YISHUN INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAM
Higher 2

NAME **ANSWERS**

INDEX NO | CG

BIOLOGY 9744/02

Paper 2 Structured Questions **9 SEPTMBER 2025**

Candidates answer on the Question Paper. **2 hours**

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, index no. and CG on this cover page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer all questions in the spaces provided on the Question paper.

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.

The number of marks is given in brackets [ ] at the end of each question or part question

At the end of the examination, **submit booklets A, B and C separately** to the invigilator.

For Examiner's Use	
Section A	
1	
2	
3	
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6	
7	
8	
9	
10	
11	
Total	**100**

This document consists of **23** printed pages and **1** blank page.

Answer **all** questions.

1 The uptake of glucose and the nutrient coupled transcellular ions traffic across epithelial cells in the small intestine has been an ongoing topic in physiological research.

Fig. 1.1 shows how protein A and protein B work together for the uptake of glucose across the cell surface membrane.

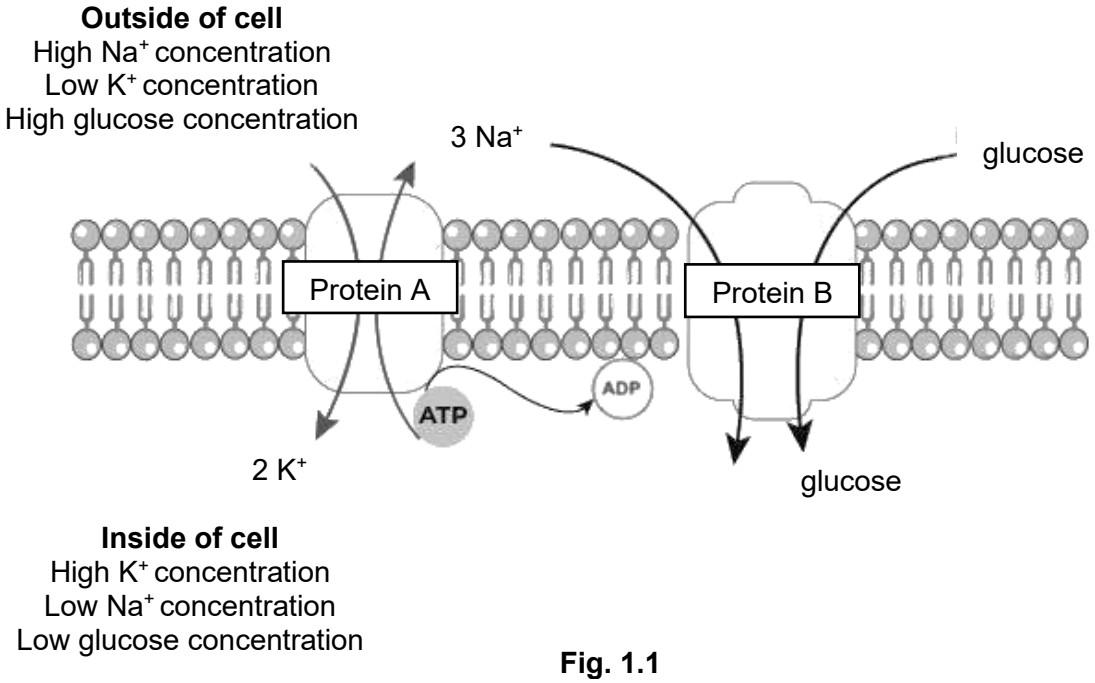

Fig. 1.1

(a) With reference to Fig. 1.1,

(i) identify Protein A

Sodium Potassium Pump (Na^+–K^+ pump) or protein pump / transport protein / carrier protein / channel protein [1]

Examiner's Comment:

As Fig 1.1 does not provide sufficient information to conclude it is ATP pump. Transmembrane and integral protein are rejected as these answers are too vague in comparison to the information provided.

(ii) describe how glucose enters the cell

1 ***(Idea of ATP Hydrolysis):*** **Protein A facilitate the movement of K^+ and Na^+ through the cell membrane**

where ATP is used /converted to ADP

2 ***(Idea of ion concentration gradient):*** **A concentration gradient is created where there is more Na^+ outside of the cell and more K^+ within the cell**

3 ***(Idea of simple diffusion of glucose):*** **Na^+ will enter the cell with glucose via protein B** [3]

(R) chemiosmosis, no ATP is generated.
(R) concentration gradient of glucose
(R) if student identify wrongly: i.e. W – potassium and X – sodium.
Max:1mark

Examiner's Comment:

Many students failed to refer to Fig1.1 to explain how glucose is brought into the cell, regurgitation of content resulted in the lost of marks.

(b) Glucose may be used for the synthesis of secretory glycoproteins.

Explain how such glycoproteins are made within the cell and secreted by the cell.

1 Glucose enters the cell via facilitate diffusion /active transport and made its way to the rER

2 Ribosomes attached to RER synthesised polypeptide chain by joining amino acids via peptide bond (idea of translation)

3 Polypeptide folds into 3D structure and undergoes initial glycosylation

4 Short chains of glucose/ oligosaccharides attached covalently to protein to form glycoprotein

5 The glycoproteins are packaged into rER / transport vesicles which pinch / bud off from the rER, transport to Golgi apparatus

6 The rER / transport vesicles transported to Golgi apparatus and fuse with the cis face of the Golgi apparatus,
where the glycoproteins undergo further chemical modification and processing as they move from cis to trans face;

7 Glycoproteins are packaged into secretory vesicles which bud off from the trans face

8 transported to the cell surface membrane via microtubules;

9 Golgi vesicles then fuse with the cell surface membrane to release the glycoproteins via exocytosis;

Any 5 of the 9 marking points

[5]

[Total: 9]

2 Laccase, a copper-containing enzyme, catalyses the formation of lignin in plants. The copper atoms within the laccase enzyme are essential for its catalytic activity, accepting electrons from the substrate and transferring the electrons to monolignols.

Fig. 2.1 is a diagram of the mode of action of laccase.

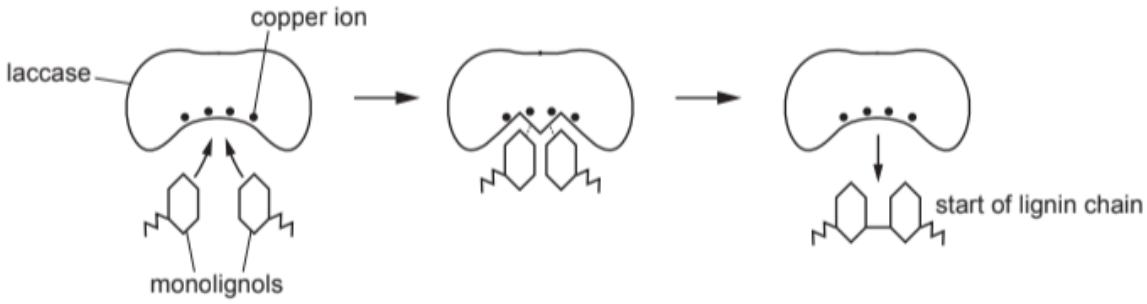

Fig 2.1

(a) Describe and explain the mode of action of laccase when catalysing the formation of lignin.

1 ***Laccase has an active site with a specific 3D shape (lock and key hypothesis) that binds to monolignol substrates***
OR active site 3D shape will change to fit substrate (induce fit hypothesis)

2 ***Substrates bind to the active site,***

forming an enzyme–substrate complex through temporary interactions

3 ***Laccase facilitates oxidation & reduction (redox) reactions***

by transferring electrons using copper

4 ***This results in the formation of bonds between monolignols***

OR initiation the polymerisation of monolignols into lignin chains;

5 ***Laccase remains unchanged at the end of the reaction***

and can catalyse further reactions;

6 ***This reaction lowers the activation energy***

required for lignin formation and increases the rate of reaction; [5]

Any 5

Examiner's Comment:
Many students interpret the copper ion as a contact residue rather than a catalytic residue.

Copper ion is responsible for the catalysis for bond formation rather than the change in conformation of active site for induced fit hypothesis.

Checkpoint 1

Identify the mechanisms by which enzymes lower the activation energy of a reaction.

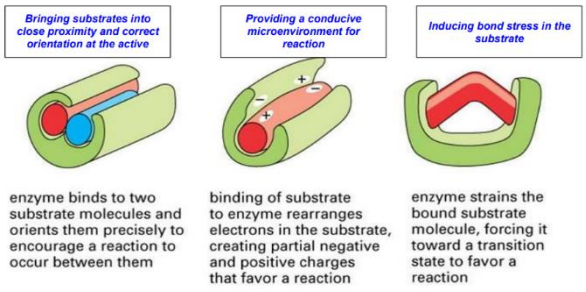

Fig. 3.10: Mechanisms to lower activation energy

In a recent study, researchers investigated how environmental pH affects the activity of laccase extracted from two plant species, *Species A* and *Species B*. The results are shown in Table 2.

