

TEMASEK JUNIOR COLLEGE
2025 JC2 PRELIMINARY EXAMINATION
Higher 2



CANDIDATE
NAME

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INDEX
NUMBER

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BIOLOGY

9744/03

Paper 3

17 September 2025

2 hours

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name in the spaces at the top of this 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.

DO NOT WRITE IN ANY BARCODES.

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

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

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

For Examiner's Use	
1	/ 30
2	/ 10
3	/ 10
4 OR 5	/ 25
Total	/ 75

Section A

Answer **all** questions.

- 1 Myeloid stem cells in the human bone marrow undergo repeated proliferation and differentiation once they receive external signals to produce more white blood cells. White blood cells are critical in fighting infections from pathogens. Such stem cells will go through cell cycles in different stages and are regulated tightly by various proteins and checkpoints found along the way.

Fig. 1.1 shows the various stages of the cell cycle and how it is regulated at the various checkpoints. The important control points of the cell cycle lie at the end of the G2 phase (G2/M transition), in mitosis (metaphase/anaphase transition) and in G1 phase (restriction point). Controls are shown in both solid and broken arrows.

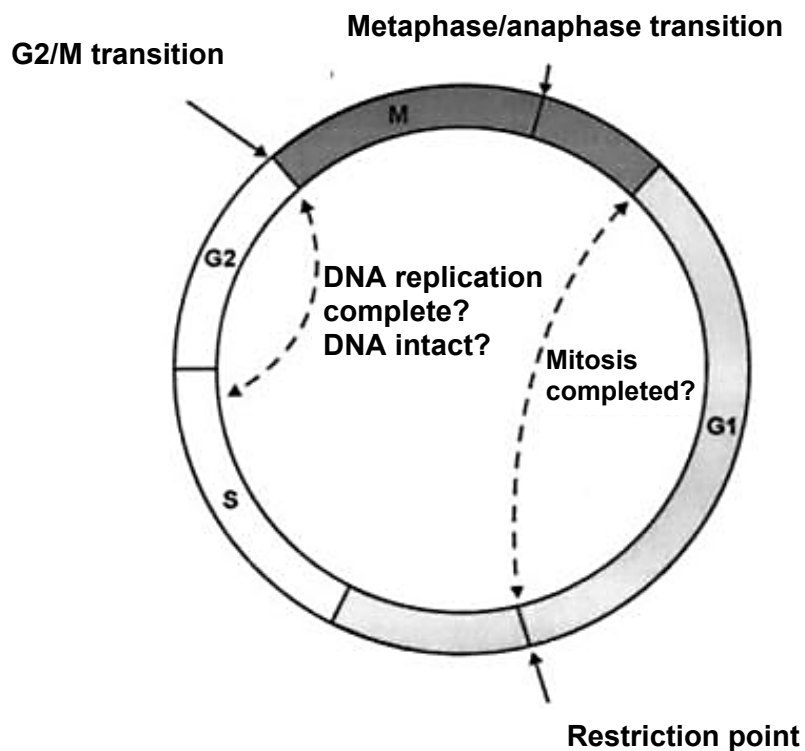


Fig. 1.1

- (a) Describe the function of metaphase/anaphase transition control and how this may prevent the development of cancer.

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..... [3]

Spindle fibres are polymers made from tubulin monomers. The removal of tubulin monomers causes spindle fibres to shorten. Scientists investigated the effect of the rate of tubulin removal on the speed of movement of chromatids during mitosis.

Fig. 1.2 shows the results of the investigation.

