H

RAFFLES INSTITUTION
2024 Year 6 Preliminary Examination

Higher 2

CANDIDATE NAME

CIVICS GROUP | 2 | 4 | S | 0 | 3 | | INDEX NUMBER | | | | | | |

BIOLOGY

9744/03

Paper 3 Long Structured and Free-response Questions

11th Sept 2024

2 hours

Candidates answer on the Question Paper.

Additional Materials: Writing paper.

READ THESE INSTRUCTIONS FIRST

Write your index number, CT group & name in the spaces at the top of this page.
Write in dark blue or black pen.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

Section B
Answer any **one** question in the writing paper provided.

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.

At the end of the examination, **hand in your essay question SEPARATELY.**

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

For Examiner's Use	
Section A	
1	**/ 30**
2	**/ 11**
3	**/ 9**
Section B	
4 or 5	**/ 25**
Total	**/ 75**

This document consists of **19** printed pages.

Raffles Institution
Internal Examination

For Examiner's Use

Section A

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

1 The human papillomavirus (HPV) is sexually transmitted and can cause the development of cervical intraepithelial neoplasia (CIN). Patients with CIN are observed to have abnormal growth of cells that line the cervix. This can lead to the development of cervical cancer.

Fig. 1.1 shows the structure of the HPV.

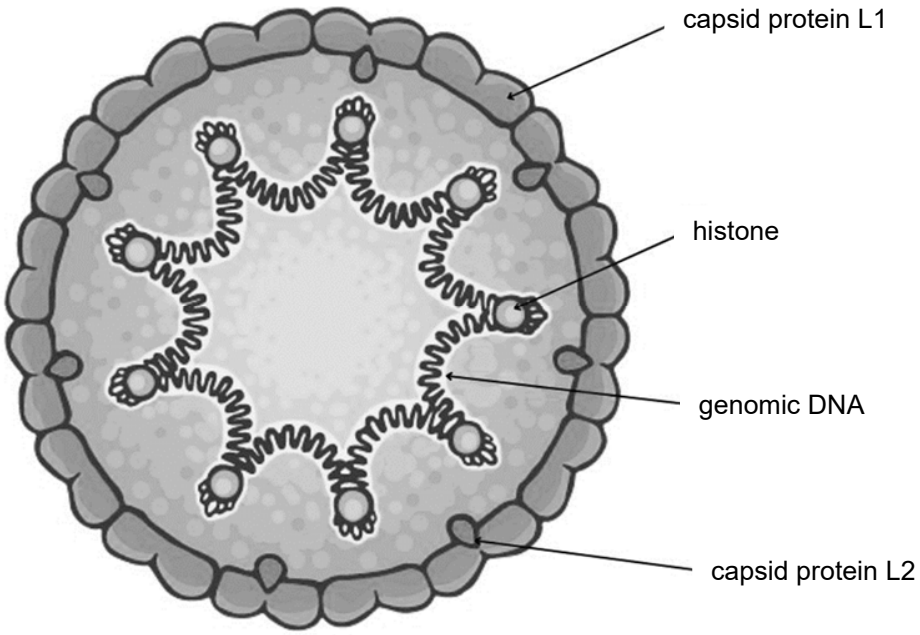

Fig. 1.1

(a) With reference to Fig. 1.1, compare the structure of HPV with a T4 bacteriophage.

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……[3]

For Examiner's Use

A recent study assessed the impact of routine vaccination against HPV on the development of CIN.

Fig. 1.2 shows the effect of HPV vaccination on the percentage of women found to have the most severe grade of CIN by cervical screening over the years.