Table 2. Laccase activity at different pH levels (arbitrary units)

pH	3	4	5	6	7	8
Species A	5	12	20	14	7	2
Species B	4	9	13	18	20	19

(b) Explain why the activity of laccase is lower at pH 3 and pH 8 for *Species A*.

1 At pH 3 and 8, the H^+ or OH^- ions disrupt ionic and hydrogen bonds in the laccase enzyme;

2 This alters the 3D shape of active site/ enzyme is denatured reducing E+S complexes/ substrate binding and thus enzyme activity; [2]

(c) Using Table 2, suggest and explain which species is likely to have a laccase adapted to alkaline conditions.

1 Species B is likely to have laccase adapted to alkaline conditions

2 Its enzyme activity remains high at 18 to 20 arbitrary units between pH 6 and 8, with an optimum at pH 7;

3 Species A shows a sharp drop in activity from 20 to 2 arbitrary units beyond its acidic optimum at pH 5

Marking point 1 + 2 or 3 [3]
If marking point 2/3 is present without data, 1 mark is given

Examiner's Comment:
Some student failed to identified an alkaline condition is above pH 7. There is also a lack of proper comparative data between A and B at the same pH.

[Total: 10]

3 Vinblastine is a chemotherapy drug used to treat cancers such as lymphoma and breast cancer.

It works by binding to tubulin, preventing the formation of microtubules, which are essential for the formation of the mitotic spindle.

Researchers investigated the effect of Vinblastine on the mitotic cell cycle of cancer cells.

Each group was treated with a different concentration of Vinblastine. After 24 hours (approximately one cell cycle, the percentage of cells in stages of mitosis was calculated.

Fig. 3.1 shows the percentage of cells in metaphase and anaphase.

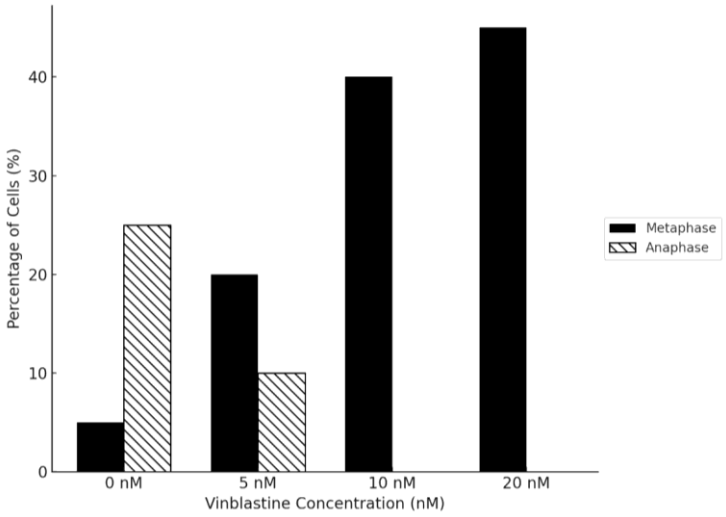

Fig 3.1

(a) **(i)** With reference to Figure 3.1, describe the effects of Vinblastine on mitotic cells.

1. **At 0 nM Vinblastine, there are more cells in anaphase (25%) than metaphase (5%) ;**

2 **As the concentration increases from 0nM to 20 nM, the percentage of cells in metaphase increases from 5% to 45%, while the percentage in anaphase decreases to 0%.**

[2]

Examiner's Comment:
Many students did not manage to get the description for MP1, which is a significant finding. Many focused on overexplaining MP2.

Students need to better structure their descriptions of data, focus on describing key findings rather than every single trend.

(ii) Explain your observations in (a)(i)

1. **Vinblastine prevents the formation of the mitotic spindle**
2. **Chromosomes cannot align properly at the metaphase plate**
3. **Spindle assembly/metaphase-anaphase/M-phase checkpoint is activated,**
4. **which prevents the separation of sister chromatids**
5. **Which causes cells to arrest in metaphase / cell arrest at metaphase and fail to enter anaphase.**

Any 4 of 5 marking points [4]

Examiner's Comment:
Many students did not manage to get MP 2 and 3, which involves the action of spindle fibre in metaphase and role of M checkpoint.

Students need to know that explain refers to using concepts they learnt to justify trends, such as processes in metaphase, anaphase and cell cycle checkpoints. Many just redescribe the data in (i) with a simple explanation that vinblastine block spindle fibre formation.

(b) Researchers are also investigating the effects of Vinblastine on meiosis in mice. As Vinblastine disrupts microtubule polymerisation, it also interferes with spindle fibre formation during meiosis.

At low concentrations, Vinblastine does not fully inhibit spindle fibre formation during meiosis, allowing some cells to proceed to anaphase. However, these cells often produce abnormal daughter cells.

(i) Describe what happens during anaphase in meiosis when Vinblastine is not present.

1. **Anaphase I: Homologous chromosomes are pulled to opposite poles of the cell by spindle fibres ;**
2. **Anaphase II: Sister chromatids are separated at the centromere and move to opposite poles.**

[2]

Examiner's Comment:
Many students did not include both anaphase I and II, seemingly forget that meiosis has two stages.

Students also did not use proper terms such as "homologous chromosomes" and "sister chromatids", giving vague terms such as chromosomes/chromatids.

(ii) Describe what happens during anaphase in meiosis when Vinblastine is present.

1. **Homologous chromosomes or sister chromatids fail to separate properly due to disrupted spindle formation (nondisjunction).** [1]

(R) Non-sister chromatids
(R) Bivalents
(BOD) Recombinant Chromosomes/ Chromatids

Examiner's Comment:
Students also did not use proper terms such as "homologous chromosomes" and "sister chromatids", giving vague terms such as chromosomes/chromatids. Bivalents are homologous chromosomes that are associated together. Should a bivalent be pulled, both chromosomes will be pulled together in the same direction.

Some students mention that daughter cells will not be formed. However, the preamble states that abnormal daughter cells will be formed.

(iii) Suggest a possible consequence to b(ii).

1. **Aneuploidy, i.e., the formation of gametes with an abnormal number of chromosomes** [1]

Examiner's Comment:
Many students did not manage to get the exact term "Aneuploidy" and gave a condition Down Syndrome/ Trisomy 21/ missing 1 chromosome instead.

Students need to understand that the preamble does not give sufficient information that the outcome will most definitely be Down syndrome, and Aneuploidy is a more accurate representation.

Many students wrote polyploidy. Students fail to realise that nondisjunction leads to unequal distribution of the chromosomes, and not the creation of an entire set of chromosomes. Moreover, polyploidy mainly occurs in plants, not animals.

[Total: 10]

4 Bacteriophages can act as vectors of gene transfer between bacteria, which increases genetic diversity.

Fig. 4.1 represents the two reproductive cycles that the lambda phage viruses can carry out.

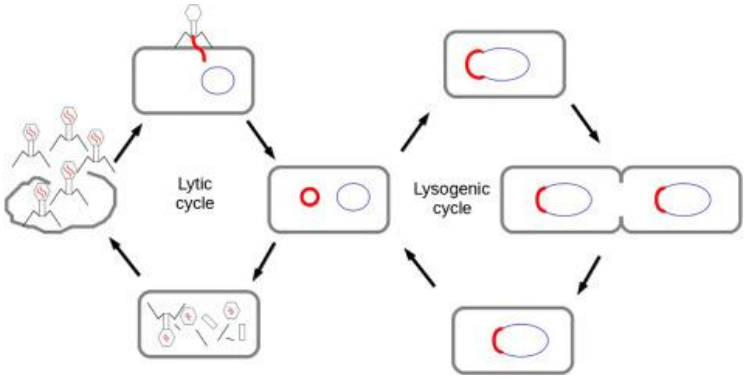

Fig 4.1

Bacteria cells which can metabolise galactose are known as gal^+ strains. Their genome contains the gal operon.

Bacteria cells which are unable to metabolise galactose are known as gal^- strain.

In an experiment, researchers infected a gal^+ strain of E. coli with the lambda phage. After inducing the prophage to enter the lytic cycle, they collected phage particles from the lysed culture and used them to infect a gal^- strain of E. coli. Some of the gal^- bacteria were later able to grow on minimal medium containing galactose as the sole carbon source.

The lambda phage typically integrates its viral genome at a specific site on the E. coli chromosome, just adjacent to the gal operon, which is responsible for galactose metabolism.

(a) Describe how the lambda phase virus allows for horizontal gene transfer between different strains of bacteria.

