H

NANYANG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

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	
2	
3	
Section B	
Total	

Section A

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

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.

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(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.

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(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.

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[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.

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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.

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(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*.

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(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.

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(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.

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(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.

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[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.

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

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(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.

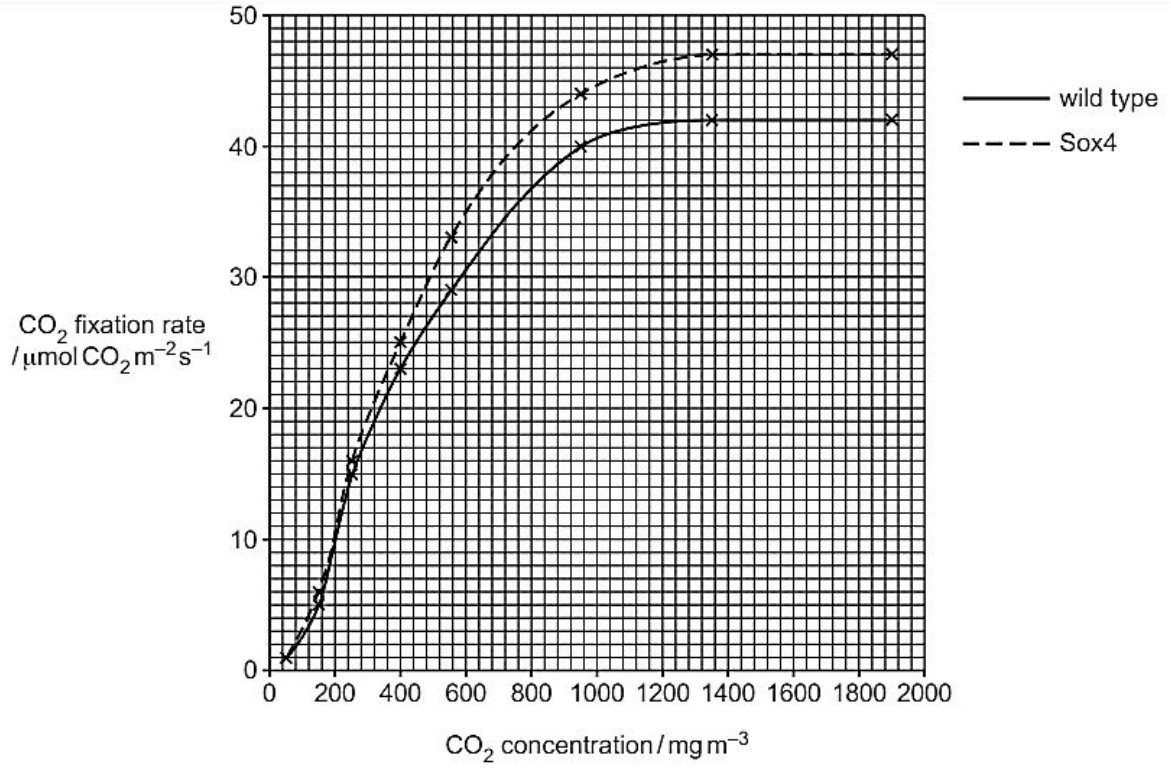

Fig. 2.1

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

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(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.

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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.

