H2

ANDERSON SERANGOON JUNIOR COLLEGE
HIGHER 2

2020 JC2 PRELIMINARY EXAMINATIONS

CANDIDATE NAME							
CLASS					INDEX NUMBER		

H2 BIOLOGY

9744/02

Paper 2 Structured Questions

16 September 2020

Candidates answer on Question Paper.
No additional Materials are required

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces at the top of this page.
Write in dark blue or black pen.
You may use a HB pencil for any diagrams or graphs.
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.

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	/ 6
2	/11
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6	/6
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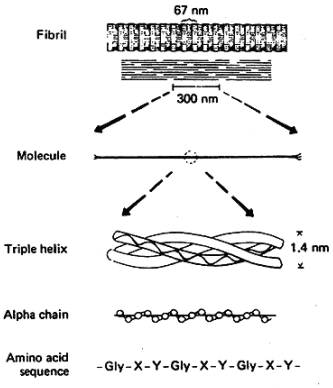
11	/9
	/100

This document consists of **16** printed pages

Anderson Serangoon JC H2 BIOLOGY 9744/02 Prelims 2020 Mark Scheme

1 (a) Glycine makes up approximately 30% of the total amino acid composition of collagen.
Explain how glycine plays an essential role in the structure of collagen.

- (glycine) amino acid with smallest/ H, R-group/ side chain;
  Reject glycine is a small/ smallest aa without reference to its R-group
- Run along the, interior/ central, axis of the helical polypeptide/;
  Reject glycine/ glycine's R-group/ project into interior
- Allow the, triple helix/ three polypeptides, to be, closely associated/ tightly pack together/ AW; (accept tropocollagen/ collagen chains/ reject collagen/ collagen molecules)
  look for idea of three compact helices
  Ignore reference to alpha helices
- Allow H-bonds to form between polypeptides (for strength);
- Further details e.g. (hydrogen) bond forms between the amide (-C(=O)NH-) hydrogen atom of glycine in one polypeptide chain and the carbonyl oxygen atom of X in an adjacent polypeptide chain



Examiner's comments:
Collagen have many level so students need to be specific to write which level are they talking about. If left vague, collagen is usually understood as the fibril or even microfiber level.

[2]

(b) Collagen is continuously broken down in the extracellular matrix by the enzyme collagenase, which catalyses the hydrolysis of the peptide bond between the amino acids glycine and isoleucine.

Describe how collagenase lowers the activation energy and increases the rate of collagen hydrolysis.

- Reference to role of contact (e.g. weak /temporary bonds)/ catalytic residues/ R-groups/ amino acids at active sites; (need to describe briefly what the contact/ catalytic residues do e.g. contact residues bind to substrate/ form bonds with substrate, catalytic residues catalyse the reaction/ hydrolyse the bond)
- hold substrate in a **correct orientation** inside its active site for hydrolysis reaction to occur ;
- **physical stress/ strain** of the peptide bond is induced, increasing the likelihood that the bond will break ;
- **altering charges** on substrate/ they **increase reactivity of peptide bond** by **altering the distribution of electrons** within the peptide bond OR **changing the charge on the peptide bond**
- **creating a more conducive micro-environment** for substrate to react

Examiner's comments:
Many students were clear that the substrate (what enter the active site) is not just collagen but specifically the peptide bond between the amino acids glycine and isoleucine. Many students wrote how the shape of the substrate being complementary to the active site, this is not suffice to describe how the activation energy is lowered just through the complementary shape, specific ideas like role of contact/ catalytic residues, physical strain being applied, charges altered are needed.

[2]

(c) Collagen is a structural protein. Collagenase is an enzymatic protein.

Describe **two** differences in the structural properties of collagen and collagenase.

Features	Fibrous proteins	Globular proteins
Structure	**Fibrous/ Long** fibres making up its structure elongated / long / rods / filaments / ropes / strands Reject linear	Folded into tertiary structure, spherical **globular** shape have, 3D / tertiary / shape / structure
	Quaternary Reject secondary	tertiary
		reference to active site: specific / complementary (to another molecule)/
Amino acid sequence	**Repetitive** sequence of amino acids. Actual sequences of amino acids may vary slightly between two samples of the same protein.	**Irregular** amino acid sequences, hence there is a large variety of amino acids in a protein. (accept not repetitive) Sequence of each protein is highly specific and never varies between two samples of the same protein
Length of polypeptide chain	Length of chain may vary in two samples of the same protein	Length always identical in two samples of the same protein
Size	Larger then collagenase Accept large	Smaller than collagen Accept small

Examiner's comments:
Many students compared the solubility between the fibrous and globular protein. Solubility is a physical property not structural property.

[2]
[Total: 6]

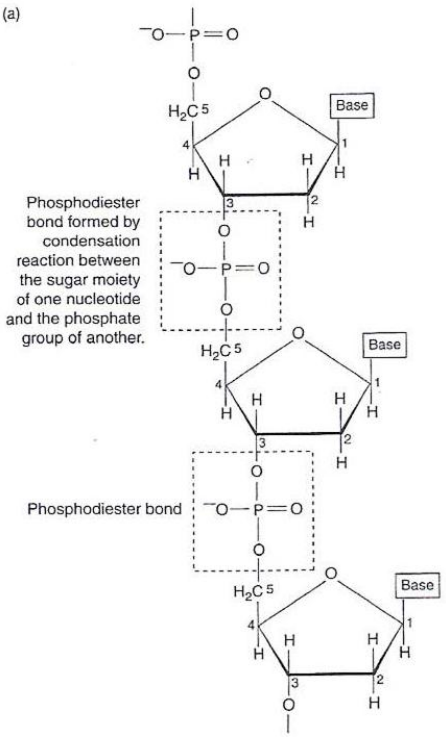
2 Taq polymerase is a thermostable DNA polymerase used in the polymerase chain reaction (PCR). It was originally extracted from a bacterium, *Thermus aquatius*, which is found in the hot springs of the Yellowstone National Park in the USA.

(a) Describe the reaction catalysed by DNA polymerases such as Taq polymerase.

- **Condensation reaction**/ release (formation) of **water molecule**
- Form **phosphodiester bond** *(not hydrogen bonds between base pairs!)*
- Between (3 'OH group) of one **DNA nucleotide** and the (5' phosphate group of) another **DNA nucleotide**
  (accept **add DNA nucleotide**)
  Reject between DNA bases
  ------- *the nitrogenous bases are not involved in the formation of phosphodiester bonds*

[2]

(a)



*Generally well-done. However there were some students who **wrote excessively** about the extension stage (and even denaturation and annealing stage) of PCR reaction, this does not answer the question!*

*Some answers were also **vague,** e.g. description on the semi-conservative mode of DNA replication / simply said replicate DNA/ elongate DNA strand/ add to the 3' end of the DNA strand using a template DNA strand ---- these answers were ignored*

When a questions asks for the reaction catalysed by an enzyme. Please give:
- ***Condensation/ hydrolysis** reaction*
- ***Name the bond** formed or broken*
- *Name the **exact functional group** of the monomer **involved***

Practise writing this for glycosidic bond/ peptide bond/ ester bond

Ignore references to proofreading/ removal or RNA primers
*------- these are not the **main function** performed by **all** DNA polymerases e.g. Taq polymerase has no proof-reading function/ there is no need to remove primers during PCR ---- give these points only in an essay or when more marks are given in the question*

(b) With reference to Fig. 2.1, explain the trend observed between points **A** and **B**.

Generally well done.

- As temperature **increases** from **42°C to 63°C** the quantity of product formed **increases** from **32 to 92 arbitrary units**
  *Take note that when question specifically asks for **trend between**, you should use the trend word **increase/ decrease** rather than higher/lower. Higher and lower only **compares two points** does not give the idea of trend **between** the two points*

- Increasing temperature **increases kinetic energy** of Taq polymerase (enzyme) and DNA nucleotides (substrate) (and primers/templates)
  Some students only mentioned K.E of substrate increases or K.E enzyme increases
  *---- it should K.E of **both** enzymes and substrate increases*

- Increase frequency of **effective collision** between enzyme and substrate *(some students simply said " effective collisions" w/o saying between what molecules)* /or increase **rate of enzyme-Substrate complex formation** [3]

(c) Explain why 95°C was chosen as the incubation temperature to test thermal stability in this experiment.