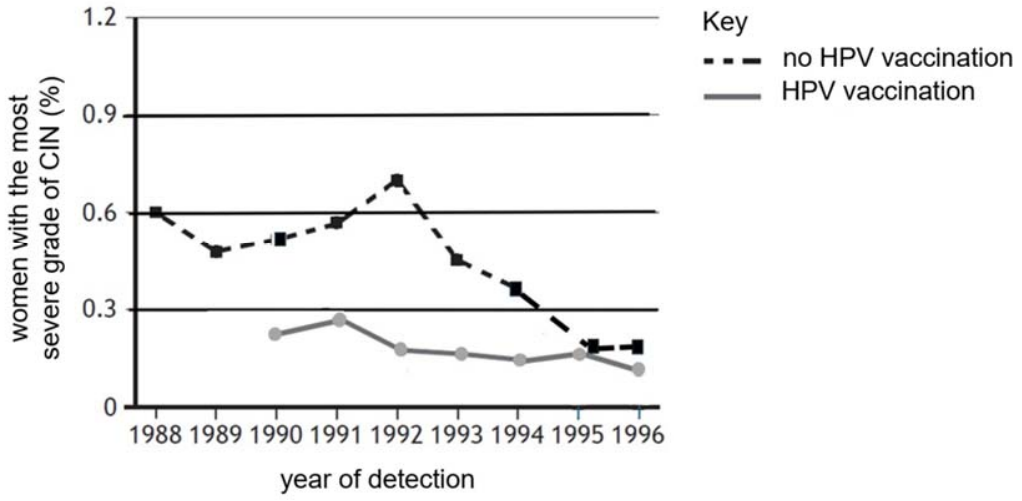

Fig. 1.2

(b) With reference to Fig. 1.2, explain how the data supports the suggestion that vaccination against HPV could lead to herd immunity.

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(c) Fig. 1.3 shows the number of cases of cervical cancer and death rate from cervical cancer in females of different ages in one year.

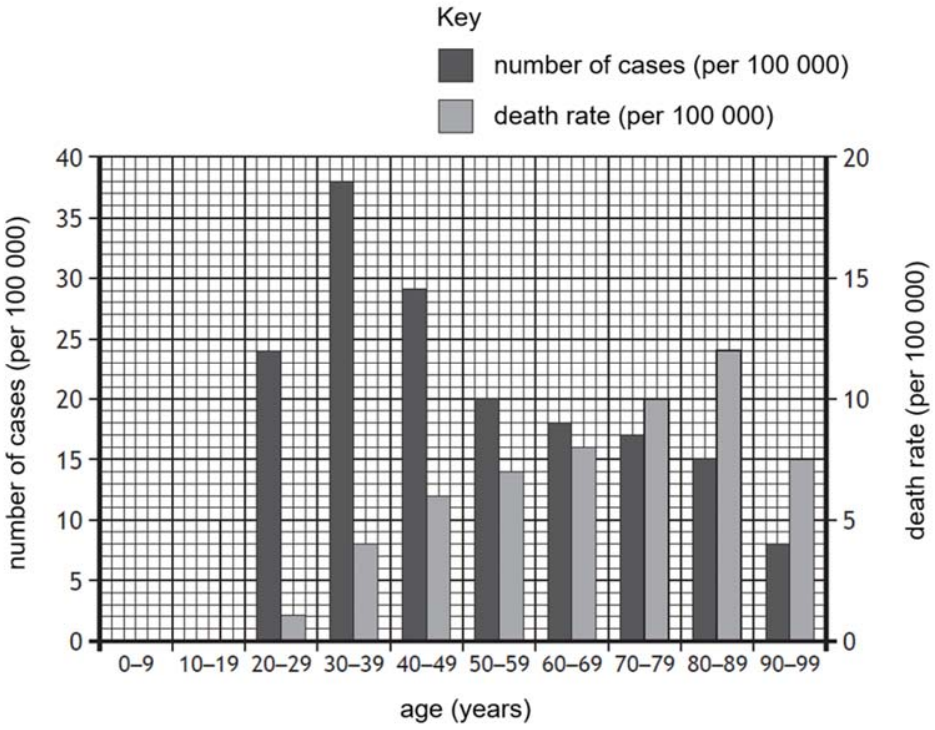

Fig. 1.3

With reference to Fig. 1.3,

(i) describe changes that occur in the number of cases of cervical cancer from the ages of 20–29 to 90–99.

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……[2]

(ii) suggest a reason for the decrease in the death rate from cervical cancer between ages 80–89 and 90–99.

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……[1]

For Examiner's Use

(iii) Express as a simplest whole number ratio, the number of cases compared to death rate at ages 30–39. [1]

_____: _____
number of cases : death rate

(iv) The human papillomavirus (HPV) is commonly associated with cases of cervical cancer. Many countries have a vaccination programme against HPV.

