



TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE
NAME

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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.

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of the page.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Section A

Answer **ALL** questions.

Section B

Answer **ONE** question.

The use of an approved scientific calculator is expected, where appropriate

You may lose marks if you do not show your working or if you do not use appropriate units.

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

OVERALL			
Paper	Score	Weighting	%
1	/30	15%	%
2	/100	30%	%
3	/75	35%	%
4	/55	20%	%
TOTAL			%
GRADE			

For examiner's Use	
Section A	
1	/ 28
2	/ 12
3	/ 10
Section B	
4 or 5	/ 25
Total	/ 75

Section A

Answer **all** questions in this section.

- 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]

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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]

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- (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.

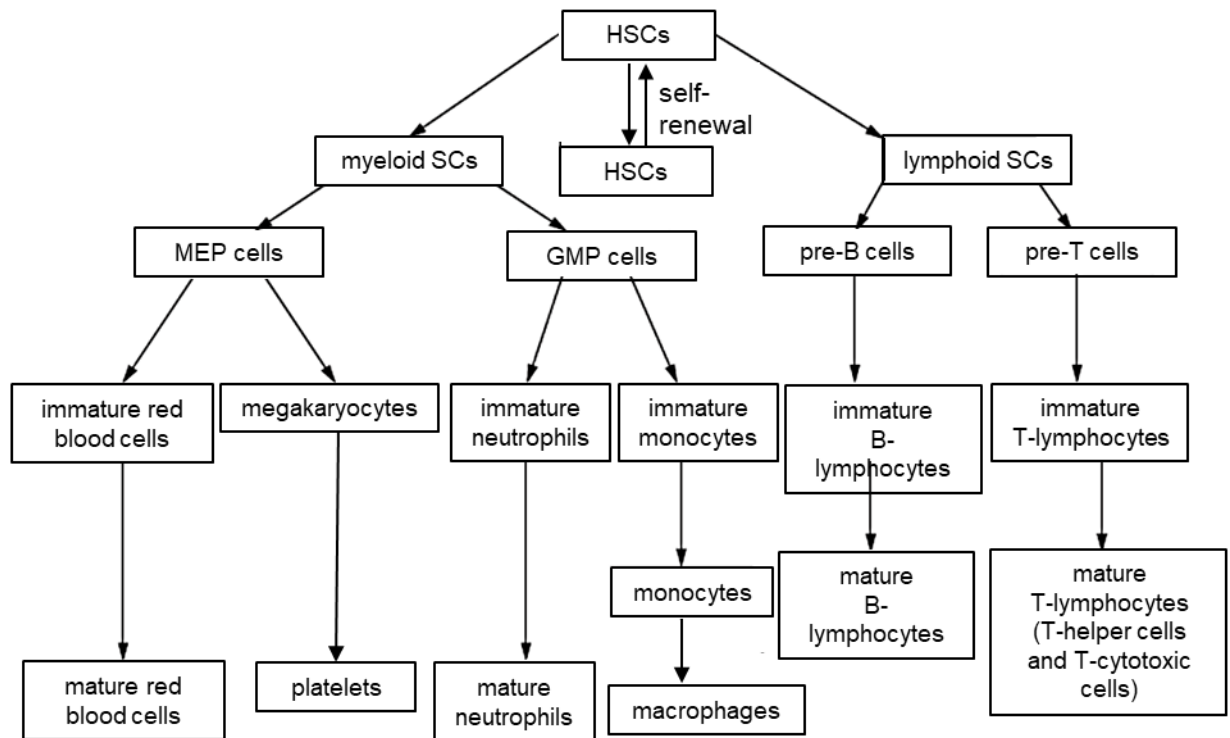


Fig. 1.1

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

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- (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]

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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.

