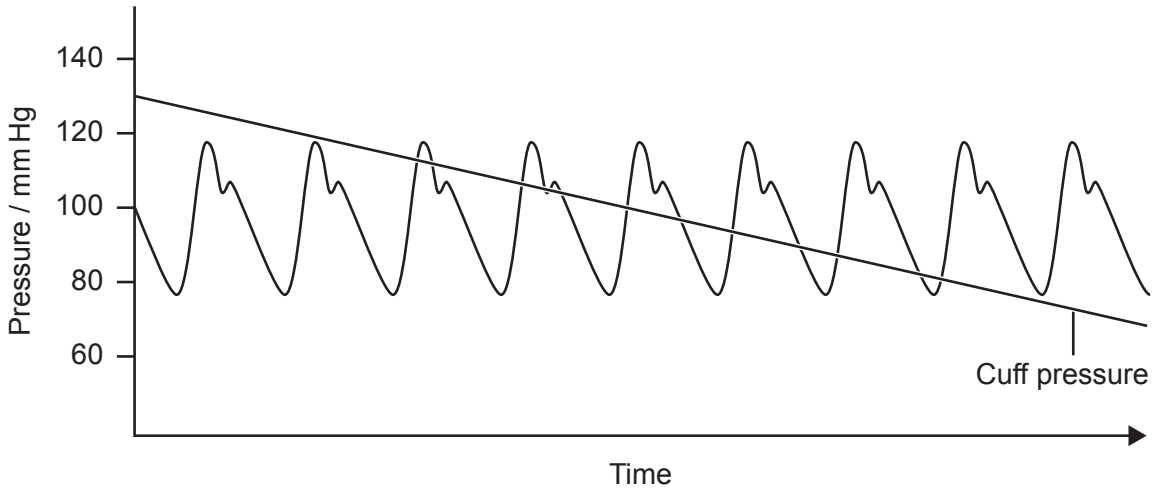
B. Decreasing the temperature

C. Decreasing the light intensity

D. Increasing the wind speed

**25.** The graph shows changes in blood pressure during the cardiac cycle, taken using a sphygmomanometer. A cuff is attached to the upper arm, inflated to stop the blood flow in the artery, then the pressure released.






What are the values of the diastolic and systolic pressures from the graph?

| | Diastolic pressure / mm Hg | Systolic pressure / mm Hg |
|---|---|---|
| A. | 120 | 76 |
| B. | 130 | 66 |
| C. | 76 | 120 |
| D. | 66 | 130 |

**Turn over**

**24.** Which environmental condition(s) would increase the rate of transpiration in plants?

I. Increased carbon dioxide concentration in the atmosphere
II. Increased temperature of the atmosphere
III. Decreased humidity of the atmosphere relative to the inside of the leaf

A. I and II only

B. III only

C. II and III only

D. I and III only

**24.** What is a reason that veins have relatively thin walls compared to arteries?

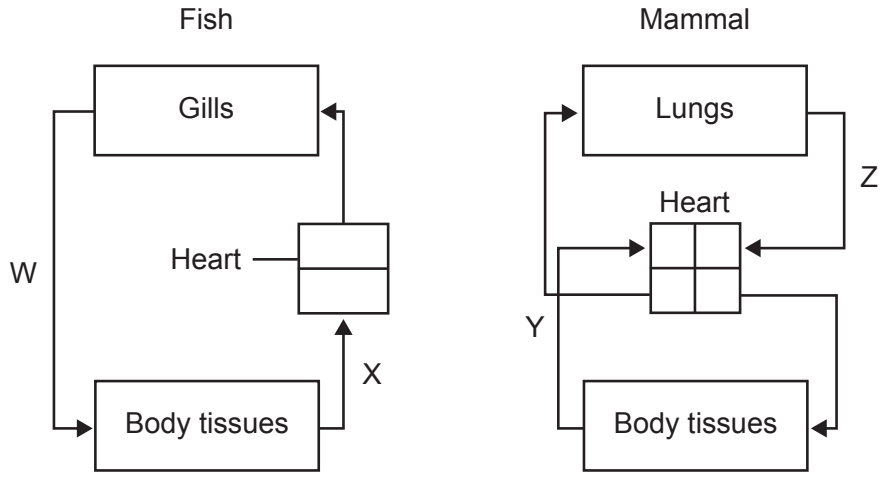
A. Allows muscle contraction to assist in blood flow

B. Prevents a blood clot forming

C. Allows exchange of materials with tissue fluid

D. Easier attachment of semilunar valves

**26.** The diagrams show blood circulation in a fish and a mammal.




Which two labels represent deoxygenated blood with the lowest pressure in each animal?

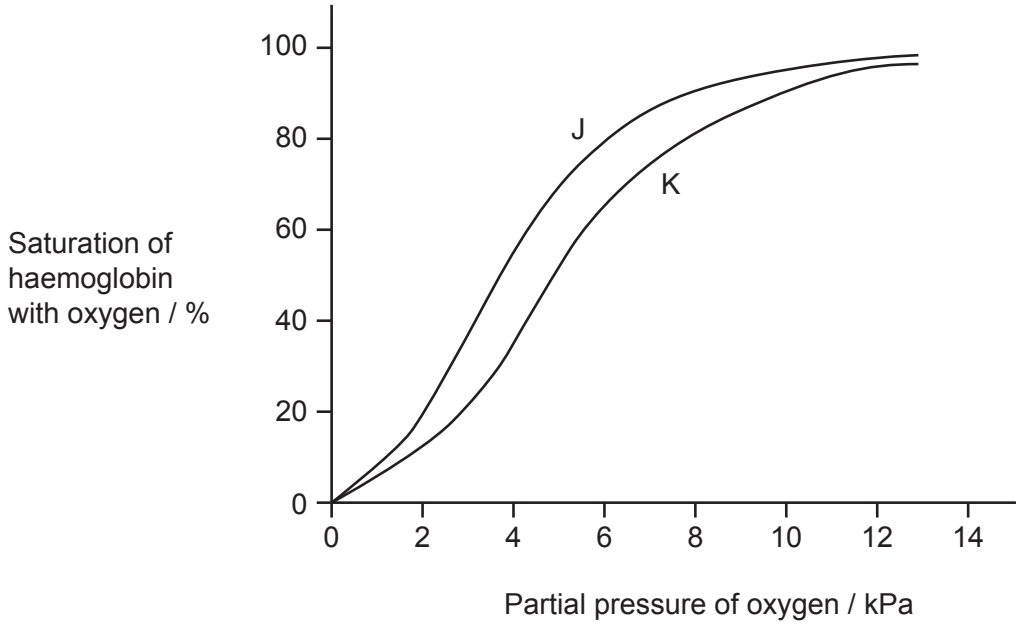
A. W and Z

B. X and Y

C. W and Y

D. X and Z

**23.** The graph shows the Bohr shift.

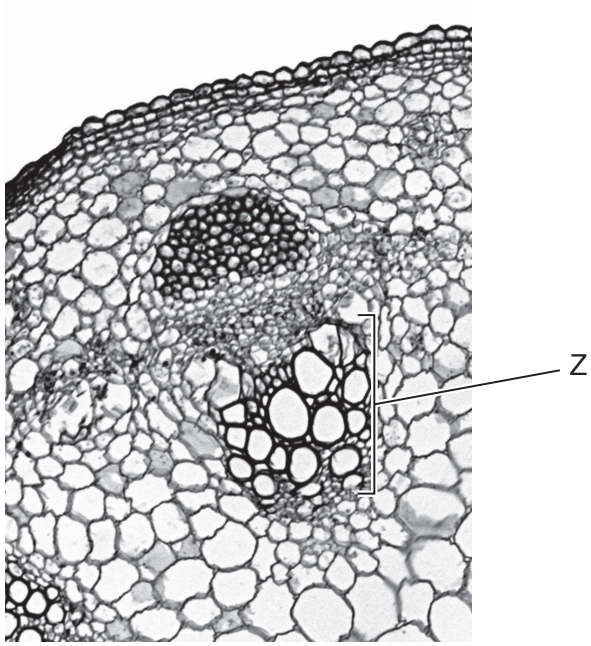



What causes the shift from J to K?

| | Carbon dioxide concentration | pH |
|---|---|---|
| A. | decrease | higher |
| B. | decrease | lower |
| C. | increase | higher |
| D. | increase | lower |

**Turn over**

**24.** The micrograph shows part of the stem of the common sunflower (*Helianthus annuus*) in cross section.




What is the name and function of the structure labelled Z?

| | Name | Function |
|---|---|---|
| A. | xylem | transport water |
| B. | phloem | transport water |
| C. | xylem | transport sugars |
| D. | phloem | transport sugars |

**25.** How is the phloem adapted for transport?

A. Sieve tube elements have many mitochondria for active transport.

B. Plasmodesmata between companion cells and sieve tube elements aid transport between them.

C. Phloem tubes unload carbon compounds at sources by pressure flow.

D. Companion cells have reduced cytoplasm to enhance loading of carbon compounds.

**24.** The micrograph shows a transverse section of blood vessels in a human leg muscle.




Which is the main contributor to the movement of blood along vessel X?

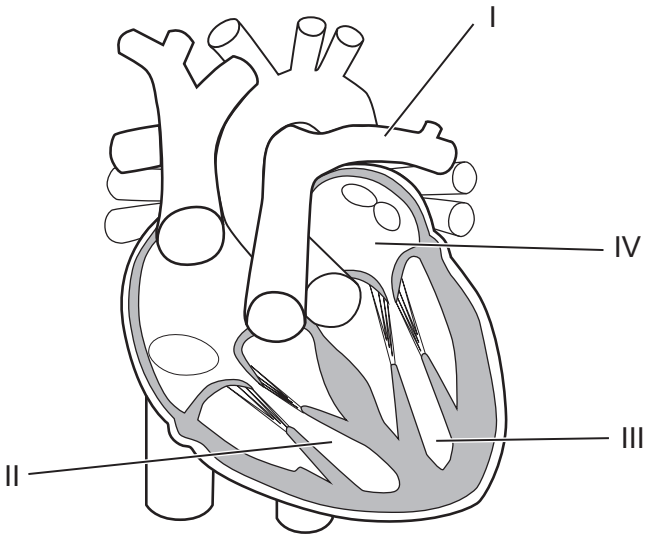
A. The smooth surface of the inner lining

B. Stretching and recoiling of the vessel walls

C. Differences in plasma solute concentration

D. Contraction of muscles adjacent to the vessel

**25.** The diagram shows the human heart.




After oxygen has been released from a red blood cell in the brain, which sequence shows the path taken by this red blood cell through the heart before it reaches the aorta?

A. I → II → III → IV

B. IV → III → II → I

C. II → I → IV → III

D. IV → III → I → II

**12.** Which is a feature of phloem sieve tube cells?

A. Numerous chloroplasts

B. No nucleus

C. Lignified walls

D. No cytoplasm

**26.** What is always a consequence of the evaporation of water from mesophyll cells in leaves of a healthy plant?

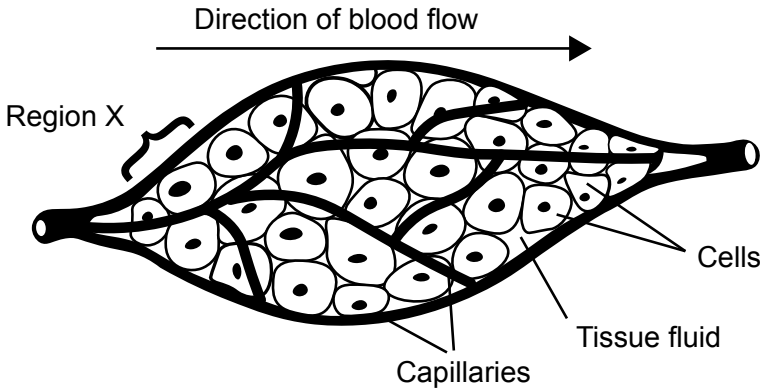
A. Plasmolysis occurs in mesophyll cells.

B. Photosynthesis stops.

C. Stomata close to reduce transpiration.

D. Water moves up the stem in the xylem.

**27.** The diagram shows where the exchange of substances between blood and tissue fluid occurs in a capillary bed.




What explains the movement of solutes between blood and tissue fluid at region X?

A. Blood plasma has a higher concentration of solutes than tissue fluid.

B. Tissue fluid has a more negative water potential than blood plasma.

C. Hydrostatic pressure is higher in blood than in tissue fluid.

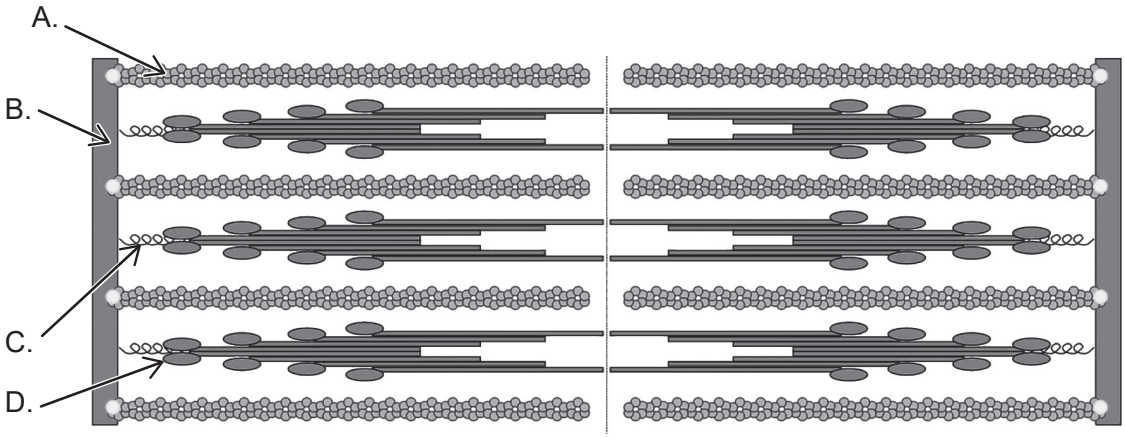
D. The permeability of capillary walls is highest at region X.

APOLLO

# Muscle and motility

7 questions

**25.** The diagram shows a contracted sarcomere. Which part will vary in length in response to relaxation of a muscle?



**15.** Which features are found in both cardiac and striated muscle?

A. Nuclei and branched myofibrils

B. Sarcomeres and unbranched myofibrils

C. Mitochondria and branched myofibrils

D. Sarcomeres and mitochondria

**23.** What is a role of one of the structures at a synovial joint such as the hip?

A. Ligaments attach muscle to bone.

B. Tendons transmit force of contraction to bone.

C. Cartilage holds bones together at the joint.

D. Muscles stretch and contract to move bones.

**23.** A titinopathy is a muscle disorder caused by titin abnormalities. What could be a consequence of abnormal titin in muscles?

A. Muscles would detach from tendons.

B. Muscles would stretch too much during relaxation.

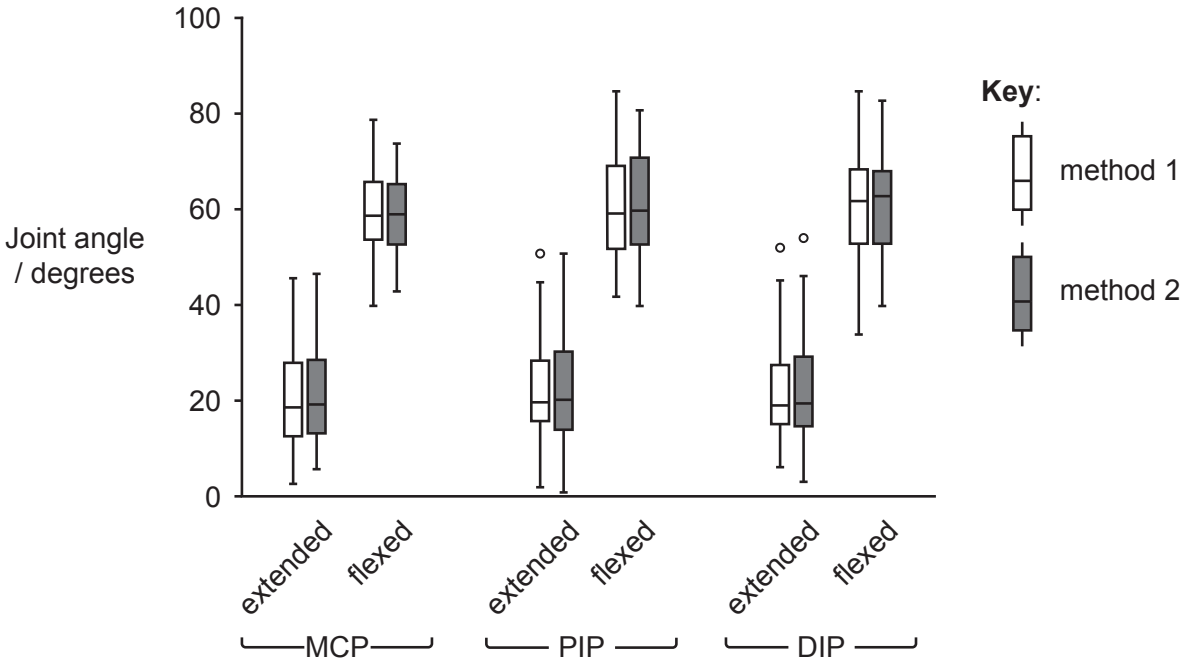
C. Muscles would have less ATP for contraction.

D. Antagonistic muscles would contract at the same time.

**Turn over**

**2.** A student used two different methods to measure the left ring finger joint angles in 120 healthy people. The metacarpophalangeal (MCP), proximal interphalangeal (PIP) and distal interphalangeal (DIP) joint angles were measured while the finger was extended (straight) or flexed (bent).

The box-and-whisker plots show the angle measurements at the different joints obtained for both methods.




**(This question continues on the following page)**

**(Question 2 continued)**

(a) (i) State the dependent variable in this experiment. [1]

. . . . . .
. . . . . .

(ii) Identify what is indicated by the circles in the plot. [1]

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. . . . . .

(b) Deduce whether method 2 is a good substitute for method 1. [1]

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(c) Evaluate the experiment used to measure the joint angles of the ring finger. [2]

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(d) Explain the reason that the angle measured by both methods is smaller in the extended than in the flexed position. [3]

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Question 2 - working space

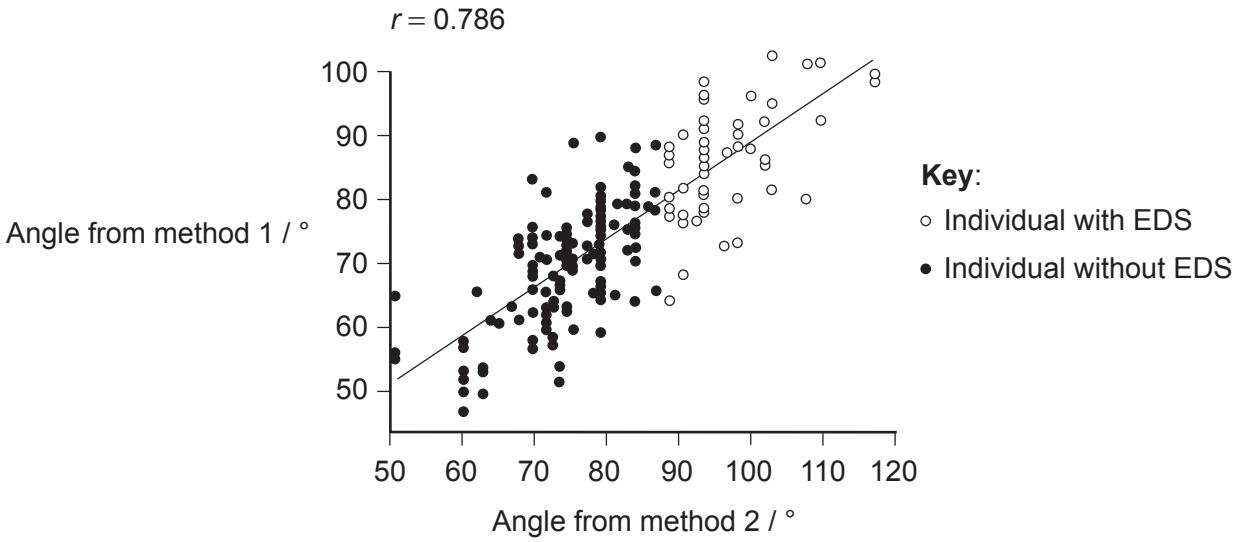
**2.** Ehlers–Danlos syndrome (EDS) causes joint hypermobility, where joint movement extends well beyond the normal range. Researchers used two different methods to measure angles of movement at a joint of the smallest (fifth) finger.

(a) Suggest in which direction the finger was moved to assess hypermobility. [1]

. . . . . .

. . . . . .

The graph shows all angles of movement of the finger, measured in degrees (°) using both methods.




(b) Suggest a method which could have been used to measure the angle of movement of the finger. [1]

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. . . . . .

(c) Estimate the threshold (minimum) angle for a diagnosis of EDS. [1]

. . . . . .

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**(This question continues on the following page)**

**(Question 2 continued)**

(d) Suggest which structure at the finger joint is affected by EDS. [1]

. . . . . .

(e) Describe the level of correlation between the data from the two measurement methods. [1]

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(f) Joints are part of the musculoskeletal system of animals, which provides support and movement to the body. Xylem provides support in plants and also transports water and minerals. Explain the adaptations of xylem for its functions. [3]

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Question 2 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**3.** (a) Outline the function of mitochondria in muscle fibres. [2]

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(b) Explain the function of actin and myosin in the sarcomeres of muscle fibres. [3]

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(c) Explain the role of the protein titin in muscle relaxation. [2]

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Question 3 - working space

APOLLO

# Adaptation to environment

4 questions

**35.** Which conditions are characteristics of tundra biomes?

A. Extreme temperature range and high precipitation

B. High temperatures and high precipitation

C. Moderate temperatures with distinct seasonal changes

D. Low temperatures with low precipitation

**1.** Which characteristic of the ringed seal (*Pusa hispida*) is a consequence of the viscosity of water?

A. Streamlined body

B. Sharp teeth

C. Claws

D. Lungs

**39.** Which of the following could be a subject of phenological research?

A. Timing of budburst in a tree species each year

B. Changes in allele frequencies in a population over time

C. The relationship between changes in ocean acidification and carbon dioxide concentration

D. The emergence of a new species of migratory bird by divergent evolution

**Turn over**

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**6.** The photo shows vegetation in the Sonoran Desert, which is part of the hot desert biome.



(a) State what a biome is. [2]

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(b) Explain **three** adaptations of plants that can help them survive in the dry conditions of hot deserts. [3]

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(c) State **one** adaptation of plants in hot deserts that can help them to resist herbivory. [1]

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Question 6 - working space

APOLLO

# Ecological niches

3 questions

**35.** What occurs during competitive exclusion between two species?

I. They compete for the same resources so cannot coexist in the same niche.
II. Competing species are regulated by predators in the ecosystem.
III. Both species are restricted to a part of their fundamental niche.

A. I and II only

B. I and III only

C. III only

D. I, II and III

**Turn over**

**36.** What describes a benefit of the relationship between coral and zooxanthellae?

A. Zooxanthellae receive carbon dioxide from the coral.

B. Zooxanthellae receive glucose from the coral.

C. Coral receives carbon dioxide from the zooxanthellae.

D. Coral receives protection from the zooxanthellae.

**36.** The preferred temperature ranges for three species of trout that are found together in freshwater lakes in North America are shown.



| Lake trout (*Salvelinus namaycush*) | Rainbow trout (*Oncorhynchus mykiss*) | Brown trout (*Salmo trutta*) |
|---|---|---|
| 6–13 °C | 12–18 °C | 11–23 °C |

What can be deduced from this information?

I. The niches for all three species overlap.
II. Brown trout have the most specialized niche.
III. Lake trout can avoid competition by living in colder water.

A. I only

B. II only

C. I and III only

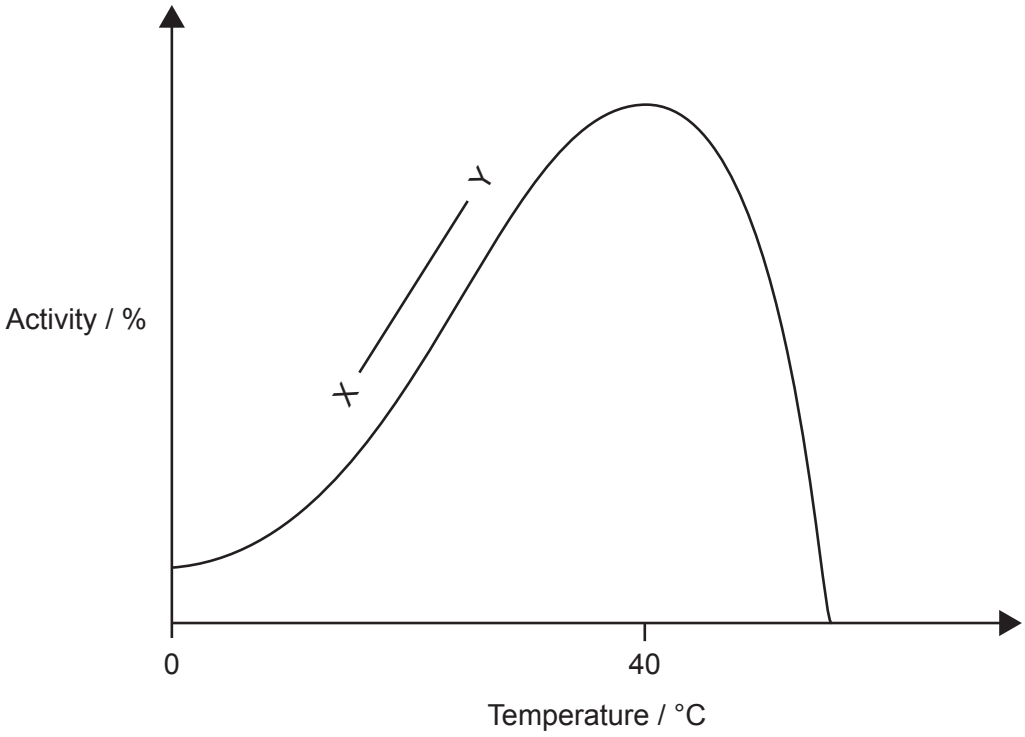
D. I, II and III

APOLLO

# Enzymes and metabolism

11 questions

**5.** The graph shows the activity of an enzyme as temperature increases.




What explains the change in enzyme activity between X and Y?

A. The enzyme is denaturing as the active site changes shape.

B. Increased collisions occur as molecules are moving faster.

C. Increased product concentration speeds up the reaction.

D. An inhibitor has been added, reducing the number of active sites.

**5.** Which process is an example of catabolism?

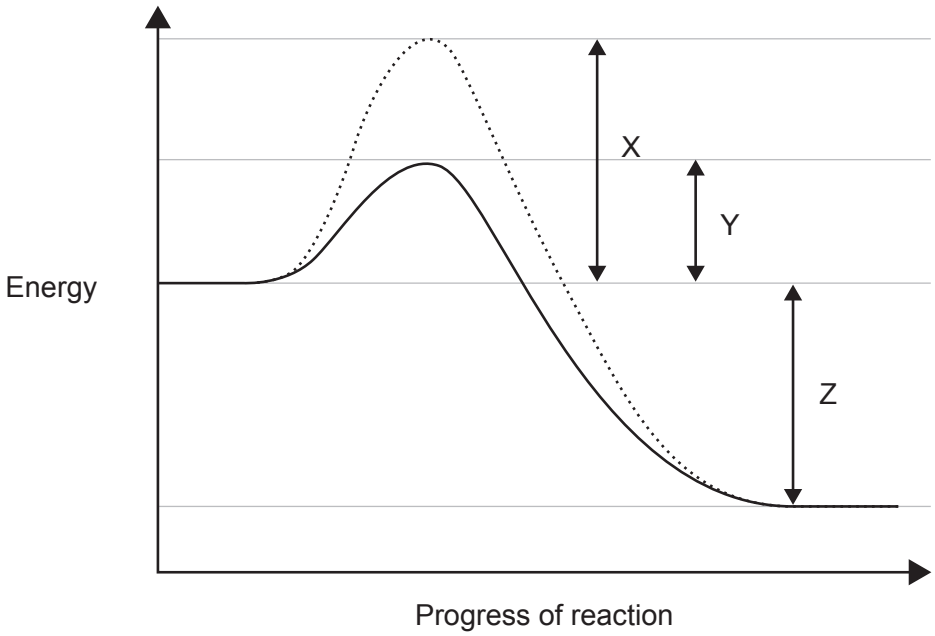
A. Protein synthesis

B. Photosynthesis

C. Oxidation of substrates in respiration

D. Glycogen formation

**5.** The graph shows energy changes during a reaction both with and without an enzyme present.




Which statement correctly identifies two of the regions labelled X, Y and Z in the graph?

