



TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE
NAME

CIVICS
GROUP

H2 BIOLOGY

9744/03

Paper 3 Long Structured and Free-response Questions

22 September 2025

2 hours

Candidates answer on the Question Paper.

No additional materials are required.

**SUGGESTED
ANSWERS**

This document consists of **27** printed pages and **3** blank pages.



Section A

Answer **all** questions.

- 1 Adult stem cells are undifferentiated cells that are found in most animal tissues.

Adult stem cells can divide throughout their lifespan to form identical stem cells (self-renewal) or to form cells that can differentiate into the functioning cells of that tissue.

- (a) Uncontrolled cell division is a characteristic feature of tumour formation from a differentiated cell.

- (i) Describe **two** other features of tumour formation from a fully differentiated cell. [2]

1. Gain of function mutations of proto-oncogenes to oncogene and loss of function mutations of tumour suppressor genes.
2. Accumulation of these mutations in a single cell.
3. No contact-inhibition, where cells continue to divide even after contact with other cells.
4. Shorter/Faster G1 and G2 phase during cell cycle.
5. Activation of telomerase gene, to code for telomerase such that shortened telomeres are prolonged after each round of replication / shorten less quickly.
6. Normal cell cycle checkpoints are not functioning / proteins needed at the checkpoints not produced.
7. AVP

Telomeres are non-coding DNA found at the end of the chromosomes. Adult stem cells have chromosomes with long telomeres.

- (ii) Explain why having long telomeres is an advantage to cells that are undergoing many rounds of cell cycles. [2]

1. After each round of DNA replication, telomeres shorten due to the end replication problem occurs.
2. Presence of telomeres ensure that no coding sequences/genes are eroded.
3. Long telomeres ensure telomeres do not reach / takes longer time to reach critical length and the cells do not undergo apoptosis.



- (b) Haematopoietic stem cells (HSCs), also called blood stem cells, are adult stem cells that are located in the bone marrow. HSCs have a role in the formation of blood cells.

Fig. 1.1 is an outline showing the formation of some of the different types of blood cell that can be formed from HSCs. The first stage is the division of HSCs to produce myeloid and lymphoid stem cells.

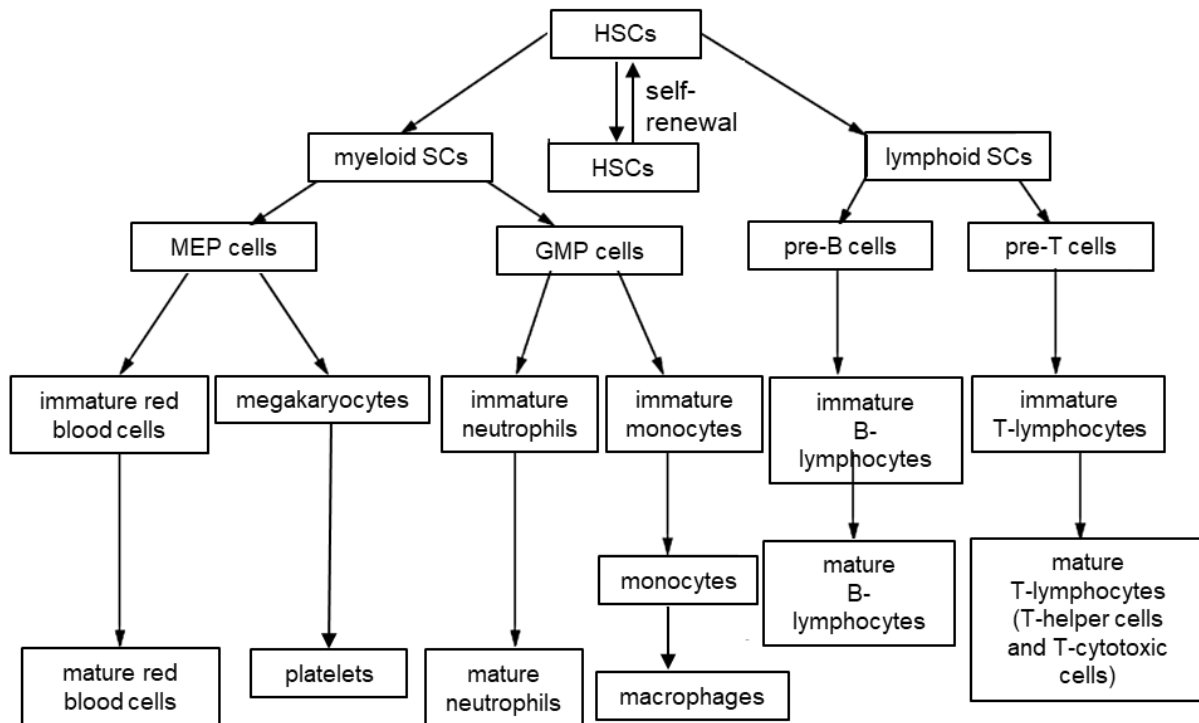


Fig. 1.1

With reference to Fig 1.1, explain why GMP cells cannot be described as haematopoietic stem cells (HSCs). [2]

- Though GMPs can undergo mitosis, they cannot divide indefinitely while HSCs can self-renew indefinitely.
- GMP cells are restricted to differentiate into neutrophils or monocytes / has limited differentiation potential, while HSCs can differentiate into all blood cell types.
- Differentiation has already started in GMP cells / GMP cells are differentiated while HSCs are undifferentiated.
- In GMP cells, (some) genes coding for proteins to carry out specialised functions are already being expressed / genes coding for multipotency are switched off.

- (c) The differentiation of T-lymphocytes begins in the bone marrow and continues in an organ known as the thymus to produce fully differentiated T-helper and T-cytotoxic cells.

In the thymus, T-lymphocytes that bind to self-antigens are destroyed.

- (i) Suggest why T-lymphocytes that bind to self-antigens need to be destroyed in the thymus. [3]

1. T-lymphocytes that bind to self-antigens need to be destroyed to prevent them from being released into the blood circulation / bloodstream.

If self-reactive T cells were released into the bloodstream,

2. these self-reactive T-cells will then release cytokines to trigger immune response against own body's cells.
3. This would result in destruction/killing of own cells (by cytotoxic T-cells)....
4. potentially causing autoimmune diseases.
5. Furthermore, if these T cells were not eliminated, they could lead to the formation of memory T cells that recognises self-antigens that would perpetuate an autoimmune response over time.
6. Will not activate self-reacting B cells (and T-cytotoxic cells).



Mature T-lymphocytes leave the thymus gland to travel throughout the body. They remain inactive inside organs, such as the spleen and lymph nodes, until activated by the presence of foreign antigens.