Use information from Fig. 1.3 to suggest why females are given the vaccine in their teenage years.

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……[2]

(v) The HPV vaccination programme is being extended to boys' schools.

Explain the advantages of:

offering the HPV vaccine to boys,

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……[2]

and carrying out the vaccination programme in schools.

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……[1]

(vi) Similar to HPV infections, infections caused by the bacterium, *Chlamydia trachomatis,* are also sexually transmitted.

Explain why the HPV vaccine will not protect girls from *C. trachomatis*.

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……[3]

(d) Like HPV, the human immunodeficiency virus (HIV) may lay dormant in the body for years without causing symptoms.

HIV is an example of a virus that spreads from other animals to humans where it causes disease.

Chimpanzees can carry the simian immunodeficiency virus (SIV), which is similar to HIV. It is thought that chimpanzees who carry antibodies for SIV do not become ill if infected with HIV. This has been investigated by scientists who are developing potential vaccines for HIV.

Tests were carried out to see if antibodies against SIV present in chimpanzees bind to HIV antigens. Test strips which contained several different HIV antigens were prepared.

When samples are applied to the test strip, a line will appear in the control region. If the sample contains antibodies to the HIV antigens present on the strip, additional lines will also appear.

Samples of chimpanzee faeces were collected from a number of sites in Gabon in central Africa. The faecal samples were prepared and then applied to the test strips.

(i) Suggest why the investigators collected faecal samples from chimpanzees rather than blood plasma samples.

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……...[1]

The scientists collected 608 faecal samples from 224 individual chimpanzees.

(ii) Describe how an investigator can prepare the faecal samples before applying them to the test strips.

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……[2]

(e) Samples from humans and chimpanzees were applied to the test strips.

1. Blood plasma samples from humans who are infected with HIV (HIV+)
2. Blood plasma samples from humans who are not infected with HIV (HIV−)
3. Faecal samples from chimpanzees who are infected with SIV (SIV+)
4. Faecal samples from chimpanzees who are not infected with SIV (SIV−)

The results of typical samples from the above four groups are shown in Fig. 1.4.

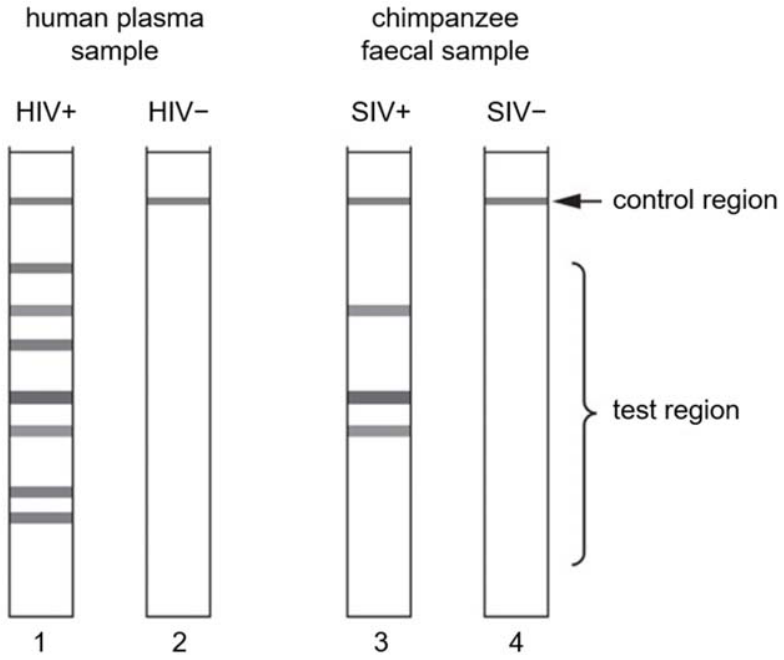

Fig. 1.4

With reference to Fig. 1.4, suggest conclusions that can be drawn about whether SIV antibodies bind to HIV antigens.

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(f) HIV infection may lead to HIV/AIDS which, if left untreated, may cause death. The effects of SIV infection in chimpanzees are usually less severe.