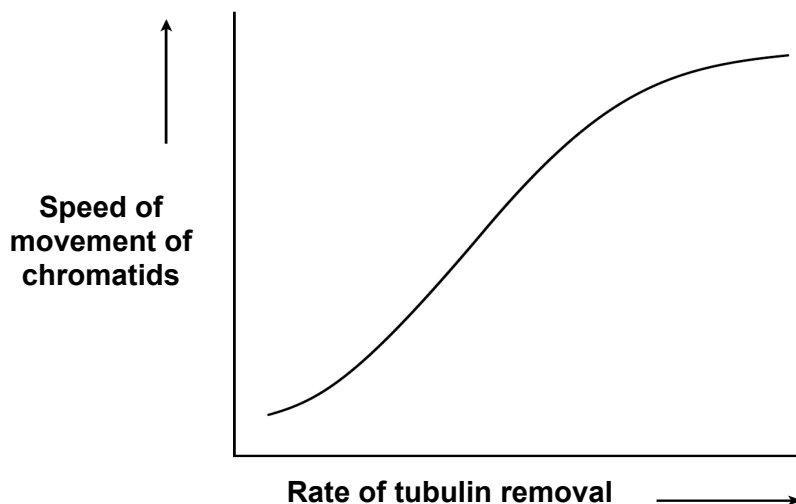


Fig. 1.2

(b) (i) Describe how these results support the role of spindle fibres in mitosis.

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..... [2]

(ii) Paclitaxel, also known as Taxol, is a microtubule structure-stabilizing drug that is commonly used to treat both early-stage breast cancer and advanced, or metastatic breast cancer.

Explain why drugs such as Paclitaxel are effective as an anti-cancer therapeutic.

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..... [2]

Chronic myeloid leukemia (CML) is a cancer of the white blood cells. Patients with CML suffer from shortness of breath and have increased risk of infection.

This slow-growing cancer arises from a disorder in the myeloid stem cells found in bone marrow. Myeloid stem cells are responsible for maintaining the red blood cell and white blood cell populations in the body.

CML patients are diagnosed via a complete blood count test, which will identify abnormal numbers of different types of blood cells in a fixed volume of blood.

Fig. 1.3 shows the blood cells in 100 ml of blood from a healthy person and a CML patient.