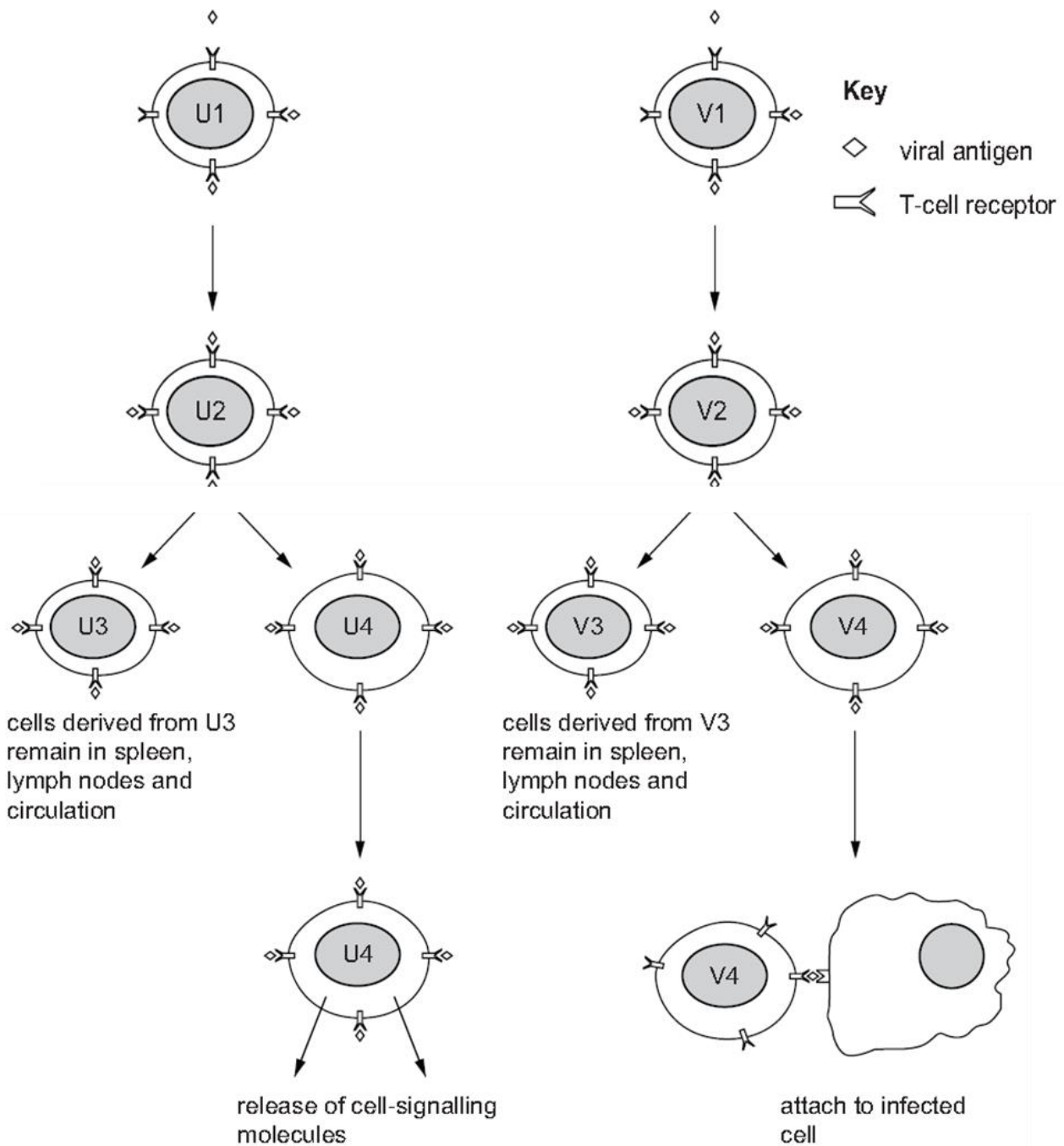


Fig. 1.2

- (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 **V4** in an adaptive immune response. [2]

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- (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]

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- (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]

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

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	
smooth endoplasmic reticulum		
Golgi body	modification of proteins and lipids	
	aerobic respiration	

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]

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- (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]

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- (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]

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(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.