Fig. 1.2 shows what happens to two mature T-lymphocytes, **U1** and **V1**, in the presence of an antigen from a virus.

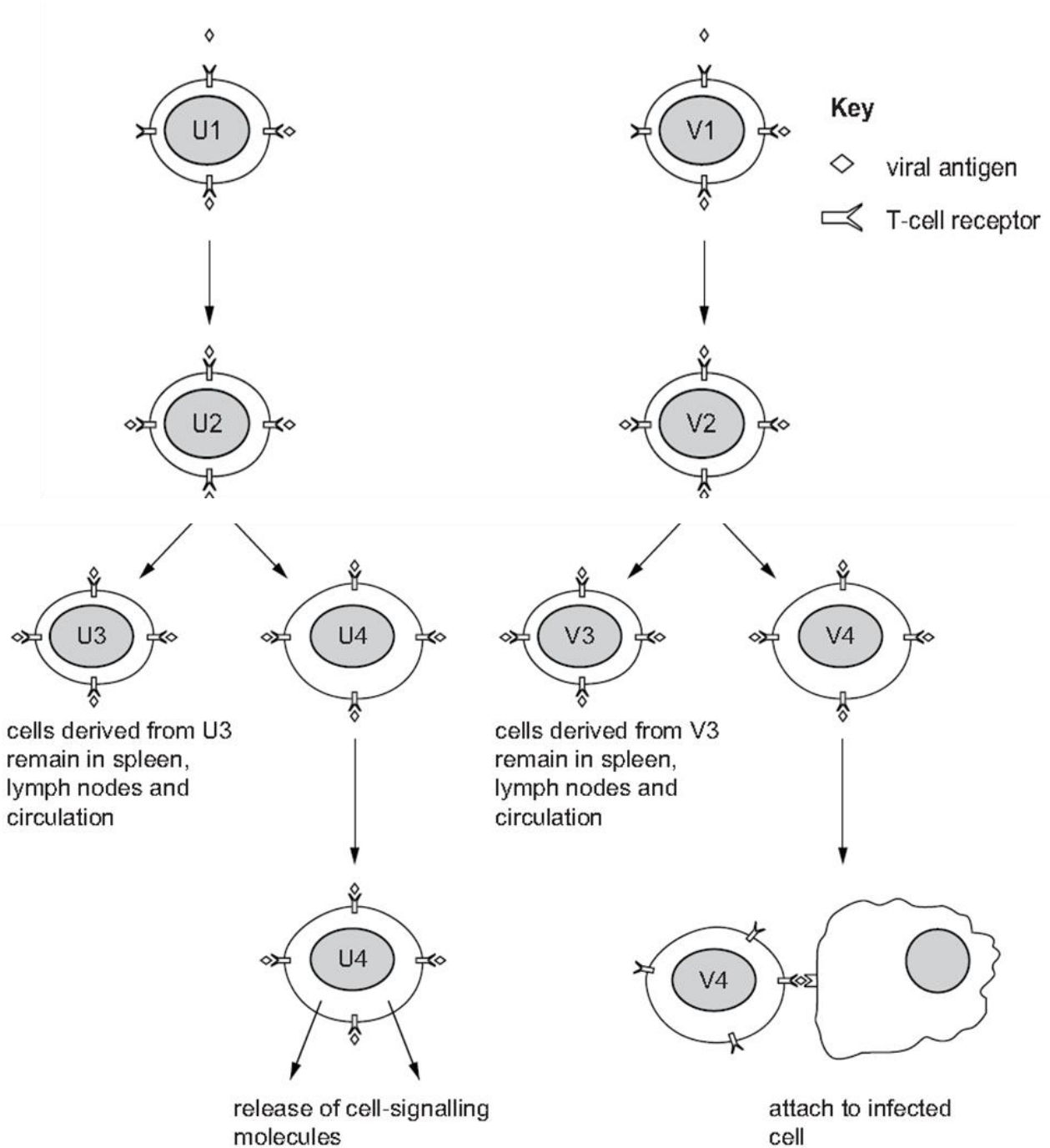


Fig. 1.2

- (ii) **U4** and **V4** are two types of mature T-lymphocyte.

Identify the names given to these types of T-lymphocytes by putting a (✓) beside the correct box. [1]

Types of mature T-lymphocytes	U4	V4
T-cytotoxic Cells		✓
T-helper cells	✓	

- (iii) Describe the roles of cells **V4** in an adaptive immune response. [2]

1. T- cytotoxic cells recognise and bind to infected cells foreign antigens presented on class I MHC.
2. Once bound, T-cytotoxic cells release perforin and granzymes.
3. Perforins form pores in the infected cell surface membrane and disrupts membrane integrity / form pores to allow granzyme to enter the cells.
4. Granzymes induce apoptosis (programmed cell death) of the infected cell.

[max 1 if T-helper cells is described]

- (d) T-helper cells play a crucial role in orchestrating the immune response against various pathogens. However, they are also the primary target of the human immunodeficiency virus (HIV), a retrovirus, which contains the enzyme reverse transcriptase. HIV infects and destroys T-helper cells, gradually reducing their numbers. This weakens the immune system, making individuals susceptible to opportunistic infections and cancers.

Explain why HIV is described as a retrovirus. [2]

1. HIV carries single-stranded (+) RNA as its genetic material/genome.
[Reject: HIV has RNA]
2. During its reproductive cycle, HIV uses its single stranded RNA as a template and is reverse transcribed to form single stranded DNA, then into double stranded DNA, by reverse transcriptase.
3. Double stranded DNA then integrates into the host's DNA/chromosome as a provirus.



- (e) In people with HIV/AIDs, a serious lung disease known as pneumocystis pneumonia can result from infection by an opportunistic pathogen known as *Pneumocystis jirovecii*.

Although the cells of many species of bacteria are the same size as those of *P. jirovecii*, research concluded that the organism is a eukaryote and is not a bacterium.

In 1988, analysis of ribosomal RNA (rRNA) resulted in *P. jirovecii* being classified as a fungus.

Studies on the structure of *P. jirovecii* have identified that the cell wall is made of polysaccharides such as chitin and 1,3- β -D-glucan.

- (i) Explain why this feature helped scientists to confirm that *P. jirovecii* is **not** a bacterium. [1]

- Bacteria have peptidoglycan cell wall but no chitin. / *P. jirovecii* has no peptidoglycan in its cell wall.

Scientists have identified other features of the cell structure of *P. jirovecii*. Some of these are listed in Table 1.1.

- (ii) Complete each row of Table 1.1 so that the table shows: [2]

- four structural features identified in *P. jirovecii*
- one function for each structural feature
- whether the structural feature present in *P. jirovecii* is also present (\checkmark) or is absent (\times) in bacterial cells.

