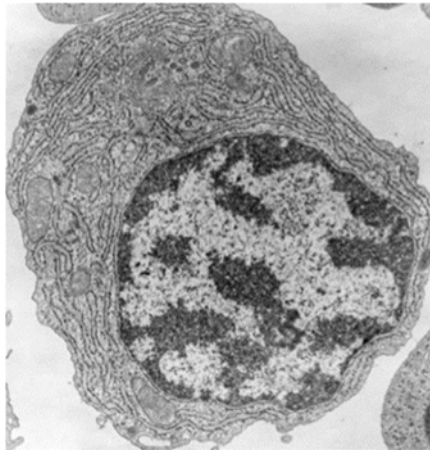


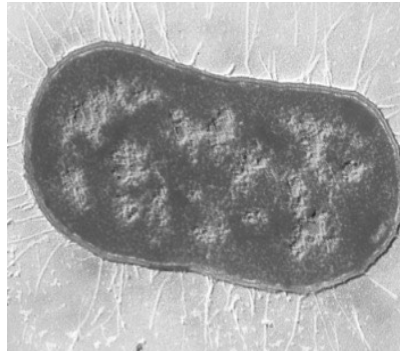
- 1 The electron micrographs 1, 2 and 3 show three different types of cells.



1



2

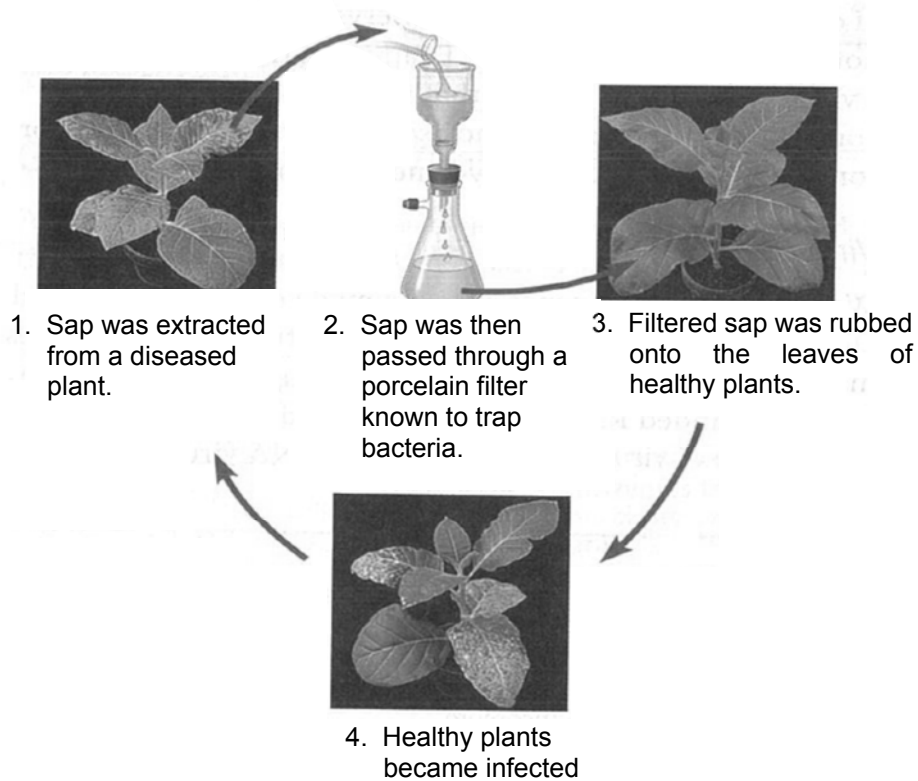


3

Which row is correct?

	electron micrograph of cell type	organelle found in cell type	description of organelle
A	1, 2 and 3	ribosomes	embedded on the smooth endoplasmic reticulum for synthesis of polypeptides
B	1 and 2 only	vacuoles	membrane-bound fluid-filled sacs
C	3 only	nucleoli	dense masses within the nuclei
D	2 only	centrioles	found in animal cells but absent in plant cells

- 2 An investigation into the properties of an agent that causes a plant disease was carried out.



The process was repeated several times and each successive group of plants developed the disease to the same extent as earlier groups.

Which statements, supporting the idea that the infectious agent is a virus, can be concluded from the experiment?

- 1 Viruses cannot replicate outside of a host cell.
- 2 Viruses are smaller than bacterial cells and can pass through a bacterium-trapping filter.
- 3 Viruses can replicate within plant cells, so their ability to cause disease remains undiluted after several transfers from one healthy plant to another.

A 1 only

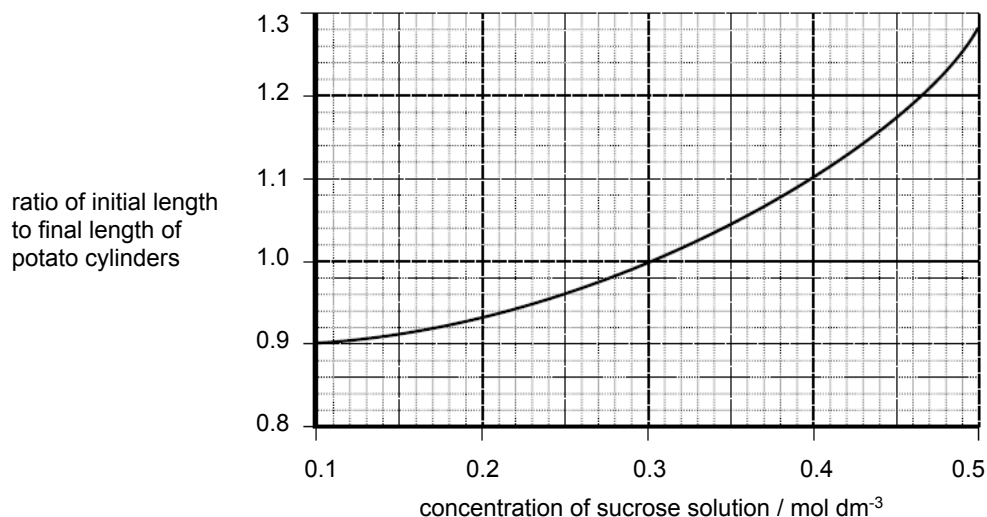
B 1 and 2

C 2 and 3

D 1, 2 and 3

- 3 In an experiment, potato cylinders were placed in sucrose solutions of different concentrations. The potato cylinders were measured before and after immersion into each sucrose solution.

The graph shows the effect of different sucrose concentrations on the length of the potato cylinders.



When the sucrose solution was less than 0.3 mol dm⁻³, water molecules moved from a region of ...1... negative water potential to a region of ...2... negative water potential. Hence, water molecules moved from the ...3... into the ...4....

If the initial length of the potato cylinder in 0.1 mol dm⁻³ sucrose solution is 5.0 cm, the final length will be ...5...cm.

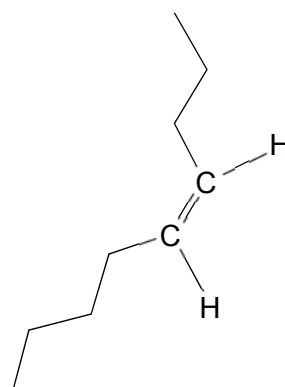
Which words correctly fill gaps 1, 2, 3, 4 and 5?

	1	2	3	4	5
A	less	more	sucrose solution	potato cells	5.5
B	less	more	sucrose solution	potato cells	4.5
C	more	less	potato cells	sucrose solution	5.5
D	more	less	sucrose solution	potato cells	4.5

- 4 Fatty acid chains of natural membrane phospholipids may be saturated or unsaturated.



fatty acid chain A



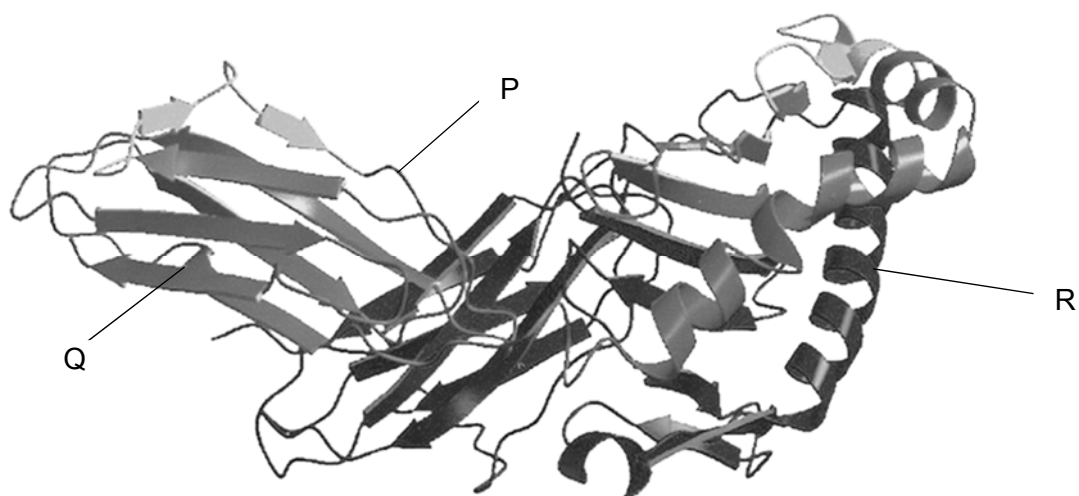
fatty acid chain B

Which statements regarding fatty acid chains A and B are correct?

- 1 The presence of phospholipids with mainly fatty acid chain A in cell membranes have increased membrane viscosity.
- 2 Fatty acid chain B is unsaturated because it contains one double bond creating a kink in the fatty acid structure.
- 3 A membrane containing predominantly fatty acid chain B has a greater fluidity than one which predominantly contains fatty acid chain A.
- 4 The presence of phospholipids with fatty acid chain B eases the passage of small, non-polar molecules, such as oxygen through membranes.

A 1, 2, 3 and 4 **B** 1, 3 and 4 only **C** 1 and 2 only **D** 2 and 4 only

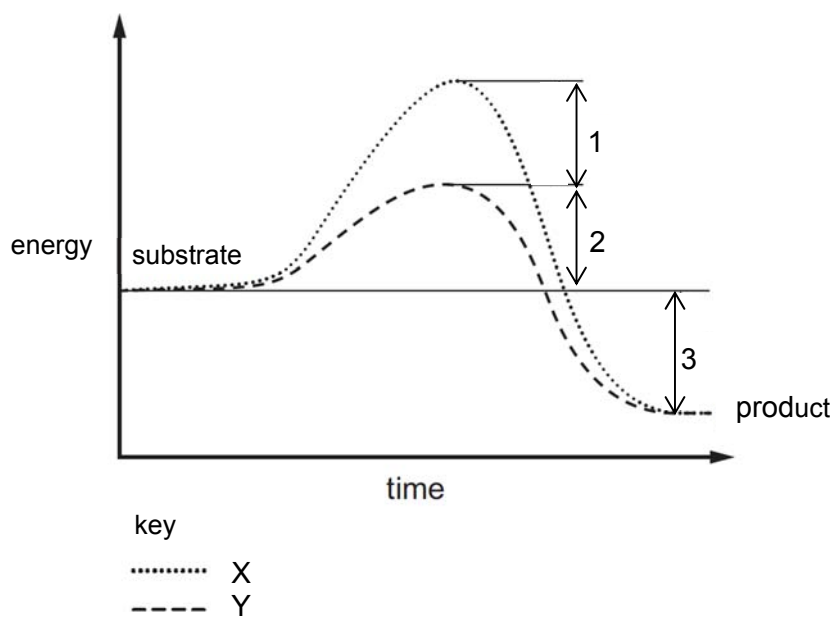
- 5 The diagram shows the ribbon model of the cell surface membrane receptor, HLA-DR1. HLA-DR1 consists of two polypeptides, where parts of the protein are labelled P, Q and R.



Which statement regarding the cell surface membrane receptor HLA-DR1 is correct?

- A In the formation of structure P, each hydrogen bond is formed between the -NH of one amino acid and the C=O group of another amino acid.
- B Q is important for the folding of the polypeptide into a specific 3D conformation of its active site.
- C R-group hydrogen bonding is involved in the formation of structure R.
- D Structures P, Q and R play a role in the formation of the quaternary structure of HLA-DR1.

- 6 The graph shows the effect of an enzyme on a reaction.



Which row correctly identifies the labels?

	reaction with enzyme	difference in activation energy	energy released during reaction
A	X	1	2 + 3
B	Y	1 + 2	3
C	X	1 + 2	1 + 2 + 3
D	Y	1	3

- 7 Once most stem cells differentiate, they lose their ability to turn into other types of cells. However, some fully differentiated cells can be stimulated to change back into stem cells in tissue culture. Such cells are called induced pluripotent stem cells (iPS cells).

In experiments with mice, it was discovered that the introduction of four genes would cause certain fully differentiated cells to change to iPS cells. Genes were introduced into host mouse cells using artificially synthesised plasmids.

There is evidence to suggest that the introduction of the four genes caused an increase in the production of telomerase reverse transcriptase (TERT) in the fully differentiated cells.

Which statements are correct?

- 1 The iPS cells are useful for research because they have the ability to differentiate into cells of the extra-embryonic membranes.
- 2 Only a few genes were required to be added because these genes were likely able to influence the activity of many other genes by coding for transcription factors.
- 3 TERT, which plays a part in maintaining the length of the telomere at the end of a chromosome, is not normally switched on in differentiated cells.
- 4 This method of creating iPS cells has less ethical concerns than harvesting embryonic stem cells.

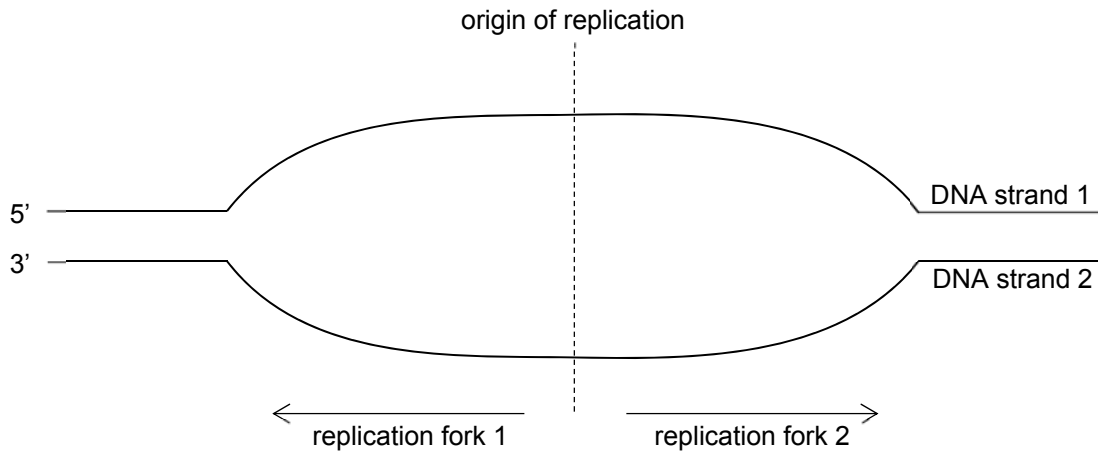
A 1, 2 and 3

B 1, 2 and 4

C 1, 3 and 4

D 2, 3 and 4

- 8 The diagram shows the replication bubble of part of a DNA molecule.

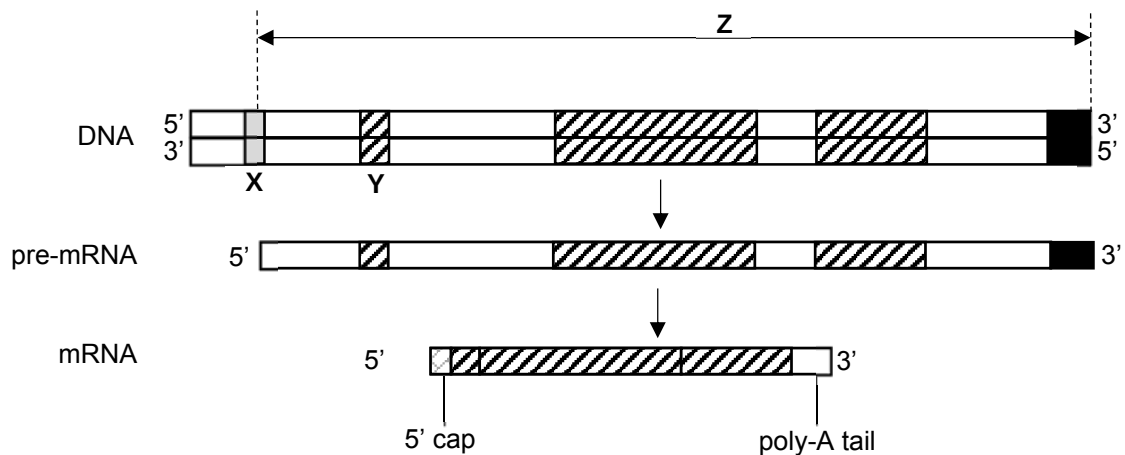


Which statements regarding the replication of DNA are correct?

- 1 At replication fork 1, synthesis of the complementary strand of DNA strand 1 is continuous.
- 2 At replication fork 2, DNA strand 1 requires multiple primers for the replication process.
- 3 Four DNA molecules are newly formed upon the completion of replication.

- A** 1, 2 and 3 **B** 2 and 3 **C** 1 and 2 **D** 1 only

- 9 The diagram shows the transcription of a gene in a eukaryotic cell.

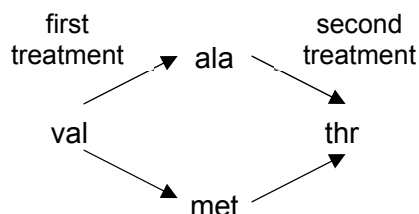


Which statements are correct?

- 1 X is not transcribed except for the transcription start site.
 - 2 RNA polymerase and transcription factors bind to Y to initiate transcription.
 - 3 Z comprises the promoter, coding region and termination sequence.
- A** 1, 2 and 3
B 1 and 3 only
C 2 and 3 only
D 1 only

- 10 A bacteria colony produces a normal protein with a known amino acid sequence.

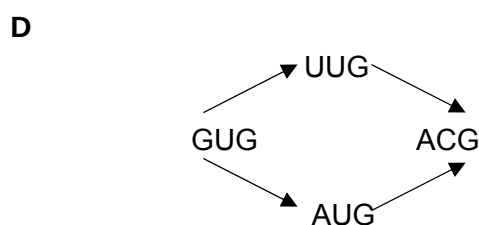
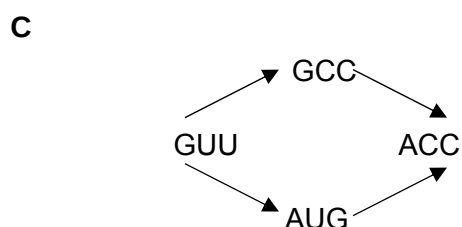
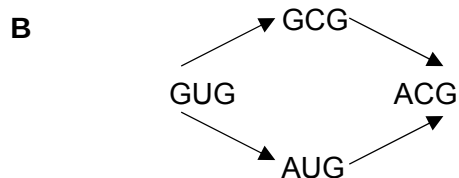
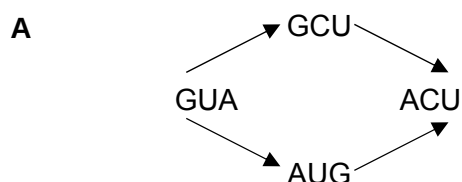
The bacteria colony was treated with the same chemical mutagen twice. This gave rise to two mutant strains of bacteria where each had a single nucleotide change at a particular mRNA codon resulting in a change of amino acid as shown in the diagram.