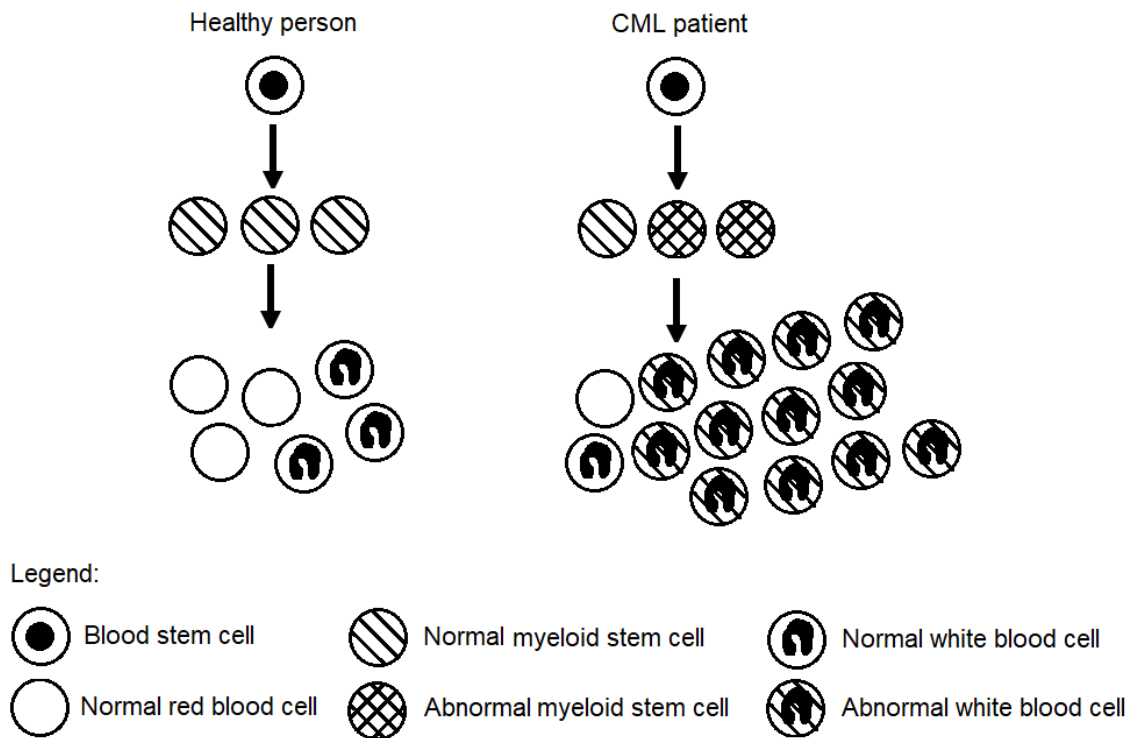


Fig. 1.3

(c) Explain what is meant by *cancer*.

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- [4]

Fig. 1.4 shows the results of the genetic study. Chromosome 2 is known to not carry ABL and BCR genes.

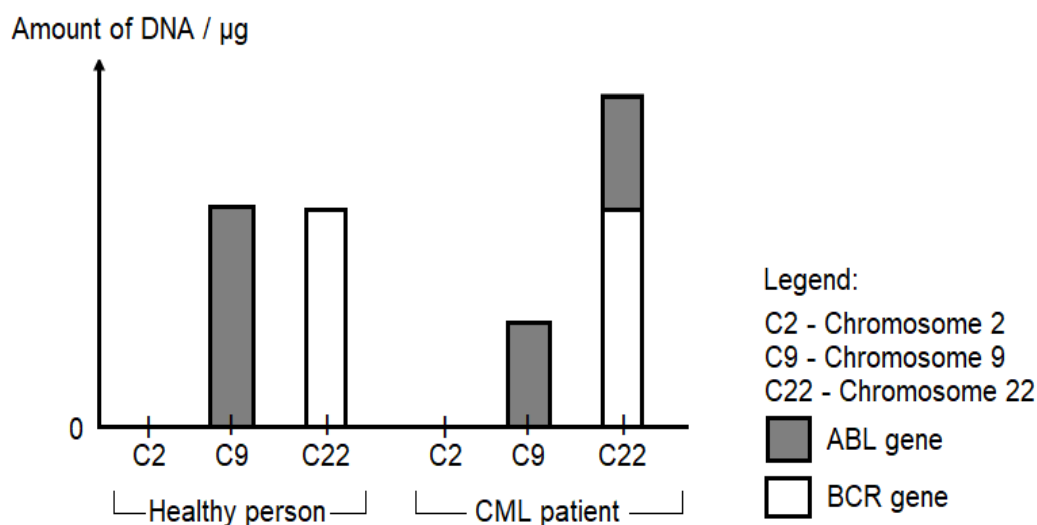


Fig. 1.4

- [1]

(ii) Suggest the purpose of screening chromosome 2.

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 [1]

Further studies revealed that CML patients that have the Philadelphia chromosome express an altered form of tyrosine kinase receptor, known as BCR-ABL. BCR-ABL is a receptor in a cell signaling pathway that stimulates cell growth. BCR-ABL receptor is observed to have a higher than normal level of activity, and abnormality in its ligand-receptor interaction.

(f) (i) Describe how a receptor tyrosine kinase receptor (RTK) such as the BCR-ABL is activated in a cell signalling pathway.

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 [2]

(ii) Suggest how the presence of a Philadelphia chromosome may lead to the development of cancer.

.....

 [2]

In the regulation of cell cycles, roles of proteins such as cyclin-dependent kinases (CDK) and cyclins are involved in allowing cells to progress to the subsequent stages of the cell cycle. For example, the formation of CDK 4-cyclin D complex is required for the completion of S phase in the cell cycle. Without this complex, the cell cycle will be arrested at the G1 phase.

Palbociclib is a novel drug with structural similarity to cyclin D was developed to treat CML by targeting cyclin-dependent kinase 4 (CDK 4). Researchers investigated the effect of Palbociclib on the concentrations of CDK 4 – cyclin D complex and free cyclin D.