Table 1.1

structural feature of <i>P. jirovecii</i>	function	present (\checkmark) or absent (\times) in bacterial cells
Ribosomes	Protein synthesis	\checkmark
Smooth endoplasmic reticulum	<ul style="list-style-type: none"> • Lipid / cholesterol synthesis/metabolism • Detoxification 	\times
Golgi body	Modification of proteins and lipids	\times
mitochondria	Aerobic respiration	\times

[1] for mitochondria and function of sER

[1] for correct identification of presence/absence in bacterial cells

P. jirovecii can adhere to the alveolar epithelial cells and the extracellular matrix (ECM). ECM is a network of fibrous proteins like elastin and collagen that supports the alveolar walls. The alveoli are tiny air sacs in the lungs that enable gas exchange.

This attachment to both alveolar epithelial cells and the ECM promotes the growth of *P. jirovecii*, which continues to adhere to these surfaces as *P. jirovecii* multiplies.

- (iii) Cell surface glycoproteins known as gpA glycoproteins are essential in allowing *P. jirovecii* cells to adhere to alveolar epithelial cells and ECM proteins.

Suggest how a gpA glycoprotein is able to adhere to alveolar epithelial cells and ECM proteins. [2]

1. gpA has complementary shape and hence binds to....
2. ... a receptor / glycoprotein / oligosaccharides on the surface of alveolar cell and to the binding sites on ECM proteins.
3. Any named bonds (except disulfide bonds).

- (iv) One consequence of the pneumonia that results from *P. jirovecii* infection is a change in the quantity of oxygen that is delivered to body tissues.

Suggest why a severe *P. jirovecii* infection will affect the quantity of oxygen that is delivered to body tissues. [2]

1. Alveolar cells/ECM surrounded by *P. jirovecii* cells which reduced the surface area
2. ECM bound to *P. jirovecii* can result in alveolar damage/ decrease elasticity of alveoli and hence impaired gas exchange.
3. The adhesion of *P. jirovecii* to alveolar epithelial cells and the extracellular matrix (ECM) may lead to damage / inflammation of the alveoli.
4. Presence of macrophage/WBC can reduce their ability to facilitate efficient gaseous exchange.
5. Hence, reduced diffusion of oxygen / gaseous exchange between alveoli and blood.

- (v) *P. jirovecii* produces an enzyme known as 1,3- β -D-glucan synthase. The enzyme catalyses the synthesis of 1,3- β -D-glucan.

The therapeutic drug caspofungin is a non-competitive inhibitor of 1,3- β -D-glucan synthase.

With reference to the mechanism of action of caspofungin, explain how the drug may be useful to treat cases of pneumonia caused by *P. jirovecii*. [4]

1. **[compulsory]** Drug / Caspofungin binds to the enzyme at a site other than the active site / allosteric site.
2. Binding changes the conformation/shape of active site.
3. Substrate is no longer complementary to the active site.
4. No/fewer enzyme-substrate complexes formed, hence less/no 1,3- β -D-glucan produced.
5. **[compulsory]** Cell wall of *P. jirovecii*/fungus not formed/weakened.
6. Water can enter the cells by osmosis, leading to lysis of the *P. jirovecii*/fungus/cell.
7. This reduces the population of *P. jirovecii* / prevent growth of *P. jirovecii* / higher chance for immune system to eliminate the fungus.

(f) *P. jirovecii* can be detected in saliva of patients.

Early diagnosis of pneumocystis pneumonia is important in reducing the transmission of the pathogen.

Scientists have developed a test strip for pneumocystis pneumonia that uses monoclonal antibodies (antibodies produced by a single clone of cells) to detect gpA glycoproteins of the fungus. Monoclonal antibodies are specific in their action.

Fig. 1.3 shows a simplified diagram of the test strip.

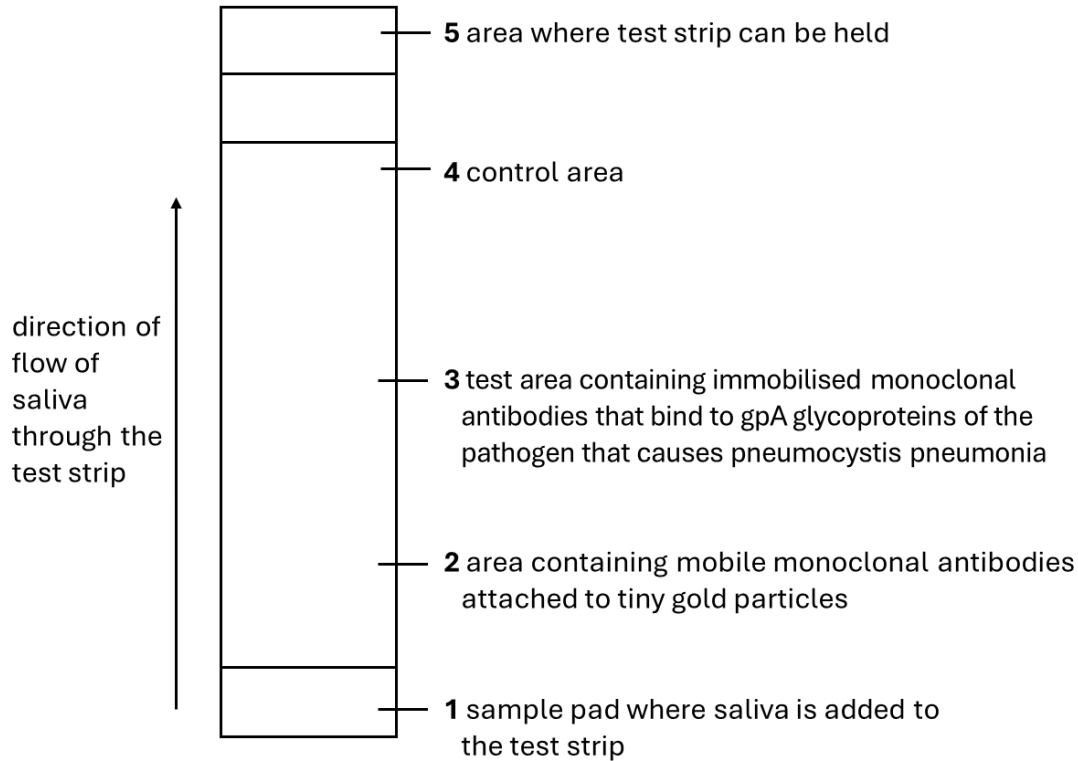


Fig. 1.3

A sample of saliva is collected and put onto the sample pad in the test strip.

The saliva moves up the test strip through area 2.