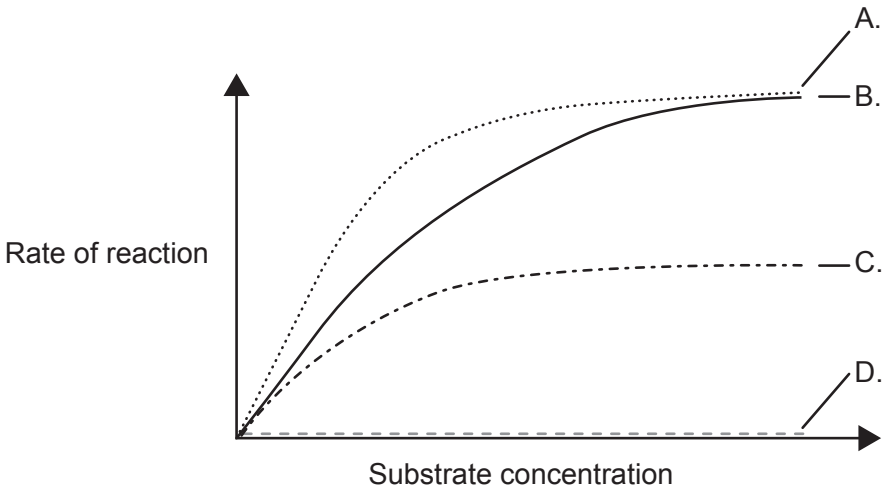
A. X is the activation energy with an enzyme and Z is the net energy released from the reaction.

B. X is the energy released from the reaction and Y is the activation energy with an enzyme.

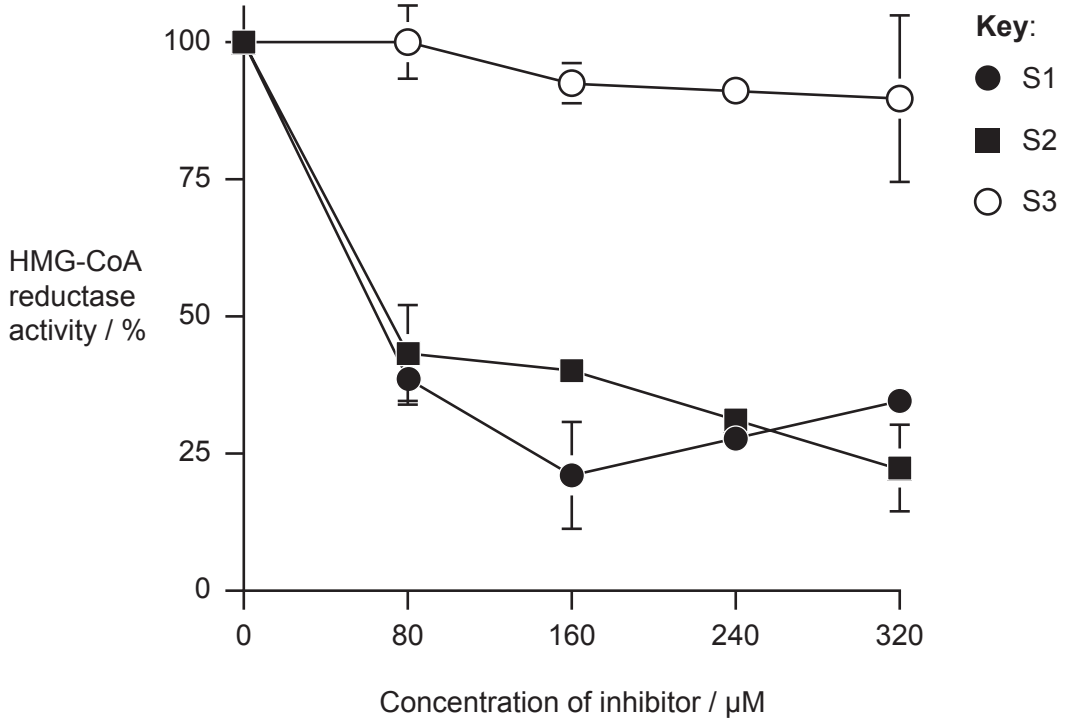
C. Y is the energy released with an enzyme and Z is the energy released when bonds are broken.

D. Y is the activation energy with an enzyme and Z is the net energy released.

**6.** The graph illustrates how enzyme-catalysed reactions can be affected by inhibitors.
Which curve shows the effect of statins on the rate of cholesterol synthesis in the body?



**3.** The inhibitory effect of three different statins (S1, S2 and S3) on the activity of HMG-CoA reductase, an enzyme involved in cholesterol metabolism in the liver, was investigated.




(a) (i) Identify an independent variable in this investigation. [1]

. . . . . .

. . . . . .

(ii) State **one** variable that needs to be controlled. [1]

. . . . . .

. . . . . .

**(This question continues on the following page)**

**(Question 3 continued)**

(b) Compare and contrast the effect of increasing concentrations of S1 and S2 on the mean activity of HMG-CoA reductase. [3]

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(c) Outline how the rate of reaction of HMG-CoA reductase can be calculated. [1]

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(d) Statins limit the synthesis of cholesterol by acting as competitive inhibitors. Distinguish between competitive and non-competitive inhibition. [1]

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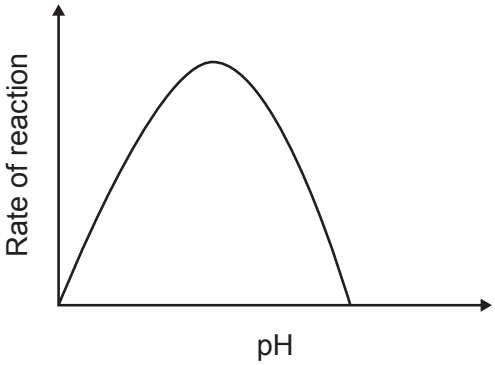
(e) Describe the role of enzymes in **one named** process that prevents infections in the human body. [2]

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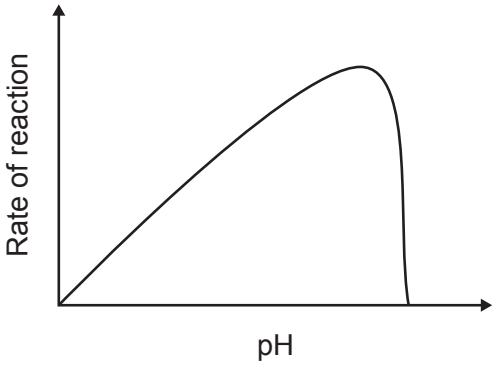
Question 3 - working space

**5.** Which graph shows the effect of pH on the rate of most enzyme-catalysed reactions?

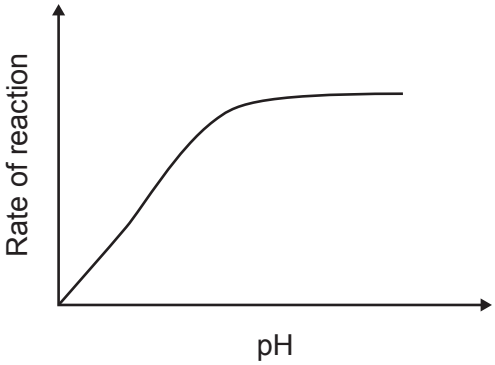
A.



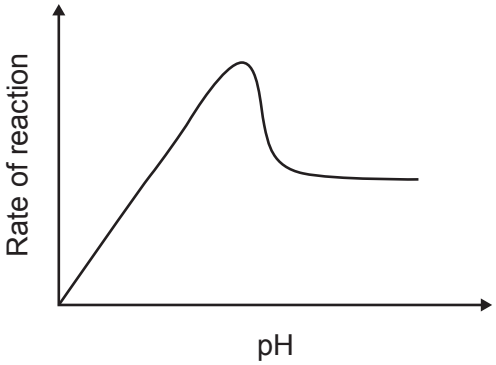

B.



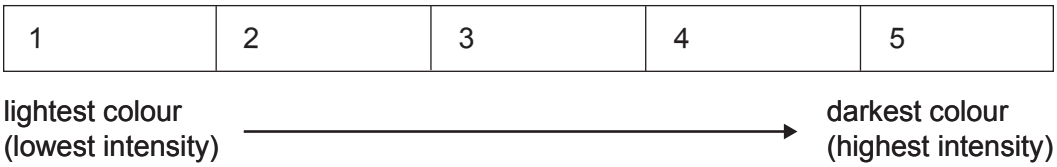

C.




D.



**6.** A solution of laundry detergent containing enzymes was used to soak some blood-stained clothes in order to remove the stains. Each item of stained clothing was soaked in a solution of a different temperature. After one hour, the stains remaining on the clothes were measured on a colour intensity scale.




| Temperature / °C | Colour intensity of stain |
|---|---|
| 10 | 4 |
| 20 | 3 |
| 30 | 2 |
| 40 | 1 |
| 50 | 5 |

What is a valid explanation for these results?

A. At 10 °C the enzymes denature.

B. At 20 °C the shape of some enzyme active sites change.

C. At 30 °C the enzyme and substrate molecules have the greatest kinetic energy.

D. At 50 °C the chance of successful binding between enzyme and substrate is low.

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**9.** The complementarity of shapes and chemical properties allows molecules to bind to each other.

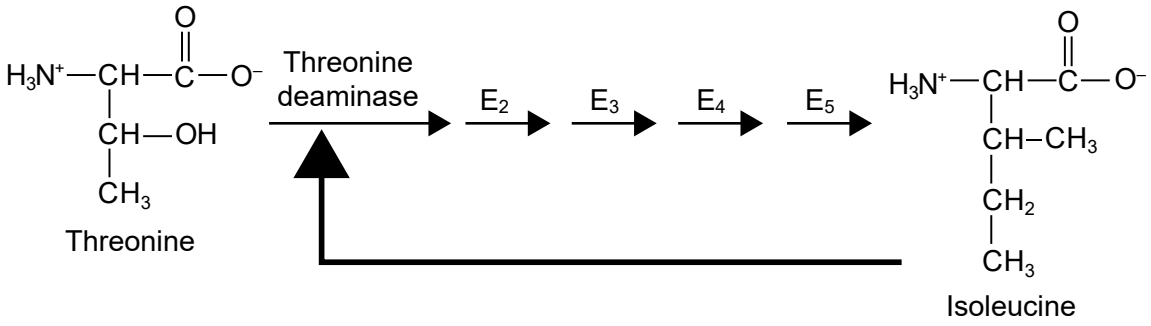
(a) Describe, with examples, the types of molecule within cell-to-cell signalling systems that are complementary to each other. [4]

(b) Explain the possible causes of changes to enzyme active sites and the consequences of these changes. [7]

(c) Outline how reversible changes to haemoglobin molecules increase the efficiency of oxygen transport within the human body. [4]

Question 9 - working space

**7.** The diagram represents the metabolic pathway that converts threonine to isoleucine.




What is a feature of this pathway?

A. The pathway is regulated by positive feedback.

B. Isoleucine is a competitive inhibitor.

C. Isoleucine is a substrate for threonine deaminase.

D. Isoleucine is an allosteric inhibitor.

**8.** What is a common feature of enzymes?

A. They all react with substrates.

B. They all decrease the rate of reaction.

C. They are all secreted from cells in vesicles.

D. They all bind to the active site of their substrate.

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**9.** Various mechanisms can lead to inhibition in biological systems. A toxin is a substance capable of disrupting metabolic processes in organisms.

(a) Describe how toxins such as DDT might concentrate in the bodies of birds. [4]

(b) Toxins often act as inhibitors. Compare and contrast competitive and non-competitive enzyme inhibition. [7]

(c) Rotenone is a naturally occurring toxin that blocks the electron transport chain in insects and fish. Outline the consequences of exposure to a toxin like rotenone for cell respiration. [4]

Question 9 - working space

APOLLO

# Cell respiration

8 questions

**6.** What is an example of an intracellular enzyme-catalysed reaction?

A. Chemical digestion in the gut

B. Glycolysis in cellular respiration

C. Blood clotting in the circulatory system

D. Recycling of acetylcholine in a synapse

**7.** What occurs during the stages of respiration?

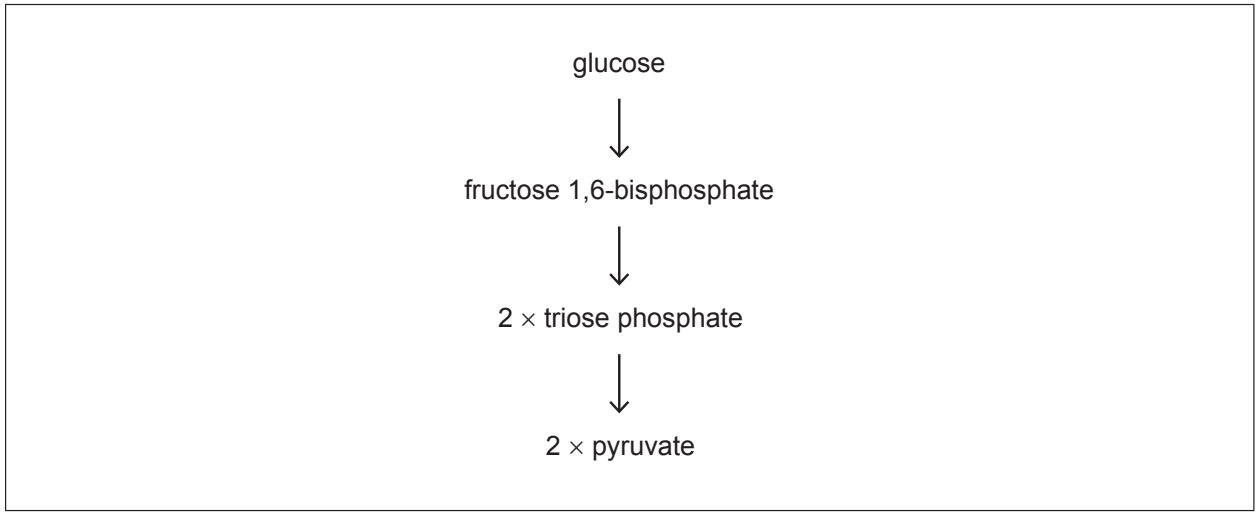
| | Stage of respiration | Decarboxylation | Reduced NAD produced |
|---|---|---|---|
| A. | Glycolysis | No | No |
| B. | Link reaction | Yes | No |
| C. | Krebs cycle | Yes | Yes |
| D. | Electron transport chain | No | Yes |

**Turn over**

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**6.** Glucose is converted to pyruvate during the glycolysis stage of respiration.




(a) On the diagram, label

(i) with P where phosphorylation occurs; [1]

(ii) with O where oxidation occurs. [1]

(b) State where in the cell glycolysis takes place. [1]

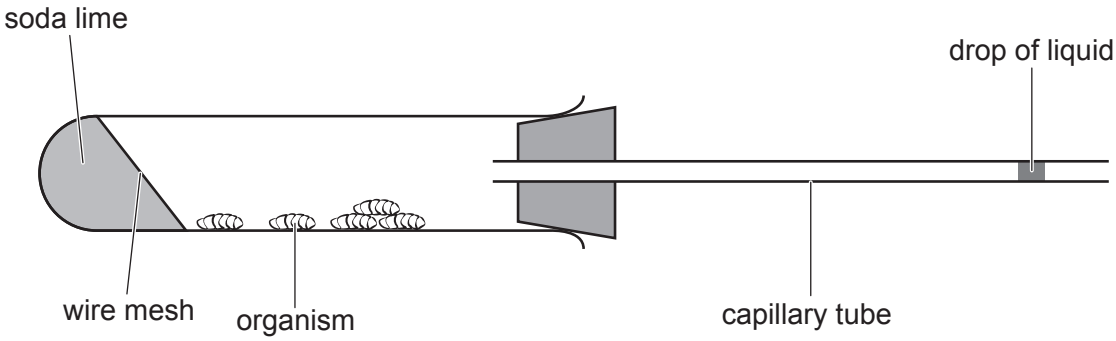
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(c) Outline how NAD is made available for glycolysis during anaerobic respiration in animal cells. [2]

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Question 6 - working space

**6.** The diagram shows a simple respirometer used to measure the rate of respiration. Soda lime is used to absorb carbon dioxide.




Which way will the drop of liquid move if the organisms are respiring aerobically?

A. The drop of liquid will not move as the volume of oxygen used in respiration equals the volume of carbon dioxide produced.

B. The drop of liquid will move left as oxygen is used up by the respiring organisms.

C. The drop of liquid will move right as carbon dioxide is produced by respiring organisms.

D. The drop of liquid will move right as carbon dioxide is produced and then left as oxygen is consumed.

**7.** Which of the following statements describes part of the Krebs cycle?

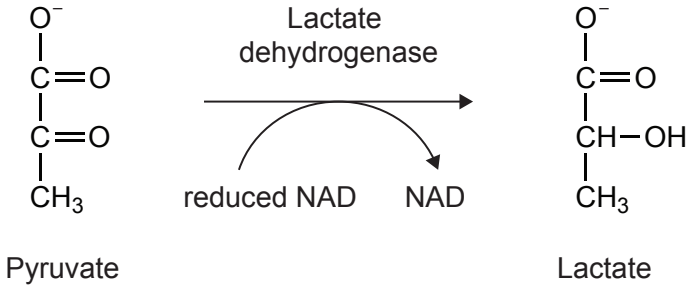
A. Reduced NAD is converted back to NAD.

B. A 4-carbon citrate binds with acetyl-CoA to form a 6-carbon intermediate.

C. Two decarboxylation reactions occur.

D. One ATP molecule is used in one stage of the cycle.

**5.** The diagram shows the chemical reaction that occurs during the last step of anaerobic respiration in human skeletal muscle cells.




Pyruvate Lactate

What is the purpose of this reaction?

A. To allow the release of energy from glucose breakdown to continue

B. To establish a concentration gradient of hydrogen ions for adenosine triphosphate (ATP) synthesis

C. To provide electrons for the electron transport chain

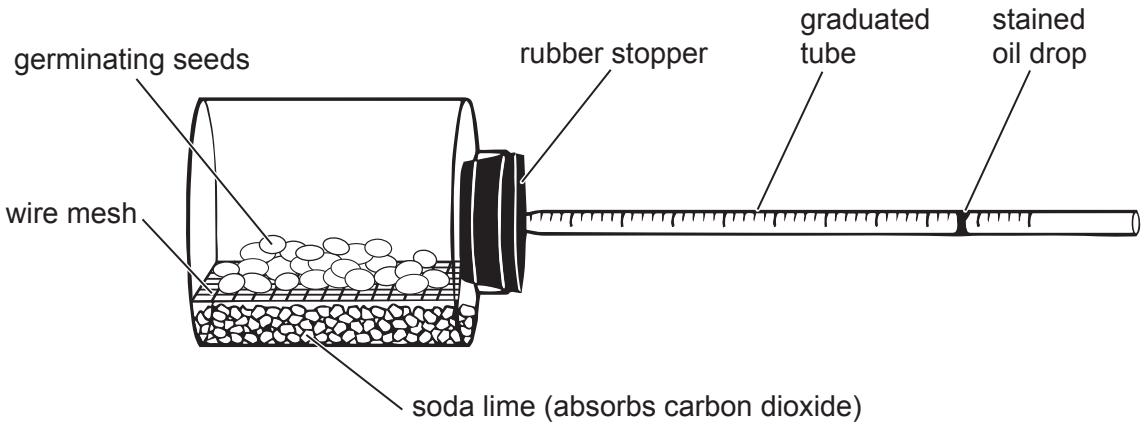
D. To reduce carbon compounds in the absence of oxygen

**Turn over**

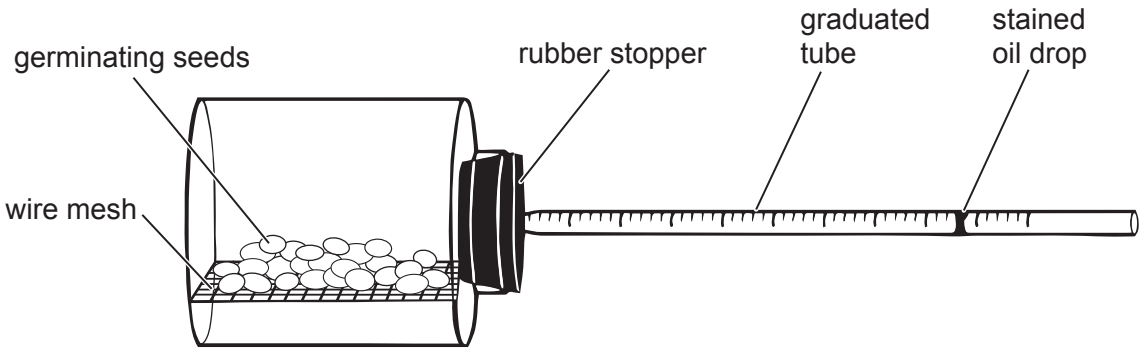
**8.** Students prepared respirometers in order to investigate respiration rates in seeds.

**diagram not to scale**

**Respirometer 1**




**Respirometer 2**




How would the results differ in the respirometers after 30 minutes?

| | Respirometer 1 | Respirometer 2 |
|---|---|---|
| A. | Oil drop does not move | Oil drop moves left |
| B. | Oil drop does not move | Oil drop moves right |
| C. | Oil drop moves left | Oil drop moves right |
| D. | Oil drop moves left | Oil drop does not move |

**34.** *Yersinia pestis* is a bacterium that caused an outbreak of bubonic plague in the 14th century. It normally produces ATP in the presence of oxygen but can still produce ATP if oxygen is absent. Which term describes this characteristic?

A. Facultative respiration

B. Facultative anaerobe

C. Obligate anaerobe

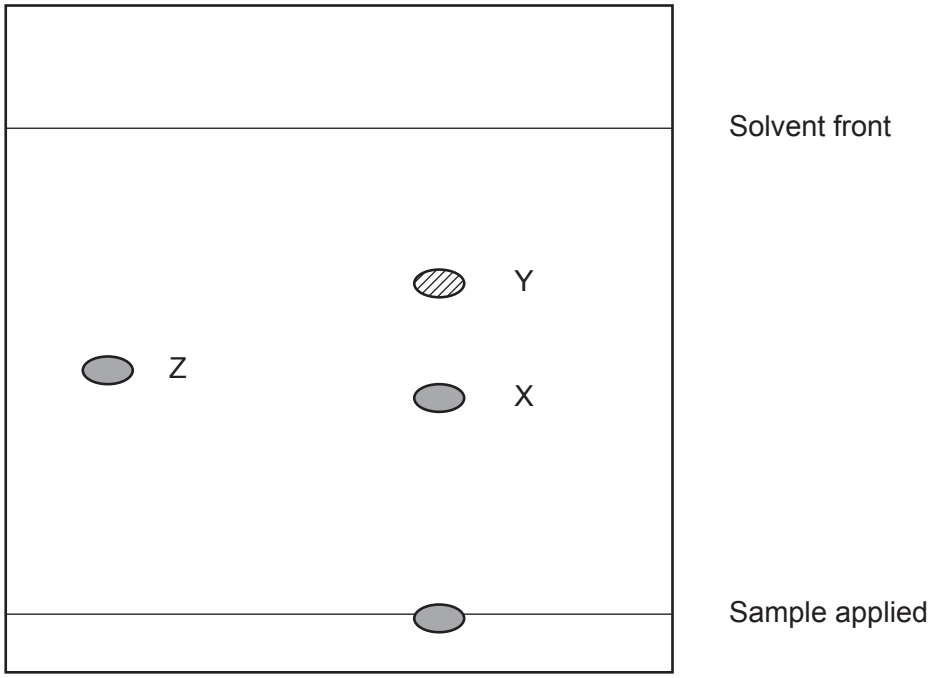
D. Obligate aerobe

APOLLO

# Photosynthesis

10 questions

**8.** The diagram shows a chromatogram of the pigments in a leaf. Substance Z is known to have an $R_f$ of 0.5.

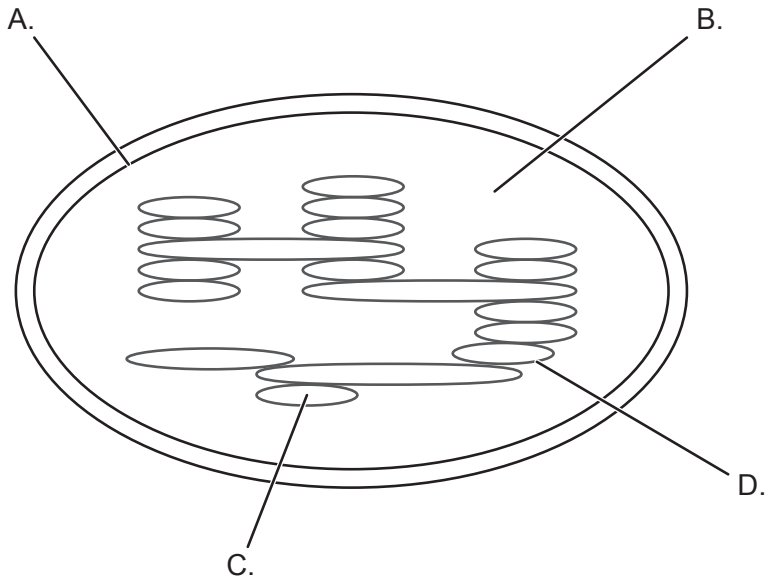



| Pigment | Colour | $R_f$ |
|---|---|---|
| Carotene | Yellow | 0.95 |
| Phaeophytin | Yellow-grey | 0.83 |
| Chlorophyll *a* | Blue-green | 0.65 |
| Chlorophyll *b* | Green | 0.45 |

What are pigments X and Y?

| | X | Y |
|---|---|---|
| A. | Chlorophyll *a* | Phaeophytin |
| B. | Chlorophyll *a* | Carotene |
| C. | Chlorophyll *b* | Carotene |
| D. | Chlorophyll *b* | Chlorophyll *a* |

**14.** The diagram shows the structure of a chloroplast. Where does the Calvin cycle occur?



**6.** Bromothymol blue is an indicator that is initially blue and turns yellow when $CO_2$ is present. Tests were carried out varying the presence of a plant (*Elodea canadensis*) and a snail (*Marisa cornuarietis*) in an aquatic environment. What condition would produce a blue colour after sampling the water?

A. Plant kept in the dark without snail

B. Plant and snail kept in the dark

C. Plant kept in the light without snail

D. Snail with no plant

**7.** What occurs during photosynthesis?

A. Water is oxidized by releasing two electrons to NADPH.

B. Glycerate-3-phosphate (GP) is oxidized by releasing two electrons to photosystem II.

C. NAD is reduced by accepting two electrons from ATP.

D. NADP is reduced by accepting two electrons from photosystem I.

**8.** The Calvin cycle continues throughout the life of a plant. In this cycle, triose phosphate is produced, which is used to form glucose. In total, how many RuBP molecules are regenerated in the process of creating one glucose molecule?