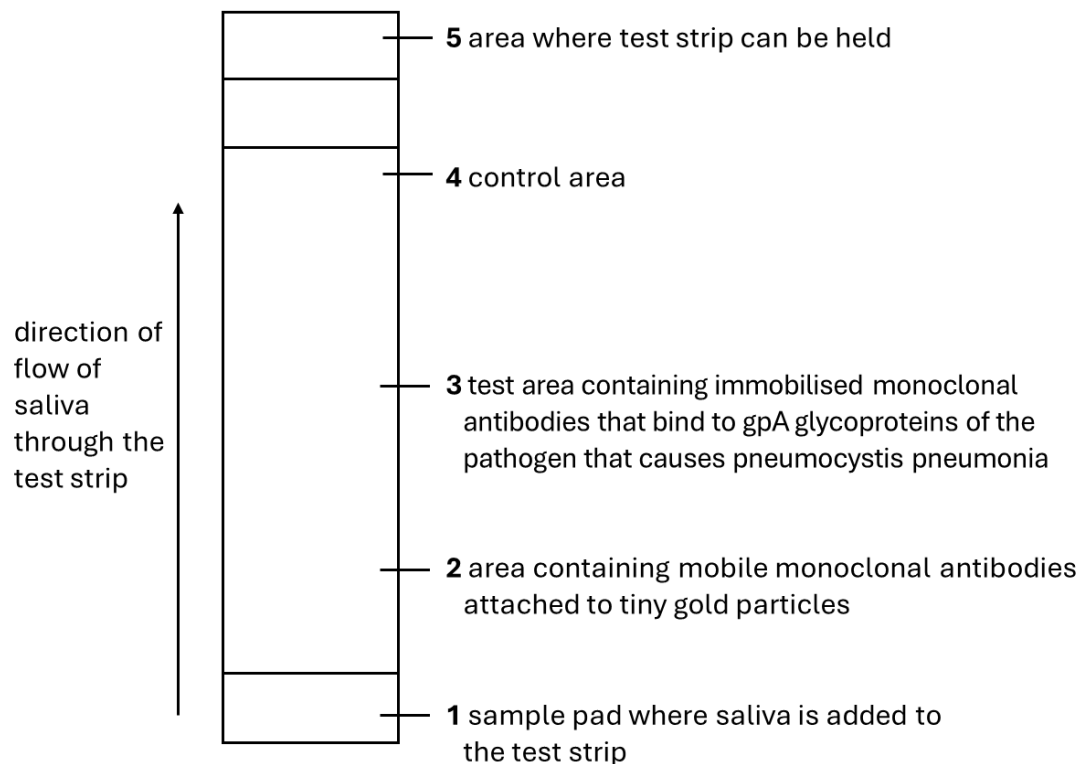


Fig. 1.3

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.

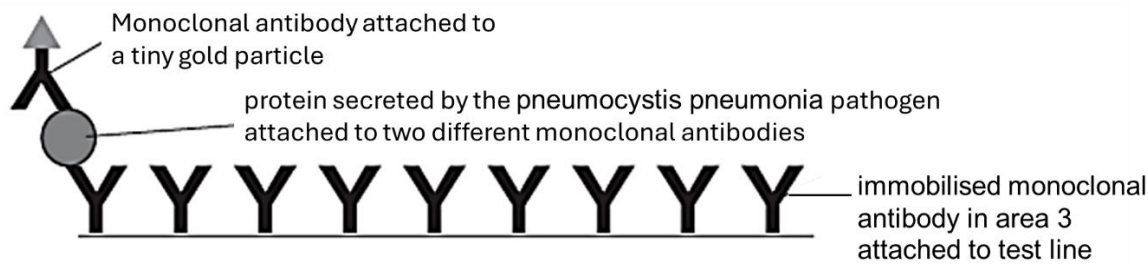


Fig. 1.4

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

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- (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]

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[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]

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- (ii) Complete Table 2.1 to show the taxonomic classification of the dugong. [2]

Table 2.1

Kingdom	Animalia
Phylum	Chordata
	Mammalia
Order	Sirenia
	Dugongidae
Genus	
Species	

- (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.