The mobile monoclonal antibodies in area 2 are attached to tiny gold particles. If these antibodies collect in test area 3, a gold line becomes visible on the test strip.

A gold line that becomes visible in area 4 confirms that the test strip is working and that the results are valid.

Fig. 1.4 shows some of the molecules in area 3 of the test strip when a positive result for pneumocystis pneumonia is obtained.

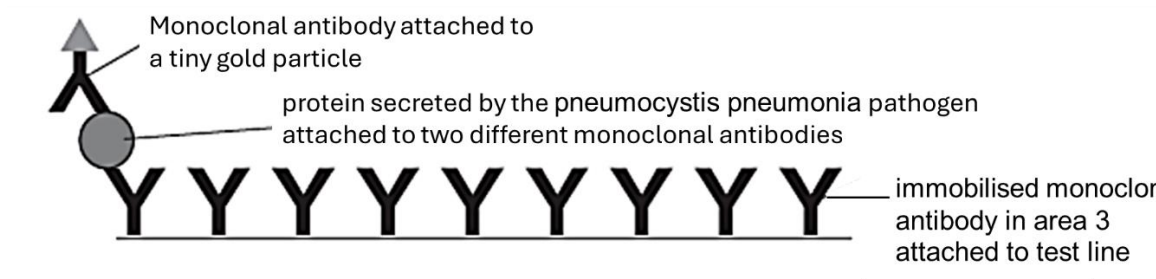


Fig. 1.4

(i) Using the information in Fig. 1.4, explain why this test is specific for pneumocystis pneumonia. [2]

- The immobile and mobile monoclonal antibodies have antigen binding site which is specific / complementary in shape to different epitopes on the glycoprotein of fungus
- *Idea that* the glycoprotein is only produced by the fungus.

(ii) Area 4 contains different immobilised antibodies to those in area 3.

The mobile monoclonal antibodies bound to tiny gold particles will bind to these immobilised monoclonal antibodies in area 4.

If the test has functioned correctly, a gold line will be visible in area 4.

Suggest why the gold line is important to show that the test strip is functioning correctly. [1]

- This ensures the mobile antibodies have successfully moved across the strip and hence functional.

[Total: 28]

- 2 The dugong, *Dugong dugon*, is a large marine mammal belonging to the order Sirenia. It inhabits warm coastal waters, including river estuaries, in regions such as the Indo-Pacific. Dugongs feed on seagrass, *Halophila ovalis*, which are sensitive to changes in water temperature and quality.

Fig. 2.1 shows an adult dugong grazing in shallow waters.



Fig. 2.1

H. ovalis grows in coastal and estuarine ecosystems.

- (a) The dugong and the seagrass belong to the domain Eukarya, which includes the kingdoms Animalia and Plantae.

- (i) State the main differences between the kingdom Animalia and the kingdom Plantae. [2]

Feature	Animalia	Plantae
Presence of cell wall	No cell wall	Cellulose cell walls present
Presence of chloroplasts	No chloroplasts / accessory pigments / PS	Chloroplast / accessory pigments / PS present
Presence of central vacuole	No central vacuole / small vacuoles	Central vacuole present
Ability to make own's organic compound	Heterotrophs / takes in nutrients from other carbon sources / organisms	Autotroph / able to photosynthesise to convert light energy to organic compounds
Energy store	Glycogen	Starch
Ability to move	Move from place to place	Unable to move from place to place

- (ii) Complete Table 2.1 to show the full classification of the dugong.

[2]

Table 2.1

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Sirenia
Family	Dugongidae
Genus	Dugong
Species	<u>Dugong dugon</u>

[1m per column]

- b) Measurements of the surface temperature of land and oceans can be taken from locations around the world. The mean global surface temperature for land and ocean combined can be calculated for a fixed time period.

Scientists calculated:

- the mean global temperature for the twentieth century
- the mean global temperature for each decade (ten years) from 1880 to 2020.

The mean temperature for each decade was compared to the mean for the twentieth century.

For each decade, the difference in temperature was calculated.

The calculated differences are shown in Fig. 2.2.

