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NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME **ANSWERS**

CLASS

BIOLOGY **9744/03**

Paper 3 Long Structured and Free-response Questions **13 September 2024**

Additional Materials: Insert, Answer booklet **2 hours**

READ THESE INSTRUCTIONS FIRST

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

Section A

Answer **all** questions in the spaces provided on the Question Paper.

Section B

Answer any **one** question on the separate Answer 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 no 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	
Section A	
1	**25**
2	**15**
3	**10**
Section B	**25**
Total	**75**

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

[Turn over

Section A

Answer **all** the questions in this section.

Information for Question 1

One way of classifying bacteria is by looking at the differences in their cell wall structure. The differences are shown by using the Gram stain.

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

Escherichia coli is a Gram-negative bacterium.

Fig. 1.1 is a diagram through the cell surface membrane and the cell wall of *E. coli*.

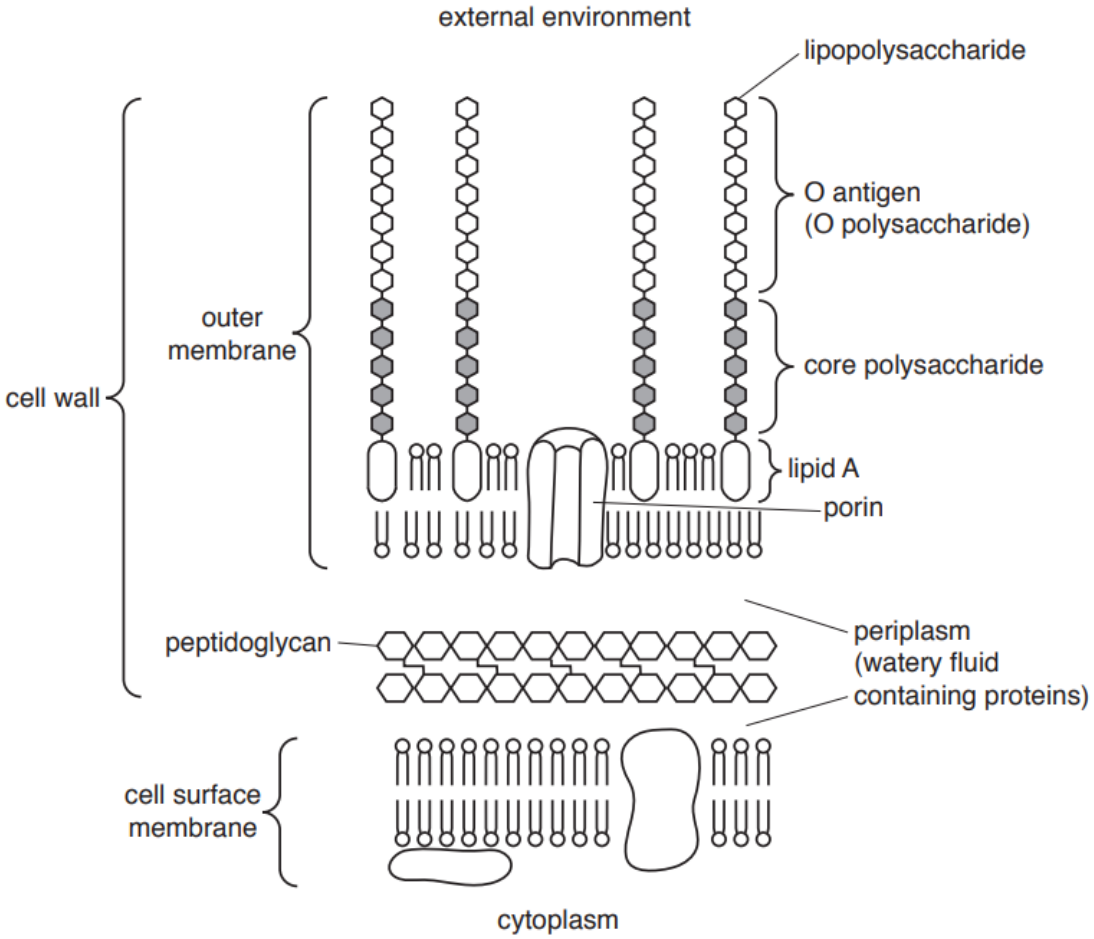

Fig. 1.1

Bacteria reproduce asexually through binary fission. Due to their fast growth and simple genetics, bacteria such as *E.coli* are widely used in molecular biology.

Fig. 1.2 shows a bacterial cell undergoing binary fission.

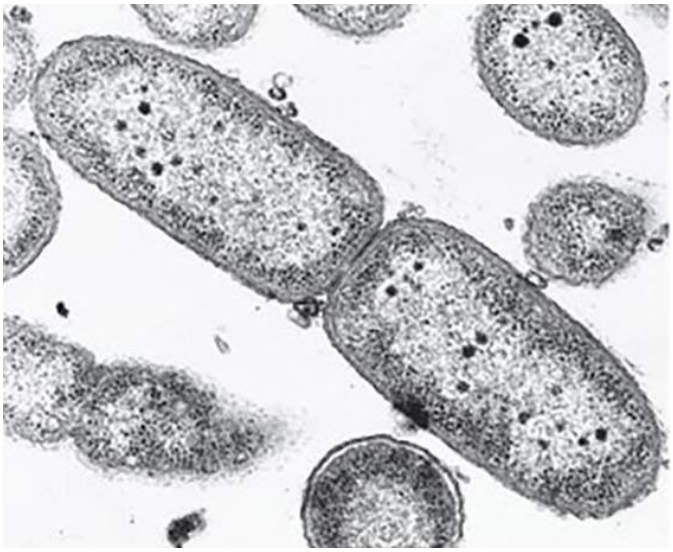

Fig. 1.2

1 Part of the information required for Question 1 is presented in the insert. Cross references to Fig. 1.1 and Fig. 1.2 are included in the questions for which Fig. 1.1 and Fig. 1.2 are relevant.

