H2

ANDERSON SERANGOON JUNIOR COLLEGE
HIGHER 2

2024 JC2 PRELIMINARY EXAMINATIONS

CANDIDATE NAME

CLASS

INDEX NUMBER

BIOLOGY

9744/02

PAPER 2
SHORT STRUCTURED QUESTIONS

12 SEPTEMBER 2024
THURSDAY

Candidates answer on the Question Paper.
No Additional Materials are required.

2 HOURS

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graph
Do not use paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 7
2	/ 10
3	/ 11
4	/ 11
5	/ 12
6	/ 10
7	/ 10
8	/ 8
9	/ 12
10	/ 4
11	/ 5
Total	**/100**

This document consists of **35** printed pages and **1** blank page

Answer **all** the questions.

1 Starch and cellulose are carbohydrates that are found in most plants.

(a) Compare between the structures of amylose and amylopectin of starch.

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..... [2]

(b) Juices that are extracted commercially from fruits can be made less cloudy by the breakdown of the cellulose cell wall using the enzyme cellulase.

In the space below, **show how** the bonds in a short section of cellulose that is made up of **three** monomers may be broken by cellulase. Add appropriate labels to your drawing.

[3]

(c) Fig. 1.1 is an electron micrograph showing parts of two plant cells. The middle lamella is a layer, composed largely of a polysaccharide known as pectin, that cements together the cell wall of two adjacent plant cells. Pectins can also be found in the cell wall of plant cells.

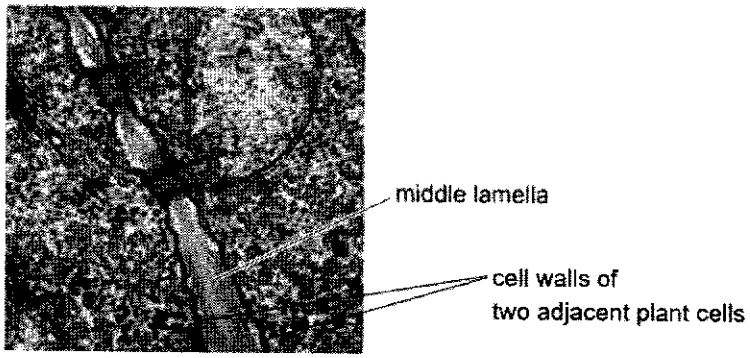

Fig 1.1

Fig. 1.2 shows a diagrammatic representation of the complex structure of the plant cell wall. Pectins are hydrophilic structures and interact with both cellulose and cross-linking glycans to hold cell walls close together. Glycans are carbohydrate molecules.

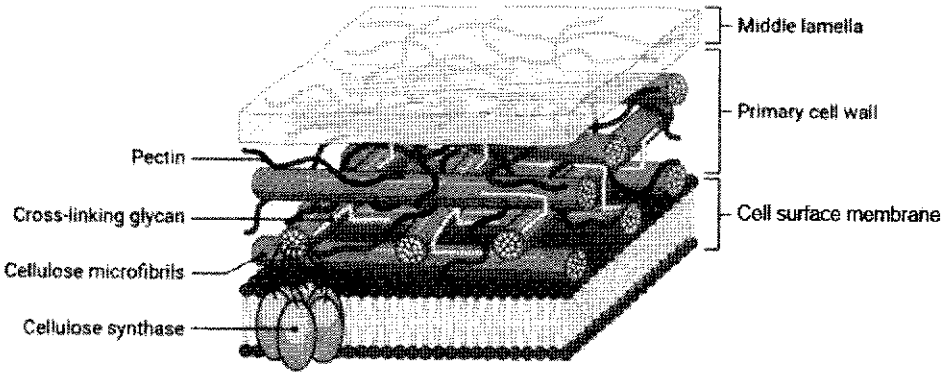

Fig. 1.2

With reference to Fig. 1.2, suggest how the structure of the cell wall facilitates the passage of water between plant cells.

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..... [2]

[Total: 7]

2 The walls of alveoli in the lungs contain some specialised epithelial cells called type II epithelial cells. These cells secrete surfactant. Surfactant helps to prevent the alveoli collapsing during breathing.

Surfactant is composed of phospholipid, cholesterol and protein.

The components of surfactant are synthesised in the rough endoplasmic reticulum and smooth endoplasmic reticulum and then passed to the Golgi body.

(a) Ribosomes are found on the surface of rough endoplasmic reticulum.

Describe the structure of a ribosome.

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(b) Identify the component(s) of surfactant that is (are) synthesised in the smooth endoplasmic reticulum.

..... [1]

(c) Fig. 2.1 shows part of a type II epithelial cell.

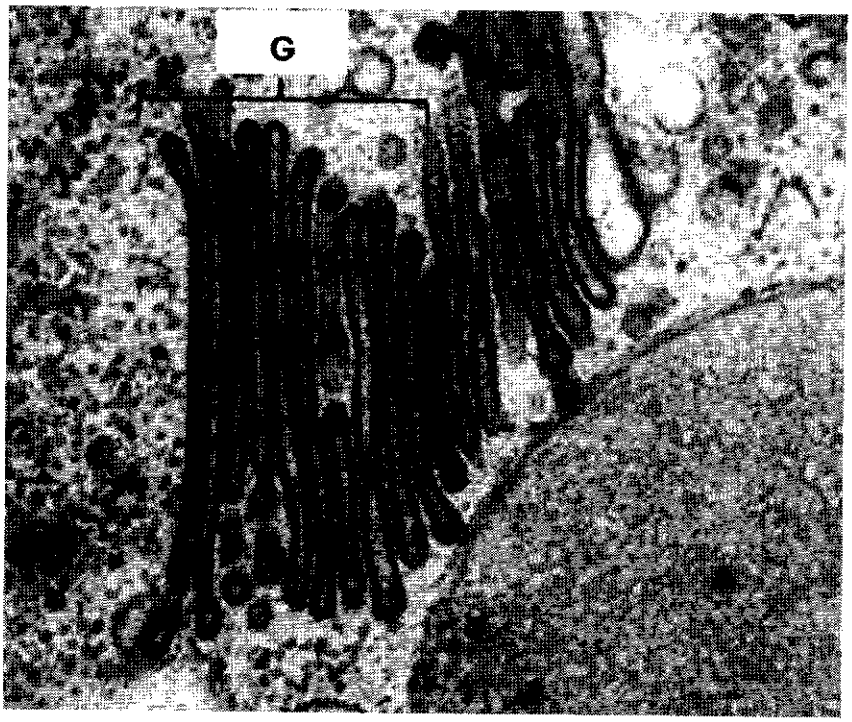

Fig. 2.1

Both the Golgi body and the smooth endoplasmic reticulum are part of the internal network of membranes in cells.

Describe structural features shown in Fig. 2.1 that identify **G** as the Golgi body and **not** the smooth endoplasmic reticulum.

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(d) The surfactant that is produced is stored in secretory organelles called lamellar bodies. Each lamellar body is surrounded by a single membrane. The surfactant in the lamellar bodies is released onto the surface of the alveolar epithelium by exocytosis.

Scientists studying the production and secretion of lung surfactant have discovered that a reduction in cholesterol in the cell surface membrane of type II epithelial cells reduces the secretion of surfactant.

Explain why secretion of surfactant is affected by a reduction in cholesterol in the cell surface membranes of type II epithelial cells.

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..... [3]

[Total: 10]

3 Keratin is the structural protein in feathers of birds. Keratin polypeptides are composed of a high proportion of cysteine amino acids.

Keratin polypeptides form fibres. The two main types of keratin in feathers are α-keratin, which consists of many α-helices, and β-keratin, which consists of many β-pleated sheets.

(a) Keratinases are proteases that can hydrolyse keratin. Many proteases are able to hydrolyse more than one type of protein.

Explain why it is possible for a protease to act on different types of protein.

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..... [2]

(b) Feathers are not easily hydrolysed because keratin is a very stable protein.

Suggest features of keratin structure that contribute to its stability.

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..... [2]

(c) Keratinases are used to degrade the large quantities of waste feathers from chickens and turkeys that are processed in the food industry. The products of feather degradation can be used in animal feed.

Scientists investigated whether three different keratinases, **K12**, **A22** and **P3**, were suitable as industrial enzymes.

The effects of temperature and pH on the activity of each keratinase were investigated.

The results are shown in Fig. 3.1 and Fig. 3.2.

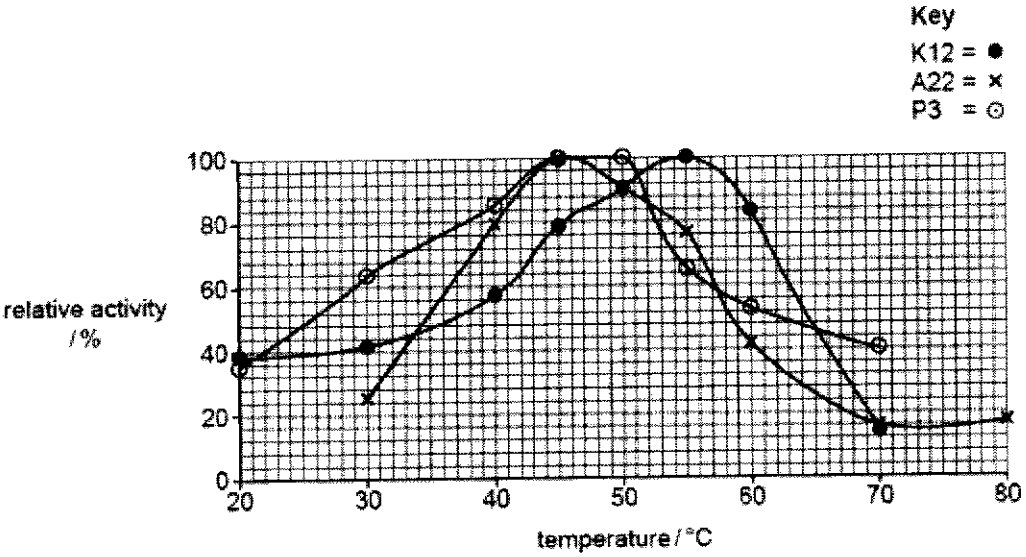

Fig. 3.1

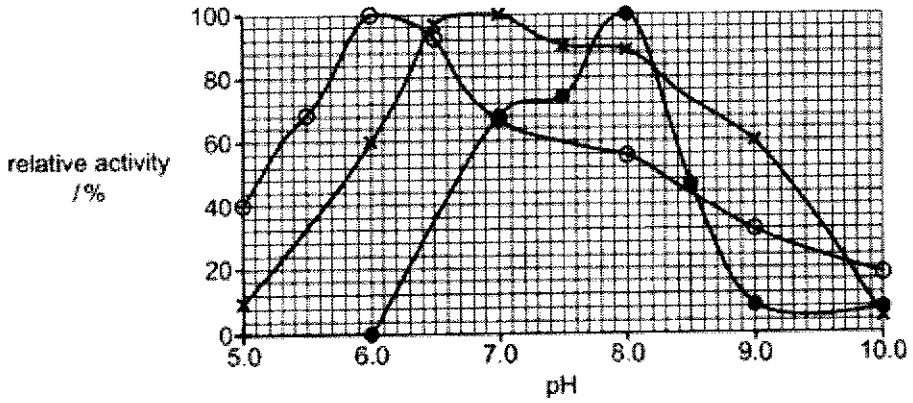

Fig. 3.2

(i) To degrade feather waste from the food industry, it is an advantage to use keratinases that show at least 60% relative activity in conditions where temperature and pH can vary widely.

Table 3.1 shows, for each keratinase, the working range of temperature and pH where at least 60% relative activity is obtained.

Use Fig. 3.1 and Fig. 3.2 to complete Table 3.1 **and** use the completed table to:

- name the keratinase that has the widest working range of temperature
- name the keratinase that has the widest working range of pH.

Table 3.1

keratinase	temperature range with at least 60% relative activity / °C	pH range with at least 60% relative activity
K12	41 – 63	
A22		6.0 – 9.0
P3	29 – 56	5.3 – 7.5

Keratinase with a relative activity of at least 60% that has:

- the widest working range of temperature .....
- the widest working range of pH ..... [2]

(ii) Explain why increasing pH from 8.0 to 9.0 decreases relative activity of keratinase **K12**.

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..... [3]

(d) Another industrial application of keratinase is to add them into detergents to remove protein-based stains on clothes.

Epsom salt, which is magnesium sulfate ($MgSO_4$), are commonly found in detergents that work well on stubborn stains.

To ascertain the effect of epsom salt on keratinases in detergents, researchers conducted an experiment to compare the relative activity of keratinase **K12** in the presence and absence (control) of $MgSO_4$. The results of the experiment are shown in Fig. 3.3.

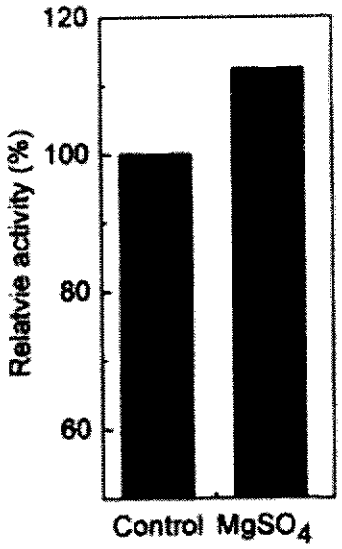

Fig. 3.3

Based on the results of the experiment, suggest a potential role of epsom salt in detergents. Explain your answer.