A group of scientists investigated the effect of SIV infection on the life expectancy of a population of chimpanzees living in the wild.

- The population of 94 chimpanzees was observed for a nine-year period.
- The ages of all the chimpanzees in the population were estimated at the start of the nine-year period.
- The chimpanzees were observed each day.
- The numbers of dead and absent chimpanzees were recorded each day.
- A statistical test was also carried out.
- Faecal samples of all the chimpanzees in the population were tested for SIV antibodies.

The results of the investigation, including the *p* value of a statistical test to see if there are differences in the percentage survival between the two groups of chimpanzees, are summarised in Table 1.1.

Table 1.1

SIV status	original number of chimpanzees in population	number of chimpanzees who died	*p* value of a statistical test
SIV–	77	11	0.031
SIV+	17	7	

Fig. 1.5 shows the percentage of chimpanzees of each age remaining in the population.

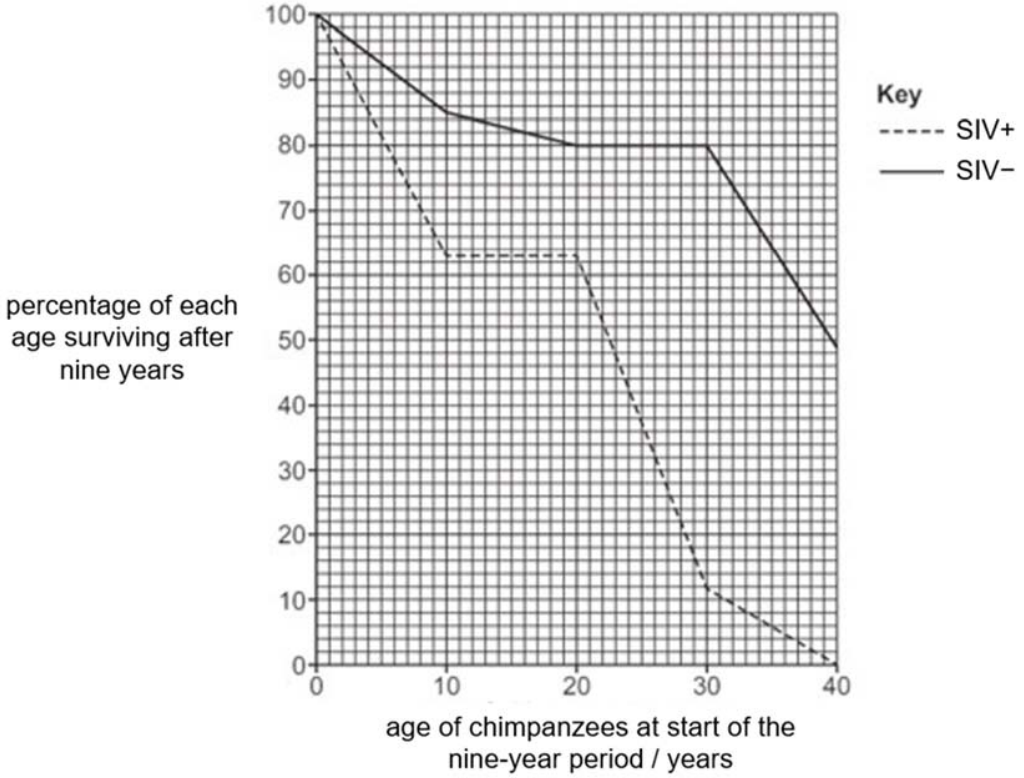

Fig. 1.5

(i) Comment on the results shown in Table 1.1 and Fig. 1.5.

Table 1.1 .....

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Fig. 1.5 .....

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.....[4]

(ii) Clinical trials on HIV vaccination sometimes involve testing the vaccines on chimpanzees.

Discuss the suitability of using chimpanzees for such trials.

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……[2]

[Total: 30]

2 Termites are a group of insects that consume a wide variety of plant material in the form of wood and leaf litter. They are able to breakdown cellulose into hexose and pentose oligomers due to the presence of symbiotic cellulolytic bacteria which produce a variety of cellulases.