- 95°C is the **highest temperature** that the enzyme will be subjected to during **PCR /** PCR denaturation occurs at 95°C so must test if DNA polymerase can withstand this temperature
- Or Accept 95°C is **sufficiently higher** than the **optimum temperature** of 75°C (must quote) *Many wrongly thought that 95°C is the optimum temperature of ThiPolB/ Taq polymerase*

Reject answer with no context: 95°C is a high enough temperature to cause unfolding

*Reject common wrong answer: 95°C is the temperature at which DNA are denatured during PCR ---- so what? There is no idea that the enzyme is already incubated with the mixture during this stage and hence will be **subjected t**o this temperature*

[1]

This part (d) of the question was badly done. Many did not know what the question want and the concept being tested.

From enzymes lecture notes:

Apparent optimum temperature

- Heat supplied increases kinetic energy of the enzymes. This has two opposing effects on enzyme activity:
  - Increase in rate of reaction due to increased frequency of effective collisions between enzyme and substrate, forming more ES complexes
  - Increase in rate of enzyme denaturation due to increased molecular vibrations of the enzymes
- Therefore, the time period for which the enzyme is incubated at a particular temperature affects its optimum temperature (***Fig. 3.6***).
  - At shorter incubation time periods, there is less denaturation of the enzymes. The rate of an enzyme-controlled reaction is higher at a specific temperature due to increased ES complex formation.
  - At longer incubation time periods, there is significant denaturation of enzymes. The rate of an enzyme-controlled reaction is lowered at the same specific temperature.
- The optimum temperature of the reaction is therefore also affected by incubation time period at a given temperature. For longer incubation time periods, the optimum temperature of the enzyme-controlled reaction is lower.

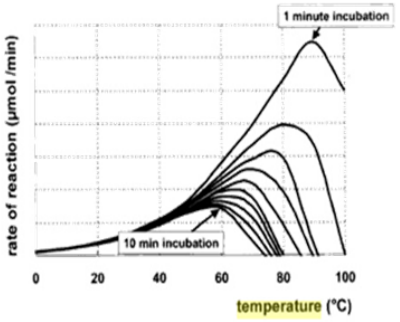


Fig. 3.6: Effect of incubation time on the optimum temperature of the enzyme-controlled reaction.

(d) With reference to Fig 2.1 and 2.2 and your own subject knowledge,

(i) suggest how the optimum temperature of TthiPolB (point **C**) in Fig. 2.1 would change if the quantity of product formed were measured after more than twenty hours rather than one hour.

- **Optimum temperature** would **decrease below 75°C** [1]

(ii) explain your answer to **(d)(i)**.

Idea of apparent optimum temperature

- idea of as the enzyme polymerase would be incubated at high temperatures/ 95°C for **longer time**/ after more than 20hours *(reject merely saying 20hours)* , **increased** denaturation/ **increased** unfolding
- Quote data: after more than 20 hours, extent of unfolding increases **drastically/significant** from 0.2 a.u (accept 0.2a.u-0.23a.u) to 0.6 a.u (accept up to 0.63 a.u)
  Many did not quote data despite the question asking for referencing to Fig. 2.2
- More enzymes loses their secondary structure where **alpha-helices** to become **random coils** (after more than 20 hrs)
- **hydrogen bonds** (formed between O atom of the –C=O group of one amino acid residue and H atom of the –N-H group of another amino acid residue) **between amino acids** of the **polypeptide backbone** are broken
- reduced effective concentration of enzyme/ less enzymes available with longer incubation time

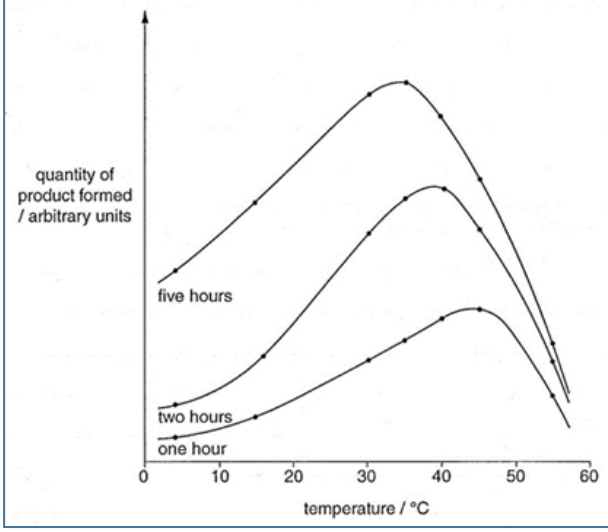
Denaturation of enzymes

- Shape of **active site** no longer **complementar**y to substrates (DNA template/ DNA nucleotides) / accept shape of active sit is lost
- Idea of high temperature causing **thermal agitations/ vibrations in enzyme molecules**
  OR **R-groups interactions** (name at least 2 bonds from hydrogen bonds, hydrophobic interactions, ionic bonds and disulfide bonds) also broken → loses/ changes in **tertiary structure** / change in **3D conformation**

Some students did not base their answer on Fig. 2.2 at all. If Fig. 2.2 was properly analysed, marks for talking about denaturation and quoting of data would have been gained, even w/o knowledge of apparent optimum temperature. [4]

Similar question on apparent optimum temperature tested in H2 N2006 and H2 2017 specimen paper.

Fig. 2.1 shows the results of an experiment in which samples containing the same concentration of enzyme and substrate were kept at different temperatures for periods of one, two and five hours. The quantities of product formed were then determined.



(a) Explain the effect of increasing temperature on the quantity of product formed for the samples kept at different temperatures for one hour. [4]

(b) Explain why the optimum temperature is lower if the quantity of product formed is measured after five hours rather than 1 hour. [2]

Answers for this question with some other related extension questions will be uploaded onto the cohort's google drive

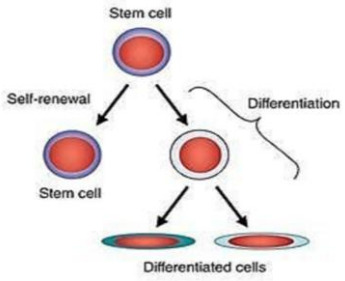
[Total: 11]

3 (a) Stem cells from human bone marrow that are involved in blood cell formation are described as multipotent, rather than totipotent.

Distinguish between multipotent cells and totipotent cells.

1. multipotent cells can give rise/ differentiate into to limited range of cell types
2. totipotent cells can give rise/ differentiate into to all/ any cell type to form whole organisms / whole range of cells / whole organism; (idea that whole organism can be form from totipotent stem cell MUST be clearly expressed)
3. multipotent cannot give rise to organs (because organs is made up of different tissues thus different cell types);
4. example of totipotent stem cell: zygotic / zygote (also accept fertilised egg);
5. example of multipotent stem cell: lymphoid/ myeloid stem cell (reject blood stem cell, haematopoietic stem cells)

Examiner's comments:



It is the daughter cells of stem cells that differentiate into the different cell types. Stem cells can self-renewal. When one stem cell undergoes mitosis to produce two daughter cells, one stays as a stem cell, and the other will go through differentiation. Practice N2018P2Q3.

Wrong Concepts include::

- *totipotent stem cells can differentiate into multipotent stem cells*
- *Totipotent stem cells' example: embryo/ embryonic stem cells (because embryonic stem cells are example of pluripotent stem cells)*
- *Multipotent stem cells' example: embryo/ embryonic stem cells (because embryonic stem cells are example of pluripotent stem cells)*

[3]

(b) **(i)** Suggest how transcription factors can reprogramme skin cells to form iPS cells.