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..... [2]

[Total: 11]

Question 4 starts on page 12

4 The "trombone" model of DNA replication hypothesises that the lagging strand template forms a loop such that each of the enzyme **P**, which is involved in leading and lagging strands synthesis, constantly associates with the replication fork.

In Fig. 4.1, structures labelled **P**, **Q** and **R** are enzymes involved in the process of DNA replication.

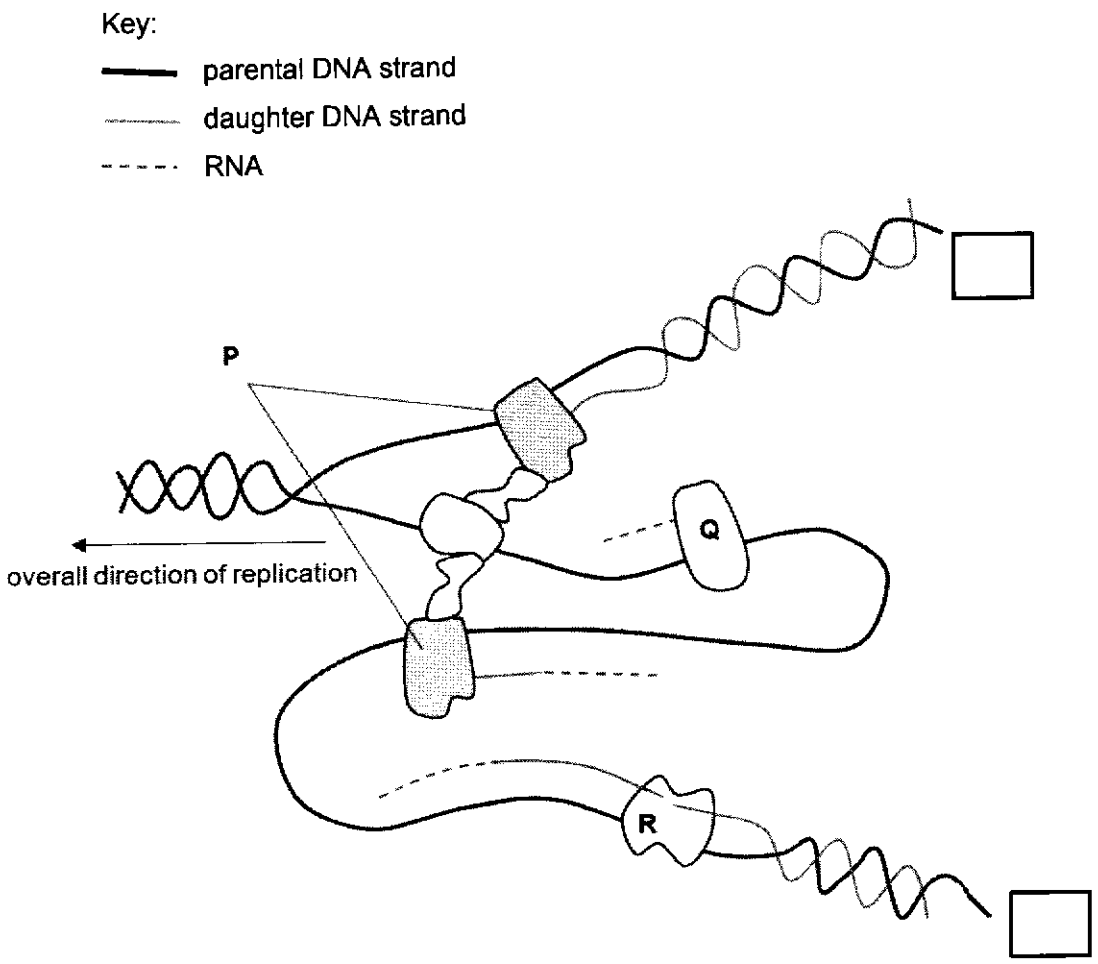

Fig. 4.1

(a) **(i)** Fill in the boxes to indicate clearly the 5' and 3' ends of the **parental** strands shown in Fig. 4.1. [1]

(ii) Name the enzymes **P** and **Q** shown in Fig. 4.1.

P .....

Q ..... [2]

(iii) Explain the importance of **R** in DNA replication.

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..... [2]

(b) DNA replication and transcription both occur in the nucleus.

The process of transcription allows the information carried in DNA to be initially transferred to pre-mRNA. The *DMD* gene encodes protein dystrophin, which plays an important role in the structure of muscles.

DMD is the largest known human gene. It contains 2 220 390 base pairs. The length of a single triplet of nucleotides can be assumed to be 1 nm.

(i) Calculate the length of the pre-mRNA transcribed from the *DMD* gene.

Show all your working.

Length of pre-mRNA = ...μm [2]

(ii) Human cells typically have a diameter of 70 μm.

Suggest **and** explain the implications of your answer to **(b)(i)** for the arrangement of *DMD* pre-mRNA molecules inside the cell.

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..... [2]

(iii) The *DMD* pre-mRNA molecule is processed to form a molecule of mRNA. During processing of the pre-mRNA molecule, over 70 sections of RNA called introns are removed. The remaining sections of RNA are combined back together to form a molecule of mRNA, which is then translated.

Explain how processing of the *DMD* pre-mRNA can result in the formation of a number of different functional proteins.

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..... [2]

[Total: 11]

Question 5 starts on page 16

5 COVID-19 and influenza flu are both contagious respiratory illnesses caused by different viruses. COVID-19 is caused by infection with a coronavirus, SARS-CoV-2, first identified in 2019. Flu is caused by infection with an influenza virus.

Fig. 5.1 shows the structures of the SARS-CoV-2 and influenza virus respectively.

Both **S** and **HA** are glycoproteins embedded in the viral envelope of the respective viruses and serve the same function. SARS-CoV-2 has an RNA genome that can be directly translated for viral proteins production.

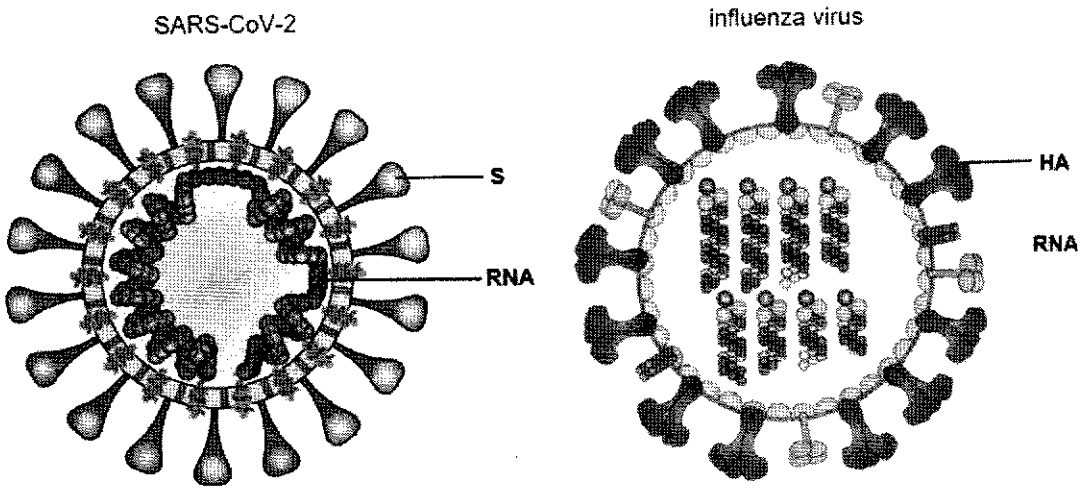

Fig. 5.1

(a) State the full name of glycoprotein **HA** and describe its function in influenza virus.

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..... [2]

(b) Other than the structures found on the viral envelopes, describe two **other** differences in the structures of SARS-CoV-2 and influenza virus.

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(c) Fig. 5.2 shows part of the reproductive cycle of SARS-CoV-2 virus.

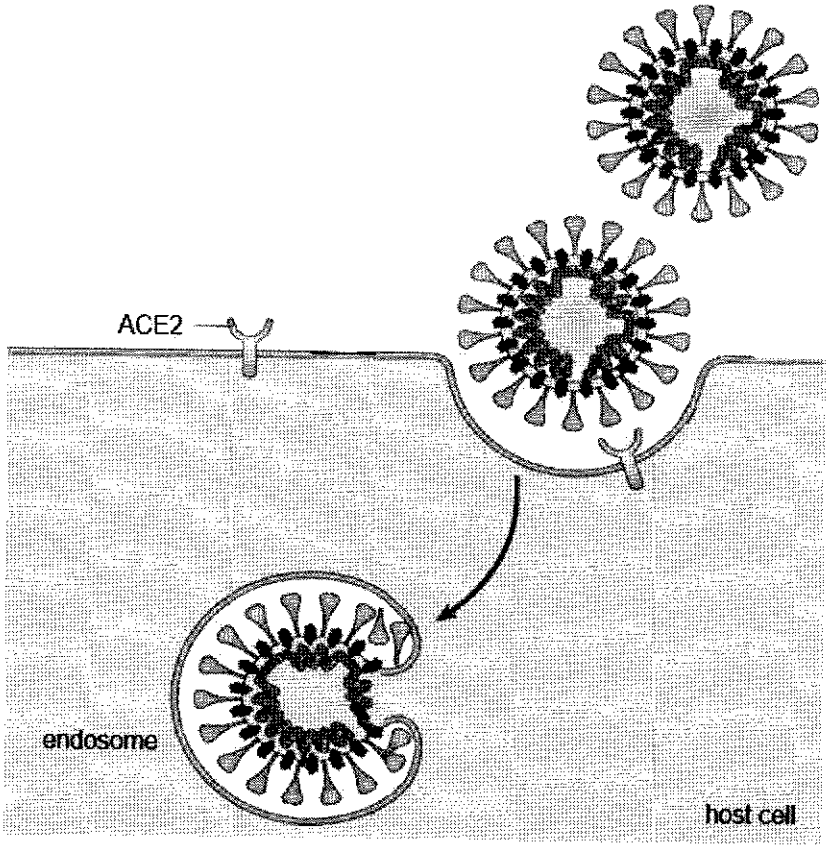

Fig. 5.2

Describe how the SARS-CoV-2 virus enters a host cell.

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..... [3]

(d) There are at least three variants of the SARS-CoV-2 since its discovery in 2019.

Similarly, there have been many different reported strains of influenza viruses with variation in their viral genome. It is also common for a particular strain of influenza to re-emerge after a few years. An example is the H7N9 strain that first infected humans with low pathogenicity in 2013 but re-emerged four years later in 2017 as a strain with high pathogenicity, as shown in Fig. 5.3.

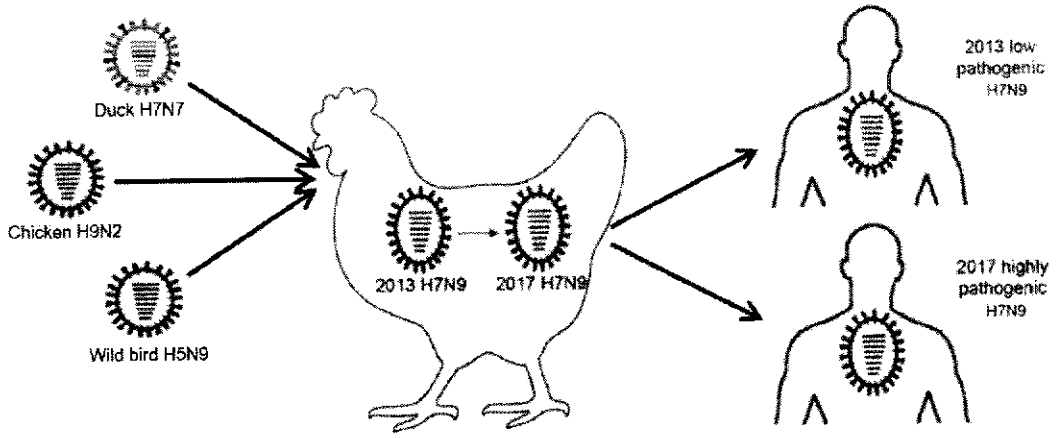

Fig. 5.3

With reference to Fig. 5.3, describe how variation in viral genomes arose and led to the formation of two H7N9 strains with different pathogenicity in humans.

formation of 2013 low pathogenic H7N9

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formation of 2017 highly pathogenic H7N9

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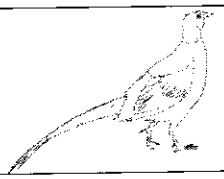
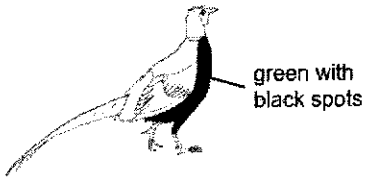
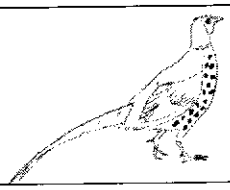
..... [5]

[Total: 12]

Question 6 starts on page 20

6 A pheasant species, *Phasianus colchicus*, also known as ring-necked pheasant, has individuals with four feather colour patterns, as shown in Table 6.1.

Table 6.1

phenotype	feather colour patterns
green	
white	
green with black spots	
white with black spots	

Two unlinked genes determine the feather colour patterns shown in Table 6.1.