Fig. 1.5 shows the concentrations of CDK 4-cyclin D complex and free cyclin D in a drug trial involving high dosages of Palbociclib.

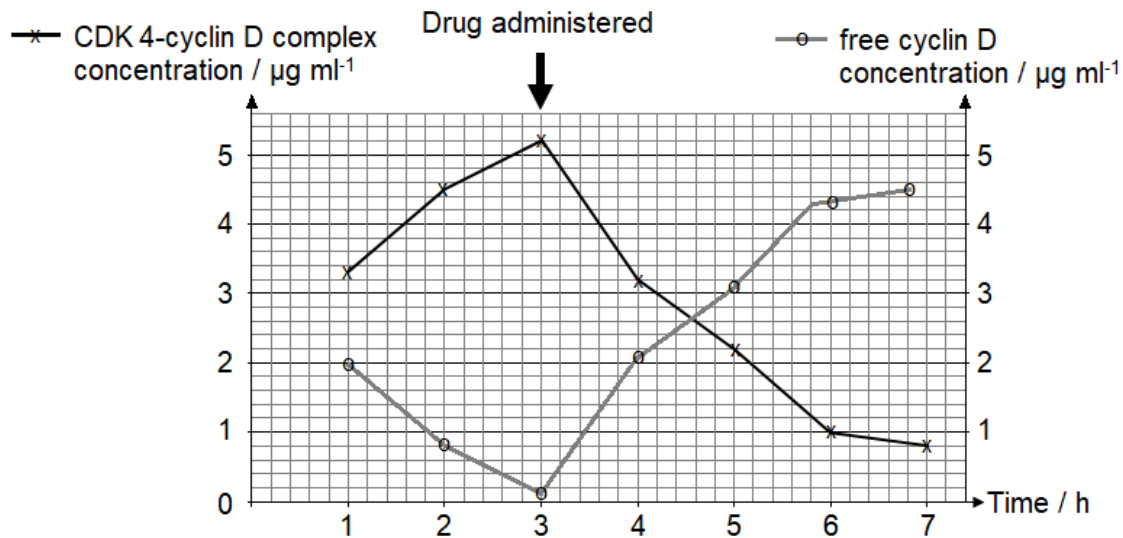


Fig. 1.5

(g) (i) Describe the changes in the CDK4-cyclin complex and free cyclin D Palbociclib concentration.

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(ii) Explain how Palbociclib could potentially be a therapeutic drug for CML.

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Upon further investigation, the researchers concluded that Palbociclib is not suited for use in cancer treatment.

(iii) Suggest why Palbociclib may not be suitable for use in cancer treatment.

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 [1]

Two genes, *CCND1* and *CCND2*, encode cyclin D proteins that play crucial role in regulation of cell cycle progression, particularly during the G1 phase. The two genes are located on different chromosomes and are responsible for the synthesis of cyclin D that forms complexes with CDK 4.

To examine whether differences in the expression level of *CCND1* and *CCND2* influence the formation of the CDK4 – cyclin D complexes, reverse transcription polymerase chain reaction (RT-PCR) was carried out on adult hair follicular cells from two patients (Patient A and B). In RT-PCR, the mRNA for both genes were isolated. Reverse transcriptase was then added to form the complementary DNA (cDNA). This cDNA is subjected to PCR to amplify it. The resultant RT-PCR product was analysed by gel electrophoresis.

Fig. 1.6 shows the results of the gel electrophoresis.

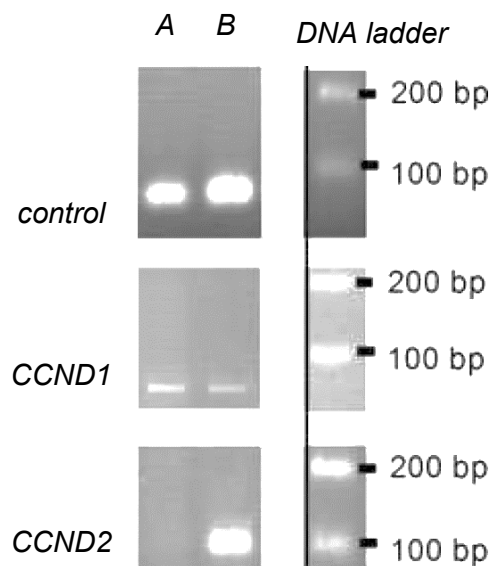


Fig. 1.6

(h) With reference to Fig. 1.6,

(i) outline the principle of gel electrophoresis;

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 [2]

(ii) compare the expression levels of CCND1 and CCND2 between patients A and B.

