Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

S24-A400U20-1

A400U20-1

FRIDAY, 14 JUNE 2024 – MORNING

BIOLOGY – A level component 2
Continuity of Life

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**18**	
2.	**15**	
3.	**11**	
4.	**14**	
5.	**11**	
6.	**22**	
7.	**9**	
Total	**100**	

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ADDITIONAL MATERIALS

A calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

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

The assessment of the quality of extended response (QER) will take place in question **7**.

The quality of written communication will affect the awarding of marks.

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Answer **all** questions.

1. (a) The placenta is the site of exchange between maternal and foetal blood. **Image 1.1** shows a section of the human placenta.

Image 1.1

(i) During pregnancy, the placenta secretes the hormone oestrogen. State **two** effects of oestrogen on the mother's body. [2]

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During human placental development, maternal uterus capillaries are lost and large spaces containing blood are formed (labelled **X** on **Image 1.1**).

(ii) Suggest how this adaptation improves exchange in the placenta. [2]

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(b) Gestational age (age of the developing foetus) is measured in weeks, from the first day of the woman's last menstrual cycle to the current date. A normal pregnancy can range from 38 to 42 weeks. Pregnancy is divided into three trimesters, each lasting for approximately three months.

A study of 730 pregnant women was carried out to investigate placental thickness as a way of estimating gestational age.

Tables 1.2A, 1.2B and **1.2C** show the results of the study.

Table 1.2A First trimester

Gestational age / weeks	Number of cases	Mean placental thickness / mm	Standard deviation
7	3	9.6	±1.9
8	7	9.0	±1.0
9	17	10.9	±1.7
10	9	10.0	±1.2
11	6	11.0	±0.9
12	13	15.3	±3.1
13	9	18.0	±3.0

First trimester mean placental thickness = 12.5 mm ±3.7 mm

Table 1.2B Second trimester

Gestational age / weeks	Number of cases	Mean placental thickness / mm	Standard deviation
14	3	18.3	±1.2
15	23	18.7	±3.7
16	27	22.0	±2.9
17	15	21.2	±3.4
18	15	23.7	±2.6
19	23	23.7	±4.3
20	17	25.4	±4.3
21	24	27.2	±4.9
22	16	28.6	±4.5
23	20	27.3	±3.3
24	12	28.9	±5.1
25	17	27.4	±5.2
26	25	32.5	±4.9

Second trimester mean placental thickness = 25.2 mm ±5.6 mm

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Table 1.2C Third trimester

Gestational age / weeks	Number of cases	Mean placental thickness / mm	Standard deviation
27	24	31.4	±4.5
28	28	32.0	±4.4
29	28	33.8	±4.4
30	21	36.0	±5.4
31	31	36.8	±4.7
32	48	36.0	±5.6
33	27	37.0	±7.0
34	28	37.3	±4.0
35	37	41.1	±7.6
36	33	39.3	±7.1
37	31	46.5	±5.6
38	33	42.5	±5.8
39	31	45.1	±6.4
40	14	43.0	±5.3
41	15	43.4	±8.3

Third trimester mean placental thickness = 38.4 mm ±7.1 mm

The placental thickness data also shows the standard deviation of the sample.

(i) State what standard deviation measures. [1]

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(ii) Explain why standard deviation is used rather than the range. [1]

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The dimensions of the placenta can be found using scans.

(iii) The volume of a placenta was found to be 1227 cm^3, with a diameter of 25 cm.

I. Use the following formula to find the thickness of the placenta.
Assume the placenta is the same thickness across its diameter.
Show your working. [3]

Volume = $\pi r^2 h$
Where r = radius of placenta
h = thickness of placenta
π = 3.14

Thickness of placenta = ... cm

II. Use your result from I. and **Tables 1.2A**, **1.2B** and **1.2C** to conclude the trimester of pregnancy. [1]

Trimester of pregnancy = ...

(iv) It was concluded that using placental thickness is an accurate way of predicting the trimester but not the gestational age in weeks of a foetus.
Use the information in **Tables 1.2A**, **1.2B** and **1.2C** to evaluate this conclusion. [3]