A. 2

B. 6

C. 10

D. 14

**Turn over**

**7.** Which group(s) produce(s) oxygen as a by-product of photosynthesis?

I. Algae
II. Cyanobacteria
III. Fungi

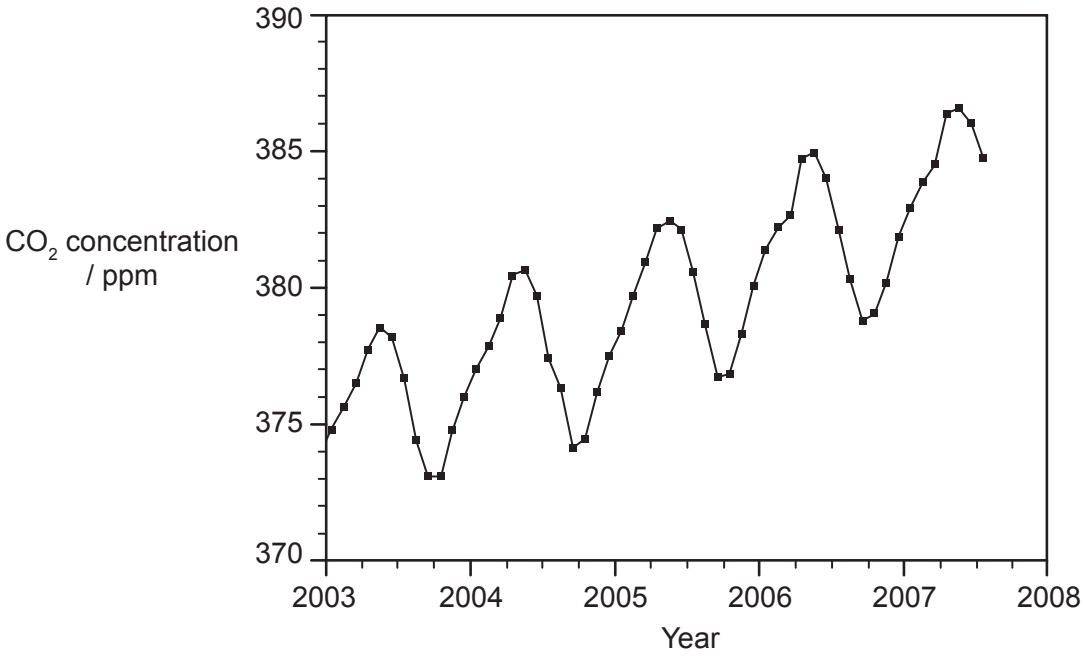
A. I only

B. I and II only

C. II and III only

D. I, II and III

**36.** The graph shows data collected at Mauna Loa, USA, for monthly mean carbon dioxide concentration.




What causes the decreases in monthly mean carbon dioxide concentration each year?

A. Combustion increases.

B. Respiration increases.

C. Decomposition increases.

D. Photosynthesis increases.

## Section B

Answer **two** questions. Up to one additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**10.** All cells require a supply of energy and can transform the energy that they obtain in different ways.

(a) Explain the properties of ATP that make it useful for distributing energy within cells. [3]

(b) Describe how cells in plants use light energy to produce ATP. [7]

(c) Compare and contrast how different types of heterotrophs obtain the energy that they need to produce ATP. [5]

**Disclaimer:**

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**References:**

**1.** Image: diegograndi, 2023. *Beautiful Fluffy White Angora Rabbit*. [image online] Available at: https://www.gettyimages.co.uk/detail/photo/beautiful-fluffy-white-angora-rabbit-royalty-free-image/1804804966 [Accessed 30 April 2024]. Source adapted.

**4.** David Nascari and Alan Sved. https://commons.wikimedia.org/wiki/File:Impact_of_arterial_blood_gases_on_alveolar_ventilation.png. Licensed under CC BY-SA 4.0 https://creativecommons.org/licenses/by-sa/4.0. Image adapted.

**5.** Gorvett, P., 2022. *Japanese Knot weed highly invasive plant*. [image online] Available at: https://www.gettyimages.co.uk/detail/photo/very-fast-growing-japanese-knot-weed-highly-royalty-free-image/1396706880 [Accessed 13 May 2024]. Reference redacted. Source adapted.

**6.** Berkshire Community College Bioscience Image Library. https://commons.wikimedia.org/wiki/File:Mesophyte_leaf_Syringia_(34850169936).jpg. Public domain.

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Question 10 - working space

**8.** What occurs in photosynthesis?

A. Photolysis occurs in photosystem I.

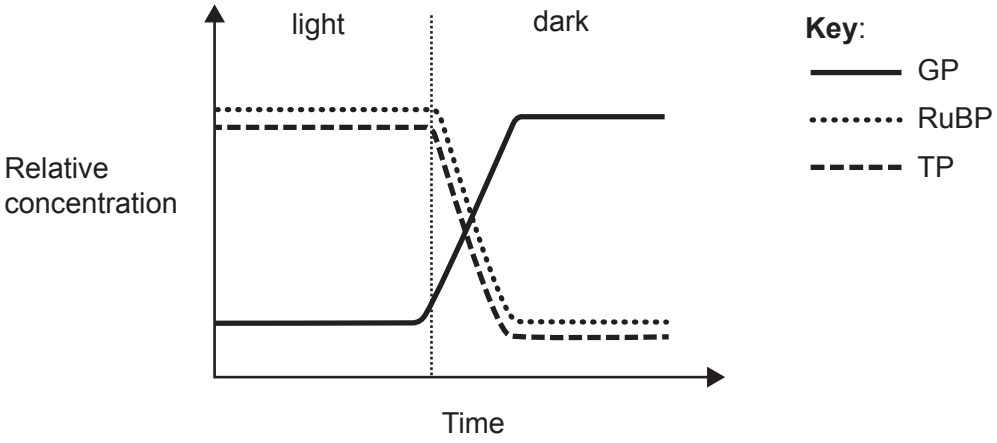
B. Electron transport chain synthesises ATP in the outer membrane of the chloroplast.

C. Oxidation of NADP occurs in photosystem I.

D. Photosystems I and II emit excited electrons.

**Turn over**

**7.** A photosynthesis experiment was set up in both light and dark conditions to determine the variations in relative concentrations of glycerate-3-phosphate (GP), triose phosphate (TP) and ribulose bisphosphate (RuBP).




What explains the results obtained in the dark conditions?

A. TP and RuBP from the light-dependent reaction are used to synthesize GP.

B. Less ATP and reduced NADP (NADPH) are available to convert GP to TP.

C. There is a low carbon dioxide supply for carbon fixation.

D. The enzyme Rubisco is only active in the presence of light.

**Turn over**

APOLLO

# Chemical signalling

14 questions

**28.** Which chemical causes positive feedback to ensure rapid ripening of fruit?

A. Auxin

B. Cytokinin

C. Epinephrine

D. Ethylene

**32.** What controls the developmental changes during puberty?

I. Increased release of gonadotropin-releasing hormone (GnRH) by the hypothalamus

II. Luteinizing hormone (LH) leading to increased sex hormone production

III. Gonadotropin-releasing hormone (GnRH) triggering the onset of increased luteinizing hormone (LH)

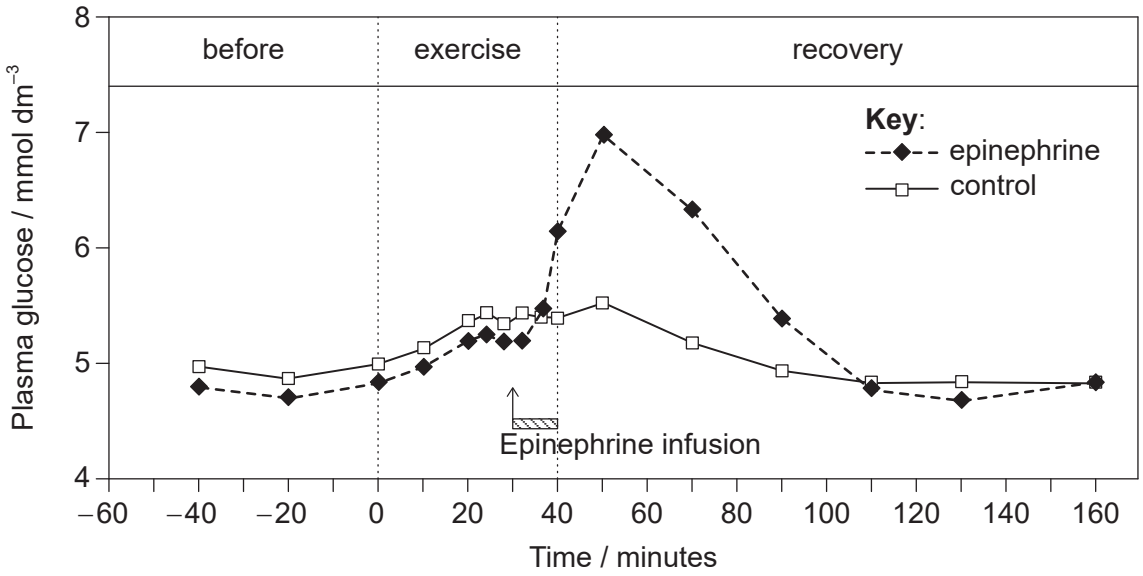
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

**18.** The graph shows changes in blood plasma glucose concentration before exercise, during exercise and during recovery with and without epinephrine (adrenaline) infusion. Epinephrine infusion was started 30 minutes into the exercise routine.




[Source: Kreisman, S.H., Ah Mew, N., Arsenault, M., Marliss, E.B., et al., 2000. *AJP Endocrinology and Metabolism* 278(5): E949–57. https://doi.org/10.1152/ajpendo.2000.278.5.E949. Reference redacted. Source adapted.]

Which action of epinephrine would result in the observed changes to plasma glucose concentration?

A. Second messenger is deactivated.

B. A G protein is activated, and cyclic AMP (cAMP) is produced.

C. Second messenger stimulates the production of ATP.

D. Cyclic AMP (cAMP) deactivates the G protein.

**26.** What plays a direct role in promoting the ripening of fruit?

A. Oestradiol

B. Auxin

C. Cytokines

D. Ethylene

**28.** Jetlag occurs when the circadian rhythm of a person changing time zones is disrupted. For what reason might they have difficulty sleeping after sunset?

A. The hypothalamus is secreting too much melanin.

B. The pineal gland is not secreting sufficient melatonin.

C. The lack of sunlight inhibits the production of vitamin D.

D. The pituitary gland is secreting too much oxytocin.

**29.** What correctly describes the action of auxin in phototropism?

A. Auxin efflux carriers actively transport auxin in and out of cells.

B. Auxin promotes hydrogen ion secretion into the cytoplasm.

C. Auxin efflux carriers are positioned in the plasma membrane on one side of the cell.

D. Auxin breaks beta-glucose links in the cell wall.

**Turn over**

**17.** What is an example of quorum sensing?

A. Expression of incomplete dominance by *Mirabilis jalapa* flowers

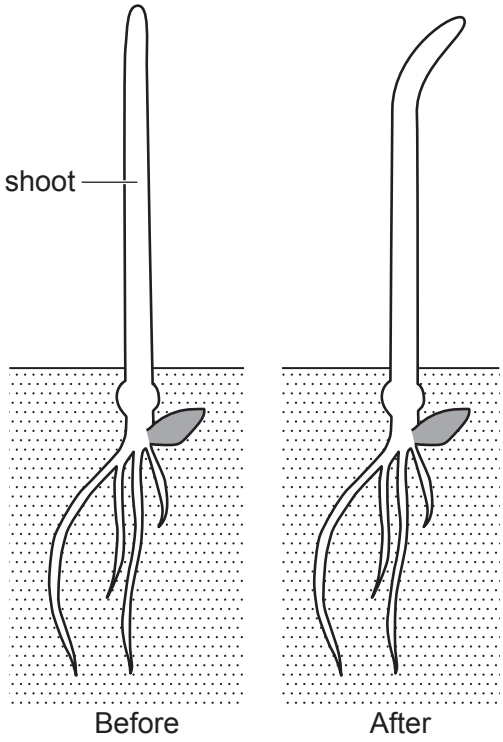
B. Spring growth of the Arctic mouse-ear chickweed *Cerastium arcticum*

C. Bioluminescence in the marine bacterium *Vibrio fischeri*

D. Biochemical control of lactase synthesis in *Escherichia coli* bacteria

**Turn over**

**27.** The image shows the response of a plant shoot to light exposure.




[Source: Kutschera, Ulrich & Niklas, Karl. (2009). Evolutionary plant physiology: Charles Darwin's forgotten synthesis. *Naturwissenschaften*. 96. 1339–1354, Springer Nature. Available at https://link.springer.com/article/10.1007/s00114-009-0604-z.]

What facilitates this response?

I. Auxin efflux carriers are located on one side of the cell.
II. Auxin promotes hydrogen ion secretion.
III. Cell walls become acidified and cellulose cross links are loosened.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

**Turn over**

**17.** Mutualistic bacterium *Vibrio fischeri* lives in the light organ of some squid species. As a result of quorum sensing, bioluminescence is produced, which camouflages squid from predators.

How does quorum sensing trigger bioluminescence?

A. At high population density, bacteria secrete ligands that bind to receptors in the squid's light organ.

B. Above a critical *V. fischeri* density, signalling molecules activate bacterial genes involved in bioluminescence.

C. A high concentration of bacterial signalling molecules causes the expression of bioluminescence genes in the squid DNA.

D. When at risk, the squid's light organ sends signals to stimulate production of bioluminescence in bacteria.

**Turn over**

**27.** What can cause hormone secretion from the pineal gland?

A. The intake of glucose

B. The sound of classical music

C. The onset of darkness

D. A decrease in body temperature

**18.** What activates a tyrosine kinase pathway in a cell following binding to a receptor?

A. Odorant molecules

B. Epinephrine

C. Taste molecules

D. Insulin

**21.** What is the cause of positive phototropism?

A. Increased concentration of auxin on the side of the stem closest to the light

B. Degradation of auxin on the side of the stem closest to the light

C. Increased concentration of auxin on the side of the stem furthest from the light

D. Degradation of auxin on the side of the stem furthest from the light

**Turn over**

**22.** Which role does positive feedback play in fruit ripening?

A. The production of ethylene leads to fruit ripening, which stops the production of ethylene.

B. The production of ethylene leads to fruit ripening, which causes more ethylene production.

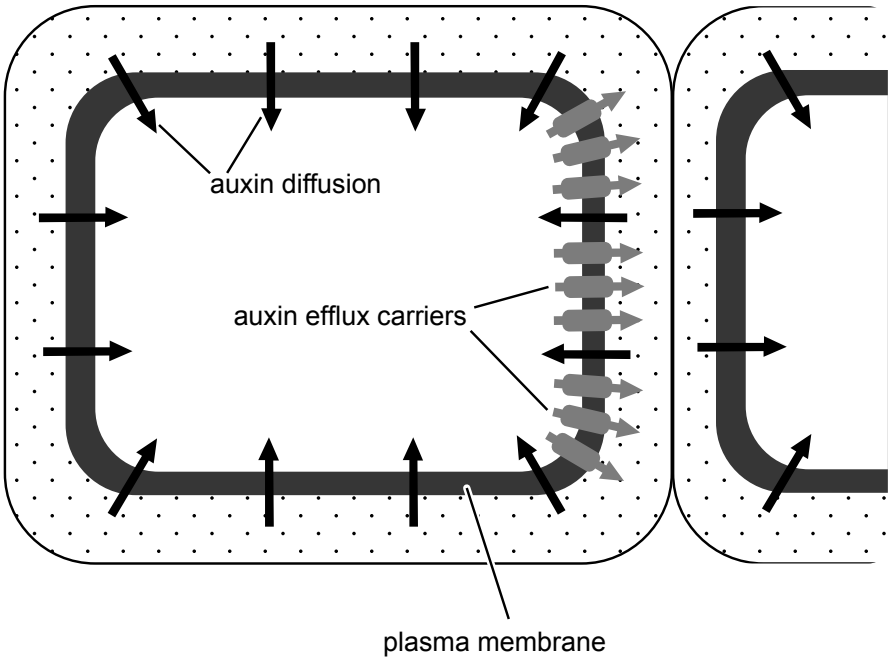
C. The production of RuBP leads to fruit ripening, which stops the production of RuBP.

D. The production of RuBP leads to fruit ripening, which causes more RuBP production.

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**3.** The diagram shows the movement of auxin across the plasma membrane of a plant cell as well as the position of auxin efflux carriers.




(a) (i) Annotate the diagram, using an arrow, to show the direction of the net flow of auxin through the cell. [1]

(ii) Identify an environmental factor that causes auxin efflux carriers to be concentrated on one side of a cell. [1]

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(b) (i) Predict the difference that could be seen using a microscope between plant meristematic cells grown in media with and without auxin. [1]

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(ii) State the hormone that interacts with auxin to integrate shoot growth. [1]

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**Turn over**

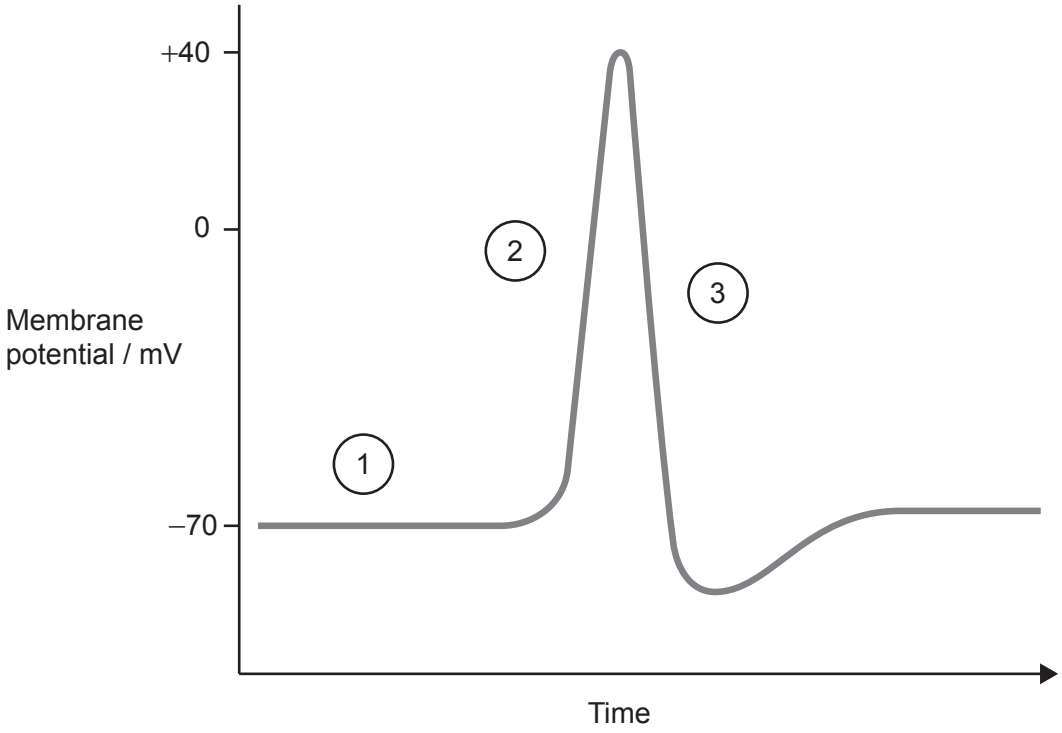
Question 3 - working space

APOLLO

# Neural signalling

16 questions

**17.** The graph below shows an action potential.




Where on the graph do the sodium channels open?

A. At 1

B. Between 1 and 2

C. At 2

D. Between 2 and 3

**Turn over**

**18.** What effect does cocaine have on neural signalling?

A. Blocks the reuptake of neurotransmitters in the synapse

B. Opens channels for positively charged ions to initiate an action potential

C. Acts as a non-competitive inhibitor of the sodium–potassium pump

D. Triggers an increase in saltatory conduction in the nodes of Ranvier

**26.** Which of these structures is most likely to be the effector in a pain reflex arc?

A. Grey matter

B. Skeletal muscle

C. Motor neuron

D. Pineal gland

**17.** What is the action of neonicotinoids on the synapse of an insect?

A. They prevent the release of acetylcholine from the presynaptic membrane.

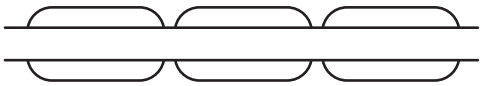
B. They increase the permeability of the presynaptic neuron to sodium ions.

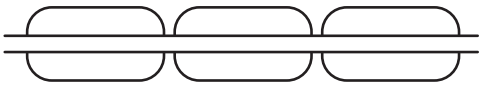
C. They bind to the acetylcholine receptor on the postsynaptic neuron.

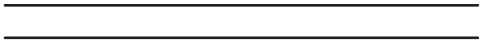
D. They block the uptake of acetylcholine in vesicles in the presynaptic neuron.

**Turn over**

**17.** The diagrams represent sections through different axons. Which axon has the slowest speed of impulse?

A. 

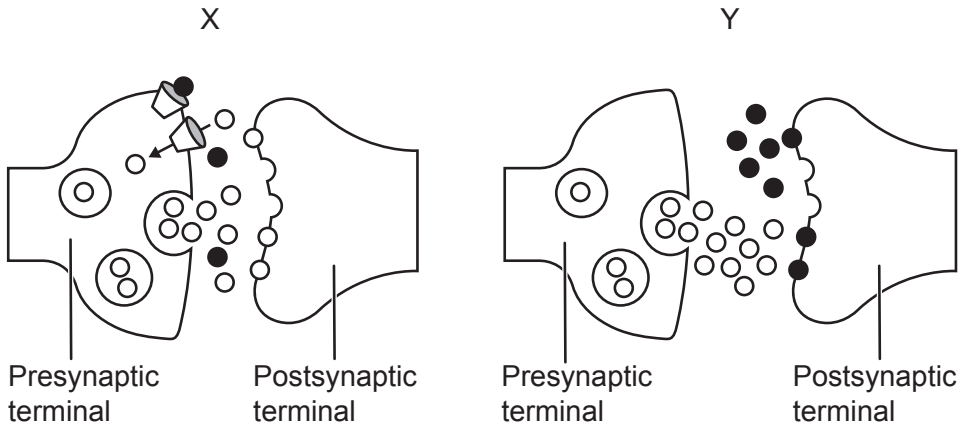
B. 

C. 

D. 

**Turn over**

**18.** Diagrams X and Y show the possible action on synaptic transmission of two exogenous chemicals.




**Key**:

○ neurotransmitter ● neonicotinoid or cocaine

Cocaine and neonicotinoids have different modes of action. Which statement identifies the correct mode of action of one of these chemicals?

A. Y shows cocaine because it prevents binding of the neurotransmitter to the postsynaptic membrane.

B. X shows neonicotinoid because it is taken up by the presynaptic terminal.

C. Y shows neonicotinoid because it binds to the neurotransmitter.

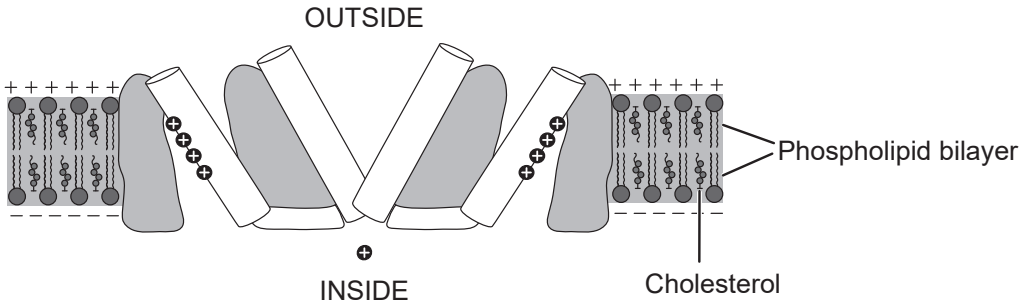
D. X shows cocaine because the neurotransmitter cannot be taken up by the presynaptic terminal.

## Section A

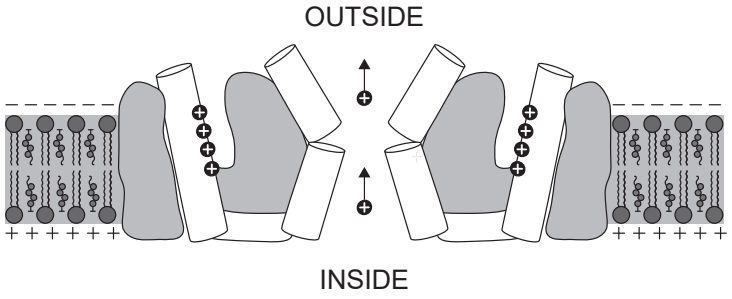
Answer **all** questions. Answers must be written within the answer boxes provided.

**3.** Voltage-gated ion channels are proteins that are embedded in the phospholipid bilayer of plasma membranes. They conduct ions at high rates, regulated by the voltage across the membrane. The diagram shows a typical voltage-gated potassium ($K^+$) channel when it is closed and when it is open.

Closed:




Open:




(a) Explain the action of the voltage-gated potassium channel during a nerve impulse. [3]

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**(This question continues on the following page)**

**(Question 3 continued)**

(b) State another type of gated ion channel. [1]

. . . . . .

(c) Outline the amphipathic characteristic of phospholipid bilayers. [1]

. . . . . .

. . . . . .

(d) Outline the effect of cholesterol on the fluidity of membranes. [1]

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(e) Outline the effect of fatty acids on the fluidity of membranes. [1]

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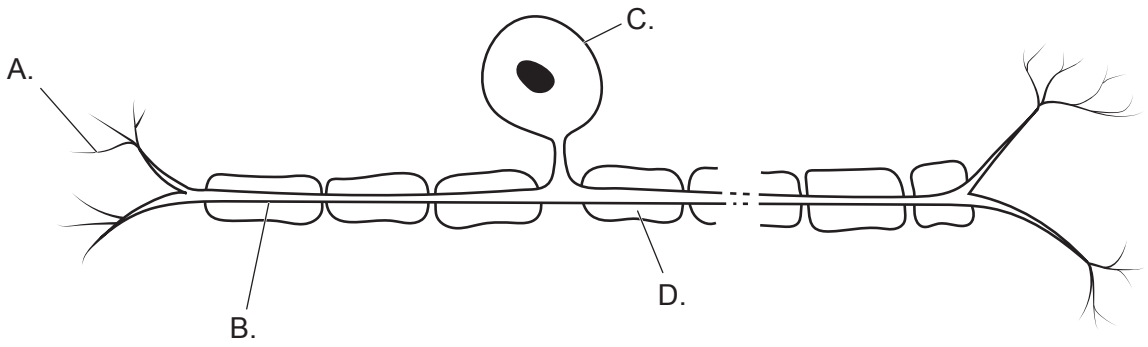
. . . . . .

Question 3 - working space

**15.** The table shows two types of gated ion channels in neurons. How are they gated?

| | Nicotinic acetylcholine receptors | Potassium channels |
|---|---|---|
| A. | voltage | neurotransmitter |
| B. | neurotransmitter | voltage |
| C. | voltage | voltage |
| D. | neurotransmitter | neurotransmitter |

**18.** The image shows a neuron. Which letter shows a dendrite?



**26.** Which is the effector in a pain reflex arc?

A. Skeletal muscle

B. Sensory nerve ending

C. Pituitary gland

D. Grey matter of spinal cord

**18.** The conduction velocity of electrical impulses was measured in different myelinated nerve fibres.

| Type of nerve fibre | Conduction velocity / m $s^{-1}$ |
|---|---|
| P | 3–10 |
| Q | 30–70 |
| R | 80–110 |

Which hypothesis would explain the higher conduction velocity of nerve fibre R, compared to nerve fibres P and Q?

A. It is the longest.

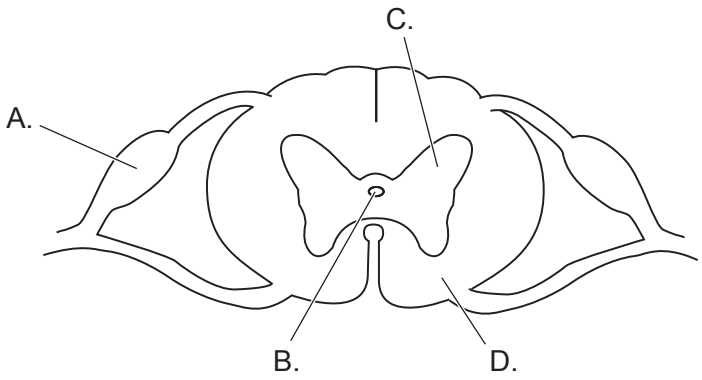
B. It has the thinnest myelin sheath.

C. It has the largest diameter.

D. It has the greatest number of mitochondria.

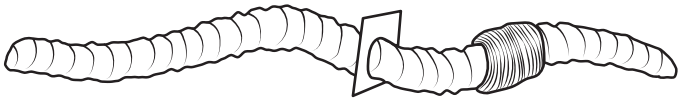
**28.** The spinal cord is involved in the coordination of involuntary actions such as the pain reflex.