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..... [2]

(j) RT-PCR is a laboratory technique combining reverse transcription of RNA into DNA and amplification of specific DNA targets using polymerase chain reaction. The technique is carried out on mRNA samples isolated from cells.

Suggest one advantage of RT-PCR compared to conventional PCR.

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..... [1]

[Total: 30]

[TURN OVER]

- 2 A certain dominant disease in humans occurs when there are more than 40 repeats of the triplet sequence 'CGG' in a particular gene.

Fig. 2.1 shows an example of one strand of the diseased allele. (CGG)₄₅ represents 45 repeats of the triplet sequence 'CGG'.

5' CAGTATGCA ----- (CGG)₄₅ ----- ATGCGTAAT 3'

Fig. 2.1

- (a) With reference to Fig. 2.1, state the sequence of the complementary strand.

..... [1]

- (b) Describe a mutation that can give rise to a variable number of repeats in an allele.

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 [2]

A genetic counsellor was tasked to determine if the child of two individuals (Individual A and B) was at risk of inheriting this disease. After obtaining the DNA of both individuals and all their immediate family members, the researcher ran the DNA through gel electrophoresis but obtained a smear.

- (c) Explain briefly how the researcher can obtain distinct bands corresponding to the gene of interest from the gel electrophoresis results.

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 [2]

(d) Suggest the significance of obtaining the DNA samples of the immediate family members.

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 [1]

Fig. 2.2 shows the outline of a pedigree for the disease described above for all individuals and a representation of a gel showing the bands that contain the gene of interest.

The DNA corresponding to each individual is directly below his or her place in the pedigree.

A dotted line is also drawn in the gel representation to indicate the position of any bands that contain DNA fragments with 40 repeats of the triplet sequence 'CGG'.