(a) One step in the digestion of cellulose involves the cleaving of a cellulose chain to form cellobiose units. The digestion starts from the C4-hydroxyl group of cellulose that is not involved in bond formation. A cellobiose unit is a disaccharide with the formula $(C_6H_7(OH)_4O)_2O$.

The type of cellulase involved is called β–1,4 glucanase.

Show on Fig. 2.1 how the section of cellulose is cleaved to form cellobiose.

Use arrows to indicate the sites of hydrolysis. You do not need to include any monosaccharides that did not form cellobiose.

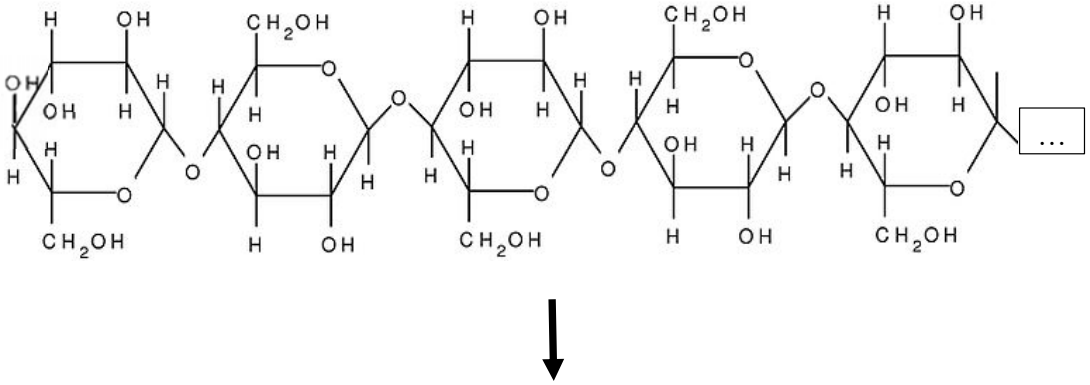

Fig. 2.1

[3]

(b) To identify the region of the gut most heavily populated by cellulolytic bacteria, scientists investigated the amount of cellulose, cellulase activity and glucose content in various locations along the alimentary canal of termites - hepatopancreas (hepatop.), anterior hindgut (ant. hindgut) and posterior hindgut (post. hindgut), including the faeces. They also measured the same variables in the leaf litter consumed by the termites.

The results of the study are shown in Fig. 2.2. The mean amount of cellulose, cellulase activity and glucose content are shown as the middle line of the boxplots.

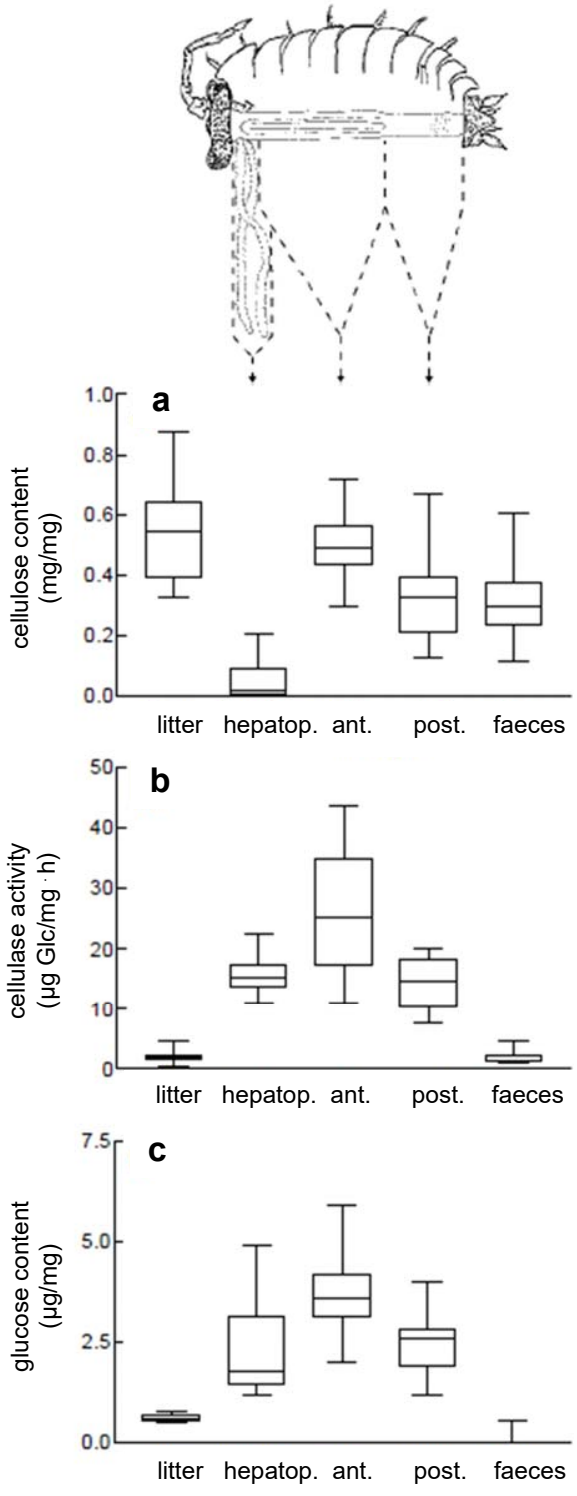
a
cellulose content (mg/mg)
1.0
0.8
0.6
0.4
0.2
0.0
litter
hepatop.
ant.
post.
faeces
b
cellulase activity (µg Glc/mg · h)
50
40
30
20
10
0
litter
hepatop.
ant.
post.
faeces
c
glucose content (µg/mg)
7.5
5.0
2.5
0.0
litter
hepatop.
ant.
post.
faeces