One gene controls whether the feather colour is green or white:

- dominant allele **G** = green
- recessive allele **g** = white.

The other gene controls whether black spots are present or not present:

- dominant allele **B** = with black spots
- recessive allele **b** = without black spots.

In birds, the sex chromosomes are referred to as **W** and **Z**, rather than **Y** and **X** as in mammals.

In *P. colchicus*:

- the heterogametic sex is the female
- male has two **Z** chromosomes and female has one **Z** and one **W** chromosome
- the gene that controls feather colour is located on the **Z** chromosome
- the gene that controls whether black spots are present or absent is located on an autosome.

Genetic crosses were carried out to investigate the inheritance of the four different feather colour patterns.

Males that were green with black spots, and homozygous at both loci, were crossed with females that were white. The F1 offspring were all green with black spots. These F1 offspring were then crossed to produce the F2 generation.

(a) Draw a genetic diagram to show the predicted feather colours of the F2 generation from F1 generation.

Insert the symbols for the alleles of the gene that controls feather colour as well as the alleles of gene that controls whether black spots are present or absent, into the table below.

key to symbols

allele coding for green feather colour	
allele coding for white feather colour	
allele coding for presence of black spots	
allele coding for absence of black spots	

genetic diagram showing the predicted feather colours:

[4]

(b) Further analysis of the results from the F2 generation showed that there were no white males or white males with black spots.

Explain why there are no white males or males that are white with black spots in the F2 generation.

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..... [2]

(c) Table 6.2 compares the observed numbers with the numbers that would be expected in the F2 generation for a normal dihybrid ratio.

Table 6.2

phenotype	observed	expected	$O - E$	$(O-E)^2$	$\frac{(O-E)^2}{E}$
green with black spots	279	281.25			
white with black spots	95	93.75	1.25	1.5625	0.017
green	96	93.75	2.25	5.0625	0.054
white	30	31.25			
				χ^2 = ...	

(i) Calculate χ^2 for the F2 generation by completing Table 6.2.

The formula for χ^2 is:

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

[2]

(ii) The critical value at $p = 0.05$ and 3 degrees of freedom is 7.815.

Comment on whether the null hypothesis should be rejected.

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..... [2]

[Total: 10]

7 The banana plant, *Musa acuminata*, is a tall herbaceous plant with very large leaves.

(a) Like all other plants, chlorophyll *a* is the main photosynthetic pigment in banana plant chloroplasts.

(i) Name two **other** photosynthetic pigments found in plant chloroplasts.

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..... [1]

(ii) Describe the role of other photosynthetic pigments found in plant chloroplasts.

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..... [2]

(b) The absorption of different wavelengths of light by photosynthetic pigments can be represented by an absorption spectrum.

Fig. 7.1 show both the absorption spectra of an extract containing all photosynthetic pigments obtained from banana leaves and another extract containing whole chloroplasts obtained from banana leaves of the same mass.

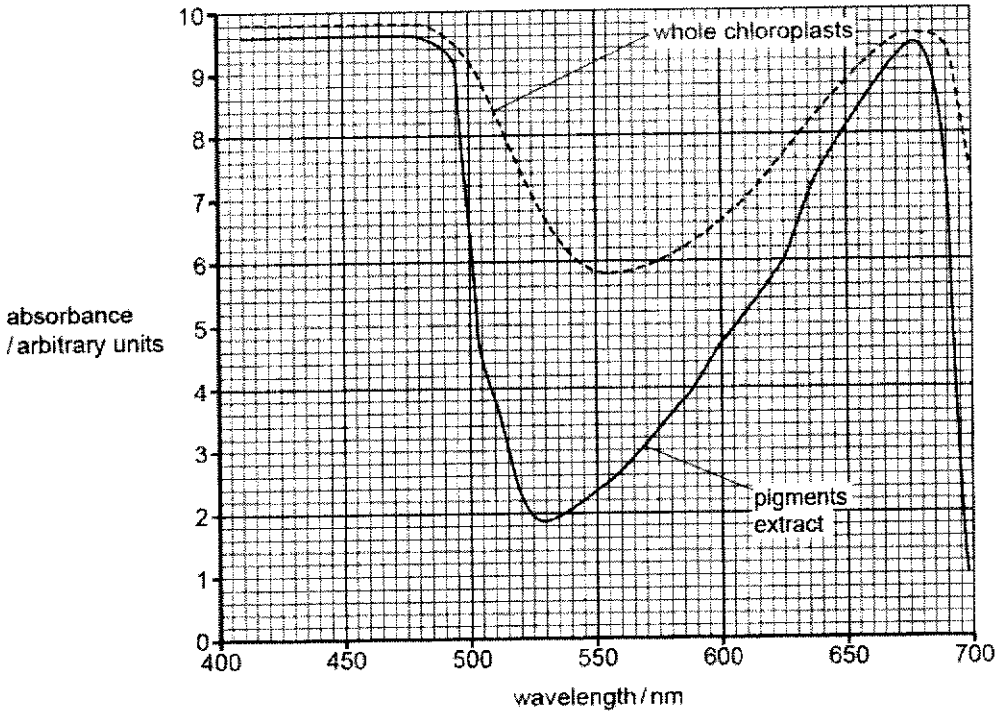

Fig. 7.1

With reference to Fig. 7.1, describe the differences between the two spectra **and** suggest explanations for the differences.

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(c) An investigation was carried out to measure the net carbon dioxide uptake by a banana plant at different light intensities.

Fig. 7.2 shows the results of the investigation.

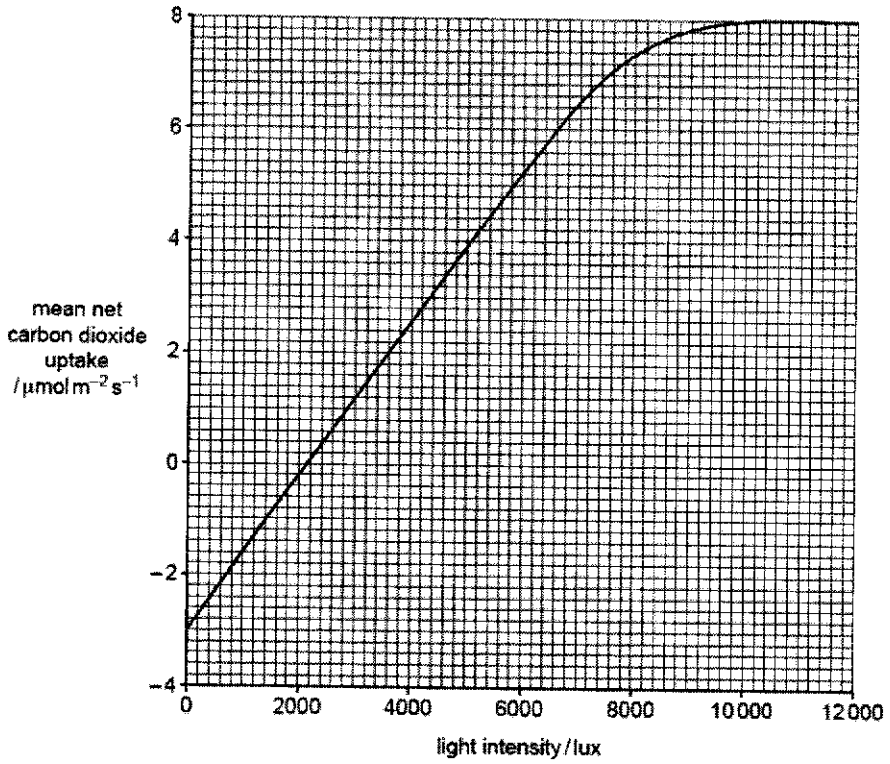

Fig. 7.2

With reference to Fig. 7.2, explain the significance of the two reference points on the growth of the banana plant.

light compensation point

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light saturation point

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..... [4]

[Total: 10]

8 The epidermal growth factor receptor (EGFR) signaling pathway is one of the most important pathways that regulate growth in mammalian cells.

Fig. 8.1 shows the epidermal growth factor (EGF) binding to EGFR on the surface of a cell.

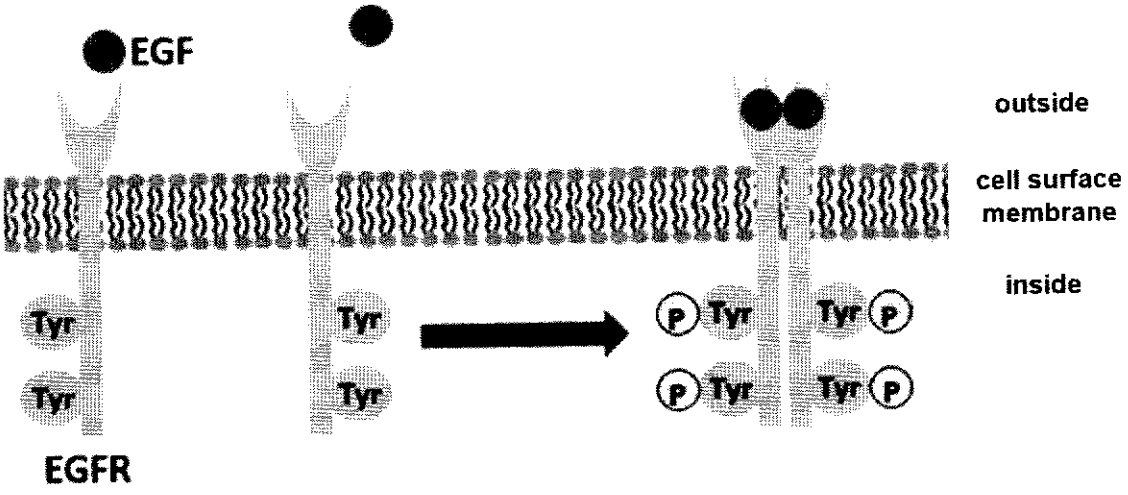

Fig. 8.1

(a) A specific region on each EGFR functions as an enzyme.

State the full name of the enzyme found on EGFR **and** describe, as precisely as possible, the reaction catalysed by the enzyme.

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..... [3]

(b) Explain why it is important that EGFR completely spans the cell surface membrane.

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..... [3]

(c) A group of scientists investigated the effect of altering EGFR activity on embryonic stem cells (ESCs) in mice.

Suggest how the scientists obtained the mouse ESCs.

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..... [2]

[Total: 8]

Question 9 starts on page 29

9 The puma, *Puma concolor*, lives in America.

Fig. 9.1 shows a puma.

Fig. 9.1

(a) There are many subspecies of puma found in America. Members of different subspecies belong to the same species but have some morphological differences and are found in different geographical locations.

Explain how the different subspecies of puma evolved.

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..... [3]

(b) Two subspecies of puma, Florida panther and Andean Mountain lion were studied. The Florida panther is critically endangered while the Andean Mountain lion is considered to have a much larger population.

Table 9.1 compares the features of the two subspecies.

Table 9.1

feature	Florida panther (*Puma concolor coryi*)	Andean Mountain lion (*Puma concolor puma*)
habitat	woodlands and swamps	Andes mountains
body mass	males : ~50-72 kg, females : ~29-45 kg	males : ~60-100 kg, females : ~40-64 kg
body length	males : ~1.8-2.2 m, females :~1.6-1.9 m	males: ~2.0-2.8 m, females: ~1.8-2.4 m
incidence rate of tail kink (a small bend or twist on one of the tail vertebrae)	25-30%	below 1%

The production of differences in phenotypes between the Florida panther and the Andean Mountain lion can be due to natural selection or genetic drift.

Based on the information in the question and your own knowledge, complete Table 9.2 to :

- show whether body size (mass and length) and presence of tail kink is due to natural selection or genetic drift,
- explain your answer

Table 9.2

mechanism	phenotype (write **body size** or **tail kink**)	explanation
natural selection		
genetic drift		

[6]

(c) Hybridisation has been observed between individuals of different subspecies of puma. The hybrid populations show high reproductive success.

Suggest how the hybrid populations are different from the pure subspecies in terms of genetic variation and potential to adapt to climate change.

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[Total: 12]

10 Tuberculosis (TB) is an important disease worldwide. Despite being preventable and treatable, TB remains one of the top infectious disease killers globally.

(a) Name the pathogen that causes TB.

..... [1]

(b) When the TB bacterial pathogens enter the lungs, they are rapidly engulfed by macrophages. Eventually, granulomas (tubercles) may form.

Describe the events that occur from the ingestion of the pathogen to the formation of granulomas.

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..... [3]

[Total: 4]

11 Pteropods are small free-swimming snails found in oceans throughout the world.

They are a food source for a variety of fish including salmon, mackerel and herring. In 2011, the health of these snails was studied in the oceans surrounding Hawaii.

A sample of these snails showed that many of them had damaged shells. Fig. 11.1 shows a healthy snail and a snail with a damaged shell found in the oceans surrounding Hawaii.