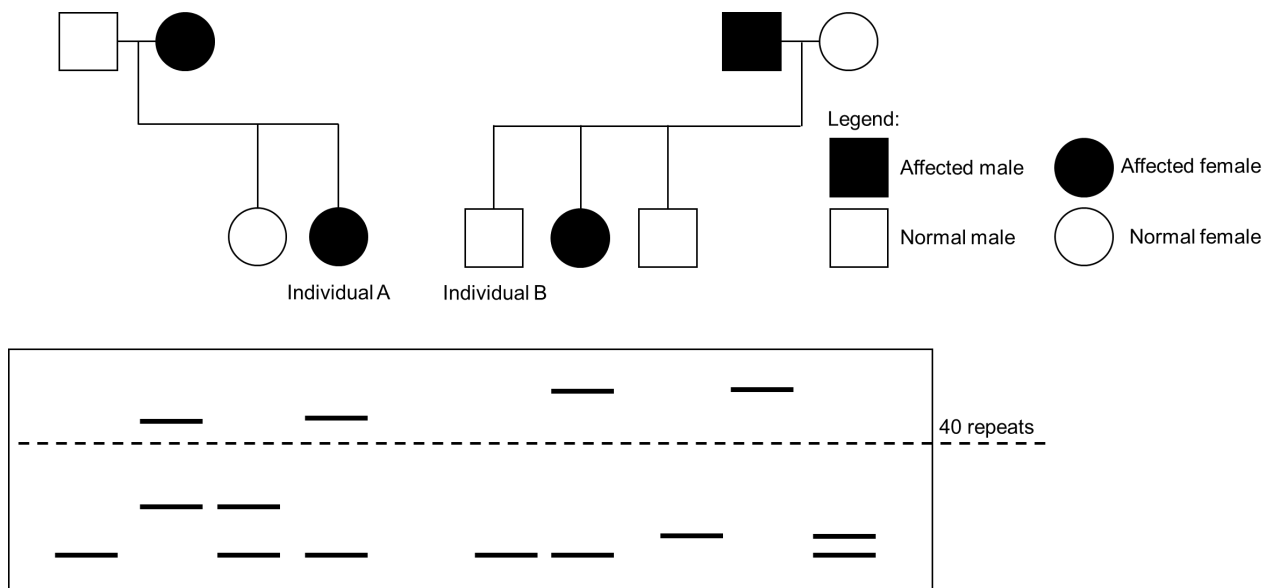


Fig. 2.2

(e) (i) Based on the information provided in this question, deduce if the gene of interest is found on an autosome or sex chromosome.

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 [1]

(ii) Explain your answer to (e)(i).

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 [2]

(iii) Hence, state the probability of the child of individuals A and B inheriting the disease.

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..... [1]

[Total: 10]

- 3 North America is home to diverse migratory bird species that travel long distances between their breeding grounds in the north and wintering grounds in the south. One such migratory bird species is the American robin, a widespread bird across North America. During the winter season, the robins will migrate from the northern region of Canada to the southern region to seek for their food source – caterpillars.

Over the years, climate changes have affected the population of American robins, affecting their migration pattern and possibly impacting their survival.

Fig. 3.1 below shows the average global temperature over the years.

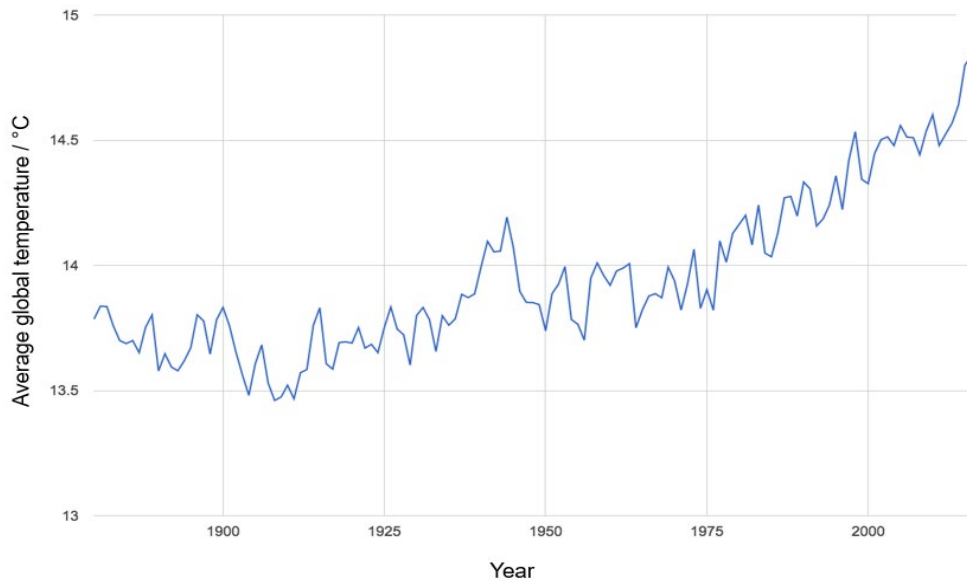


Fig. 3.1

Fig. 3.2 shows the migration period of the robins from north Canada to south Canada in 1950 and 2000 while Fig. 3.3 shows the period where there is great abundance of caterpillars in south Canada in 1950 and 2000.