The mRNA codons for some amino acids are shown in the table.

alanine (ala)	leucine (leu)	threonine (thr)	valine (val)
GCU	UUU	ACU	GUU
GCC	UUC	ACC	GUC
GCA	UUA	ACA	GUA
GCG	UUG	ACG	GUG

Assuming that both treatments resulted in a single nucleotide change each, which diagram correctly shows the codons that were translated into alanine, methionine, threonine and valine?



- 11** In order to replicate, the ends of a eukaryotic chromosome contain a special sequence of DNA called a telomere.

When cells undergo mitotic division, some of these repeating sequences are lost. This results in the shortening of the telomeric DNA.

What is a consequence of the loss of repeating DNA sequences from the telomeres?

- A** The cell will begin the synthesis of different proteins.
- B** The cell will begin to differentiate as a result of the altered DNA.
- C** The number of mitotic divisions the cell can make will be limited.
- D** The production of mRNA will be reduced.

- 12** Gene transfer refers to the movement of genetic material between cells. There are two types of gene transfer in prokaryotes:

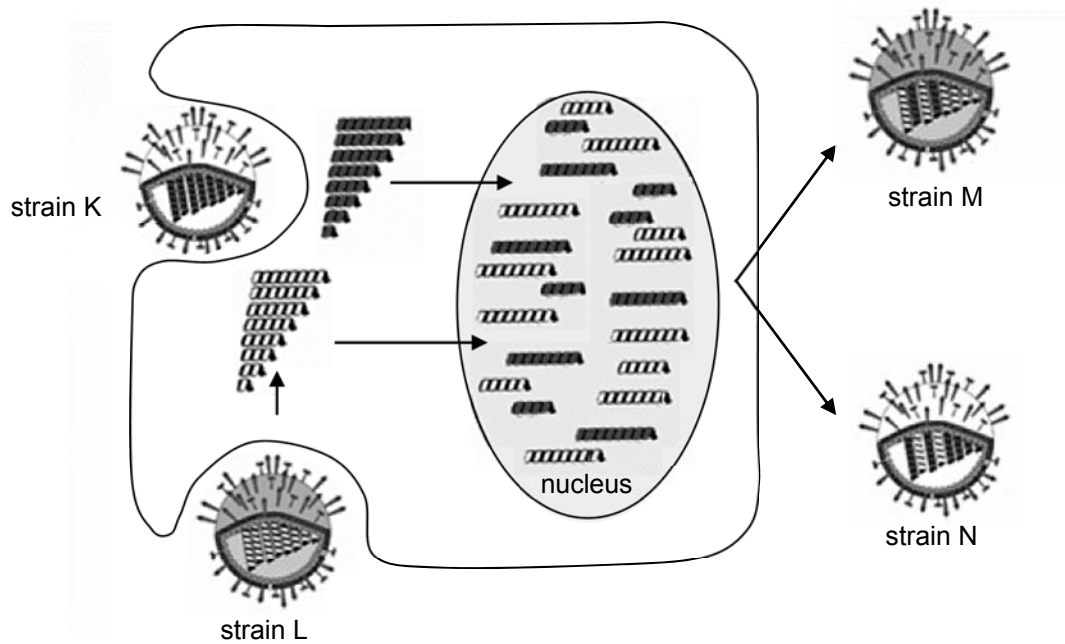
- vertical gene transfer where the transfer of genes is from parent to offspring
- horizontal gene transfer where the transfer of genes is between two bacterial strains.

Which statements correctly describe the two types of gene transfer?

- 1 Horizontal gene transfer consists of binary fission, conjugation and transduction.
- 2 Horizontal gene transfer and not vertical gene transfer results in genetic variation.
- 3 Both forms of gene transfer lead to bacterial strains acquiring new antibiotic resistance.

- A** 1, 2 and 3 **B** 1 and 3 **C** 2 only **D** 3 only

- 13 The diagram show the emergence of new influenza strains, M and N, resulting in antigenic shift in influenza A.



Which events lead to antigenic shift?

	name of event	description
1	mutation	mutations in the viral genomes of strains K and L occurred in the cell resulting in strains M and N
2	recombination of viral genome	recombination of strains K and L resulted in new strains M and N
3	reassortment of viral genome	reassortment of the viral genomes of strains K and L occurred only when both strains infect the same cell

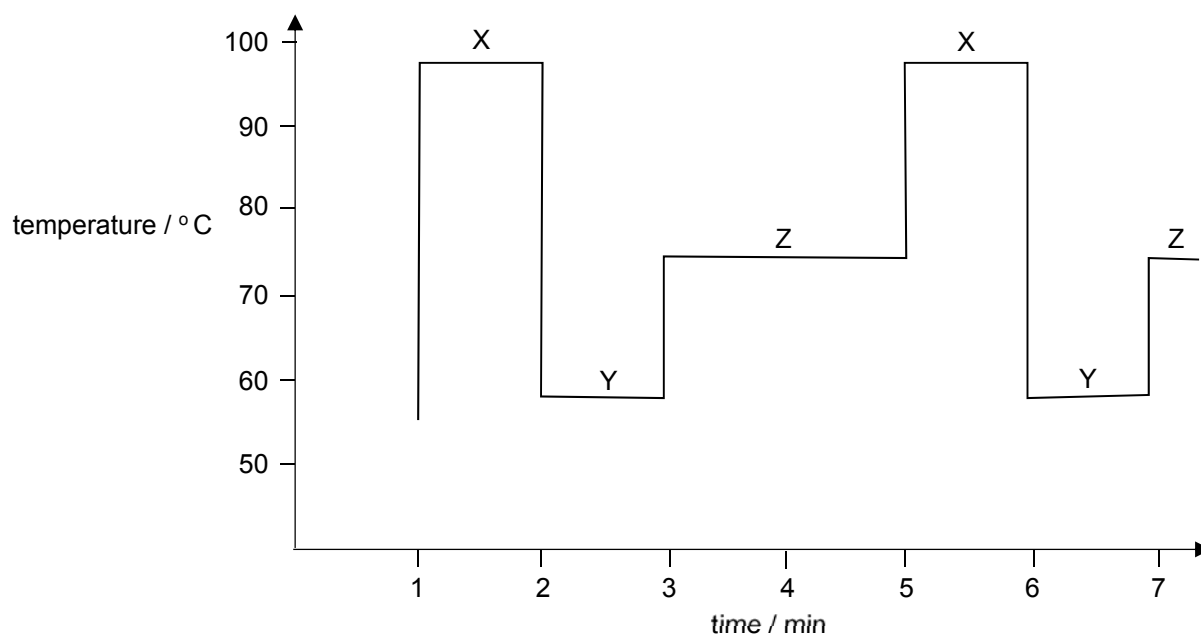
A 1, 2 and 3

B 2 and 3

C 3 only

D 2 only

- 14 The graph shows the thermal cycling of a DNA sample during polymerase chain reaction (PCR).

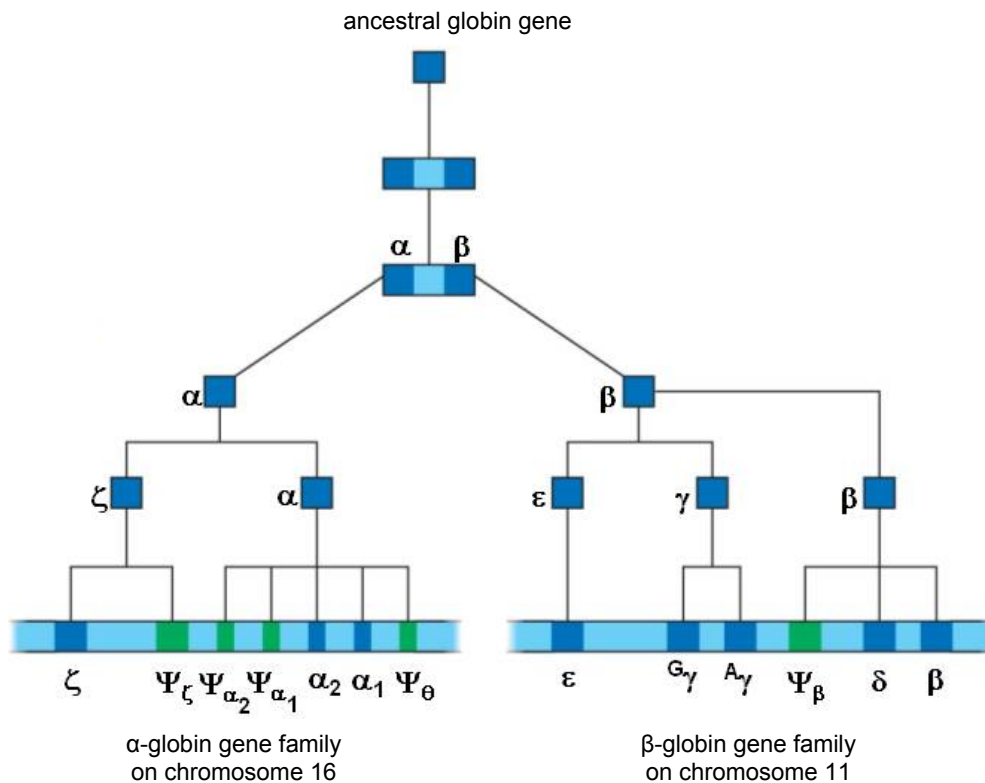


Which row is correct regarding the formation and breakage of bonds involved in PCR at steps X, Y and Z?

	step	stage in PCR	hydrogen bonds	phosphodiester bonds
A	Y	annealing of primers	forms	forms
B	Y	denaturation of DNA	forms	breaks
C	Z	extension of DNA	forms	forms
D	X	annealing of primers	breaks	breaks

- 15** Multigene families are defined as groups of genes with sequence homology and related overlapping functions. It is thought that these genes arose from a common ancestral gene that has accumulated mutations over time.

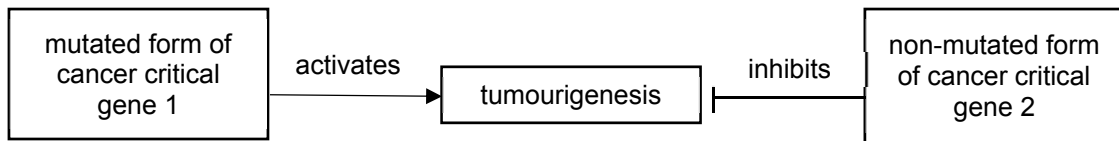
The globin gene family is one such example and the diagram shows how the gene family arose.



Which mechanism best explains how the globin gene family was formed?

- A** Multiple unequal crossovers of the α and β globin RNA occur during mitosis to result in the different gene families.
- B** A germline mutation occurred where the ancestral globin gene was duplicated forming α and β globin gene, each with their own subsequent point mutations.
- C** A point mutation in the ancestral gene promoter resulting in the formation of a new origin of replication, and hence the repeated replication of a specific portion of the genome.
- D** Several copies of the α and β globin genes are duplicated over time, each with different degree of nonsense mutation leading to globin chains of varying functions.

- 16** Proto-oncogenes and tumour suppressor genes are cancer critical genes. The diagram shows how mutations in these genes play a role in the generation of tumours, which is known as tumourigenesis.



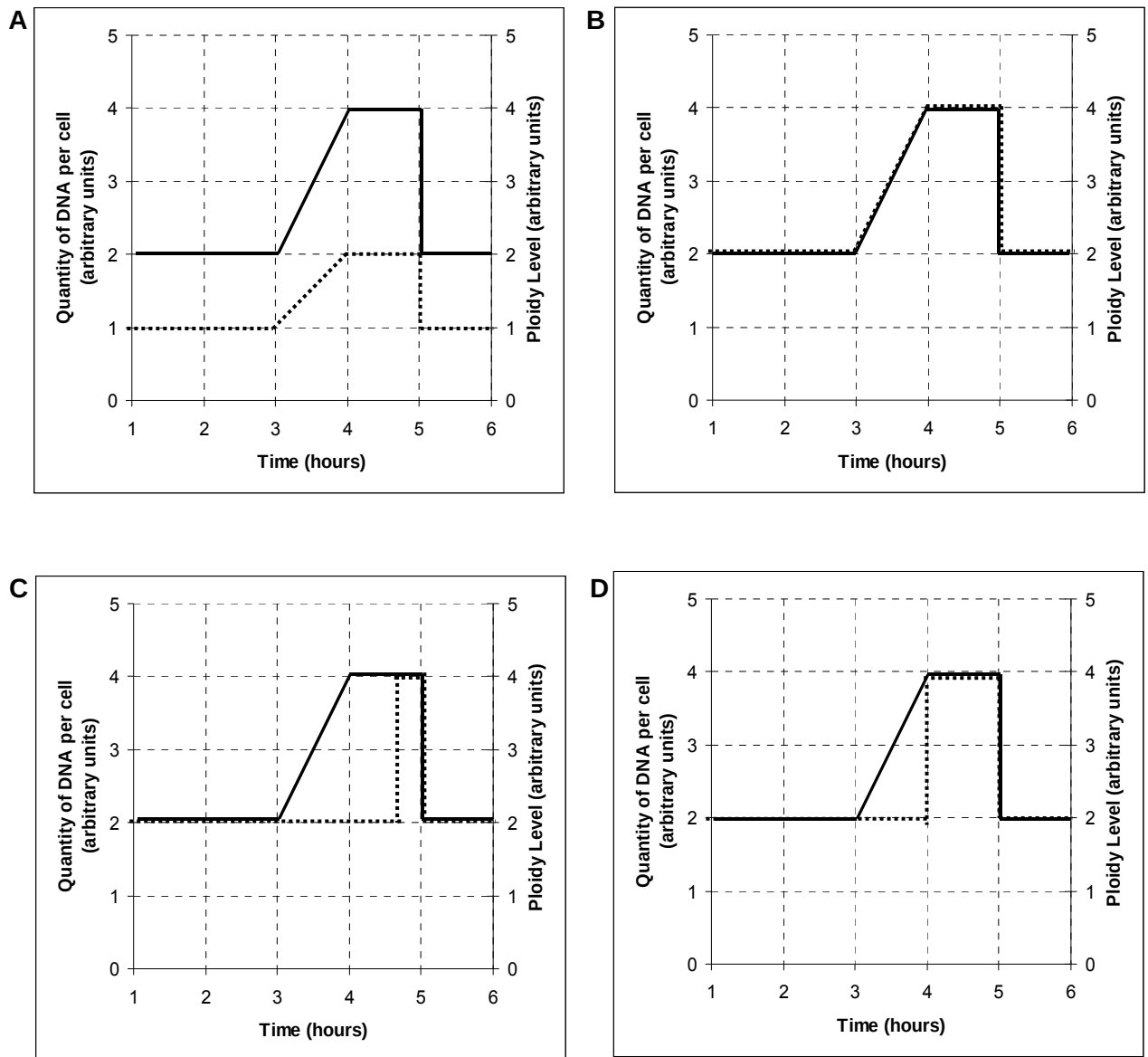
MicroRNA (miRNA) is a type of RNA that binds by complementary base pairing to mRNA. A miRNA, specific to the mRNA of either the mutated form of cancer critical gene 1 or the non-mutated form of cancer critical gene 2, is added to normal cells. The binding results in the repression of translation.

Which row is correct?

	tumour suppressor gene	binding of miRNA	result of miRNA binding
A	mutated form of cancer critical gene 1	mRNA of non-mutated form of cancer critical gene 2	tumourigenesis occurs
B	non-mutated form of cancer critical gene 2	mRNA of mutated form of cancer critical gene 1	no tumourigenesis
C	mutated form of cancer critical gene 1	mRNA of mutated form of cancer critical gene 1	tumourigenesis occurs
D	non-mutated form of cancer critical gene 2	mRNA of non-mutated form of cancer critical gene 2	no tumourigenesis

17 The ploidy level and quantity of DNA of a diploid cell varies during a cell cycle.

Which graph represents this variation?

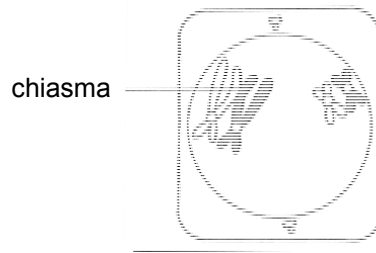


key

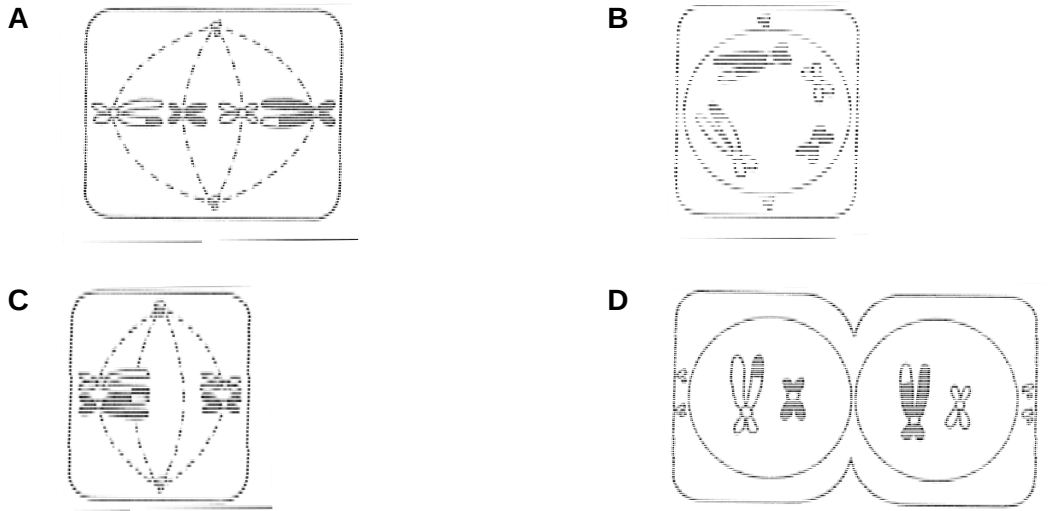
— quantity of DNA

..... ploidy level

18 The diagram shows a cell undergoing meiosis.



Which diagram represents the next stage in the process?



19 Read the following statements.

- Gibberellins belong to a group of chemicals known as terpenoids and are made up of the elements carbon, hydrogen and oxygen only.
- In the pea plants that Mendel studied, the stem length gene, *Le / le*, controls the length between nodes.
- Pure-breeding, tall pea plants were crossed with pure-breeding, dwarf pea plants. The F₁ generation plants were all of the same height. When these were crossed, the numbers of tall and dwarf plants in the F₂ generation were counted. There were 787 tall and 277 dwarf plants.
- The dwarf variety of the pea plant lacks gibberellin.
- Addition of gibberellin to the dwarf plants results in conversion of the dwarf to the tall phenotype.

What can be concluded from these statements?

- A** Heterozygous genotypes for the stem length gene are of an intermediate height, as only 50% of the product of gene expression is synthesised.
- B** The lack of a ratio of 3 tall pea plants to 1 dwarf pea plant in the F₂ generation means that there is an environmental effect contributing to height in pea plants.
- C** The *Le / le* gene codes for the protein gibberellin, with only the *LeLe* or *Lele* genotypes expressing gibberellin and with the *lele* genotype unable to express gibberellin.
- D** There is at least one altered triplet code in the dwarf allele of the *Le / le* gene, producing a polypeptide with an altered tertiary structure and resulting in a non-functioning protein.