Bioinformatics is the collection, processing and analysis of biological data using computer software. The application of bioinformatics allows whole sequences of homologous genes to be compared across different bacterial species.

(a) Explain why bioinformatics can used to compare gene sequences and suggest a conclusion that can be made from the percentage similarity data obtained.

any one from:

why

1 large amount of, data / DNA sequences ;

2 fast / accurate / efficient ; A description of fast / accurate / efficient / detects each small difference = accurate

any one from:

conclusions

3 more similarity the more recent a common ancestor / AW ;

4 molecular clock ;

[2]

(b) Humans use antibiotics to treat bacteria infections. Different types of antibiotics work in different ways to either kill or inhibit the reproduction of the bacteria.

(i) Outline how penicillin acts on bacteria **and** use Fig. 1.1 to suggest why penicillin has little or no effect at treating diseases caused by Gram-negative bacteria.

A antibiotic for penicillin throughout

Max 2

1 weakens /AW, the cell wall¬ ; I punches holes / holes made

2 acts, on growing cells / when cell wall being synthesised;

3 inhibits / binds to / AW, enzymes / transpeptidases (for cross linkage formation) ; I ref. to synthesis of peptidoglycan

4 prevents formation of cross, links / linkages (between peptidoglycan / murein molecules) / AW ;

Max 2

Suggestions why antibiotic is less effective on gram negative

5 outer membrane prevents / interferes with / protects from / AW, entry (of penicillin) ; A idea of, more difficult / further, to reach peptidoglycan layer

6 proteins in outer membrane may pump out antibiotic ; A presence of efflux pumps

7 enzymes may be present (in periplasm) to degrade antibiotic / AW ;

8 suggestion that antibiotic cannot cross hydrophobic region of (outer) membrane ;

9 AVP ; e.g. proportionally, less / lower concentration of, penicillin reaches murein for, enzyme / transpeptidase, inhibition

[3]

(ii) The use of antibiotics has resulted in the emergence of antibiotic resistant bacteria.

Antibiotics such as nalidixic acid acts as an inhibitor of an enzyme involved in DNA replication.

Suggest how a substitution mutation in the gene coding for this enzyme could result in antibiotic resistance.

Change in mRNA codon, therefore change in amino acid;

Change in R group, resulting in change in bonds formed;

Change in specific 3-D conformation / tertiary structure (A change in pp folding / coiling),

change in binding site for antibiotic (R active site), therefore antibiotic cannot bind

[4]

(c) The outer membrane of E.coli contains transport proteins called OmpF porins. These porins allow the passive movement of water, ions and small, polar molecules across the outer membrane. Each OmpF porin is formed from three identical polypeptides.

(i) Suggest **and** explain the features of an OmpF porin as a membrane transport protein.

four from:

1 channel protein ; A pore protein / has a pore / has a channel

2 channel / pore, can form from polypeptides or (protein) has quaternary structure ;

3 hydrophilic R-groups, on amino acids lining channel / face inwards (towards channel) ;

A hydrophilic, lining / channel A water-filled, channel / AW A idea that passage is through hydrophilic region of protein

4 allows facilitated diffusion ; A diffusion alone if in context of through the protein but R if via phospholipid bilayer

5 increases permeability for, movement of water / osmosis ; I faster

6 no (specific) binding sites / (channel) not specific / not selective / allows more than one type of substance through / AW ;

7 globular ;

8 AVP ; e.g. ref. to hydrophobic part of protein, faces / interacts with, hydrophobic, region / core / fatty acid tails ref. to hydrophilic parts of, protein / polypeptide, extend into, external environment / periplasm / aqueous regions / AW

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[4]

(ii) *E. coli* can regulate the number of OmpF porins in the outer membrane to adapt to changing conditions. One control mechanism used by *E. coli* involves the production of a small mRNA molecule known as micF.

micF binds to the part of the mRNA molecule containing the START codon for the OmpF polypeptide.

Explain how the presence of micF prevents production of OmpF porins.

Binding between RNA and micF via CBP;

two from:

translation, cannot / does not, begin / occur

or

polypeptide / protein, synthesis, cannot occur / decreases ;

I ompF not made

A chain of amino acids

R transcription does not occur so translation does not occur

R if in context of mutation or enzyme inhibition

mRNA cannot attach to, ribosome / small subunit / ribosomal subunit ;

(first) tRNA (with UAC anticodon) / tRNA carrying met, cannot bind (to START codon) ;

.....

[3]

(d) Fig. 1.1 shows that the outer membrane of the cell wall of *E. coli* contains lipopolysaccharides(LPS). These are not present in the cell surface membrane. Each LPS consists of a lipid and a polysaccharide portion.

The O antigen is the outer part of the polysaccharide portion of the LPS. It faces the aqueous external environment.

(i) Define the term *polysaccharide*.

(composed of) many / chain of / polymer of / AW, monosaccharides / sugar monomers / sugar units ;

A glucose, molecules / residues

A more than two / many sugars

further detail ; e.g. carbohydrate

may be, branched / unbranched in context of polysaccharide

macromolecule in context of polysaccharide

glycosidic bonds in context of between sugar monomers

(sugar monomers) joined by condensation reactions

.....