1. **Specialised transduction where the lambda phage integrates as a prophage into host genome**
2. **Spontaneous induction resulted in incorrect excision of phage genome where host bacterial gene(s) adjacent to phage being excised together ;**
3. **Both phage and bacterial genes are wrongly packaged into the capsid of the phage resulting in transducing phages ;**
4. **Bacteria lyse, transducing/new phages attach to another host and injected bacteria DNA from first host into the second host;**
5. **which then integrates into new host's genome by homologous recombination;**
   (R) Generalised Transduction/Transformation/ Conjugation

[4]

Examiner's Comment:
Question is poorly done, with the lack of attempt by many students. Many are unable to name the process, specialised transduction.

Many students indicated that the lambda phage will undergo generalised transduction, which is unlikely since the lambda phage will integrate its viral genome into the host chromosome first. Hence any mention of the degradation of genome first will be rejected.

Many students confused the three processes of horizontal gene transfer together. Many starts with the bacteriophage injecting the viral genome, and subsequently the production of a sex pilus. Conjugation and Transformation does not require the presence of a bacteriophage.

Some confused generalised and specialised transduction when they mentioned that the viral genome is integrated to the bacteria genome during the lytic cycle.

Some students are confused between the genome.
- (R) Integration of bacterial genome into host chromosomes
- (R) Integration of viral genome into host plasmid

(b) Compare generalised and specialised transduction.

1. **S1: Both involve bacteriophages transferring bacterial DNA from one cell to another, increasing genetic variation.**
2. **S2: Both result in horizontal gene transfer and genetic variation**
3. **S3: Both involve incorporation of bacterial DNA into recipient cell by recombination**
4. **D1: In generalised transduction, any random fragment of host bacterial DNA can be transferred while in specialised transduction, only specific genes adjacent to prophage insertion site are transferred**
5. **D2: Generalised transduction occurs during the lytic cycle when phages package host DNA by mistake, vs Specialised transduction occurs during lysogenic cycle when prophage is excised incorrectly**
6. **D3: General transduction produces both a normal and transducing phage, while specialised transduction produces only a transducing phage.**

Any 1 from S1,S2,S3 + any 1 from D1,D2,D3 [2]

Examiner's Comment:
Many students forget that "Compare" requires both similarities and differences and are hence capped at only 1 mark.

Students are unable to identify that the specific genes excised for specialised transduction should be genes adjacent to prophage insertion site.

Many students mention that Generalised transduction involve the T4 phage, while specialised transduction involve the Lambda phage. However, this is too specific of a comparison. Generally, generalised transduction involves a virulent phage, while specialised transduction involves a temperate phage.

(c) The gal operon in E. coli contains genes that encode enzymes required for the breakdown of galactose.

In absence of galactose, the Gal repressor protein (GalR) binds to operator sites, forming a DNA loop that prevents RNA polymerase from binding and initiating transcription.

Using knowledge of the lac operon, state the type of regulation shown by the gal operon, and describe what happens when galactose is present in the cell.

1. **Negative Regulation (Repressor Protein is involved) / Inducible Operon (Operon can be switched on)**
2. **Galactose binds to gal repressor protein (GalR),**

   causing GalR to change into an inactive confirmation
3. **GalR cannot bind to operator,**

   operon is switched on / RNA polymerase can bind to promoter ;
4. **Structural genes of the gal operon are transcribed,**

   and translated to produced enzymes that metabolism galactose.

   (R) Positive Regulation

[4]

Examiner's Comment:

Many students indicate positive regulation. Positive regulation promotes genetic expression by an activator protein that increases gene transcription, while negative regulation suppresses it through a repressor protein that blocks transcription. A repressor protein, rather than a activator protein is present, hence it should be negative regulation.

Many students are confused between the binding site of the GalR and RNA polymerase. The repressor protein binds to the OPERATOR, while RNA polymerase binds to the PROMOTER.

Many students stop their explanation at transcription/ formation of transcription initiation complex. Students should include translation in for a full explanation.

Some students fail to understand the context, by mentioning

- Lac operon instead of Gal operon
- Production of enzymes that synthesize galactose instead of metabolising galactose

[Total: 10]

5 A student was task to investigate a segment of DNA using the Polymerase Chain Reaction (PCR).

(a) **(i)** State the number of the targeted DNA segments obtained after 18 cycles of the PCR.

2^{18} / 262144 [1]

(ii) The instruction was to use a concentration of 200μM of deoxyribonucleotide triphosphate (dNTP). The student used only 150 μM of dNTP.

Predict and explain the most significant consequence.

1 **Predict 1: The amount of amplified DNA segments <u>will be less than 262144</u> / <u>unable to complete 18 cycles of PCR</u>**

(idea of less targeted DNA produced)

2 **Predict 2: A significant larger amount of <u>shorter sequences</u>**

than the targeted sequence will be generated *(idea of shorter seq)*

3 **Explain: <u>insufficient dNTP is used to grow</u> OR**

extend the targeted DNA sequence [2]

Any 1 from MP1&2 + MP3

<u>Examiner's Comment:</u>

dsDNA is separated to ssDNA due to high temperature in the cycling of the PCR not because there is insufficient dNTP.

The number of cycle is preset into the programme of the PCR machine, poor phrasing which elude to the lack of this setup is rejected.

After rectifying **5(a)(ii)**, the student performed an agarose gel electrophoresis.

Fig. 5.1 shows the result of the gel electrophoresis.

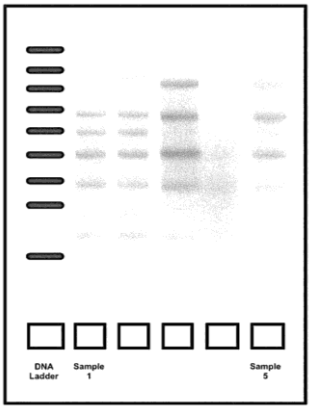

Fig. 5.1

(iii) The student noticed that the samples did not yield clear distinct bands.

Suggest a reason for the student's observation.

There were many DNA segments that are of similar lengths

which resulted in the smearing appearance;

Or agarose has large pores / low resolution; unable to sort each DNA that are of similar length

[1]

Examiner's Comment:
From the presence of the DNA ladder, that each band is separated properly. Answers such as insufficient time to separate the DNA sample or any other improper techniques are unacceptable.

The student was recommended to perform a southern blot with the agarose gel electrophoresis obtained in **5(a)(iii)**.

(b) Describe the steps in southern blot.

1 **A nitrocellulose/nylon membrane/paper is laid over the gel**

containing separated DNA fragments ;

2 **The gel is supported on a layer of sponge**

in a bath of alkaline solution ;

3 **Paper towels are stacked on top of the nitrocellulose membrane to**

wick buffer through the gel and nitrocellulose membrane by capillary action

4 **The membrane is then baked in an oven at 80°C for 2 hours/exposed to UV**

to fix the DNA fragments firmly onto nitrocellulose membrane.

5 **The nitrocellulose membrane is peeled off the gel and placed in a sealed plastic bag of solution**

containing radioactive probes OR fluorescent probes for incubation;

6 **The nitrocellulose membrane is subjected to autoradiography**

by exposing it to an X-ray film/photographic film OR UV

[6]

[Total: 10]

6 The original principles of inheritance were established by Mendel through his experiments with pea plants. In the early 1900s, scientists studied the inheritance of traits in animals and found that these traits followed similar patterns.

However, when researchers examined the inheritance of body colour in a species of beetles, they observed a different pattern.

These beetles use a ZW sex determination system, in which males are homogametic (ZZ) and females are heterogametic (ZW). The gene controlling body colour in these beetles has two alleles, **G** and **g**. Allele **G**, which gives a grey body colour, is dominant over allele **g**, which gives a black body colour.

When scientists crossed two grey beetles that were heterozygous for this gene, the resulting offspring showed a phenotypic ratio of 6 grey males : 3 grey females : 2 black males : 1 black female, rather than the expected 6 grey males : 6 grey females : 2 black males : 2 black females. This experiment was repeated over 300 times, producing a total of 1,598 offspring. In every case, the same 6 : 3 : 2 : 1 ratio was consistently observed.

(a) Explain why the scientists repeated the experiment over 300 times.

1 Repeating the experiment is to ensure the results were reliable / consistent

OR not due to random chance [1]

(R) Accuracy/ due to chance

Examiner's Comment:
Many candidates were able to attempt an explanation for why the experiment was repeated over 300 times, but a significant number displayed confusion between the concepts of **accuracy** and **reliability**. While some responses mentioned "accuracy," this is not appropriate in this context, as repeating an experiment is not aimed at improving the accuracy of results, but rather their **reliability**.

Accuracy refers to how close a measured or observed value is to the true or accepted value. It is typically improved through careful methodology and use of appropriate instruments. **Reliability**, on the other hand, refers to the **consistency and repeatability** of results. An experiment is considered reliable if similar results are obtained when it is repeated multiple times under the same conditions.

Some candidates also mentioned the importance of a large sample size but did not link this to the purpose of reducing the effect of random errors or chance events, which is central to reliability. Merely stating that a large sample is important is insufficient without a clear rationale.