- 20 The table shows the results of a series of crosses in a species of small mammal.

coat colour phenotype		
male parent	female parent	offspring
dark grey	light grey	dark grey, light grey, albino
light grey	albino	light grey, white with black patches
dark grey	white with black patches	dark grey, light grey
light grey	dark grey	dark grey, light grey, white with black patches

What explains the inheritance of the range of phenotypes shown by these crosses?

- A one gene with a pair of co-dominant alleles
 B one gene with multiple alleles
 C sex linkage of the allele for grey coat colour
 D two genes, each with a dominant and recessive allele
- 21 In the fruit fly, *Drosophila melanogaster*, four genes whose recessive alleles code for black body (B/b), curved wings (C/c), purple eyes (P/p) and vestigial wings (V/v) are linked on chromosome 2.

The table shows some distances apart of the gene loci, as determined by breeding experiments.

gene loci	distance between loci / map unit
B/b and P/p	6.0
B/b and V/v	18.5
P/p and V/v	12.5
P/p and C/c	21.0
V/v and C/c	8.5

What is the correct sequence of the loci on chromosome 2?

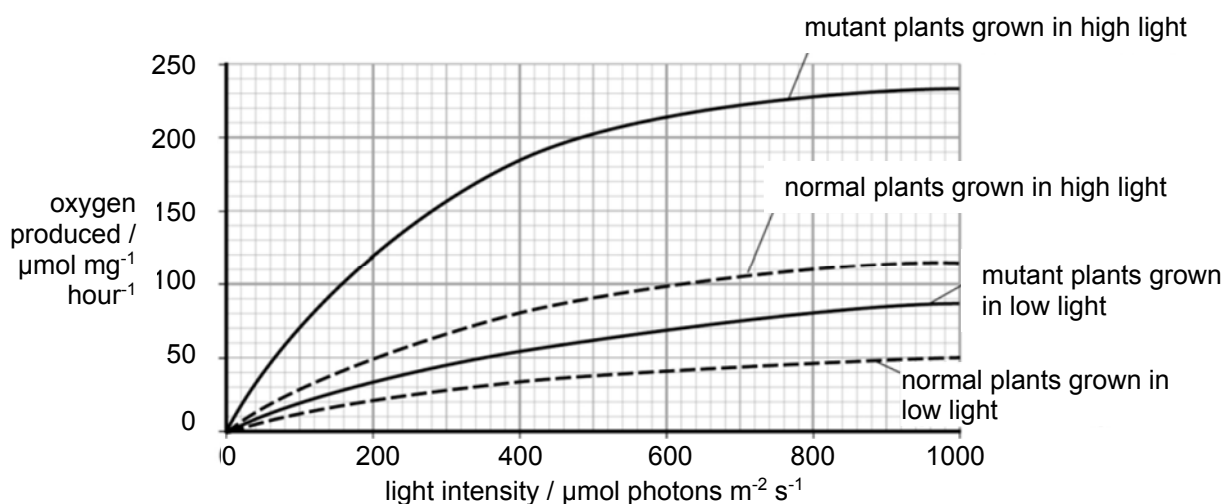
- A B/b P/p V/v C/c
 B C/c V/v B/b P/p
 C P/p V/v C/c B/b
 D V/v B/b P/p C/c

- 22** Chloroplasts contain chlorophyll a and chlorophyll b. Scientists found tobacco plants with a mutation that caused them to make more chlorophyll b than normal tobacco plants. They investigated the effect of this mutation on the rate of photosynthesis.

The scientists carried out the following investigation.

- They grew normal and mutant tobacco plants. They grew some of each in low light intensity and grew others in high light intensity.
- They isolated samples of chloroplasts from mature plants of both types.
- Finally, they measured oxygen production by the chloroplasts they had isolated from the plants.
- In each trial, the scientists collected oxygen for 15 minutes.

The graph shows the scientists' results.

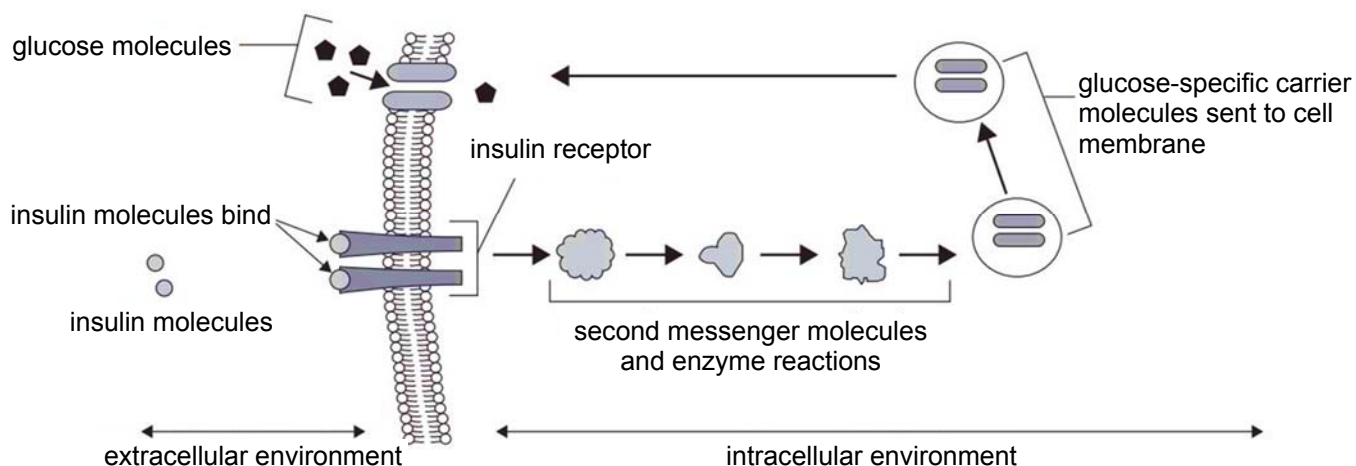


What can be concluded by the scientists based on the results they obtained?

- 1 The mutant plants that produced more chlorophyll b would grow faster than normal plants in all light intensities.
- 2 At all light intensities, chloroplast from mutant plants have a faster production of ATP and NADPH, leading to the faster rate of light-independent reaction.
- 3 The difference in the oxygen produced by the chloroplasts over 15 minutes from the mutant plants grown in low and high light intensities at a light intensity of 500 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$ during these trials is 35 $\mu\text{mol O}_2 \text{mg}^{-1}$.

- A** 1, 2 and 3
B 1 and 2
C 1 and 3
D 2 and 3

- 23 The diagram shows a summary of the steps in an insulin signalling pathway that results in increased glucose uptake.



A scientist studied the insulin signalling pathways of two female patients, X and Y.

The results are as follows:

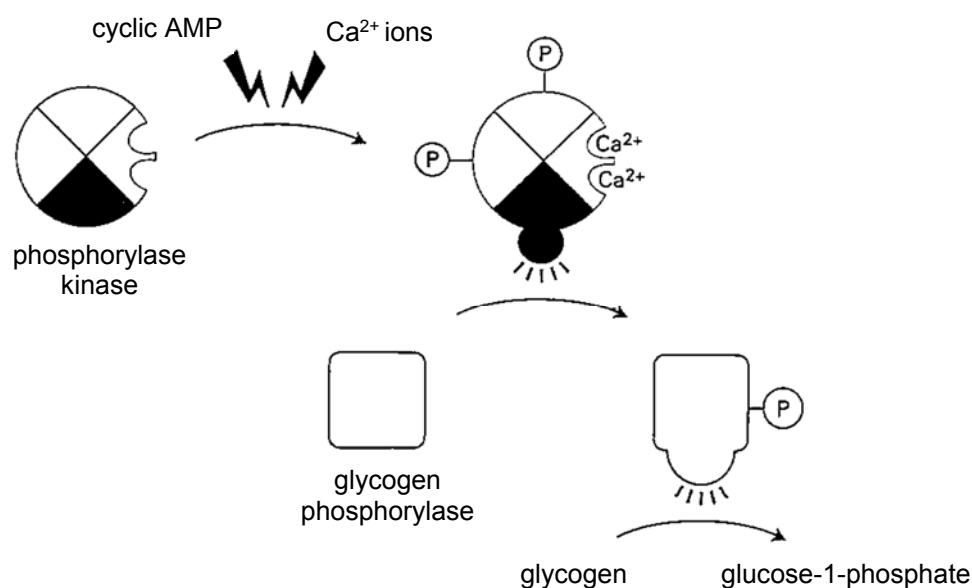
- patient X has a similar pathway as that shown in the diagram
- patient Y has a mutation in the gene that encodes the insulin receptor.

Which statements can be concluded from the study?

- 1 Insulin acts as a hydrophilic signalling molecule.
- 2 There would be more glucose-specific carrier molecules in patient Y's cell membranes than in patient X's.
- 3 The binding of insulin molecules to the receptor initiates signal transduction and the uptake of glucose into patient X's cells.
- 4 The presence of insulin in patient Y's cells would cause an increase in the concentration of the second messenger molecules.

- A** 1, 2, 3 and 4
B 1, 2 and 4
C 1 and 3
D 3 only

- 24 The diagram shows how the enzyme phosphorylase kinase integrates signals from the cyclic AMP-dependent and Ca^{2+} -dependent signalling pathways.



The following statements describe the series of reactions that occur to control glycogen breakdown in liver and muscle cells.

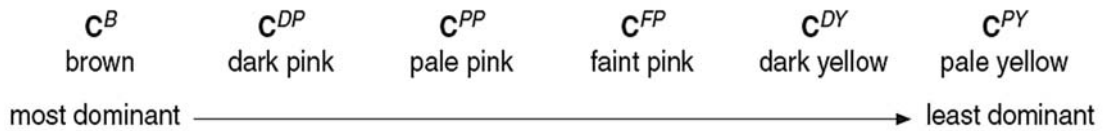
- 1 Phosphorylase kinase is composed of four subunits.
- 2 One subunit is the protein kinase that catalyses the addition of phosphate to the glycogen phosphorylase to activate it for glycogen breakdown.
- 3 The other three subunits are regulatory proteins that control the activity of the catalytic subunits. Two of these three subunits contain sites for phosphorylation by PKA, which is activated by cyclic AMP.
- 4 The remaining subunit is calmodulin, which binds Ca^{2+} ions when its cytosolic concentration rises.
- 5 The regulatory subunits control the equilibrium between active and inactive conformations of the catalytic subunit.

Which statement can be concluded?

- A Phosphorylase kinase has a tertiary level of protein structure.
- B Glycogen phosphorylase is broken down and releases glycogen from glucose-1-phosphate molecules.
- C Phosphorylase kinase adds a phosphate group to glycogen phosphorylase, inhibiting the latter.
- D Binding of Ca^{2+} ions to calmodulin activates calmodulin to produce a cellular response.

- 25 A student recorded the shell colour and banding pattern of all empty shells of the brown-lipped snail, *Cepaea nemoralis*, found in a small deciduous wood. Wide variation in shell colour and banding pattern, which are genetically controlled, was shown. Of the shells collected, 38% were damaged and 62% were intact.

Gene **C** codes for the colour of the shell. There are six alleles.



Gene **B** codes for the presence or absence of bands. There are two alleles.

B^0 = unbanded, dominant allele

B^B = banded, recessive allele

Which conclusion drawn from this information is valid?

- A In the wood, brown, unbanded phenotypes will occur in the highest frequency and banded, pale yellow phenotypes will occur in the lowest frequency.
- B More than one selection pressure is likely to be acting to maintain the polymorphism shown in shell colour and banding pattern in the wood.
- C Predation by birds, such as the song thrush, is the only selection pressure acting on *C. nemoralis* in the small deciduous wood.
- D The proportion of each phenotype in the population of *C. nemoralis* in the wood will be similar to the proportion of each phenotype recorded for the empty shells.

- 26** The rufous bristlebird, *Dasyornis broadbenti*, is a ground-dwelling songbird. The rufous bristlebird is found in gardens near thick, natural vegetation and builds nests in shrubs close to the ground. The rufous bristlebird feeds on ground-dwelling invertebrates. It is a weak flyer and is slow to go back to areas from which it has been previously eliminated.

Two distinct populations of rufous bristlebird exist in Victoria, Australia. The distribution of each population is shown on the map of Victoria. The distance between Population A and Population B is over 200 km and both of the rufous bristlebird populations in Victoria are small.



With reference to Darwin's theory of natural selection, which statements explain why the rufous bristlebird is at risk of extinction?

- 1 There is reduced genetic variation in the limited gene pool, thus reducing the chances of survival.
- 2 There is insufficient variation in the population to survive within their current environment.
- 3 Inbreeding could result in an increased chance of genetic diseases.
- 4 Changes in allele and genotype frequencies is random due to genetic drift.
- 5 Being ground-dwelling, the eggs of the rufous bristlebirds may be frequently eaten.

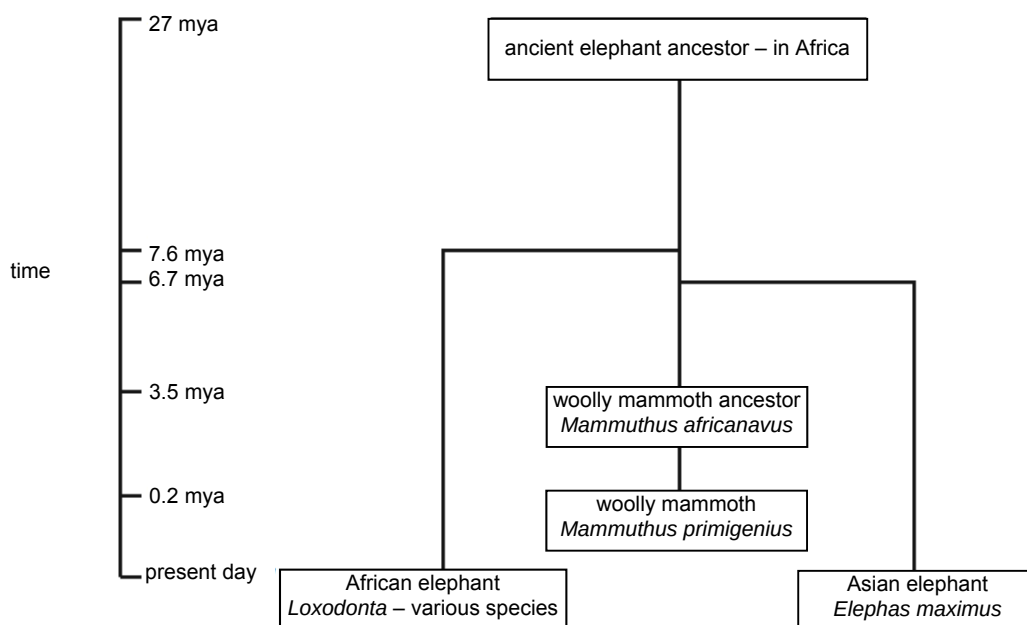
A 1, 2, 3, 4 and 5 **B** 1, 2, 4 and 5 **C** 1, 2 and 3 **D** 3, 4 and 5

- 27 The extinct woolly mammoth, *Mammuthus primigenius*, was closely related and similar in size to present-day elephants. It was herbivorous and highly adapted to very cold climates, with a dense undercoat and small, fur-lined ears. The table shows information about woolly mammoths inferred from extensive fossil evidence.

number of years ago	event	abundance of mammoths
200 000	woolly mammoths first appeared in north-east Siberia and later spread to Europe, Asia and North America	very high
120 000 – 100 000	climate warmed	moderate
100 000	climate cooled again	
15 000	first evidence of human hunting where a spear was found in a mammoth vertebrae	low
14 000 – 10 000	mammoths extinct in North America, Europe and most of Northern Asia	very low, found only in Siberia
3900	last woolly mammoth died on an island off the coast of Siberia	non-existent

It has been suggested that elephant-like ancestors of the woolly mammoth left Africa 3.5 million years ago (mya) and lived in Central Europe. The diagram shows a summarised phylogenetic tree based on mitochondrial and chromosomal DNA from fossils and living elephants.

not to scale



Which statements correctly describe the evolution of elephants?

- 1 Allopatric speciation occurred when *M. africanavus* left Africa and characteristics of *M. primigenius* changed through speciation due to different environments.
- 2 Within the species *M. africanavus*, genetic differences accumulated and variation led to adaptive radiation.
- 3 *M. primigenius* had limited genetic variation and due to increased hunting by humans, was unable to evolve.
- 4 *E. maximus* lives in an environment with more stable selection pressures compared to *M. primigenius*.

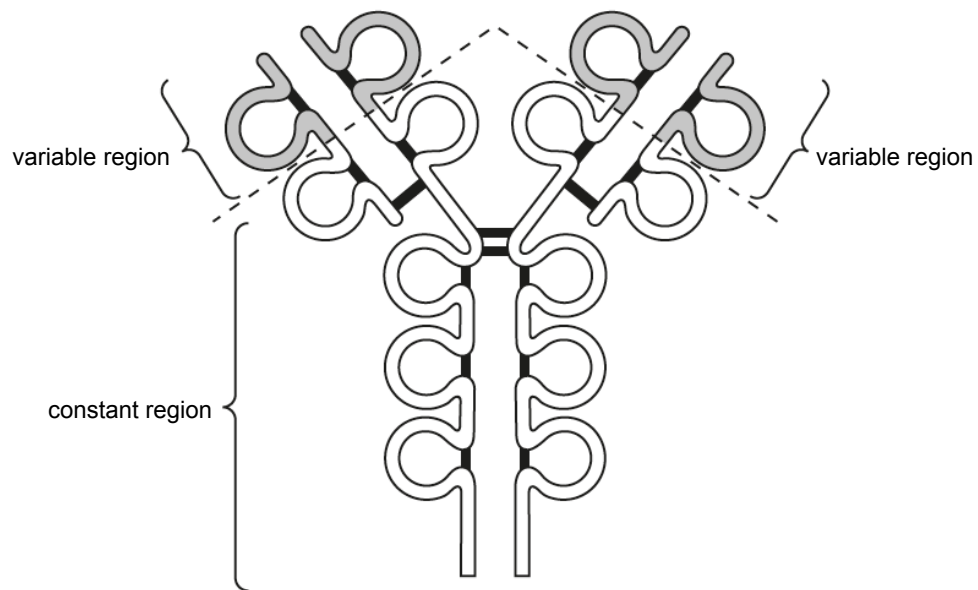
A 1, 2 and 4

B 1, 3 and 4

C 1 and 3

D 3 and 4

28 The diagram shows the structure of an antibody molecule.



How many of the statements are correct?

- 1 The two variable regions have different amino acid sequences from each other, which increase the diversity of antigens that the antibody can bind to.
- 2 Only the light chains form the antigen-binding sites.
- 3 The hypervariable region within each variable region provide the structural basis for the diversity of the binding sites.
- 4 The antibody can have multiple epitopes at the variable region to allow the antibody to bind to many types of antigen.