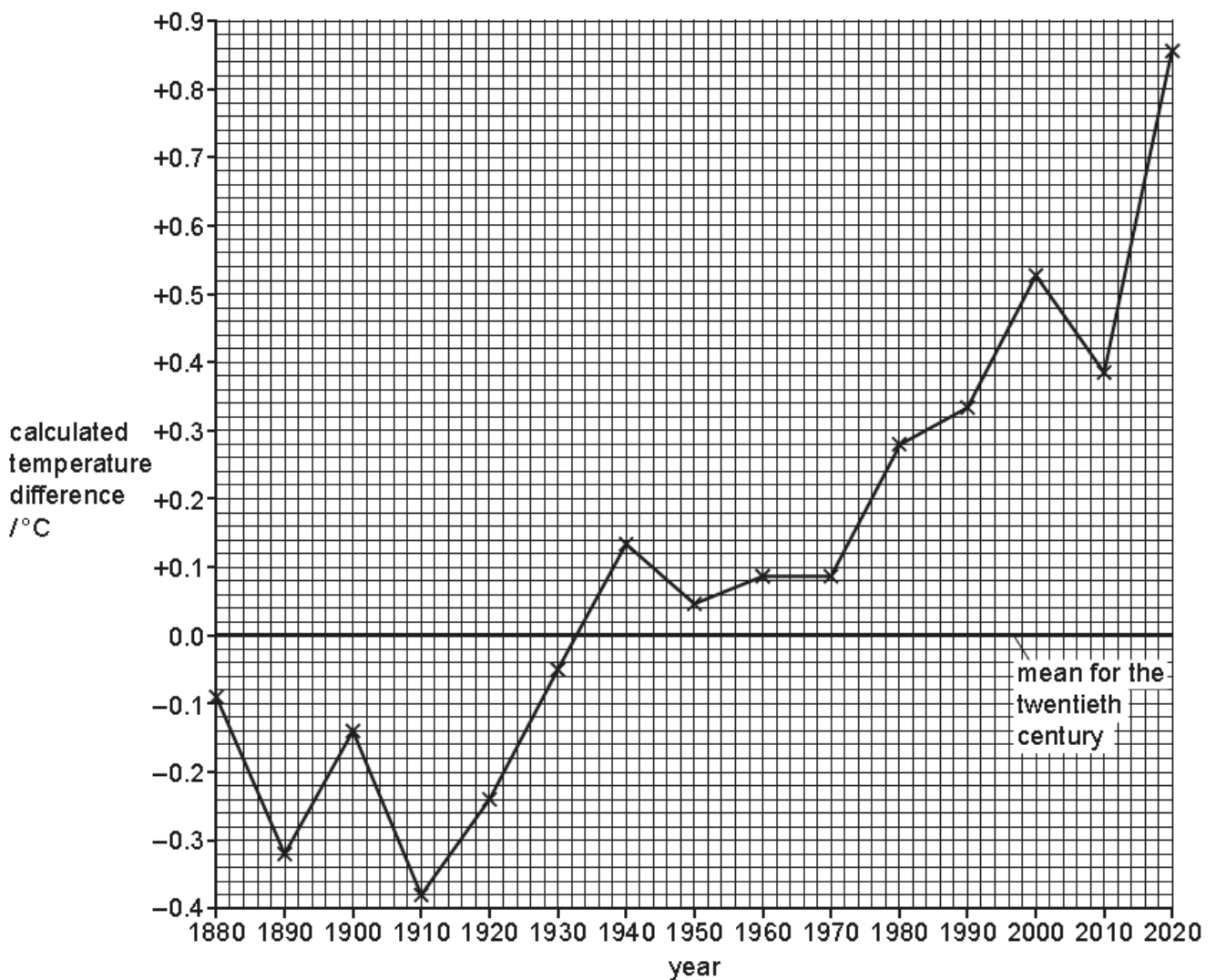


Fig. 2.2

(i) Describe the results as shown in Fig. 2.2. [4]

1. **(describe)** Over the years, mean global temperature difference increased, with fluctuations in some decades.
2. **(data)** From 1880 to 2020, the mean global surface temperature difference increases from -0.09°C to $+0.86^{\circ}\text{C}$, with fluctuation.
3. **(describe)** From 1880 to 1933, the global temperatures were lower than mean, while from 1933 to 2020, the global temperatures were above mean.
4. **(data)** From 1880 to 1933, the mean global surface temperature difference fluctuates between -0.38°C to 0.0°C + from 1933 to 2020, temperature increases from 0.0°C to 8.6°C .
5. **(describe)** From 2010 to 2020, the temperature difference increased steeply, showing a clear upward trend.
6. **(data)** From 2010 to 2020, the temperature difference increased steeply from 0.38 to 0.86°C .

[Data: accept +/- 0.01]

[Any 4, at least 1 for data]

(ii) Calculate the overall rate of increase in temperature per decade between 1980 and 2020.

Show your working.

Write your answer in **two** significant figures.

[2]

$$\text{Rate of increase} = (0.86 - 0.28) / 4 = 0.15 \quad \text{OR}$$

$$\text{Rate of increase} = (0.85 - 0.28) / 4 = 0.14$$

- Correct working showed
- Correct answer in 2 s.f.

..... $^{\circ}\text{C}$ per decade



- (iii) Dugong populations have decreased worldwide since 1980.

Suggest **two** reasons for the decrease in dugong populations. [2]

Climate Change-Related:

1. Rising sea temperatures may cause seagrass die-offs in many regions, reducing the food source for dugongs.
2. Rising temperatures (beyond optimal / may cause drought) may reduce the number of water habitats available for dugongs.
3. Stronger and more frequent occurrence of cyclones and typhoons, damage seagrass beds, reducing food availability for dugongs /
4. These extreme weather conditions also increase sedimentation in coastal waters, making it harder for dugongs to find food.
5. Increased CO₂ levels in the atmosphere lead to ocean acidification, which can disrupt the growth of seagrass, reducing food availability for dugongs.

Other Human-Related:

4. Expanding cities / tourism / infrastructure projects/ coastal development/AVP destroy seagrass bed and shallow coastal habitats where dugongs live and feed.
5. Oil spills / agricultural runoff / plastic waste / AVP pollute the waters, harming both dugongs and their food sources.
6. Dugongs may get caught in fishing nets and trawlers, leading to accidental deaths.
7. In some regions, dugongs are hunted for meat/ oil/ bones illegally.

[Total: 12]

- 3 The European honey bee, *Apis mellifera*, is a social insect that lives in colonies. Each colony contains one active egg-laying adult queen, many non-reproductive adult workers that collect food, and many larvae. Only a few of these larvae are able to develop into new queens.

Recently, in many countries the number of European honey bees has decreased. In order to conserve this species, efforts have been made to uncover the reasons for this decrease. The decrease has been linked to several causes, one of which is greater use of pesticides. Two pesticides that are suspected of causing harm are:

- chlorpyrifos (CPF), which is an organophosphate insecticide
- Pristine®, which is a fungicide.

These are sprayed onto crop plants before flowering. When the crops flower, the honey bees visit the flowers to collect food (nectar and pollen) and then take it back to the hive. They store nectar as honey and store a mixture of pollen and honey as 'bee bread'.

These pesticides either kill the honey bees directly or may have these effects:

- damage the immune system of the honey bees, increasing the risk of infection by viruses
- prevent the development of replacement queens to take over the hive and form new colonies.

In an investigation into the effects of pesticides, several colonies of European honey bees were fed pollen from plants treated in one of three different ways:

- **A** – pollen with CPF
- **B** – pollen with CPF + Pristine®
- **C** – pollen free from pesticide.

For each treatment, the researchers recorded the:

- pesticide concentration in the pollen
- pesticide concentration in the bee bread
- pesticide concentration in the honey bees.

Samples of pollen, bee bread and honey bees were analysed for CPF and Pristine®. The results, expressed as mean concentrations \pm SD (standard deviation), are shown in Table 3.1.

Table 3.1

Type of pollen fed to honey bees	Pesticide concentration in pollen / parts per billion		Pesticide concentration in bee bread / parts per billion		Pesticide concentration in honey bees / parts per billion	
	CPF	Pristine®	CPF	Pristine®	CPF	Pristine®
A – pollen with CPF	967 \pm 12	0	310 \pm 12	0	80 \pm 27	0
B – pollen with CPF + Pristine®	942 \pm 35	529 \pm 84	293 \pm 13	381 \pm 21	73 \pm 33	23 \pm 23
C – pollen free from pesticide	0	0	0	0	0	0

(a) Contrast the pesticide concentration detected in bee bread and in honey bees, when the honey bees are fed with pollen A and B. [2]

- The concentration of both pesticides is higher in bread than in bees + cite 1 pair of relevant fig
- *idea that* There is a relatively high standard deviation in bees, suggesting the data is spread out wider in bees. + cite 1 pair of relevant fig

- (b) Queen larvae from colonies that had never been exposed to pesticide were placed in colonies supplied with pollen **A**, **B** or **C**.

The number of queen larvae that completed development into adults and the number that died during development were counted for each treatment. A chi-squared test (χ^2) was then performed to test the assumption that CPF has no effect on whether queen larvae complete their development. This was done using the data from the treatment with pollen **A** and the treatment with pollen **C**. The calculated χ^2 value corresponded to $p < 0.05$.