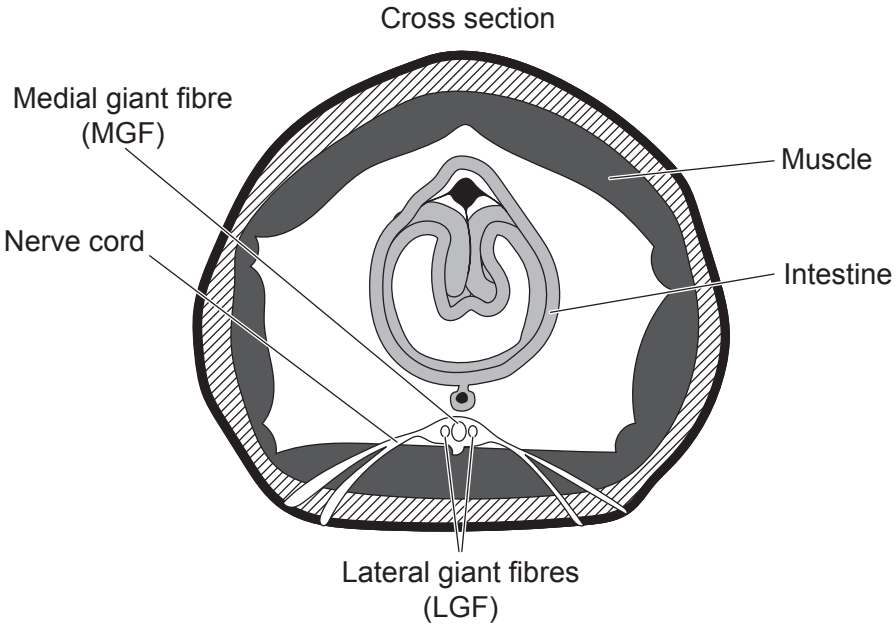
Where are synapses between sensory neurons and interneurons found?



**3.** Earthworms (*Lumbricus terrestris*) have a nerve cord on the ventral (underside) side of their body. It contains three nerve fibres (axons), each with a very large diameter, which extend along the whole length of the nerve cord. There is one medial giant fibre (MGF) and two lateral giant fibres (LGFs). The diameter of the MGF is 1.4 times larger than the LGF.

Scientists developed a non-invasive method to record giant nerve fibre activity. The response from the MGF was measured by the electrical activity produced when touching the front segments of the earthworm while the LGF was measured when touching the back segments.






**(This question continues on the following page)**

**(Question 3 continued)**

The table shows the mean conduction rates, standard deviation (SD) and number of individual measurements of MGF and LGF action potentials in each earthworm. At the end of the table, the mean and standard error (SE) for 9 of the earthworms are shown.

| | MGF | | | LGF | | |
|---|---|---|---|---|---|---|
| **Earthworm** | **Mean conduction rate / $m s^{-1}$** | **SD / $m s^{-1}$** | **Number of measurements** | **Mean conduction rate / $m s^{-1}$** | **SD / $m s^{-1}$** | **Number of measurements** |
| 1 | 38.1 | 5.1 | 24 | 13.7 | 2.0 | 21 |
| 2 | 31.4 | 6.8 | 17 | 13.4 | 1.8 | 13 |
| 3 | 29.2 | 4.7 | 13 | 11.4 | 2.2 | 19 |
| 4 | 29.7 | 7.5 | 17 | 11.7 | 2.8 | 12 |
| 5 | 29.7 | 4.1 | 6 | 11.4 | 1.6 | 16 |
| 6 | 36.1 | 5.8 | 23 | 13.6 | 2.1 | 16 |
| 7 | 30.1 | 4.9 | 17 | 12.8 | 2.7 | 19 |
| 8 | 33.5 | 4.4 | 16 | 11.9 | 1.5 | 18 |
| 9 | 32.2 | 5.3 | 23 | 13.7 | 2.1 | 21 |
| 10 | 33.3 | – | 1 | 15.5 | 2.0 | 3 |
| **Mean / $m s^{-1}$** | **32.2** | | | **12.6** | | |
| **SE / $m s^{-1}$** | | **1.0** | | | **0.3** | |

**(This question continues on the following page)**

**(Question 3 continued)**

(a) State the apparatus used to show the resting and action potentials. [1]

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(b) (i) Distinguish between SD and SE. [2]

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(ii) Suggest **one** reason for not calculating the SD for earthworm 10. [1]

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(c) (i) Calculate how many times faster the mean MGF is compared to the mean LGF. [1]

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(ii) Suggest **one** possible reason that the conduction rate in the MGF is much faster than in the LGF. [1]

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**(This question continues on the following page)**

**(Question 3 continued)**

(d) Explain saltatory conduction. [3]

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Question 3 - working space

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**8.** Interactions in biological systems may have harmful or beneficial effects.

(a) Explain, using an example, how competitive inhibitors interfere with enzyme activity. [4]

(b) Describe the role of neurotransmitters in synaptic transmission and how transmission can be disrupted by exogenous chemicals. [7]

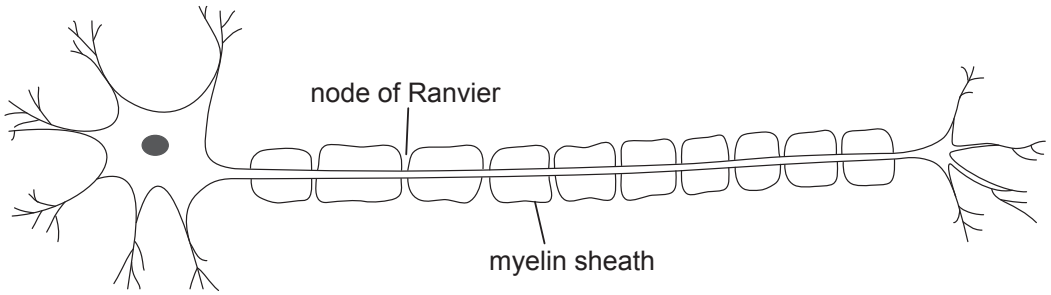
(c) Discuss the consequences of infection with HIV. [4]

Question 8 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**3.** The diagram shows a cell from the nervous system.




(a) Outline how the myelin sheath and nodes of Ranvier increase the speed of an action potential along a neuron. [2]

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(b) Compare and contrast the movement of particles across plasma membranes by simple diffusion and facilitated diffusion. [2]

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(c) Describe the effect of neonicotinoid pesticides on synaptic transmission in insects. [3]

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Question 3 - working space

**28.** How is involuntary peristalsis in the intestine directly controlled in humans?

A. By the endocrine system

B. By the central nervous system (CNS)

C. By the sympathetic nervous system

D. By the enteric nervous system (ENS)

APOLLO

# Defence against disease

7 questions

**27.** Which cell type is part of the innate immune system?

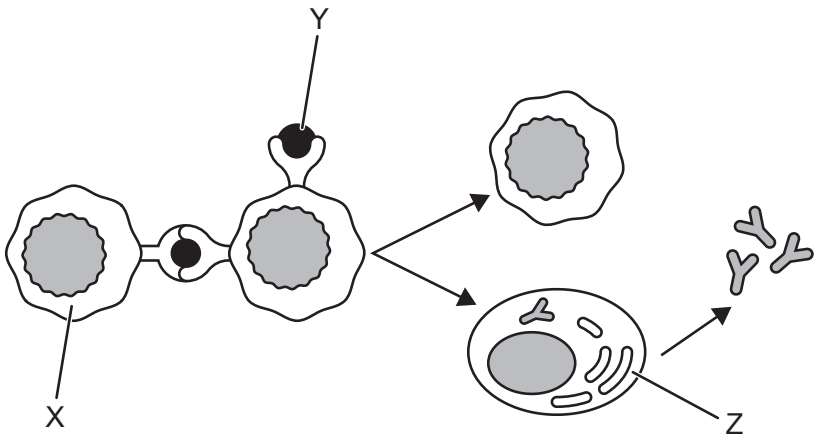
A. Phagocytes

B. B-lymphocytes

C. T-lymphocytes

D. Helper T-cells

**27.** The diagram shows stages in an immune response.




What is represented by labels X, Y and Z?

| | X | Y | Z |
|---|---|---|---|
| A. | helper T-cell | antibody | plasma cell |
| B. | B-cell | antigen | memory B-cell |
| C. | helper T-cell | antigen | plasma cell |
| D. | B-cell | antibody | memory B-cell |

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**5.** Adaptive immunity leads to cells that are infected by viruses being killed, resulting in immune memory which is the basis of vaccination.

(a) Distinguish between innate and adaptive immune response. [1]

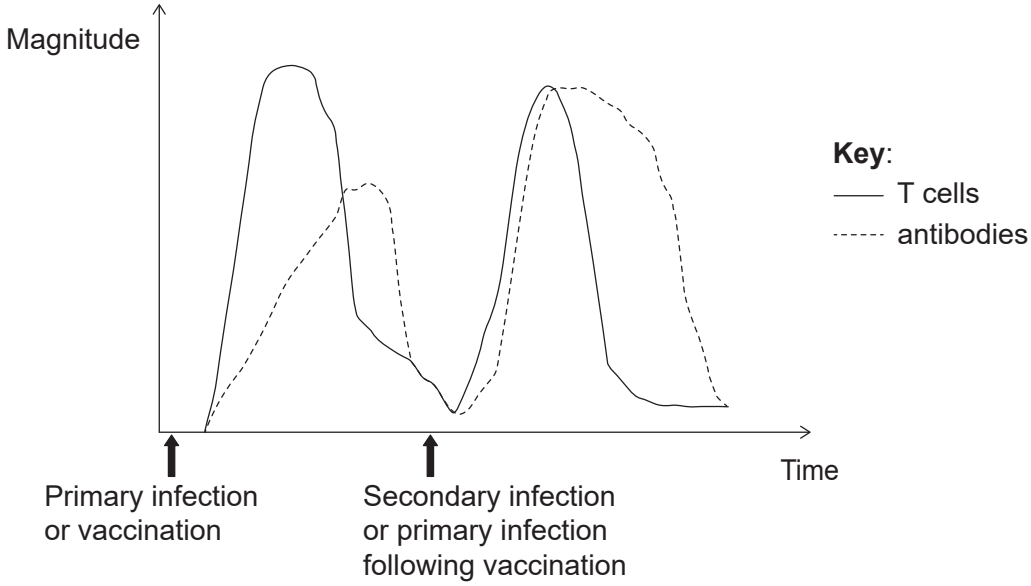
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**(This question continues on the following page)**

**(Question 5 continued)**

The graph shows the magnitude of the immune response after infection or after vaccination over time.




(b) Explain reasons that the T-cells peak before the antibodies after primary infection or vaccination, but T-cells peak at the same time as the antibodies after secondary infection or primary infection following vaccination. [2]

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(c) Different types of vaccine are used to prevent viral diseases. Justify this statement in terms of the structure of viruses. [2]

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Question 5 - working space

**28.** Which function is primarily associated with helper T-cells in the immune system?

A. Phagocytosis of pathogens

B. Activation of other cells in the immune system

C. Antibody production

D. Retention as memory cells

**26.** Which of the following will cause the production of antibodies during an infection?

A. Conversion of fibrinogen to fibrin by thrombin

B. B-cell activation by helper T-cells and antigens

C. Plasma cell activation by platelets

D. Activation of phagocytes by infected body cells

**Turn over**

**29.** Which cell is a component of the innate immune system?

A. T lymphocyte

B. Phagocyte

C. B lymphocyte

D. B memory cell

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**8.** There are a number of advantages to specificity.

(a) Explain how vaccination can result in specific immunity to a viral disease. [7]

(b) Outline the role of membrane proteins in the movement of specific ions at specific times in the transmission of nerve impulses. [4]

(c) Describe the barriers that exist to hybridization between species. [4]

Question 8 - working space

APOLLO

# Populations and communities

14 questions

**36.** A capture–mark–release–recapture experiment was used, together with the Lincoln index formula (population size estimate = M × N/R), to estimate the population size of common periwinkles (*Littorina littorea*) on a rocky shore. The table shows the data collected.



| | |
|---|---|
| Individuals captured and marked initially | 100 |
| Individuals recaptured | 50 |
| Marked individuals recaptured | 10 |

What is the estimated size of the population?

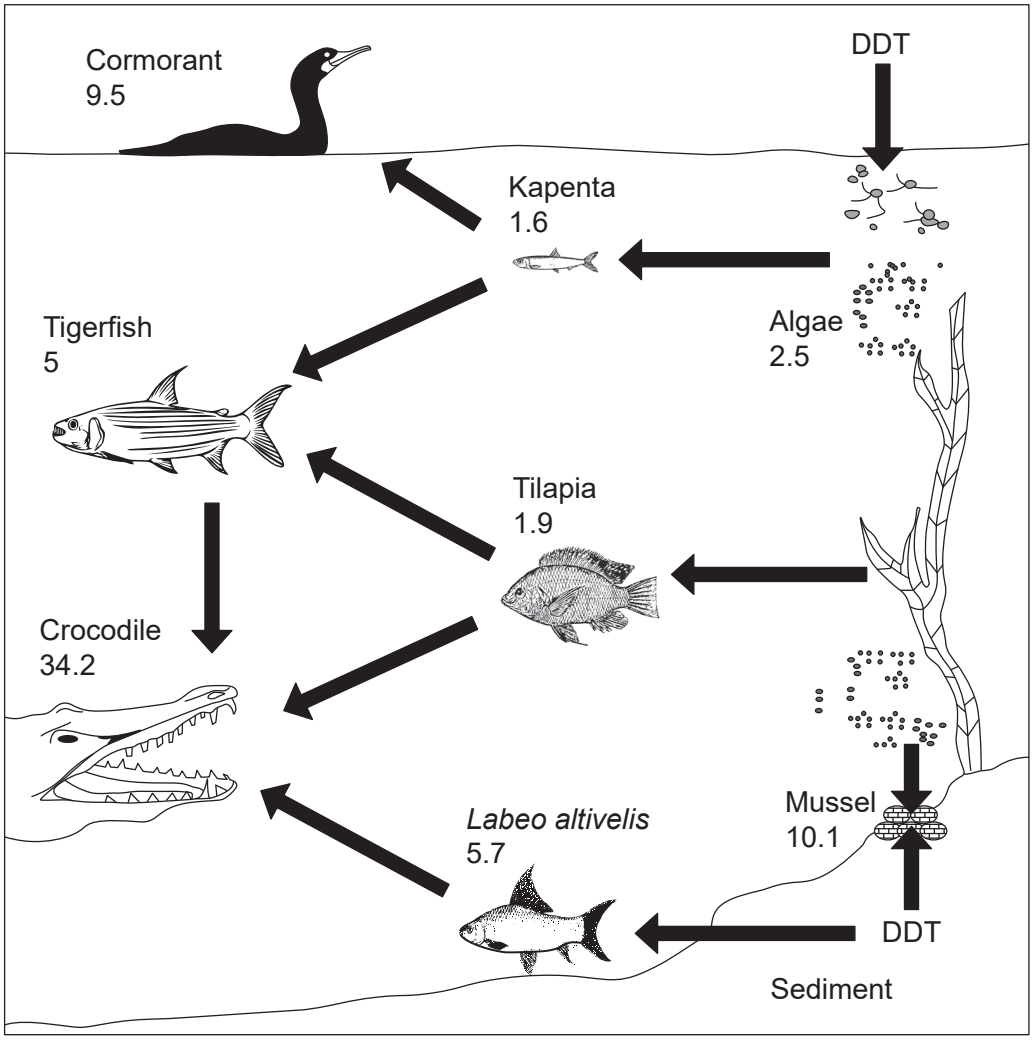
A. 160

B. 500

C. 1000

D. 5000

**2.** The diagram shows levels of DDT, a pesticide, in an aquatic food web in Lake Kariba, Africa. Numbers represent ppm (parts per million) of DDT in fat tissue.




(a) Justify the observation that the crocodile has a higher mean DDT level than the cormorant or tigerfish. [2]

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**(This question continues on the following page)**

**(Question 2 continued)**

(b) Identify, with a reason, which fish would be the safest to consume. [2]

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(c) Outline how the population size of tilapia could be estimated. [3]

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(d) Discuss the impact of overfishing in Lake Kariba and how sustainable harvesting of resources can be assessed. [4]

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Question 2 - working space

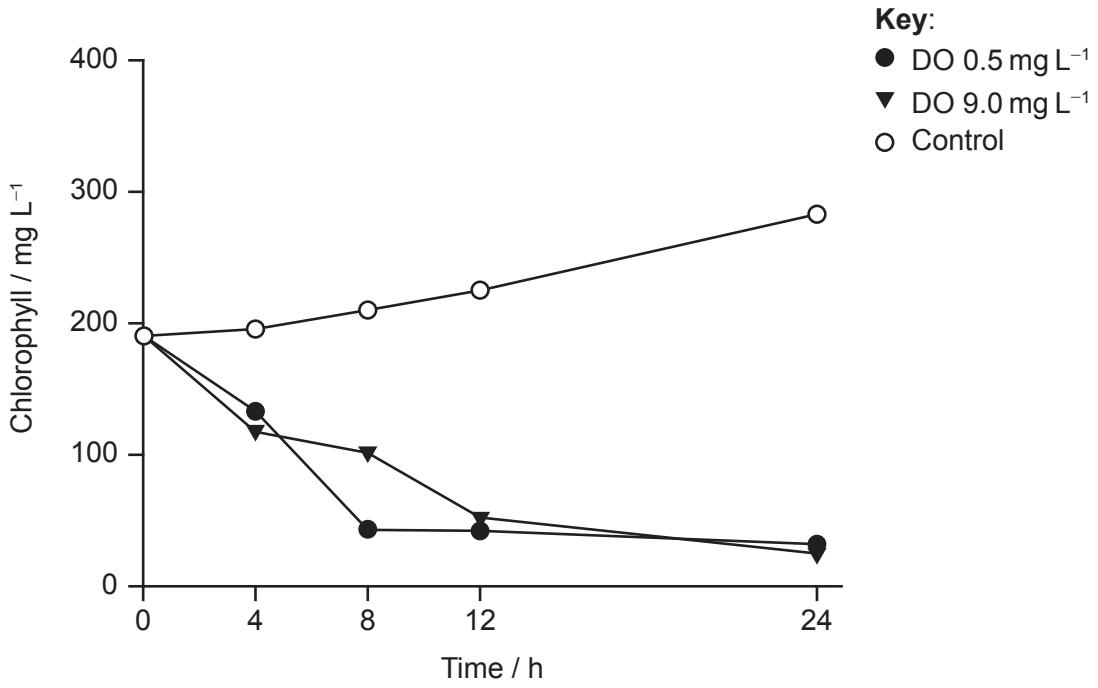
## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**1.** Freshwater mussels are molluscs found in rivers and lakes worldwide. They filter water for food and remove algae, bacteria and detritus, improving the water quality.



Researchers in South Korea placed mussels (*U. douglasiae*) in water containing cyanobacteria, a type of photosynthetic bacteria that cause eutrophication of rivers and lakes. The density of cyanobacteria is proportional to the concentration of chlorophyll in the water. The filtration rate by mussels can be determined by measuring the change in concentration of chlorophyll at various time intervals. The experiments were conducted with two different levels of dissolved oxygen in the water (DO). In the control experiment, no mussels were present and the DO level was 9.0 mg $L^{-1}$.




**(This question continues on the following page)**

**(Question 1 continued)**

(a) Estimate the concentration of chlorophyll in the water of the control after 18 hours. [1]

. . . . . .

(b) Distinguish between the density of cyanobacteria when mussels are absent (control) and when mussels are present at $DO = 9.0\,mg\,L^{-1}$. [1]

. . . . . .

. . . . . .

(c) Suggest a reason for the change in the chlorophyll concentration of the control during the experiment. [1]

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(d) Compare and contrast the filtration by the mussels at the different oxygen levels over the period of the experiment. [2]

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. . . . . .

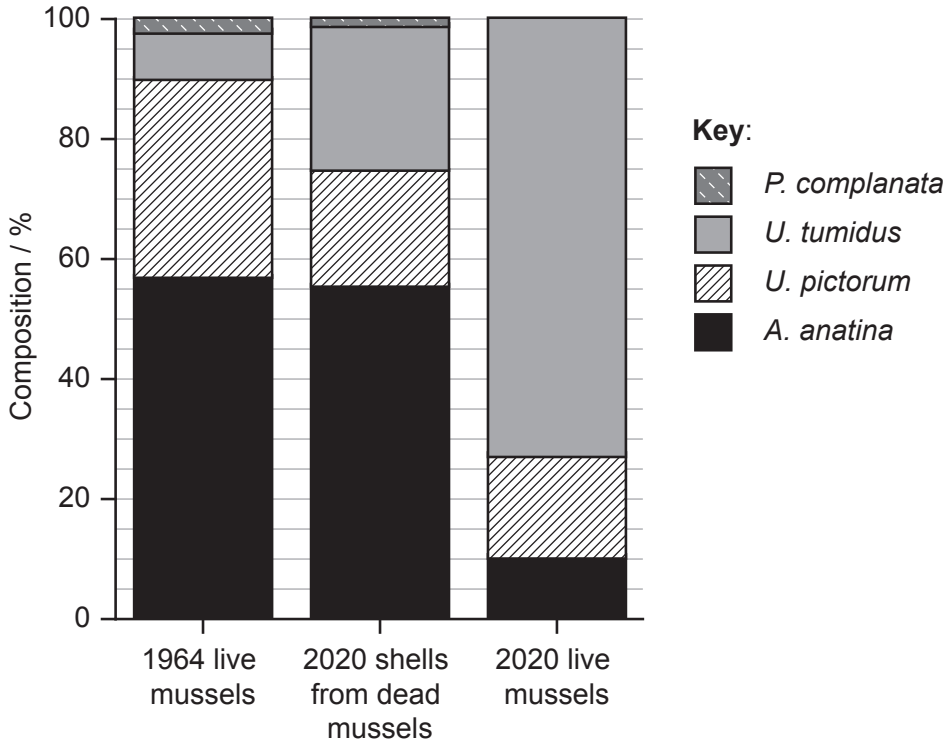
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**(This question continues on the following page)**

**(Question 1 continued)**

In 2020, scientists studied the population density of four species of mussel (*A. anatina*, *U. pictorum*, *U. tumidus* and *P. complanata*) in the River Thames in the United Kingdom. The results were compared with a previous study carried out at the same location in 1964. The chart shows the percentage of each type of live mussel found in both studies, as well as the percentage of shells from dead mussels found in 2020.




(e) Estimate the percentage of live mussels found in 1964 that were *U. pictorum*. [1]

. . . . . .

. . . . . .

(f) State, giving **one** reason, whether the population of mussel shells found in 2020 more closely resembled the live percentage composition found in 1964 or 2020. [1]

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**(This question continues on the following page)**

**(Question 1 continued)**

(g) Discuss whether the data shows that the population of *U. tumidus* has increased since 1964. [2]

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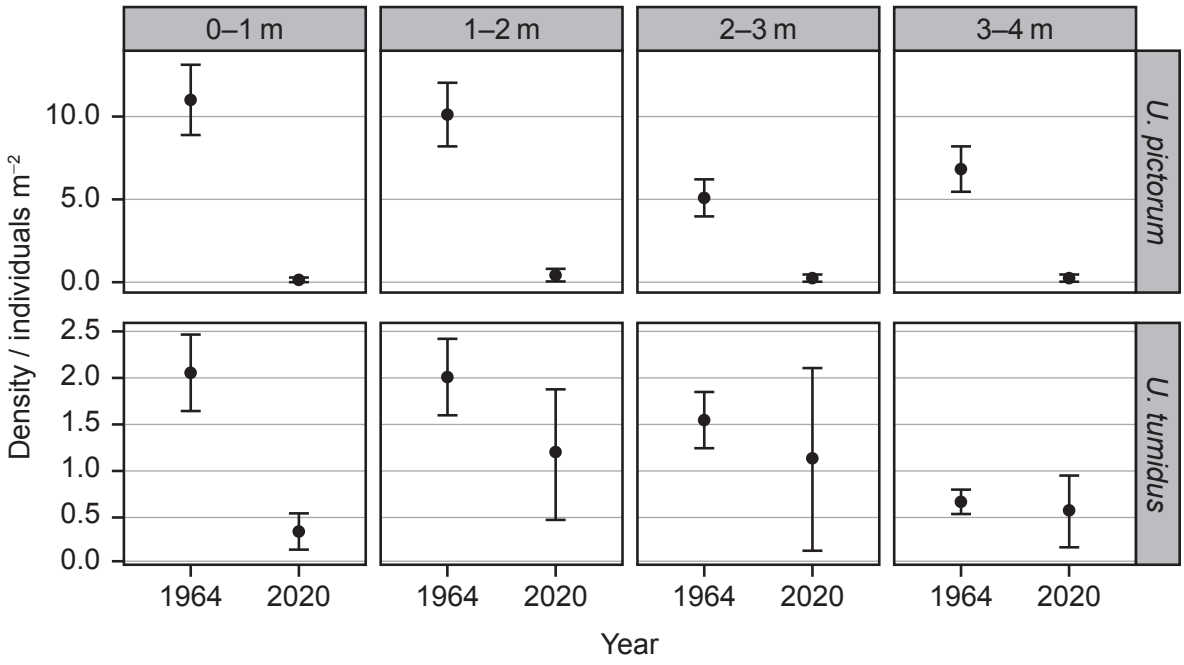
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**(This question continues on the following page)**

**(Question 1 continued)**

The researchers also studied the density of mussels at ranges of different water depths. The graph shows the results for two species, *U. pictorum* and *U. tumidus*.




(h) Calculate the mean percentage decrease in *U. pictorum* density in 1964 when increasing depth from 1–2m to 2–3m. [1]

. . . . . %

(i) Compare and contrast changes in mean density of both species between 1964 and 2020. [2]

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**(This question continues on the following page)**

**(Question 1 continued)**

(j) Using all the data, deduce with reasons whether the water quality of the River Thames changed from 1964 to 2020. [2]

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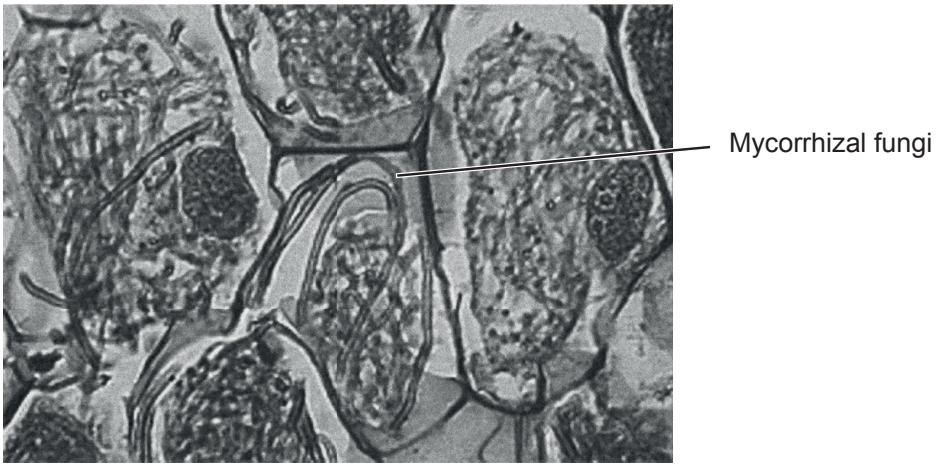
Apollo | Original source crop | 292

Question 1 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**3.** The image shows mycorrhizal fungi growing between the cells of a recently germinated orchid plant.




(a) (i) State the type of interspecific relationship shown by mycorrhizal fungi and plants in the orchid family (*Orchidaceae*). [1]

. . . . . .
. . . . . .

(ii) State **one** benefit of the relationship experienced by the orchid. [1]

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(b) Explain how a **named** plant can reduce competition by allelopathy. [3]

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Question 3 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**5.** The photograph shows Japanese knotweed, *Reynoutria japonica*, which is native to Japan, China and Korea. It has been introduced into other regions of the world and is now an invasive alien species in parts of Europe and North America. Dense groups of stems often develop with a height of up to 3 metres, which prevent other plants from growing.



(a) State the biological term for a group of organisms of the same species living in an area. [1]

. . . . . .

(b) Suggest **two** ways in which a plant such as *Reynoutria japonica* could prevent the growth of other plants. [2]

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**(This question continues on the following page)**

**(Question 5 continued)**

(c) Some insect species form interspecific relationships with *Reynoutria japonica*. Identify the relationship with these insect species:

(i) *Apis mellifera* (honey bee), which collects nectar from the flowers of *Reynoutria japonica*; [1]

. . . . . .

(ii) *Aphalara itadori*, which feeds on the shoots and young leaves of *Reynoutria japonica*. [1]

. . . . . .