.....

[2]

(ii) Some strains of *E. coli* are pathogenic. Different pathogenic strains have different O antigens.

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

three from:

1 specificity / specific (in correct context) ;

2 (B / T, -) lymphocytes have receptors complementary to antigen ; A immunoglobulins / antibody as receptors for B-lymphocyte A surface molecules as receptors for T-lymphocytes

3 (different) antigens, stimulate / activate / AW, (different) B-lymphocytes / T-lymphocytes ; A antigens stimulate an immune response

4 idea that different antibodies, synthesised / produced / AW, for different (O) antigens / O polysaccharides / lipopolysaccharides ;

5 memory cells will, not respond to different antigen / only respond to same antigen / AW ;

6 different O-antigens can, be composed of different sugars ; A can have different shapes

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[3]

(e) **(i)** With reference to Fig. 1.2, identify two events that occur during binary fission that do **not** occur during mitosis in human cells.

assume reference to binary fission unless stated otherwise

any two from:

~~DNA replication ; A idea of, doubling / duplicating, DNA~~

cell, elongation / gets longer ; A cell increases in size

cell wall formation ;

(includes) cytokinesis / described ;

max 1 if two ideas correct describing events that only occur in mitosis

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.....

.....

[2]

(ii) Binary fission produces genetically identical daughter cells unlike meiosis in sexual reproduction. Genetic variation is key to the survival of a species.

Outline briefly two possible ways in which variation can be introduced into the bacterial population.

- Random spontaneous mutations

- Transduction occurs when bacteria genes / DNA is transferred from one bacterial cell to another by a phage + incorporation into host genome by integration / homologous recombination;

- Transformation occurs when naked foreign DNA released from lysed bacteria into surrounding environment is taken up by bacteria using specific cell surface proteins + incorporation into host genome by homologous recombination;

- Conjugation occurs when the F plasmid is transferred from a F+ donor cell to a F- recipient cell through direct contact;

Ony mark once for homologous recombination.

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[2]

[Total: 25]

2 Photosynthesis is an energy transfer process that results in the production of carbohydrate. It has two stages: the light-dependent stage and the light-independent stage.

Cyclic photophosphorylation and non-cyclic photophosphorylation are essential pathways in photosynthesis that occur in the light-dependent stage.

(a) (i) Describe the similarities and differences between cyclic photophosphorylation and non-cyclic photophosphorylation.

Similarities

Photoactivation of chlorophyll / AW, occurs in **both A** excite electrons

ETC involved in **both**;

ATP produced in **both**;

[3]

differences

	cyclic	non-cyclic	
4	only PSI	PSI and PSII both involved	;
5	no, reduced NADP / oxygen, produced	reduced NADP / oxygen, produced	;
6	no photolysis **or** no oxygen-evolving complex involved	photolysis **or** oxygen-evolving complex involved	;
7	electrons emitted from PSI returned to PSI **or** PS1 is source of electrons	electrons emitted from PSII are replaced by water **or** water is source of electrons	;

(ii) Explain why herbicides that prevent cyclic photophosphorylation and non-cyclic photophosphorylation stop carbohydrates from being produced in the chloroplast.

*Any **two** from:*

No ATP and reduced NADP made;

No GP / TP made

Or

No Calvin cycle / light-independent reaction;

No regeneration of RuBP;

[2]

(b) The rate of regeneration of RuBP in the Calvin cycle is known to limit the rate of photosynthesis.

Sedoheptulose-1,7-bisphosphatase (SBPase) is an enzyme in the Calvin cycle that controls the rate of regeneration of RuBP. SBPase is coded for by the gene *SBPase*.

In an experiment, wheat plants were genetically modified to make more SBPase by introducing the *SBPase* gene from another grass species, *Brachypodium distachyon*. The resulting GM wheat plants were named Sox4.

- Wild type plants (not GM) and Sox4 plants were grown.
- A leaf from the wild type plant was placed in a sealed glass vessel.
- The carbon dioxide (CO_2) concentration in the vessel was increased so that the intercellular air spaces also had an increase in CO_2 concentration.
- The other environmental conditions were kept constant.
- The rate of fixation of CO_2 was measured for the leaf.
- The experiment was repeated with a leaf from a Sox4 plant.

Fig. 2.1 shows the rate of fixation of CO_2 by the leaves of wild type plants and Sox4 plants when the intercellular air space CO_2 concentration was increased.