The percentage of queen larvae that completed development into adults was also calculated for each treatment. The results are shown in Fig. 3.1.

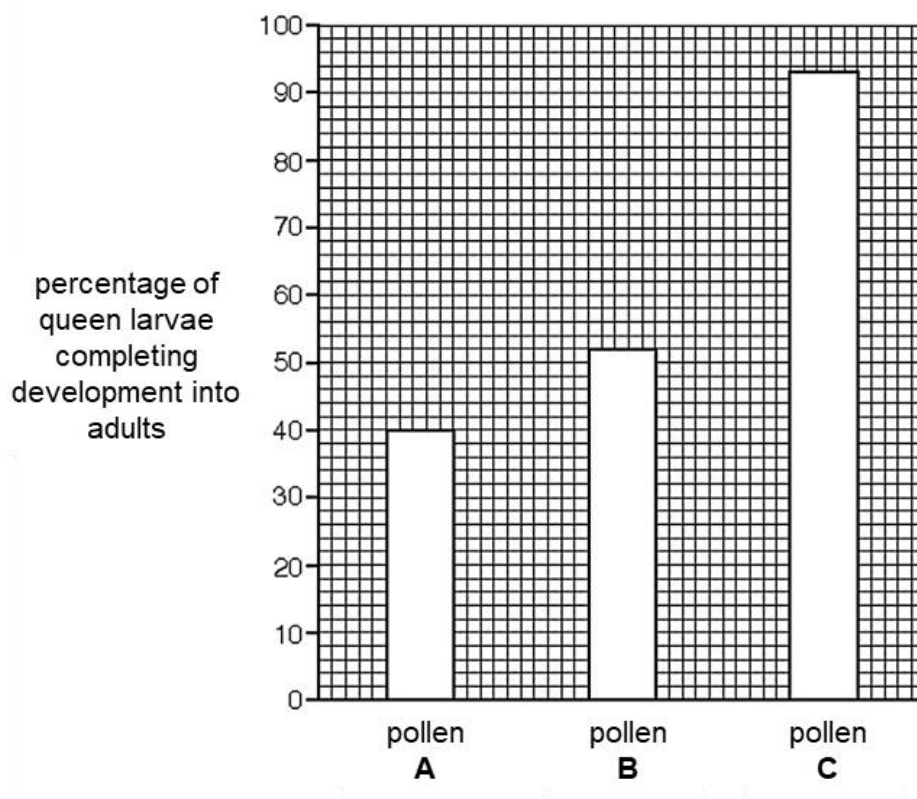


Fig. 3.1

Comment on the results shown in Fig. 3.1, including reference to the χ^2 value and its corresponding p value. [4]

1. Less queen larvae complete development when given pesticides (pollens A and B) as compared to those not exposed / given pollen C
2. **[cite fig]** Only 40% and 52% of queen larvae completed development when given pesticides in pollen A and B respectively, while 93% of those not exposed/given pollen C completed development.
3. Pollen A has greater effect on development than pollen B. / **Pristine decreases the negative effects of CPF.**
4. **[cite fig]** Only 40% of queen larvae completed development when given pesticides in A while 52% of those given pesticides in B completed development.
5. Since $p < 0.05$, the difference in the numbers of queen larvae completing development between observed (treatment A) and expected (treatment C) is significant / not due to chance.
6. CPF reduces the percentage of queen larvae completing development into adult stage.

(max 3 if no figures cited)



- (c) Newly emerged adult queens from colonies fed pollen **A**, **B** or **C** were analysed for the presence of the deformed wing virus (DWV), one of the twenty-two viruses that infect honey bees.

The results are shown in Fig. 3.2.

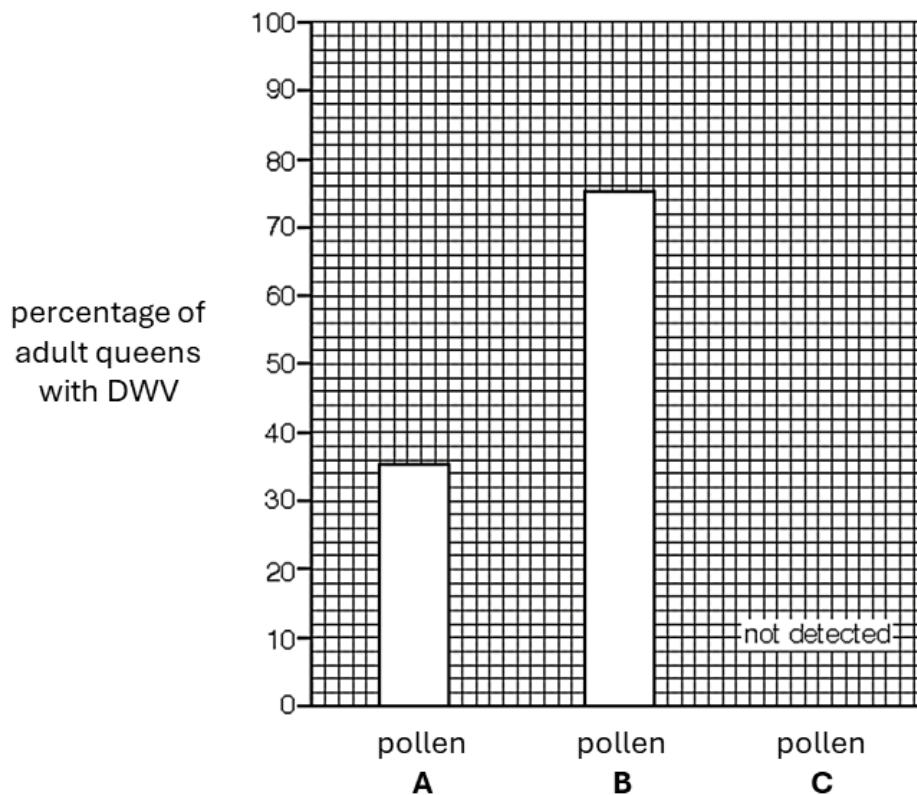


Fig. 3.2

The investigators hypothesised that increased infection with DWV in the bees fed with CPF and Pristine® resulted from reduced effectiveness of the immune system. Honey bees do not have adaptive immunity.

Organophosphates such as CPF block G-protein linked receptors.

The fungicide Pristine® inhibits the electron transport chain on the cristae of mitochondria.