A one

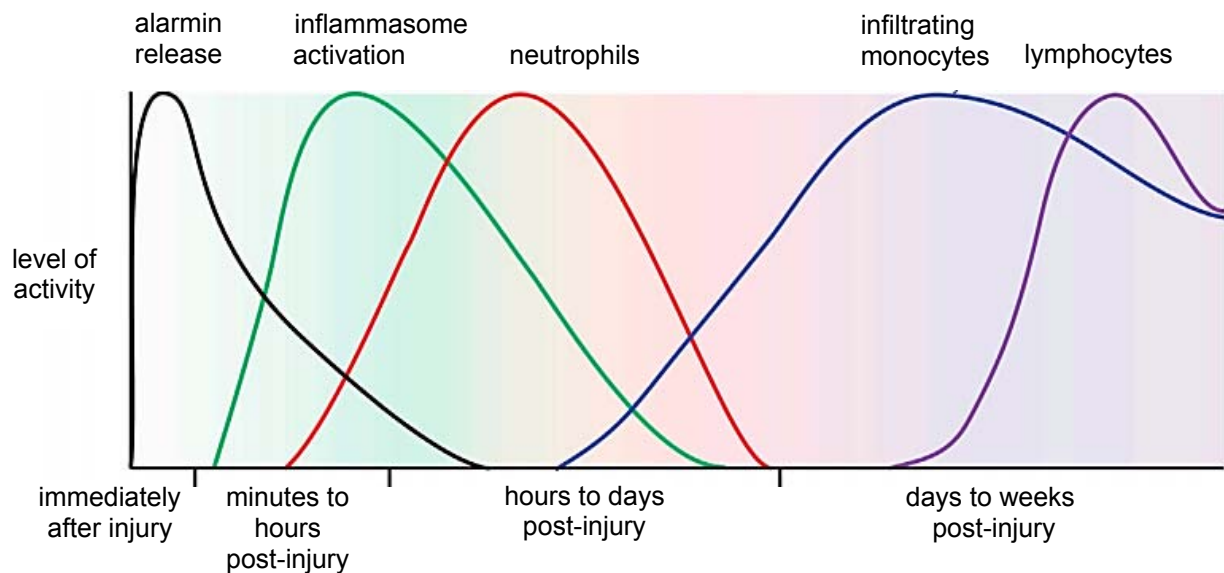
B two

C three

D four

29 The graph shows the kinetics of the molecular and cellular immune responses to a brain injury.

- Alarmins, also known as danger signals, are released rapidly in the extracellular fluid during infection and tissue damage.
- Levels of inflammasome are elevated soon, and when activated, triggers production of cytokines.
- Neutrophils arrive hours after injury and stay for several days, while monocytes begin infiltrating within the first day and remain present.
- Lymphocytes begin to arrive days to weeks post-injury.



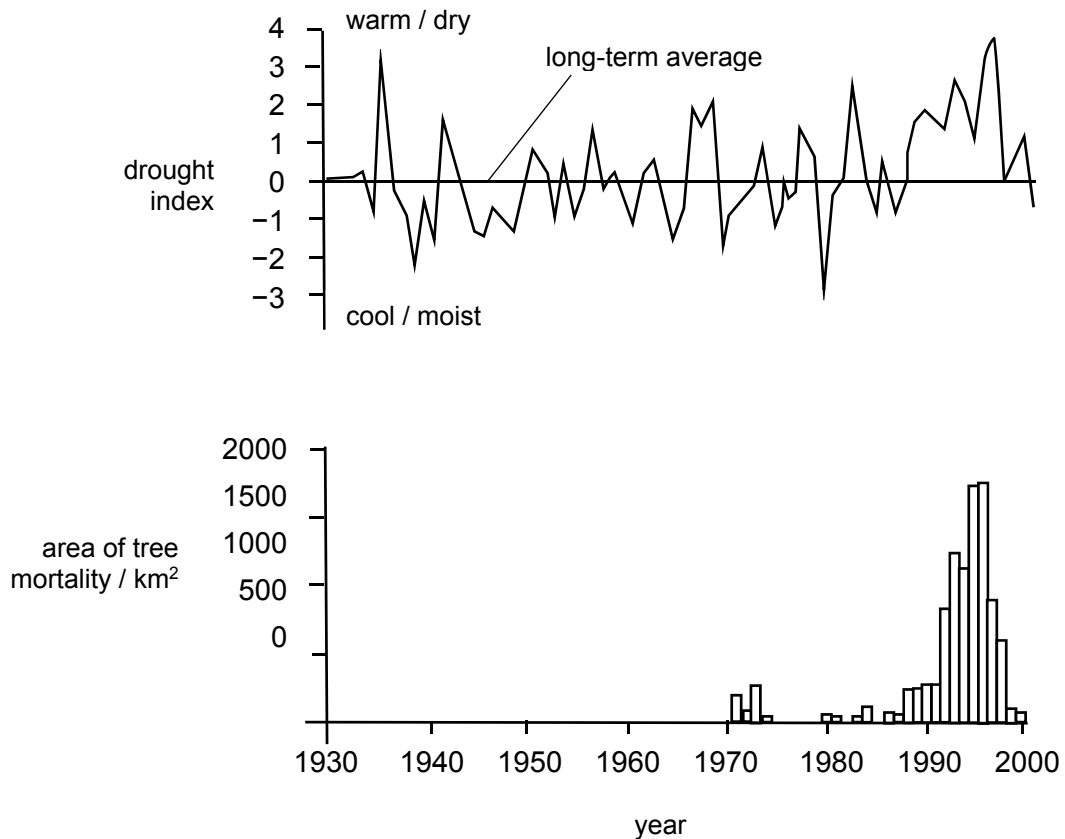
Which statement is **not** true?

- A Neutrophils are the first cells recruited to the wound site in order to ingest, kill and digest pathogens.
- B The pathogens secrete cytokines via inflammasomes to attract passing neutrophils to the injury site, resulting in the peak in neutrophil levels.
- C Monocytes enter the extravascular tissues and differentiate into macrophages, which unlike neutrophil, survive in the injury site for long periods.
- D Lymphocytes undergo clonal selection and clonal expansion, and remained in high levels post-injury due to the retention of memory cells.

- 30 With climate change, some regions on Earth are experiencing warmer temperatures. Warmer temperatures favour some species of pest, for example the spruce beetle, *Dendroctonus rufipennis*.

Since the first major pest outbreak, the spruce beetles have severely destroyed approximately 400,000 hectares of trees in Alaska and the Canadian Yukon.

The graphs show the drought index, a combination of temperatures and precipitation and the area of spruce trees destroyed annually.



Which statement best explains the trends observed in the graphs?

- A From the late 1980s, prolonged period of drought and warm weather led to tree mortality because warmer climate resulted in an increased number of generations of the spruce beetles.
- B Between 1930 and 1970, there was no tree mortality because the spruce beetles were had other food sources.
- C The pest outbreak occurred because wet, cool climate caused the spruce beetles to be more active and thus reproduce at a faster rate.
- D The spike in tree mortality was likely not related to climate, but due to a random catastrophic event that wiped out an entire patch of forest.

--END OF PAPER--

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HWA CHONG INSTITUTION (COLLEGE SECTION)
2018 JC2 9744 H2 BIOLOGY
PRELIMINARY EXAMINATIONS PAPER 1 MARK SCHEME

MULTIPLE CHOICE QUESTIONS

QUESTION	CORRECT ANSWER
1	B
2	C
3	A
4	A
5	D
6	D
7	D
8	C
9	D
10	B
11	C
12	C
13	C
14	C
15	B

QUESTION	CORRECT ANSWER
16	B
17	C
18	C
19	D
20	B
21	A
22	A
23	C
24	D
25	A
26	A
27	C
28	A
29	B
30	A

BOOKLET I

QUESTION 1

Fig. 1.1 shows a goblet cell from the colon of a rat, which can be found scattered among the epithelial cells that line the intestinal tract. The goblet cell produces mucus that is subsequently packaged into mucigen granules before being secreted out of the cell.

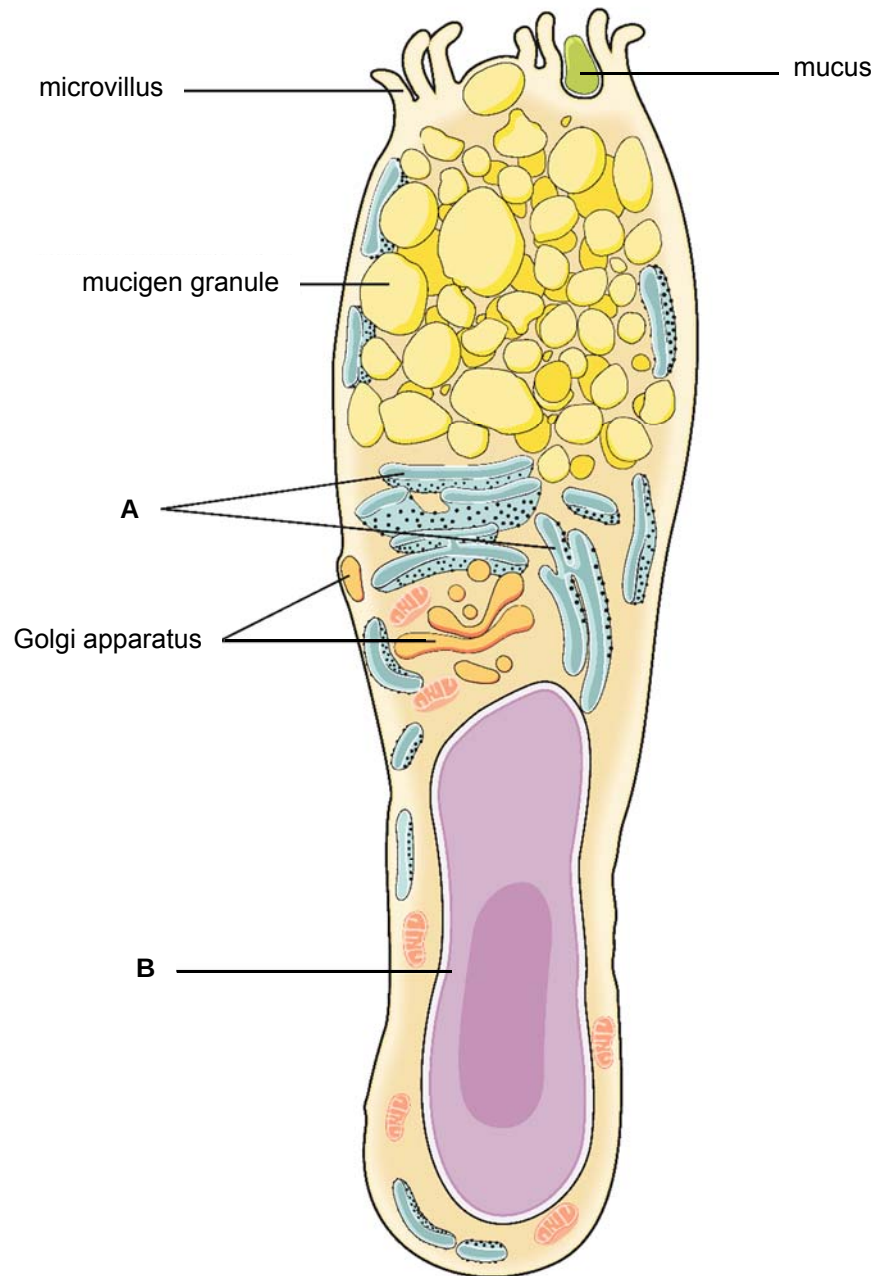


Fig. 1.1

(a) Name the organelles **A** and **B** shown in Fig. 1.1.

A :

B :

[2]

- (b) Explain how organelles **A** and **B** are adapted to allow the goblet cell to secrete mucus out of the cell.

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[4]

- (c) In 1967, Lynn Margulis proposed the theory of endosymbiosis, which states that mitochondria and chloroplasts of eukaryotes evolved from ancient prokaryotes. It proposed that these ancient prokaryotes were engulfed by other bacterial cells and both benefitted from the relationship – this has led to the evolution of eukaryotic cells.

Describe how the similarities between mitochondria and prokaryotic cells support the theory of endosymbiosis.

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[2]

[Total: 8]

QUESTION 2

Fig. 2.1 is a diagram representing the transport of glucose from the intestinal lumen to the extracellular fluid across an intestinal epithelial cell. Three proteins are labelled **P**, **Q** and **R**.

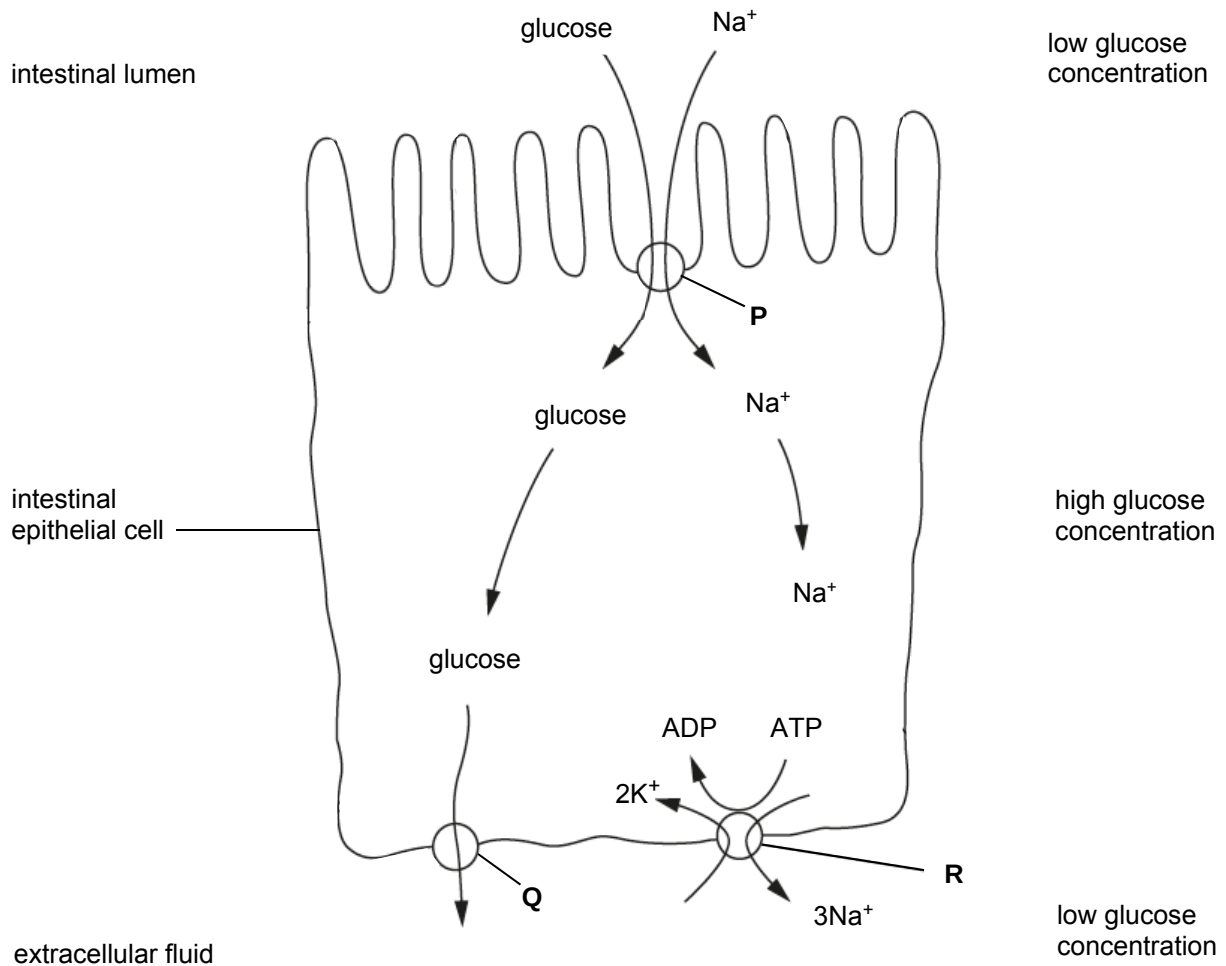


Fig. 2.1

- (a) Describe what is meant by *facilitated diffusion*.

[1]

- (b) Identify which transport protein, **P**, **Q** or **R**, is involved in facilitated diffusion.

[1]

- (c) Explain how glucose is transported from the intestinal lumen to the extracellular fluid.

[4]

- (d) Suggest why R is necessary in facilitating the transport of glucose across the epithelial cell in Fig. 2.1.

[2]

[Total: 8]

QUESTION 3

Fig. 3.1 shows the gene expression of a ribosomal protein, rS2.

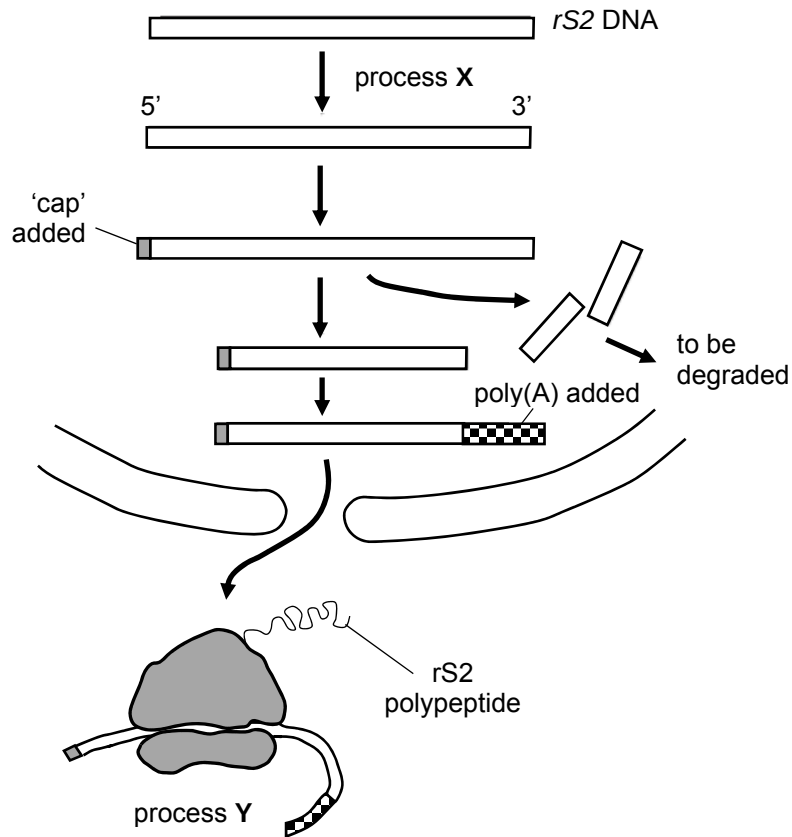


Fig. 3.1

- (a) Describe the main structural features of a ribosome.

[2]

- (b) State the role of the *rS2* promoter.

[1]

- (c) List three ways by which process X differs from process Y.

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..... [3]

- (d) Suggest how a mature ribosome is assembled upon the completion of process Y.

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..... [3]

[Total: 9]

QUESTION 4

Fig. 4.1 is an electron micrograph showing ribosomes involved in protein synthesis in an *Escherichia coli* cell.