Question 5 - working space

**36.** In the mutualistic relationship between mycorrhizae and Orchidaceae, what role do mycorrhizae play?

A. Nutrient absorption

B. Photosynthesis

C. Carbon dioxide production

D. Providing shelter

**Turn over**

**39.** Surtsey, a volcanic island approximately 32 km from the south coast of Iceland, is a new island formed by volcanic eruptions that took place from 1963 to 1967. It has been legally protected since its formation and is free from human interference.

What changes are likely to have been observed since the formation of Surtsey?

A. Cyclical succession as the climax community changes

B. Secondary succession when animal species arrived

C. Arrested succession due to the drainage of wetlands

D. Primary succession including an increase in size of plants

**Turn over**

**36.** What is an example of a population control mechanism within a community?

A. Bottom-up control of herbivores by a top predator

B. Top-down control of grasses by consumers

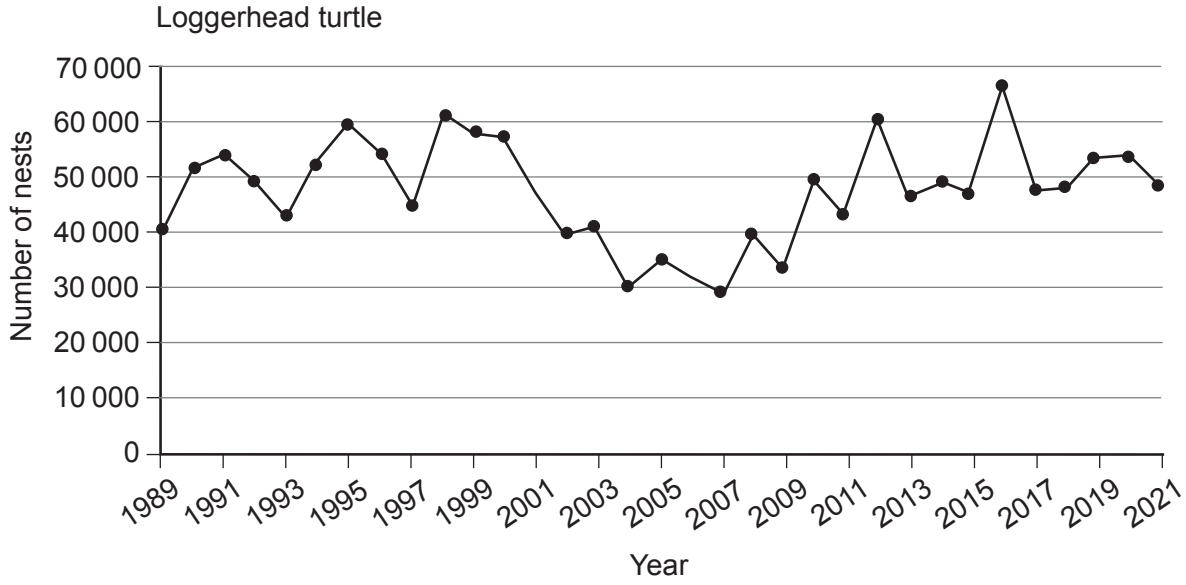
C. Top-down control of a plant species by soil nutrient availability

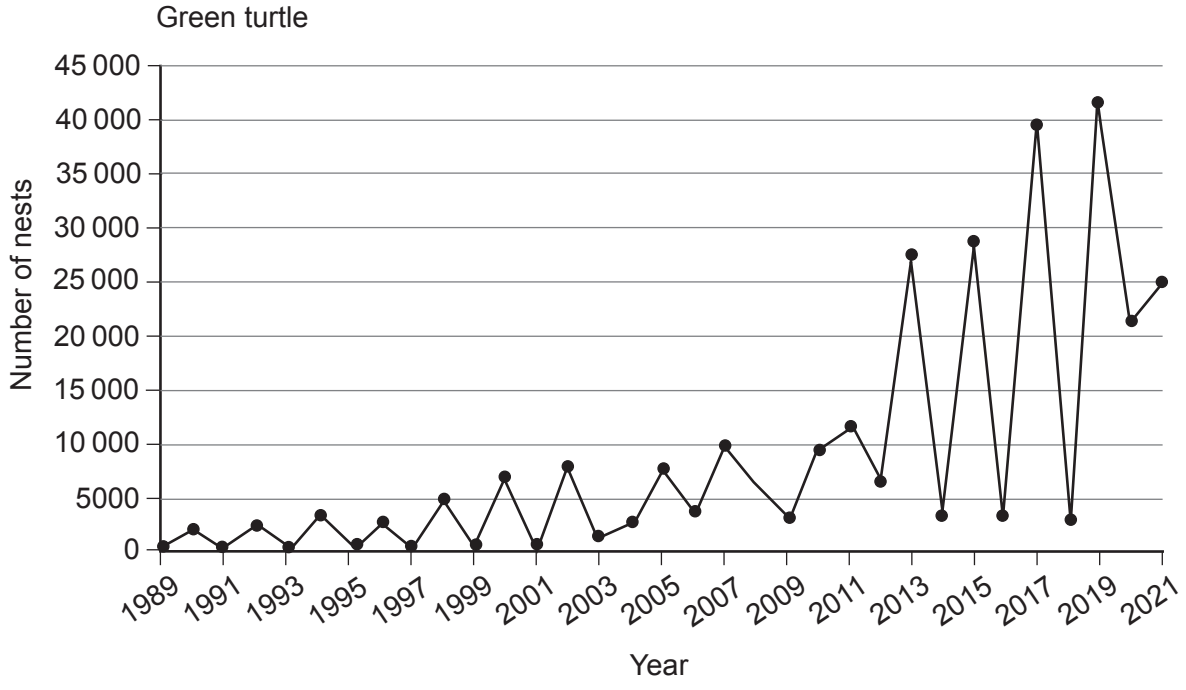
D. Bottom-up control of dissolved oxygen by corals

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**1.** To estimate the size of the turtle population, the Fish and Wildlife Research Institute (FWRI) conducted an annual survey along the coast of Florida from 1989 to 2021. They counted the number of turtle nests on selected beaches where turtles lay their eggs. The graphs show the results for the loggerhead turtle (*Caretta caretta*) and the green turtle (*Chelonia mydas*).




**(This question continues on the following page)**

**(Question 1 continued)**

(a) State the year in which most loggerhead turtle nests were counted in the survey. [1]

. . . . . .

. . . . . .

(b) Compare and contrast the change in the annual number of nests for the two species of turtle. [3]

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(c) Suggest the limitations of only using nesting turtles to estimate the annual population. [2]

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**(This question continues on the following page)**

**(Question 1 continued)**

Mortality or injury from being struck by a motorized water vessel (boat or craft) is a considerable risk for all turtles. Researchers studied stranded (dead, sick or injured) turtles found in Florida from 1986 to 2014, and identified those with a vessel strike injury (VSI). The turtles were classified as having either a definite vessel strike injury (DVSI) or a probable vessel strike injury (PVSI). The table shows the results for six species of turtle.

| Species | Number of stranded turtles | Number with a DVSI | Number with a DVSI or a PVSI | % with a DVSI | % with a DVSI or a PVSI |
|---|---|---|---|---|---|
| Loggerhead (*Caretta caretta*) | 19 111 | 4217 | 5983 | 22.1 | 31.3 |
| Green (*Chelonia mydas*) | 11 631 | 2763 | 3758 | 23.8 | 32.3 |
| Kemp's ridley (*Lepidochelys kempii*) | 2738 | 413 | 714 | 15.1 | 26.1 |
| Leatherback (*Dermochelys coriacea*) | 620 | 133 | 213 | 21.5 | 34.4 |
| Hawksbill (*Eretmochelys imbricata*) | 635 | 57 | 94 | 9.0 | 14.8 |
| Olive ridley (*Lepidochelys olivacea*) | 4 | 0 | 0 | 0.0 | 0.0 |
| Unknown | 1067 | 108 | 200 | 10.1 | 18.7 |

**(This question continues on the following page)**

**(Question 1 continued)**

(d) State which species had the greatest percentage of stranded turtles with a DVSI. [1]

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(e) Suggest a reason for the difference between the percentage of each species that had DVSIs. [1]

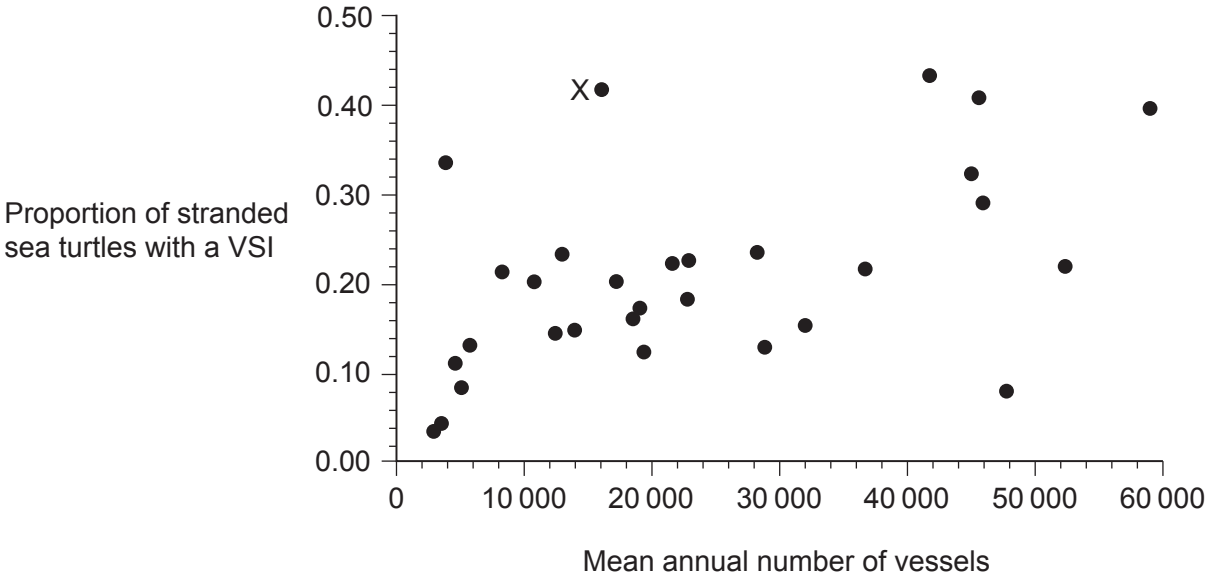
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**(This question continues on the following page)**

**(Question 1 continued)**

The graph shows the mean annual number of vessels in coastal regions of Florida and the proportion of stranded turtles found with a VSI.




(f) State the relationship between mean annual number of vessels and turtles with VSIs. [1]

. . . . . .

. . . . . .

(g) A researcher suggested that the point labelled X is considered atypical. Outline a reason for this researcher's opinion. [1]

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**(This question continues on the following page)**

**(Question 1 continued)**

(h) Evaluate the hypothesis that water vessels are the main cause of turtle deaths in Florida. [3]

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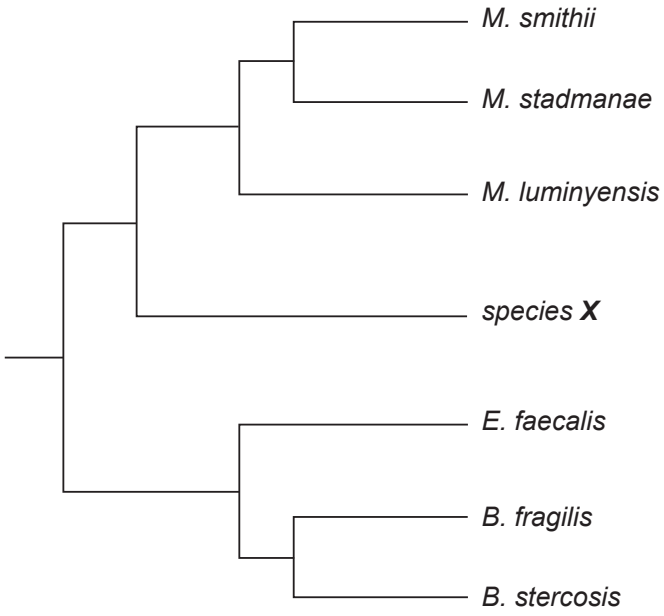
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Question 1 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**7.** The gut of a healthy human contains more than 1000 species of bacteria. Some of these species are shown in the cladogram.




(a) Identify, with a reason, whether the cladogram shows species **X** is more closely related to *M. luminyensis* or to *E. faecalis*. [2]

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**(This question continues on the following page)**

**(Question 7 continued)**

(b) Scientists have found that *B. fragilis* and *B. stercosis* are keystone species in the human gut ecosystem.

(i) Define keystone species. [2]

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(ii) Over time, the populations of different species of bacteria in the human gut can produce a stable climax community.

Suggest how some antibiotics, prescribed for bacterial infections, can disrupt the climax community in the gut. [2]

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. . . . . .

(c) Outline a difficulty in applying the biological species concept to bacteria. [1]

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Question 7 - working space

**37.** Which is a density-independent limiting factor for a kangaroo?

A. A forest fire

B. Predation

C. Climate change

D. Eutrophication

**38.** Black walnut (*Juglans nigra*) secretes the chemical juglone into the soil surrounding its roots. Juglone inhibits cell respiration in other species of plants. What does this example illustrate?

A. Mutualism

B. Intraspecific competition

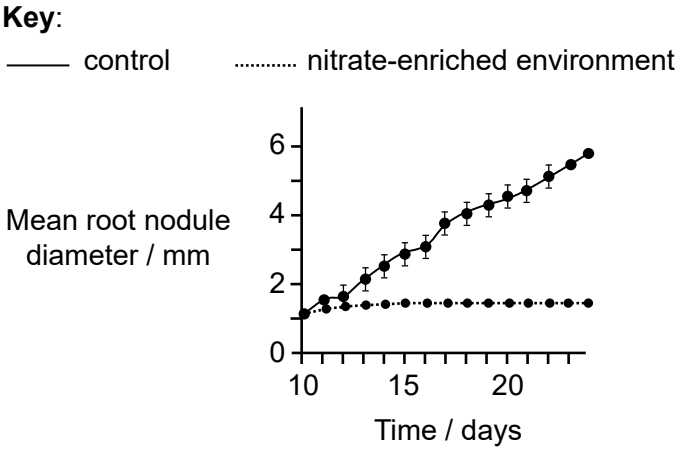
C. Allelopathy

D. Parasitism

**3.** *Rhizobium* is a genus of bacteria that live in the roots of flowering plants in the family Fabaceae. The plants form nodules surrounding a population of *Rhizobium*. The bacteria fix nitrogen from the air into nitrogen compounds, especially ammonium, which are made available to the host plant.



The graph shows changes in the diameter of root nodules for plants grown in a nitrate-enriched environment and a control group grown in a nitrate-free environment.




(a) Outline the concept of mutualism with respect to this example. [2]

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**(This question continues on the following page)**

**(Question 3 continued)**

(b) Distinguish between the cells in *Rhizobium* and Fabaceae. [2]

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(c) Suggest a reason that mutualistic relationships often involve species from distantly related groups of organisms. [1]

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(d) Analyse the results of the experiment. [3]

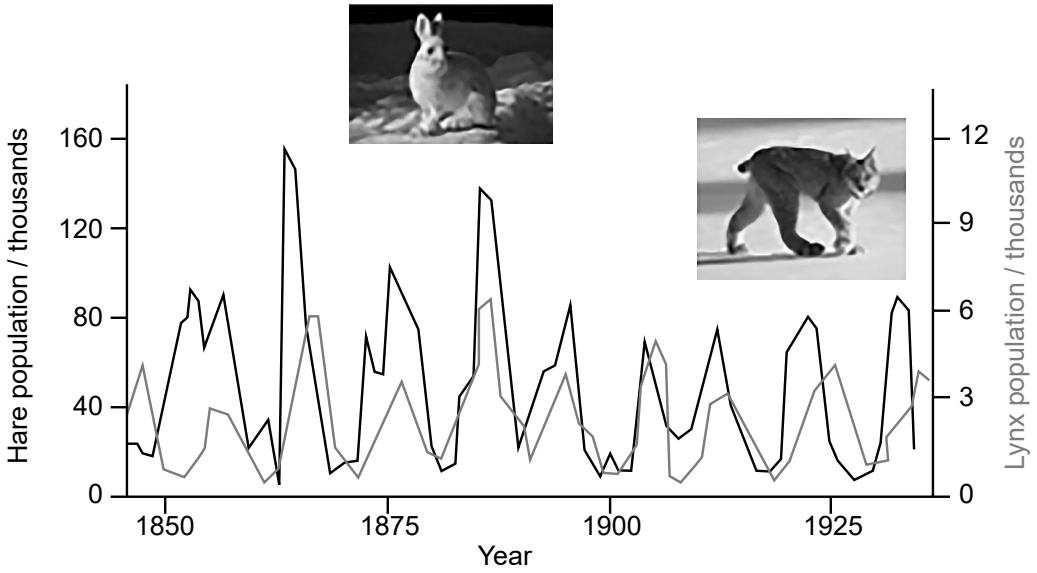
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Question 3 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**5.** Predation may result in a cyclic pattern of population changes, as for example in the case of the lynx, *Lynx canadensis* (predator), and the hare, *Lepus americanus* (prey).




(a) The predator benefits from a predator-prey relationship by obtaining food. Suggest how the hare population could benefit from this relationship. [1]

. . . . . .

. . . . . .

(b) Outline the factors that contribute to the carrying capacity of prey organisms in a predator-prey relationship. [2]

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**(This question continues on the following page)**

**(Question 5 continued)**

(c) (i) Outline how the hare population size can be estimated using the mark-release-recapture method. [2]

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. . . . . .
. . . . . .
. . . . . .

(ii) State **one** assumption that is made when using this method to estimate population size. [1]

. . . . . .
. . . . . .

Question 5 - working space

APOLLO

# Transfers of energy and matter

10 questions

**37.** Which organisms use oxidation of simple inorganic substances as an energy source?

A. Photoautotrophs

B. Heterotrophs

C. Chemoautotrophs

D. Saprotrophs

**37.** Studies show that adding iron to the ocean's surface triggers the growth of phytoplankton. What could be a short-term consequence of stimulating phytoplankton growth in this area?

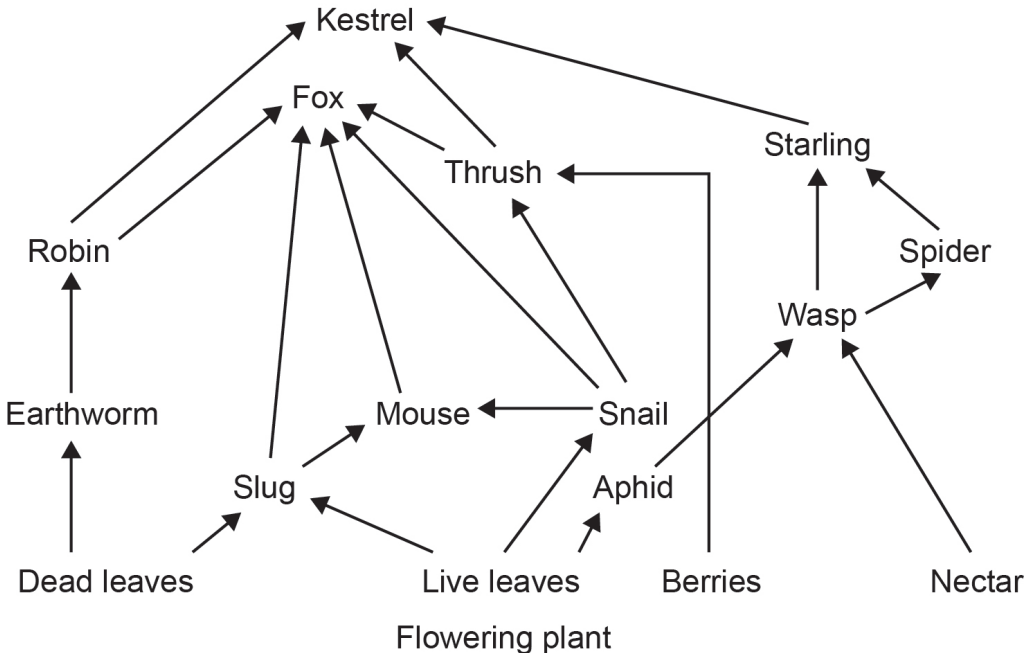
A. Rate of photosynthesis increases, so the ocean becomes the source of carbon.

B. Uptake of carbon dioxide into the ocean decreases, so it becomes a sink of carbon.

C. Rate of respiration increases, increasing the pH of the ocean.

D. Rate of photosynthesis increases, resulting in an increased uptake of carbon dioxide into the ocean.

**35.** A terrestrial food web is shown.




How many species in the food web are **only** primary consumers?

A. 3

B. 4

C. 5

D. 6

**Turn over**

**40.** Which action will decrease carbon sequestration?

A. Afforestation

B. Primary production

C. Deforestation

D. Rewetting peatlands

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**References:**

**1.** Malsam, L., 2020. *Macro of Gerris lacustris or common pond skater*. [image online] Available at: https://www.gettyimages.co.uk/detail/photo/macro-of-gerris-lacustris-or-common-pond-skater-royalty-free-image/1225103683?phrase=pond+skater&adppopup=true [Accessed 13 May 2024]. Source adapted.

**2.** Darekk2. https://commons.wikimedia.org/wiki/File:Nucleosome_organization.png. CC BY-SA 3.0. https://creativecommons.org/licenses/by-sa/3.0. Source adapted.

**4.** X: Keertana, A., n.d. [*Protein X*]. [online] Available at: https://simplemed.co.uk [Accessed 18 April 2024]. Reference redacted. Source adapted.

Y: Nevit Dilmen. https://commons.wikimedia.org/wiki/File:1K6F_Crystal_Structure_Of_The_Collagen_Triple_Helix_Model_Pro-_Pro-Gly103_04.png. CC BY-SA 3.0. http://creativecommons.org/licenses/by-sa/3.0/. Source adapted.

Z: AzaToth. https://commons.wikimedia.org/wiki/File:Myoglobin.png. Public domain.

**21.** Devitt, T.J., Baird, S.J.E. and Moritz, C., 2011. *Ensatina eschscholtzii ring species*. [image online] Available at: https://commons.wikimedia.org/wiki/File:Ensatina_eschscholtzii_ring_species.jpg [Accessed 18 April 2024]. Source adapted. This file is licensed under the Creative Commons Attribution 2.0 Generic license: https://creativecommons.org/licenses/by/2.0/deed.en.

**25.** Peter Southwood. https://commons.wikimedia.org/wiki/File:Oxygen-Haemoglobin_dissociation_curves.svg. Public domain. Source adapted.

**27.** VectorMine. 2018. https://www.gettyimages.co.uk/detail/illustration/cells-and-t-cells-schematic-diagram-vector-royalty-free-illustration/907993572?phrase=Vectormine%20immune%20response&adppopup=true. Source adapted.

**33.** Philcha, 2008. *Vertebrate n octopus eyes*. [image online] Available at: https://commons.wikimedia.org/wiki/File:Vertebrate_n_octopus_eyes.png [Accessed 23 April 2024]. Source adapted. Public domain.

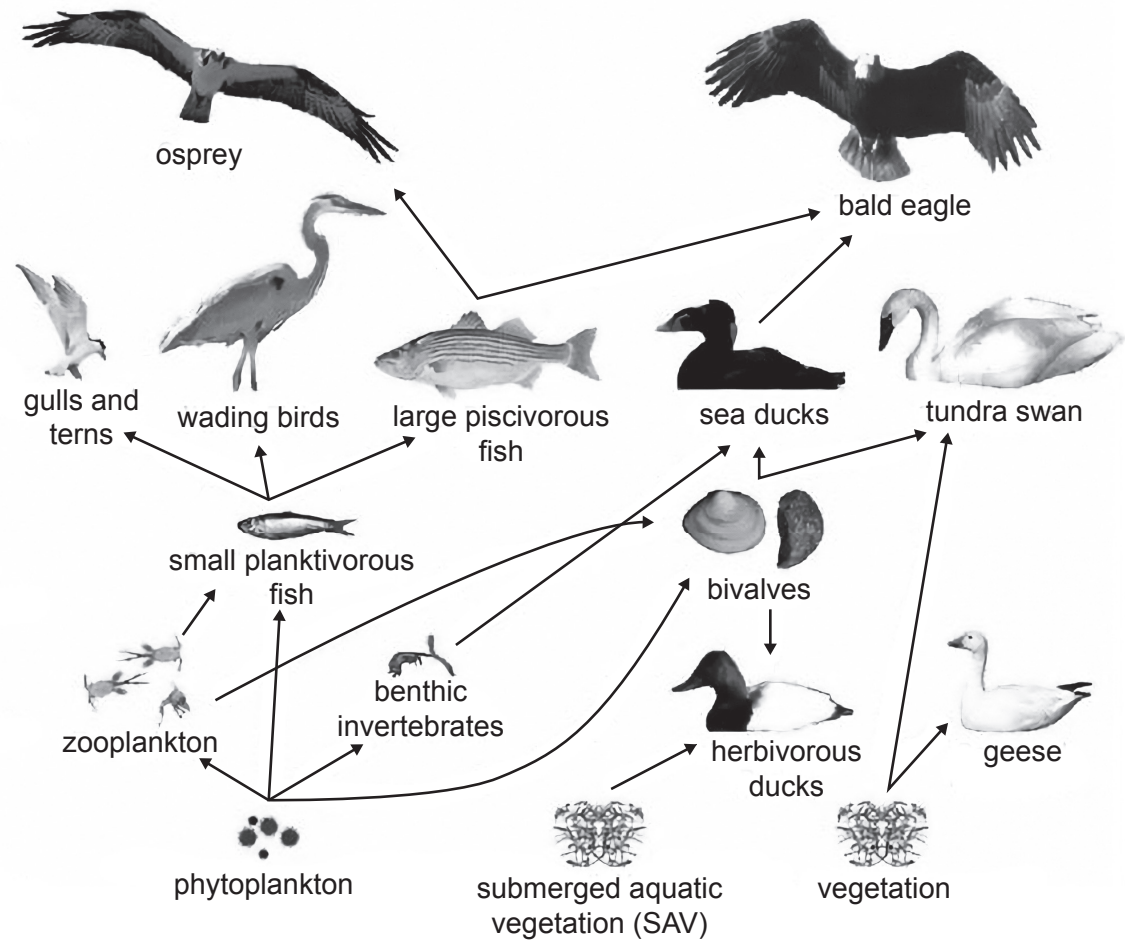
**34.** Minami Himemiya. https://commons.wikimedia.org/wiki/File:Prorocentrum_micans.jpg. Licensed under CC BY-SA 3.0. https://creativecommons.org/licenses/by-sa/3.0.

**36.** NOAA Global Monitoring Laboratory, n.d. *NOAA In Situ Carbon Dioxide* ($CO_2$) *Measurements*. [online] Available at: https://gml.noaa.gov/obop/mlo/programs/esrl/co2/co2.html [Accessed 18 April 2024]. Source adapted.

**37.** Per Harald Olsen. https://commons.wikimedia.org/wiki/File:Guppy_pho_0048.jpg. Licensed under CC BY 3.0. https://creativecommons.org/licenses/by/3.0. Source adapted.

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**37.** The image shows a food web from Chesapeake Bay, USA.




Which organisms are tertiary consumers in at least one food chain?

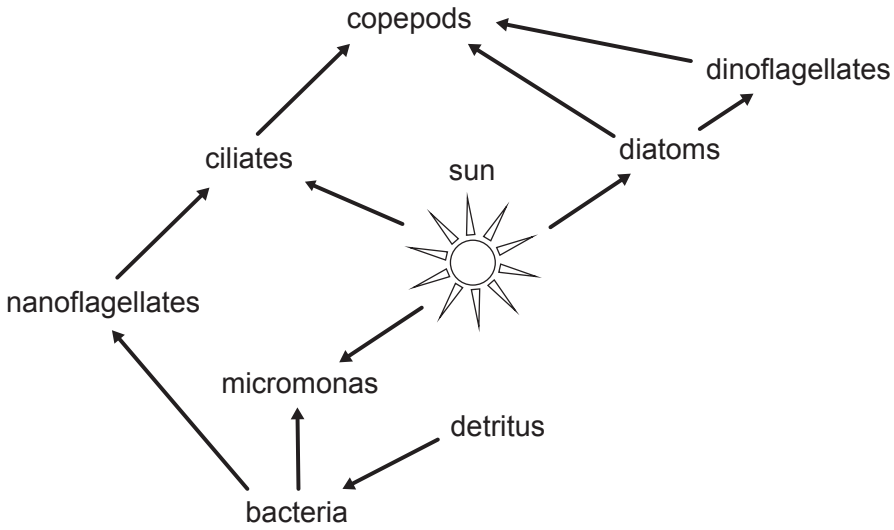
A. Small planktivorous fish and tundra swans

B. Herbivorous ducks and bald eagles

C. Wading birds and geese

D. Ospreys and benthic invertebrates

**35.** The diagram shows the flow of energy between some Arctic species.




Which organism is a mixotroph?