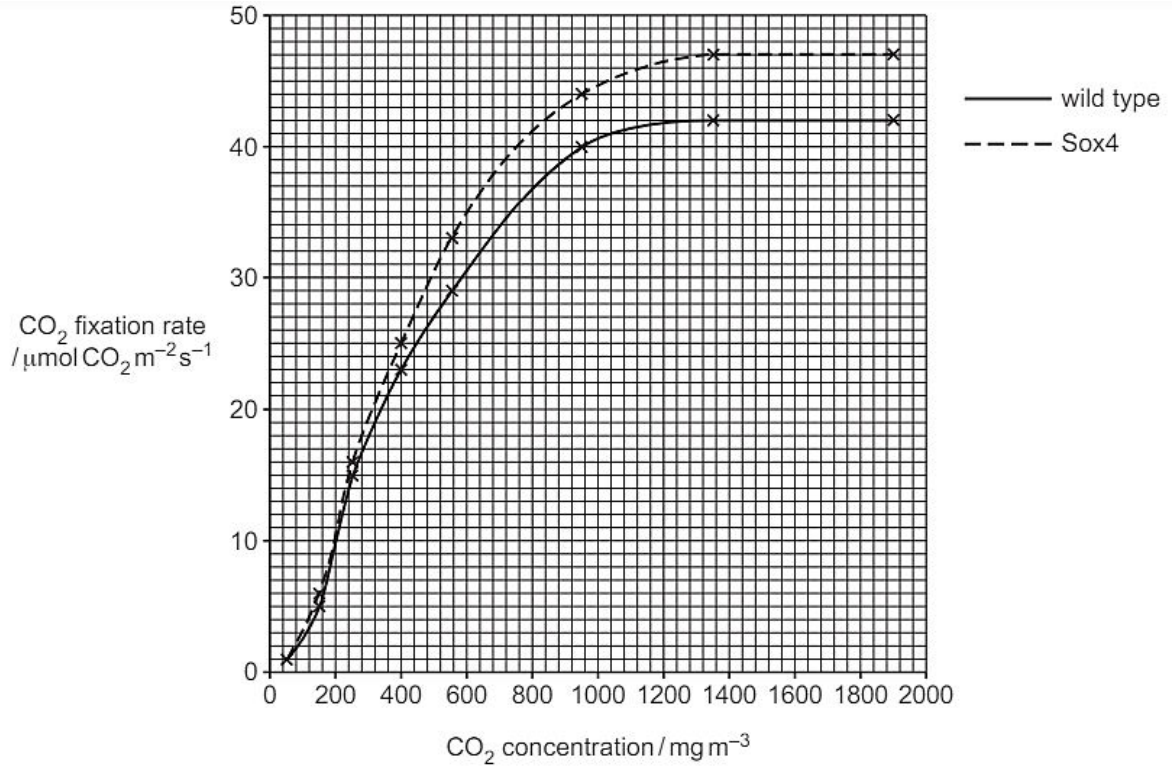

Fig. 2.1

(i) With reference to Fig. 2.1, describe **and** explain the results shown by the wild type plants.

As the CO_2 concentration increases, the rate of fixation of CO_2 increases;

(as) CO_2 concentration is the limiting factor;

As the CO_2 concentration increases, the rate of fixation of CO_2 remains the same / plateaus;

(as) CO_2 concentration is no longer the limiting factor;

Paired data quote with units to support, mp1 / mp3;

	CO_2 concentration / mg m^{-3}	CO_2 fixation rate / µmol CO_2 m^{-2} s^{-1}
mp1	50 ±10	1 ±0.25
	1200–1280	42 **A** 41.75
mp3	from 1200–1910	42 **A** 41.75

[3]

(ii) With reference to Fig. 2.1, explain the differences in the rate of fixation of CO_2 between wild type plants and Sox4 plants.

The rate of fixation of CO_2 is higher in Sox4 compared to wild type

or

Sox 4 reaches a higher (maximum) rate of CO_2 fixation;

(wild type) 42 vs (Sox4) 47µmol $CO_2m\text{-}^2s^{-1}$

(Sox4 has) more SBPase

or

There is a faster (rate of) regeneration of RuBP

or

(new) SBPase more effective;

More RuBP to react with CO_2 / rubisco;

[2]

Phytochromes are able to detect red light and far-red light, which are required for photosynthesis to occur in plants.

Upon reception of light by the phytochrome receptor, two signal transduction pathways are elicited in a Sox4 plant cell as show in Fig. 2.2. Both pathways eventually result in the synthesis of enzymes involved in chlorophyll production.