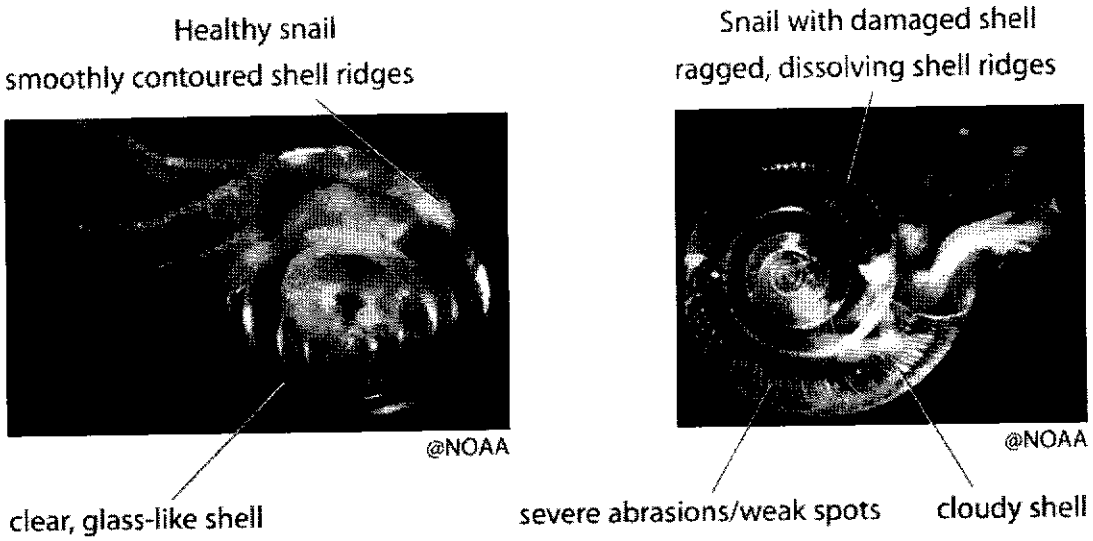

Fig. 11.1

The pH of sea water affects calcium-rich shell formation in these snails. The changes in carbon dioxide concentration and pH have been recorded in oceans surrounding Hawaii island as shown in the Fig. 11.2.

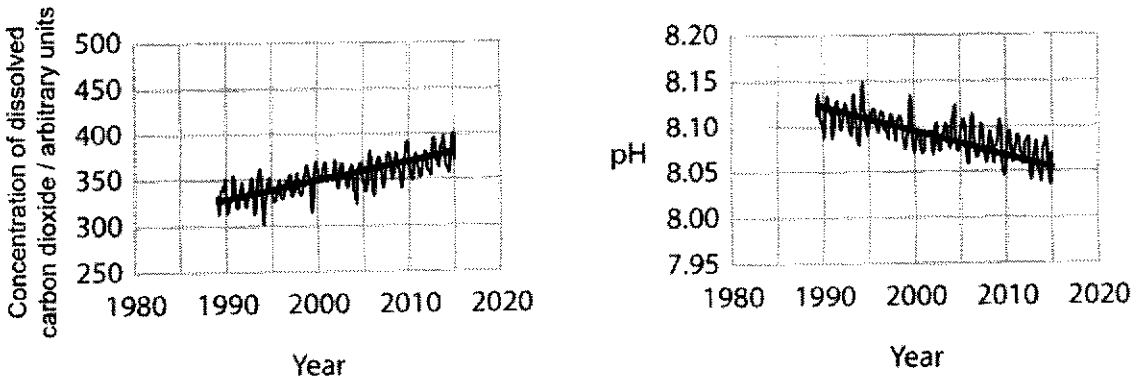

Fig. 11.2

(a) With reference to Fig. 11.2, explain the relationship between increased carbon dioxide emissions and the pH of the oceans.

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(b) Using the information provided in this question, suggest the impact of change in ocean pH on fish populations.

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..... [3]

[Total: 5]

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H2

ANDERSON SERANGOON JUNIOR COLLEGE
HIGHER 2
ANSWERS

2024 JC2 PRELIMINARY EXAMINATIONS

CANDIDATE NAME

CLASS

INDEX NUMBER

BIOLOGY

9744/02

PAPER 2
SHORT STRUCTURED QUESTIONS

12 SEPTEMBER 2024
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Candidates answer on the Question Paper.
No Additional Materials are required.

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9	/ 12
10	/ 4
11	/ 5
Total	/100

This document consists of **13** printed pages and **1** blank page

Answer **all** the questions.

1 Starch and cellulose are carbohydrates that are found in most plants.

(a) Compare between structures of amylose and amylopectin of starch.

Similarity (max 1)

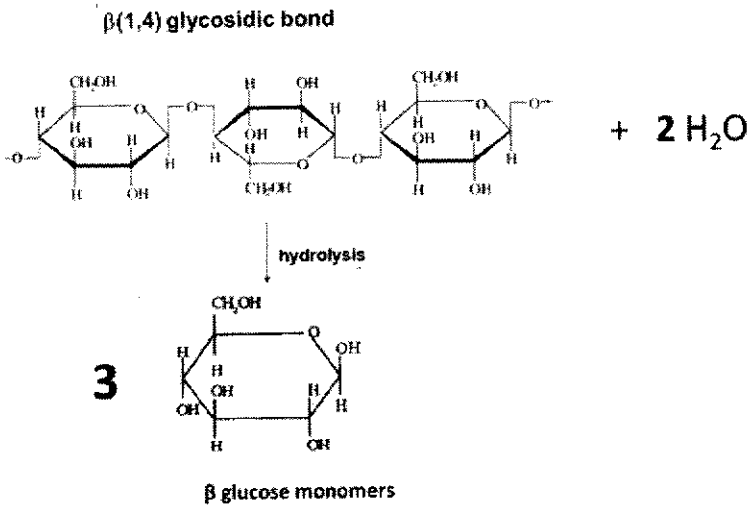
1. Both are composed of α-glucose monomers.
2. Both contain α(1,4) glycosidic bonds between monomers.

Difference (max 1)

1. Amylopectin contain α(1,4) glycosidic bonds and α(1,6) glycosidic bonds while amylose only contain α(1,4) glycosidic bonds. (A: amylopectin contain α(1,6) glycosidic bonds while amylose do not.)
2. Amylopectin is branched while amylose is unbranched. [2]

(b) Juices that are extracted commercially from fruits can be made less cloudy by the breakdown of the cellulose cell wall using the enzyme cellulase.

In the space below, **show how** the bonds in a short section of cellulose that is made up of **three** monomers may be broken by cellulase. Add appropriate labels to your drawing.



1. **Structures of cellulose** with **indication of 'continuity'** for polymer + correct rotation + correctly labelled **glycosidic bond**
2. **Correct structure of 3 β-glucose monomer** correctly drawn including H
3. **Type of reaction labelled (hydrolysis) + 2 water molecules indicated as reagents** [3]

Fig. 1.1 is an electron micrograph showing parts of two plant cells. The middle lamella is a layer, composed largely of a polysaccharide known as pectin, that cements together the cell wall of two adjacent plant cells. Pectins can also be found in the cell wall of plant cells.

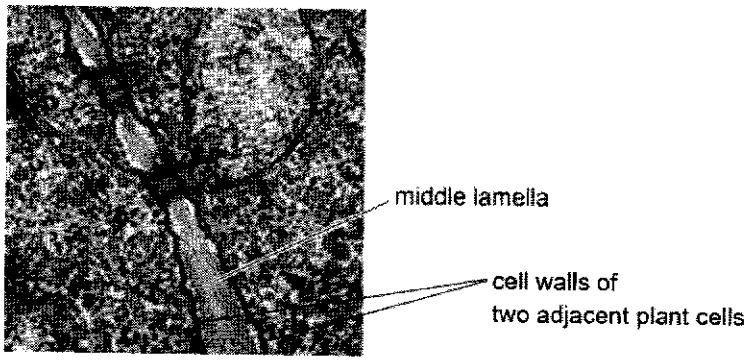


Fig 1.1

Fig. 1.2 shows a diagrammatic representation of the complex structure of the plant cell wall. Pectins are hydrophilic structures and interact with both cellulose and cross-linking glycans to hold cell walls close together. Glycans are carbohydrate molecules.

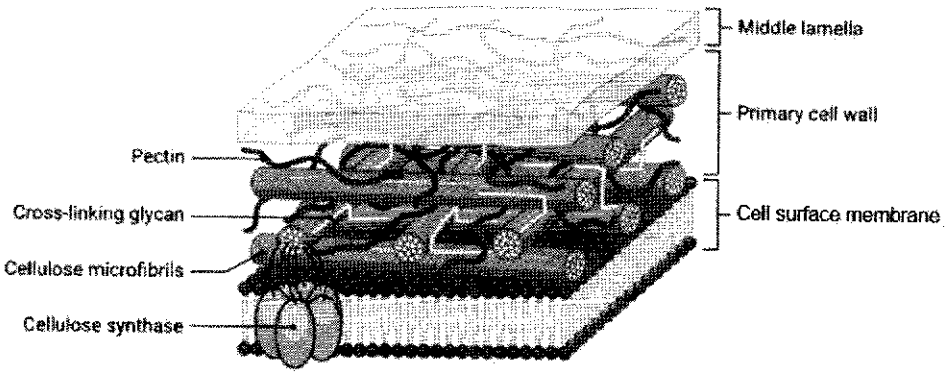


Fig. 1.2

(c) With reference to Fig. 1.2, suggest how the structure of the cell wall facilitates the passage of water between plant cells.

1. cellulose microfibrils arranged in a **crisscross pattern/ interwoven structure** that creates large intermolecular **spaces or pores** between the microfibrils to allow movement of water or small molecules
2. Presence of **hydrogen bond** cross-linking between cellulose microfibrils to form a **strong network** of cellulose fibres (maintaining the interwoven structure)
3. presence of pectins that are able to interact and **form hydrogen bonds with water / hydrophilic molecules**
4. AVP (crosslinking glycans linking **two or more** cellulose microfibrils to strengthen network

[2]

Easy: 4, Moderate: 3, Challenging: 0 [Total: 7]

2 The walls of alveoli in the lungs contain some specialised epithelial cells called type II epithelial cells. These cells secrete surfactant. Surfactant helps to prevent the alveoli collapsing during breathing.

Surfactant is composed of phospholipid, cholesterol and protein.

The components of surfactant are synthesised in the rough endoplasmic reticulum and smooth endoplasmic reticulum and then passed to the Golgi body.

(a) Ribosomes are found on the surface of rough endoplasmic reticulum.

Describe the structure of a ribosome.

1. Composed of **rRNA** and **proteins**
2. Each ribosome consists of a **large** (60S) and a **small subunit** (40S) (making up a 80S ribosome)
3. Each ribosome has **1 mRNA and 3 tRNA** (A, P, E) **binding sites.** *(reject merely saying A,P,E site)*
4. Contains **ribozyme / peptidyl transferase** in the **large ribosomal subunit (** An rRNA molecule complex (of the large ribosomal subunit)) [3]

(b) Identify the component(s) of surfactant that is (are) synthesised in the smooth endoplasmic reticulum.

Phospholipid and cholesterol [1]

(c) Fig. 2.1 shows part of a type II epithelial cell.

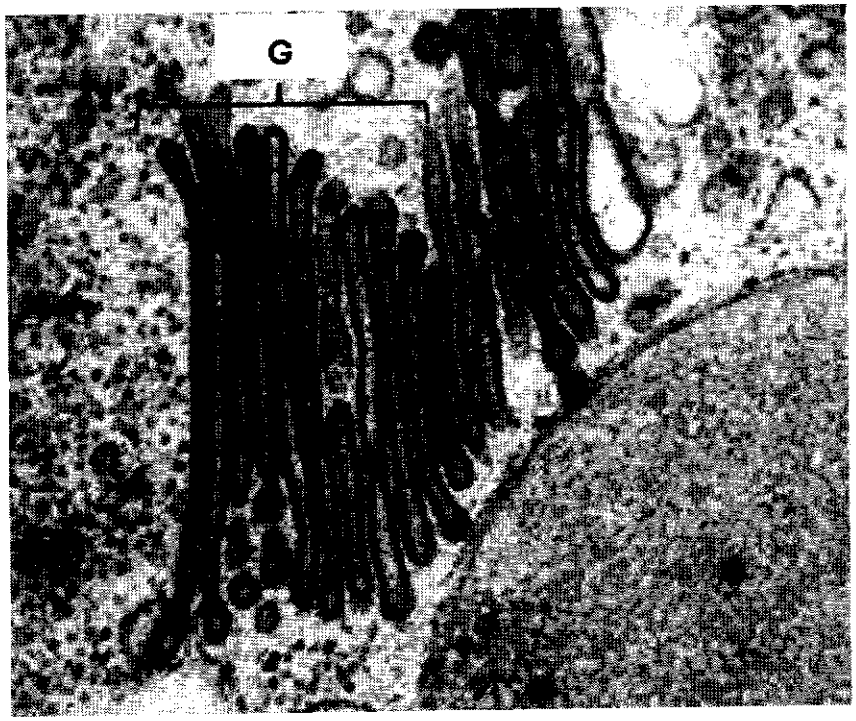
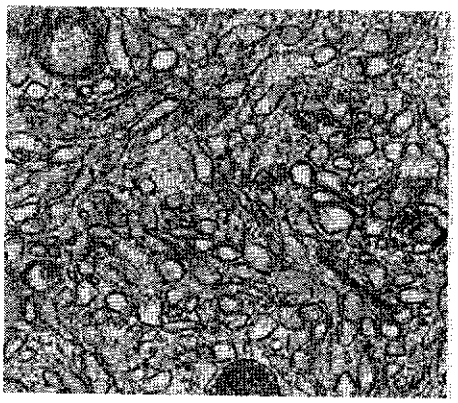


Fig. 2.1

Both the Golgi body and the smooth endoplasmic reticulum are part of the internal network of membranes in cells.

Describe structural features shown in Fig. 2.1 that identify **G** as the Golgi body and **not** the smooth endoplasmic reticulum.