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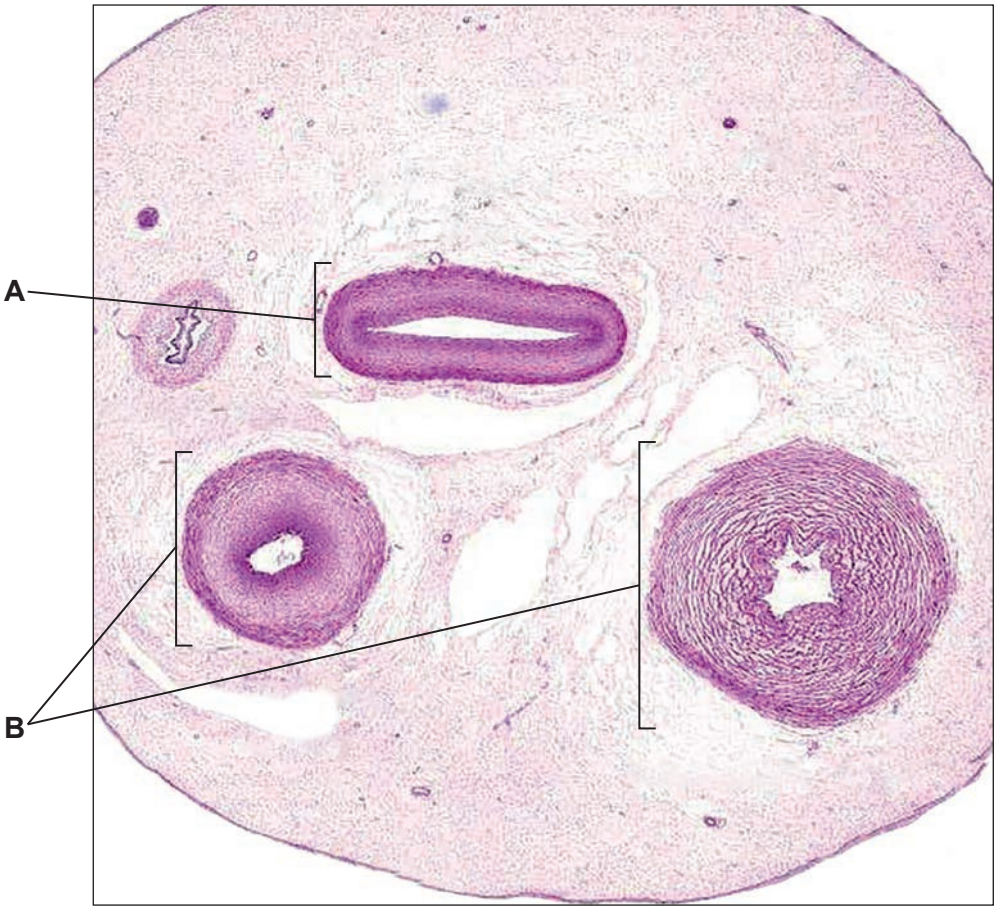
(c) **Image 1.3** shows a cross-section through the umbilical cord. Three blood vessels are labelled. The blood vessels labelled **B** are the same type of blood vessel.

Image 1.3



(i) Identify the type of blood vessels labelled **A** and **B**. [1]

A .....

B .....

(ii) Using the letters **A** or **B**, complete **Table 1.4** by identifying which blood vessel has the higher concentration of the following molecules. [1]

Table 1.4

Molecules	Blood vessel **A** or **B**
oxygen and glucose	
urea	

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(d) During and after birth, the mother's posterior pituitary gland releases the hormones oxytocin and prolactin.

State the effects of:

(i) oxytocin during birth; [1]

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(ii) prolactin after birth. [1]

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(e) After the baby is born, the placenta and the umbilical cord can be used as a source of stem cells. These may be used for replacing damaged tissues and organs when the baby grows older.
It is better to take the baby's stem cells from the umbilical cord rather than the placenta.
Suggest the reason for this. [1]

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2. The Human Genome Project set out to sequence the 3 billion base pairs that make up human DNA and to identify all the genes in the human chromosomes. The project was set up in 1990 and involved scientists working in 18 different countries.

DNA samples were collected from a group of volunteers. The samples had their identification removed.

(a) (i) Suggest why it was important to the **volunteers** that the DNA samples had their identification removed. [2]

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(ii) Suggest **two** ways in which the Human Genome Project may lead to improved treatments for genetic medical conditions. [2]

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(b) DNA base sequencing has also been completed for other organisms to determine evolutionary relatedness. The base sequences coding for some of their proteins have been completed, including haemoglobin.

Haemoglobin is a globular protein with a quaternary structure that transports oxygen around the body of many animals.

(i) Explain the meaning of quaternary structure. [1]

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Beta-globin (β-globin) is one of the sub-units found in the haemoglobin molecule. It is coded for by the β-globin gene.