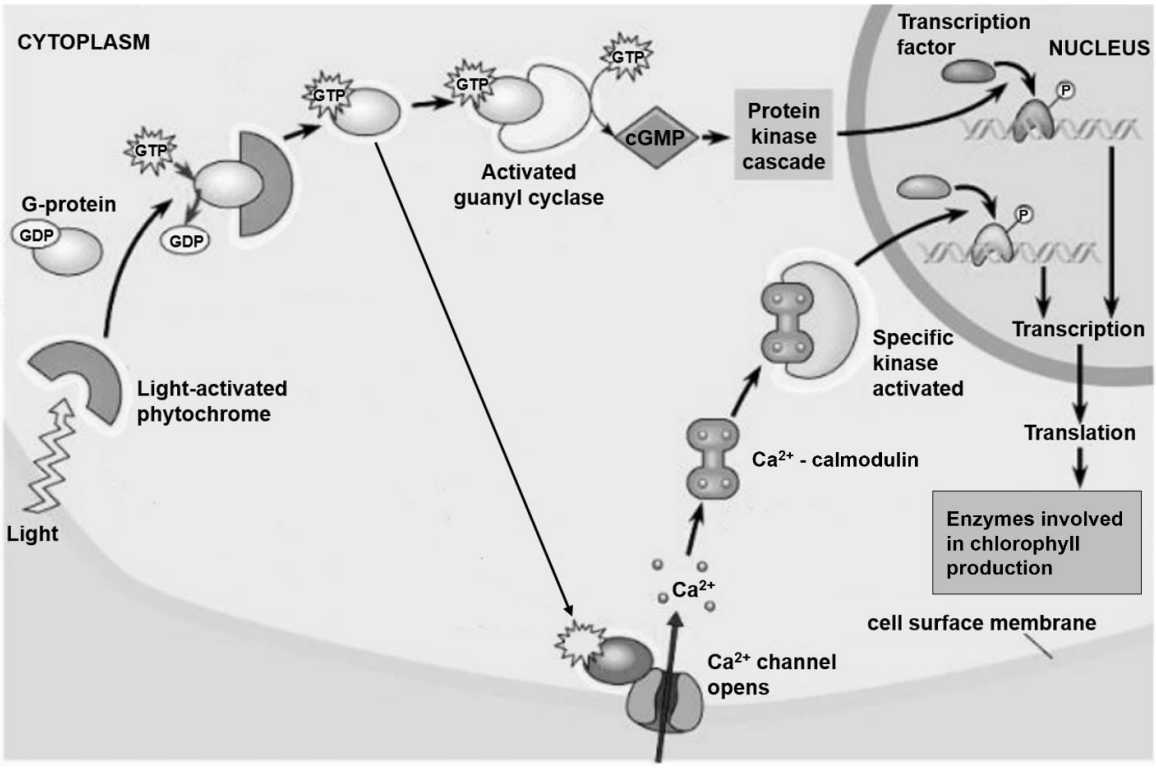

Fig. 2.2

(c) With reference to Fig. 2.2,

(i) identify the second messengers involved in the signalling pathway.

cGMP and Ca2+ / calcium ions; (all or none)

[1]

(ii) explain **one** step of the signal transduction stage in the cytoplasm that illustrates signal amplification.

1. The conversion of GTP to cGMP by guanyl cyclase / activation of G protein by phytochrome / protein kinase cascade;
2. A small number of activated guanyl cyclase can result in the production of a large amount of cGMP;

OR

A small number of activated phytochrome can result in the activation of a large number of G-proteins;

OR

Each protein kinase can result in activation of a large number of downstream protein kinases;

[2]

(iii) compare the activation of calmodulin with that of the final protein kinase in a protein kinase cascade.

Similarity:

1. Both calmodulin and the protein kinase undergo conformational change to become activated;

Differences:

2. Calmodulin is activated through the binding of 4 calcium ions;
3. Protein kinase is activated through phosphorylation by an upstream protein kinase;

[2]

[Total: 15]

3 The Hayflick limit is the number of cell division a normal somatic, differentiated human cell can undergo before cell division stops.

(a) Using your knowledge on DNA replication in cells, explain how the Hayflick limit occurs.

- Ref. to end-replication problem;
- RNA primer removed at 5' end of daughter DNA strand;
- DNA polymerase cannot replace it with DNA nucleotides due to a lack of 3' OH;
- The telomeres shorten to the critical length that stops further cell division;

[3]

Cancer cells can escape the Hayflick limit. Paclitaxel is a drug used in the treatment of some forms of cancer.

Researchers investigated the effect of Paclitaxel on the mitotic cell cycle of cancer cells:

- The cancer cells were grown for two days and then divided into groups.
- Each group was treated with a different concentration of Paclitaxel.

After 28 hours (one cell cycle):

- The percentage of cells in stages of mitosis was calculated.
- The ratio of the number of cells in anaphase to the number of cells in metaphase was determined.

Fig 3.1 shows the results of the investigation.