- Attach to **promoter/ enhancer/ silencers** (of specific gene);
- Stimulate/inhibit transcription/RNA polymerase/ transcriptional initiation complex formation; (reject: gene expression because it is too vague, does not give a clear idea how TF is involved in gene expression)
- Examples of genes that would be switched on (genes coding for characteristics of pluripotent/ telomerase/ CND/ off (genes coding for characteristics of skin cells)

Examiner's comments:
TF can be interpreted as general TF or specific TF like activators/ repressors). *TF are not methyl transferase, so they are not involved in the methylation/ demethylation of DNA thus formation of euchromatin/ heterochromatin.*

Students should not assume that genes that are not expressed in skin cells are definitely genes that can unlock the potency of the cells. [2]

(ii) Using all the information provided, evaluate the use of iPS cells to treat type I diabetes in humans.

1. 1 mark to quote data (can be group A at the beginning and end treatment/ compare group A and group B)
2. (Effective as) group A/with iPS/treated lower than group B/with diabetes;
3. (Effective as) group A similar to group C/without diabetes;
4. (Investigation) mice and human are mammals → effects may be similar;
5. (Investigation) done on mice not humans;
6. Only shows results for 12 weeks/short-time period / long-term effects not known; [3]

Examiner's comments:
Generally well done. Some students did not make reference to group A/B/C at all. Some students carelessly refer the group of subjects to be humans when they are mice.

(c) Suggest **two** advantages of using stem cell therapy in treating type I diabetes.

- Long term solution – self-renew/ less harm inflicted because less pain because no need for daily intravenous injection of insulin/ save cost (daily injections can be costly)
- Cell can regulate dosage based on negative feedback vs injection is fixed dosage or that is possibility of overdose/ underdose of insulin

Examiner's comments:
Generally not well-done. Students mistook the question to be like N2018P2Q3(c) "Explain how the use of iPSCs may overcome some of the ethical concerns of using other types of stem cells in medical research and treatment." This question does not limit stem cell therapy to iPSC only so it is not limiting to advantages of iPSCs.

Students should compare stem cell therapy with the traditional way of treating diabetes which is insulin injection. Dialysis is for patients kidney failure not specifically for type I diabetes patients. [2]

[Total: 10]

4 (a) Describe how the results in Fig. 4.1 provided evidence for the semi-conservative mode of DNA replication.

This question was badly done despite it being a standard question on experimental evidences of DNA replication and there being a similar question in tutorial.

Main problems for this question were:

- *Writing all about the results w/o **key concepts or keywords** on **semi-conservative mode of DNA replication***
- *Not using/ wrongly using the term DNA **molecule** and **DNA strand***
- *Not realising that the figure shows the density of **DNA molecules** rather than density of individual strands*

E.g. of a common answer with no use of keywords/ no use of DNA molecule or strands: Cells are at the middle of 14N and 15N mark then they start to shift towards the 15N mark, thus the new cells now contain 15N14N and 14N14N

E.g. of not using molecule and strand properly: DNA molecule contained half of N14 and half of N15 / form a 15N-14N strand

Either 0 generation to 1st generation	OR 1st generation to 2nd generation
• ^{15}N-^{15}N parental molecule unzips/ or strands **separates**,	• OR ^{5}N-^{14}N parental molecule unzips and) or strands **separates**
• each ^{15}N strand acts as **template**	• OR Each ^{15}N and ^{14}N DNA strand act as **template**
• for the synthesis of **complementary** light/^{14}N DNA strand/ via **complementary base pairing** *For this mark point, reject merely saying (the template strand is exposed) so that 14N daughter strand can bind complementarily to it.* *------ must have idea of daughter strand being **synthesised***	• OR for the synthesis of **complementary** ^{14}N DNA strand / via **complementary base pairing**
If not context given at all, then max 2 marks are awarded for correctly talking about separation and template (1 mark) , synthesis of complementary strand (1m)	
Can award two marks for describing results of 1st and 2nd generation	
• results in(**all)** daughter molecules of **intermediate density** *(not mass/ not stain!)* /hybrid/ made up of ^{15}N-^{14}N daughter strands OR forms daughter DNA molecules of intermediate density, each consists one heavy/ ^{15}N parental strand and one light ^{14}N newly synthesized strand as seen in generation 1 (seen in 20mins)	• **Half** of the daughter DNA molecules would consist of one ^{15}N parental strand and one ^{14}N daughter strand each (resulting in intermediate density). The other **half** would consist of one ^{14}N parental strand and one ^{14}N daughter strand each (resulting in light density) (seen in 38 mins)

Please practise a similar question in N2013 P2Q3

[4]

(b) Fig. 4.2 is an electron micrograph showing DNA replication occurring in a cell.

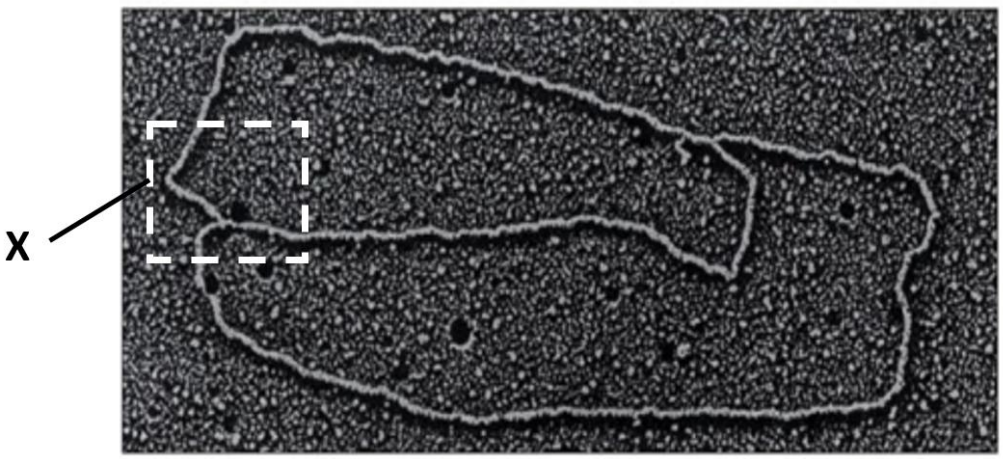
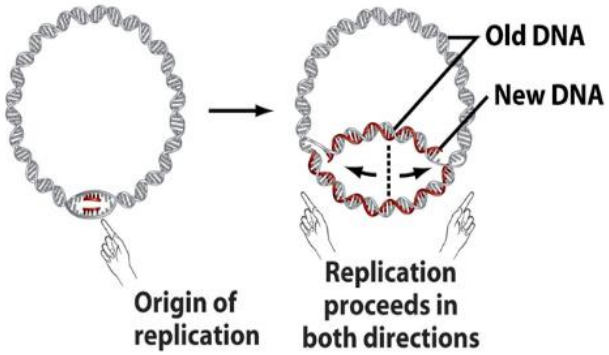


Fig. 4.2



(b) **(i)** State **two** evidences in Fig. 4.2 which show DNA replication is occurring inside a prokaryotic cell.

Some students misinterpreted the question and thought the question was asking for an evidence which shows DNA replication is occurring (ignoring the "prokaryotic cell')

- Presence of only **one** replication bubble
  Reject merely saying "a replication bubble"
  ---this is to distinguish between students who misinterpreted the question as asking for evidence which shows DNA replication is occurring (ignoring the "prokaryotic cell')
- **Circular** DNA

Reject:
DNA is not membrane bound / no nuclear envelope/ no nuclues
No presence of membrane bound organelle
*---- Please write answers based on **what you see**, not what you cannot see. This could be a very close-up of the nucleus, such that the nuclear envelope is actually present but its not seen in the field of view of the microscope!*

Reject DNA is not very highly condensed
----- during DNA replication, DNA in both prokaryotes and eukaryotes are not supposed to be highly condensed. This is to allow enzymes and proteins to access the DNA template for replication

[2]

(ii) With reference to Fig. 4.3, explain why DNA replication at each replication fork is described as asymmetrical replication.