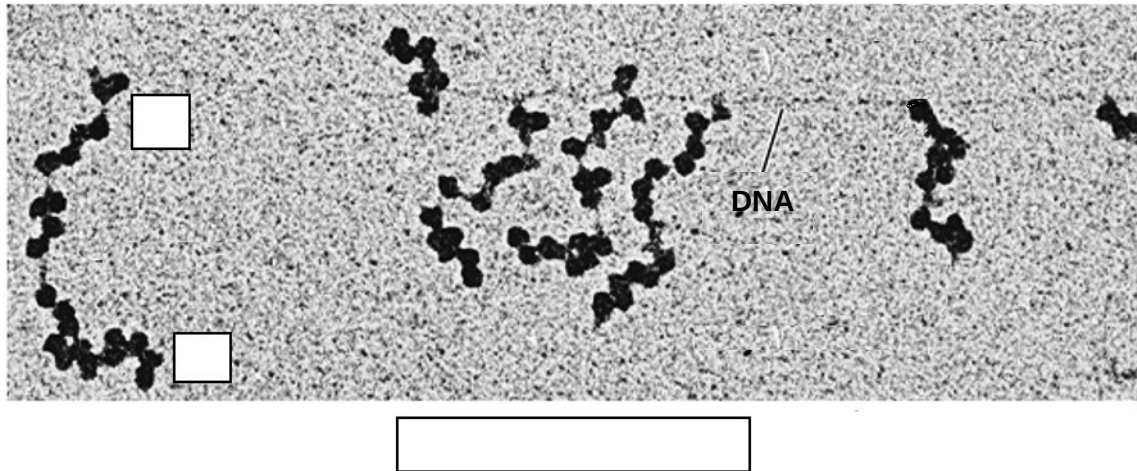


Fig. 4.1

- (a)(i) On Fig. 4.1,
- label the 3' and 5' ends of the polynucleotide in the square boxes provided
 - draw an arrow in the rectangular box provided to indicate the direction of transcription.
- [2]

- (ii) The mechanism of protein synthesis shown in Fig. 4.1 is unique to prokaryotes. Explain why this is so.

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[4]

- (b) In *E. coli* cells, transcription is regulated by a cluster of genes known as an operon, which can be either inducible or repressible. The *trp* operon is one such operon.

(i) Explain if the *trp* operon is inducible or repressible.

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.....

..... [2]

(ii) Describe what happens when tryptophan is absent in *E. coli*.

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..... [3]

- (c) *E. coli* was cultured in a growth medium with all the essential nutrients except tryptophan. Fig. 4.2 shows the changes in concentration of enzymes involved in tryptophan synthesis over time.

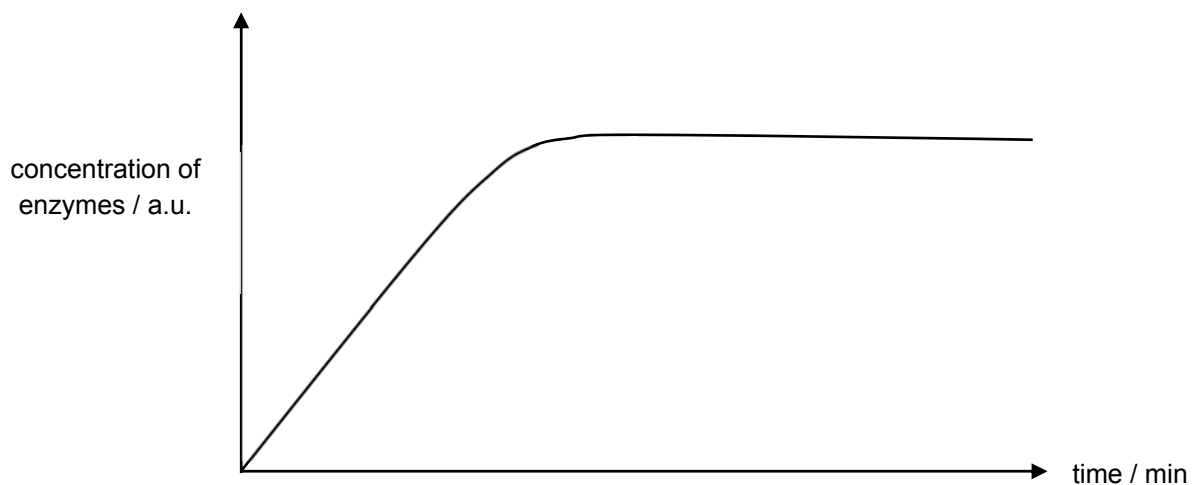


Fig. 4.2

As tryptophan is intrinsically synthesised, it is also utilised by *E. coli* at the same time.

Draw an arrow with the label X on Fig. 4.2 to indicate the time at which excess tryptophan was added to the growth medium. [1]

[Total :12]

QUESTION 5

Flooding is a severe threat for survival of terrestrial plants, mainly because it severely impedes the gas diffusion rate. Rice (*Oryza sativa*) is the only cereal that can be cultivated in the frequently flooded rivers.

An investigation was carried out into the effect of flooding on the growth of the submerged stems of rice plants. Young rice plants were grown in a container in which the level of water was increased in 10 cm steps, over a period of seven days. The mean length of the submerged internodes (lengths of stem between two leaves) and the concentration of ethylene in the rice stems was measured each day. As a control, rice plants were grown in identical conditions but the water level was kept constant throughout the seven days. The results are shown in Fig. 5.1.

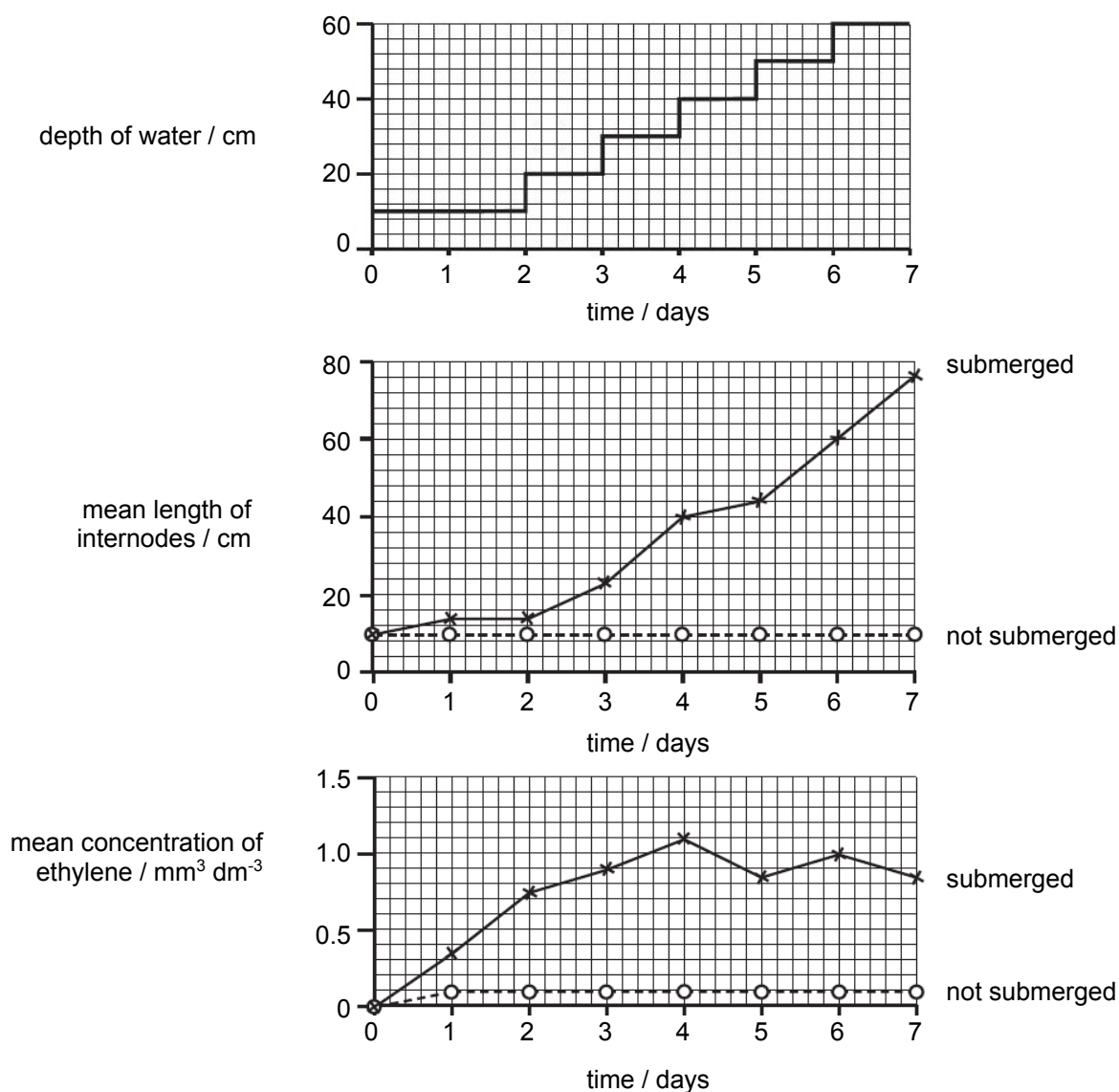


Fig. 5.1

- (a) Describe the effects of increasing water level on the mean length of the submerged internodes and mean concentration of ethylene in rice stems.

[4]

- (b) Rice plants, when submerged for long periods of time, have evolved a survival strategy by increasing their internode lengths. The plant hormone that initiates this is gaseous ethylene. Submergence limits gaseous exchange, causing entrapment of gases and an increase in ethylene concentration within the cell.

Fig. 5.2 shows the effect of increased ethylene gas in cells of the rice plant. ETR1 and EIN2 are transmembrane proteins embedded in the membrane of the endoplasmic reticulum (ER).

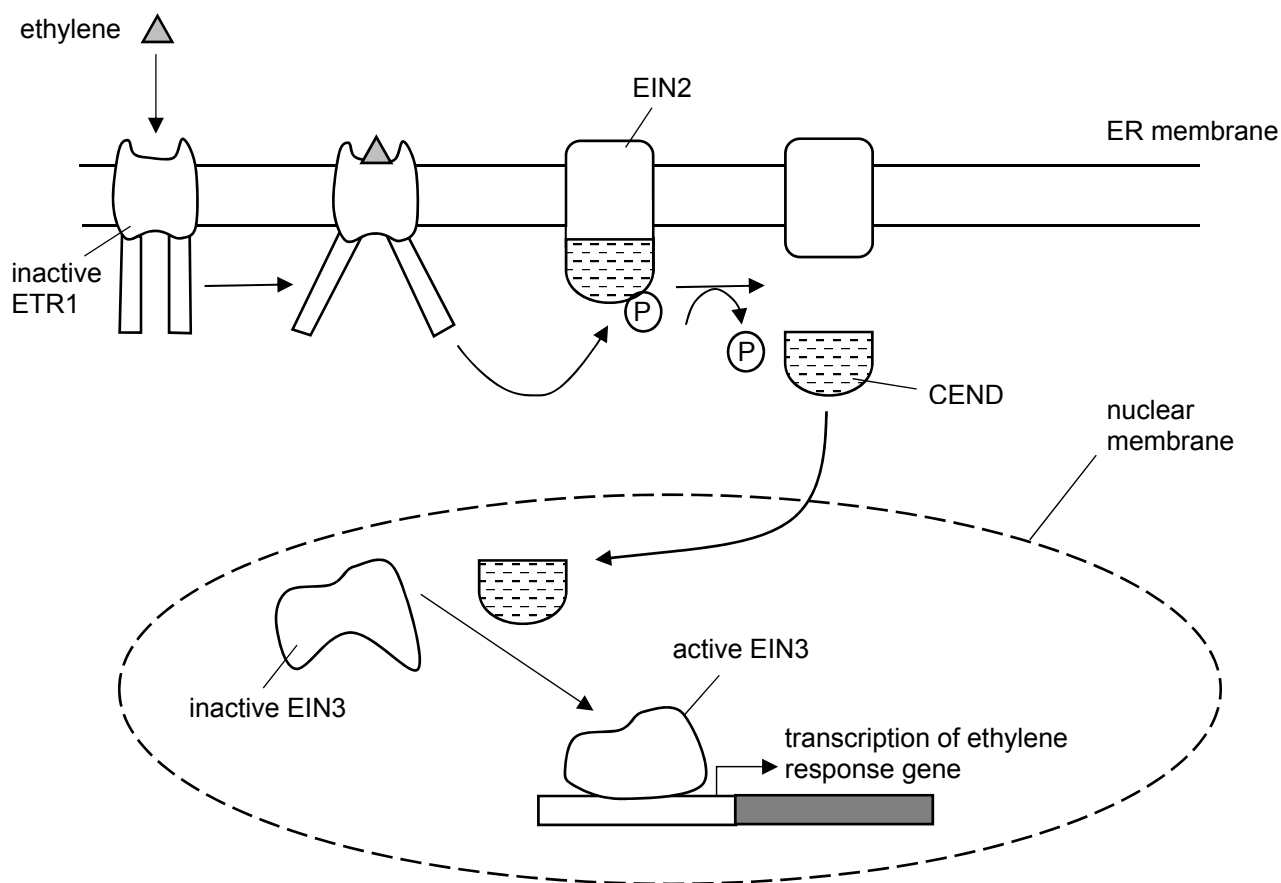


Fig. 5.2

- (i) Suggest how CEND is activated.

[2]

(ii) Explain how CEND increases the rate of transcription of the ethylene response gene.

[4]

(iii) Flooding is an indirect consequence of global warming.

Suggest how scientists can make use of these findings to mitigate the effects of flooding.

[1]

[Total: 11]

QUESTION 6

Actively dividing eukaryotic cells pass through a series of stages collectively known as the cell cycle.

- (a) Identify and describe what happens during the longest stage in a cell cycle.

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.....

[3]

(b) A study on the synthesis and destruction of cyclins in dividing clam embryos was carried out, and consisted of the following steps.

- Radioactively labelled amino acid, ^{35}S -methionine was added to a suspension of fertilized clam eggs.
- The suspension was divided into two and colchicine was added to one.
- Duplicate samples were obtained at 5-minute intervals:
 - one to detect radioactivity in cyclin by autoradiography and
 - the other to identify stages of mitotic cell cycle by fixing and staining the cells.

The results are shown in Fig. 6.1.

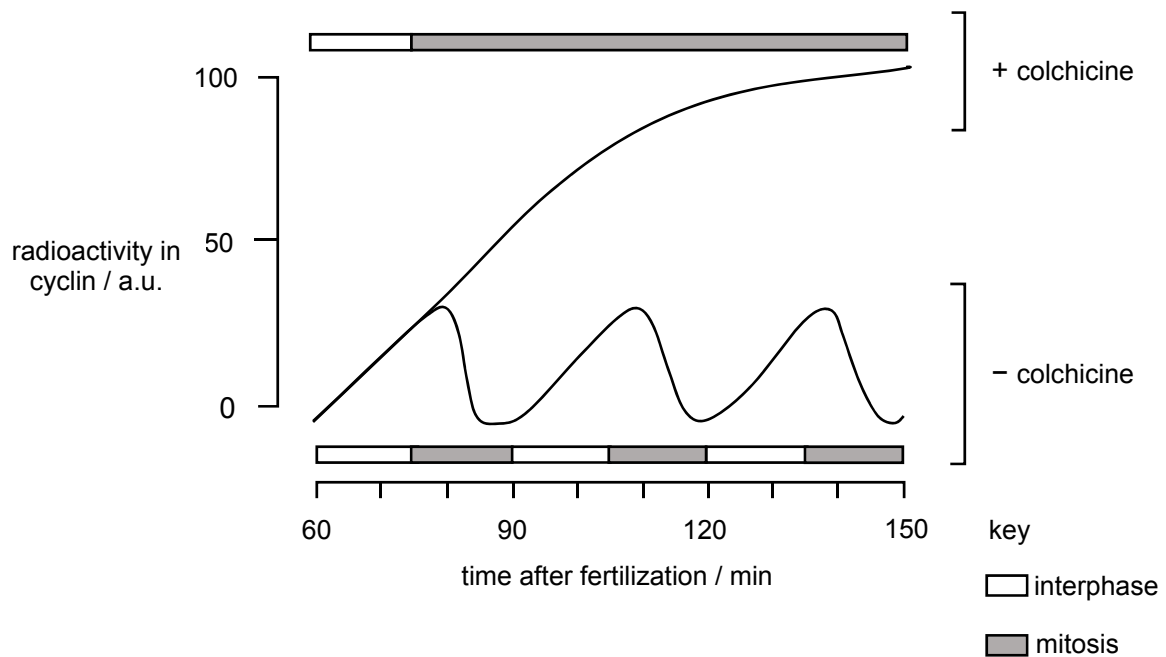


Fig. 6.1

Using the information shown in Fig. 6.1, describe and explain the effect of colchicine on mitosis.

[4]

(c) Research has shown that colchicine exerts its effect on tubulin molecules that make up microtubules. It is proposed that colchicine could be used to treat cancer.

(i) Explain how colchicine could be used for the treatment of cancer.

.....

.....

.....

.....

..... [2]

(ii) Suggest a potential side effect of using colchicine in cancer treatment.

.....

..... [1]

[Total: 10]

QUESTION 7

Some pigeons have smooth heads, like their wild ancestors had. But on some domestic pigeons, the feathers on the back of the head and neck stand up to form a crest as shown in Fig 7.1. The gene controlling presence of crest is located on a different chromosome from the gene controlling plumage colour.

**Fig. 7.1**

When an ash-red female pigeon with no crest was crossed with an ash-red male pigeon with crest, all of the offspring had no crest. Table 7.1 shows the results of the cross.

Table 7.1

phenotype	number of offspring
ash-red male, no crest	7
ash-red female, no crest	3
blue female, no crest	4

Using the results shown in Table 7.1, a geneticist proposed a hypothesis which predicted a 3:1 ratio of ash-red:blue phenotype.

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

Where Σ = sum of
 O = observed value
 E = expected value

(a)(i) Using the formula above, calculate the value for χ^2 . Show your working clearly.

- (ii) Given the critical value for χ^2 at $p = 0.05$ with one degree of freedom is 3.84, draw a conclusion and explain why this conclusion should be treated with caution.

[3]

- (b) In pigeons, presence of crest is autosomal and the allele for no crest (**D**) is dominant to crest (**d**).

Plumage colour, on the other hand, is sex-linked and controlled by three alleles. Ash-red allele (**A**) is dominant to blue (**B**), which is dominant to brown (**N**).

- In birds, the sex chromosomes are referred to as Z and W, rather than X and Y as in mammals. The W chromosome has no genes that affect plumage colour.
- The heterogametic sex is the female, not the male. Thus the male has two Z chromosomes (ZZ) and the female has one Z and one W chromosome (ZW).

Using the symbols for the alleles stated on page 23, draw a genetic diagram to explain the results shown in Table 7.1.

[5]

- (c) Suggest a method for the breeder to determine the genotype of a blue male pigeon with crest.

[2]

[Total: 12]

QUESTION 8

Chloroplasts belong to a group of organelles called plastids. Although different types of plastids have different structures and functions, one type of plastid can change into another type of plastid in response to environmental or developmental signals.

- Example 1: plants grown in the dark have plastids called etioplasts which lack chlorophyll. If these plants are exposed to light, the etioplasts quickly change into chloroplasts.
- Example 2: chloroplasts in surface tissues of tomato fruits change into plastids called chromoplasts as the fruits ripen. Thylakoid membranes break down and chlorophyll synthesis stops. Chromoplasts synthesise and accumulate red lycopene and orange β -carotene pigments.

- (a) For each of these examples, explain the effect on the rate of photosynthesis of one type of plastid changing into another type of plastid.

example 1

.....

.....

.....