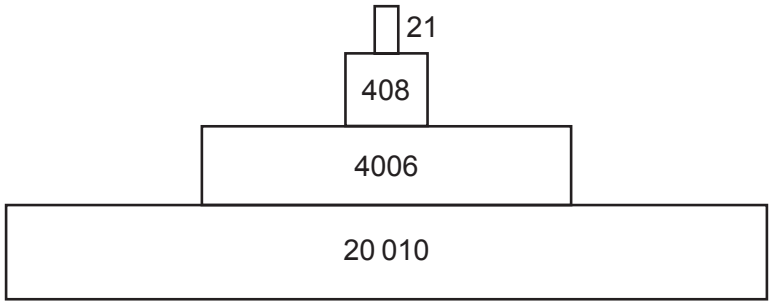
A. Bacteria

B. Nanoflagellates

C. Micromonas

D. Copepods

**37.** The diagram shows a pyramid of energy. The unit is $kJ\,m^{-2}\,year^{-1}$.




What is a valid conclusion from the data displayed in the pyramid?

A. Producers lose almost $16\,000\,kJ\,m^{-2}\,year^{-1}$ as they reflect some sunlight.

B. $4006\,kJ\,m^{-2}\,year^{-1}$ is gained by primary consumers.

C. Tertiary consumers use $408\,kJ\,m^{-2}\,year^{-1}$ in life processes.

D. $21\,kJ\,m^{-2}\,year^{-1}$ is used by detritivores.

**40.** Increased leaching of nitrogen fertilizers disrupts the stability of aquatic ecosystems such as lakes. What change is expected if nitrogen leaches into a lake over time?

A. Wilting of surface plants

B. Increased biochemical oxygen demand (BOD)

C. Weakened mollusc shells

D. Bioaccumulation of pollutants at higher trophic levels

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**References:**

**24.** Calvo, J.L., 2018. *Muscular artery, vein and nerve bundles surrounded by adipose tissue, near a lymph node*. Available at: https://www.shutterstock.com/image-photo/muscular-artery-vein-nerve-bundles-surrounded-785176687?dd_referrer=. Source adapted.

**31.** From *The New England Journal of Medicine* [online], Lichtenbelt, W.D. van M., Vanhommerig, J.W., Smulders, N.M., Drossaerts, J., Kemerink, G.J., Bouvy, N.D., Schrauwen, P. and Teule, G.J.J., Cold-Activated Brown Adipose Tissue in Healthy Men, Vol. 360, No. 15, Figure 1, © 2009 Massachusetts Medical Society. Reprinted with permission from Massachusetts Medical Society. Available at: https://www.nejm.org/doi/full/10.1056/nejmoa0808718 [Accessed 22 October 2024]. Source adapted.

**32.** Sourakov, A., 2015. Temperature-dependent phenotypic plasticity in wing pattern of *Utetheisa ornatrix bella* (*Erebidae*, *Arctiinae*). *Tropical Lepidoptera Research*, June 2015, Vol. 25, No. 1. Available at: https://journals.flvc.org/troplep/article/view/89750 [Accessed 14 November 2025]. Source adapted.

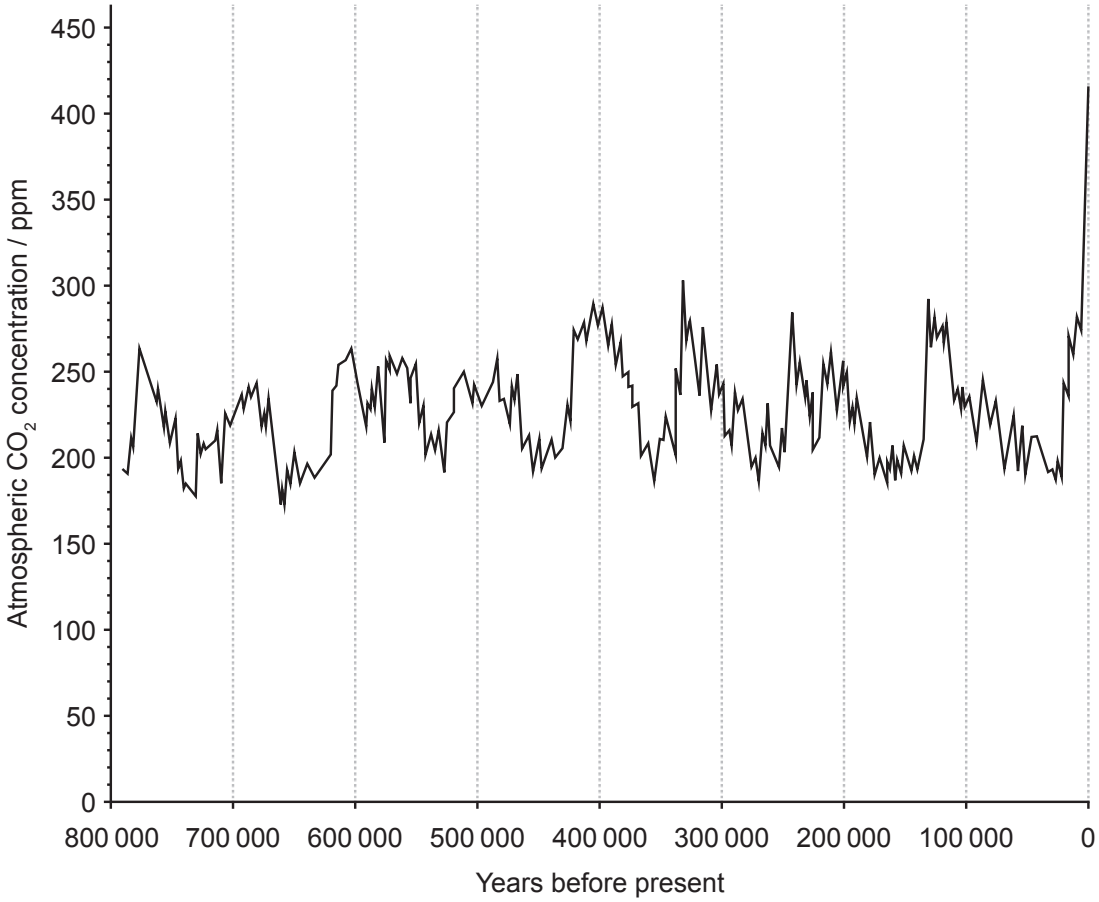
**34.** Gaveau, D.L.A., Sloan, S., Molidena, E., Yaen, H., Sheil, D., Abram, N.K., Ancrenaz, M., Nasi, R., Quinones, M., Wielaard, N. and Meijaard, E., 2014. *Plos One*, [online] Available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0101654 [Accessed 17 October 2024]. Reference redacted. Source adapted.

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## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**4.** The graph shows carbon dioxide ($CO_2$) concentration in the atmosphere during the past 800 000 years. The data was produced by measuring the $CO_2$ concentration of air bubbles trapped in cores of Antarctic ice.




**(This question continues on the following page)**

**(Question 4 continued)**

(a) State **one** metabolic process that removes $CO_2$ from the atmosphere. [1]

. . . . . .

. . . . . .

(b) The graph shows long-term fluctuations in atmospheric $CO_2$ concentration of about 80 ppm. The decreases in $CO_2$ concentration are probably due to oceans acting as a sink by holding large quantities of dissolved $CO_2$.

Identify **two** other examples of natural sinks that can remove carbon from the carbon cycle and reduce atmospheric $CO_2$ concentration. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) The graph shows a recent extremely rapid increase in atmospheric $CO_2$ concentration. Explain **two** anthropogenic causes of this increase. [2]

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. . . . . .

Question 4 - working space

**35.** What are common features of holozoic nutrition and saprotrophic nutrition?

| | Mostly fungi and bacteria | Secretion of enzymes to digest food | Ingestion of food particles |
|---|---|---|---|
| A. | ✓ | ✓ | ✗ |
| B. | ✓ | ✗ | ✓ |
| C. | ✗ | ✓ | ✗ |
| D. | ✗ | ✗ | ✗ |

**Turn over**

APOLLO

# DNA replication

6 questions

**9.** Which enzyme is associated with proofreading during DNA replication?

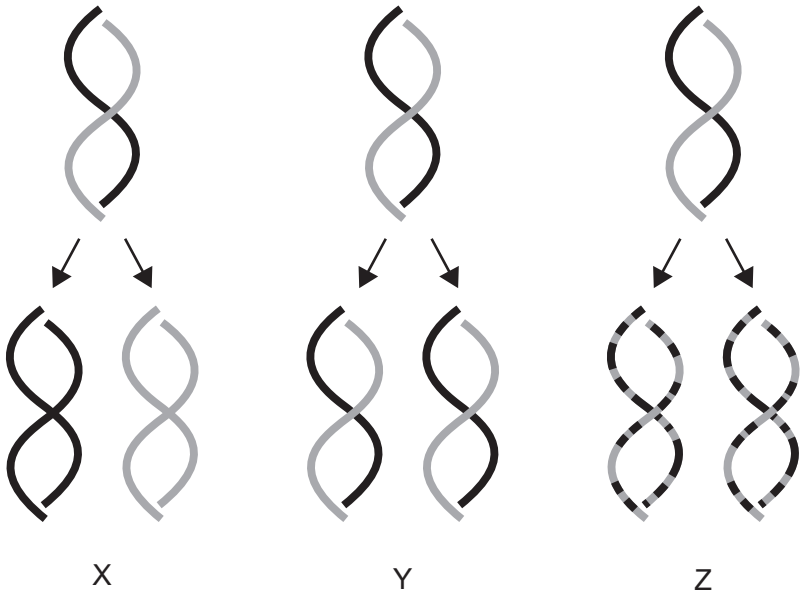
A. DNA primase

B. DNA helicase

C. DNA polymerase III

D. DNA ligase

**9.** Which diagram(s) illustrate(s) semi-conservative replication of DNA?




A. X only

B. Y only

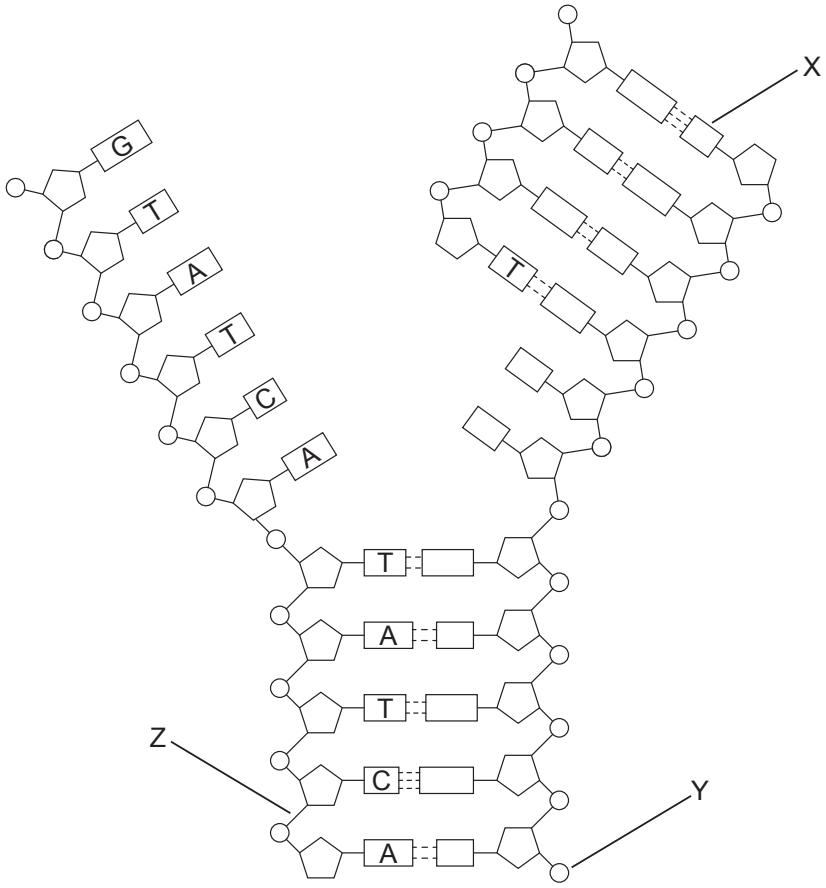
C. Z only

D. X and Y only

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**3.** The diagram shows a nucleic acid, with some of the bases indicated.




(a) Identify the type of nucleic acid shown in the diagram. [1]

. . . . . .

(b) Determine with a reason whether the diagram shows transcription or replication. [1]

. . . . . .

. . . . . .

**(This question continues on the following page)**

**(Question 3 continued)**

(c) Deduce the base indicated by X on the diagram. [1]

. . . . . .

(d) Identify the terminal indicated by Y on the diagram. [1]

. . . . . .

(e) (i) Identify the type of bond indicated by Z on the diagram. [1]

. . . . . .

(ii) Several enzymes can catalyse the formation of this type of bond. Explain how **two** enzymes catalyse it during the process shown in the diagram. [2]

. . . . . .
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. . . . . .
. . . . . .

Question 3 - working space

**10.** DNA fragments can be amplified by the polymerase chain reaction (PCR) to obtain many identical copies that can be used in forensic investigations.

What is a function of primers in PCR?

A. To form hydrogen bonds between complementary bases

B. To proofread the newly synthesized DNA copies

C. To keep double-stranded DNA fragments separated

D. To identify the regions of DNA that need to be replicated

**3.** Which property of DNA explains how genetic information can be replicated accurately?

A. Complementary base pairing

B. The double helical shape

C. 5’ – 3’ bonding in the sugar-phosphate backbone

D. The ability of DNA to bind to histones

**9.** What is a reason that Taq polymerase is a suitable enzyme for use in the polymerase chain reaction (PCR)?

A. It can work at a wide range of pH.

B. It works at higher temperatures than most enzymes.

C. It can separate two strands of DNA.

D. It allows DNA to be replicated without the use of primers.

APOLLO

# Protein synthesis

7 questions

**10.** What occurs during translation?

I. Polypeptides synthesised on ribosomes
II. RNA polymerase catalyses polypeptide synthesis
III. Complementary base pairing between codons and anticodons

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

**Turn over**

**10.** Which sequence of mRNA bases and amino acids could be produced by transcription and translation of the DNA molecule shown?

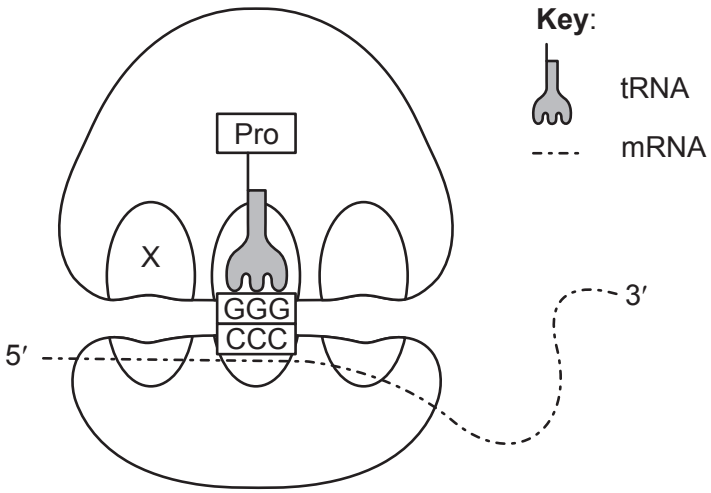
3′ AAAGTGGCACGTATATTT 5′
5′ TTTCACCGTGCATATAAA 3′

2nd base in codon

| 1st base in codon | U | C | A | G | 3rd base in codon |
|---|---|---|---|---|---|
| **U** | Phe | Ser | Tyr | Cys | **U** |
| | Phe | Ser | Tyr | Cys | **C** |
| | Leu | Ser | **STOP** | **STOP** | **A** |
| | Leu | Ser | **STOP** | Trp | **G** |
| **C** | Leu | Pro | His | Arg | **U** |
| | Leu | Pro | His | Arg | **C** |
| | Leu | Pro | Gln | Arg | **A** |
| | Leu | Pro | Gln | Arg | **G** |
| **A** | Ile | Thr | Asn | Ser | **U** |
| | Ile | Thr | Asn | Ser | **C** |
| | Ile | Thr | Lys | Arg | **A** |
| | Met | Thr | Lys | Arg | **G** |
| **G** | Val | Ala | Asp | Gly | **U** |
| | Val | Ala | Asp | Gly | **C** |
| | Val | Ala | Glu | Gly | **A** |
| | Val | Ala | Glu | Gly | **G** |

| | Sequence of mRNA bases | Sequence of amino acids |
|---|---|---|
| A. | UUU-GAG-GCU-CGA-UAU-UUU | Phe-Glu-Ala-Arg-Tyr-Phe |
| B. | AAA-CUC-CGA-GCU-AUA-UUU | Lys-Leu-Arg-Ala-Ile-Phe |
| C. | UUU-CAC-CGU-GCA-UAU-AAA | Phe-His-Arg-Ala-Tyr-Lys |
| D. | AAA-GUG-GCA-CGU-AUA-UUU | Lys-Val-Ser-Arg-Ile-Phe |

**11.** A ribosome with three binding sites, an mRNA molecule and a tRNA molecule are shown.




What would be the effect of blocking the left-hand binding site labelled X?

A. The GGG tRNA would not be able to exit the ribosome.

B. A second tRNA would not be able to bind.

C. A second tRNA would enter the right-hand binding site.

D. The ribosome would move to the left.

**10.** The table shows information on the genetic code of four different mRNA sequences. Which sequence demonstrates degeneracy in the genetic code?

| | mRNA sequence | Amino acids |
|---|---|---|
| A. | UUU UUA UCU | Phe Leu Ser |
| B. | CUU CCU CUU | Leu Pro Leu |
| C. | AUG ACG AAG | Met Thr Lys |
| D. | GUU GGU GUG | Val Gly Val |

**9.** Which of the following is a consequence of the degeneracy of the genetic code?

A. Codons affected by mutagens always code for non-functional proteins.

B. There are variations in the amino acid sequences for the same protein.

C. Some base mutations cause no changes in protein structure.

D. A codon may code for more than one amino acid in response to environmental changes.

**20.** What is a consequence of nucleases binding to mRNA?

A. Transcription stops.

B. mRNA binds to ribosomes.

C. More mRNA is synthesized.

D. mRNA cannot be translated again.

**11.** The table shows the mRNA codons for three amino acids.

| Valine | Threonine | Proline |
|---|---|---|
| GUU | ACU | CCU |
| GCC | ACC | CCC |
| GCA | ACA | CGA |
| GCG | ACG | CCG |

Which substitution mutation of a base triplet on a DNA strand will lead to the same polypeptide being formed at translation?

A. TGA to TCA

B. CGT to CTA

C. CAA to CGA

D. GCT to GGA

**Turn over**

APOLLO

# Mutation and gene editing

9 questions

**11.** A DNA sequence before and after a mutation is shown.

**Before mutation** 3′ TAC TCC TGC TTC 5′

**After mutation** 3′ TAC TGC TGC TTC 5′

The table contains mRNA codons and their associated amino acids.

| mRNA codon | Amino acid |
|---|---|
| AUG | Met |
| AGG | Arg |
| ACG | Thr |
| AAG | Lys |
| UAC | Tyr |
| UCC | Ser |
| UGC | Cys |
| UUC | Phe |

What would be the effect of this mutation on the translated polypeptide?

A. Thr would replace Arg.

B. Cys would replace Ser.

C. There would be an extra Arg.

D. There would be no change in the amino acid sequence.

**11.** What is gene knockout used for?

A. Increasing protein production by editing a gene

B. Investigating the function of a gene by replacing it to make it inoperative

C. Identifying the presence of a gene by editing it to produce a different protein

D. Editing a gene to initiate cell death

**Turn over**

**27.** Azithromycin is an antibiotic commonly used to treat pneumonia, an infection of the lungs caused by *Streptococcus pneumoniae*. A patient was diagnosed for the second time with pneumonia, but the same antibiotic was ineffective this time. What biological explanation might there be for this?

A. *S. pneumoniae* had mutated.

B. *S. pneumoniae* had developed antibodies for the antibiotic.

C. The patient was immune to the antibiotic.

D. The patient had antibiotic remaining from the first treatment.

**Turn over**

**10.** The sequence of DNA bases coding for part of a polypeptide is shown.

AAG TTA CCC GAG TTT AGT



What is the fourth mRNA codon transcribed from the DNA if the base indicated by the arrow is deleted?

A. UCA

B. CUC

C. TCA

D. AGT

**19.** Which characteristic is shared by all tumours?

A. Cells metastasize from the primary tumour

B. They result from mutations

C. Spherical in shape

D. Malignancy

**11.** Two DNA sequences are shown.

| | |
|---|---|
| **Sequence 1** | CACGTGGACTGAGGACTCCTC |
| **Sequence 2** | CACGTGGACTGAGGACACCTC |

What type of mutation is occurring between sequence 1 and sequence 2?

A. Substitution

B. Polyploidy

C. Insertion

D. Deletion

**11.** Knockout organisms are used as models in research. The p53 knockout mouse is named after p53, a gene which codes for a protein that normally suppresses the growth of cancerous tumours.

How could scientists use p53 knockout mice in cancer research?

A. To extract tumour suppressor protein from p53 knockout mice for cancer treatments

B. To obtain functional copies of the p53 gene to use in gene replacement therapy

C. To investigate the effect of new anti-cancer drugs on mouse tumours

D. To study the effect of mutations on the expression of the p53 gene

**22.** What is **always** a consequence of single-nucleotide polymorphisms (SNPs) within a species?

A. Different proteomes

B. Different genomes

C. Deletion mutations

D. Insertion mutations

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**10.** Changes in the form of biological molecules lead to changes in their function.

(a) Outline the role of UV radiation as a mutagen. [4]

(b) Explain how the function of DNA is linked to its molecular structure. [7]

(c) Describe the use of gene knockout technology in research. [4]



**References:**


**2.** *Electron micrograph of cells from the leaf of a corn plant*, n.d. [image online] Available at: <http://innolearn.weebly.com/bio-cell.html> [Accessed 9 December 2020].

**3a.** Smith, R.S., 2008. The Role of Auxin Transport in Plant Patterning Mechanisms. *PLoS Biol*, 6(12): e323. https://doi.org/10.1371/journal.pbio.0060323.

**4b.** Left image:
[*Alveoli in the lungs of a human*], n.d. [image online] Available at: <http://medcell.med.yale.edu/histology/respiratory_system_lab.php#slides> [Accessed 9 December 2020].

Right image:
[*salt water fish gills histology*], n.d. [image online] Available at: <https://br.pinterest.com/pin/255297872605284426/> [Accessed 9 December 2020].

**4c.** *Transmission electron micrograph of the S1 segment of a rat proximal tubule*, n.d. [image online] Available at: <https://abdominalkey.com/anatomy-of-the-kidney/> [Accessed 9 December 2020].

**5.** Wani, n.d. [*Hare and lynx populations*]. [image online] Available at: <https://www.cleanpng.com/png-cat-snowshoe-hare-eurasian-lynx-lotkavolterra-e-3913514/> [Accessed 29 July 2020].

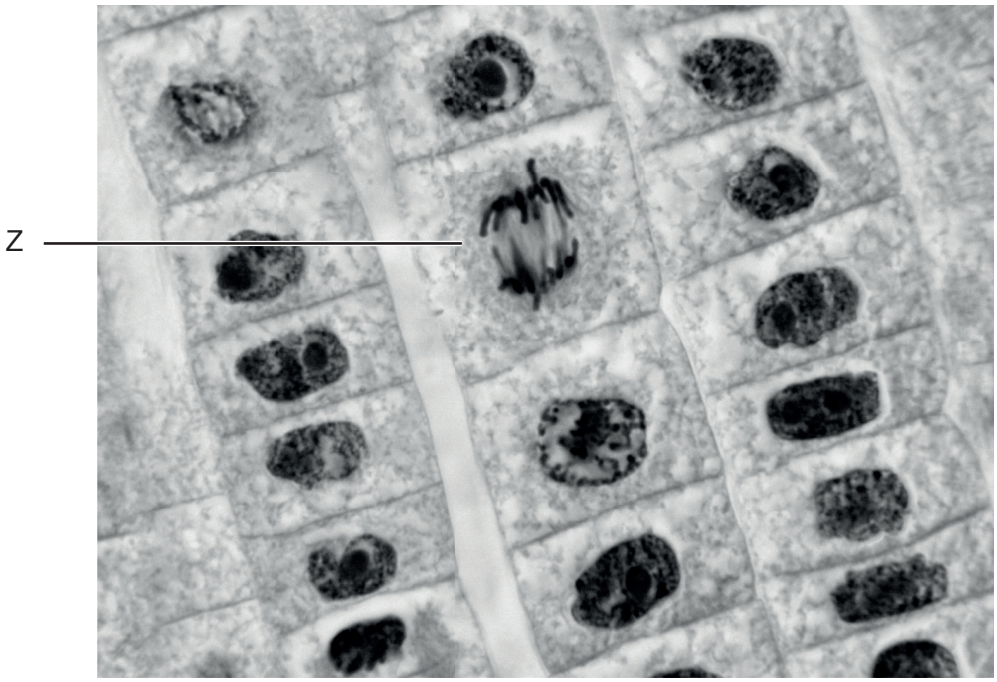
Question 10 - working space

APOLLO

# Cell and nuclear division

9 questions

**19.** The micrograph shows onion (*Allium cepa*) root tip cells dividing by mitosis.




In which phase is cell Z?

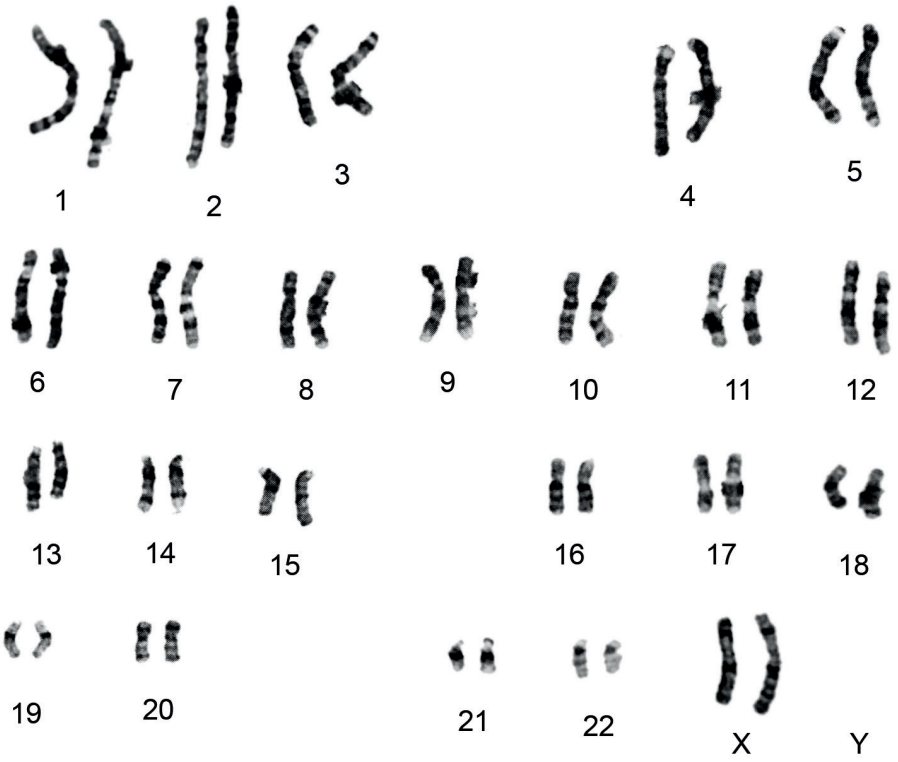
A. Interphase

B. Prophase

C. Metaphase

D. Anaphase

**22.** The karyogram is taken from a primate.




All primates have the same sex determination chromosomes. From which primate is the karyogram?