[Describe asymmetrical replication max 3] ***point-to-point comparison*** *is not necessary but* ***preferred***

- The leading strand is **synthesized continuously** while the lagging strand is synthesized **discontinuously** in **short fragments/ in Okazaki fragments**
- The leading strand is synthesized **towards the replication fork** while the Okazaki fragments/ lagging strand is **synthesised away from the replication fork**

Reject merely saying opposite direction
Reject reference to ori, towards ori, away from ori ---- ori is not clearly visible as a structure in diagram
Reject replication occurs in the 5' to 3' direction versus 3' to 5' direction

- **Multiple**(accept 2) **RNA primers** are needed to synthesize the lagging strand, while only **one RNA primer** is needed to synthesize the leading strand

Reject lagging strand needs DNA ligase while leading strand does not need ligase
------ leading strand requires ligase as well since leading strand has a primer

Most students gained 2 to 3 marks for describing the asymmetrical replication but did not gain full marks because the ***reasons for the asymmetrical replication*** *were not given*

[Explain at least 1]

- DNA polymerase only adds **DNA nucleotides** to the **free 3' end** of the newly synthesized strand/ DNA polymerase synthesize DNA only in the 5' to 3' direction / as the active site of DNA polymerase is complementary to the free 3'OH end of the newly synthesised strand
  Accept DNA replication occurs in the 5' to 3' direction
  --- but answer must be phrased as a ***reason*** *rather than just a description of replication*

This reason was less commonly given

- The **parental/ template** DNA **strands** are **anti-parallel/ opposite directions /** one is **5' to 3'** direction, the other **3' to 5' direction**

Reject daughter strands are antiparallel to each other
--- two new daughter strands are not complementary base-paired to each other, hence it is not meaningless to say there are antiparallel to each other [4]

[Total: 10]

5 (a) (i) State the name of the structures **A**, **B** and **C** shown in Fig. 5.1.

- A – (Icosahedral nucleo)**capsid head**
- B – **Tail** (sheath) (ignore non-contractile)
  Accept Tail core protein
- C – **Tail fibre** (singular)

Common wrong answer: baseplate pin / tail pin

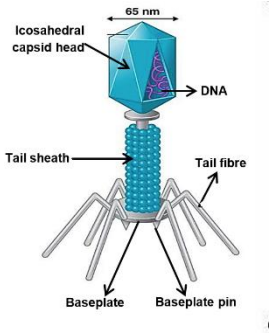


Fig 13: Model of T4 phage

[3]

(ii) Describe the role of prophage in the genetic recombination of bacteria.

Some students NAQ and described
- *integration process during lysogenic cycle*
- *lysogenic cycle/ described lytic cycle*
- *advantage of replication of prophage silently in the host cell*

*The above answers do not address prophage help in **genetic recombination of bacteria**.*
What is a prophage?
*When the λ dsDNA genome **integrates** into a specific site on the bacterial chromosome.*
*At this stage the **phage genome** is known as a **prophage***

Many also didn't know what a prophage is.
And wrongly described " prophage infects/ injects/ bind to bacterial cell" or some thought prophage is a transducing phage

- Name process as **specialised transduction**;
- A (small specific) portion of the **bacterial DNA adjacent to the prophage** (site) is **excised together with prophage** (when prophage excises itself from the donor bacterium's chromosome);
- The excised DNA (containing bacterial DNA and part of prophage) is **packaged into capsid** of new / progeny / transducing (lambda) phage

- Lambda / transducing phage *(not called recombinant phage , not called prophage!)* (carrying the excised DNA) **infects** a **new / recipient/ another bacterium** and **injects donor bacterial DNA** into recipient bacterium or integrates its DNA together with **donor DNA** into new bacteria
  *This point must have idea of a **new/ recipient/ another bacterium** being infected and idea of **donor DNA** being introduced*

[3]

Diagram from Virus notes, illustrating lysogenic and lytic cycle of lambda phage

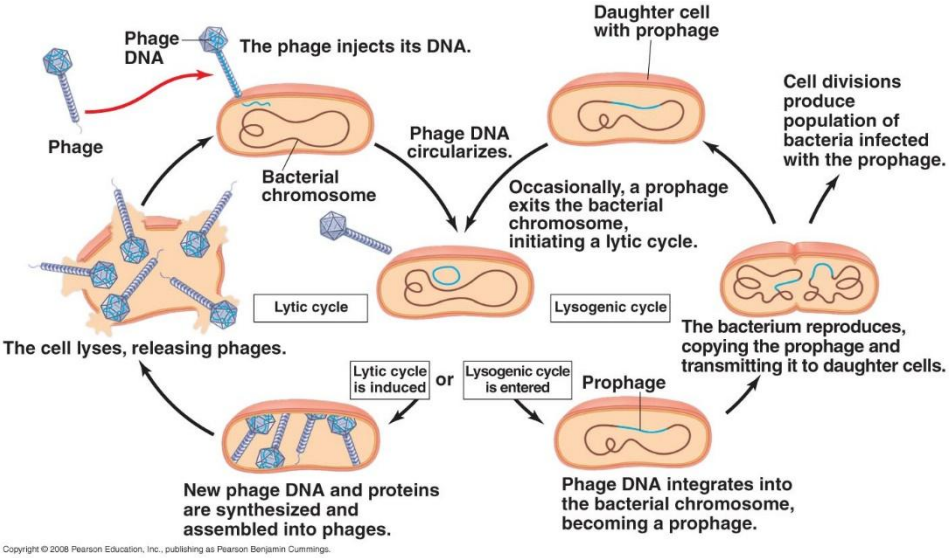
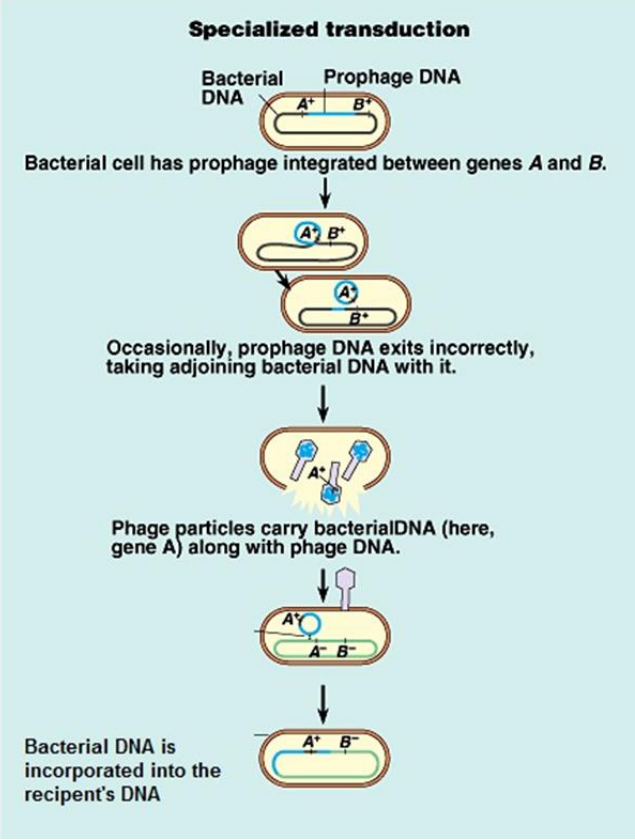


Diagram from Bacteria notes, illustrating how the switch from lysogenic to lytic cycle in lambda phage can lead to specialised transduction



(c) Globally, there has been an increase in multi-drug resistant bacterial infections that cannot be treated with antibiotics. This has led some scientists to propose the use of bacteriophages, such as T4 phages for therapy, in replacement of antibiotics.

Explain why phages are effective in killing multi-drug resistant bacteria upon entry.