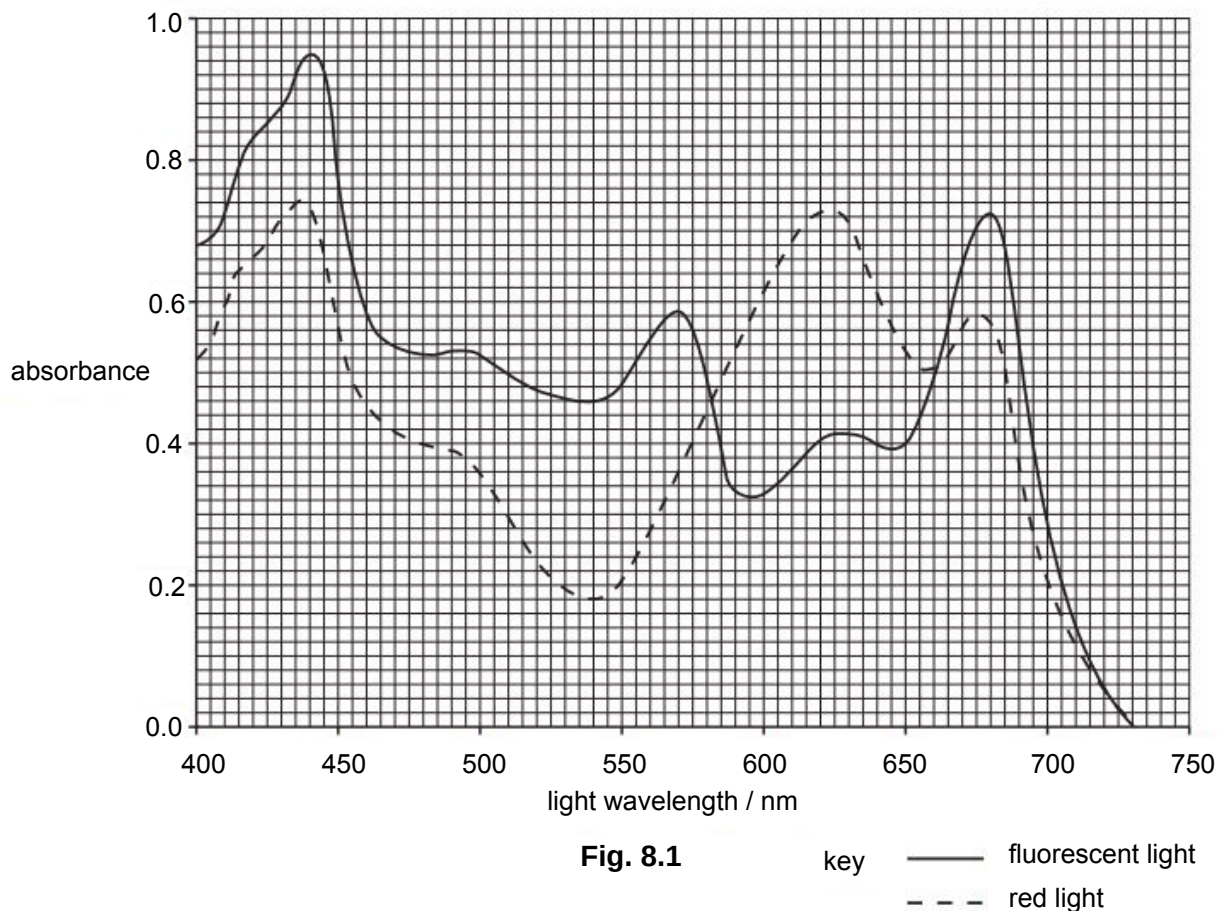
example 2

.....

.....

..... [4]

- (b) Fig. 8.1 shows the absorption spectra of a type of photosynthetic bacteria, cyanobacteria, grown under two different lighting conditions. One group was grown under fluorescent light and the other group under red light. The range of light wavelengths absorbed by each group of cyanobacteria was then measured under identical lighting conditions.



- (i) Define the term *absorption spectrum* for photosynthesis.

[1]

- (ii) With reference to Fig. 8.1, explain the effect of different lighting conditions on the absorption spectra of the two groups of cyanobacteria.

[3]

[Total: 8]

QUESTION 9

Bats are perhaps the most unusual and specialized of all mammals. Together with birds, they are the only extant vertebrates that are capable of powered flight. Bats live in hollow trees, caves and have limited flying range. They have mastered the night skies largely by using echolocation to perceive their surroundings and find their prey in the dark.

- (a) Suggest how the ability to use echolocation may have evolved from an ancestor that did not have that ability.

[4]

The pipistrelle is the most common species of bat in Europe, the Mediterranean and Asia. It was originally thought that all pipistrelles belong to the same species, *Pipistrellus pipistrellus*. However, in the 1990s, it was decided that there were two species: *Pipistrellus pipistrellus* and *Pipistrellus pygmaeus*.

Table 9.1 shows data for both species.

Table 9.1

species	mean body mass (g)	mean wingspan (m)	range of echolocation call (kHz)	colour
<i>P. pipistrellus</i>	5.5	0.22	42–47	medium to dark brown
<i>P. pygmaeus</i>	5.5	0.21	52–60	medium to dark brown

- (b)(i)** Name the genus to which the *P. pygmaeus* belongs.

[1]

- (ii) Using the data in Table 9.1, suggest why pipistrelles were originally classified as one species.

[2]

Scientists have reconstructed phylogeny for both the *P. pipistrellus* and the *P. pygmaeus*. Fig. 9.1 shows the results of a phylogenetic analysis based on a 402 base pair portion of the *cytochrome b*, *cyt b*, gene.

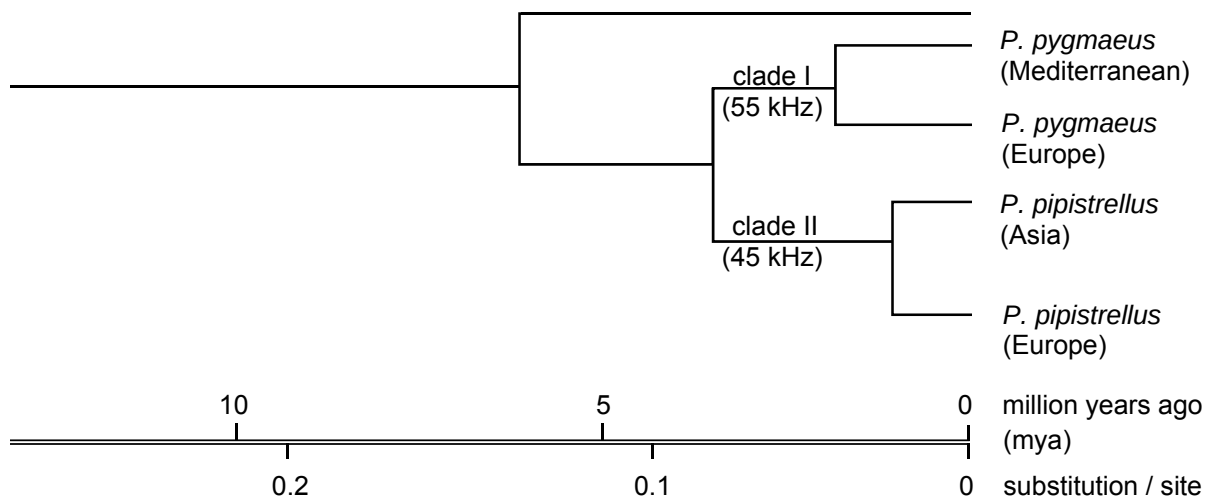


Fig. 9.1

- (c)(i) Using the information given in Table 9.1 and Fig. 9.1, discuss how both morphological and molecular data support the findings that *P. pipistrellus* and *P. pygmaeus* belong to different species.

[3]

- (ii) In more recent phylogenetic studies using other forms of molecular data, scientists have shown that *P. pipistrellus* and *P. pygmaeus* may have undergone convergent evolution in Europe, the Mediterranean and Asia.

Suggest how this is possible.

[2]

[Total: 12]

QUESTION 10

The main cause of tuberculosis (TB) in humans is the bacterium, *Mycobacterium tuberculosis*.

Most cases of the disease involve the lungs. The bacterium can enter cells and remain inactive in a latent state. However, the bacterium can become active to produce symptoms of the disease.

In a person with active TB, the pathogen can be present in airborne droplets that are exhaled. Generally, a healthy person who inhales these droplets has effective defence mechanisms in the gas exchange system to prevent infection.

(a) One example of a defence mechanism against pathogens in the gas exchange system involves the action of macrophages.

(i) State the location in the body where macrophages have their origin.

..... [1]

(ii) Describe the mode of action of a macrophage.

.....
.....
.....
.....
.....
.....
..... [3]

(iii) It is sometimes possible for *M. tuberculosis* to survive within macrophages.

Suggest **one** way in which *M. tuberculosis* may survive within a macrophage.

.....
..... [1]

- (b) The standard treatment for TB continues for six months and initially involves the use of four different antibiotics.

If no antibiotic resistance is detected, the treatment is reduced to two of the four antibiotics. The two antibiotics used are rifampicin and isoniazid.

Suggest the benefits of beginning the treatment with four different antibiotics.

[2]

Multidrug-resistant TB (MDR-TB) occurs if resistance develops to rifampicin and isoniazid.

The treatment for MDR-TB can last up to 30 months and involves different antibiotics to the standard treatment.

Table 10.1 shows the number of reported cases of TB and MDR-TB in the South-East Asia region between 2005 and 2014, as published by the World Health Organization (WHO).

Table 10.1

year	total number of reported cases of TB	total number of reported cases of MDF-TB
2005	1 947 603	68
2006	2 104 673	779
2007	2 202 149	918
2008	2 287 803	1717
2009	2 328 230	2560
2010	2 332 779	4263
2011	2 358 127	6615
2012	2 331 455	14 957
2013	2 297 033	18 384
2014	2 580 605	17 386

(c) TB is a disease of global importance.

Discuss the factors influencing the trends shown in Table 10.1.

[3]

[Total: 10]

--- END OF PAPER ---

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2018 JC2 9744 H2 BIOLOGY
PRELIMINARY EXAMINATION PAPER 2 MARK SCHEME

QUESTION 1

- (a) Name the organelles **A** and **B** shown in Fig. 1.1. [2]

A: Rough endoplasmic reticulum

B: Nucleus

- (b) Explain how organelles **A** and **B** are adapted to allow the goblet cell to secrete mucus out of the cell. [4]

Organelle A

Structure

- Organelle A contains extensive network of cisternae

Function

- Provides increased membrane surface area, for the embedment of ribosomes
- lumen allows folding of polypeptide into native conformation

Organelle B

<i>Structure</i>	<i>Function</i>
• The nuclear envelope	• protects DNA from degradation
• The nuclear envelope is perforated with pore	• to enable movement of mRNA from the nucleus to cytoplasm
• It contains genes	• that codes for proteins

- (c) Describe how the similarities between mitochondria and prokaryotic cells support the theory of endosymbiosis. [2]

- Both mitochondria and prokaryotic cells have ribosomes which are similar, in terms of size/ RNA sequences as compared to cytoplasmic ribosomes of eukaryotic cells
- Like prokaryotic cells, mitochondria have circular DNA which are not associated with histones
- The inner membranes of mitochondria have enzymes that are similar to those found in the plasma membranes of prokaryotic cells

[Total: 8]



QUESTION 2

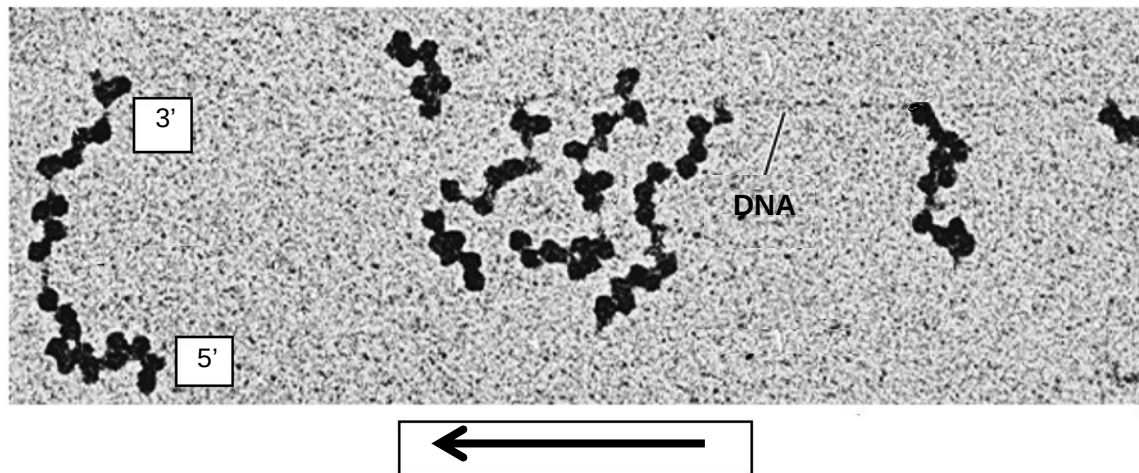
- (a) Describe what is meant by facilitated diffusion. [1]
- Transport of solutes down a concentration gradient to aid of a transport protein embedded in the membrane
- (b) Identify which transporter is involved in facilitated diffusion in Fig. 2.1. [1]
- Transporter Q
- (c) Explain how glucose is transported from the intestinal lumen to the extracellular fluid. [4]
- Glucose entering the cell together with sodium ions via transporter P
 - By active transport
 - Glucose leaving the cell via the transporter Q
 - By carrier-mediated facilitated diffusion
- (d) Suggest why R is necessary in facilitating the transport of glucose across the epithelial cell in Fig. 2.1. [2]
- Protein R keeps a low concentration of Na^+
 - To drive the glucose transporter P
- [Total: 8]

QUESTION 3

- a) Describe the main features of ribosome structure. [2]
- Ref. to the ribosome comprising of both ribosomal proteins and ribosomal RNA (rRNA)
 - The ribosome consists of small and large ribosomal subunits
 - Small ribosomal subunit has a mRNA binding site
- b) State the role of the rS2 promoter. [1]
- The rS2 promoter contains RNA polymerase binding site to initiate formation of transcription initiation complex
- c) List three ways by which process X differs from process Y. [3]
- Point to point comparisons on the following points
- Ref. to different templates
 - Ref. to different enzymes used
 - Ref. to type of covalent bonds formed
 - Ref. to location of cell where the process occurred.
- d) Suggest how a mature ribosome is assembled upon the completion of process Y. [3]
- The synthesized rS2 polypeptide folds into its specific 3D conformation
 - Ref. to where it associates with rRNA
 - Ref. to assembly of small and large ribosomal subunits in cytoplasm to form a mature ribosome
- [Total: 9]

QUESTION 4

Fig. 4.1 is an electron micrograph showing ribosomes involved in protein synthesis in an *Escherichia coli* cell.



(a)(i) On Fig. 4.1,

- label the 3' and 5' ends of the polynucleotide in the square boxes provided
 - draw an arrow in the rectangular box provided to indicate the direction of transcription.
- [2]

(ii) The mechanism of protein synthesis shown in Fig. 4.1 is unique to prokaryotes.

Explain why this is so.

[4]

- Simultaneous transcription and translation occurs uniquely in prokaryotes
- Due to the absence of nuclear membrane/ envelope
- mRNA can be degraded easily/ unstable
- Thus, simultaneous transcription and translation occurs in order to speed up the process of protein synthesis

(b) In *E. coli* cells, transcription is regulated by a cluster of genes known as an operon, which can be either inducible or repressible. The *trp* operon is one such operon.

(i) Explain if the *trp* operon is inducible or repressible.

[2]

- The *Trp* operon is a repressible operon
- The *Trp* operon is normally switched on and switched off upon accumulation of the tryptophan

(ii) Describe what happens when tryptophan is absent in *E. coli*.

[3]

- The *trp* repressor acts as a corepressor, which is absent
- Thus, the *trp* repressor is in an inactive conformation and cannot bind to the operator
- RNA polymerase can bind to promoter to allow the transcription of *trp* operon genes/ the operon to be switched on

- (c) *E. coli* was cultured in a growth medium with all the essential nutrients except tryptophan. Fig. 4.2 shows the changes in concentration of enzymes involved in tryptophan synthesis over time.

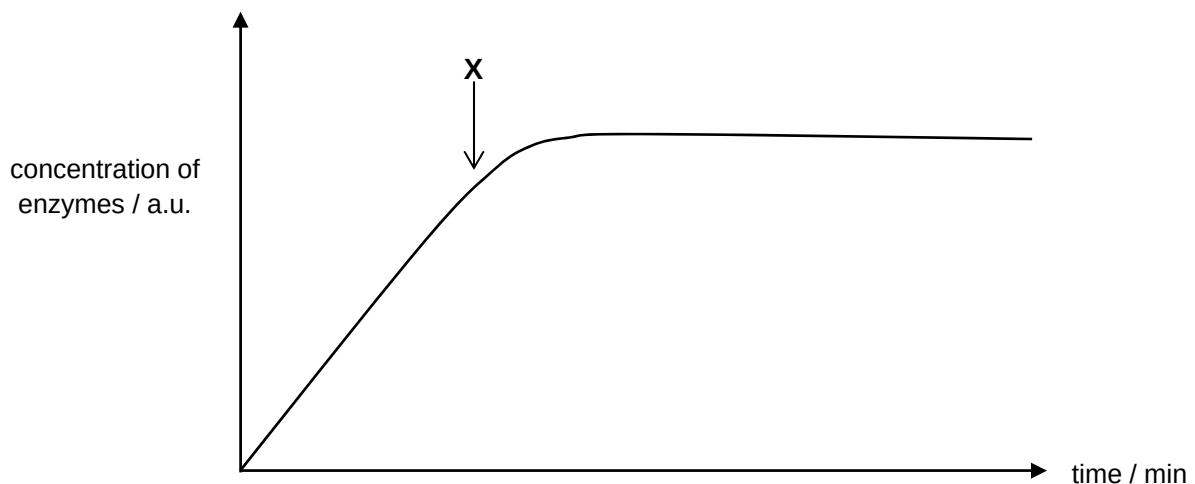


Fig. 4.2

As tryptophan is intrinsically synthesised, it is also utilised by *E. coli* at the same time.

Draw an arrow with the label **X** on Fig. 4.2 to indicate the time at which excess tryptophan was added to the growth medium. [1]

[Total: 12]

QUESTION 5

- (a) Describe the effect of increasing water level on the mean length of the submerged internodes and the mean concentration of ethylene in rice stems. [4]

- As depth of water increases, mean length of internodes increases
- 2 depths + 2 mean lengths
- As depth of water increases to 30 cm, mean concentration of ethylene increases to a maximum of $1.1 \text{ mm}^3 \text{ dm}^{-3}$
- As depth of water increases to 60 cm, mean concentration of ethylene plateaus at $0.9 \text{ mm}^3 \text{ dm}^{-3}$

- (b)(i) Suggest how CEND is activated. [2]

- Active ETR1 causes dephosphorylation of CEND-EIN2 complex
- CEND dissociates from EIN2

- (ii) Explain how CEND increases the rate of transcription of the ethylene response gene. [4]

- Active CEND diffuses into nucleus
- Active CEND binds inactive EIN3 and activates EIN3
- Ref. to active EIN3 binding enhancer of ethylene response gene
- Ref. to stabilisation of transcription initiation complex

- (iii) Flooding is an indirect consequence of global warming. Suggest how scientists can make use of these findings to mitigate the effects of flooding. [1]

- Flooding of crop land can become more frequent / intense
- Ref. to genetic modification of crops to increase flood tolerance
- Ref. to maintenance of a steady food supply

[Total: 11]

QUESTION 6

(a) Identify and describe what happens during the longest stage in a cell cycle. [3]

- Ref to interphase

G₁ phase of interphase

- Cells increase in size and acquire ATP
- Intensive cellular gene expression occurs

S phase of interphase

- Each DNA molecule undergoes semi-conservative DNA replication

G₂ phase of interphase

- Centrioles replicate and the mitotic spindle begins to form

(b) Using the information shown in Fig. 6.1, describe and explain the effect of colchicine on mitosis. [4]

- Untreated cells alternated between interphase and mitosis every 30 minutes whereas colchicine-treated cells entered mitosis at 75 minutes but remained there for hours
- Prevent degradation of cyclins
- Inactivation of cyclin-dependent kinases (Cdks), hence mitosis cannot be completed
- Ref. to disruption of the formation of spindle fibre leading to incompleteness of mitosis

(c) Research has shown that Colchicine exerts its effect on tubulin molecules that make up the microtubules. It is proposed that colchicine could be used to treat cancer.