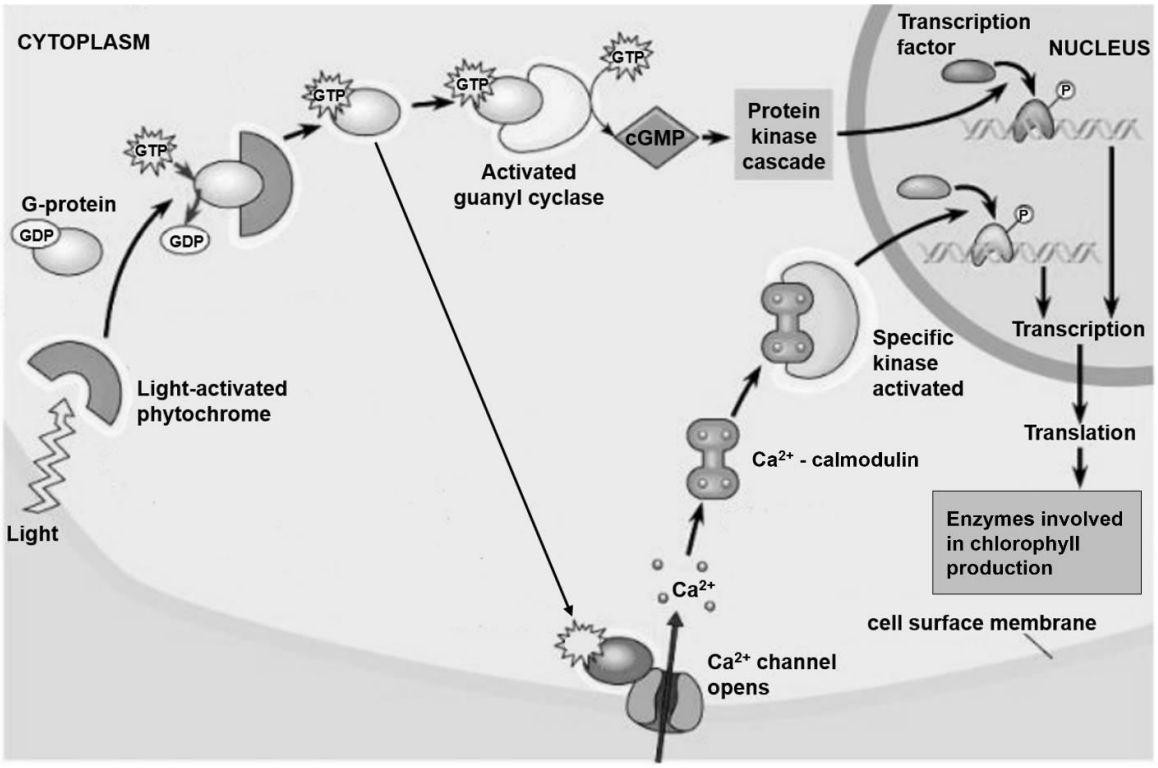

Fig. 2.2

(c) With reference to Fig. 2.2,

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

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

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

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[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.

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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.