A. Human female

B. Chimpanzee female

C. Human male

D. Chimpanzee male

**19.** What occurs in cell division during both mitosis and meiosis?

A. Condensation of DNA by supercoiling in telophase

B. Movement of microtubules to move chromatids in anaphase

C. Pairing of homologous chromosomes in prophase

D. Crossing over between chromosomes in metaphase

**30.** A cell with 46 chromosomes goes through the process of spermatogenesis. What is the outcome of this process?

A. One cell with 46 chromosomes and 3 polar bodies

B. Four cells with 46 chromosomes each

C. One cell with 23 chromosomes and 3 polar bodies

D. Four cells with 23 chromosomes each

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**8.** Eukaryotes are a diverse group of organisms, including animals and plants.

(a) Distinguish between structures in animal and plant cells. [3]

(b) Outline adaptations of animals to herbivory and ways in which plants are adapted to resist herbivores. [4]

(c) Compare and contrast the processes of mitosis and cytokinesis in animal and plant cells. [8]

Question 8 - working space

## Section B

Answer **two** questions. Up to one additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**8.** Members of a species typically all have the same number of chromosomes.

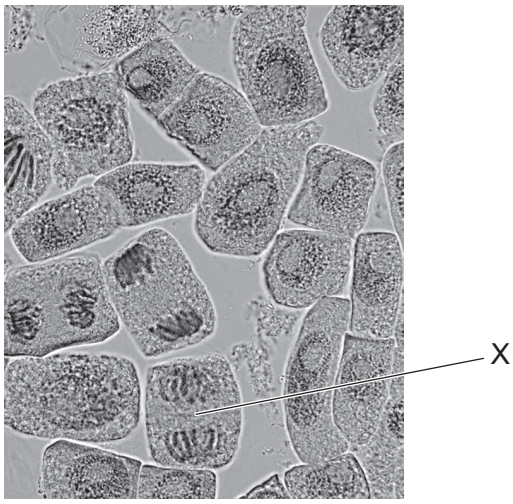
(a) Explain the need for both fusion of gametes and meiosis in a **sexual** life cycle. [4]

(b) Describe the events in interphase and mitosis that ensure that the chromosome number does not change during an **asexual** life cycle. [7]

(c) Discuss the barriers to hybridization between species and how polyploidy can overcome these barriers. [4]

Question 8 - working space

**19.** The micrograph shows cells in an onion root (*Allium cepa*) undergoing mitosis.




What is happening at X?

A. Unequal cytokinesis by budding

B. Assembly of cell membrane and cell wall by vesicles

C. Contraction of a ring of actin and myosin proteins

D. Movement of chromosomes by microtubules

**19.** In which order do the following steps occur in a cell that divides by meiosis?

1 Separation of homologous chromosomes

2 DNA replication

3 Crossing over

4 Pairing of homologous chromosomes

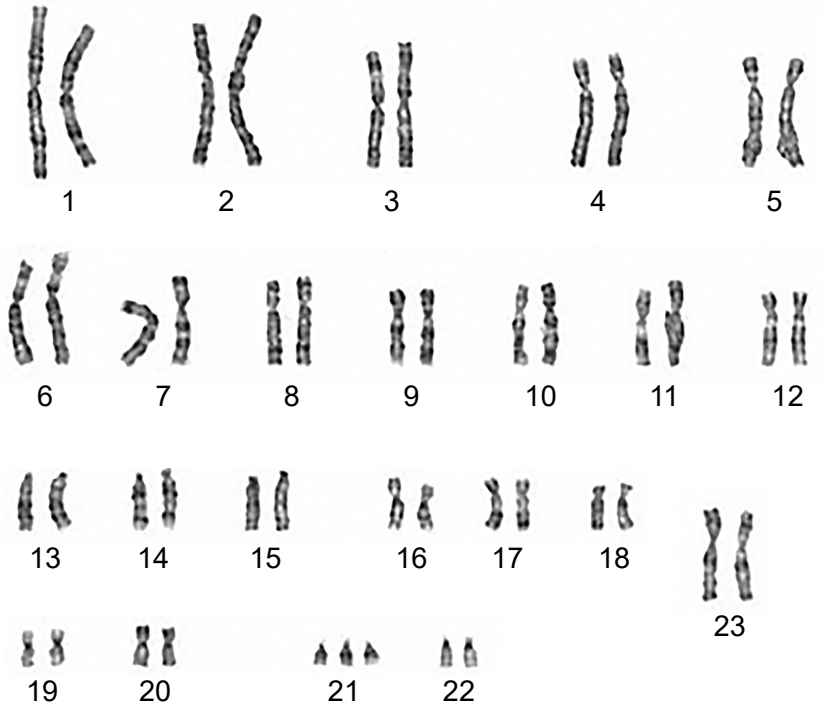
A. $2 \rightarrow 4 \rightarrow 3 \rightarrow 1$

B. $2 \rightarrow 3 \rightarrow 4 \rightarrow 1$

C. $4 \rightarrow 3 \rightarrow 2 \rightarrow 1$

D. $4 \rightarrow 2 \rightarrow 3 \rightarrow 1$

**23.** The karyogram shows a chromosome abnormality in a human female.




What could cause the abnormality to arise?

A. Failure of homologous chromosomes to separate during gamete formation

B. Chromosome 21 replicating after fertilization

C. A gene mutation of the mother’s chromosomes during cell division

D. Polyploidy occurring during anaphase I of meiosis in both parents

APOLLO

# Gene expression

5 questions

**20.** Scientists measured methylation levels of amino acids in chromosome 2 in twin studies. The methylation levels of twin 1 were significantly and consistently higher than those of twin 2. What could be proposed to explain this data?

A. Modification to the histone of twin 1

B. Removal of the histone from the chromosome in twin 2

C. The DNA base sequence of twin 1 was altered

D. Cytosines in promoters of twin 2 are more methylated than in twin 1

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**1.** Angora rabbits (*Oryctolagus cuniculus*) have soft and silky coats with fine hairs that grow about 30 mm per month. These hairs can be collected and used as wool. Hair growth in mammals depends on stem cells in the base of hair follicles called dermal papilla cells.



Research was carried out to investigate the role of the *WIF1* gene in hair growth. Wool was collected from 6-month-old angora rabbits. Expression of the *WIF1* gene was assessed by measuring the quantity of *WIF1* mRNA produced in cells taken from each rabbit. The rabbits were divided into groups according to their rate of wool production (low or high).

The table shows mean wool production per rabbit in the low and high wool production groups and relative expression of the *WIF1* gene.

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**(This question continues on the following page)**

**(Question 1 continued)**

(a) Calculate the difference in mean wool production between the high and low wool production groups. [1]

. . . . . .

(b) (i) Identify the relationship between wool production and relative expression of *WIF1*. [1]

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(ii) Discuss whether the data in the table shows a causal relationship between *WIF1* expression and wool production. [2]

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**(This question continues on the following page)**

**(Question 1 continued)**

Proteins produced by expressing the *WIF1* gene bind to a group of glycoproteins used in chemical signalling. This signalling can promote or inhibit transcription of other genes.

Rabbit dermal papilla cells growing in liquid tissue culture were modified in two different ways by introducing a genetically engineered loop of DNA (plasmid) with or without a copy of the *WIF1* gene:

- pcDNA-*WIF1*: a plasmid carrying a copy of the *WIF1* gene
- pcDNA: the same plasmid without the *WIF1* gene

The expression of three genes, EGF, SFRP2 and CCND1, was measured in the modified rabbit dermal papilla cells. The bar chart shows the results.

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(c) Identify the control treatment. [1]

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(d) Outline the effect of pcDNA-*WIF1* on the expression of each of the three genes. [3]

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**(Question 1 continued)**

In other species, expression of *WIF1* has been found to affect rates of apoptosis (programmed cell death) and cell proliferation. These two processes were measured in the modified rabbit dermal papilla cells. The pie charts show apoptosis rates, and the graph shows cell proliferation rates.

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(e) Explain how expression of the *WIF1* gene could affect the rate of wool production in angora rabbits, using evidence from the data in the question. [4]

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Question 1 - working space

**32.** Scientists incubated larvae of the moth *Utetheisa ornatrix* at either 15 °C or 22 °C until they hatched. They found the hatched moths had different wing colour patterns due to phenotypic plasticity.

Moth from larvae incubated at 15 °C



Moth from larvae incubated at 22 °C



Which of the following explains the observed differences in wing colour?

A. Colder temperatures induce mutations in genes for wing colour.

B. The expression of genes for wing colour is affected by temperature.

C. A mutation makes moths less visible to predators in cold climates.

D. Wing colour is the result of polygenic inheritance.

**10.** Which are examples of non-coding DNA?

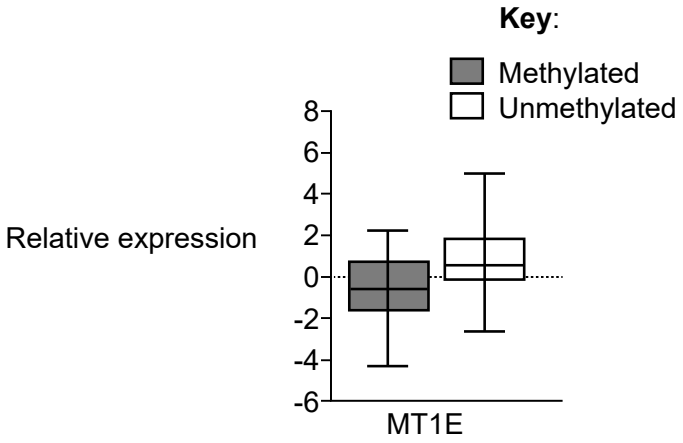
A. Dominant and recessive alleles

B. Promoters and telomeres

C. Oncogenes and tumour suppressor genes

D. Introns and exons

**19.** The graph shows the effect of methylation on the expression of MT1E, a gene involved in the control of prostate cancer development. Patients with a reduced expression of this gene are more likely to develop prostate cancer.




What are effects of MT1E methylation?

A. It reduces transcription of MT1E, increasing the risk of prostate cancer.

B. It increases translation of MT1E, reducing the risk of prostate cancer.

C. It reduces replication of MT1E, reducing the risk of prostate cancer.

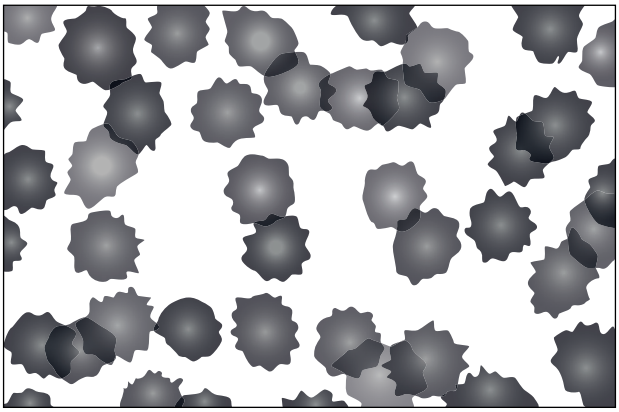
D. It increases the chances of mutation in proto-oncogenes, increasing the risk of prostate cancer.

APOLLO

# Water potential

6 questions

**20.** The image shows human blood cells immersed in a solution.



What can be deduced from the image?

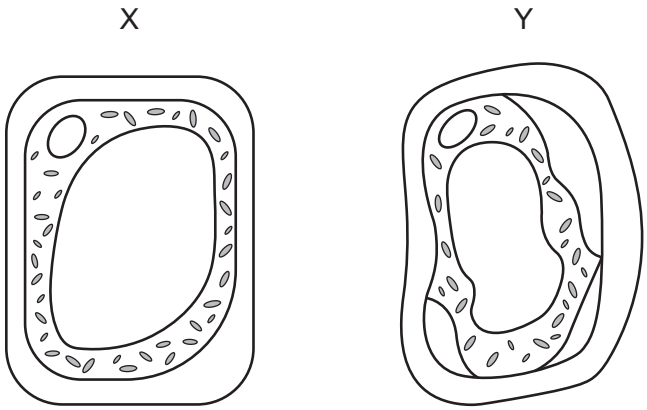
A. The solution is hypotonic as the cells are crenated.

B. The solution is hypotonic as the cells are turgid.

C. The solution is hypertonic as the cells are crenated.

D. The solution is hypertonic as the cells are turgid.

**20.** Two plant cells are shown as they appear in different solutions X and Y.



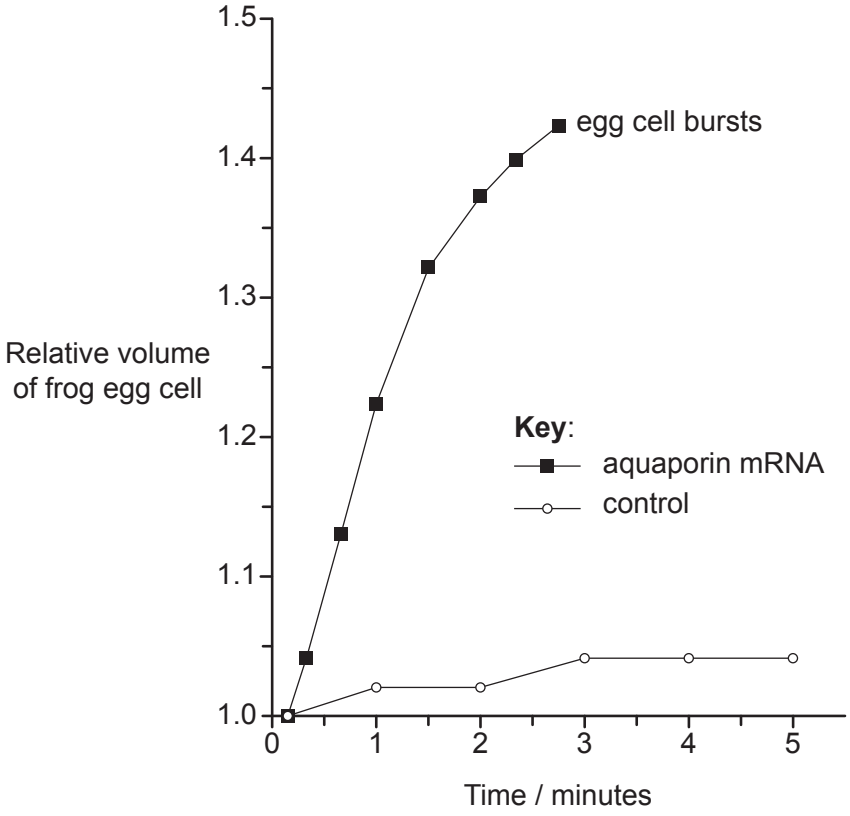

What happens to water and pressure potential inside the cell if it is moved from solution X to solution Y?

| | Water potential | Pressure potential |
|---|---|---|
| A. | does not change | decreases |
| B. | decreases | decreases |
| C. | does not change | increases |
| D. | increases | increases |

**2.** In the early 1990s, investigations involving egg cells from the African clawed frog (*Xenopus laevis*) led to the discovery of membrane channel proteins called aquaporins.

In one investigation, scientists injected 10 frog egg cells with a solution containing mRNA encoding for an aquaporin, and another 10 frog egg cells with distilled water (control cells). All the frog egg cells were then incubated in a hypotonic solution. The volume of the frog egg cells was then measured during a period of five minutes.

The graph shows the mean results of the investigation.




(a) State the direction of net movement of water across the plasma membrane of all the frog egg cells between 0 and 3 minutes. [1]

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**(This question continues on the following page)**

**(Question 2 continued)**

(b) (i) Explain the reasons for the different results obtained for the frog egg cells with aquaporin mRNA and the control frog egg cells. [2]

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(ii) Discuss the role of aquaporins in the collecting ducts of a human kidney when the water content of blood is too low. [3]

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(c) Outline the reason that the results are displayed as mean relative volumes rather than mean volumes. [1]

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(d) Comment on the reliability of the results of this investigation. [1]

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**(Question 2 continued)**

(e) In investigations of this type, scientists usually find that there is a short time delay between the introduction of mRNA into a cell and the effect on the cell. Explain this observation. [2]

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Question 2 - working space

**20.** The water potential of a plant cell is $-0.24\,\text{kPa}$. If the pressure potential of the cell is $0.46\,\text{kPa}$, what is the solute potential of that cell?

$$\Psi_w = \Psi_s + \Psi_p$$

A. $0.22\,\text{kPa}$

B. $-0.22\,\text{kPa}$

C. $0.70\,\text{kPa}$

D. $-0.70\,\text{kPa}$

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**4.** (a) Explain how the pressure potential and solute potential change inside a plant root cell when it is placed into a solution that is more hypotonic than the cell's cytoplasm. [3]

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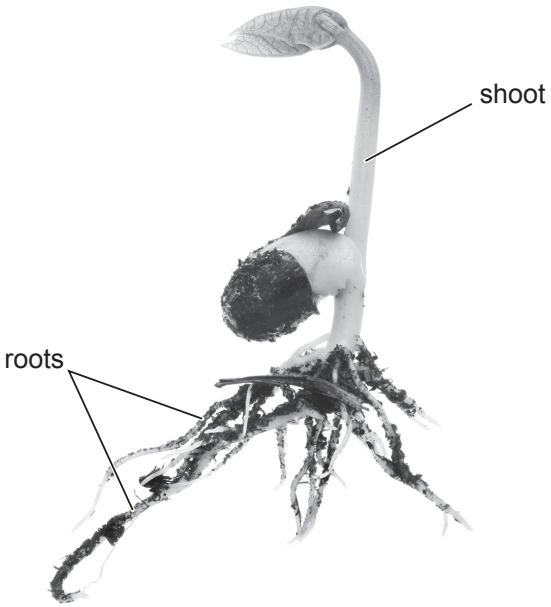
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(b) The photograph shows a seedling (young plant) of the family Fabaceae. The shoot and roots have been labelled.




(i) Explain how root pressure is generated to cause movement of water through seedlings. [2]

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**(This question continues on the following page)**

**(Question 4 continued)**

(ii) State the name and site of production of **two** phytohormones that regulate the growth of seedlings. [2]

| Name of phytohormone | Site of production |
|---|---|
| | |
| | |

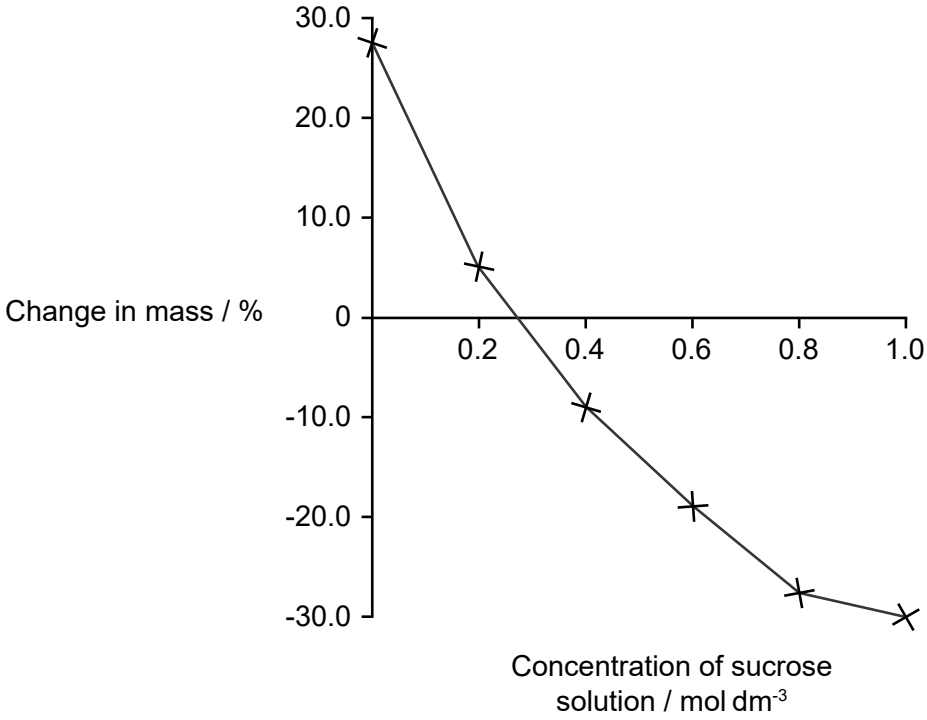
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Question 4 - working space

**1.** Beetroot (*Beta vulgaris*) tissue was cut into pieces of similar size and shape. The masses of the individual pieces were measured. Three pieces of beetroot were placed in each of six sucrose solutions of different concentrations.

After three hours, the pieces of beetroot were removed from the solutions, surface dried and their masses recorded. The mean percentage change in mass of the beetroot in each solution was calculated and displayed in the graph.




| Concentration of sucrose solution / mol $dm^{-3}$ | Change in mass / % |
|---|---|
| 0.0 | 28.0 |
| 0.2 | 5.0 |
| 0.4 | –9.0 |
| 0.6 | –19.0 |
| 0.8 | –28.0 |
| 1.0 | –30.0 |

**(This question continues on the following page)**

**(Question 1 continued)**

(a) (i) State the independent variable in this experiment. [1]

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(ii) Outline the reason that beetroot pieces of similar size and shape are needed in order to obtain reliable results. [2]

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(b) Suggest a reason for expressing the changes in mass as percentages. [1]

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(c) Explain the effect of the 0.0 mol $dm^{-3}$ sucrose solution on the water potential of the beetroot pieces. [3]

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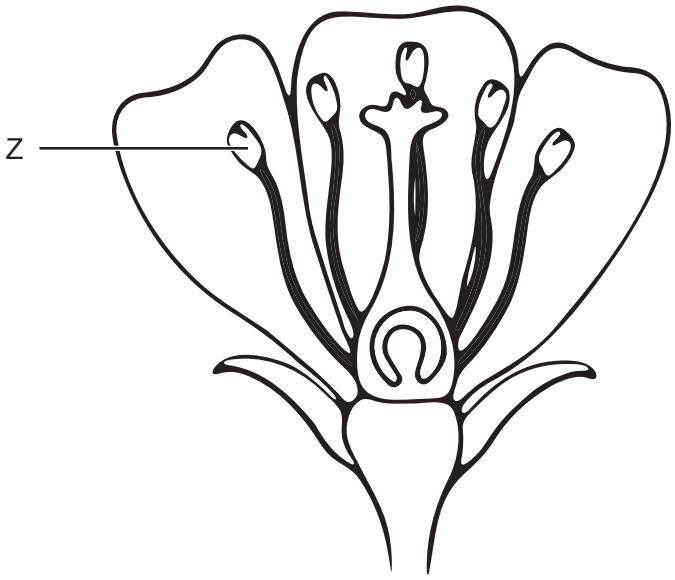
Question 1 - working space

APOLLO

# Reproduction

6 questions

**29.** The diagram shows a cross-section of a flower.




What describes the structure labelled Z?

A. Structure Z is the anther, which is part of the stamen.

B. Structure Z is the stigma, which is part of the stamen.

C. Structure Z is the anther, which is part of the carpel.

D. Structure Z is the stigma, which is part of the carpel.

**29.** Cherry trees (*Prunus avium*) have two self-incompatibility alleles. What benefit do self-incompatibility alleles have?

A. They decrease genetic variation.

B. They prevent inbreeding.

C. They decrease the chances of mutations taking place within the gametes.

D. They prevent the plant from releasing pollen at certain times of the year.

**30.** What happens during fertilization in humans?

A. The nuclear membranes of sperm and egg break down.

B. The sperm enters the egg.

C. The chromosomes undergo joint meiosis.

D. Mitochondria in the zygote come from sperm and egg.

**29.** Oogenesis and spermatogenesis produce gametes. What is the sequence of events in gamete formation?

A. Mitosis → differentiation → meiosis → cell growth

B. Meiosis → differentiation → mitosis → cell growth

C. Mitosis → cell growth → meiosis → differentiation

D. Meiosis → cell growth → mitosis → differentiation

**29.** Flowering plants can use either self-pollination or cross-pollination when they carry out sexual reproduction. Which plants are most likely to cross-pollinate?

A. Plants that are hermaphrodites

B. Plants whose anthers and stigmas mature at the same time

C. Plants with flowers that have much longer stamens than stigmas

D. Plants that are either male or female

**30.** Gametogenesis produces sex cells for sexual reproduction. What distinguishes oogenesis from spermatogenesis in humans?

A. The first meiotic division starts at puberty.

B. Mitosis produces many cells for gametogenesis.

C. Unequal division of cytoplasm occurs at cytokinesis.

D. Haploid gametes are produced at the end of meiosis II.

APOLLO

# Inheritance

10 questions

**31.** A *Mirabilis jalapa* plant with red flowers was crossed with one with white flowers. All plants in the F1 generation had pink flowers. What phenotype ratio would be expected in the F2 generation?

A. 100 % pink

B. 50 % red and 50 % white

C. 25 % white, 50 % pink and 25 % red

D. 75 % red and 25 % white

**31.** Pink flowers arise from the incomplete dominance between red and white flowers in the four o'clock flower (*Mirabilis jalapa*). A pink-flowering variety is crossed with a white-flowering variety.



What could be the possible phenotypes of the offspring?

A. White flowers only

B. Pink and white flowers

C. Red and white flowers

D. Pink flowers only

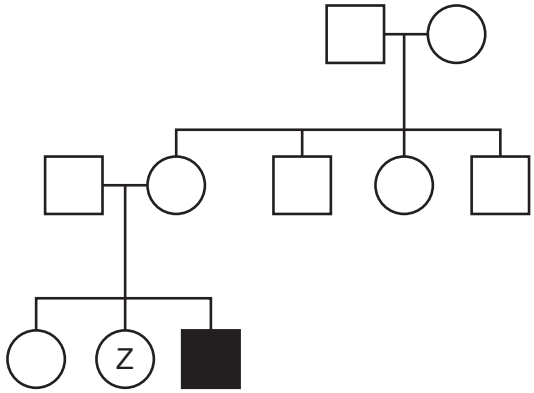
**32.** Phenylketonuria is caused by a mutation to a gene. Which genotype would result in the condition and what is the consequence?

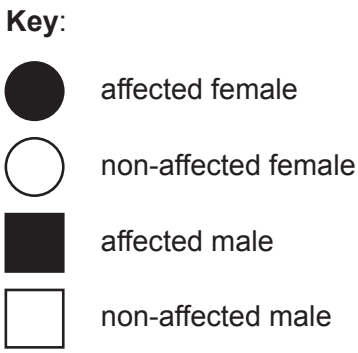
| | Genotype | Consequence |
|---|---|---|
| A. | AA only | Tyrosine is converted to phenylalanine |
| B. | aa only | Tyrosine is not converted to phenylalanine |
| C. | AA and Aa | Phenylalanine is converted to tyrosine |
| D. | aa only | Phenylalanine is not converted to tyrosine |

**31.** When white flowers of the species *Mirabilis jalapa* are fertilized by pollen from red flowers, the resulting plants produce pink flowers. What is the pattern of inheritance and the reason for this?

| | Inheritance | Reason |
|---|---|---|
| A. | incomplete dominance | offspring show both parental phenotypes |
| B. | codominance | offspring show both parental phenotypes |
| C. | incomplete dominance | offspring show a blended phenotype of the parents' |
| D. | codominance | offspring show a blended phenotype of the parents' |

**30.** The pedigree chart shows the incidence of colour blindness in three generations of a family. Colour blindness is caused by a sex-linked recessive allele.




What could the genotype of individual Z be?

A. $X^BX^B$ only

B. $X^BX^b$ only

C. $X^BX^B$ or $X^BX^b$

D. $X^bX^b$ or $X^BX^b$

**31.** A heterozygous fruit fly (*Drosophila melanogaster)* with straight wings and red eyes was crossed with a curly-winged, sepia-eyed homozygous fruit fly. The offspring produced are shown in the table.

| Phenotype | Number of offspring |
|---|---|
| straight wings, red eyes | 25 |
| straight wings, sepia eyes | 24 |
| curly wings, red eyes | 26 |
| curly wings, sepia eyes | 25 |

What conclusions can be drawn from this experiment?