(i) Explain how colchicine could be used for the treatment of cancer. [2]

- Colchicine inhibits the assembly of microtubules
- Chromosomes are unable to attach to microtubules
- Cell division cannot proceed and hence uncontrolled cell division is prevented

(ii) Suggest a potential side effect of using colchicine in cancer treatment. [1]

- Colchicine is not cell-specific and hence, (even) normal cells cannot undergo cell division

[Total: 10]

QUESTION 7

(a)(i) Using the formula above, calculate the value for χ^2 . Show your working clearly. [2]

$$\frac{(10-10.5)^2}{10.5} + \frac{(4-3.5)^2}{3.5} = 0.0952$$

(ii) Given the critical value for χ^2 at $p = 0.05$ with one degree of freedom is 3.84, draw a conclusion and explain why this conclusion should be treated with caution. [3]

- χ^2 calc (= 0.095) < χ^2 crit (= 3.84)
- probability that observed number differs from expected ratio of 3:1 due to chance > 0.05, not significant
- it is based on a small sample

(b) Using the symbols for the alleles stated on page 23, draw a genetic diagram to explain the results shown in Table 7.1. [5]

Parental phenotypes ash-red female, no crest ash-red male, crest

Parental genotypes

$Z^A W D D$

×

$Z^A Z^B d d$

Gametes

$W D$ $Z^A D$

$Z^A d$ $Z^B d$

Punnett square

		Male gametes	
		$Z^A d$	$Z^B d$
Female gametes	$W D$	$Z^A W D d$	$Z^B W D d$
	$Z^A D$	$Z^A Z^A D d$	$Z^A Z^B D d$

Offspring genotypic ratio 1 $Z^A W D d$: 1 $Z^B W D d$: 1 $Z^A Z^B D d$: 1 $Z^A Z^A D d$

Offspring phenotypic ratio

1 ash-red female, no crest : 1 blue female, no crest : 2 ash-red male, no crest

Observed numbers

3

4

7

(c) Suggest a method for the breeder to determine the genotype of a blue male pigeon with crest. [2]

- Cross with brown female
- If 50% brown, 50% blue in males, male is heterozygous at that gene locus

[Total: 12]

QUESTION 8

- (a) For each of these examples, explain the effect on the rate of photosynthesis of one type of plastid changing into another type of plastid. [4]

Example 1

- Rate of photosynthesis increases
- Ref to explanation on how the rate of photosynthesis is affected

Example 2

- Rate of photosynthesis decreases
- Ref. to explanation on how the rate of photosynthesis is affected

- (b)(i) Define the term *absorption spectrum* for photosynthesis. [1]

A graph of the amount of light absorbed at different wavelengths by the cyanobacteria / photosynthetic pigment

- (ii) With reference to Fig. 8.1, explain the effect of different lighting conditions on the absorption spectra of the two groups of cyanobacteria. [3]

- Ref. to data about cyanobacteria grown in fluorescent light vs in red light
- Ref. to reasons to support the effect of different lighting conditions on the absorption spectra of the cyanobacteria

[Total: 8]

QUESTION 9

- (a) Suggest how the ability to use echolocation may have evolved from an ancestor that did not have that ability. [4]

- Selection pressure is lack of competition for food / prey
- Individuals with allele(s) / gene(s) for echolocation have a selective advantage
- Echolocation allele(s) / gene(s) passed on to next generation
- Over many generations frequency of echolocation allele increases

- (b)(i) Name the genus to which the *P. pygmaeus* belongs. [1]

Pipistrellus

- (ii) Using the data in Table 9.1, suggest why pipistrelles were originally classified as one species. [2]

- Ref. to similar / same, (body) mass at 5.5g
- Ref. to similar wingspan at 0.21-0.22m
- Ref. to similar / same, colour at medium to dark brown

- (c)(i) Using the information given in Table 9.1 and Fig. 9.1, discuss how both morphological and

molecular data support the findings that *P. pipistrellus* and *P. pygmaeus* belong to different species. [3]

- Morphological data indicate different range of echolocation but both species show structural / anatomical homologies
- Molecular data as in *cyt b* gene sequence homology shows differences in the substitution site
- *P. pygmaeus* and *P. pipistrellus* are in different clades I & II respectively

(ii) In more recent phylogenetic studies using other forms of molecular data, scientists have shown that *P. pipistrellus* and *P. pygmaeus* may have undergone convergent evolution in Europe, the Mediterranean and Asia.

Suggest how this is possible. [2]

- Ref. to evolving independently in different areas / under similar selection pressure, Europe, the Mediterranean and Asia
- Ref. to bats living in similar ecological niches / subjected to similar environments, hollow trees / caves and have limited flying range

[Total: 12]

QUESTION 10

(a) (i) State the location in the body where macrophages have their origin. [1]

Bone marrow

(ii) Describe the mode of action of a macrophage. [3]

- Detection / recognition
- Engulfs / envelops, pathogen / bacterium
- Forms, vacuole / vesicle / phagosome
- Ref. to lysosome fusion
- Ref. to hydrolytic / digestive, enzymes

(iii) It is sometimes possible for *M. tuberculosis* to survive within macrophages.

Suggest **one** way in which *M. tuberculosis* may survive within a macrophage. [1]

- Prevent fusion of phagosome with lysosomes
- Produces inhibitors for / deactivates, lysosomal enzymes or forms resistant spore / is resistant to digestive enzymes

(b) The standard treatment for TB continues for six months and initially involves the use of four different antibiotics. [2]

- Increases chances of, killing, all bacteria
- If bacteria are resistant to one antibiotic, then still susceptible to other antibiotics
- Reduces chance of mutations arising / if bacteria susceptible mutations unlikely to occur against all antibiotics

(c) TB is a disease of global importance.

Discuss the factors influencing the trends shown in Table 10.1.

[3]

- Overall trend for both is increase
- Rate of increase in cases of MDR-TB greater than rate of increase in cases of TB
- Ref. to problems with people living in, poorly ventilated accommodation / close proximity to each other
- Vaccination programmes not able to prevent increase / herd immunity insufficient
- Qualified ref. to link between, HIV / HIV/AIDS, and TB
- Less money available for, longer drug treatment / vaccination, by, health authorities / governments
- Ref. to some success of, prevention / treatment programme

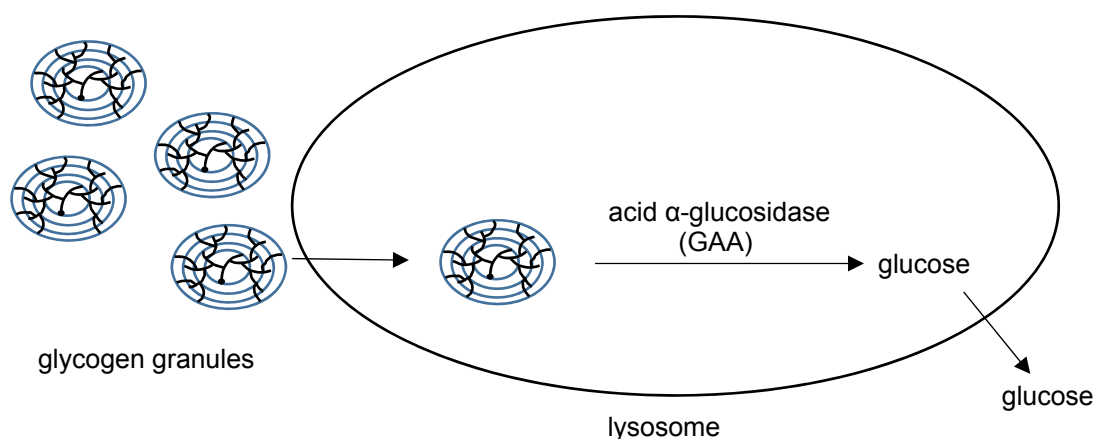
[Total: 10]

BOOKLET I

SECTION A

QUESTION 1

Glycogen is a readily mobilised storage form of glucose. Fig. 1.1 shows how glycogen metabolism occurs within smooth muscle cells when energy is required. A lysosomal enzyme, acid α -glucosidase (GAA), catalyses this reaction. GAA is the only enzyme that hydrolyses glycogen to glucose in the acidic environment of the lysosome.

**Fig 1.1**

(a)(i) Describe how the structure of glycogen is related to its function.

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..... [2]

(ii) Explain the significance of localising GAA in the lysosomes.

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..... [3]

Autophagy involves degradation and recycling of both damaged and worn out organelles such as mitochondria and lysosomes. Lysosomes are key players in the autophagic process. Impaired autophagy is associated with a wide range of diseases such as Pompe disease.

Pompe disease is a lysosomal glycogen storage disease caused by deficiency of GAA. The deficiency of GAA leads to glycogen accumulation within the lysosome and subsequent enlargement of the organelle. Cells with enlarged lysosomes are damaged and undergo extensive autophagy which may be unsuccessful.

To determine whether an individual suffers from Pompe disease, smooth muscle cells are isolated and observed. Cells were collected from six healthy and six diseased individuals each. These cells were categorised based on the amount and localisation of glycogen deposits in the cells as follows:

- types 1 to 3 showed varying degrees of glycogen deposits in the cells, but not specifically within lysosomes
 - type 1: no visible glycogen granules
 - type 2: scattered glycogen granules
 - type 3: large amount of glycogen granules
- type 4 cells showed significant glycogen deposits within lysosomes
- type 5 cells showed extensive autophagy of glycogen-containing lysosomes.

Fig. 1.2 shows the frequency of cells with the varying types of glycogen deposits found in both healthy and diseased individuals.

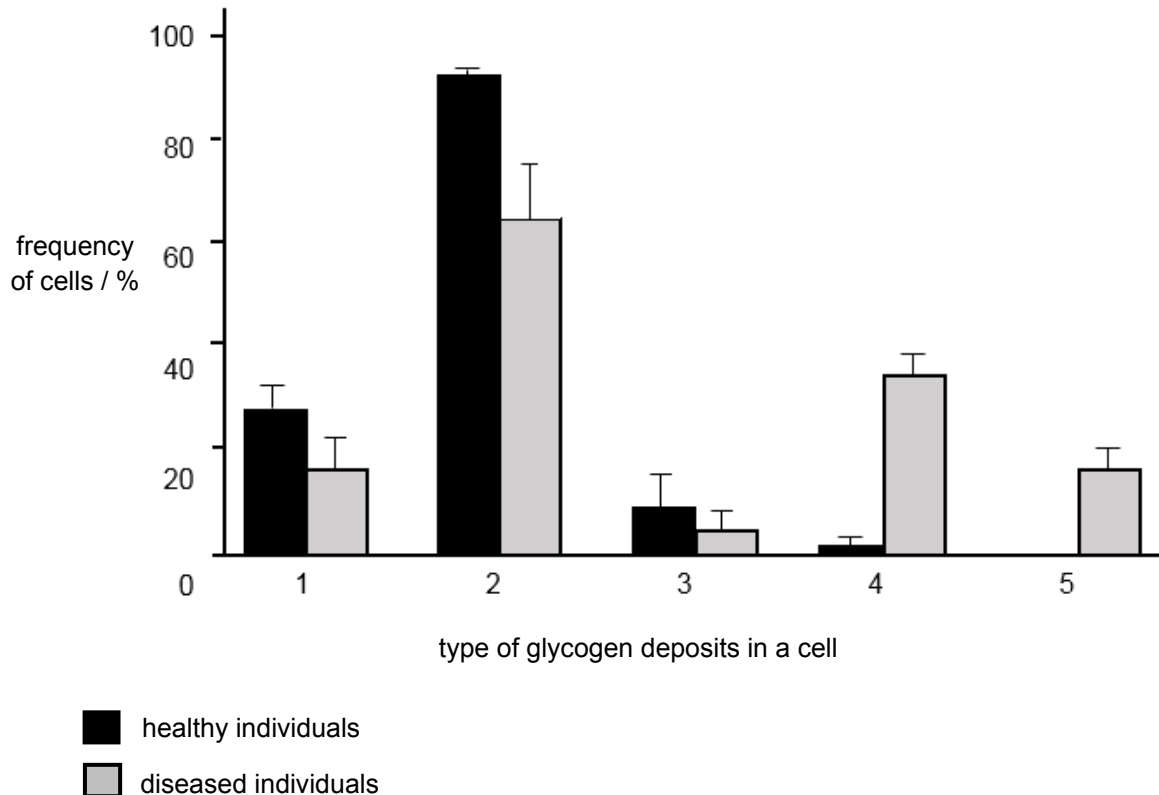


Fig. 1.2

(b)(i) Account for the results shown in Fig. 1.2.

[4]

(ii) Suggest how the mutated *GAA* gene results in cellular damage.

[2]

Pompe disease is inherited in an autosomal recessive manner. Fig. 1.3 shows the pedigree analysis of two families with more than one individual affected with Pompe disease.

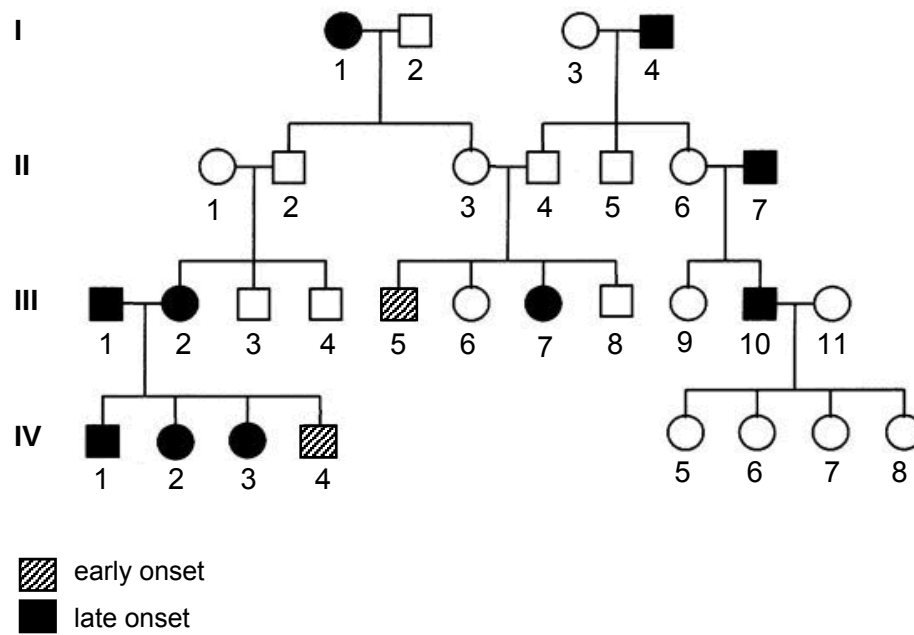


Fig. 1.3

(c)(i) With reference to Fig. 1.3, explain why Pompe disease is an autosomal recessive disease.

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..... [3]

(ii) None of the children of individuals **III-1** and **III-2**, other than individual **IV-4**, suffered from early onset Pompe disease. Suggest in whom and in what organ a mutation occurred that accounts for this.

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..... [2]

In Pompe disease, there is a broad spectrum of phenotypes that range from infantile-onset form to late-onset form. Disease severity primarily depends on level of GAA enzymatic activity that is related to the different mutations in the GAA gene.

Table 1.1 shows the three types of classification for Pompe disease.

Table 1.1

	classic infantile-onset	non-classic infantile-onset	late-onset
onset	few months of birth	by the age of 1	later in childhood, adolescence, or adulthood
severity	most severe	moderately severe	least severe
symptoms	progressive muscle loss, loss of motor, respiratory and cardiac functions leading to respiratory failure		

(d) Explain how genotype is linked to phenotypes of Pompe disease.

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[3]

Enzyme replacement therapy (ERT) is an approved treatment for Pompe individuals. Active GAA enzymes are extracted and purified from *in vitro* sources. During ERT, these enzymes are administered to the Pompe individuals through intravenous infusions directly into the bloodstream on a weekly basis.

(e)(i) Explain how ERT is used to treat Pompe individuals.

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[4]

(ii) Suggest why Pompe individuals require weekly infusions of active GAA enzymes.

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[2]

[Total: 25]

QUESTION 2

Almost a decade before the discovery of penicillin, the controversial practice of bacteriophage therapy was being developed as a treatment for bacterial infections in humans. However, it was eventually eclipsed by the rise of antibiotics.

Research into bacteriophage therapy is increasing in popularity in recent years due to the emergence of pathogenic bacteria resistant to most, if not all, currently available antibiotics. This has become a critical problem in modern medicine.

Fig. 2.1 shows how bacteriophage therapy was carried out.

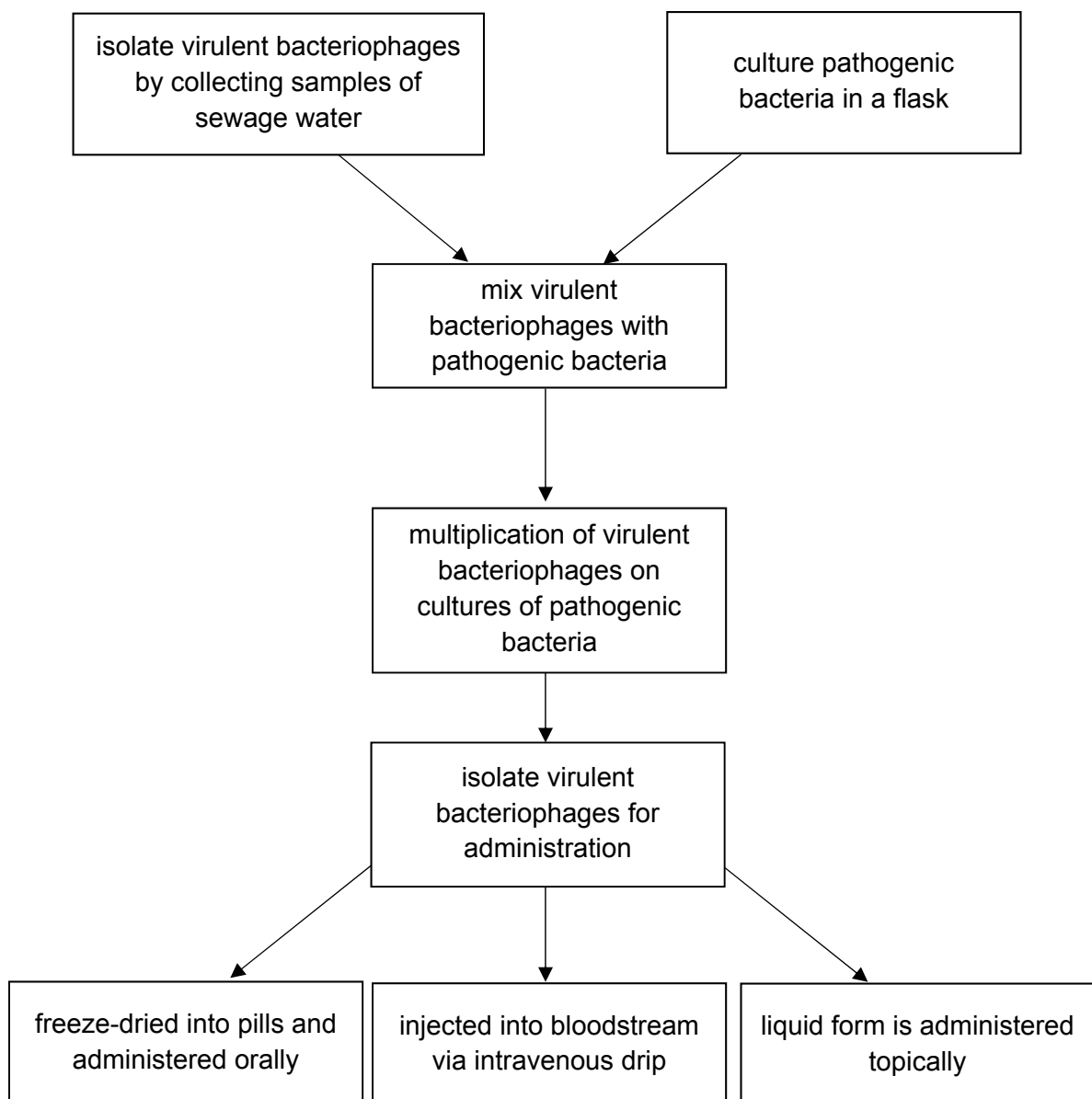


Fig. 2.1

- (a) Explain why there is a need to mix isolated bacteriophages with pathogenic bacteria.