Fig. 2.2

With reference to Fig. 2.2,

(i) suggest where majority of the cellulolytic bacteria were found;

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(ii) suggest why there was very little to no glucose found in the faeces of the termites;

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……..[1]

(iii) explain why leaf litter was included in this study.

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……..[1]

(c) Termites are also known to produce methane as a by-product in the process of breaking down cellulose. The global methane emission from this source is estimated to be 20 million tonnes each year.

Explain how termites can worsen the effects of climate change as global temperature increases.

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……[3]

[Total: 11]

For Examiner's Use

3 The method for producing seedless watermelons was developed by Professor H. Kihara, a Japanese scientist at Kyoto University in 1939. His methods yielded commercially available seedless watermelons in 1951.

Production of viable triploid (3n = 33) watermelon seeds using colchicine, a chemical that is used to induce polyploidy in plants, is shown in Fig. 3.1. Colchicine works by interfering with mitosis, preventing the proper assembly of microtubules in the mitotic spindle.

Colchicine is first applied to diploid (2n = 22 chromosomes) watermelon seedlings to obtain tetraploid (4n = 44 chromosomes) plantlets. Tetraploid female plants are then crossed with normal diploid male plants to obtain triploid seeds.

Seedless watermelon fruits are stimulated to form when haploid (n = 11) pollen from normal diploid male plants pollinate female flowers from triploid plants.