1. Cisternae/ membrane-bound sacs are **not interconnected / independent**
2. Cisternae are **more elongated** (than tubular)
3. Cisternae/ sacs are **stacked**
4. presence of **vesicles at the end** of the sacs/ cisternae
5. more **uniform in shape**



[3]

(d) The surfactant that is produced is stored in secretory organelles called lamellar bodies. Each lamellar body is surrounded by a single membrane. The surfactant in the lamellar bodies is released onto the surface of the alveolar epithelium by exocytosis.

Scientists studying the production and secretion of lung surfactant have discovered that a reduction in cholesterol in the cell surface membrane of type II epithelial cells reduces the secretion of surfactant.

Explain why secretion of surfactant is affected by a reduction in cholesterol in the cell surface membranes of type II epithelial cells.

Without cholesterol, (any 2)
1. movement of phospholipids are not restricted
2. because there are less cholesterol molecules for phospholipids to bump into to lose their **kinetic energy**
3. absence (of spacer) to separate phospholipids / so that they **pack closely together** / more hydrophobic interactions between phospholipids

AND
4. membrane becomes too fluid / too rigid / solidify such that is cannot **fuse** with the membrane of lamellar body during exocytosis [3]

Easy: 8, Moderate: 2, Challenging: 0 [Total: 10]

3 Keratin is the structural protein in feathers of birds. Keratin polypeptides are composed of a high proportion of cysteine amino acids.

Keratin polypeptides form fibres. The two main types of keratin in feathers are α-keratin, which consists of many α-helices, and β-keratin, which consists of many β-pleated sheets.

(a) Keratinases are proteases that can hydrolyse keratin. Many proteases are able to hydrolyse more than one type of protein.

Explain why it is possible for a protease to act on different types of protein.

1. *idea that* **active sites** of proteases are **complementary** in **shape to peptide bonds** which are found in all proteins;

2. suggestion that **active site** has (some) **flexibility** for **hydrolysing / binding to / similar substrates**; *(accept description of induced fit hypothesis)*

3. AVP ; e.g. (large enzyme / enzyme complex, with) **more than one active site** [2]

(b) Feathers are not easily hydrolysed because keratin is a very stable protein.

Suggest features of keratin structure that contribute to its stability.

1. (**high** proportion of) **disulfide bonds** / disulfide bridges / covalent bonds (because of cysteines);

2. **High** proportion of **hydrogen bonds** found in α-helices and β-pleated sheets;

3. Idea of **tight / close packing** of chains / polypeptides so **peptide bonds are not accessible** [2]

Keratinases are used to degrade the large quantities of waste feathers from chickens and turkeys that are processed in the food industry. The products of feather degradation can be used in animal feed.

Scientists investigated whether three different keratinases, **K12**, **A22** and **P3**, were suitable as industrial enzymes.

The effects of temperature and pH on the activity of each keratinase were investigated.

The results are shown in Fig. 3.1 and Fig. 3.2.

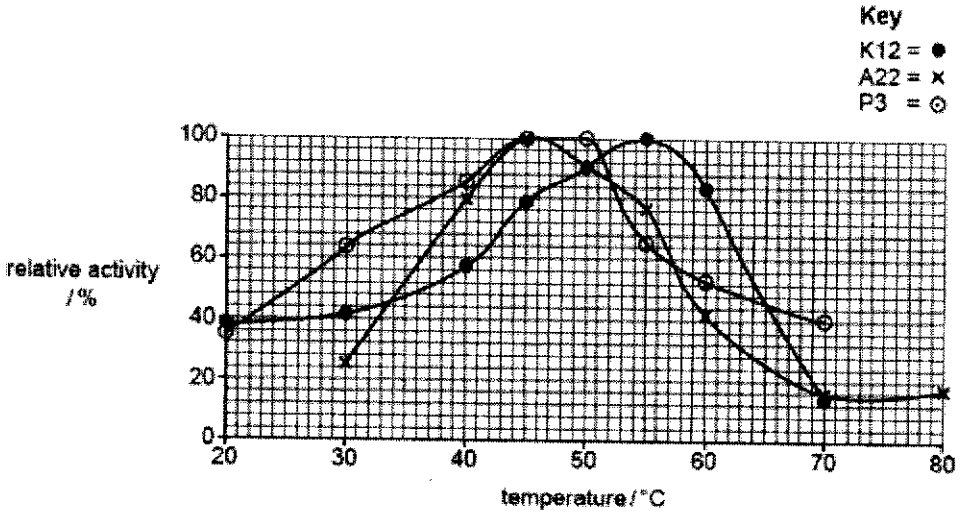


Fig. 3.1

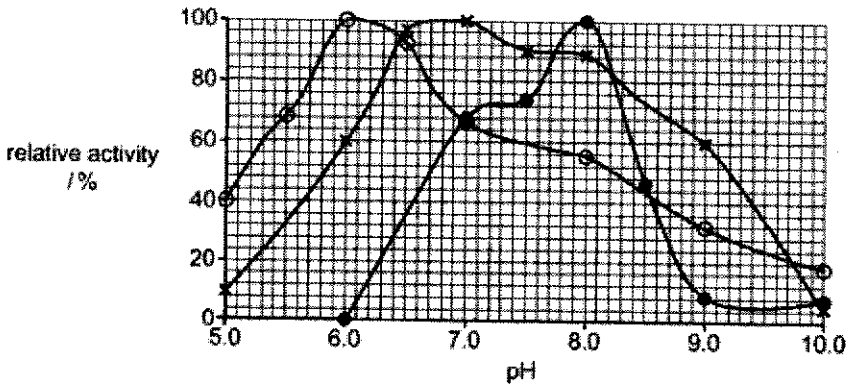


Fig. 3.2

(c) To degrade feather waste from the food industry, it is an advantage to use keratinases that show at least 60% relative activity in conditions where temperature and pH can vary widely.

Table 3.1 shows, for each keratinase, the working range of temperature and pH where at least 60% relative activity is obtained.

Use Fig. 3.1 and Fig. 3.2 to complete Table 3.1 **and** use the completed table to:

- name the keratinase that has the widest working range of temperature
- name the keratinase that has the widest working range of pH.

Table 3.1

keratinase	temperature range with at least 60% relative activity / °C	pH range with at least 60% relative activity
K12	41 – 63	**6.8/6.9-8.4**
A22	**36/36.5 – 57** A: 57.1/57.2	6.0 – 9.0
P3	29 – 56	5.3 – 7.5

Keratinase with a relative activity of at least 60% that has:

- the widest working range of temperature .....**P3**.....
- the widest working range of pH .....**A22**.....

1. 2 correct blanks in table (1m)
2. 2 correct keratinase in blanks (1m)

[2]

(d) Explain why increasing pH from 8.0 to 9.0 decreases relative activity of keratinase **K12**.

1. **Concentration of H+ ions decreases** that alters the **charges on the R groups;**
2. of **catalytic and contact amino acid residues** (accept either catalytic or contact?) at the **active site** of K12;
3. **disrupts formation of ionic bonds** and hydrogen bonds;
4. that results in **changes in tertiary structure/3D conformation of K12 active site** such that it is **less complementary in shape to substrate** (keratin) (reject no longer complementary);
5. **decreases frequency of effective collisions** between K12 and keratin / **decreases rate of enzyme-substrate complexes formed** and hence lowered relative activity.

[3]

Another industrial application of keratinase is to add them into detergents to remove protein-based stains on clothes.

Epsom salt, which is magnesium sulfate ($MgSO_4$), are commonly found in detergents that work well on stubborn stains.

To ascertain the effect of epsom salt on keratinases in detergents, researchers conducted an experiment to compare the relative activity of keratinase K12 in the presence and absence (control) of $MgSO_4$. The results of the experiment is shown in Fig. 3.3.

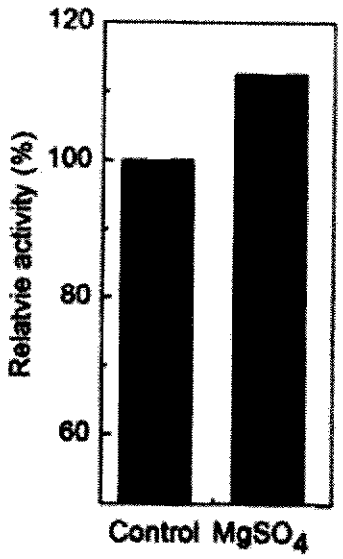


Fig. 3.3

(e) Based on the results of the experiment, suggest a potential role of epsom salt in detergents. Explain your answer.

1. Addition of epsom salt/magnesium sulfate ($MgSO_4$) **increases/enhances** relative activity of keratinase K12 by **15%;**

2. Magnesium sulfate would most likely be a **cofactor** (R: coenzyme) of keratinase. [2]

Easy: 4, Moderate: 6, Challenging: 1 [Total: 11]

4 The "trombone" model of DNA replication hypothesises that the lagging strand template forms a loop such that each of the enzyme **P,** which is involved in leading and lagging strands synthesis, constantly associates with the replication fork.

In Fig. 4.1, structures labelled **P, Q** and **R** are enzymes involved in the process of DNA replication.

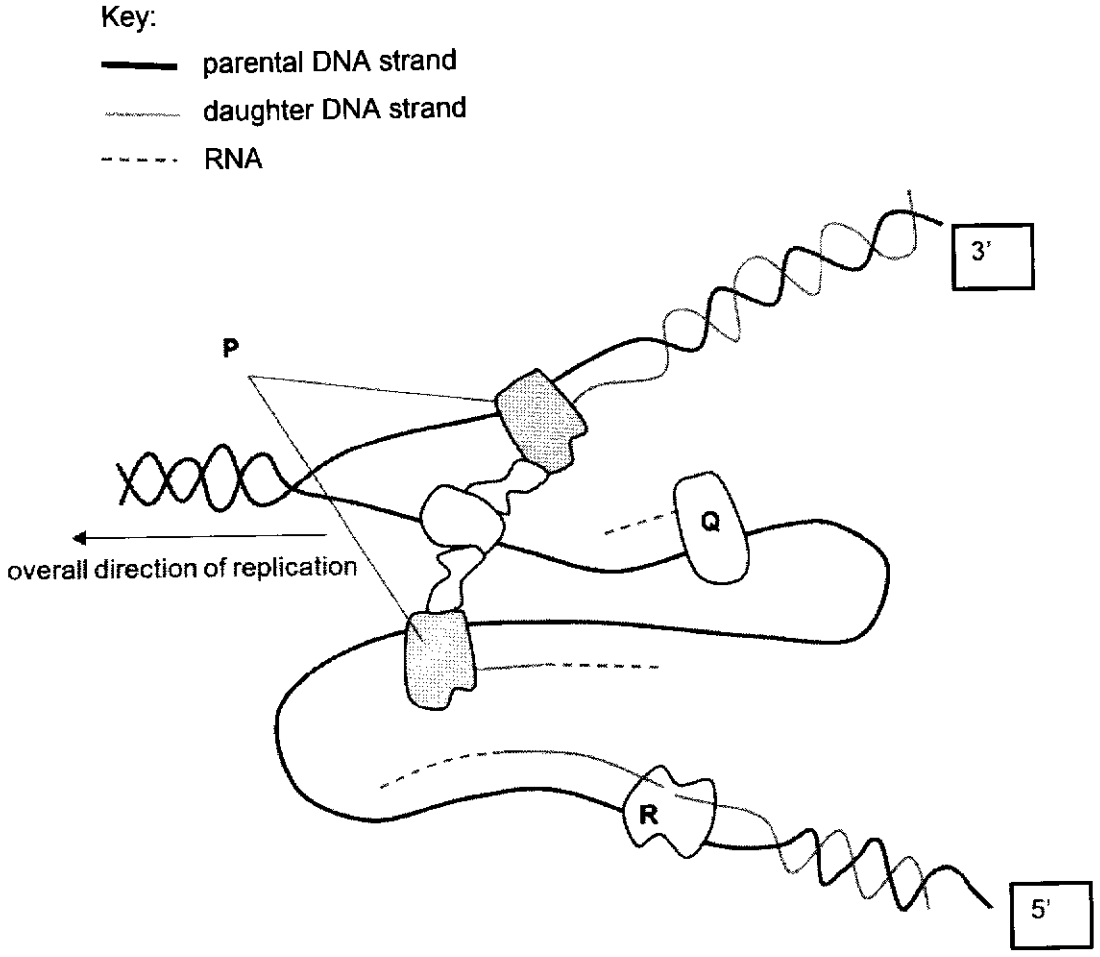


Fig. 4.1

(a) **(i)** Fill in the boxes to indicate clearly the 5' and 3' ends of the **parental** strands shown in Fig. 4.1. [1]

(ii) Name the enzymes **P** and **Q** shown in Fig. 4.1.
P: **DNA polymerase**

Q: **Primase** [2]

(iii) Explain the importance of **R** in DNA replication.

1. **DNA ligase** catalyses the formation of **phosphodiester bonds** between adjacent **DNA nucleotides**;
2. of an **okazaki fragment** and **growing DNA chain** + to produce a **continuous DNA strand**

[2]

DNA replication and transcription both occur in the nucleus.

The process of transcription allows the information carried in DNA to be initially transferred to pre-mRNA. The *DMD* gene encodes protein dystrophin, which plays an important role in the structure of muscles.