To improve, candidates should ensure they are **familiar with key scientific terminology** and understand how they apply in experimental design. When justifying experimental procedures, it is important to use precise terms and explain the **purpose behind those procedures**, such as distinguishing between accuracy and reliability.

(b) Explain how test crosses can be used to determine the genotype of grey-body in beetles.

1 A test cross involves crossing the grey beetle (unknown; Gg/GG)

with a black beetle that is homozygous recessive for the g allele;

2 If the grey beetle is homozygous dominant (GG),

all offspring will only show the grey phenotype/show 100% grey phenotype;

3 If the grey beetle is heterozygous (Gg),

the offspring will show a mix of grey and black phenotypes; [3]

Test Cross (GG x gg) → All grey

	g	g
G	Gg (Grey)	Gg (Grey)
G	Gg (Grey)	Gg (Grey)

Test Cross (Gg x gg) → 50% grey, 50% black (ratio of 1:1)

	g	g
G	Gg (Grey)	Gg (Grey)
g	gg (Black)	Gg (Black)

Examiner's comment:

The majority of candidates demonstrated a good understanding of how test crosses can be used to determine the genotype of a beetle with a dominant grey-body phenotype. These candidates correctly stated that the test cross involves mating the grey-bodied beetle (with an unknown genotype) with a black-bodied beetle that is **homozygous recessive** for the body colour gene. They also clearly described how the **phenotypic ratio of the offspring** can be used to infer the genotype of the grey beetle.

However, some candidates lost marks due to **ambiguous phrasing**, such as referring to crossing with "homozygous recessive alleles" rather than a **homozygous recessive genotype or individual**. Precision in genetic terminology is important to avoid confusion. A few others confused the test cross with a **reciprocal cross** used to determine sex linkage, or incorrectly assumed that the test cross involves a homozygous dominant individual, which defeats the purpose of the test.

In addition, some candidates misunderstood the concept of an "unknown genotype" by not recognising that it refers to individuals showing the **dominant phenotype**, whose genotype could either be homozygous dominant or heterozygous. This indicates a gap in understanding the **relationship between genotype and phenotype** in monohybrid crosses.

To strengthen understanding, candidates are encouraged to revise the purpose and procedure of test crosses and practise writing clear, accurate genetic explanations using appropriate terms such as "homozygous," "heterozygous," "dominant," "recessive," and "phenotypic ratio." Drawing simple Punnett squares during revision can also help visualise genotype-phenotype relationships more effectively.

(c) The scientists discovered that a gene located on the Z chromosome of the beetle might be responsible for the deviation from the expected phenotypic ratio. This gene has two alleles: $\mathbf{Z^D}$ and $\mathbf{Z^d}$.

$\mathbf{Z^D}$ is the dominant allele, while $\mathbf{Z^d}$ is the recessive allele.

Further genetic analysis revealed that the genotypes $\mathbf{Z^dWGG}$, $\mathbf{Z^dWGg}$, and $\mathbf{Z^dWgg}$ were absent among the offspring from the cross between the two grey beetles heterozygous for the body colour gene.

Suggest **one** possible reason for the absence of these genotypes in the results.

1 The Z^dW genotype may be lethal,

causing female embryos with this combination to die before birth; [1]

Examiner's comment:
This question required candidates to apply their understanding of inheritance patterns and genotype-phenotype relationships to a novel context involving sex-linked alleles. Unfortunately, many candidates did not perform well, with only a small number successfully identifying the intended biological explanation.

A common error was the mention of **epistasis**, **sex linkage**, or **linked genes** without further elaboration, which although related to genetics, did not directly address the **specific context** of the question. Many candidates appeared to rely on rote recall rather than engaging analytically with the **information provided**, such as the pattern of **missing genotypes** (ZdWGG, ZdWGg, ZdWgg) and the implication that these were all female (W chromosome) offspring carrying the Zd allele.

Candidates were expected to deduce that the absence of these genotypes suggests that such **female embryos with the ZdW genotype did not survive**, pointing to a **lethal effect** associated with this particular genetic combination. This inference aligns with the expectation that a viable offspring population would otherwise include a full spectrum of genotypes unless lethality had occurred.

To improve in such data-based questions, candidates are encouraged to **carefully analyse the given context**, identify what is unusual (e.g. missing genotypes), and logically infer **biological explanations** based on genetic principles. Practising with unfamiliar scenarios and honing inference skills from genotype patterns will enhance performance in such application-type questions.

(d) Use the symbols G, g, Z^D, Z^d and W.

Draw a genetic diagram to explain the results of the cross between the two grey beetles that were heterozygous for body colour gene.

State the expected genotypic ratio and show the observed phenotypic ratio is obtained.

Parental phenotype	Male, Grey	Female, Grey
Parental genotype	Z^DZ^dGg	Z^DWGg
Parental gametes	Z^DG Z^Dg Z^dG Z^dg	Z^DG Z^Dg WG Wg

Random fertilisation

	Z^DG	Z^Dg	Z^dG	Z^dg
Z^DG	Z^DZ^DGG Male, Grey	Z^DZ^DGg Male, Grey	Z^DZ^dGG Male, Grey	Z^DZ^dGg Male, Grey
Z^Dg	Z^DZ^DGg Male, Grey	Z^DZ^Dgg Male, Black	Z^DZ^dGg Male, Grey	Z^DZ^dgg Male, Black
WG	Z^DWGG Female, Grey	Z^DWGg Female, Grey	Z^dWGG Lethal	Z^dWGg Lethal
Wg	Z^DWGg Female, Grey	Z^DWgg Female, Black	Z^dWGg Lethal	Z^dWgg Lethal

Offspring genotypic ratio

6 Z^DZ-G_ : 3 Z^DWGG : 3 Z^dWG_ : 2 Z^DZ-gg : 1 Z^DWgg : 1 Z^dWgg

Offspring phenotypic ratio

6 grey males : 3 grey females : 2 black males : 1 black female

1 ***Correct parental genotype ;***
2 ***Correct parental gametes AND gametes are circled ;***
3 ***Correct offspring genotype in punnet square ;***
4 ***Correct offspring phenotype to genotype ;***
5 ***Correct offspring genotypic ratio ;*** [5]

Examiner's comment:
This question required candidates to draw a **genetic diagram** involving both an **autosomal gene** (body colour: G/g) and a **sex-linked gene** (ZD/Zd on the Z chromosome), and to deduce both **expected genotypic ratios** and **observed phenotypic outcomes**. However, many candidates struggled, with a considerable number either leaving the question unattempted or making critical conceptual errors.

One major difficulty was in **correctly determining the genotypes of the parental beetles**, which were described as *grey-bodied and heterozygous for body colour*. Some candidates attempted to cross **two beetles of the same sex**, suggesting uncertainty about how to set up a valid genetic cross. Others were confused by the **ZW sex-determination system** used in the context—where **males are homogametic (ZZ)** and **females are heterogametic (ZW)**—as opposed to the human XY system. This confusion led to incorrectly assigned gametes and flawed Punnett squares.

Among those who correctly set up a 4×4 Punnett square with 16 genotype combinations, many did not proceed effectively beyond this point. Candidates often failed to:

- **Identify and omit the four genotypes involving the ZdW combination**, which were specified earlier as **lethal**.
- **Assign phenotypes to the remaining 12 viable genotypes** based on both body colour and the Z-linked gene.

These difficulties suggest a gap in **interpreting and integrating contextual genetic information**, particularly across **sex-linked and autosomal traits**, and an underdeveloped ability to apply Punnett square results to generate **meaningful phenotypic and genotypic ratios**.

To improve, candidates should practise:

- Interpreting genetic crosses involving **sex chromosomes beyond the familiar XY system**.
- Systematically assigning **gametes**, constructing **Punnett squares**, and translating genotypic outcomes into **phenotypic ratios**.
- Using contextual clues, especially from previous parts of a question, to inform and refine their analysis.

The ability to connect prior information (such as the **lethality of ZdW genotypes**) to a new question is key to mastering data-based genetics questions at the H2 level.

[Total: 10]

7 Cyanobacteria are photosynthetic prokaryotes that carry out both photosynthesis and respiration. Under favourable conditions (e.g. high nutrient availability, sunlight), they may undergo rapid population growth, forming harmful algal blooms in aquatic ecosystems.

These blooms can disrupt oxygen levels and produce toxins.

To explore potential strategies for managing such blooms, researchers tested the effects of inhibitor **Y**, a compound known to disrupt the light-dependent reactions of photosynthesis.

After inhibitor **Y** was administered, researchers observed a progressive decline in net oxygen evolution.

Both PSI and PSII electron carriers remained in a reduced state for prolonged periods of time.