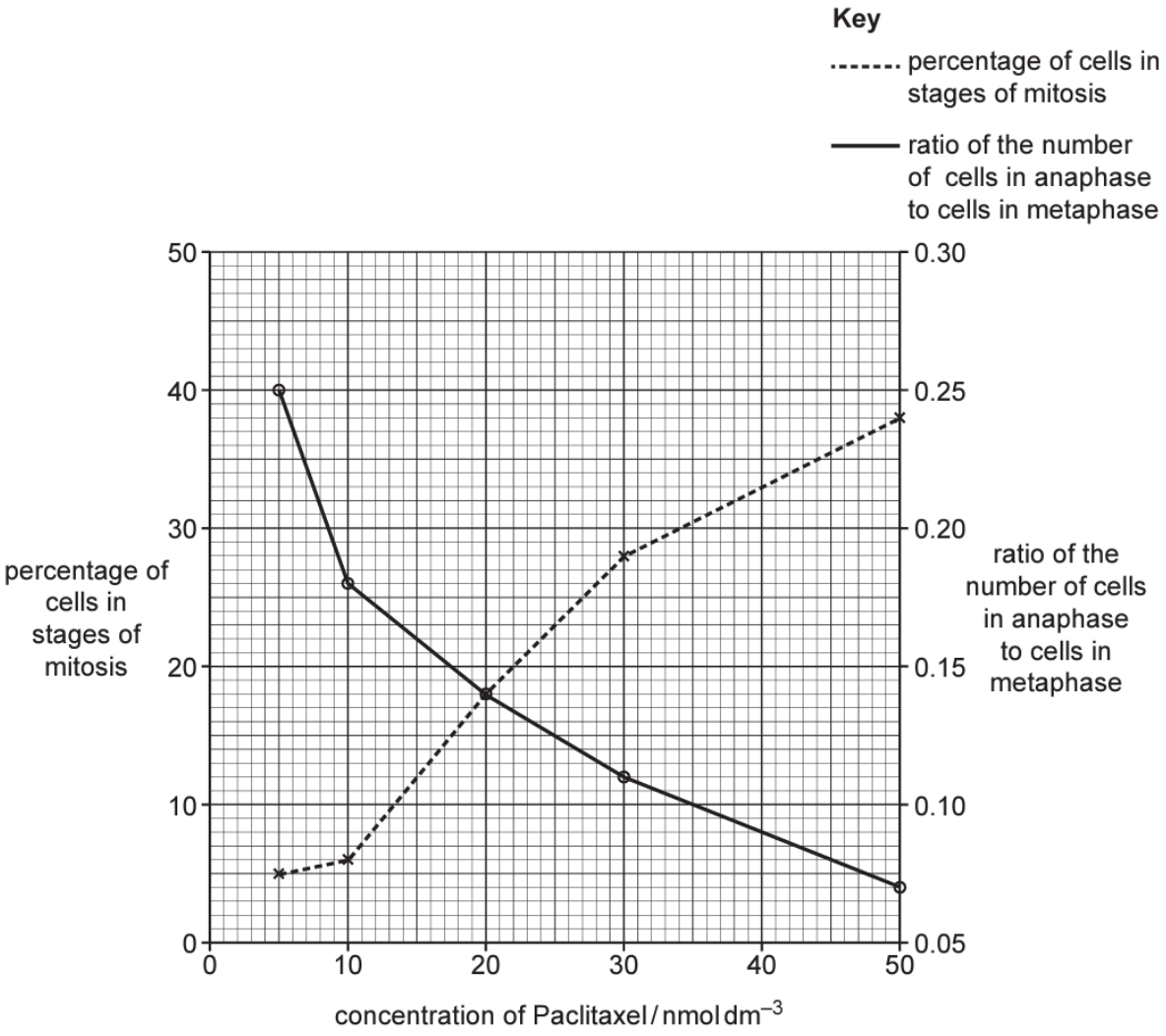

Fig. 3.1

(b) With reference to Fig. 3.1,

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

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

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(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.

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[2]

[Total: 10]

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 role of complementarity in cellular mechanisms. [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]

Civics Group	Index Number	Name (use BLOCK LETTERS)	**H2**

ST. ANDREW'S JUNIOR COLLEGE
2024 JC2 PRELIMINARY EXAMINATIONS

H2 BIOLOGY **9744/03**

Paper 3 Booklet A

Wednesday 11th September 2024 2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagram, graph or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.
Write your answers in the spaces provided on the question paper.

All working for numerical answers must be shown.

Conceptual error (C)	Data Quoting (D)	Expression (E)	Misreading the question (Q)

For Examiners' Use	
1	/30
2	/45
3	
4 or 5	
Total	**/75**

This document (Booklet A) consists of **10** printed pages.

[Turn over]

Answer **all** *questions*.

QUESTION 1

Colorectal cancer is the cancer of the colon and the rectum. Colorectal cancer is Singapore's top killer, affecting more than 1,865 cases each year. Colorectal cancer usually starts as a non-cancerous polyp (a growth of tissue) on the inner lining of the colon or rectum which may develop into cancer over time.

The Wnt signaling pathway is associated with the widest array of biological processes, including cell proliferation, differentiation, and diseases such as neurodevelopmental diseases and cancer.

Fig. 1.1 shows the Wnt signalling pathway. When Wnt signalling pathway is activated by binding of ligand Wnt to the LPR5/6-Frizzled receptor, β-catenin binds to other transcription factors and activate transcription of target genes.