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- (b) With reference to its reproductive cycle, suggest how a virulent bacteriophage could be used to treat bacterial infections.

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- (c) Explain why bacteriophage therapy may be a better mode of treatment than antibiotics.

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- (d) Suggest and explain for the controversial nature of this form of bacteriophage therapy.

[3]

[Total: 13]

QUESTION 3

Bacteria may be classified according to differences in cell wall structure. The differences are shown by using the Gram stain.

- A Gram-positive bacterium has a cell wall mainly composed of a thick layer of peptidoglycan.
- A Gram-negative bacterium has a more complex cell wall. This wall is composed of a much thinner layer of peptidoglycan and an outer layer known as the outer membrane.

Escherichia coli is a Gram-negative bacterium.

Fig. 3.1 is a diagram through the cell surface membrane and the cell wall of *E. coli*.

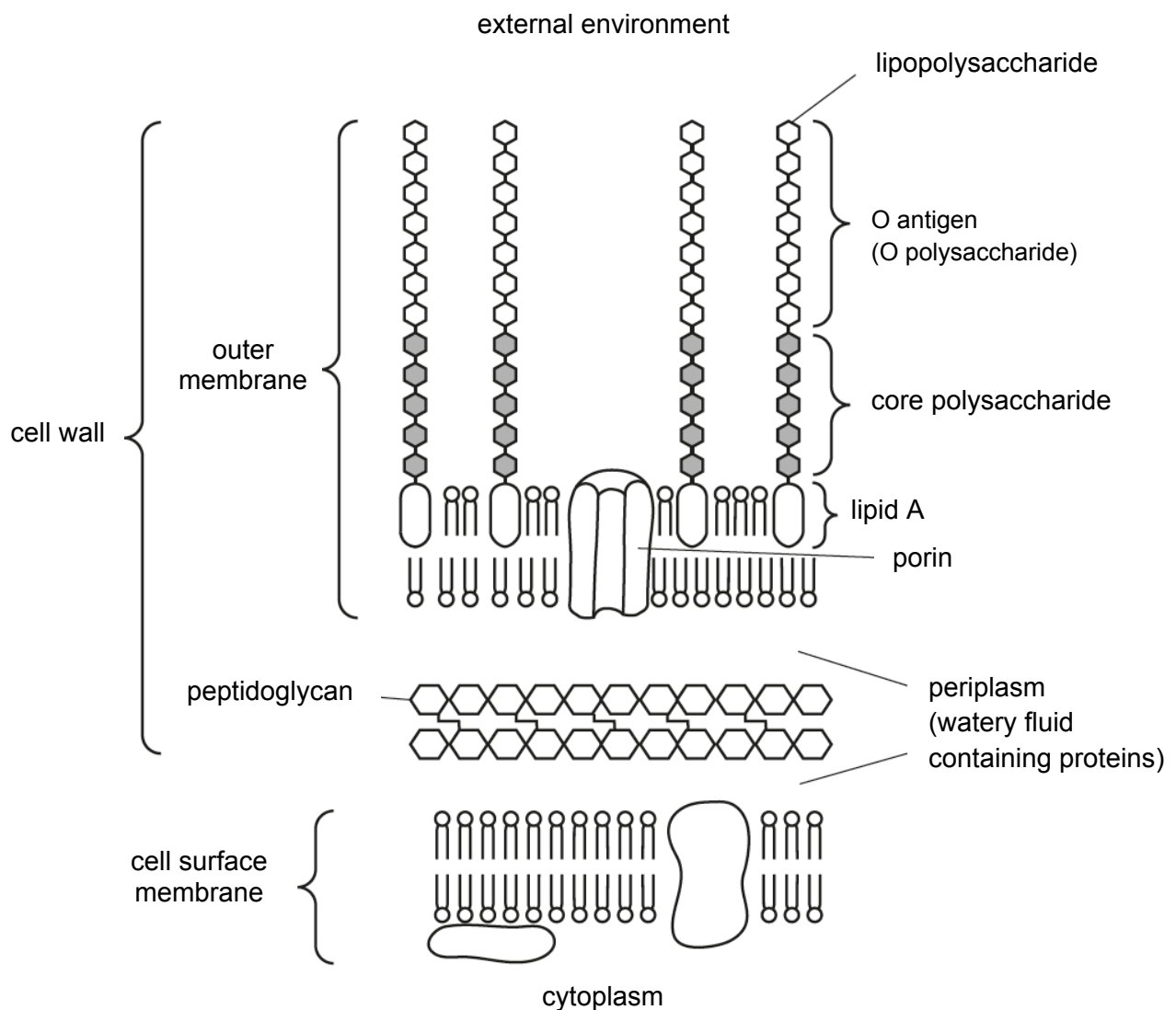


Fig. 3.1

- (a) The antibiotic penicillin kills bacteria by causing them to lyse. It is more effective in treating diseases caused by Gram-positive bacteria than diseases caused by Gram-negative bacteria.

Outline how penicillin acts on bacteria and use Fig. 3.1 to suggest why penicillin has little or no effect at treating diseases caused by Gram-negative bacteria, such as some strains of *E. coli*.

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..... [4]

- (b) Using Fig. 3.1, suggest the possible roles of the periplasm in bacteria.

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..... [2]

Fig. 3.1 shows that the outer membrane of the cell wall of *E. coli* contains lipopolysaccharides, which are not present in the cell surface membrane.

(c)(i) Define the term *lipopolysaccharide*.

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....., [2]

- (ii) The O antigen is the outer part of the polysaccharide portion of the lipopolysaccharide, facing the aqueous external environment. Some strains of *E. coli* are pathogenic. Different pathogenic strains have different O antigens.

Suggest and explain why infection with one pathogenic strain of *E. coli* does not provide immunity to a different pathogenic strain.

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[Total: 12]

--- END OF SECTION A ---

SECTION B

Answer **one** question in this section.

Write your answers on the lined paper provided at the end of this Question Paper.

Your answer should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in parts **(a)** and **(b)**, as indicated in the question.

QUESTION 4

- (a)** Eukaryotic chromatin, the DNA-nucleosome polymer, is a dynamic molecule that exists in different configurations during the course of the cell cycle.

Describe how DNA is packaged in a cell and discuss the advantages of the eukaryotic chromatin being a dynamic molecule. [14]

- (b)** The study of identical twins provides an opportunity for exploring the extent to which epigenetics and environmental factors contribute to phenotypic variation in humans. Epigenetics is the study of heritable changes in gene expression that do not involve changes to the underlying DNA sequence. Epigenetic silencing turns gene off, contributing to differential gene expression in specialised cells.

Describe how epigenetic silencing may occur and discuss the extent to which epigenetic silencing accounts for identical twins being phenotypically non-identical. [11]

[Total: 25]

QUESTION 5

- (a)** The flow of electrons in oxidation-reduction reactions is responsible, directly or indirectly, for all work done by living organisms. Plants generate cellular energy in the form of ATP by the same process of chemiosmosis.

Describe the process of chemiosmosis and discuss the importance of electron flow in both chloroplasts and mitochondria that leads to chemiosmosis, with particular emphasis on the role of membrane proteins. [14]

- (b)** In plants, carbon dioxide (CO₂) and water (H₂O) are the products of cellular respiration while they are the reactants in photosynthesis. Tropical rain forests are estimated to be responsible for approximately 20% of global photosynthesis, yet the consumption of large amounts of CO₂ by living trees is thought to make little or no net contribution to reduction of global warming.

Explain how photosynthesis and cellular respiration are related to the climate and discuss the contributing factors that continue to bring about global warming even with large amounts of CO₂ being consumed by trees in the tropical rainforests. [11]

[Total: 25]

--- END OF SECTION B ---

--- END OF PAPER---

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HWA CHONG INSTITUTION (COLLEGE SECTION)
2018 JC2 9744 H2 BIOLOGY
PRELIMINARY EXAMINATION PAPER 3 MARK SCHEME

SECTION A

QUESTION 1

(a) (i) Describe how the structure of glycogen is related to its function. [2]

- Ref. to glycogen being a large molecule and hence allowing storage
- Ref. to specific bonds in glycogen and their relevant function of either storage or easy hydrolysis

(ii) explain the significance of localising GAA into the lysosomes. [3]

- Ref. to idea of lysosome being an acidic environment, hence optimal GAA
- Ref. to idea of compartmentalisation
- Ref. to idea of regulated hydrolysis of glycogen

(b) (i) Account for the results shown in Fig. 1.2. [4]

- Ref. to idea of glycogen deposit in healthy and diseased individuals
- Ref. to appropriate supporting quote
- Ref. to idea of diseased individuals having significant glycogen deposits in lysosomes
- Ref. to appropriate supporting quote

(ii) Suggest how the mutated GAA gene results in cellular damage. [2]

- Ref. to idea of low concentration of GAA enzymes
- Ref. to relevant consequence resulting in cellular damage

(c) (i) With reference to Fig. 1.3, explain why Pompe disease is an autosomal recessive disease. [3]

- Ref. to why Pompe is autosomal
- Ref. to appropriate supporting quote
- Ref. to why Pompe is recessive
- Ref. to appropriate supporting quote



(ii) None of the children of individuals **III-1** and **III-2**, other than individual **IV-4**, suffered from early onset Pompe. Suggest in whom and in what organ a mutation occurred that accounts for this. [2]

- Ref. to either individuals III-1 / III-2
- Ref. to gonads

(d) Explain how genotype is linked to phenotypes in Pompe disease. [3]

- Ref to idea of different mutations present
- Ref to idea of different levels of GAA enzyme activity
- Reference to appropriate quotation from table 1.1 to support conclusion

(e) (i) Explain how ERT works to treat Pompe individuals. [4]

- Ref. to idea of Pompe individuals absent GAA enzymes
- Ref. to transport of active GAA in blood to cells
- Ref. to endocytosis and fusion with lysosomes
- Ref. to reduction in symptoms in diseased individuals

(e)(ii) Suggest why Pompe individuals require weekly infusions of active GAA enzymes. [2]

1. Ref. to idea of degradation of active GAA enzymes
2. Ref. to idea of the need to maintain minimum levels of active GAA enzymes to prevent symptoms of Pompe

[Total: 25]

QUESTION 2

- (a) Explain why there is a need to mix isolated bacteriophages with pathogenic bacteria. [2]
- Ref to bacteriophages causing lysis of the pathogenic bacteria
 - Ref to bacteriophage multiplication
- (b) With reference to its reproductive cycle, suggest how a virulent bacteriophage could be used to treat bacterial infections. [5]
- Tail fibres attach to specific receptor sites
 - DNA is extruded
 - Halt synthesis of host DNA, RNA and proteins
 - Hijack host cell ribosomes and DNA polymerase to synthesise viral proteins and replicate viral DNA
 - Assembly of new virion particles
 - Lyse pathogenic bacteria thus treating the infection
- (c) Explain why bacteriophage therapy may be a better mode of treatment than antibiotics. [3]
- Bacteriophage is more specific
 - Overcomes problems of drug resistance
 - Does not kill natural microflora
- (d) Suggest and explain for the controversial nature of this form of bacteriophage therapy. [3]
- Ref to safety / ethical / social, concerns
 - Ref to the need to modify host bacteria which could make them more pathogenic
 - Ref to the possibility of mutations to target recipient body cells instead of bacteria cells

[Total: 13]

QUESTION 3

(a) Outline how penicillin acts on bacteria and use Fig. 3.1 to suggest why penicillin has little or no effect at treating diseases caused by Gram-negative bacteria, such as some strains of *E. coli*. [4]

- Penicillin weakens the cell wall by binding to and blocking transpeptidases
- Thereby preventing the formation of, cross links / linkages, between NAM residues in the transpeptidation step during cell wall synthesis
- The weakened cell wall cannot withstand the pressure potential and the cells eventually would burst.
- Presence of the outer membrane, prevents / interferes with / protects from, entry of penicillin.

(b) Using Fig. 3.1, suggest the possible roles of the periplasm in bacteria. [2]

- Periplasm is where peptidoglycan synthesis occurs
- Periplasm contain proteins for secretion / folding / oxidation
- Periplasm contain proteases / nucleases / phospholipases/ phosphatases

(c)(i) Define the term *lipopolysaccharide*. [2]

- Each lipopolysaccharide consists of a lipid and a polysaccharide chain made up of repeating units of monosaccharides
- Ref. to covalent bond between lipid and carbohydrate

(ii) Suggest and explain why infection with one pathogenic strain of *E. coli* does not provide immunity to a different pathogenic strain. [4]

- Ref to different strains of bacteria containing different antigens
- Ref to antigens composed of different sugars
- Upon infection with one pathogenic strain, the antigens will trigger an immune response whereby receptors of the lymphocytes are specific/complementary to the antigen of *E. coli*
- Ref to different antibodies synthesised for different antigens / O polysaccharides / lipopolysaccharides

[Total: 12]

SECTION B**QUESTION 4**

- (a) Eukaryotic chromatin, the DNA-nucleosome polymer, is a dynamic molecule that exists in different configurations during the course of the cell cycle.

Describe how DNA is packaged in a cell and discuss the advantages of the eukaryotic chromatin being a dynamic molecule. [14]

- DNA coiled around histone proteins
- Histones having positively-charged residues form ionic bonds with the negatively-charged sugar-phosphate backbone of DNA.
- with linker DNA, gives a “beads on a string” look/ 10nm chromatin fibre
- DNA is further folded or coiled to produce the 30-nm chromatin fibre/ solenoid.
- Histone H1 and linker DNA are involved
- scaffold proteins are involved
- in condensing the 30-nm chromatin fibre to form looped domains
- which further coil to produce condensed chromosome
- Allow the DNA to be more compact to fit into the nucleus
- Ref to ability to regulate gene accessibility
- Ref to the idea of allowing/ preventing, RNA polymerase, to gain access to promoter to turn genes off/on
- DNA does not get entangled and break mitosis/ meiosis
- Ref to enabling cell division / mitosis / meiosis to occur successfully
- Ref to uncondensed chromatin allows for ease of DNA replication

- (b) The study of identical twins provides an opportunity for exploring the extent to which epigenetics and environmental factors contribute to phenotypic variation in humans. Epigenetics is the study of heritable changes in gene expression that do not involve changes to the underlying DNA sequence. Epigenetic silencing turns gene off, contributing to differential gene expression in specialised cells.

Describe how epigenetic silencing may occur and discuss the extent to which epigenetic silencing accounts for identical twins being phenotypically non-identical. [11]

- DNA methylation, addition of methyl groups to cytosine nucleotides
- DNA methylation changes the 3D conformation of DNA
- Methylated DNA to recruit histone deacetylases
- Histone deacetylation, removal of acetyl groups of lysine residues in histone tails
- Lysine residues regain their positive charges, increase in the affinity of the histone complex for DNA
- Consequently, the chromatin becomes more compact
- Different genes may be switched on / off in one twin but are not expressed in the other
- Different environmental factors
- Diet and e.g of type of diet
- Difference in exposure to sunlight, resulting in difference in skin colour
- Difference in lifestyle/ exposure to mutagens

[Total: 25]

QUESTION 5

- (a) The flow of electrons in oxidation-reduction reactions is responsible, directly or indirectly, for all work done by living organisms. Plants generate cellular energy in the form of ATP by the same process of chemiosmosis.

Describe the process of chemiosmosis and discuss the importance of electron flow in both chloroplasts and mitochondria that leads to chemiosmosis, with particular emphasis on the role of membrane proteins. [14]

- Ref to a proton gradient is generated across a membrane
- Ref to synthesis of ATP
- Ref to ATP synthase
- Ref to energy is released
- Ref to proton pumps to actively pump H^+ into thylakoid lumen / intermembrane space
- Membranes are impermeable to H^+ leading to generation of proton gradient
- Ref to role of PSII / PSI in light harvesting
- Light energy excite an electron in PSII / PSI to higher energy
- Capture of electron by primary electron acceptor
- Electrons are passed down electron carriers through a series of redox reactions
- Flow of electron to the final electron acceptor NADP, reducing it to NADPH
- Ref to ETC embedded in the inner mitochondrial membrane contributes to the chemiosmotic gradient for ATP synthesis
- Ref. to NADH and $FADH_2$ being reoxidised, when they donate electrons / reducing the electron carriers
- Flow of electrons to final electron acceptor, oxygen to form water

QWC:

Clear and unambiguous communication of a breadth of ideas on the process of chemiosmosis as well as photosynthesis and cellular respiration.

- (b) In plants, carbon dioxide (CO_2) and water (H_2O) are the products of cellular respiration while they are the reactants in photosynthesis. Tropical rain forests are estimated to be responsible for approximately 20% of global photosynthesis, yet the consumption of large amounts of CO_2 by living trees is thought to make little or no net contribution to reduction of global warming.

Explain how photosynthesis and cellular respiration are related to the climate and discuss the contributing factors that continue to bring about global warming even with large amounts of CO_2 being consumed by trees in the tropical rainforests. [11]

- Greenhouse gases (GHGs) like CO_2 and CH_4 trap and absorb heat at the Earth's surface, keeping the Earth warm
- Ref to uptake of atmospheric CO_2 by photosynthetic organisms
- Ref to sugar molecules formation in the Calvin cycle
- Heterotrophs consume plants to obtain the energy trapped
- Heterotrophs break down sugars / other forms of respiratory substrates
- Ref to CO_2 being produced during link reaction and Krebs cycle
- Ref to the idea of anthropogenic factors, being man-made / actions of humans
- Deforestations leads to the cessation of CO_2 absorption
- Burning of fossil fuels due to increase in global demand for energy
- Ref to how agriculture / rice cultivation / landfill waste / food choices / increase in the consumption of meat contribute to global warming

- Leading to increase livestock farming / domestication of animals / ideal conditions for bacteria to decompose organic material / waste decomposes in absence of O_2 / enteric fermentation of ruminant animals
- Ref to drastic increase in amount of CO_2 and CH_4 emissions

QWC:

Scientific argumentation exemplified by linking coherently photosynthesis and cellular respiration to the climate as well as how causal factors bring about global warming.

[Total: 25]