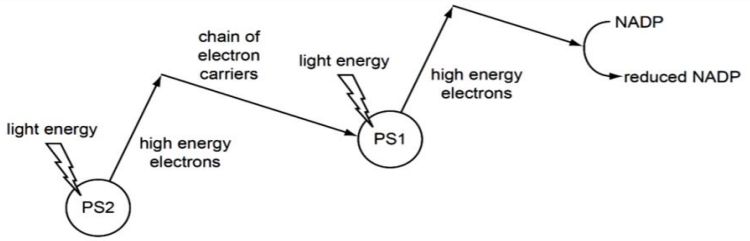

Fig 7.1

(a) **(i)** With reference to Fig 7.1, state the enzyme which inhibitor **Y** acts on and explain why there is a progressive decline in net oxygen evolution.

1. NADP reductase

2. Inhibition of NADP reductase prevents the transfer of electrons from electron carrier to the final electron acceptor NADP+/ NADP

3 Electron carriers remained reduced in PSII and PSI, photolysis of water is inhibited, resulting in a decrease in oxygen production.

4 Manganese (Mn) - containing Enzyme

5 Mn- containing enzyme catalyses the photolysis of water to produce electrons for the electron deficit in P680

6 Inhibition of Mn-containing enzyme inhibits photolysis of water; oxygen will not be produced as a by product hence a decline in net oxygen evolution.

Either MP1,2,3 and MP4,5,6 [3]

Examiner's Comment:

Many students confuse the processes of photosynthesis and respiration.

- Some indicate cytochrome C, which is an enzyme found in the mitochondria, for aerobic respiration, not photosynthesis.
- Some indicate that oxygen is the final electron acceptor, which is true for respiration but oxygen is a by product of the photolysis of water for photosynthesis.

Many students confuse photolysis and hydrolysis. Hydrolysis involves breaking chemical bonds by adding water, while photolysis involves breaking chemical bonds using light energy.

(ii) A student suggested that small amount of oxygen still produced at high concentrations of Inhibitor Y due to cyclic photophosphorylation.

Explain whether this statement is correct.

1. **The student is incorrect because**

   cyclic photophosphorylation only involves PSI and does not involve PSII;

2. **hence there will be no photolysis of water at PSII,**

   oxygen will not be produced as a by-product [2]

Examiner's Comment:
Many students did not realise that cyclic photophosphorylation only involves 1 photosystem, while non-cyclic involves 2.

(b) Research has shown that the Krebs cycle in cyanobacteria is incomplete. Specifically, the enzyme 2-oxoglutarate dehydrogenase (2-OGDH) is absent or inactive in many species.

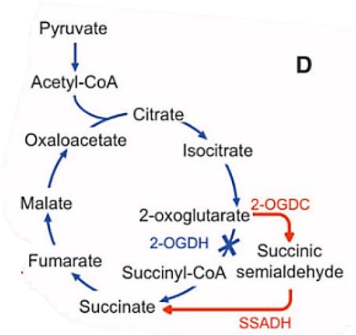

Fig. 7.2

(i) Describe the key purpose of the Krebs Cycle

1. **Generate reduced coenzymes, NADH and $FADH_2$**
2. **for ATP production via oxidative phosphorylation**
3. **Produce ATP or GTP directly via substrate-level phosphorylation**
4. **Complete oxidation of glucose with release of carbon dioxide 4 CO2**
5. **Regeneration of oxaloacetate**

Any 3 of 5 marking points [3]

(ii) With reference to Fig 7.2, explain how cyanobacteria still carry out essential metabolic functions despite missing 2-OGDH.

1. **2-oxoglutarate is not converted into succinyl-CoA, and instead enters an alternative pathway that**
2. **produces succinate (and succinic semialdehyde) via different enzymes.**
3. **Succinate allows for regeneration of oxaloacetate**
4. **Succinate allows for production of co-enzymes such as NADH and FADH2**

Any 2 of 4 marking points [2]

[Total:

8 Epidermal Growth Factor Receptor (EGFR) is a receptor tyrosine kinase (RTK) protein present on the cell surface, which is mainly expressed in epithelial cells.

It gets activated upon binding to its specific ligands like EGF (Epidermal Growth Factor), TGF (Transforming Growth Factor) and induces down-stream signalling pathways that ultimately lead to cell differentiation and proliferation.

Fig 8.1 represents the molecular structure of an EGFR in the cell surface membrane before and after binding to a ligand.

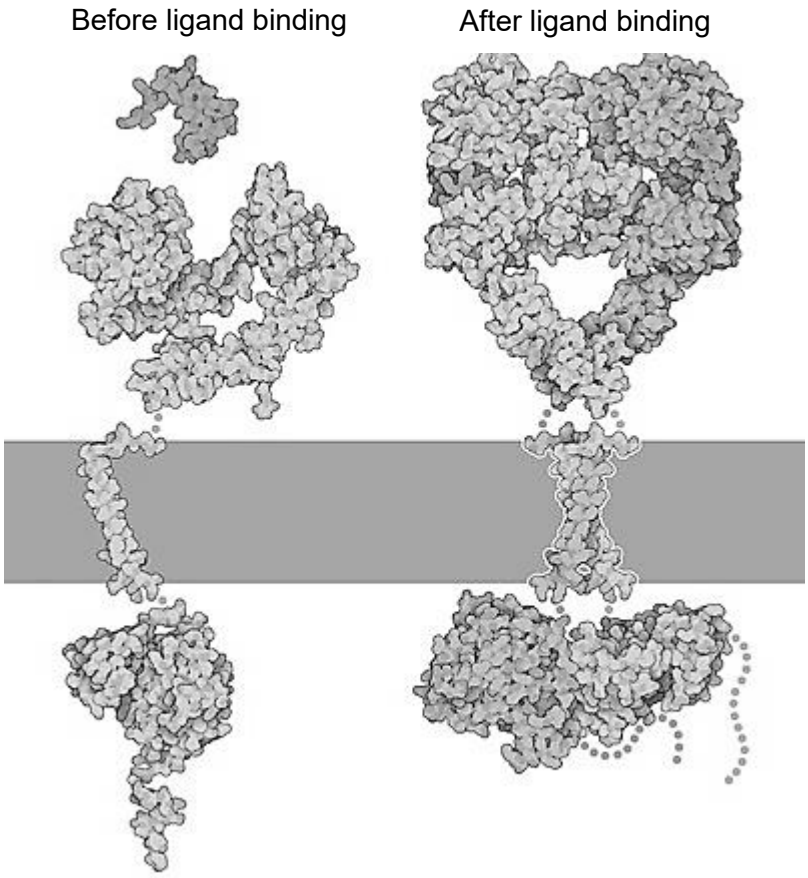

Fig. 8.1

(a) With reference to Fig. 8.1, explain how the molecular structure of the EGFR relates to its function.

S1 **The [extracellular domain] of EGFR has a specific [binding site]**

F1 **that allows it to bind to the [ligand, such as EGF];**

S2 **Ligand binding induces a [conformational change]**

F2 **that allows two EGFR molecules to undergo [dimerisation];**

S3 **The [intracellular tyrosine kinase domains] are brought into proximity**

F3 **enabling [autophosphorylation]**

S4 **The [transmembrane domain] contains [hydrophobic amino acids]**

F4 **where they interact with the [hydrophobic core of the phospholipid bilayer], allowing EGFR to be [anchored in the cell surface membrane]** [3]

Accept S2 and F3 together as one marking point

Examiner's Comment:

This question assessed candidates' ability to relate the **structure of a receptor protein (EGFR)** to its **function**, using information provided in **Fig. 8.1**. However, many candidates either left this question unattempted—likely due to **poor time management**—or failed to make effective use of the diagram provided.

Among those who attempted the question, a common issue was the **failure to focus on the molecular domains of EGFR**. Candidates often included **unrelated content**, such as signalling pathways involving **IRS-1** or other downstream components of the insulin receptor pathway, suggesting confusion between receptor types.

Other responses went **beyond the scope of the question**, discussing **phosphorylation cascades and cellular responses**, instead of focusing on how **specific structural features of EGFR (extracellular domain, transmembrane domain, and intracellular kinase domain)** relate to **its initial functional roles**, such as **ligand binding, dimerisation, and autophosphorylation**.

Stronger responses explicitly:

- Identified the **extracellular domain** as having a **ligand-specific binding site** (e.g. for EGF).
- Noted that ligand binding induces a **conformational change** that enables **dimerisation**.
- Recognised that **dimerisation brings the intracellular tyrosine kinase domains** into proximity, facilitating **autophosphorylation**.
- Mentioned the **transmembrane domain's hydrophobic amino acids** allow anchoring of the receptor within the **phospholipid bilayer**.

To improve, candidates should practise:

- Carefully reading what the question is asking (e.g. **structure-function relationships**).
- Referring directly to **figures provided** in the exam.
- Avoiding irrelevant or overly extended answers that go beyond the marks allocated or scope defined.