A comparison of the following sequences was made between human, rabbit, mouse and chimpanzee:

- DNA base sequence of the exons of the β-globin gene
- DNA base sequence of the introns of the β-globin gene
- Amino acid sequence of the β-globin sub-unit.

The results are shown in **Table 2**.

Table 2

β-globin sequences being compared	Sequence similarity / %		
	Bases of exons	Bases of introns	Amino acids
human / chimpanzee	100.0	98.4	100.0
human / rabbit	89.3	67.0	90.4
human / mouse	82.1	61.0	80.1

(ii) I. With the human and chimpanzee comparison, the amino acid sequence is identical but the base sequence of the intron is different.

Mutations in the base sequences of the introns do not affect the amino acid sequence. Explain why. [1]

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II. The base sequence of the exons can be different but still code for the same amino acid sequence. Explain why. [1]

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(c) ATP is the universal energy currency. Cytochrome c is a protein involved in the electron transport chain in ATP production. Cytochrome c consists of 104 amino acids.

(i) Calculate the minimum number of nucleotides needed to code for cytochrome c. [1]

Minimum number of nucleotides = ...

(ii) Cytochrome c is more useful than haemoglobin for studying how closely related different organisms are. Suggest **one** reason for this. [1]

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(d) Double-stranded DNA can be taken from different species. The molecules are heated to make the DNA single-stranded.

(i) Explain how heating results in single-stranded DNA. [1]

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Single-stranded DNA from one species is then mixed with single-stranded DNA from another species. These are allowed to bond together and form hybrid DNA molecules. The temperatures at which the hybrid DNA can be separated again into single strands (separation temperature) can give an indication of evolutionary relatedness.

(ii) Biologists formed hybrid DNA from a human and a chimpanzee and from a human and an orangutan.
Suggest why hybrid human / chimpanzee DNA separated at higher temperatures than hybrid human / orangutan DNA. [3]

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(iii) Hybrid DNA molecules were formed from single strands of DNA from several individuals of the **same** species. There were differences in the separation temperatures of the different hybrid DNA molecules, even though they were from the same species.
Explain a reason for this. [1]

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(e) When DNA is extracted from plant cells the enzyme cellulase may need to be added.
Explain why cellulase is not needed when extracting DNA from human cells. [1]

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3. Glucose-6-phosphate dehydrogenase (G6PD) is an enzyme found in all cells of the body. It is involved in converting glucose to pentose sugars. During this reaction a co-enzyme is produced that protects the cell membrane from oxidative damage.

This co-enzyme is also produced in oxidative phosphorylation.

(a) (i) Red blood cells do not contain mitochondria. Use all the information given to conclude why red blood cells are at greater risk of membrane damage than other body cells. [2]

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(ii) State the name of **two** nucleotides that contain pentose sugar. [1]

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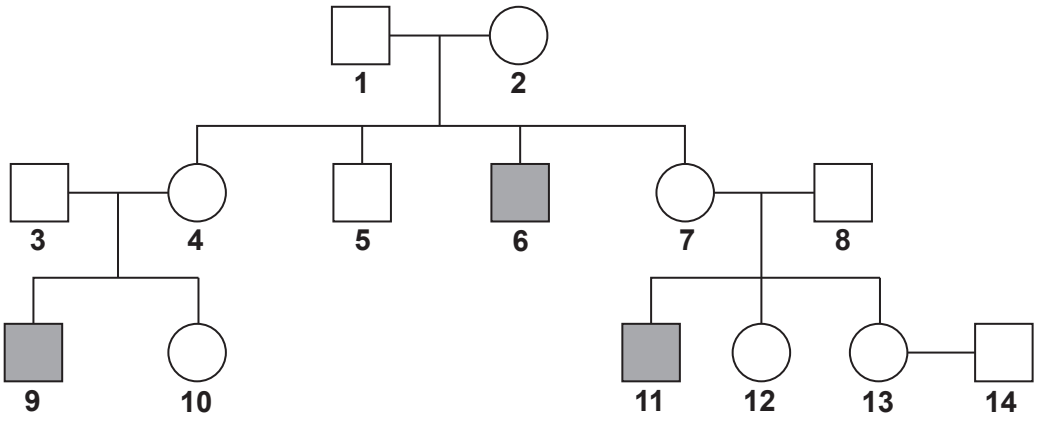
(b) G6PD deficiency is a hereditary condition in which red blood cells break down when the body is exposed to certain foods, drugs, infections or stress. The gene coding for G6PD is found on the X chromosome.

Image 3 shows the inheritance of G6PD deficiency in one family.