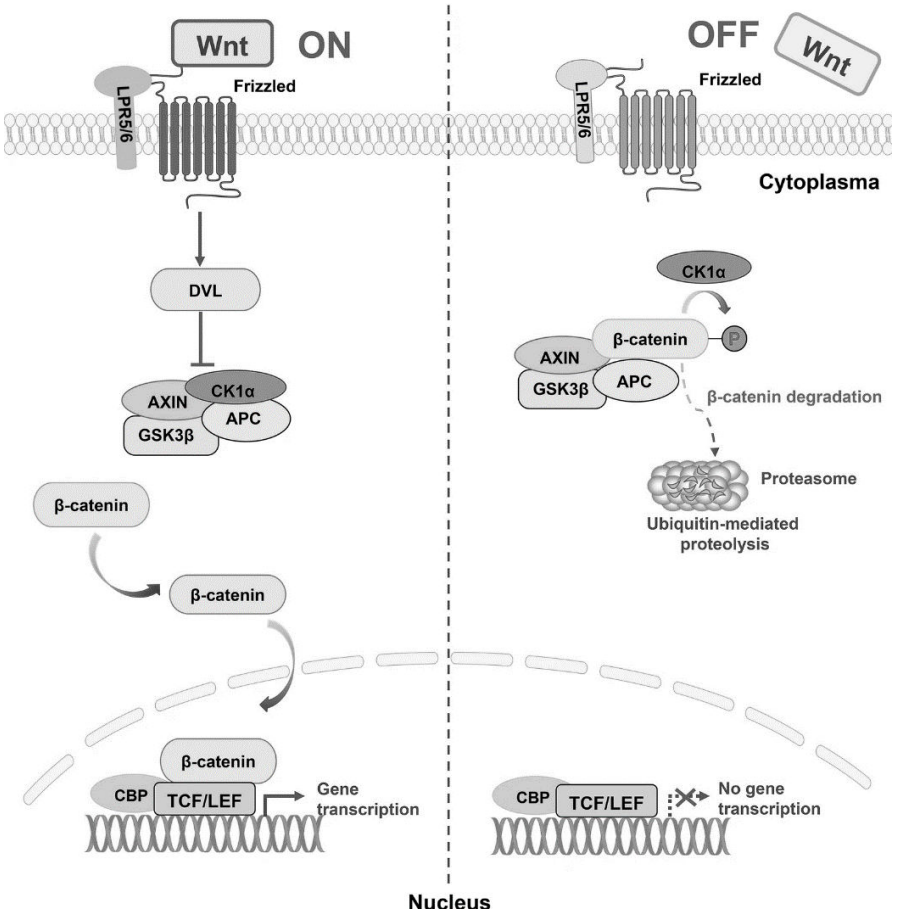

Fig. 1.1

(a) With reference to Fig. 1.1, state the level of gene expression that regulates β-catenin.

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(b) Suggest how β-catenin bind to proteins APC and AXIN when the signalling pathway is inactivated.

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(c) In development of colorectal cancer, APC gene is one of the first mutation that occurs. Using Fig. 1.1 and your knowledge, explain why cancer requires the accumulation of mutation.

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(d) Within the proteasome, β-catenin is digested into amino acids. Using a diagram, show how two amino acids are digested from a dipeptide.

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Fig. 1.2 shows the cell cycle and types of cyclin and CDK that promotes each stage of the cell cycle. Cyclin D is a positive regulator of the cell cycle and promotes G1 to S phase transition when bound to CDK4.

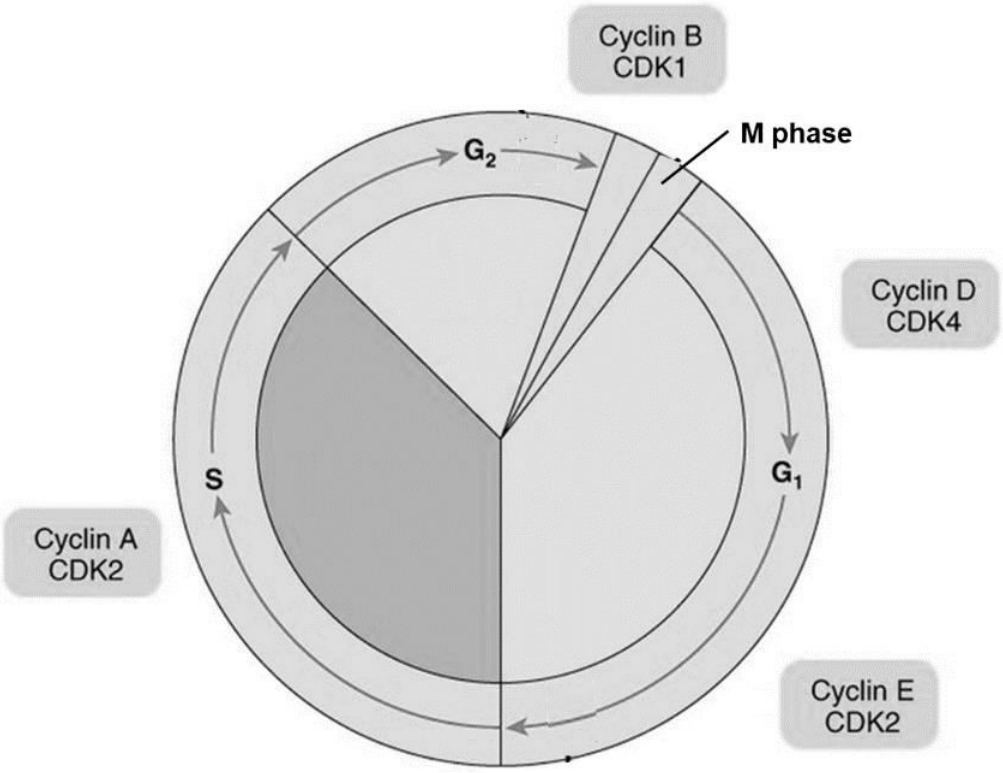

Fig. 1.2

(e) (i) State two events that happens during G1 phase of the cell cycle.