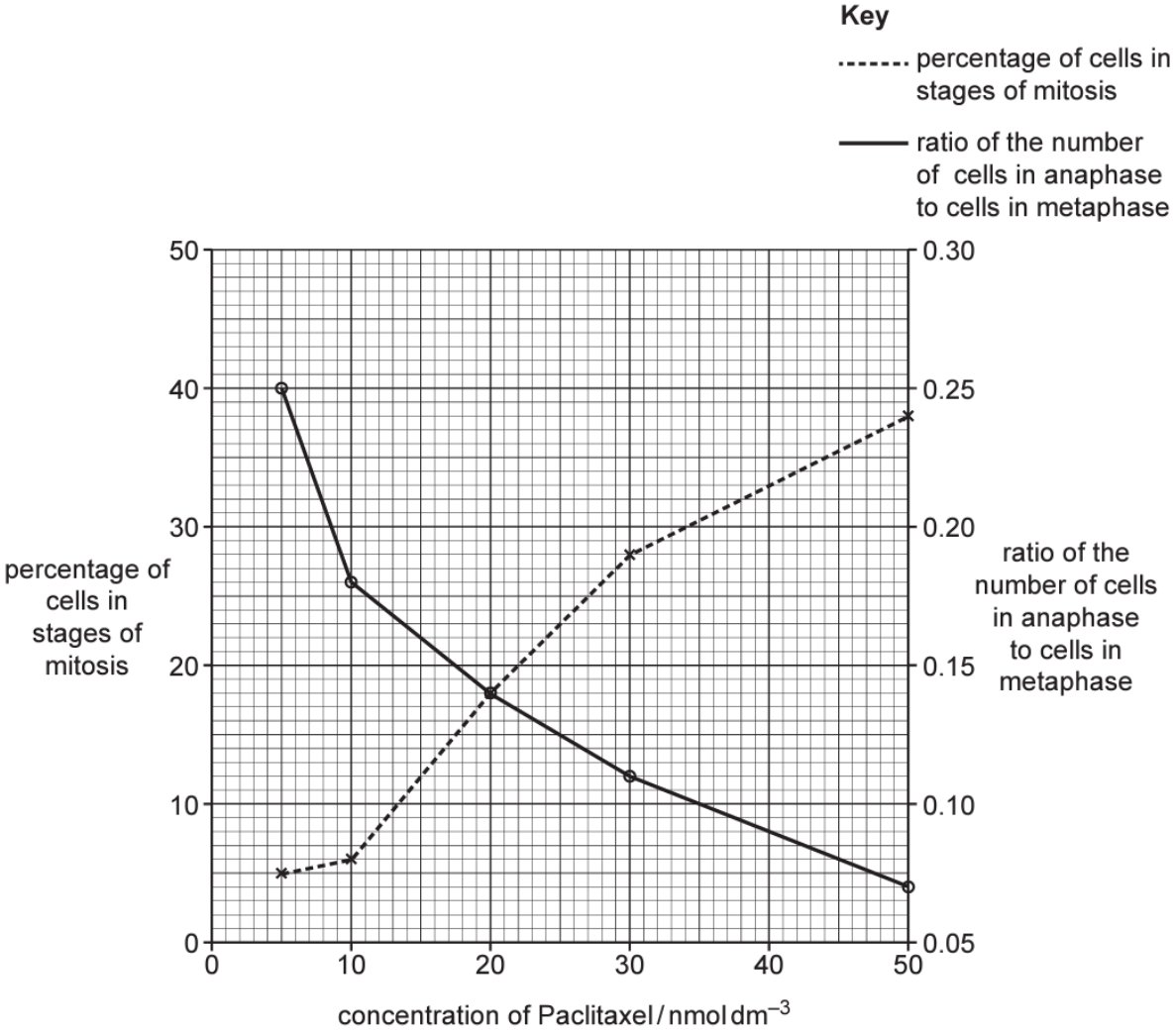

Fig. 3.1

(b) With reference to Fig. 3.1,

(i) describe the effect of Paclitaxel on the mitotic cell cycle.

as concentration of Paclitaxel increases, the ratio of cells in anaphase to those in metaphase reduces / there are a greater proportion of cells in metaphase than in anaphase ;

as the concentration of Paclitaxel increases, the percentage of cells in mitosis is increasing ;

use of data to support a described trend ;

[3]

(ii) explain the effect of Paclitaxel on the mitotic cell cycle.

suggested mechanism for halt in metaphase **;**

e.g. centromeres do not divide

prevents spindle fibres shortening

prevents movement of chromatids to opposite poles (because sister chromatids still held together) cells do not pass the (metaphase) checkpoint

AVP **;**

[2]

(c) Under natural circumstances another group of cells in the body, the germ line cells, also **exhibits stem-cell like property** whereby they can divide indefinitely. However, they are not the same as cancer cells.

Suggest the differences that can be seen in cancer cells compared with normal germ line cells.

Refer to table below.

[2]

[Total: 10]

feature	cancer cell	normal germ line cell
type of cell division	mitosis	mitosis and meiosis
exhibit contact inhibition	no	yes
need for growth factor	no	yes
cell cycle checkpoints	non-functional	functional
cell cycle arrest for DNA repair or to trigger apoptosis	continue to divide to accumulate mutations	cannot proceed with cell cycle when mutation / DNA damage is detected for repair or to trigger apoptosis
mutations in genes controlling cell cycle	yes	No / less
ability to induce angiogenesis and metastasis	yes	no
Nature of cell division	Uncontrolled	Unlimited
Ability to give rise to specialized cells	No	yes

Section B

Answer **one** question in this section.

Write your answers on the separate answer booklet provided.

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

Your answers must be in continuous prose, where appropriate.

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

4 (a) Discuss the of complementarity in cellular merole chanisms. [13]

(b) Outline how the level of mRNA of the same gene across different human cell types is controlled and explain the significance of each level of control. [12]

[Total: 25]

5 (a) Discuss the various roles of hydrogen bonding in ensuring the continuity of life. [13]

(b) Outline how variation can arise in living organisms and explain the significance of having variation in a population. [12]

[Total: 25]

4 (a) Discuss the role of complementarity in cellular mechanisms. [13]

1. Complementary shape;;
2. Complementary base pairing;;
3. Complementary interaction;;
4. allows for specificity of reaction;;

Complementary shape

5. Substrate(s) fit into the active site of enzyme;
6. via lock and key hypothesis;
7. And induced fit hypothesis;
8. To form enzyme-substrate complex;

9. DNA to fit into binding site of proteins
10. To regulate replication;
11. And gene expression;

12. Ligand/ signaling molecule to fit into binding site of receptors;
13. Allows for cell signaling;
14. Binding of substances to transport proteins;
15. Allows for movement of substances across cell membrane;
16. and viral entry;

Complementary interaction

17. H bonds between polar groups;
18. Hydrophobic interaction between non-polar groups;
19. Ionic bonds between oppositely charged groups;
20. Allows for folding of polypeptide into 3D shape;
21. Stability of biomolecules;

Complementary base pair

22. A-T (A-U) and C-G;
23. Allows for stability of DNA double helix;
24. Allows for replication of DNA;
25. Allows for the synthesis of mRNA/transcription;
26. allows for the binding of (anticodon on) tRNA to (codon on) mRNA;

4 (b) Outline how the level of mRNA of the same gene across different human cell [12]

types is controlled and explain the significance of each level of control.

DNA (Chromosomal) Level

Gene expression is switched on by:
1. Ref to reduced association between DNA and histone resulting in decreased compaction;
2. allow **general transcription factors and RNA polymerase to access promoter**, allow transcription to occur @reverse argument
3. **Histone acetylation** by **histone acetyltransferase**;
4. **Histone demethylation** by **histone demethylase;**

Gene expression is switched off by:
5. Ref to increased association/ compaction between DNA and histone, resulting in increased compaction;
6. **prevent RNA polymerase from accessing the promoter**.
7. **DNA methylation** by **DNA methyltransferase**, resulting in recruitment of HDACs;
8. **alter the shape** of the promoter sequence;

Significance
1. *(Idea of)* **longer term switching genes** on and off to restrict active genes to those required (by the cell line),
2. *Ref to idea* differential gene expression, where only specific genes are expressed in different specialized cells types;
3. so **more efficient / less wasteful of resources**. [marked once]

Transcriptional Control

Gene expression is switched on by:

1. **Binding/Assembly** of **general transcription factors and RNA polymerase** to the promoter;
2. form **transcriptional initiation complex** for transcription initiation.
3. **Activator** binds to **enhancer** to cause the **bending of DNA** so as to **stabilize** the transcription initiation complex at the promoter, thereby **increases rate** of transcription.