Focusing on how **each domain contributes to the receptor's activation** will help in answering similar application questions involving receptor proteins.

(b) Fig. 8.2 shows the structure of the ligand TGF. TGF can bind to EGFR.

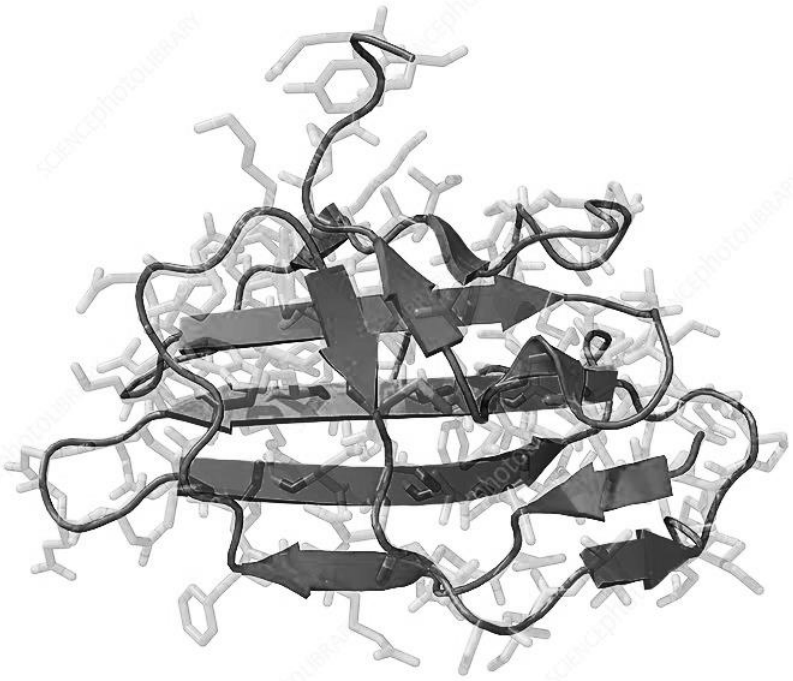

Fig. 8.2

With reference to Fig. 8.2, explain why EGFR must be in the cell membrane.

1 TGF is a protein and therefore a large, hydrophilic macromolecule

2 TGF cannot pass through the hydrophobic core of the cell surface membrane Hence, EGFR must be a membrane-bound receptor to allow extracellular EGFR to bind and trigger intracellular signalling; [2]

Examiner's comment:

This question assessed candidates' understanding of **why EGFR must be embedded in the cell surface membrane**, based on the molecular characteristics of its ligand, **TGF**, as shown in **Fig. 8.2**. While many candidates attempted this question, responses varied in quality due to **misinterpretation** and a **lack of clear reference to the figure**.

A common error was **confusing EGFR and TGF**, with some candidates incorrectly identifying **EGFR as the ligand** instead of the receptor. Others described features of TGF's **protein structure** but did not relate this to the key point: that TGF is a **large, hydrophilic macromolecule**, and therefore **cannot pass through the hydrophobic core** of the phospholipid bilayer.

Stronger responses correctly identified:

- That **TGF is a protein**, making it a **large, hydrophilic macromolecule**.
- That it **cannot diffuse across the cell surface membrane** due to the **hydrophobic interior** of the lipid bilayer.
- Therefore, EGFR must be a **membrane-bound receptor**, positioned at the **cell surface**, to detect **extracellular ligands** and trigger **intracellular signalling**.

To improve, candidates should pay close attention to the **wording of the question**, especially when asked to **refer to a figure**. In this case, Fig. 8.2 clearly depicted **TGF**, and not EGFR, requiring candidates to centre their answer on the **properties of the ligand**. Developing a solid understanding of how **ligand size and polarity** influence receptor location is essential when tackling questions about **cell signalling mechanisms**.

(c) Fig 8.3 shows the sequence of events after the binding of TGF to EGFR.

ERK and AKT are kinases that phosphorylate specific regulatory proteins. These phosphorylated regulatory proteins are imported into the nucleus to trigger a cellular response that leads to cell survival and proliferation.

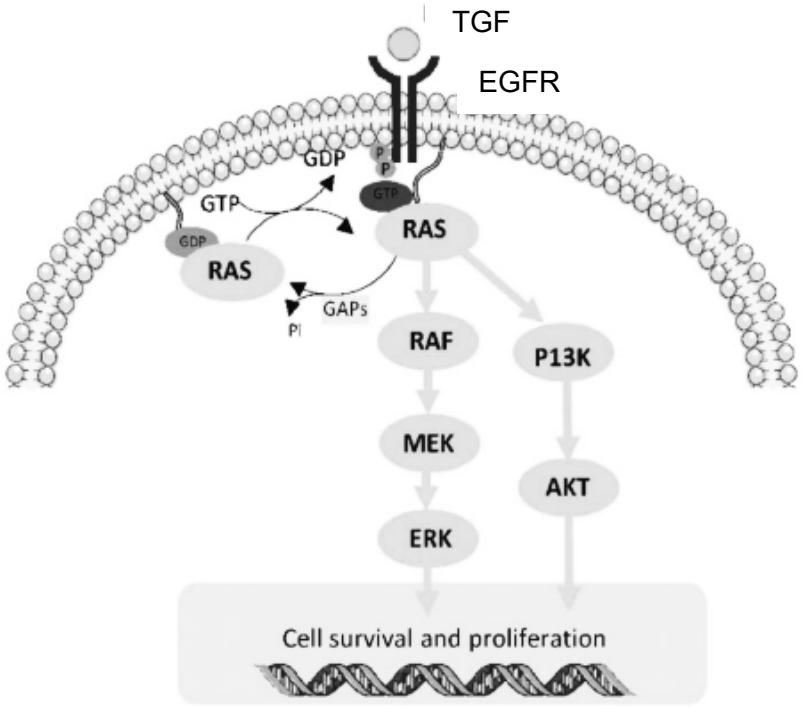

Fig 8.3

Using information provided,

(i) Suggest a possible identity for regulatory proteins phosphorylated by ERK and AKT.

Transcription factors / Specific transcription factors / activators / repressors [1]

Examiner's comment:

This question required candidates to interpret the **signal transduction pathway** shown in Fig. 8.3 and deduce the likely identity of the **regulatory proteins** that are phosphorylated by the kinases **ERK and AKT**, which then enter the nucleus to trigger a **cellular response**. Many candidates, however, failed to provide a biologically appropriate answer, with a number leaving the question unattempted.

A common issue was the **lack of attention to the clue "regulatory proteins"** in the question. Instead of inferring that these are most likely **transcription factors**, many candidates listed **irrelevant components** such as:

- Structural genes (e.g. **proto-oncogenes**, **tumour suppressor genes**),
- Enzymes involved in replication or transcription (e.g. **DNA polymerase**, **helicase**),
- Incorrect signalling proteins from the pathway itself (e.g. **RAS**, **AKT**, **ERK**),
- Promoters or histone-modifying enzymes, which are **not proteins being phosphorylated**, but rather are **targets or binding regions**.

Stronger responses correctly inferred that the phosphorylated regulatory proteins must be **transcription factors**—as these are proteins that **regulate gene expression** upon entering the nucleus, aligning perfectly with the described **cellular outcome of survival and proliferation**.

To improve, candidates should practise:

- Extracting and **interpreting key phrases** from question stems (e.g. "regulatory proteins", "imported into nucleus", "trigger response"),
- Recognising the **central role of transcription factors** as downstream effectors in many signalling pathways,
- Applying familiar biological concepts to **novel or semi-unfamiliar signalling diagrams**.

Being attentive to **clues in the phrasing** of the question and connecting them to known biological functions will support stronger deductive reasoning in such application questions.

(ii) explain how the activation of the receptor leads to cell survival and proliferation.

1 Phosphorylated tyrosines activates RAS

by phosphorylating RAS-GDP to RAS-GTP ;

2 RAS-GTP trigger a [phosphorylation cascade]

amplifying the signal;

3 The cascade leads to activation of [transcription factors]

that are imported into the nucleus;

4 These transcription factors switch on

[genes controlling cell survival and proliferation]; [4]

Examiner's comment:

This question required candidates to explain the **sequence of molecular events** following the **activation of EGFR**, leading to **cell survival and proliferation**. Unfortunately, many responses demonstrated a lack of precision in following the pathway outlined in **Fig. 8.3**, with a number of candidates missing key mechanistic steps or misinterpreting the role of specific molecules.

Firstly, several candidates **overlooked the phrase "activation of the receptor"** and began their answers with **ligand binding**, which was **not required**, as the question assumed receptor activation had already occurred. This consumed time and added unnecessary detail without addressing the question's focus on **downstream signalling events**.