A. The wing shape and eye colour genes are on the same chromosome.

B. The alleles of both genes are codominant.

C. Individuals with straight wings and sepia eyes must be the result of crossing over.

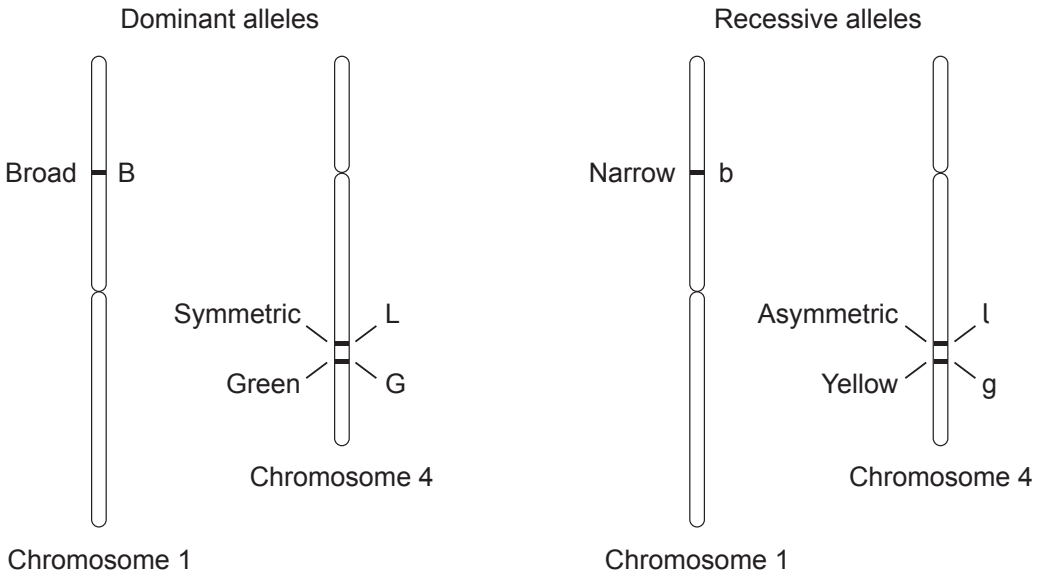
D. The genes for wing shape and eye colour are not linked.

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**6.** Scientists determined the loci of three genes on chromosomes 1 and 4 of the thale cress plant (*Arabidopsis thaliana*). All three genes are involved in influencing the characteristics (width, symmetry and colour) of the plant's leaves.

The diagrams show the names and symbols of the alleles of these genes.




**(This question continues on the following page)**

**(Question 6 continued)**

(a) The expected ratio of phenotypes in the offspring of a cross between a plant with narrow, yellow leaves and a plant heterozygous for the genes for leaf width and colour is 1:1:1:1.

Justify this expected ratio using a Punnett grid or other diagram. [3]

(b) Explain whether a ratio of 1:1:1:1 would be expected in the offspring of a cross between a plant with asymmetric, yellow leaves and a plant heterozygous for the genes for leaf symmetry and colour. [2]

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Question 6 - working space

**31.** Female grasshoppers have XX sex chromosomes and males have XO, signifying a single X chromosome. An X chromosome will be present in only half of the male gametes. A recessive mutation is induced by radiation in the X chromosome of a male. In which generation will the effect of this radiation appear?

A. F1 females

B. F1 males

C. F2 females

D. F2 males

**Turn over**

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**6.** In humans, sex is determined genetically and human populations have approximately equal numbers of males and females in each generation.

(a) Outline how sex is determined in humans. [2]

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(b) Down syndrome is a genetic condition in which the cells of an individual contain three copies of chromosome 21. Explain how non-disjunction leads to trisomy 21. [3]

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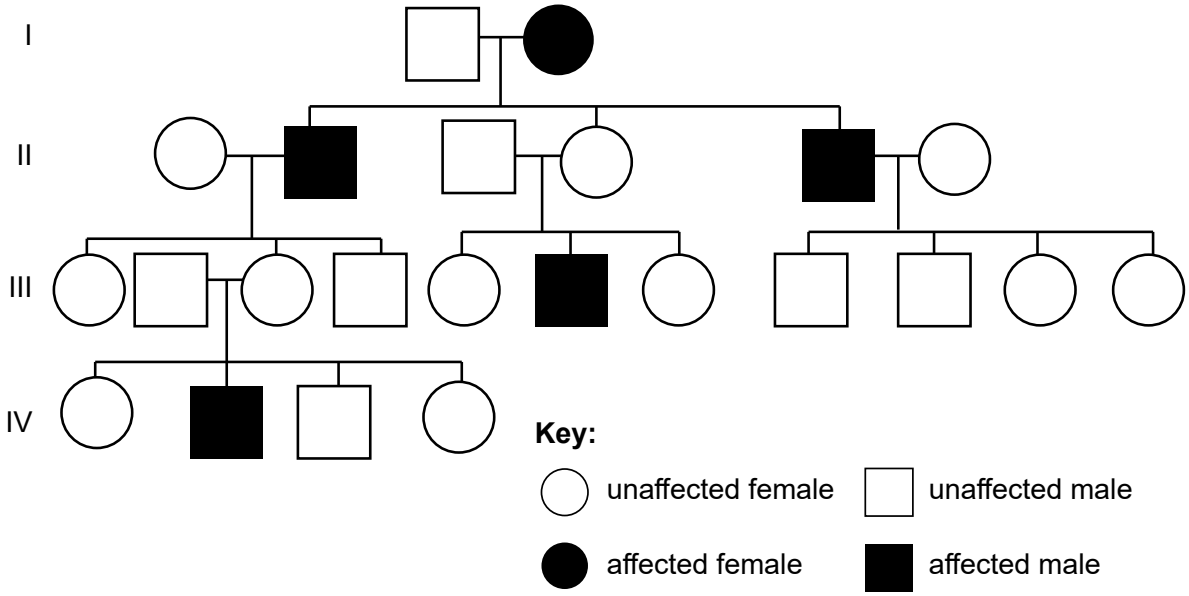
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**(Question 6 continued)**

(c) The pedigree chart shows the inheritance of hemophilia in a human family over four generations. Symbols represent the phenotype of the individual.




Explain the evidence from this chart that the condition may be sex-linked. [2]

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Question 6 - working space

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**7.** Two alleles of a gene influence body colour in *Drosophila*. The dominant allele B results in a brown body colour while the recessive allele b codes for black body. In addition, two alleles of another gene determine wing shape; normal wings (V) are dominant over vestigial wings (v).

In a dihybrid cross between a double heterozygote for body colour and wing shape (BbVv) and a homozygous recessive for both traits (bbvv), the following offspring were obtained:

- brown body, normal wings: 29
- brown body, vestigial wings: 8
- black body, normal wings: 10
- black body, vestigial wings: 33

(a) Identify the recombinant phenotypes amongst the offspring. [1]

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(b) Explain whether these results fit the predicted Mendelian ratios for this cross. [2]

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(c) Outline the statistical test that could be used to provide more evidence of the type of inheritance. [2]

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Question 7 - working space

APOLLO

# Homeostasis

7 questions

**30.** How is blood glucose regulated?

| | Deviation of blood glucose level from normal | Hormone secreted by pancreas | Effect |
|---|---|---|---|
| A. | higher | glucagon | muscles break down glycogen into glucose |
| B. | higher | insulin | small intestine slows glucose absorption |
| C. | lower | glucagon | liver converts glycogen to glucose |
| D. | lower | insulin | kidney reabsorbs more glucose |

**Turn over**

**32.** What is a reason for the changes in blood flow during exercise?

A. Increased blood flow to the kidneys removes waste products from exercise.

B. Blood flow to the brain decreases so that blood is diverted to the kidneys.

C. Increased blood flow to the skin removes heat.

D. Increased blood flow to the digestive system provides more glucose to muscles.

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**8.** Water has unique properties and is needed by all living organisms to survive. Without water, life on Earth as we know it would not exist.

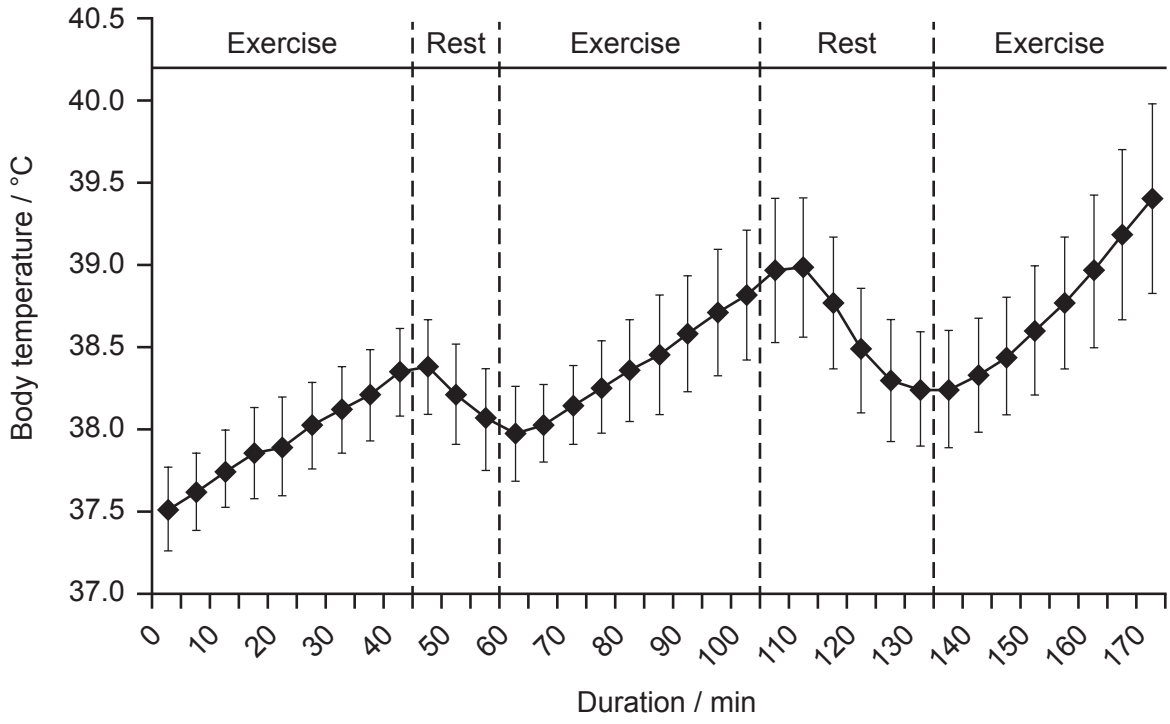
(a) Outline how the cohesive properties of water benefit living organisms. [4]

(b) Describe how the melting of ice and changes in ocean currents can lead to ecological changes. [4]

(c) Explain the hormonal control of osmoregulation in the kidney by negative feedback. [7]

Question 8 - working space

**32.** These results were obtained by measuring the body temperature of people exercising on a hot and humid day.




What mechanism could result in the changes seen during rest periods?

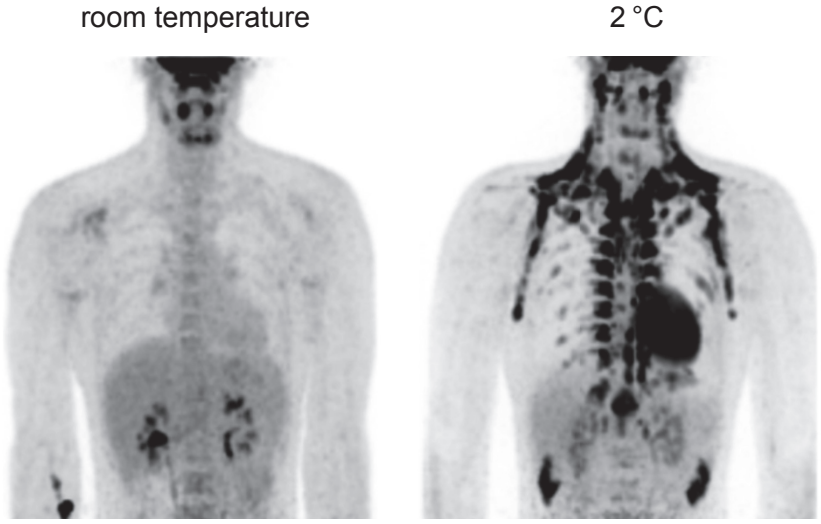
A. Shivering

B. Uncoupled respiration in brown adipose tissue

C. Vasodilation in the skin

D. Hair erection

**31.** The dark areas in the PET/CT scanning images show the activity of brown adipose tissue in an adult human at room temperature (20 °C) and 2 °C.




How does brown adipose tissue contribute to regulating body temperature at 2 °C?

A. It provides adenosine triphosphate (ATP) for muscle contraction when shivering.

B. It further insulates the body so that internal heat is not lost.

C. It turns into thick layers of white adipose tissue to prevent hypothermia.

D. It breaks down fat to generate heat but not ATP.

**Turn over**

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**9.** Living organisms have mechanisms for preventing or reducing change.

(a) Explain how mutation is avoided during DNA replication. [4]

(b) Describe the mechanisms used to keep blood glucose levels within narrow limits in humans. [7]

(c) Explain the need for isotonic conditions in human blood plasma and tissue fluid. [4]

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Question 9 - working space

**30.** How would the body respond to a rise above normal body temperature?

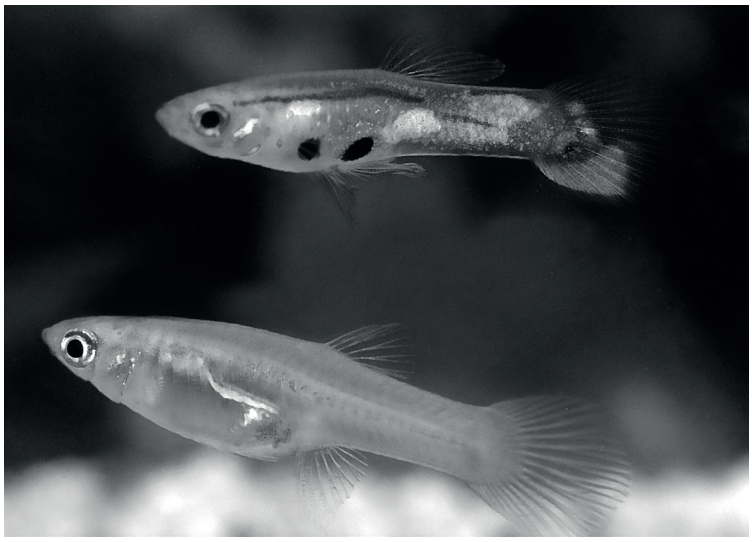
| | Type of feedback | Response |
|---|---|---|
| A. | positive | increased secretion from sweat glands |
| B. | positive | spread limbs to increase surface area |
| C. | negative | vasodilation of skin blood vessels |
| D. | negative | shivering |

APOLLO

# Natural selection

9 questions

**38.** John Endler's experiments modelled sexual and natural selection in Trinidadian guppies (*Poecilia reticulata*) by controlling selection pressures.



What did the experiments of John Endler demonstrate?

A. Guppies have no predators in their natural habitat.

B. Male guppies prefer dull-coloured females for mating.

C. Predation influences the colour of guppies in different environments.

D. Guppies are not affected by the presence of other fish species.

**38.** Mutations and sexual reproduction both play a role in generating variation, upon which natural selection acts. What describes how variation is generated?

I. Mutations generate new alleles.

II. Mutations generate new combinations of alleles.

III. Sexual reproduction generates new alleles.

A. I only

B. III only

C. II and III only

D. I and III only

**37.** John Endler experimented on populations of guppies (*Poecilia reticulata*) with different colouration. A male guppy fish is shown with large spots, which makes the fish more attractive to females, but more visible to predators.



The table shows the male colouration of guppy fish and number of predators in three different ponds.

| | **Predator X** | **Predator Y** | **Male guppy colouration** |
|---|---|---|---|
| Pond 1 | 12 | 0 | Large colourful spots |
| Pond 2 | 15 | 0 | Medium colourful spots |
| Pond 3 | 5 | 17 | None/very small drab spots |

What can be concluded from the data?

A. There is a positive correlation between numbers of predator X and size of spots.

B. Predator Y has least influence on colouration.

C. There is a negative correlation between number of predators and size of spots.

D. There is no sexual selection.

**38.** What is an outcome of selection?

A. Directional selection increases the size of the gene pool.

B. Stabilizing selection increases allele frequencies of phenotypic extremes.

C. Disruptive selection increases genetic variance in a population.

D. Sexual selection leads to allopatric speciation.

**38.** The Hardy–Weinberg equation, used to calculate expected genotype frequencies in a population in genetic equilibrium, is:

$$p^2 + 2pq + q^2 = 1$$

The length of the mouthparts in an insect population is controlled by a gene with two alleles: long mouthparts (dominant) and short mouthparts (recessive). The frequency of the allele for long mouthparts is 0.72. What is the expected genotype frequency of individuals with short mouthparts?

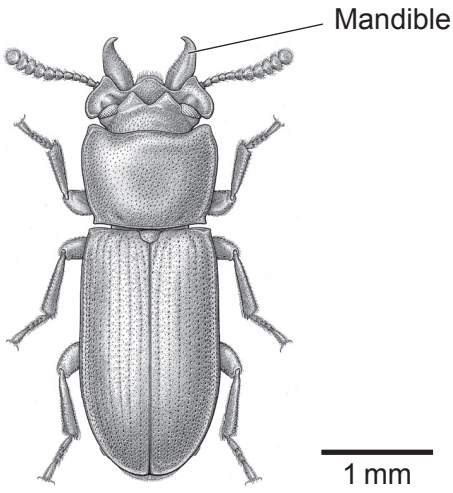
A. 0.52

B. 0.40

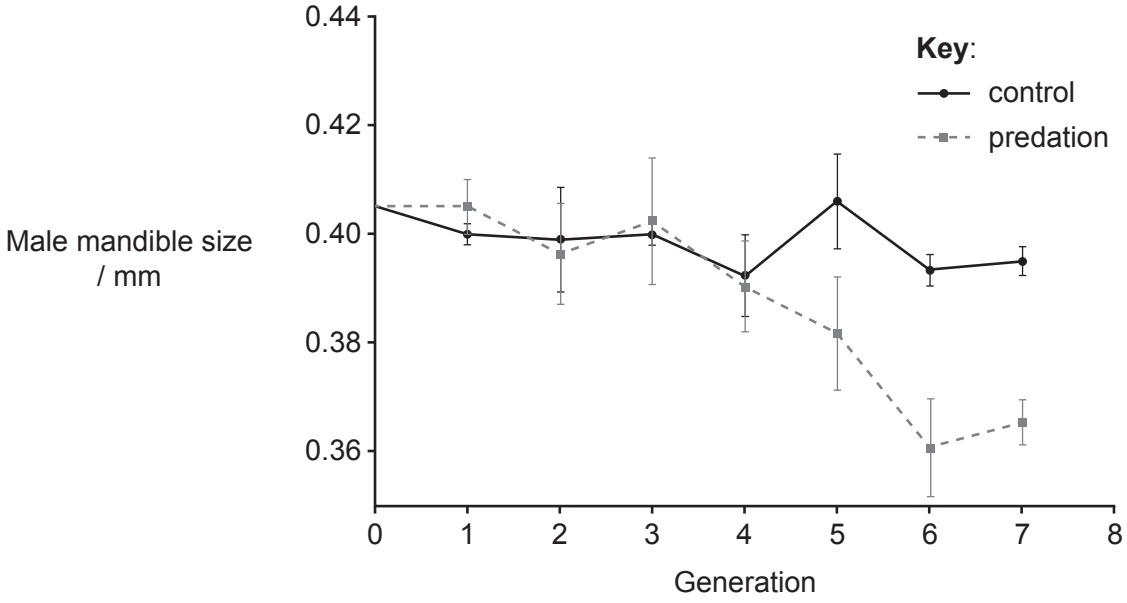
C. 0.28

D. 0.08

**4.** Mandible (mouthpart) size is variable in the male broadhorned flour beetle (*Gnatocerus cornutus*).




In a laboratory experiment, scientists investigated how natural selection by predation on flour beetles by the larger assassin bug (*Amphibolus venator*) affected male mandible size. The graph shows the mean and standard deviation (SD) male mandible size over seven generations in three replicate experiments. Control populations were not subjected to predation.




(a) (i) State the reason that a ruler is not a suitable piece of equipment for precisely measuring the length of the mandible. [1]

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**(This question continues on the following page)**

**(Question 4 continued)**

(ii) Suggest how the mandible size of the flour beetles could have been measured in this experiment. [1]

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(b) List **two** variables that need to be kept constant in this experiment. [2]

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(c) Describe the trend for male mandible size with predation. [2]

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(d) Explain how natural selection by predation affects male mandible size in flour beetles. [4]

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**4.** Diagram: Bousquet Y, et al., 2018. Figure 36; *Gnatocerus* (*Gnatocerus*) *cornutus* (Fabricius, 1798). [image online] Available at: https://commons.wikimedia.org/wiki/File:Gnatocerus_(Gnatocerus)_cornutus_(10.3897-zookeys.728.20602)_Figure_36.jpg. Licensed under the Creative Commons Attribution 4.0 International license: https://creativecommons.org/licenses/by/4.0/deed.en. [Accessed 30 September 2024]. Source adapted.

Graph: Okada, K., Katsuki, M., Sharma, M.D., et al., 2021. Natural selection increases female fitness by reversing the exaggeration of a male sexually selected trait. *Nat Commun* 12, 3420. https://doi.org/10.1038/s41467-021-23804-7. Licensed under a Creative Commons Attribution 4.0 International License: https://creativecommons.org/licenses/by/4.0/. Source adapted.

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Question 4 - working space

## Section B

Answer **two** questions. One additional mark is available for the construction of your answers for each question. Answers must be written within the answer boxes provided.

**10.** There is evidence that RNA was used as a genetic material in living organisms before DNA.

(a) Describe the structure of RNA and the evidence that it was the first genetic material used to store information. [5]

(b) Describe how analysis of DNA base sequences can be used in the conservation of biodiversity. [3]

(c) Explain the causes and consequences of changes in the base sequences of DNA in a species over many generations. [7]

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Dridi, B., Fardeau, M.-L., Ollivier, B., Raoult, D. and Drancourt, M., 2012. *Methanomassiliicoccus luminyensis* gen. nov., sp. nov., a methanogenic archaeon isolated from human faeces. *International Journal of Systematic and Evolutionary Microbiology*, [online] Available at: https://www.microbiologyresearch.org/content/journal/ijsem/10.1099/ijs.0.033712-0 [Accessed 6 December 2024]. Source adapted.

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Question 10 - working space

**39.** What assumption is made when using the Hardy-Weinberg equation for calculating changes in allele frequencies in a population?

A. The population size is large.

B. Natural selection is taking place.

C. Mutations are occurring in the population.

D. There is variation among the phenotypes of the population.

**40.** Domestic dogs (*Canis familiaris*) have evolved from grey wolves (*Canis lupus*). Evidence suggests that the domestication of dogs first occurred around 30 000 years ago. Which best describes the evolution giving rise to the domestic dog?

A. The wolf produced offspring in large numbers which underwent natural selection.

B. Variations in the wolf population that resembled modern dogs favoured wolf survival.

C. Wolves showing favourable traits were selected for breeding.

D. Dogs were better suited to changes in the natural environment than wolves.

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APOLLO

# Stability and change

2 questions

**39.** What occurs during primary succession?

A. Saprotrophs are the first to colonize bare rock.

B. The amount of primary production remains stable.

C. There is a decrease in species diversity.

D. There is an increase in the complexity of food webs.

**39.** Which of these conditions is/are necessary for genotype frequencies to fit the Hardy–Weinberg equation?

I. Homozygous recessive phenotypes have lower survival.

II. Mating is random.

III. The population is small.

A. I only

B. II only

C. II and III only

D. I, II and III

APOLLO

# Climate change

5 questions

**40.** What is the main driver of contemporary climate change?

A. The burning of fossil fuels, releasing greenhouse gases into the atmosphere

B. Natural variability in solar radiation, causing periodic shifts in temperature

C. Ocean currents regulating heat distribution, influencing weather patterns

D. Volcanic eruptions heating the atmosphere

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**References:**

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**40.** What is a consequence of ocean water having a very high temperature?

A. Decreased bleaching of coral reefs

B. Increased production of oxygen

C. Increase in energy flow through food chains

D. Reduced nutrient upwelling to the surface

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**8.** What is an advantage of free-air carbon dioxide enrichment experiments (FACE)?

A. The carbon dioxide uptake by plants is controlled.

B. Temperature can be controlled.

C. Water can be controlled.

D. Data can more accurately represent future rates of photosynthesis.

**Turn over**

## Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

**2.** Average human internal (core) body temperature is 36.4 °C, with slight variations between day and night. The average surface temperature of the Earth in the 20th century was 13.9 °C. It has now risen to 14.8 °C.

(a) (i) Outline **one** change that happens in the human body in response to a rise in body temperature above 36.4 °C. [1]

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(ii) Identify with a reason whether this response is positive or negative feedback. [1]

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(b) Explain how the burning of fossil fuels has contributed to the increase in the Earth's temperature. [2]

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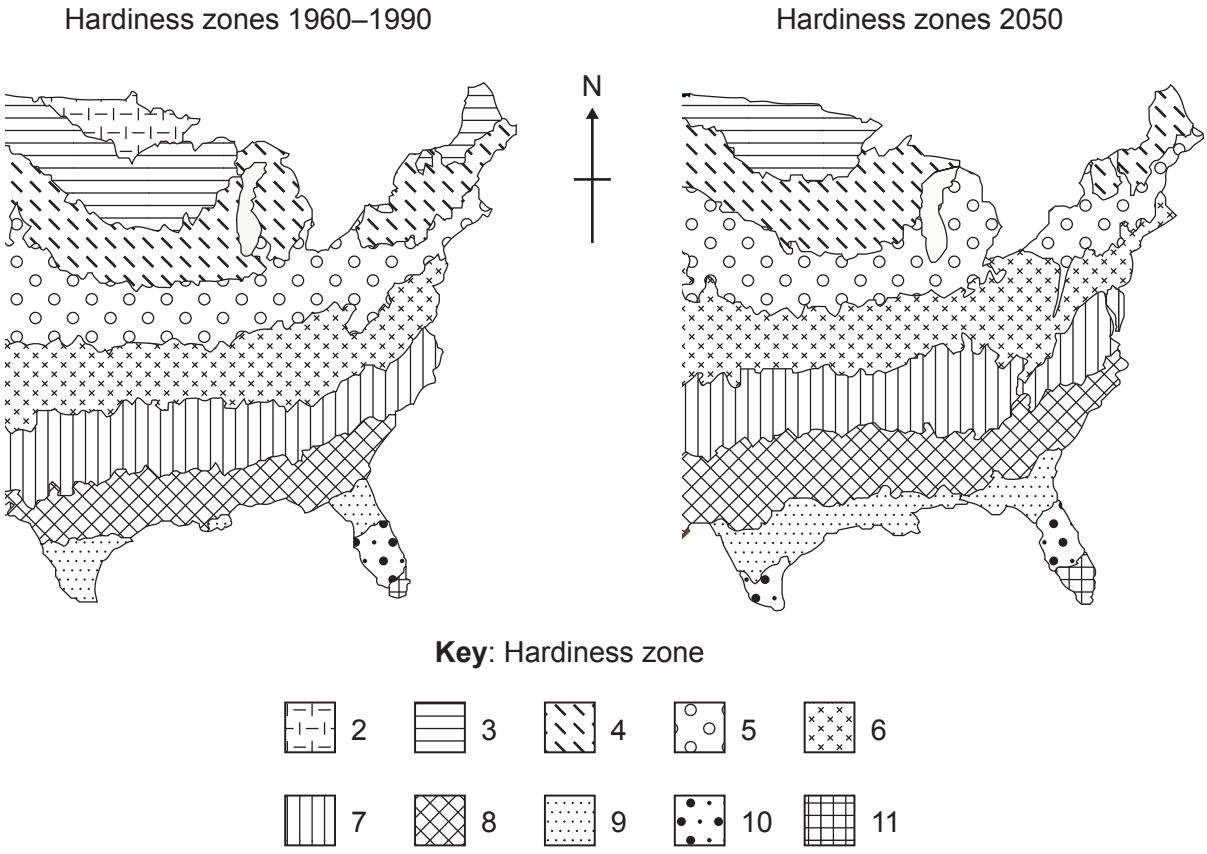
(c) Melting polar ice due to global warming is reducing reflection of sunlight from the Earth. Identify with a reason whether this will result in positive or negative feedback. [1]

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Question 2 - working space

**40.** The data shows how the hardiness zones in part of North America are predicted to change over the next 25 years. A hardiness zone is an area that has a certain average annual minimum temperature, a factor relevant to the survival of many plants. The lower the number, the more cold-resistant the plants must be.




What is a likely consequence of this change for tree species?

A. Tree species will spread northwards as climate changes.

B. Tree species that are not cold-resistant will decline.

C. There will be no change in the distribution of the tree species.

D. Tree species that currently live in the north will outcompete other tree species.

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