Gene expression is switched off by:

4. **Repressor** binds to **silencer** and **prevent transcription** of the gene;
5. Any ONE of the possible effects:
   - Block and impede RNA polymerase's progress
   - **recruits enzymes/ histone deacetylase** (A: any other effect), causing **chromatin compaction**
   - recruit proteins that bind to general transcription factors and destabilise transcription initiation complex
   - prevent activators to enhancers (which are adjacent or overlapping silencers0

Significance

4. *(Idea that*)Rate of transcription / expression can be regulated (at this level), **to meet short term requirement of the cell/ temporal**.
5. Appropriate e.g. Insulin/ relevant hormone production

Post-Transcriptional Control

1. Addition of 5' 7-methylguanosine cap and 3' Poly(A) tails during post-transcriptional modification/ RNA processing is important to:
2. Any ONE of the effects:
   - **protect the mRNA from degradation by exonucleases/hydrolytic enzymes**, hence increases the half-life of mRNA.
   - **facilitate the export** of mature mRNA from **nucleus to cytosol**.
   - act as **site of attachment for translational initiation factors** to promote the binding of ribosomes to promote translation.

3. RNA splicing of pre-mRNA by spliceosome occurs where all **introns are excised** and **exons are spliced** together to produce mature mRNA.
4. Alternative RNA splicing, the **same pre-mRNA** synthesized in **different cell types** have **all introns excised** but **different combinations of exons are spliced together**

Significance

6. (Idea *that)* Ensures the **stability of mRNA** and hence the **stability of gene expression**.
7. *(Idea that)* Allow for production of **different proteins** variants from **a single gene** when alternative splicing occur.
8. *Ref to* relevant examples hexokinase in muscle cells vs brain cells;/calcitonin vs calcitonin gene related peptide (thyroid vs neuron)

5 (a) Discuss the various roles of hydrogen bonding in ensuring the continuity of life. [13]

A) [Role in maintaining protein structure]

1. For maintaining {secondary structures / α-helices and β-pleated sheets} in proteins, formed **between** peptide bonds **/** –CO group of one amino acid and –NH group of another amino acid (in the same chain) ;

2. For maintaining tertiary/quaternary structure of proteins, formed between polar R groups of amino acid residues ;
3. *[Named example with elaboration – max 1 mark]* ***Ref. to*** hydrogen bonds present between the three polypeptide chains of a tropocollagen molecule / ***ref. to*** structure of haemoglobin e.g mainly α-helixes in α- and β-chains or holding of 4 subunits comprises of 2 α- and 2 β-chains of haemoglobin / (***ref. to*** GPLR – *awarded under markpoint 11*) ;

4. Specific 3D conformation of proteins dictates their specific functions
5. *[Named **1** example – max 1 mark]* ***Ref. to*** enzyme e.g. DNA polymerase, lipase **; *ref to*** function of respective enzyme ;

B) [Role in enzyme-substrate interaction]

6. To allow substrate to bind weakly to the active site of enzyme
7. *[Named **1** example – max 1 mark]* ***Ref. to*** a enzyme-substrate pair ; e.g. amylase and starch.

C) [Role in structural support]

8. Many hydrogen bonds present in biological molecules can result in high tensile strength, therefore provide structural support ;
9. *[Named **1** example – max 1 mark]* Cellulose has hydrogen bonds between cellulose chains to produce cellulose fibres
   [**DO NOT award** for collagen as hydrogen bonds are found only within tropocollagen and hydrogen bonds are only one aspect that contribute to the tensile strength in collagen fibre – other aspects are staggered arrangement of tropocollagen, covalent bonds involving lysine and hydroxylysine of tropocollagen];

D) [Role in solubility]

10. To allow (hydrophilic / polar / charged) substances to be **soluble in aqueous environment**
11. *[Named **1** example – max 1 mark]* ***Ref. to*** named globular protein e.g haemoglobin / ***Ref. to*** named enzyme **;** having **{**hydrophilic / polar / charged**}** R-groups of amino acid residues **projecting outwards from** surface of protein

E) [Role in holding proteins in cell membranes]

12. Hydrogen bonds formed between **{**hydrophilic/polar**}** phosphate heads of phospholipids and **{**hydrophilic/polar/charged**}** R groups of amino acids of membrane proteins, helps to hold the protein in place in membrane.