Suggest **and** explain how blocking G-protein linked receptors and inhibiting the electron transport chain will reduce the effectiveness of the immune system. [4]

blocking G-protein linked receptors

- **idea of** G-proteins linked receptors are involved in cell signalling.
- Immune response depends on cell signalling + example (binding of cytokines to receptors on immune cells)

inhibiting the electron transport chain

- Less ATP is produced as aerobic respiration stopped.
- Actions of immune system require ATP + example (phagocytosis by phagocytic cells requires ATP)

[Total: 10]



Section B

Answer **one** question in this section.

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

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 parts **(a)** and **(b)**, as indicated in the question.

- 4** In eukaryotic cells, gene expression consists of two main stages: transcription, which occurs in the nucleus, and translation, which takes place in the cytoplasm. The RNA and polypeptides produced at each stage are often further processed or modified. These modifications can result in the synthesis of multiple distinct proteins or proteins with different activities or functions from a single gene.

Additionally, these and many other cellular processes occur within specialised membrane-bound compartments in the cell, allowing for spatial and functional organisation.

- a)** Contrast the processes of transcription and translation in eukaryotic cells and explain how a single gene can encode multiple proteins or proteins with different activities or functions. [13]

- b)** Explain the significance of compartmentalization in eukaryotic cells. [12]

[Total: 25]

- 5** Photosynthesis and respiration are two fundamental biological processes that involves transformation of energy.

- a)** Compare the process of energy transformation in photosynthesis and aerobic respiration. [13]

- b)** Explain how climate change might impact these fundamental biological processes in plants and animals. [12]

[Total: 25]



- 4 In eukaryotic cells, gene expression consists of two main stages: transcription, which occurs in the nucleus, and translation, which takes place in the cytoplasm. The RNA and polypeptides produced at each stage are often further processed or modified. These modifications can result in the synthesis of multiple distinct proteins or proteins with different activities or functions from a single gene.

Additionally, these and many other cellular processes occur within specialised membrane-bound compartments in the cell, allowing for spatial and functional organization.

- a) Contrast the processes of transcription and translation and explain how a single gene can encode multiple proteins or proteins with different activities or functions. [13]

	FEATURE	TRANSCRIPTION	TRANSLATION
1	Template	DNA template strand	mRNA
2	Enzyme	<u>RNA polymerase</u> catalyses the formation of phosphodiester bonds between adjacent ribonucleotides.	<u>Peptidyl transferase</u> of ribosomes catalyzes the formation of peptide bond between adjacent amino acids
3	Start of process	Transcription starts at the <u>promoter/TATA Box</u>	Translation starts at the <u>start codon / AUG</u>
4	End of process	Transcription terminates at the <u>terminator</u>	Translation terminates at the <u>stop codon / UAA,UAG or UGA</u>
	Bond between basic units	A <u>phosphodiester bond</u> is formed between the 5' phosphate group of the incoming nucleotide and 3'OH group of the growing RNA transcript.	<u>Peptide bonds</u> are formed between adjacent amino acids.
5	Direction of Reading of template	RNA polymerase moves along and reads the DNA template strand in a <u>3' to 5' direction</u> .	Ribosomes move along and read the mRNA molecule from the <u>5' to the 3' end</u> .
6	Raw material(s)	Free ribonucleotides / ribonucleoside triphosphates.	Amino acids attached to tRNA.
7	Product(s)	mRNA, tRNA, rRNA	Polypeptide chain
8	Fate of products	Products exit the nucleus and migrate to the cytoplasm	Polypeptide remain in the cytoplasm or are secreted out of the cell

explain how a single gene can encode multiple proteins or proteins with different activities or functions

- 10 Alternative splicing allows a single gene to encode multiple proteins.
- 11 All introns are excised and different combinations of exons are spliced together...
- 12 ...resulting in different mRNA sequences that are translated into different amino acid sequence / polypeptide chain / proteins.
- 13 Process carried out by spliceosomes.
- 14 **Give actual example:** Troponin T gene encodes different (but related) troponin T proteins in different tissues (skeletal muscle cells vs cardiac muscle cells) due to alternative splicing of same pre-mRNA.
- 15 Post-translational modifications can alter the activity of proteins without changing their primary sequence, allowing a single gene product to have different functions under different conditions.

Proteolytic Cleavage:

- 16 Cleavage of methionine (first amino acid) to form functional/active protein
- 17 Cleavage of polypeptide to form the functional/active protein.
- 18 **Give e.g.:** Proteolytic cleavage of C-peptide from inactive pro-insulin, allows for production of functional insulin.

Biochemical/covalent modifications:

- 19 Phosphorylation / addition of phosphate group to protein ...
- 20 ...to activate or deactivate protein / enzymes / receptors.
- 21 **Give e.g.:** The phosphorylation of tyrosine residues in receptor tyrosine kinases activates signaling cascades involved in cell growth and differentiation.
- 22 Glycosylation / addition of one or more sugar monomers to protein...
- 23 ... to allow for proper protein folding / protein stability / protein trafficking / protein localization / cell-cell interactions / signal transduction / AVP.
- 24 Methylation / Demethylation – addition / removal of methyl groups to ...
- 25 ...allow for proper protein interaction / protein stability / protein localization / protein trafficking / cell-cell interactions / signal transduction / AVP.
- 26 **Give specific e.g.:** Methylation of histones result in tighter interactions between histones (due to increased hydrophobic interactions), resulting in reduced transcription of gene.
- 27 **Give specific e.g.:** Methylation of protein kinase / membrane receptors



- 28 Ubiquitination / addition of ubiquitin molecules on proteins marked for degradation and no longer carry out its function / activity.
- 29 Acetylation / Deacetylation – addition / removal of acetyl groups on proteins to activate/deactivate proteins.
- 30 Give specific e.g.: Acetylation of histones neutralise the ionic bonds between histones and DNA, resulting in loosen chromatin structure / increased transcription of gene.
- 31 Give specific e.g.: Acetylation of the tumor suppressor protein p53 regulates its DNA binding, stability, and interaction with other proteins.



b) Explain the significance of compartmentalization in eukaryotic cells. [12]