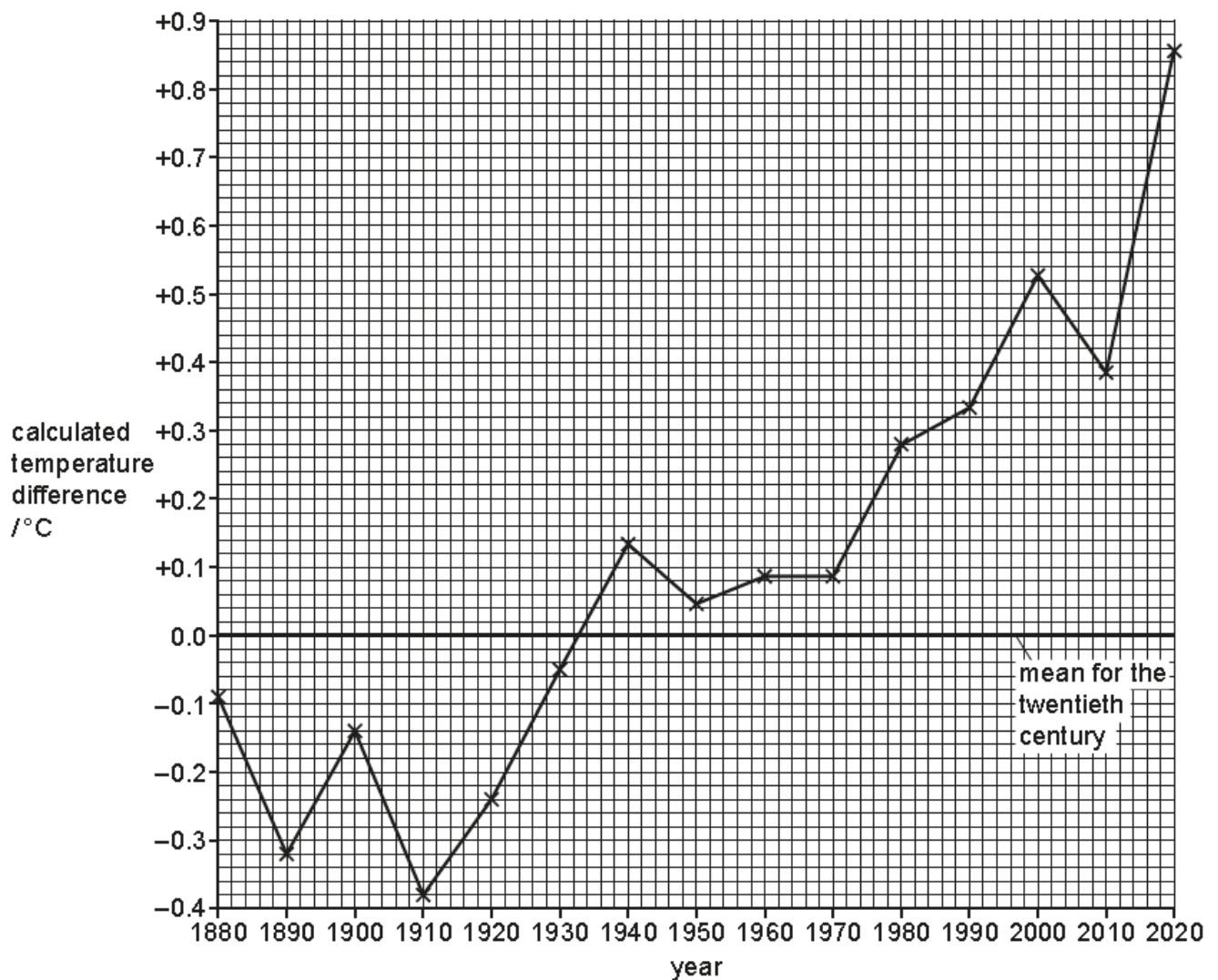


Fig. 2.2

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

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- (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]

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

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

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[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]

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- (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.