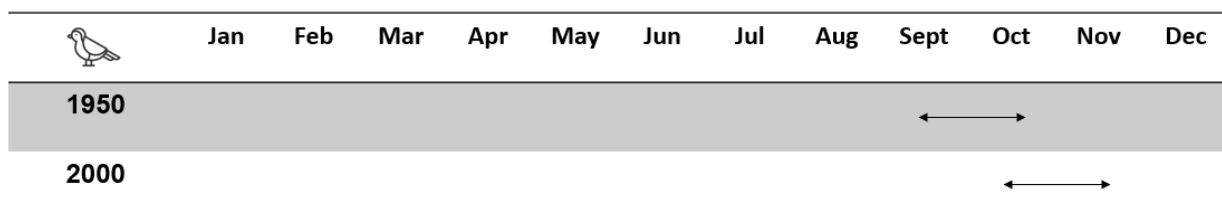


Fig. 3.2

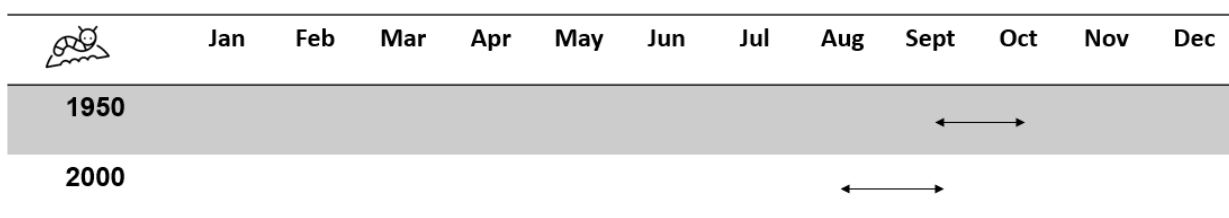


Fig. 3.3

Climate change has been said to affect the American robins migratory phenology.

- (a) Suggest what is meant by the term “phenology”.

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..... [1]

- (b) With reference to Fig. 3.1 and 3.2, describe and explain how climate change has caused the change in the migration pattern.

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- (c) Suggest why caterpillars are found in abundance earlier in the year in 2000 as compared to 1950, as shown in Fig. 3.3.

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(d) Comment on how changes shown in Fig. 3.2 and Fig. 3.3 can impact the American robins.

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[Total: 10]

Section B

Answer **one** question in this section.

Write your answers 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 (a)** In 1665, Robert Hooke discovered cells using one of the first microscopes ever invented. Subsequently, the biologists Matthias Schleiden and Theodor Schwann summarised a large number of observations by themselves and others.

Their conclusions have come to be known as the cell theory and forms the foundation for understanding the reproduction and growth of all organisms.

Using a named example, describe the cell theory and discuss how we can determine if an unknown entity is a cell. [10]

- (b)** Describe how complementarity between biomolecules enable eukaryotic cells to carry out their diverse functions. [15]

[Total: 25]

- 5 (a)** There are many methods to classify organisms.

Describe some methods and explain their limitations. [10]

- (b)** With named examples, explain how anatomical and molecular homology support Darwin's theory of evolution on descent with modification. [15]

[Total: 25]

This image shows a full page of white paper designed for handwriting practice. It features 20 evenly spaced, horizontal dotted lines that run across the entire width of the page. The lines are thin and light gray, providing a guide for letter height and placement without being distracting. There is no text or other markings on the page.



A series of 25 horizontal dotted lines spanning the width of the page, intended for writing.



This image shows a full page of a worksheet designed for handwriting practice. It consists of approximately 20 horizontal rows. Each row is defined by two parallel dotted lines, creating a series of uniform gaps for writing. The entire page is otherwise blank, with no margins, text, or other markings.



A series of 25 horizontal dotted lines spanning the width of the page, providing a guide for handwriting practice.



This image shows a full page of white paper designed for handwriting practice. It features approximately 20 evenly spaced horizontal dotted lines running from left to right across the entire width of the page. There are no margins, text, or other markings present.



A series of 25 horizontal dotted lines spanning the width of the page, providing a guide for handwriting practice.



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This image shows a full page of a worksheet designed for handwriting practice. It consists of approximately 20 horizontal rows. Each row is defined by two parallel dotted lines, creating a series of uniform gaps for letter height. The entire page is otherwise blank, with no margins, text, or other markings.