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(ii) With reference to Fig. 1.2 and the information provided, explain how does increase in gene expression of cyclin D increase the risk of cancer development.

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(f) One of the target genes activated by β-catenin is cyclin D. State the type of gene β-catenin is and explain your answer.

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A commonly used therapy for patients diagnosed with an advanced stage of colon cancer is vinblastine, which destabilizes the structures of tubulins in microtubules by binding to them. Fig. 1.3 shows the action of vinblastine.

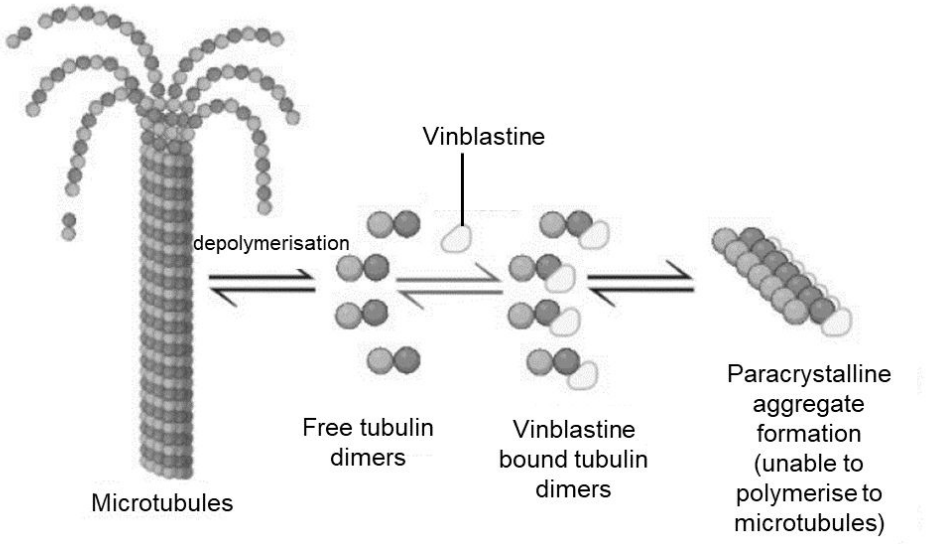

Fig. 1.3

The mechanism of action of vinblastine was investigated over a range of concentrations. The percentage of cells in mitosis and ratio of anaphase to metaphase in cells exposed to this drug *in vitro* for a fixed time were recorded. The data are displayed in Fig. 1.4. The x-axis in both graphs are of unequal intervals to allow the concentrations of vinblastine used to be represented.

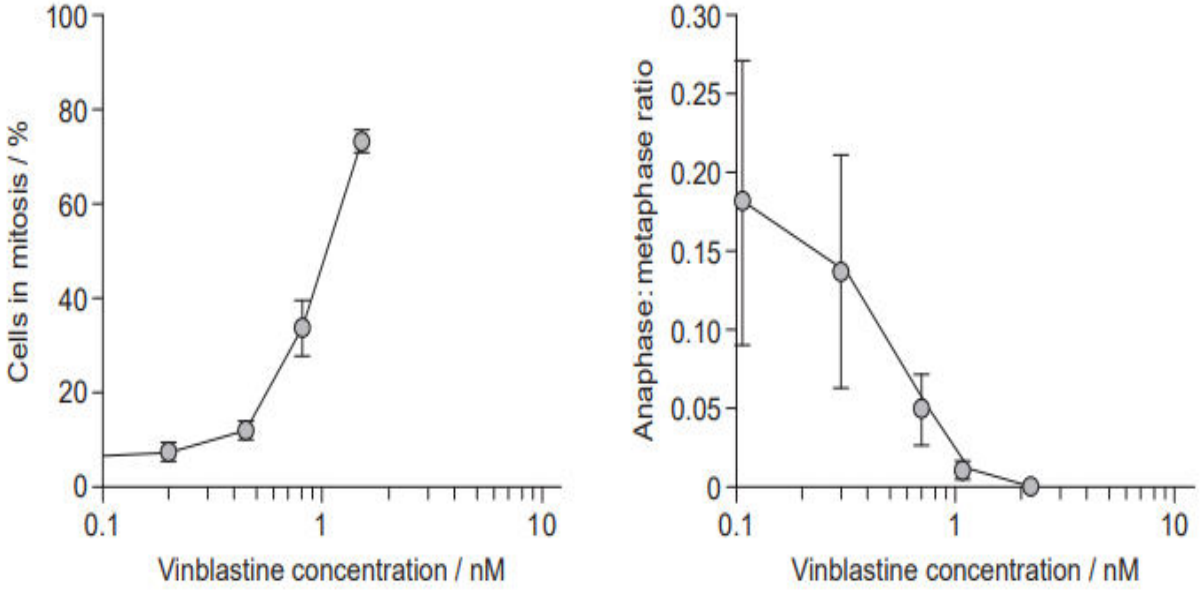

Fig. 1.4

(g) With reference to Fig. 1.3 and Fig. 1.4, explain how vinblastine work as an anti-cancer drug.