DMD is the largest known human gene. It contains 2 220 390 base pairs. The length of a single triplet of nucleotides can be assumed to be 1 nm.

(b) (i) Calculate the length of the pre-mRNA transcribed from the *DMD* gene.

Show all your working.

1. Number of codons in pre-mRNA = $\frac{2\,220\,390}{3}$ = 740 130
2. length of pre-mRNA in μm = $\frac{740\,130}{1000}$ = **740 μm** (3.s.f.) (accept in nm, accept 740130 nm?)

NOTE: 1 μm = 10^3 nm

Most calculations were completed correctly. Some candidates made errors in converting units leading to factor of ten errors.

Length of pre-mRNA = ... **μm**

[2]

(ii) Human cells typically have a diameter of 70 μm.

Suggest **and** explain the implications of your answer to **(b)(i)** for the arrangement of *DMD* pre-mRNA molecules inside the cell.

1. For the **pre-mRNA** to be stored within a cell and **nucleus smaller** & **shorter** than itself;
2. the pre-mRNA must be **compacted** by being **coiled/condensed/folding via H bonds**.

Most candidates appreciated the **relative sizes of the mRNA molecule and nucleus** and were able to develop appropriate explanations.

pre-mRNA is compacted in the nucleus through a combination of RNA-binding proteins, ribonucleoprotein complexes, association with the nuclear matrix and chromatin, and the assembly of the splicing machinery. [2]

self-folding of pre-mRNA in the nucleus plays a significant role in compacting the molecule. This folding is a dynamic process that is influenced by the RNA sequence, the presence of RNA-binding proteins, and the ongoing processes of transcription and splicing.

(iii) The *DMD* pre-mRNA molecule is processed to form a molecule of mRNA. During processing of the pre-mRNA molecule, over 70 sections of RNA called introns are removed. The remaining sections of RNA are combined back together to form a molecule of mRNA, which is then translated.

Explain how processing of the *DMD* pre-mRNA can result in the formation of a number of different functional proteins.

1. [state process] **Alternative splicing** occurs where **introns** and one or more **exons** are removed, then **exons flanking introns are joined** together.
2. producing **different mature mRNAs with different combinations of exons** from the **pre-mRNA**, translation results in different proteins from different mRNAs as templates.
3. translation produces polypeptides with **different amino acids sequences,** which **fold differently** to produce proteins with **specific 3D conformations** hence different functions. [2]

Many candidates found this question challenging and suggestions were often incomplete. Some candidates incorrectly considered permutations for the mRNA that included the sections of RNA that had been removed

Easy: 2, Moderate: 7, Challenging: 2 [Total: 11]

5 COVID-19 and influenza flu are both contagious respiratory illnesses caused by different viruses. COVID-19 is caused by infection with a coronavirus, SARS-CoV-2, first identified in 2019. Flu is caused by infection with an influenza virus.

Fig. 5.1 shows the structures of the SARS-CoV-2 and influenza virus respectively.

Both **S** and **HA** are glycoproteins embedded in the viral envelope of the respective viruses and serve the same function. SARS-CoV-2 has an RNA genome that can be directly translated for viral proteins production.

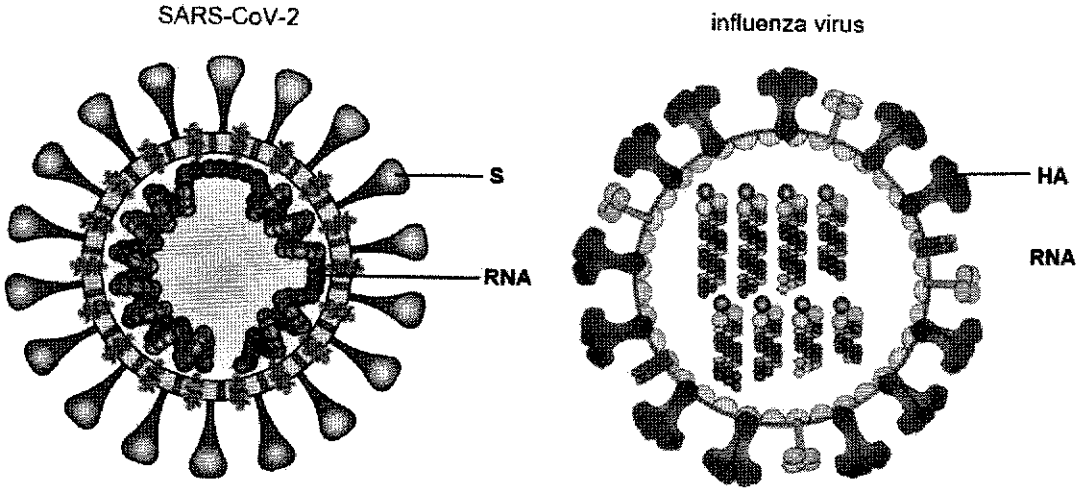


Fig. 5.1

(a) State the full name of glycoprotein **HA** and describe its function in influenza virus.

1. **Haemagglutinin**
2. Binds to **specific sialic acid receptors** on host cell membrane for **attachment/adsorption**

[2]

(b) Other than the structures found on the viral envelopes, describe two **other** differences in the structures of SARS-CoV-2 and influenza virus.

Feature	SARS-CoV-2	influenza virus
Type of RNA genome	positive sense RNA	negative sense RNA
Structure of nucleic acid	1 single molecule	8 segments A: 8 molecules
Association of RNA polymerases with segmented genome	Absent	Present (3 circles)

[2]

Fig. 5.2 shows part of the reproductive cycle of SARS-CoV-2 virus.

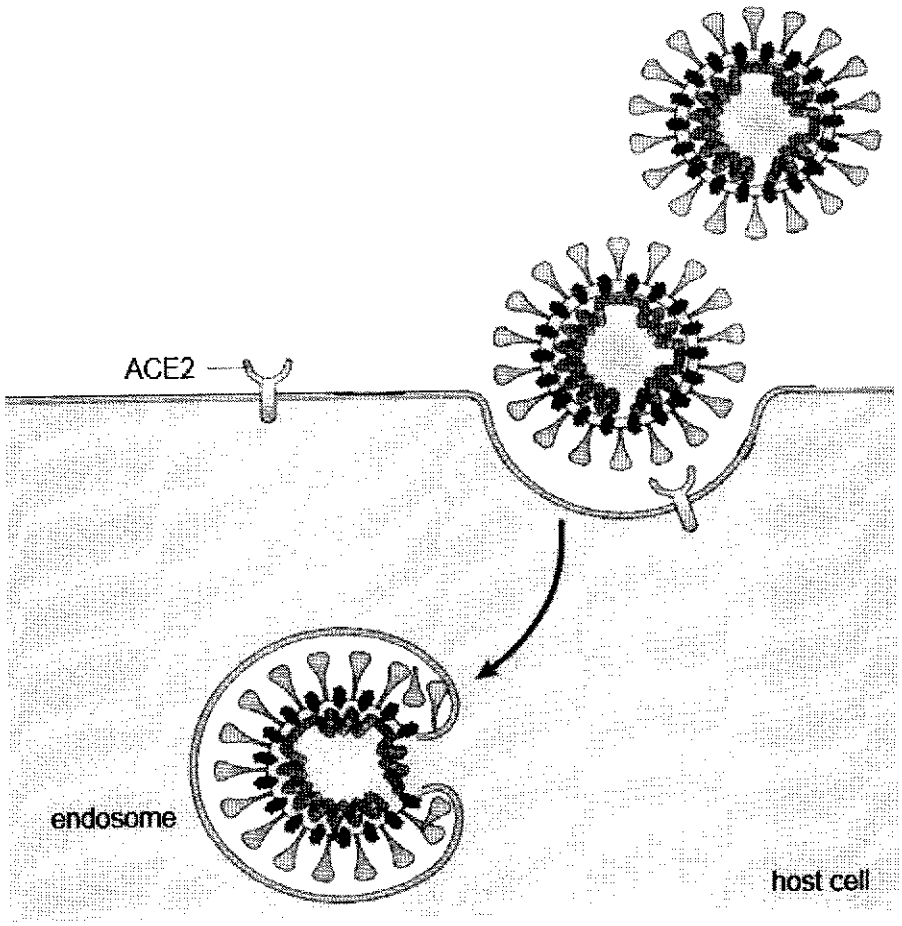


Fig. 5.2

(c) Describe how the SARS-CoV-2 virus enters a host cell.

1. S glycoprotein binds to specific receptors ACE2 on host cell membrane that are **complementary in shape**
2. Virus is taken into host cell via **receptor-mediated endocytosis**
3. **Host cell membrane invaginates** and **entire virus is enclosed** within an endosome
4. **Viral envelope fuses** with the **membrane** of the endosome
5. To result in the **release of nucleocapsid into the cytoplasm** of the host cell [3]

There are at least three variants of the SARS-CoV-2 since its discovery in 2019.

Similarly, there have been many different reported strains of influenza viruses with variation in their viral genome. It is also common for a particular strain of influenza to re-emerge after a few years. An example is the H7N9 strain that first infected humans with low pathogenicity in 2013 but re-emerged four years later in 2017 as a strain with high pathogenicity, as shown in Fig. 5.3.

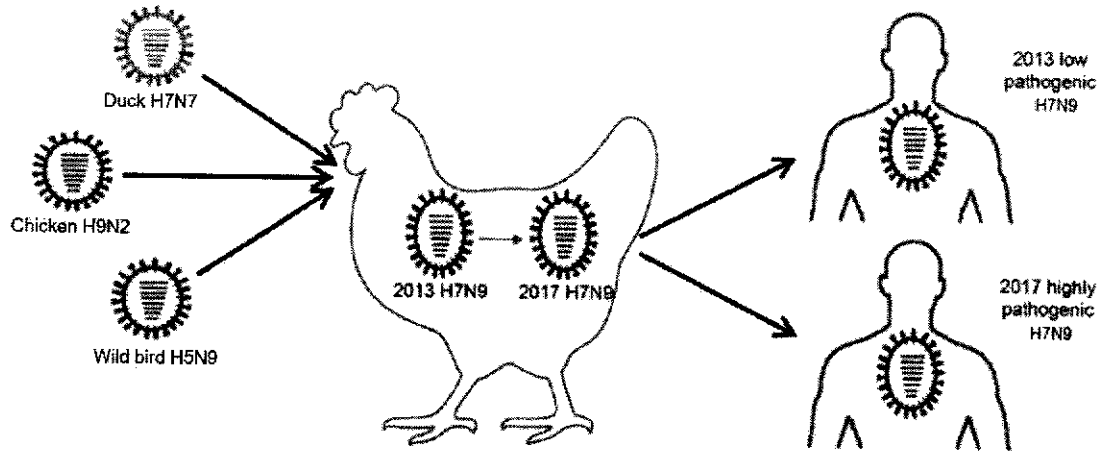


Fig. 5.3

(d) With reference to Fig. 5.3, describe how variation in viral genomes arose and led to the formation of two H7N9 strains with different pathogenicity in humans.

Formation of 2013 H7N9 (low pathogenicity)

1. Ref. to **antigenic shift**
2. where **three different strains of influenza viruses** (H7N7, H9N2 and H5N9) **infected the same chicken host** at the **same time**.
3. **Reassortment/recombination of 8 segments** of influenza virus genome in **one capsid** within host **cell** (that results in a new strain of H7N9 with different HA and N antigens from the three initial strains).
4. Ref to segmented genome with **H7** gene from **duck** + segmented genome with **N9** gene from **wild bird**

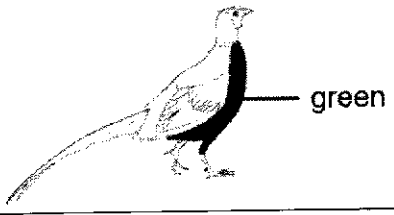
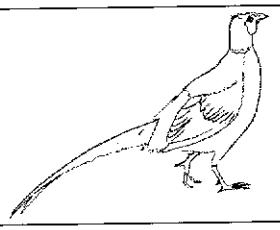
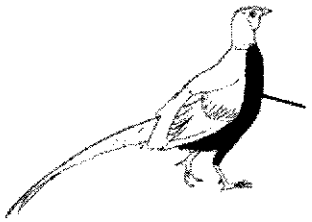
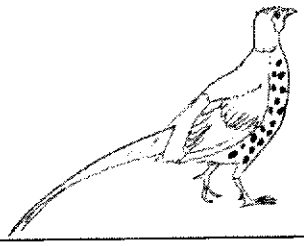
Formation of 2017 H7N9 (high pathogenicity)

5. Ref. to **antigenic drift**
6. **Gradual accumulation of mutations** in HA and NA genes
7. Due to **lack of proofreading** mechanism of influenza's **RNA-dependent RNA polymerase**
8. Results in a **change of 3D conformation / shape** of glycoproteins that is **more complementary in shape/ has higher affinity** to the sialic acid receptors in human host cell membranes [5]

Easy: 4 , Moderate: 7, Challenging: 1 [Total: 12]

6 A pheasant species, *Phasianus colchicus*, also known as ring-necked pheasant, has individuals with four feather colour patterns, as shown in Table 6.1.

Table 6.1

phenotype	feather colour patterns
green	
white	
green with black spots	
white with black spots	

Two unlinked genes determine the feather colour patterns shown in Table 6.1.

One gene controls whether the feather colour is green or white:
- dominant allele **G** = green
- recessive allele **g** = white.

The other gene controls whether black spots are present or not present:
- dominant allele **B** = with black spots
- recessive allele **b** = without black spots.