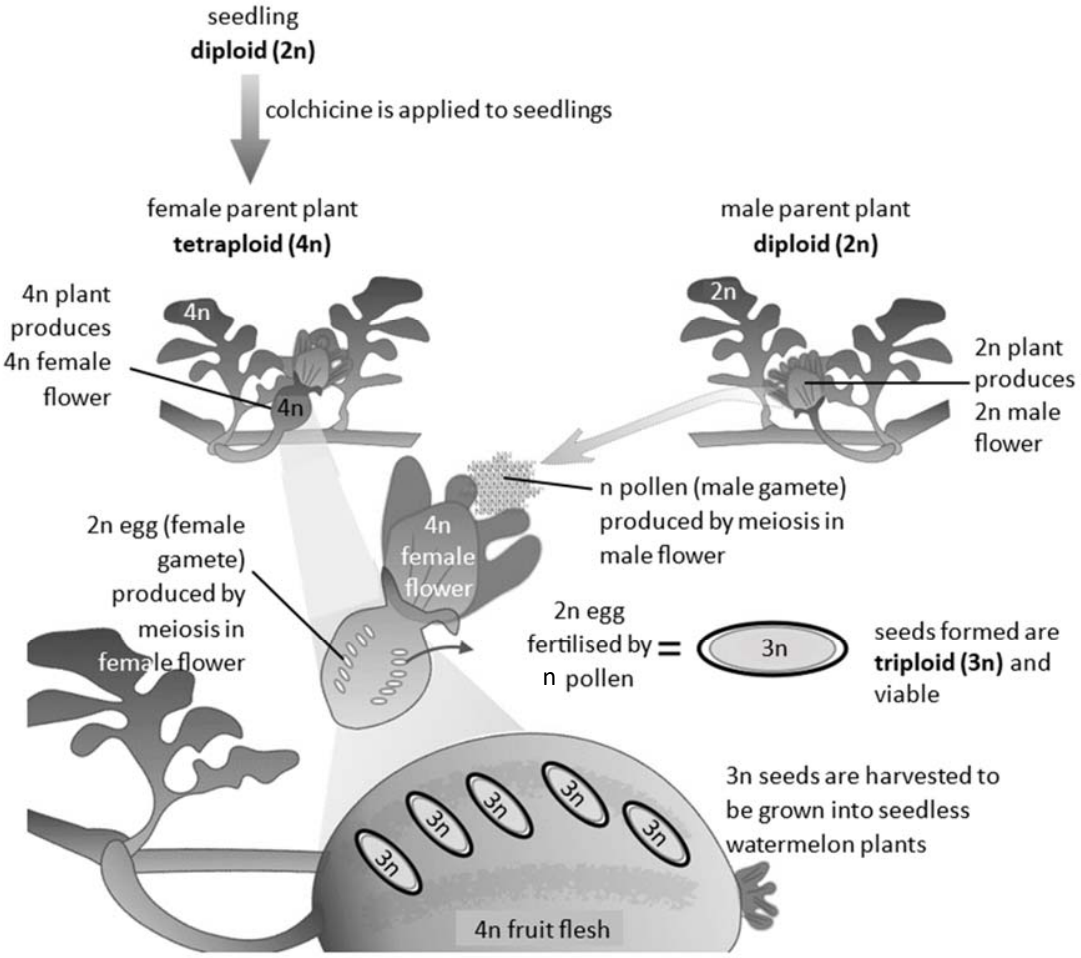

Fig. 3.1

The triploid seeds produced in the process shown in Fig. 3.1 are then grown into adult plants that will form seedless watermelon.

(a) (i) Explain how application of colchicine to diploid (2n = 22 chromosomes) watermelon seedlings resulted in formation of tetraploid (4n = 44 chromosomes) plants as seen in Fig. 3.1.

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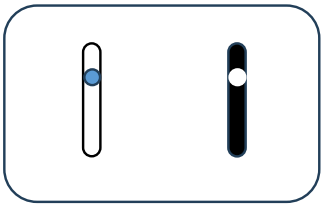
……[3]

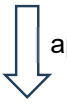
For Examiner's Use

(ii) Using  to represent one chromosome in a haploid set of chromosomes, fill up the cell diagrams in Fig. 3.2 to show how application of colchicine to diploid (2n = 22 chromosomes) watermelon seedlings resulted in formation of tetraploid (4n = 44 chromosomes) plantlets. Do note that only one cell of each plant is shown.



A diploid (2n) cell from the seedling before cell division

A diploid (2n) cell from the seedling at prophase



application of colchicine

A tetraploid (4n) cell from the plantlet

Fig. 3.2

[2]

(iii) Explain why gametes fail to form in the triploid (3n = 33) female flower.

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……..[1]

(b) The identification of tetraploids can be based on stomatal density. Stomata density is not influenced by external factors such as temperature and water content of the plant tissue. Stomata counting is a suitable, easy and reliable method because their numbers in many plantlets can easily be estimated relatively quickly and easily.