13. *[Named **1** example – max 1 mark]* ***Ref. to*** transmembrane protein embedded in membrane e.g. Receptor tyrosine kinase (RTK) / G-protein Linked Receptor (GPLR)

F) [Role of H-bonds between complementary base pairs in nucleic acids]

14. Allows complementary base pairing to occur in nucleic acid interactions

15. Adenine (A) binds to Thymine (T) / Uracil (U) via 2 hydrogen bonds **;** Cytosine (C) binds to Guanine (G) via 3 hydrogen bonds

*[Allow **1** Named example for molecule – max 2 marks]*

- [***E.g.*** In DNA]

16. Hydrogen bonds stabilize double helical DNA molecule **;**

17. Role of storing genetic information.

- [***E.g.*** In tRNA]

18. Intra-molecular hydrogen bonding in tRNA allows tRNA to fold into a clover-leaf structure

19. ***Ref.*** *to* role of tRNA – carries amino acids to the ribosome for synthesis of polypeptide

- [***E.g.*** In rRNA]

20. Intra-molecular hydrogen bonding in rRNA allows rRNA to fold into a precise 3D structure to complex with ribosomal proteins to form ribosome

21. ***Ref.*** *to* role of ribosome – translation machinery

- [***E.g.***. In snRNA]

22. Intra-molecular hydrogen bonding in snRNA allows **snRNA** to fold into a precise 3D structure to complex with spliceosomal **proteins** to form spliceosome

23. ***Ref.*** *to* role of spliceosome – splicing of primary mRNA transcript to produce mature mRNA

- [***E.g.*** In Telomerase RNA]

24. Intra-molecular hydrogen bonding in telomerase RNA allows **telomerase RNA** to fold into a precise 3D structure to complex with **protein** (TERT) to form the telomerase enzyme

25. *Ref. to* role of telomerase – restore telomere length to ensure infinite division in stem cells

*[Allow **1** Named example for process – max 1 mark]*

- [***E.g.*** During DNA replication]

26. Important in DNA replication, where daughter DNA strand is synthesized via adding complementary deoxyribonucleotides to template DNA to ensure accurate transmission of genetic information.

- [***E.g.*** During Transcription]

27. Important in transcription, where RNA is synthesized via adding complementary ribonucleotides to template DNA

- [***E.g.*** During Translation]

28. Important in translation, where codons on mRNA complementary base pair with anticodon on tRNA to ensure correct sequence of amino acids forms the polypeptide

G) [Role of H bonds in carbohydrate structure]

29. H bonds helps maintain the helical structure in amylose

30. *AVP*

31. **QwC: [1m]** Clear organised flow without ambiguity AND at least 1 mark awarded for **THREE** different roles *(any three from items **A** to **F**)* of hydrogen bonds, each role with one named example.

5 (b) Outline how variation can arise in living organisms and explain the significance of [12]

having variation in a population.

How variation arise:

*In **[E]**ukaryotes* **[Max 5]**

1 (ref to idea of) Meiosis **and** fertilisation generates the genetic variation within a sexually reproducing population;
2 During prophase I, ***crossing over*** occurs between the non-sister chromatids of homologous chromosomes;
3 leading to new allelic combinations on a chromosome;
4 During metaphase I, ***independent assortment*** of ***homologous chromosomes*** occurs where the orientation of bivalents is random, as chromosomes line up along the metaphase plate ®metaphase II;
5 leading to different chromosomal combinations in different gametes, *(upon independent segregation of homologous chromosomes at Anaphase I)*;
6 2^n different combinations of (chromosomes in) gametes, where n represents the haploid number of chromosomes in the species, can be obtained as a result of meiosis;
7 Random, fusion / fertilisation of these gametes carrying different combinations of chromosomes adds to genetic variation of the zygote formed;

AVP, ref to variations arising from asexual reproduction (budding) in yeast (not in syllabus);

In **[B]**acteria **[Max 4]**

1 Bacteria are asexually reproducing organisms;

2 (Transformation) Bacterial cells take up foreign DNA from the surrounding medium via a cell surface receptor during transformation;
3 (Transduction) During transduction, DNA can be transferred from one bacterial cell to another by a phage when it infects a donor bacterium and injects its phage DNA into the bacterium;
4 An error in the reproductive cycle result in a host cell's DNA to be packaged within a phage capsid; *(in generalised/ specialised transduction)*
5 The (new/ resultant) phage (containing the wrongly packaged bacterial DNA) released can infect / attach to another (recipient) bacterium and inject the piece of bacterial DNA acquired from the first cell.
6 Incorporation of foreign DNA into its own DNA (via homologous recombination / insertion/ integration) *note: integration of DNA only happens in transduction.*
7 (Conjugation) During conjugation, there is attachment/ bind/ contacts of F^+ and F^- bacterium via sex pilus made by F+ cell. Sex pilus retracts, the two bacteria cells come into physical contact;
8 Single strand of F plasmid breaks at origin of transfer and is transferred from F+ donor cell to F- recipient cell via cytoplasmic mating bridge;

[M]UTATIONS *In both populations*

1 Gene Mutations occurs to generate new alleles;
2 E.g. deletion/ insertion/ substitution resulting in changes in nucleotide differences;
3 Chromosomal mutations leading changes in chromosomal structure/ number;
4 E.g. chromosomal translocation/ deletion/ duplication or aneuploidy/ polyploidy;

[S]ignificance [Max 7]

27

1 Variation describes the differences in characteristics/ phenotypes / means the presence of different characteristics;
2 due to presence of different alleles in the different individuals in a population;
3 There can be continuous / discontinuous variation due to interaction of genotype and environment;
4 resulting in differential reproductive success / different survival rates;
5 allowing for natural selection to take place;
6 Variations in characteristics are subjected to selection pressure from the environment;
7 variants with favourable characteristics will survive to maturity, reproduce and pass down their favourable alleles to their offspring;
8 Contribute to the evolution of the population by generating further changes to the allele frequencies in the gene pool of the population
9 (idea of) speciation can occur as gene pools of populations become more different from each other over time;
10 Resulting in reproductive isolation/ **no** interbreeding/ **no** production of fertile, viable offspring;