In birds, the sex chromosomes are referred to as **W** and **Z**, rather than **Y** and **X** as in mammals.

In *P. colchicus*:

- the heterogametic sex is the female
- males have two **Z** chromosomes and females have an **Z** and a **W** chromosome
- the gene that controls feather colour is located on the **Z** chromosome

- the gene that controls whether black spots are present or not is located on an autosome.

Genetic crosses were carried out to investigate the inheritance of the four different feather colour patterns.

Males that were green with black spots, and homozygous at both loci, were crossed with females that were white. The F1 offspring were all green with black spots.

These F1 offspring were then crossed to produce the F2 generation.

(a) Draw a genetic diagram to show the predicted feather colours of the F2 generation from F1 generation.

Insert the symbols for the alleles of the gene that controls feather colour as well as the alleles of gene that controls whether black spots are present or not.

key to symbols

allele coding for green feather colour	
allele coding for white feather colour	
allele coding for presence of black spots	
allele coding for absence of black spots	

genetic diagram showing the predicted feather colours:

F1 phenotype: Green male with black spots X Green female with black spots

F1 genotype: Z^GZ^g **Bb** X Z^GW **Bb**

gametes: Z^G **B**, Z^G **b**, Z^g **B**, Z^g **b** / Z^G **B**, Z^G **b**, **WB**, **Wb**

Punnett square:

	$Z^G B$	$Z^G b$	WB	Wb
	$Z^G Z^G$ BB	$Z^G Z^G$ Bb	$Z^G W$ BB	$Z^G W$ Bb
$Z^G B$	male green + black spots	male green + black spots	female green + black spots	female green + black spots
	$Z^G Z^G$ Bb	$Z^G Z^G$ bb	$Z^G W$ Bb	$Z^G W$ bb
$Z^G b$	male green + black spots	male green	female green + black spots	female green
	$Z^G Z^g$ BB	$Z^G Z^g$ Bb	$Z^g W$ BB	$Z^g W$ Bb
$Z^g B$	male green + black spots	male green + black spots	female white + black spots	female white + black spots
	$Z^G Z^g$ Bb	$Z^G Z^g$ bb	$Z^g W$ Bb	$Z^g W$ bb
$Z^g b$	male green + black spots	male green	female white + black spots	female white

[4]

1m – F1 phenotype + correct F1 genotype (no ecf/ no marks for symbol table)
1m – correct gametes (can ecf)
1m – correct Punnett square (only require circled gametes + genotypes) (can ecf)
1m – link genotype to phenotypic ratio

genotypes	phenotypic ratio
$Z^G Z^G$ Bb, 2 $Z^G Z^G$ Bb, 2 $Z^G Z^g$ Bb, $Z^G Z^g$ BB	6 male green with black spot
$Z^G W$ BB, 2 $Z^G W$ Bb	3 female green with black spot
$Z^G Z^G$ bb, $Z^G Z^g$ bb	2 male green
$Z^G W$ bb	1 female green
$Z^g W$ BB, 2 $Z^g W$ Bb	3 female white with black spot
$Z^g W$ bb	1 female white

1m – accept 9:3:3:1 ?

(b) Further analysis of the results from the F2 generation showed that there were no white males or white males with black spots.

Explain why there are no white males or males that are white with black spots in the F2 generation.

- no allele on W chromosome/ only Z^G is present in the gametes in female parent / allele g only exists on the Z chromosome (in gametes of male parent) ;
- (so all) males will inherit only inherit dominant green allele / allele G (on the Z chromosome) from maternal parent/ W chromosome will only be inherited by female offspring;
- (so) no matter what the male offspring inherit from the male parent, Z^G or Z^g , there is at least one Z^G allele/ Z^G allele can mask the effect of Z^g allele, thus male will always be green.

[2]

(c) Table 6.2 compares the observed numbers with the numbers that would be expected in the F2 generation for a normal dihybrid ratio.

Table 6.2

phenotype	observed	expected	$O - E$	$(O-E)^2$	$\frac{(O-E)^2}{E}$

green with black spots	279	281.25			
white with black spots	95	93.75	1.25	1.5625	0.017
green	96	93.75	2.25	5.0625	0.054
white	30	31.25			
				χ^2 = ...	

(i) Calculate χ^2 for the F2 generation by completing Table 6.2.

The formula for χ^2 is:

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

[2]

phenotype	observed	expected	$O - E$	$(O-E)^2$	$\frac{(O-E)^2}{E}$
green with black spots	279	281.25	**-2.25**	**5.0625**	**0.018**
white with black spots	95	93.75	1.25	1.5625	0.017
green	96	93.75	2.25	5.0625	0.054
white	30	31.25	**-1.25**	**1.5625**	**0.05(0)**
				0.139/ 0.14	

(ii) The critical value at p = 0.05 and 3 degrees of freedom is 7.815.

Comment on whether the null hypothesis should be rejected.
any two from:

- **do not reject** null hypothesis/ (reject: accept null hypothesis)
- $\chi 2$ value / 0.139 / 0.14, is **lower** than, the critical value / 7.815 ;
- the observed numbers are **not significantly different** to the expected numbers, at p = 0.05) / any **differences are due to chance** ;
- allow ecf from 5(a)

[2]

Easy: 3 , Moderate: 4, Challenging: 2 [Total: 10]

7 The banana plant, *Musa acuminata*, is a tall herbaceous plant with very large leaves.

(a) Like all other plants, chlorophyll *a* is the main photosynthetic pigment in banana plant chloroplasts.

(i) Name two **other** photosynthetic pigments found in plant chloroplasts.
1. chlorophyll b / carotene / xanthophyll / carotenoids (any two) [1]

(ii) Describe the role of other photosynthetic pigments found in plant chloroplasts.
1. act as accessory pigments that absorb light / photons
2. pass energy on to specialised chlorophyll a in the reaction centre of light harvesting complex/photosystem
3. absorb different wavelengths of light / wavelengths not absorbed by chlorophyll a [2]

(b) The absorption of different wavelengths of light by photosynthetic pigments can be represented by an absorption spectrum.

Fig. 7.1 show both the absorption spectra of an extract containing all photosynthetic pigments obtained from banana leaves and another extract containing whole chloroplasts obtained from banana leaves of the same mass.

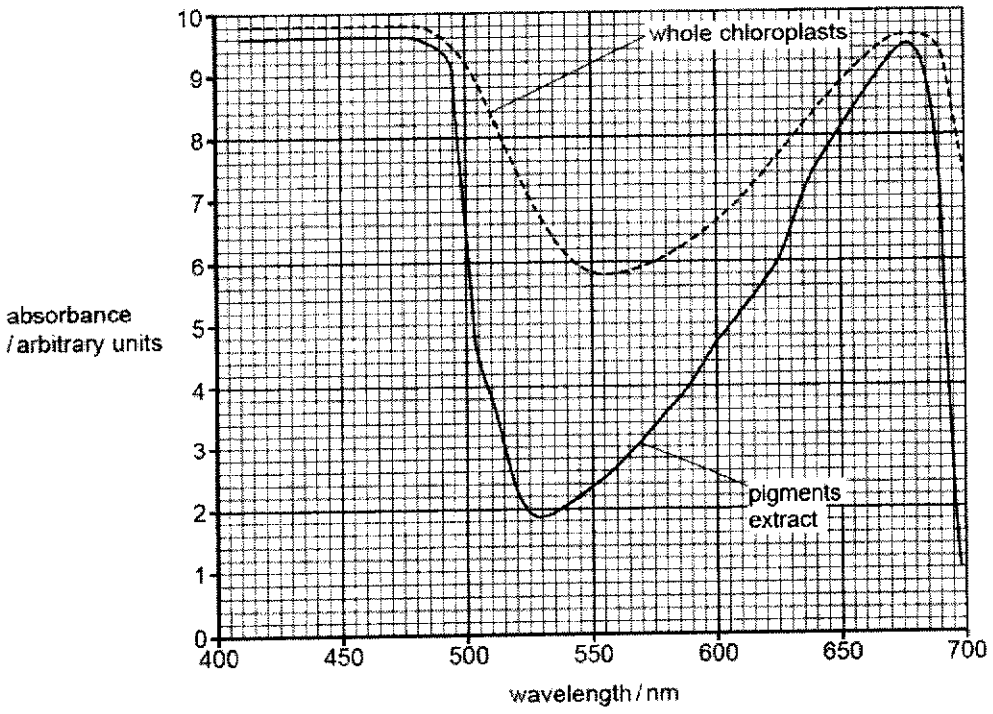


Fig. 7.1

With reference to Fig. 7.1, describe the differences between the two spectra **and** suggest explanations for the differences.

Differences (max 2)

1. absorption is higher for whole chloroplasts than pigment extract for all wavelengths of light
2. quote comparative data at one specified wavelength (see table below)

wavelength / nm	absorbance / au ±0.05	
	whole	pigment
500	9.2	6.4
510	8.4	3.8
520	7.4	2.3
525	7.0	1.95
530	6.6	1.85
540	6.2	2.05
550	5.8	2.35
560	5.8	2.7
600	6.65	4.7
650	8.85	8.1
670	9.6	9.2

3. greatest difference in absorption at 525 / 530 nm

Explanation (max 2)

4. ref to arrangement of pigments in chloroplasts allow for better absorption in chloroplasts / **thylakoid membranes are stacked**
5. idea of whole chloroplasts **containing more pigments due to increased surface area:volume ratio for embedment of more pigments** while
6. AVP: extraction process of pigments from banana leaves might not be effective to extract all pigments.

[3]

An investigation was carried out to measure the net carbon dioxide uptake by a banana plant at different light intensities.

Fig. 7.2 shows the results of the investigation.

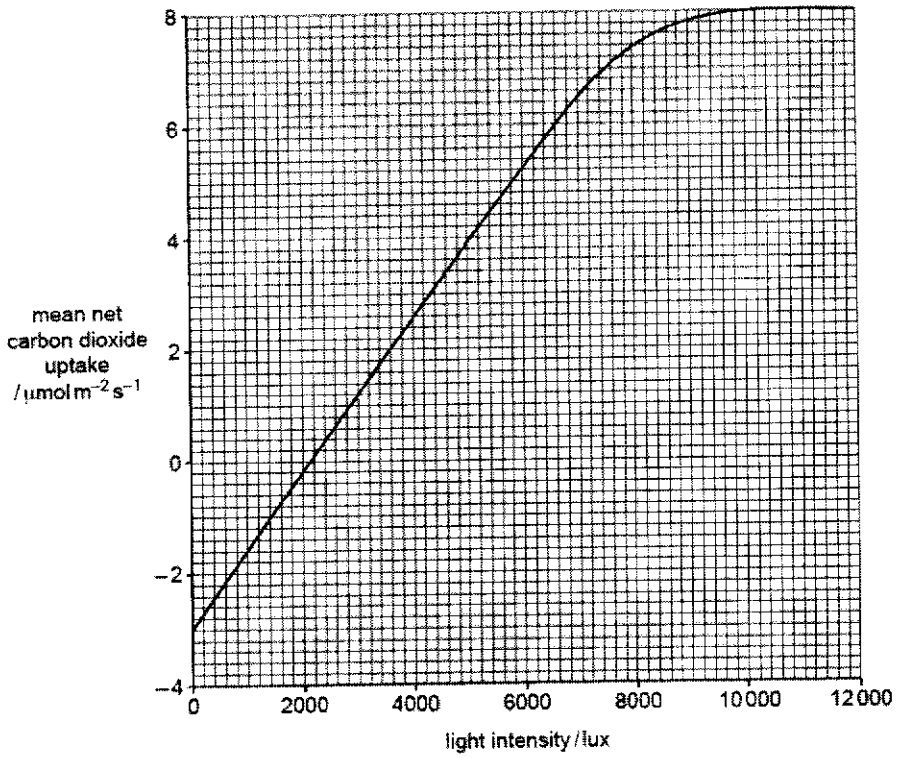


Fig. 7.2

(c) With reference to Fig. 7.2, explain the significance of the two reference points on the growth of the banana plant.

Light compensation point .....

1. At light intensity of **2100 lux**, mean net carbon dioxide uptake is 0 μmol m^{-2} s^{-1}
2. Idea that **rate of respiration equals rate of photosynthesis** at compensation point,
3. rate of **glucose** used as respiratory substrate equals **rate of production from photosynthesis -> no net change growth**.

Light saturation point .....

4. As light intensity further increases from **10 000 lux to 12 000 lux** / Light saturation point is reached at 10 000 lux, mean net carbon dioxide uptake reaches a maximum of 8 μmol m^{-2} s^{-1}
5. light intensity is no longer limiting / carbon dioxide concentration or temperature now limiting
6. **Highest rate** of photosynthesis (that is higher than rate of respiration) / **highest rate** of production of glucose -> **highest increase in growth** *[award once idea of glucose production leading to biomass]*

[4]

Easy: 3, Moderate: 4, Challenging: 3 [Total: 10]

8 The epidermal growth factor receptor (EGFR) signaling pathway is one of the most important pathways that regulate growth in mammalian cells.

Fig. 8.1 shows the epidermal growth factor (EGF) binding to EGFR on the surface of a cell.