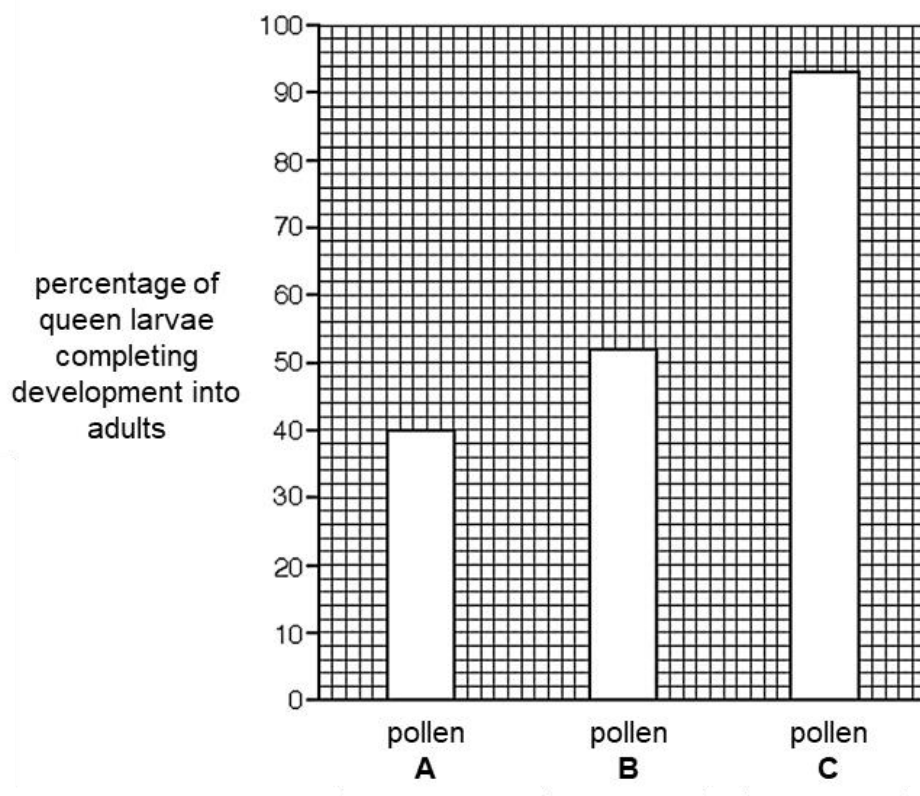


Fig. 3.1

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

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- (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.

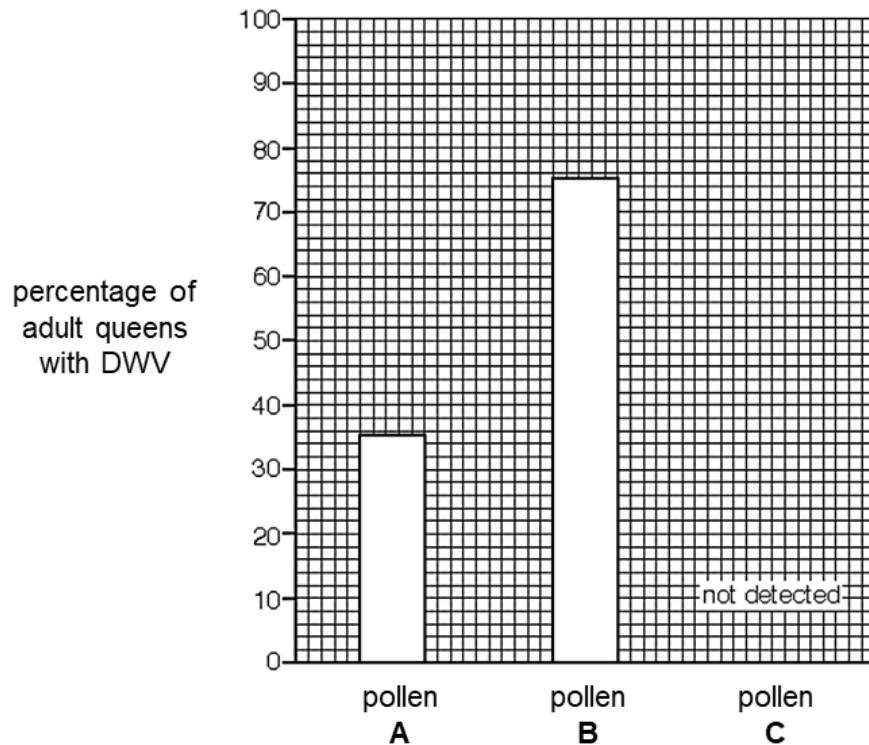


Fig. 3.2

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

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inhibiting the electron transport chain

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[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 compartmentalisation in eukaryotic cells. [12]

[Total: 25]

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

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

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

[Total: 25]

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