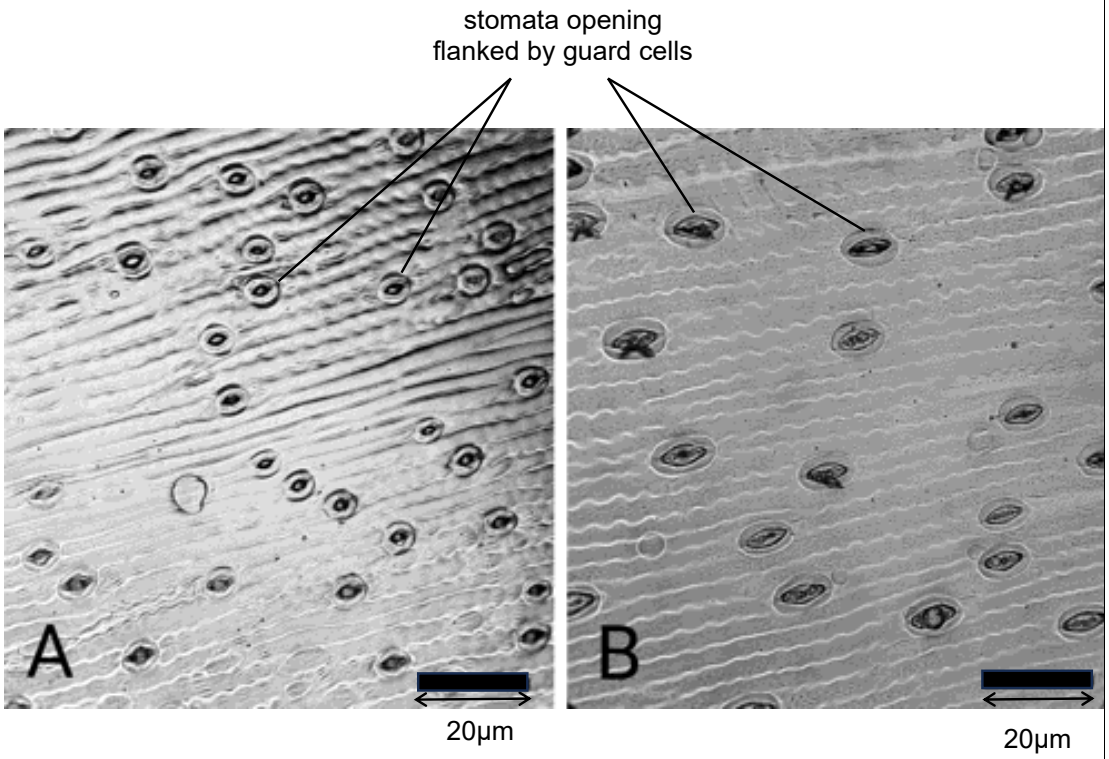

Fig. 3.3

The imprints of the diploid (2n) and tetraploid (4n) leaves shown in Fig. 3.3 were produced by applying nail varnish to the bottom side of the leaf. The dry nail varnish showing the difference in stomata density between the leaves A and B were then peeled off and viewed under the microscope.

Stomata density is known to be lower in tetraploid (4n) leaf than diploid (2n) leaf.

Using the information in Fig. 3.3 and counting only whole stomata,

(i) calculate the stomata density in Fig. 3.3, A and B, and conclude which is the tetraploid (4n) leaf.

Tetraploid (4n) leaf: ……..[3]

[Total: 9]

For Examiner's Use

Section B

Answer **one** question in this section.

Write your answers on the separate answer paper 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)** and **(b)**, as indicated in the question.

4 **(a)** Explain why the offspring produced by the same parents are different in appearance. [15]

(b) In normal cellular respiration, glucose is used in aerobic respiration in the presence of oxygen to produce energy. However, in cancer cells, it is observed that even in the presence of oxygen, there is an increased glucose uptake and lactic acid production.

Despite being a less efficient process in energy production compared to aerobic respiration, cancer cells are still able to produce the same amount of energy in the same amount of time via this method.

Describe this method of energy production in cancer cells and suggest how it may be beneficial to cancer cells. [10]

[Total: 25]

5 **(a)** Molecular techniques are used to detect genetic diseases, where some of the steps involve the concept of "complementarity".

With reference to the mutation that causes sickle cell anaemia, outline the molecular techniques used to determine the genotype of an unaffected individual and explain the role of "complementarity" in specific steps of the molecular techniques used. [15]

(b) Discuss how the fluidity of membranes is important to allow for different types of transport across membranes. [10]

[Total: 25]

End of Paper