1. The T4 phage DNA codes for endonuclease that hydrolyses the bacterial DNA. (accept nuclease/ genome/ bacterial chromosome)
2. Phage synthesise lysozyme to break down the bacterial peptidoglycan cell wall. (Reject bacterial cell membrane/ cell surface membrane)
3. With the cell wall damaged, water enters cell by osmosis → causes the cell to (swell and) burst. (accept osmotic lysis)
4. Large number of phage released upon host cell lysis (100-200 phage particles) → can infect new/ more cells;
5. Reference to specificity of phages to a particular host (narrow host range); [3]

Examiner's comments:
Generally well done.

[Total: 9]

6 (a) Describe the role of structure **T** in the process of genetic recombination of bacteria.

- (genetic recombination) Conjugation
- (name of structure **T**) Conjugation tube/ mating bridge/ (accept: sex pilus)
- from F+ (to F- cell)
- Form the physical contact via (between bacterial cells)
- Transfer of plasmid from donor to recipient cell.
- One example of phenotypic change: Gain antibiotic resistance/ Resistance to heavy metals/ Ability to use new metabolites/ Produce toxins [3]

Examiner's comments:
Generally well done.

Wrong terms/ concepts:
- *F^+ /F^- plasmid*
- *Conjugation is between F^+ and F^- plasmid*
- *Exchange of plasmids*

(b) With reference to Fig. 6.2, describe and explain the effect of temperature on the frequency of transfer of genetic materials.

- (Describe - Quote data) At 25°C, frequency of transfer is higher at $1.00E^{-06}$ than at 37°C which is only at $1.00E^{-10}$/ higher by $1.00E^{-04}$
- Lower temperature lower kinetic energy, lesser vibrations between bacterial cells
- Conjugation tube more stable/ not easily broken/ more stable physical contact → better transfer of plasmid

Examiner's comments:
Generally well done for data quoting. But the explanation was very geared towards to proteins denaturing but we are looking at 37°C which is not a high temperature so protein denaturation will not be happening.

[3]

[Total: 6]

7 (a) (i) Name stages **A** and **B**.

Stage A: Interphase
Stage B: Prophase [1]

Examiner's comments:
- *Interphase was missed out by many candidates for stage A. One way to tell it is interphase is the presence of a clearly defined nuclear envelope, as the nuclear envelope only disintegrates in prophase.*
- *Many students wrote wrongly that stage B is metaphase, anaphase, or telophase. They did not see that the chromosomes are actually not arranged along equator and not separating, but rather random which is the case of prophase;*
- *The dyes target proteins (histones, spindle fibres).*

(ii) Describe what happens in between stage **A** and stage **B**.

1. Nuclear envelope disintegrates;
2. Chromatin fibres coil / condense to become chromosomes;
3. Each chromosome consists of two genetically identical sister chromatids joined at the centromere;
4. Nucleolus disappears;
5. Spindle fibres form;
6. Centrioles migrate to opposite poles (reject: ends) of the cell; [3]
7. Organelles replicate (in G2);
8. Centrioles duplicate/ divides (in G2)

Examiner's comments:
- *The stage between interphase and prophase should be G2 and early prophase. Hence, answers pertaining to G1 and S phase of interphase are not accepted.*
- *Discussions on the checkpoints are also irrelevant;*
- *Chromatids are not the same as chromatin (fibres);*
- *Some students wrongly thought the process show stages in meiosis rather than mitosis;*
- *No marks are given for any description pertaining to other stages in mitosis;*

(b) (i) With reference to Fig. 7.2, name the structures labelled **X** and state a visible feature which enabled its identification.

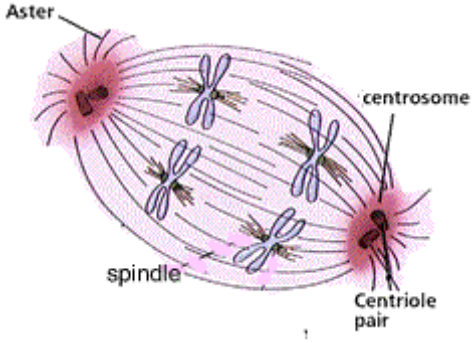
- (A pair of) **centrioles**
- **9 triplets** (of **microtubules**) arranged in a ring

OR

- A pair of hollow cylindrical structures

OR

- lying at right angles to each other



Examiner's comments:
- *Most students were able to name X correctly, but some did not realise it is to be written as plural. Marks are given but this should not be the case.*
- *Common wrong answers were centrosome, asters, ribosomes.*
- ***Vague explanations** are rejected: "shape of 2 structures are a visible feature which enables its identification" → so what is the shape?*
- *Not many people realise that asters are not common as answers in the A levels. They are just very short spindle fibres towards the plasma membrane.*
- *Centrosome is a region containing a pair of centrioles.* [2]

(ii) Describe the role of **X** in the elongation of the cell during anaphase of mitosis.

1. Aid in formation of non-kinetochore microtubules;
2. Non-kinetochore microtubules lengthen/ overlap / interact with other non-kinetochore microtubules from opposite pole of the spindle (at the equator / metaphase plate);

Examiner's comments:
Most students wrote about kinetochore microtubules, and did not realise that they are irrelevant to the elongation of the cell;

[2]

(c) State **one** way in which the behaviour of chromosomes in mitosis differs from their behaviour in meiosis.

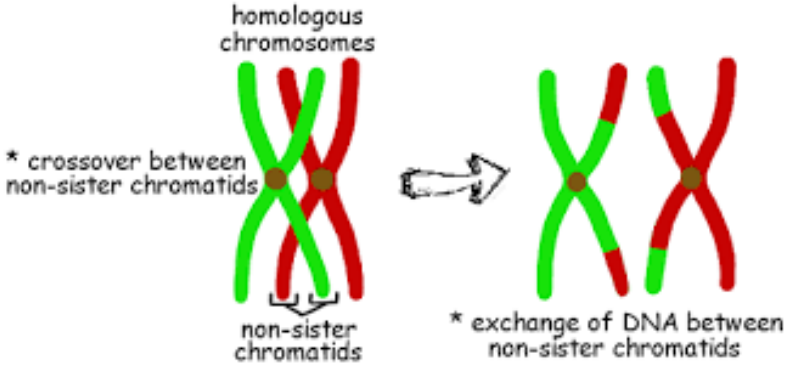
(Any 1 comparison below):

Feature	Mitosis	Meiosis
Synapsis	No pairing of homologous chromosomes to form bivalents in mitosis	Pairing of homologous chromosomes in Prophase I of meiosis to form bivalents
Crossing over	No crossing over occurs (between non-sister chromatids of homologous chromosomes)	Crossing over occurs/ chiasmata forms between non-sister chromatids of homologous chromosomes in Prophase I
Pairing of chromosomes	In metaphase of mitosis, chromosomes line up singly at the equator/ metaphase plate	In metaphase I of meiosis, homologous pairs of chromosomes line up at the equator/ metaphase plate
Anaphase	Separation of (genetically identical) sister chromatids during anaphase of mitosis	Separation of homologous chromosomes (each composed of two sister chromatids) during anaphase I of meiosis

[1]

Examiner's comments:

- *Wrong phrasing includes "In meiosis, chromosomes pair up to form homologous chromosomes". This is wrong!*
- ***Homologous chromosomes are present in both mitosis and meiosis**; The difference is their behaviour;*
- *Hence it is wrong to say homologous chromosomes are not present in mitosis.*
- *Diploid and haploid answers are not accepted as they do not pertain to chromosomal behaviour; the orientation of the chromosomes in terms of being the equator being perpendicular is true only between metaphase I and metaphase II;*
- *Some students are confused with sister chromatids and non-sister chromatids. Sister chromatids are joined at the same centromere. They become non-identical sister chromatids only after crossing over. BUT non-sister chromatids belong to different chromosomes!*



- *Separation of homologous chromosomes occur in meiotic anaphase I, while sister chromatids separate in mitotic anaphase.*
- *Most students did well for this part of the question.*

[Total: 9]

8 (a) Draw a genetic diagram in the space below to explain the observed results.