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Colon cancer has a high mortality rate as it has a high recurrence rate. Despite recent improvements in treatments, early diagnostic techniques are required. With early detection and diagnosis, prognosis for the disease should improve.

Long non-coding RNAs (lncRNAs) are a class of RNAs whose transcripts are over 200 nucleotides in length, which do not have a protein coding capacity. They are found to have various roles in carcinogenicity and molecular mechanisms. Research has shown that the lncRNA small nucleolar RNA host gene 1 (SNHG1) contributes to the promotion of tumor development.

A group of researchers would like to investigate if SNHG1 is a potential biomarker to be used for early detection of colon cancer. They obtained colon cancer cells and adjacent non-cancerous colon cells from 16 patients. The relative expression of SNHG1 in the cancerous cells (tumour) and normal cells are shown in Fig. 1.5. Each line connects samples taken from the same patient.

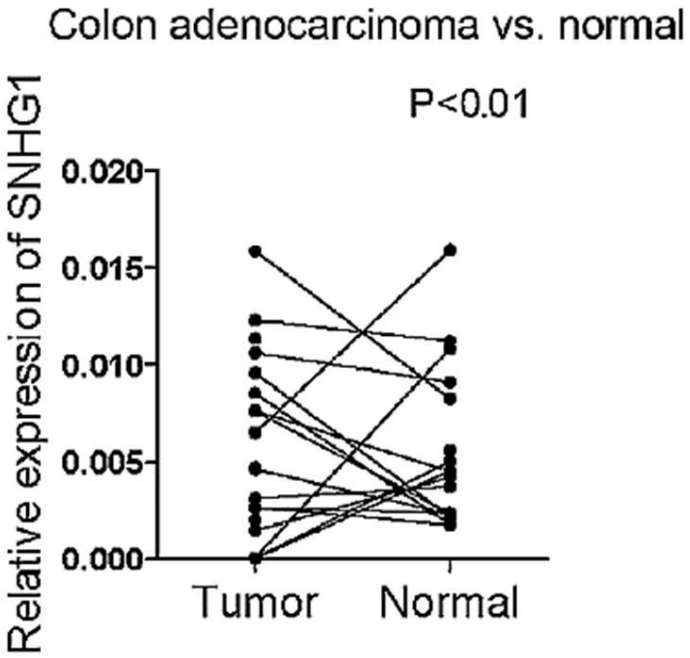

Fig. 1.5

(h) (i) Explain what a line with a positive gradient represents.

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(ii) Based on the results, the researchers concluded that SNHG1 is a suitable biomarker for early detection of colon cancer. Do you agree or disagree with their conclusion? Explain your answer.

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The same group of researchers wanted to find out if SNHG1 promote tumour development via Wnt signalling pathway. They used a colon cancer cell line (HCT-116) and knocked down the expression SNHG1 (i.e., SNHG1 not expressed). Cell line with SNHG1-knock down was labelled as sh-SNHG1. The control had normal expression of SNHG1.

Protein analysis on concentration of β-catenin and cyclin D was carried out in the control and sh-SNHG1 group. Fig. 1.6 shows the results. The darker the band, the higher the concentration of protein present.

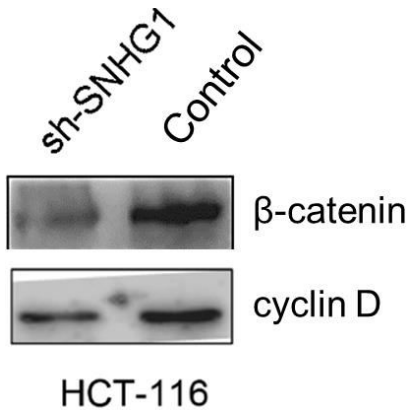

Fig. 1.6

(i) With reference to Fig. 1.6, describe the results and comment if SNHG1 promotes tumour development via the Wnt signalling pathway.

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[Total: 30]