Secondly, many responses **did not effectively reference Fig. 8.3**. Candidates often made vague statements such as "kinases are activated" rather than explaining how **RAS-GTP initiates a phosphorylation cascade**, where each kinase activates the next via phosphorylation, **amplifying the signal**. Additionally, some confused the activation states of RAS, incorrectly stating that **RAS-GDP is the active form**, when in fact **RAS-GTP** is the active, signalling form.

Another common omission was the **nuclear import of phosphorylated transcription factors**. Candidates frequently jumped from kinase activation directly to gene expression, missing the **key step** where phosphorylated regulatory proteins are transported into the nucleus to modulate transcription.

Stronger responses accurately described:

- That **phosphorylated tyrosine residues activate RAS**, converting **RAS-GDP to RAS-GTP**.
- That **RAS-GTP initiates a phosphorylation cascade**, amplifying the signal via sequential activation of kinases.
- That this leads to the **activation and nuclear import of transcription factors**, which **switch on genes controlling cell survival and proliferation**.

To improve, candidates should:

- Follow the **sequence of events** described in diagrams carefully.
- Use **precise molecular terms** (e.g. RAS-GTP, phosphorylation cascade, transcription factors).
- Practise describing signalling pathways step-by-step, ensuring **no key steps are skipped or confused**.

This structured approach will enhance clarity and biological accuracy in pathway-based explanation questions.

[Total: 10]

9 In 1862, Charles Darwin was in his London office when a colleague sent him a Madagascar orchid specimen, *Angraecum sesquipedale*, with a 30 cm nectar tube, with the nectar itself pooled only at the very bottom. “Good Heavens,” Darwin wrote in a letter to a friend, “what insect can suck it?”

In 1867 Alfred Russel Wallace published an article in which he supported Darwin's hypothesis that such an insect with a 30 cm tongue could be found in Madagascar.

Fig 9.1 shows a drawing of *Angraecum sesquipedale* that was found in a herbarium.

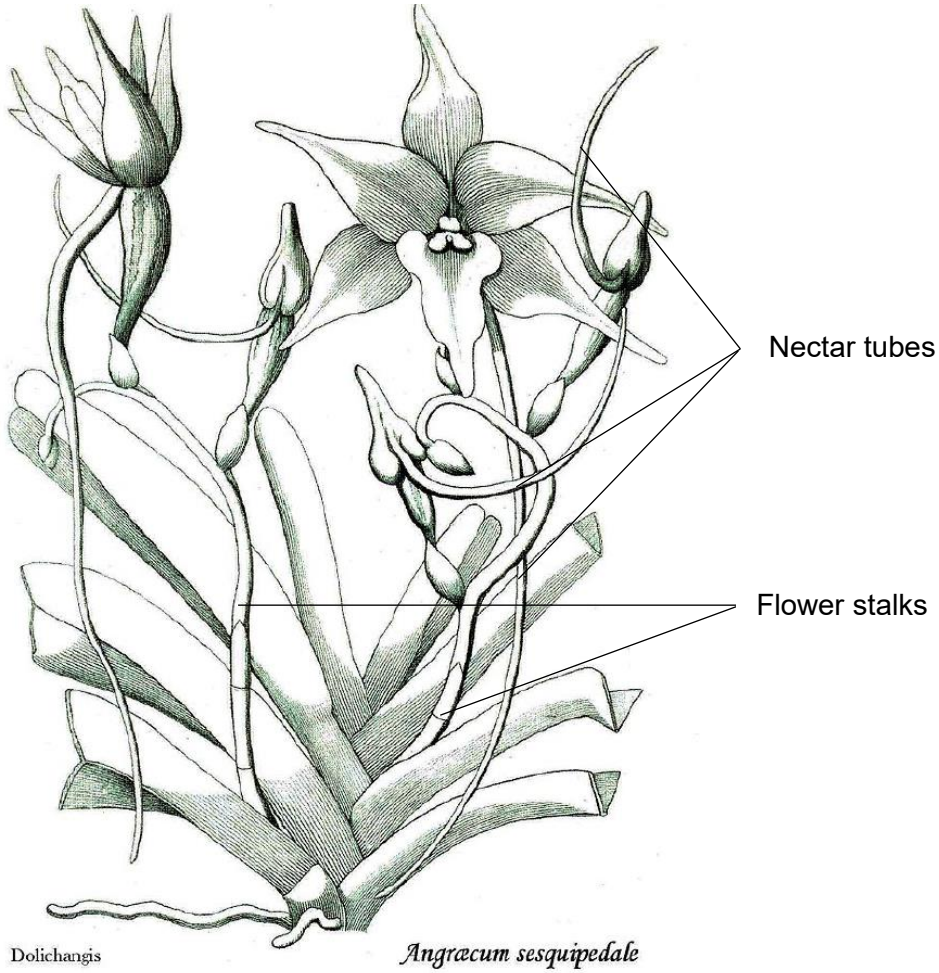

Fig. 9.1

(a) **(i)** Suggest why Wallace predicted the insect could be found in Madagascar.

Given that the orchid is found in Madagascar,

the pollinator should be found near its food source. [1]

Examiner’s Comment:
Only words and phrases that suggest tha the orchid’s nectar is the food and the moth is the pollinator will be awarded the mark.

In 1903, the insect in question was discovered. The species was named *Xanthopan morgani praedicta*, reflecting its prediction by Charles Darwin and Alfred Russel Wallace.

The proboscis of *Xanthopan morgani praedicta* is long enough to reach the nectar tubes of the orchid.

Fig. 9.2 shows a specimen of *Xanthopan morgani praedicta*.

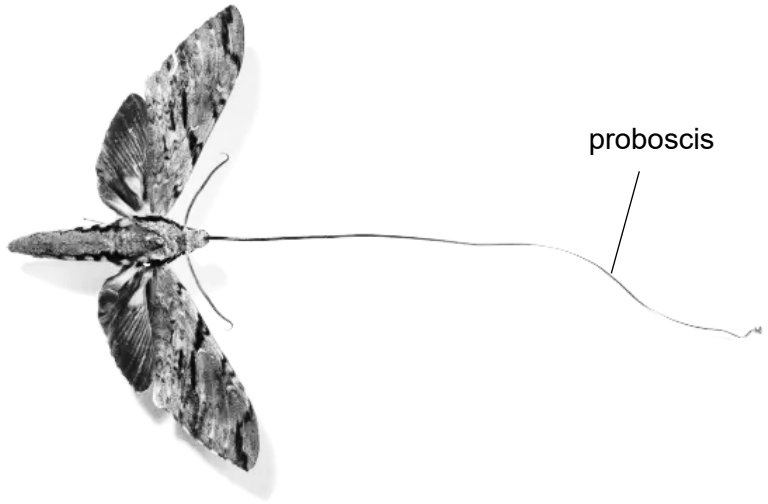

Fig 9.2

(ii) Using Darwin's theory of evolution, explain how *Xanthopan morgani praedicta* and *Angraecum sesquipedale* have such unique phenotypes which differ from other moths and orchids respectively.

1 Within moth and orchid populations, there was [natural variation] in traits such as [proboscis length] and [nectar tube length] due to [mutation and genetic recombination]

2 Orchids with [longer nectar tubes] were more likely to be pollinated by moths with [longer proboscises], thus producing more offspring and passing on this trait

3 Moths with [longer proboscises] could access [more nectar], improving their [survival and reproductive success], so this trait also became more common

4 Over time, [descent with modification] resulted in the accumulation of these advantageous traits in each species, leading to [specialised phenotypes] that differ from other moths and orchids;

[4]

Explanation:
The two species co-evolution, where each species exerts selective pressure on the other, leading to adaptations.

Both moth and the orchid created selective pressure on one another

The need for effective pollination (for the orchid) and nectar access (for the moth) created evolutionary pressures that led to

specialized traits in both organisms that exclude other moths and orchids.

Herbariums are archives of dried plant specimens from different regions, and time periods. These collections document the diversity of plant life and provide valuable information for researchers.

(b) State two types of investigations that researchers can perform by having access to a herbarium.

1 Investigate the concept of species by morphology / morphological species concept;

2 and via the ecology concept of species/ecology species concept from the records.

3 changes in physiology features within a species over time (Macro evolution)

4 reclassification of the taxonomy / amending the classification [2]

Any of the above 2 points

Examiner's Comment:
There may not be viable DNA found in the dried specimens. Alternatively, in the process of extracting the DNA, the specimens will be compromised or destroyed which defeat the purpose of having such a collection. Thus, any answers related to genetic reference will be rejected.

In evolutionary studies, scientists often compare DNA sequences to infer phylogenetic relationships between organisms.

In animals, mitochondrial DNA (mtDNA) is commonly used. In flowering plants like *A. sesquipedale*, researchers prefer to use the chloroplast genome for similar reasons.

(c) Explain why chloroplast genomes is the preferred choice.