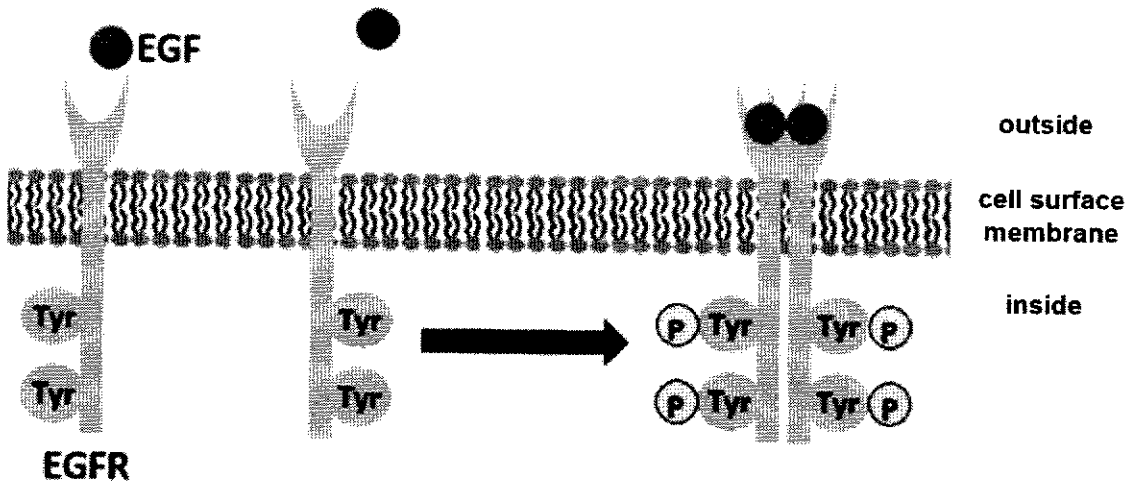


Fig. 8.1

(a) A specific region on each EGFR functions as an enzyme.

State the full name of the enzyme found on EGFR **and** describe, as precisely as possible, the reaction catalysed by the enzyme.

1. Tyrosine kinase

2. **Phosphorylation/** tyrosine kinase (region on one receptor) add a **phosphate group** from an **ATP molecule**
3. to the **other** receptor at the **tyrosine residues** (on their intracellular tail) [3]

(b) Explain why it is important that EGFR completely spans the cell surface membrane.

At least 1 about outside of cell
1. allow binding of the **EGF** at the **extracellular binding site**

2. This is because EGF is too **large (accept polar)** → Cannot pass through **small transient pores**
   OR EGF is **hydrophilic** → cannot pass/ diffuse through **hydrophobic core** of the membrane

3. Can cause the two EGFR to **dimerise** (to fully activate EGFR)

At least 1 about inside of cell
4. Binding/ dimerization resulting in (tyrosine kinase) **intracellular** region of the EGFR to be activated to activate relay proteins / phosphorylationcascade /

5. Allowing **signal to be relayed to** the **inside** of the cell [3]

(c) A group of scientists investigated the effect of altering EGFR activity on embryonic stem cells (ESCs) in mice.

Suggest how the scientists obtained mouse ESCs.

Any 1

1. Extract **egg cells** (from female mice) and **sperm cells** from (male) mice
2. **Fuse/ fertilise** the egg cell with sperm cell **outside of the body/ in-vitro/ in culture**

Compulsory point

3. extract out the **inner cell mass of the blastocys**

[2]

Easy: 6, Moderate: 2, Challenging: 0 [Total: 8]

9 The puma, *Puma concolor*, lives in America.

Fig. 9.1 shows a puma.

Fig. 9.1

(a) There are many subspecies of puma found in America. Members of different subspecies belong to the same species but have some morphological differences and are found in different geographical locations.

Explain how the different subspecies of puma evolved.

Any 3

1. idea of ancestral puma population colonizing different environments/ecological niches in different parts of North American providing **different selection pressure.**
2. dea of **adaptation** to their own environment: / different **traits** was selected in different environment / different **individuals** (idea of different traits) are selected for
3. **natural selection/ genetic drift occurs independently** as each population of birds **accumulate their own mutations / gene pools diverge/allele frequency are altered differently**
4. (independent because) **geographical isolation/ geographical barriers** between the puma occur → **no/ reduced gene flow** between each population

[3]

(b) Two subspecies of puma, Florida panther and Andean mountain lion were studied. The Florida panther is critically endangered, while the Andean mountain lion is considered to have a much larger population.

Table 9.1 compares the features of two subspecies.

Table 9.1

feature	Florida panther (*Puma concolor coryi*)	Andean mountain lion (*Puma concolor puma*)
habitat	woodlands and swamps	Andes mountains
body mass	males ~50-72 kg, females ~29-45 kg	males ~60-100 kg, females ~40-64 kg
body length	males ~1.8-2.2 m, females ~1.6-1.9 m	males ~2.0-2.8 m, females ~1.8-2.4 m
incidence rate of tail kink (a small bend or twist on one of the tail vertebrae)	25-30%	below 1%

The production of differences in phenotypes between the Florida panther and the Andean mountain lion can be due to natural selection or genetic drift.

Based on the information in the question and your own knowledge, complete Table 9.2 to :

- show whether body size (mass and length) and presence of tail kink is due to natural selection or genetic drift,
- explain your answer

Table 9.2

mechanism	phenotype (write **body size** or **tail kink**) 1m	Explanation 5m
natural selection	body size	Quote data 1. Andean mountain lion has **larger/heavier** body mass and **longer** body length compared to Florida panther: quote data 29 to 72 kg, 1.6 to 2.2m versus 40 to 110kg , 1.8 to 2.8m Accept converse Having larger size in colder habitat / smaller size in warmer habitat is a **selectively advantage** 2. Larger size means more fat reserves/ to keep warm / Need to be larger and stronger to withstand the harsh cold conditions? (reject vague) Accept larger body size for conservation of heat 3. Larger animals have a lower surface area-to-volume ratio compared to smaller animals. This means they lose heat more slowly and retain warmth better, 4. Smaller animals may be able to find and use cooler microhabitats more easily, such as burrows or shaded areas. 5. small animals They might also have lower metabolic rates relative to their size, which can help them manage the heat better.

genetic drift	tail kink	Quote data 1. Florida panther has higher incidence rate of tail kink compared to florida : quote data 25-30% versus below 1% Accept converse 2. presence of tail kinks is not **adaptive** in nature/ does not provide **selectively advantage** or disadvantage / **not important for survival** 3. The higher incidence rate of tail kinks in Andean mountain lion is due to genetic drift where **random changes** in allele frequencies in **small** population from one generation to the next due to **chance** event 4. Change occur by due to **chance** events / Causing **allele encoding tail kink** to be higher **by chance**

[6]

(c) Hybridisation has been observed between individuals of different subspecies of puma. The hybrid populations show high reproductive success.

Suggest how the hybrid populations are different from the pure subspecies in terms of genetic variation and potential to adapt to climate change.

Max 2 from

1. (hybrid populations have) **more, genetic variation / alleles**
2. Idea of more potential to **adapt** to climate change
3. Since they contain genes) / alleles/ t of **both (parent) species**

Hence population / more likely to have genes/ phenotypes related

4. Related to heat tolerance/ drought tolerance / being more nocturnal to avoid higher daytime temperature / ability to effect diet change due to shift in ranges of prey / spatial awareness for migration to new territory

[3]

Easy: 4 , Moderate: 5, Challenging: 3 [Total: 12]

10 Tuberculosis (TB) is an important disease worldwide. Despite being preventable and treatable, TB remains one of the top infectious disease killers globally.

(a) Name the pathogen that causes TB.

Mycobacterium tuberculosis [1]

(b) When the TB bacterial pathogens enter the lungs, they are rapidly engulfed by macrophages. Eventually, granulomas (tubercles) may form.

Describe the events that occur from the ingestion of the pathogen to the formation of granulomas.

1. Inside phagosome, *M. tuberculosis* inhibits **fusion of phagosome/phagocytic vesicle with lysosome/**
2. *M. tuberculosis* then **reproduce/divide/ multiply** (by binary fission inside the macrophages)
3. (accept if infront mention macrophages) The infected macrophages releases **cytokines and/or chemokines**, triggering **inflammation / recruit immune cells (accept more macrophages) (to site of infection)**
4. Over time, the **clustering (reject accumulation, accept surround) of immune cells** (around infected macrophages/ pathogen) (if did not say immune cells then must give at least 2 examples including neutrophils, dendritic cells, T and B cells, etc.) forms a **tubercle/ granuloma**

[3]

Easy: 1, Moderate: 3, Challenging: 0 [Total: 4]

11 Pteropods are small free-swimming snails found in oceans throughout the world.

They are a food source for a variety of fish including salmon, mackerel and herring. In 2011, the health of these snails was studied in the oceans surrounding Hawaii .

A sample of these snails showed that many of them had damaged shells. Fig. 11.1 shows a healthy snail and a snail with a damaged shell found in the oceans surrounding Hawaii.

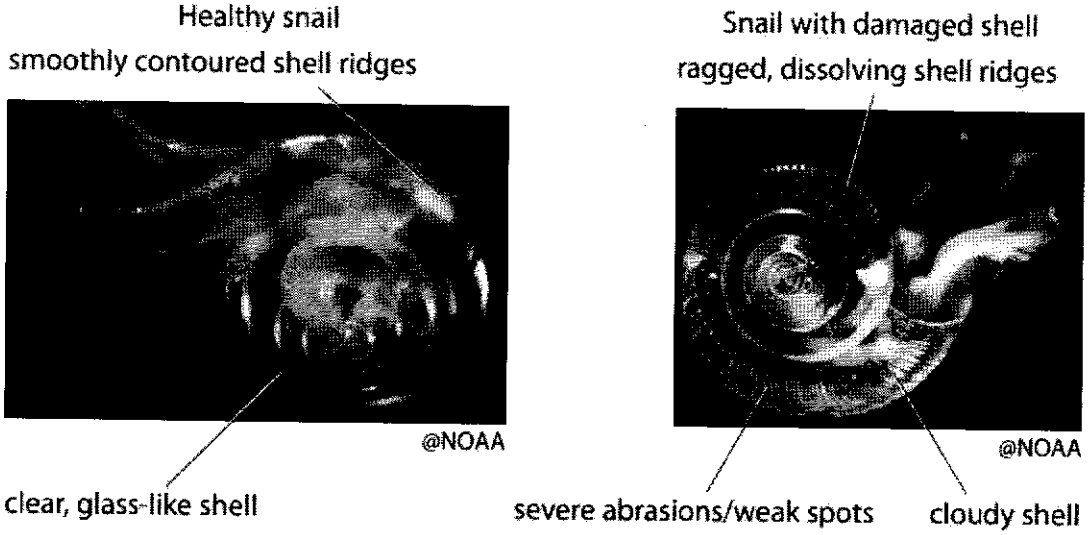


Fig. 11.1

The pH of sea water affects calcium-rich shell formation in these snails. The changes in carbon dioxide concentration and pH have been recorded in oceans surrounding Hawaii island as shown in the Fig. 11.2.

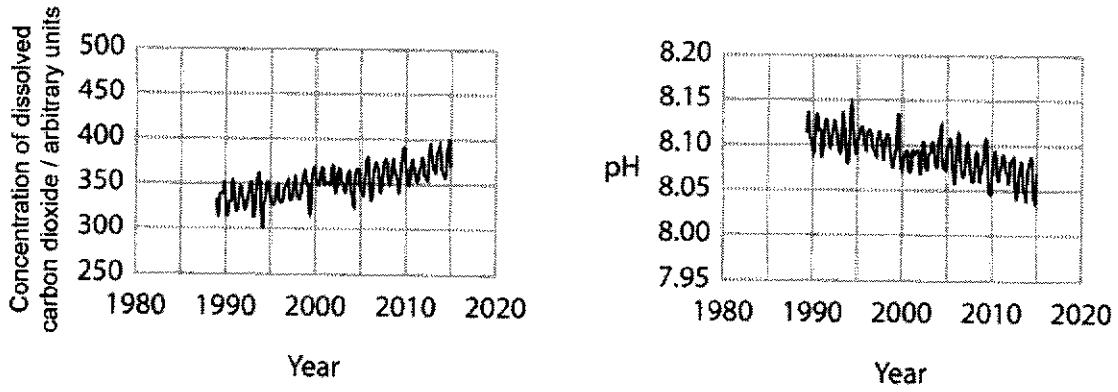


Fig. 11.2

(a) With reference to Fig. 11.2, explain the relationship between increased carbon dioxide emissions and the pH of the oceans.

- *(explain relationship between CO2 in atmosphere and CO2 in ocean)* increased carbon dioxide emissions → **increase** carbon dioxide in the **atmosphere** thus **increases carbon dioxide dissolves/absorbed in the oceans → reduction in pH**/ higher the acidity [2]
- *(describe data)* Concentration of dissolves carbon dioxide increased from 325a.u. in 1989 to 375 a.u.in 2015, pH decreases from 8.125 in 1989 to 8.05 in 2015.

(b) Using the information provided in this question, suggest the impact of change in ocean pH on fish populations.

- higher acidity dissolves the shell structure faster than they form→ increases the percentage of snails with damaged shells
- Snails spend a lot of energy trying to repair their shells, thus aren't able to put that energy into growth or reproduction →
- These snails will not survive/ decrease in population of snails therefore less food available for fish / impact on food chains and food webs in the oceans → Therefore reduction in fish populations
- (accept) There may be an initial increase in fish population due to snails becoming more vulnerable to predation

[3]

Easy: 2, Moderate: 2, Challenging: 1 [Total: 5]