F1 phenotype:	disk shaped squash	x	disk shaped squash
F1 genotype: [1 mark]	AaBb	x	AaBb
Gametes:	AB, Ab, aB, ab (circled)		AB, Ab, aB, ab (circled)

Punnett Square [1 mark];

Gametes	AB (circled)	Ab (circled)	aB (circled)	ab (circled)
AB (circled)	AABB	AABb	AaBB	AaBb
Ab (circled)	AABb	AAbb	AaBb	Aabb
aB (circled)	AaBB	AaBb	aaBB	aaBb
ab (circled)	AaBb	Aabb	aaBb	aabb

F2 genotypic ratio: [1 mark]	9 A_B_:	3 A_bb : 3 aaB_	1 aabb
F2 phenotypic ratio: [1 mark: including showing how phenotype is linked to genotype]	9 disk shape	6 spherical shape	1 long shape

[4]

Examiner's comments:

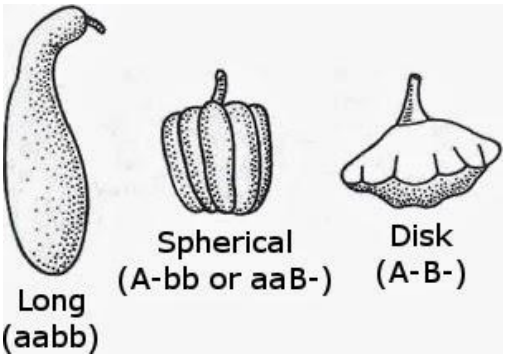
- *2 genes yet showing one characteristic (shape of squash) shows that this is epistasis.*
- *Some students thought this is co-dominant or linked genes with crossing over.*
- *Students did not realise that epistasis is based on a modified 9:3:3:1 ratio, so this is 9:6:1. Some students attempted to calculate the ratio and got funny ratio numbers.*
- *The correct way to calculate epistasis ratio is to take the number/total x 16;*
- *Students **must** show the link between genotype and phenotype;*

(b) State the genotypes of the two pure-breeding parents.

- aaBB and AAbb;

Examiner's comments:

- *Common errors include AABB and aabb;*



[1]

(c) Explain how different genotypes give rise to the spherical shape.

- Idea that either A OR B allele results in sphere
- Idea that allele A and allele B codes for different enzymes;
- Idea of a metabolic pathway, with sphere being an intermediate, and disk being the shape if both enzymes coded by allele A and B are present (long is when no functional enzymes are present);

Examiner's comments:

- *Poorly done. Most students could not explain in terms of a metabolic pathway, or the idea of A and B allele codes for functional enzymes that give rise to the sphere or disk shape;*
- *Many did not realise that the disk shape is a result of BOTH allele A and allele B, and that long shape is a result of homozygous recessive in both genes;*

[3]

(d) A chi-squared test is performed, and the results show that there is no significant difference between observed numbers and expected numbers derived from a genetic cross.

Suggest why the actual numbers recorded do not always match the expected numbers exactly.

- The sample size is too small when collecting experimental data;
- Different survival rate for sperm/egg/zygotes with particular genotypes;
- Adverse environmental conditions affecting survival and growth;
- Error in judging named phenotypes;
- Non-random assortment in meiosis/ AW;
- Non-random fertilization/ described fusion of gametes
- AVP, e.g. mutation.

(Any 2)

Examiner's comments:

- *Poorly done. Those who scored identified sample size being too small*

[2]

- *Some stated "chance" events, without explaining that the chance events include mutations, adverse environment that did not result in all plants growing;*
- *Random events are commonly cited, but a completely random event would give rise to the theoretical ratio; It is **non-random** events that results in deviation from theoretical ratio in reality;*

[Total: 10]

9 **(a)** Suggest why plant cells with chloroplasts also contain mitochondria.

- ATP synthesised in chloroplasts stays within chloroplasts/ stroma/ only for use in photosynthesis
- to provide energy for reactions in the Calvin cycle/ light-independent stage
- ATP synthesised in mitochondria is transported out to cytosol
- to provide energy for mitosis, active transport (specify a use in cell)

[3]

Examiner's comments:

- *Poorly done. Not many students knew that chloroplasts can synthesize its own ATP (by photophosphorylation) and this ATP is **NOT** used for cellular activities. Calvin cycle uses ATP that comes only from the chloroplast light dependent reaction itself!*
- *Many students wrote irrelevant information about mitochondrion produces carbon dioxide for photosynthesis, which explains why mitochondria are important in a plant cell. Actually, plants can get CO_2 from the atmosphere;*
- *Another wrong answer includes how at night, there is no photosynthesis, so mitochondrion makes ATP for the chloroplast so Calvin cycle can continue. This is wrong! Repeating again, Calvin cycle uses ATP that comes only from the chloroplast light dependent reaction itself!*
- *Some students knew that mitochondria make ATP for the cellular usage BUT fail to cite an example of usage, such as active transport, etc.*

(b) On Fig 9.1, draw a line to show:

(i) **one** location where substrate level phosphorylation occurs.

Label the line with the letter **S and** state the **name of the stage of respiration** occurring at that location. [1]

- Correctly points to **matrix of mitochondrion**, labelled as **S: Krebs cycle**
  OR
- Correctly points to **cytoplasm** , labelled as **S: glycolysis**

(ii) **one different** location where the hydrogen atoms that are involved in oxidative phosphorylation come from.

Label the line with the letter **H and** state the **name of the stage of respiration** occurring at that location. [1]

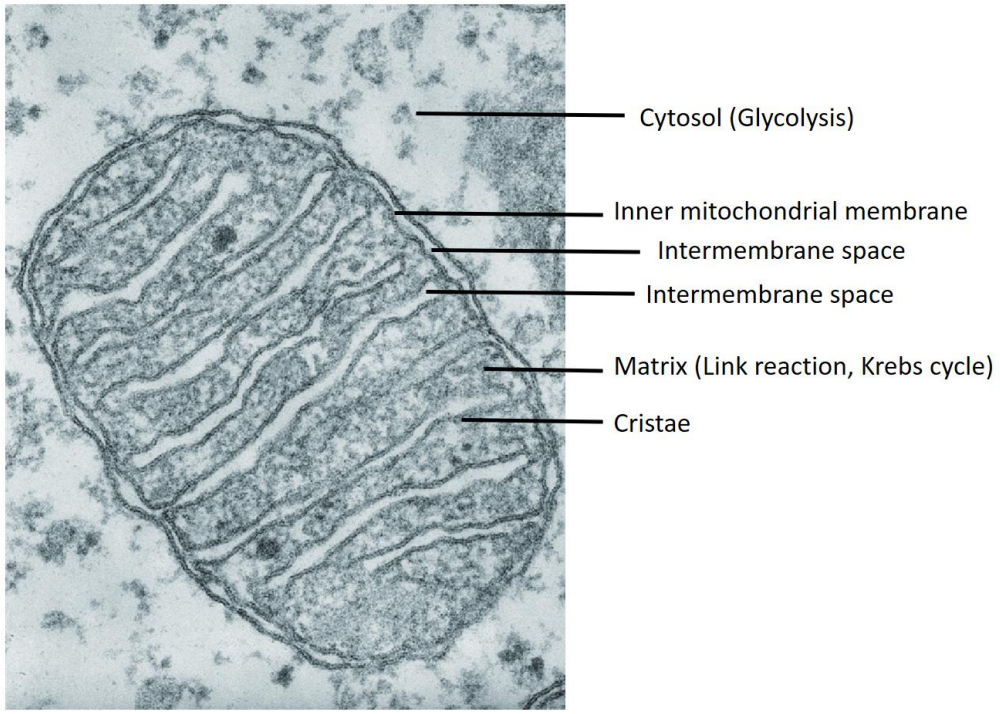
- Correctly points to **matrix of mitochondrion**, labelled as **H: Krebs cycle / H: link reaction**

OR

- Correctly Points to **cytoplasm ,** labelled as **H: glycolysis**

Examiner's comments:

- *Hydrogen atoms for oxidative phosphorylation come from NADH and $FADH_2$.*
- *Link reaction does not make ATP by substrate level phosphorylation, but some candidates did not know this. SLP occurs only in glycolysis and Krebs cycle.*
- *There were many wrong answers including those that stated oxidative phosphorylation as the source of hydrogen.*
- *Many candidates thought glycolysis occurs in the mitochondrion.*
- *Not many people know the structure of the various parts of mitochondrion and their role. It is important to familiarise yourself with this:*



(c) **(i)** State how oxygen is involved in oxidative phosphorylation and in photophosphorylation.