1. Compartmentalization in eukaryotic cells refers to the presence of membrane-bound organelles that separate cellular functions into distinct regions.
2. **Separation of Cellular Processes**
Different biochemical reactions occur in specific organelles, preventing interference and allowing efficient multitasking.
3. **Increased Efficiency in Metabolism / Faster Reaction Rates in Biochemical Pathways**
Enzymes and substrates are concentrated in appropriate organelles, enhancing the rate of enzyme-catalysed / metabolic reactions.
4. **Protection of Cellular Components from harmful biochemical reactions.**
Harmful biochemical reactions (e.g., digestion by lysosomes) are confined to prevent cellular damage.
5. **Specialization of Organelles**
Organelles such as mitochondria (ATP production) and the Golgi apparatus (protein modification) perform distinct functions, optimizing cell function.
6. **Energy Production Optimization**
Mitochondria compartmentalize aerobic respiration, allowing efficient ATP generation through oxidative phosphorylation.
7. **Efficient Protein Synthesis and Processing**
Ribosomes on the rough ER synthesize proteins, which are modified and packaged by the Golgi apparatus before being transported.
8. **Regulation of Gene Expression**
The nucleus protects and organizes genetic material, allowing controlled gene expression and mRNA processing before translation.
9. **Isolation of Genetic Material**
The nuclear envelope separates transcription (in the nucleus) from translation (in the cytoplasm), ensuring proper RNA processing.
10. **Intracellular Transport and Vesicle Trafficking**
Organelles use vesicles to transport proteins and molecules, maintaining compartment-specific functions.
11. **Efficient Waste Disposal**
Lysosomes digest unwanted cellular materials and damaged organelles, preventing accumulation of waste.
12. **Detoxification and Protection Against Toxins**
The smooth ER detoxifies harmful substances, preventing toxic buildup in the cytoplasm.
13. **pH Regulation in Organelles**



Organelles maintain unique pH levels, optimizing enzyme activity (e.g., lysosomes function at acidic pH).

14. Calcium Storage and Release

15. The smooth ER stores calcium ions, releasing them when needed for cellular signaling and muscle contractions.

16. Spatial Organization of Cellular Processes

Cytoskeletal components and organelles maintain cellular shape and organization, ensuring proper division and intracellular transport.

17. Prevention of Unwanted Cross-Reactions

By isolating metabolic pathways (e.g., fatty acid oxidation in peroxisomes), cells avoid conflicting biochemical interactions.

18. Efficient Response to Cellular Signals

Compartmentalized signaling pathways allow precise and rapid responses to external stimuli.

19. Evolutionary Advantage

The presence of membrane-bound organelles allows eukaryotic cells to perform more complex functions, giving them an advantage over prokaryotic cells.

20. AVP

Give extra mark if student can give specific example. [e.g. Lysosome has acidic pH for optimal functioning of enzymes]

Conclusion

Compartmentalization in eukaryotic cells enhances **efficiency, regulation, and specialization**. Without it, cellular processes would be chaotic and inefficient, limiting the development of multicellular organisms.



5 Photosynthesis and respiration are two fundamental biological processes that involves transformation of energy.

a) Compare the process of energy transformation in photosynthesis and aerobic respiration. [13]

Similarity:

1. Both produce ATP (in at least one of its stages).
2. Both involve redox reactions / electron transport chains to transfer energy.
3. Both rely on a proton gradient across membranes to drive ATP synthesis via chemiosmosis.
4. Both have cyclic components - the Calvin cycle in photosynthesis and the Krebs cycle in cellular respiration.

Differences

	Features	Photosynthesis	Aerobic Respiration
1	Location	chloroplasts	Mitochondria and cytosol
2	Energy Transformation	light energy into chemical energy (triose phosphate)	chemical energy (glucose) into ATP
3	Energy source	Light energy from the sun	Chemical energy from glucose
4	Stages involved	Light dependent reaction and Calvin Cycle	Glycolysis, Link Reaction, Krebs Cycle and Oxidative Phosphorylation
5	Electron carriers	NADP ⁺ / NADPH	NAD ⁺ , FAD / NADH, FADH ₂
6	Production of ATP	ATP is produced during the light-dependent reactions	ATP is produced during oxidative phosphorylation
7	Use of ATP	ATP produced are only used within the chloroplast	ATP produced are using in the cell / for cellular processes
8	Carbon dioxide involvement	Fixed CO ₂ (Calvin cycle)	Release CO ₂ (Link reaction and Krebs cycle)
9	Role of oxygen	Produced as a by-product during photolysis of water (LDR)	Final electron acceptor during oxidative phosphorylation
10	Role of water	Reactant for photolysis (of water)	Water released as by-product during oxidative phosphorylation
11	Dependency	Dependent on sunlight	Can occur day and night if glucose is available
12	Products	Glucose and O ₂	CO ₂ and H ₂ O

Electron donor and final electron acceptor relevant?

b) Explain how climate change might impact these fundamental biological processes in plants and animals. [12]

Climate change can significantly impact both photosynthesis and cellular respiration through several mechanisms:

Temperature Increase:

1. Rate of photosynthesis and respiration generally increase with temperature...
2. as kinetic energy between enzymes and substrates increases, increasing the rate of enzyme-substrate complexes formed.



3. However, photosynthetic enzymes and respiratory enzymes have optimal temperature ranges - **Higher temperatures** may **denature** these **enzymes**, reducing the rate of both processes.
4. Plants respire continuously, even at night. **Warmer nights** due to climate change lead to higher respiration rates, **consuming more carbohydrates** and reducing net carbon gain, especially in crops like rice and wheat.

CO₂ Concentration:

5. Higher CO₂ levels, more CO₂ for carbon fixation, hence rate of photosynthesis increases, enhancing plant growth.
6. However, this effect may be limited by other factors like nutrient availability / water stress/ temperature threshold.

Water Availability:

7. Drought reduces water availability for photolysis.
8. Plants **close stomata** in hot and dry condition/drought **to reduce water loss**...
9. ...**reducing CO₂ intake** hence reduces rate of photosynthesis.

Ozone Layer Depletion:

10. Increased UV radiation due to ozone depletion can damage photosynthetic pigments and reduce photosynthesis efficiency.

Nutrient Cycling:

11. Changes in soil temperature and moisture can affect nutrient availability, impacting photosynthesis and plant growth.

Ocean Acidification:

12. Increased CO₂ absorption by oceans can lead to acidification, affecting marine photosynthetic organisms like phytoplankton.

Disruption of Seasonal Patterns:

13. Changes in temperature and precipitation patterns can disrupt seasonal growth cycles, affecting photosynthesis and plant productivity.

Increased Frequency of Extreme Weather Events:

14. Events like heatwaves and droughts can directly impact photosynthesis by damaging crops and altering growing conditions.

Increased reactive oxygen species (ROS)

15. Heat stress can lead to overproduction of ROS during respiration, especially in mitochondria. This can damage cell structures and impair respiratory pathways in plants and animals.

Carbon use outpaces carbon gain

16. If respiration increases more than photosynthesis, plants use up their carbohydrate reserves, weakening growth and reducing yield.

Disruption in mitochondrial function

17. Studies show that heat and drought stress can alter mitochondrial membrane integrity, affecting ATP synthesis efficiency in plant cells.



Increased respiration contributes to feedback in climate change

18. Warmer conditions increase plant respiration, releasing more CO₂ into the atmosphere, amplifying global warming, resulting in a negative feedback loop.