1 The [chloroplast genome is highly conserved] across plant species,

meaning many [genes and structures are shared], allowing reliable comparisons between distantly related plants;

2 [Chloroplasts are inherited maternally] in most plants, so there is [no recombination],

making the inheritance pattern [simpler to trace] than nuclear DNA;

3 The chloroplast genome has a [slower mutation rate] than nuclear DNA,

preserving [evolutionary signals over longer timescales];

4 The chloroplast genome is [relatively small], around 120,000–160,000 base pairs,

making it [cheaper and easier to sequence];

5 Chloroplast genomes are [well-characterised and extensively studied],

so there are [reference sequences and tools] available;

6 Chloroplasts are [abundant in plant cells],

making their DNA [easier to extract in large amounts];

7 **Chloroplasts originated from [endosymbiotic cyanobacteria], giving their genome a [distinct evolutionary lineage] that is useful for phylogenetic analysis;**

Explanation:
The chloroplast genome tends to be relatively conserved across plant species, meaning that many of the same genes and structures are found in chloroplasts across different plants. This allows researchers to use shared genetic markers to compare distant plant species more effectively.
Chloroplasts are typically inherited exclusively maternally in most plants (i.e., from the mother plant). This uniparental inheritance reduces the complexity of phylogenetic analysis because it avoids the recombination that happens with nuclear DNA, which is inherited from both parents.
The chloroplast genome evolves at a relatively slow rate compared to other genomes, such as nuclear DNA.
Chloroplast genomes are well-studied and have been extensively sequenced
Chloroplast genomes are relatively small (compared to nuclear genomes), typically around 120,000–160,000 base pairs. This makes them easier and less expensive to sequence than larger nuclear genome
Chloroplasts originated from an endosymbiotic event involving cyanobacteria. This evolutionary history gives the chloroplast genome a distinct evolutionary signal compared to the nuclear genome.
Chloroplasts are present in large numbers within plant cells, making them a rich source of DNA. [3]

Any 3

[Total: 10]

10 Monoclonal antibodies (mAbs) are a type of protein made in the lab that function like human antibodies and can be used to treat various diseases, including some cancers.

They are engineered to target specific antigens, such as those found on cancer cells, and can be used to restore, enhance, modify, or mimic the immune system's attack on unwanted cells.

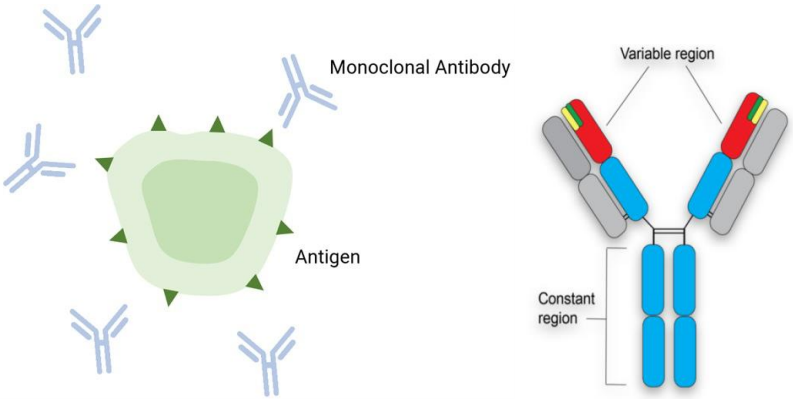

Fig 10.1

Researchers developed a monoclonal antibody therapy targeting the spike protein of a viral strain. The treatment was initially effective, but over time, new viral variants with mutations in the spike protein emerged, rendering the therapy less effective.

In contrast, individuals who had recovered from natural infection were still able to produce effective antibodies against the new variants.

(a) Explain why individuals who recover from infection are more likely to produce antibodies that can bind to new variants of the virus.

1 Natural infection activates diverse B cells which undergo somatic hypermutation to produce a variety of antibodies
2 This process leads to high-affinity antibodies, including some that may bind to new viral variants
3 In contrast, monoclonal antibodies are identical and bind to a single epitope, so they may become ineffective if that epitope mutates [3]

(b) Both monoclonal antibody therapy and vaccination can be used to protect against viral infections.

Explain why vaccination often provide longer-lasting protection. than monoclonal antibody therapy.

1 Vaccines stimulate the body's adaptive immune response,
2 leading to the production of memory B cells and plasma cells that continue producing antibodies over time.
3 In contrast, monoclonal antibodies are a form of passive immunity, and do not trigger memory cell formation,
4 so their effects are short-lived as the antibodies are eventually broken down. [2]
Any 2 of 4 marking points

[Total:5]

11 Fig. 11.1 shows the percentage cover of live corals, coral transplant by man and the temperature of the sea surface over 40 years.

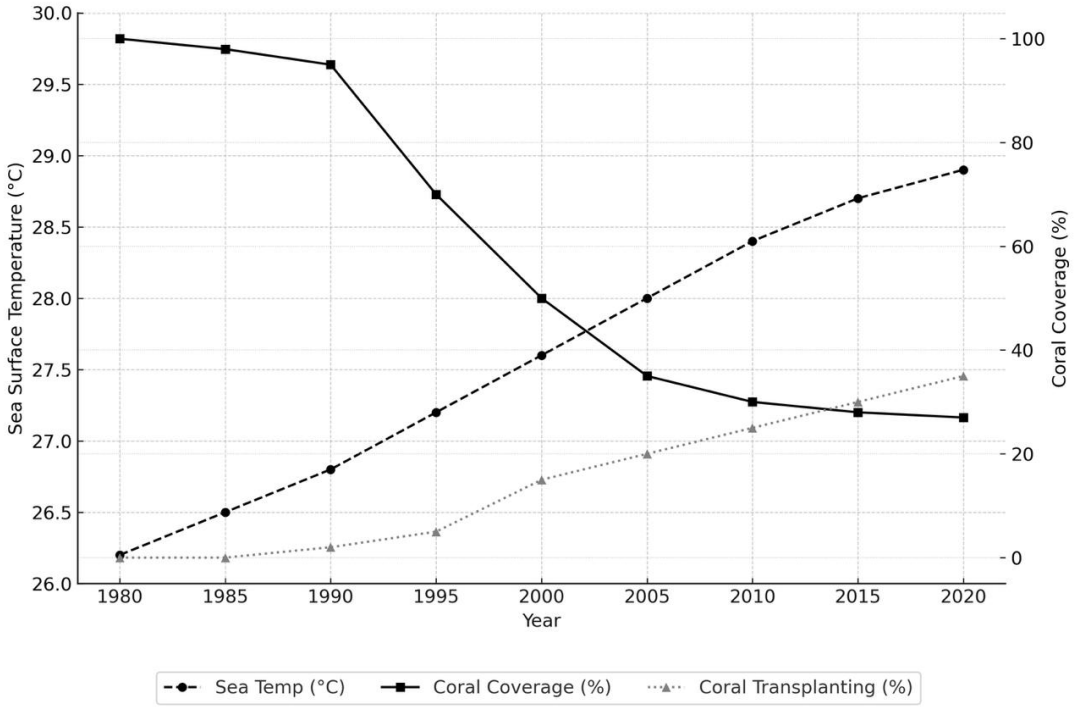

Fig. 11.1

(a) Using Fig. 11.1, describe the change in sea surface temperature and the percentage coverage of live corals.

1 From 1980 – 1990 there is a slight decrease of coral coverage from 100%- 90% as sea surface temperature rises from 26.1 -26.5°C.

2 A steep decline of 90-36% in the coral coverage from 1990 – 2005 as the temperature 26.8 – 28 °C.

3 A gradual decrease in coral of 36-24% as temperature continue to increase from 28 – 28.9 °C between 2005 - 2020

Each point must include duration, coral coverage %, temperature °C

No award of mark for every point where wrong graph/ axis is read from [3]

Examiner's Comment:

Student must make fair comparative data analysis which contain duration (years), temperature and coral coverage in each set.

Common mistake included, reading off the wrong axes and graphs. It should be obvious to the student that there is no such value as -0 and as such, the second y-axis does not contain any negative values.

(b) Using the information provided, explain whether coral transplanting is a successful strategy to combat shrinking coral habitat.

1 Not successful. Corals are temperature sensitive, from the data it suggests that they do not thrive when the sea surface temperature exceed 26 °C

2 Corals are bleached when the temperature exceed 26 °C

3 Temperature of the sea is continuously increasing

4 **Despite increasing transplanting coral coverage up to almost 40%, the overall coral coverage has slowed down and yet to show sign of increase**

Any 3

No mark awarded for deriving to the wrong conclusion even if there are correct explanation. [3]

Examiner's Comment:

The question demanded students to state whether coral transplant was either successful or not. Answer that did not fall into either categories will be rejected.

Many students failed to understand that coral coverage percentage included the percentage of transplant.

[Total: 6]