- Oxygen acts as **final electron acceptor** in oxidative phosphorylation.
- Oxygen is formed from **photolysis of water** during (non-cyclic) photophosphorylation [2]

Examiner's comments:

- *Photolysis of water is often missed out by many candidates;*

(ii) Some bacteria can survive in anaerobic conditions by utilising light energy to drive the production of ATP in the cell membrane. In such conditions, the bacteria make a special protein, bacteriorhodopsin. Bacteriorhodopsin is a protein that acts like a light-activated proton pump. The mechanism of action of bacteriorhodopsin is shown in Fig. 9.2.

Using the information in Fig. 9.2 and your knowledge of photophosphorylation and oxidative phosphorylation, explain how bacteria with bacteriorhodopsin make ATP in anaerobic conditions.

Compulsory point
1. (photons of) **light absorbed** by **bacteriorhodopsin/ bacteriorhodopsin uses light energy that strikes**
(reject light activates bacteriorhodopsin/ light open the channel)
2. change in **shape** of bacteriorhodopsin
3. **pumps protons** from the cytoplasm to the space between the cell membrane and cell wall (reject: intermembrane space)

(Describe chemiosmosis: Max 2 below)
4. generates a **proton gradient** across the cell membrane
5. **protons diffuses (reject: active transport)** through (channel of) **ATP synthase**
6. generates **proton motive force**
7. which drives the **phosphorylation of ADP , forming ATP**

Examiner's comments:
- *Some candidates wrote irrelevant stuff like anaerobic respiration, and even made irrelevant reference to mitochondrial and chloroplast! There was also incorrect reference to the use of glucose which is not shown in Fig. 9.2*
- *Students must use Fig. 9.2 to first answer the question, throwing in keywords from what they have learnt. And not use their own outside knowledge and force it in the answer which is not supported by Fig. 9.2.*
- *Answers like intermembrane space is not accepted if it does not make reference to the figure on the space between cell wall and cell membrane.*
- *Description of chemiosmosis is the one that usually generate marks for the candidates;*

[4]

[Total: 11]

10 **(a)** Explain the relationship between phylogeny and classification.

1. Classification is organisation of species into groups based on **observable shared characteristics**
   - (Accept if never write "observable" and AW/idea of visible)
   - (Reject if never write "shared" but accept AW/idea of similar, common)
   - (For "characteristics", can accept: trait, morphological features / structures, phenotype, but reject: similarities in analogous structures because can also be homologous structures)

2. Classification may not take into consideration **evolutionary relationship** *(Reject: ancestry relationship)* between the species

3. Phylogeny is organisation of species according to particular characteristics / molecular homology, which takes into **consideration evolutionary relationship** between the species.
   - (For "evolutionary relationship" can accept: [time of] evolution / divergence from common ancestor)

[2]

(b) **(i)** State the term used to describe the relationship between forelimb structures shown in Fig. 10.2.

Homologous structures

Common wrong answers:

- Vestigial structures
- Morphology
- Morphological features
- Anatomical homology
- Morphological species concept
- Divergent evolution
- Microevolution / evolution

[1]

(ii) With reference to Fig. 10.2, explain how the structures of *Archaeopteryx* provide evidence to support the hypothesis that modern birds (such as pigeon) descended from small dinosaurs (such as *Ornitholestes*).

Any 4

1. Fossil records of the extinct ***Archaeopteryx*** (underline *Archaeopteryx*) may **allow for comparison** of the bone structures / anatomy / morphological structures / conserved structures with the extinct (ancestor) ***Ornitholestes*** and **pigeon** (descendant);

2. *Archaeopteryx* is a **transitional/intermediate fossil**;
   (Reject: "Archaeopteryx is an intermediate between Ornitholestes and pigeon" → transitional fossil is the proper scientific term used to describe the fossilised remains of an organism that has traits common to both an ancestral species and its derived descendant species. This is especially important where the descendant group is sharply differentiated by gross anatomy and mode of living from the ancestral group. If you only used the word intermediate, the dictionary says that it means "coming between two things in time, place, character" which is not the same as a transitional fossil)

3. Presence of **many homologous structures / idea of similarity of the basic plan of bone structures / give examples of bone structures that are similar common to both *Ornitholestes* and pigeon** / all 3 (will support the hypothesis that they are closely related, that the *Ornitholestes* is the ancestor of the modern birds such as the pigeon);
   (Mark was awarded if student compared all 3 species with examples, benefit of doubt (BOD) given if student mentioned "small dinosaurs" → inferred for you as small dinosaurs = both Ornitholestes and Archaeopteryx)

4. *Archaeopteryx* (transitional fossil) **reveals ancestral characteristics** / description of characteristic such as long bony tail / teeth from *Ornitholestes* which have been **lost over time** and are absent in (modern birds such as the) pigeon;

[4]

5. It allow **reveals characteristics (such as longer arms / feathers) found in** (modern birds such as the) **pigeons** / descendants which are present in the *Archaeopteryx* / transitional fossil but were **not found in *Ornitholestes*** (all these characteristics are unique to each group but are not found in the other groups of organisms);

6. It **shows descent with modification**, where structures from ancestral *Ornitholestes* species are modified over time
   OR
   *Accept full description of descent with modification (but the underlined words must be present) → **ancestral** characteristics are **modified over many generations** to **adapt** to **new selection pressure** / the descendant species inherited characteristics from the ancestor species but are **modified over generations** to better adapt to the environment/new selection pressure;*
   (Reject: detailed explanation of how Darwin's theory of natural selection could have resulted in evolution from Ornitholestes to Archaeopteryx, and then to pigeons → this is NAQ as the question asked for "how structures [from the fossil] of Archaeopteryx provide evidence" which means how did the fossil provide support that birds may have descended from dinosaurs. The question did not ask you about how (steps) the dinosaurs evolved to become birds

   Moreover, usually natural selection is used to explain microevolution, changes in allele frequencies in the gene pool of a population from one generation to the next.

   ***Microevolution** is mainly concerned with small scale patterns of evolution. **Macroevolution**, which is the context of this question, is the descent of different species from a common ancestor over many generations. Characteristics present in an ancestral organism are altered in its descendants over time as they face different environmental conditions and hence different selection pressures. Macroevolution looks at evolution at a large scale over time, at or above species level.)*

7. For them to adapt to **different selection pressures** in different environment (Supports Darwin's Theory of Natural Selection too);
   (Reject: "the bone structures of the Archaeopteryx, Ornitholestes and pigeons are similar because of convergent evolution" → the phylogenetic tree given in Fig. 10.1 shows that all 3 organisms share a common ancestor [though not very recent], meaning that the structures are likely homologous structure due to divergent evolution from a common ancestor.)

   Other rejected answers:

   Misconceptions:
   "As dinosaurs are now extinct, we can conclude that modern birds descended from dinosaurs." → not true that when an organism goes extinct it must have left descendants. It is also not true that organisms still alive today cannot be an ancestral species that have descendant species.

Misphrasing:
"Modifying the Archaeopteryx population to the pigeon today." → does not fully convey the meaning of "descent with modification" like adapting to new, different selection pressure.

(c) Suggest why it is not possible to determine the phylogeny of the dinosaur and birds from the morphological features of the fossils.

Any 2

- Fossils may be **incomplete / damaged** / distorted (therefore unable to investigate/study anatomical homology → compare morphological features/structures and determine phylogeny accurately);
  *(Reject: need to find more fossil / absence of transitional fossils because NAQ → question asked you why cannot tell evolutionary relationship from **morphological features**, not the problems you will face trying to find evolutionary relationship from fossils.)*
  (Reject: fossils decompose rapidly / fossils are taken from hundreds of years ago and hence will not provide accurate data to determine phylogeny of dinosaurs and hence cannot do ancestor-tracing → students who think wrongly that fossils can decompose are not familiar with how fossils are formed. Fossils are actually rocks that can only be damaged by weathering and maybe human activity.)

- Morphological features is **not sufficient** and instead **molecular homology from genome / DNA / rRNA / amino acid sequence** is needed (for comparison of e.g. nucleotide sequence by multiple sequence alignment) to construct the phylogeny (idea of comparing DNA base sequence)
  OR
  Small differences in morphological features would indicate that the organism are closely related, however, they may have large differences in DNA sequences which indicates that they distantly related / do not share a recent common ancestor, this is contradictory.

Idea of subjectivity

- morphological features may look different due to **divergent evolution** where even though the birds are closely-related, they evolve **homologous structures** due to **different selection pressure** (in different environment) ;

- cannot determine if morphological features **look similar due to homology** or sharing of common ancestor **or due to convergent evolution** where the dinosaurs and birds not closely related evolve **analogous structures** due to **common / same / similar selection pressure**;
  (Reject: misconception that similar structures in different environments is due to chance → it's due to similar selection pressure in the different environment.)
  *(Reject ideas that are correct but **missing keywords**: "there may be some animals that may appear morphologically similar but may not have a common ancestor. This could be due to same selection pressures that may be found in the environments that these animals live together and hence may develop similar morphological features." → missing keywords analogous structures and convergent evolution.)*

- It is **difficult to quantify how much/many morphological differences** in structures **is sufficient** to show that the organisms are **not closely related / did not diverge from a common ancestor;** [2]

OR
It is **difficult to quantify how much/many morphological similarities** in homologous structures **is sufficient** to show that the organisms are **closely related / share a common ancestor;**

Reject vague explanations about subjectivity:
- *"Morphological features is subjective and it is difficult to determine the degree of similarity / difference between fossils" / "morphological features are quite similar and cannot be differentiated" / "unable to tell for sure the morphological differences, it is too subjective") → the problem is not whether I can tell the similarities / differences, the problem is, just from these similarities or differences, I can't tell evolutionary relationships*
- *"Fossils are limited in telling us information" → not clear what information.*

Other rejected answers:
- *Many students talked about we cannot check if they can interbreed and hence cannot tell phylogeny → this is incorrect, as we are not checking if they are the same species. Question is asking about phylogeny, which is whether the 3 different species are closely / distantly related.*

[Total: 9]

1 1 (a) With reference to Fig. 11.1, explain how influenza virus in inhaled air can be prevented from entering the epithelial cells of the respiratory tract by the innate immune system.

Chemical barrier

1. **Nasal cavity or upper respiratory tract** covered with **mucus** *(produced by goblet cells)* that **traps** foreign particles, including viruses;
   (Reject: mucous membrane → it does not mean mucus. This refers to a layer of cells that surrounds body organs and body orifices)
   (Reject: mucus washes away influenza → no it does not. It requires cilia to sweep mucus and trapped influenza out)

2. The mucus also **prevents** influenza from **adhering / attaching to the epithelium / epithelial cells / description of how mucus prevents haemagglutinin from binding to receptors containing sialic acid**;

3. The entrapped virus is then carried/swept back to the throat / pharynx (together with the mucus) by **ciliary action** *(sweeping action of cilia [plural])* of epithelial cells and swallowed. / In the **lower respiratory tract**, foreign particles, including viruses, are brought up by the **ciliary action** of epithelial cells.
   (Reject: "hair" instead of "cilia".)

Innate immune cells

4. (Alveolar) macrophages (in mucus / on epithelial layer of cells) **phagocytose** influenza viruses / engulf them by **phagocytosis**, preventing them from infecting epithelial cells;
5. Macrophages / infected cells secrete cytokines and chemokines which recruit more phagocytes / name phagocytes;
   (No need to talk about what happens inside the macrophage)

[3]

Other rejected answers:

- *"Cells in lung airways secrete lysozyme which breaks down the virus"* → *lysozyme breaks down bacterial peptidoglycan cell walls, not viruses (see page 7 of infectious diseases (I) lecture notes)*
- *"Epithelial cells form tight junctions"* → *NAQ because question asked how innate immune system **prevent virus from entering** the epithelial **cells**). This answer is more for prevent virus from entering the body / blood.*

(b) **(i)** Explain why T lymphocyte **K** has responded to the antigen during the immune response, but not T lymphocytes **J** and **L**.

1. (Naïve) T lymphocyte K with (specific) **T cell receptors** (TCR) *(Reject: wrong terms such as antigen receptors, cell surface receptors)* **binds** to **epitope / antigen** (peptide) **presented on the MHC** of macrophage/dendritic cell;

2. **Only** T lymphocyte K has a T cell receptor has a **complementary shape** to epitope of antigen; *(Reject: corresponds / identical / same / referring to T cell receptors having a specific/particular shape → because it doesn't explain why it can bind, which is because it has complementary shape to the epitope)*
   OR ref to different / wrong shapes of receptors on J and / or L that are not complementary in shape to epitope of antigen; [2]

(ii) Describe process **X**.

Process X: Clonal expansion and differentiation

1. This **activates** selected T lymphocyte K to **divide via mitosis**
2. to produce **genetically identical/clones** of daughter T cell K which
3. **differentiate** to form **effector** CD4 **T helper** and CD8 **cytotoxic T cells**;
   (Reject if did not name all the effector cells since the figure labelled "effector cells" for you already)
   (Reject: "differentiate by mitosis" → these students confused differentiation and mitosis → differentiation involves differential gene expression, leading to the cell becoming more specialised, mitosis is simply cell division) [2]

(c) Describe **two** ways in which antigen presentation differs in phagocytes and B lymphocytes.

NOTE: the answers below are not in complete sentences, which is required for exams. They are only for your reference.

Any 2:

Features	**Phagocytes**	**B lymphocytes**
Process to internalise antigen	Phagocytosis → pathogen in phagosome	Receptor-mediated endocytosis → pathogen in endosome
Purpose of antigen presentation	To activate naïve T cells	To activate itself
Target cells	Antigen peptide presented to both naïve CD4 and CD8 T cells	Antigen peptide presented to CD4 T helper cell (already) activated by the same antigen
NOTE: Answers below are about similarities → to include in answer for students to study but will not be awarded marks since question asked for differences.		
Antigen processing	• Phagosome/endosome fuses with lysosome → form phagolysosome/endolysosome. • Hydrolytic enzymes from the lysosome digest/breakdown antigens into smaller peptides	
Antigen presentation	• Peptide antigen binds MHC proteins in ER → form peptide-MHC complexes. • Peptide-MHC complexes transported to cell surface via embedding in membrane of transport vesicles, the Golgi body and then secretory vesicles. • Vesicles fuse with cell surface membrane → peptide-MHC complexes are embedded on cell surface membrane of APC & antigen is presented to naïve T cells (for phagocytes) T helper cells activated by the same antigen (for B lymphocytes) for recognition.	

[2]

Reject misconceptions:

- *"Phagocytes phagocytose the entire pathogen while B lymphocytes take in only part of the pathogen / antigen"*
- *"Phagocytes present both soluble and insoluble antigens while B lymphocytes present soluble antigens."*
- *"Phagocytes take in the antigen only, but B lymphocytes take in both the antigen and the B cell receptor."*
- *"Phagocytes present the antigens on MHC molecules while B lymphocytes present the antigens on B cell receptor."*

[Total: 9]