Image 3



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(i) State **two** factors that affect an organism's phenotype. [2]

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(ii) G6PD deficiency is caused by a recessive allele.
Explain this statement. Use a suitable example from **Image 3** to support your answer. [2]

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The following symbols represent the chromosomes and alleles carried by individuals in **Image 3**.

$\mathbf{X^G}$ = an X chromosome carrying the unaffected allele
$\mathbf{X^g}$ = an X chromosome carrying the allele for G6PD deficiency
Y = a Y chromosome

(iii) Using these symbols, state **all** the possible genotypes for the following individuals in **Image 3**. [3]

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5 .....

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10 .....

(iv) A genetic screening test shows that individual **13** is a carrier of the allele for the G6PD deficiency.

Determine the probability that a child of individuals **13** and **14** will be a male with G6PD deficiency. [1]

Probability = ...

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4. **Images 4.1A** and **4.1B** show two forms of the same species of Mexican tetra fish (*Astyanax mexicanus*).

Image 4.1A

surface form

Image 4.1B

cave form

The surface form is found in streams open to the sky.
The cave form is blind and found in streams inside caves.

Scientists collected fish of both forms.

(a) A **surface form** fish was bred with a **cave form** fish and offspring were produced. Describe the next steps that would need to be taken to show the two forms were from the same species. Explain your answer. [2]

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(b) The energetic cost of tissues can be measured as the oxygen demand per gram of tissue per hour ($mg\,O_2\,g^{-1}hour^{-1}$).

The scientists investigated the energetic cost of vision in Mexican tetra fish. Eight fish of each form were studied. The oxygen demand for the whole body and for the eyes was calculated.

The results for the **surface form** are shown in **Table 4.2**.

Table 4.2

	Oxygen demand per g of fish / $mg\,O_2\,g^{-1}\,hour^{-1}$								
	Fish 1	Fish 2	Fish 3	Fish 4	Fish 5	Fish 6	Fish 7	Fish 8	Mean
whole body	0.844	0.852	0.861	0.841	0.839	0.848	0.850	0.840	.....
eyes	0.102	0.095	0.104	0.083	0.084	0.101	0.103	0.098	0.096

(i) Calculate the mean whole body oxygen demand per g of fish.

Write your answer in the space in Table 4.2. [2]

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(ii) Explain why the units for oxygen demand are given per gram of fish. [1]

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The oxygen demand shows that the eyes in the surface form use approximately 11% of the total energy of the whole body.

The percentage of oxygen demand for the eyes of the **cave form** was zero.

(iii) Suggest the advantage of the difference in energetic cost for eyes for the **cave form**. [2]

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It has been suggested that the two forms of fish will eventually become separate species due to allopatric speciation.

(iv) Explain what is meant by allopatric speciation. [2]

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It had been suggested that the **cave form** may have developed due to a small population undergoing genetic drift.

(v) Explain why genetic drift has a bigger impact on small populations. [2]

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(c) A group of scientists recently studied the genomes of the two forms of fish.

The scientists found the two forms of fish had very similar genomes but there were much higher levels of methylation in the **cave form** when compared with the **surface form**.

Methylation is the addition of methyl groups to bases.

Suggest what these findings may show about the effect of the levels of methylation present in the DNA of the **cave form**. Explain your answer. [3]

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5. Black wattle (*Acacia mearnsii*) is a plant that lives in dry environments that are subjected to forest fires. Black wattle seeds have elaiosomes. These are structures containing lipids and proteins. The seeds are shown in **Image 5**.

Image 5

(a) It has been found that there are more saturated fatty acids than unsaturated fatty acids in the elaiosomes.

(i) State **one** difference between saturated and unsaturated fatty acids. [1]

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(ii) Describe a chemical test to show the presence of protein in the elaiosome. [1]

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(b) The elaiosome attracts ants. The seeds are taken into the ants' underground nest and the elaiosomes are fed to the ants' larvae while the seeds are discarded.

Explain how the presence of the elaiosome is an advantage to the black wattle plant. [2]

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(c) When a forest fire occurs, the heat stimulates the black wattle seeds to germinate. The heat results in the rapid expansion of the seed coat, causing it to crack.

(i) Explain **one** way that the cracking of the seed coat allows the seed to begin to germinate. [2]

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(ii) Suggest **two** advantages to plants that grow from seeds after a forest fire. [2]

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(d) When areas of forest are burned, nitrogen oxides are released into the air in the smoke. These dissolve in rainwater to produce nitrites.

After a forest fire, lakes and rivers close to the fire experience a sudden growth in the production of microscopic algae.

Use the information to explain the sudden growth of microscopic algae. [3]

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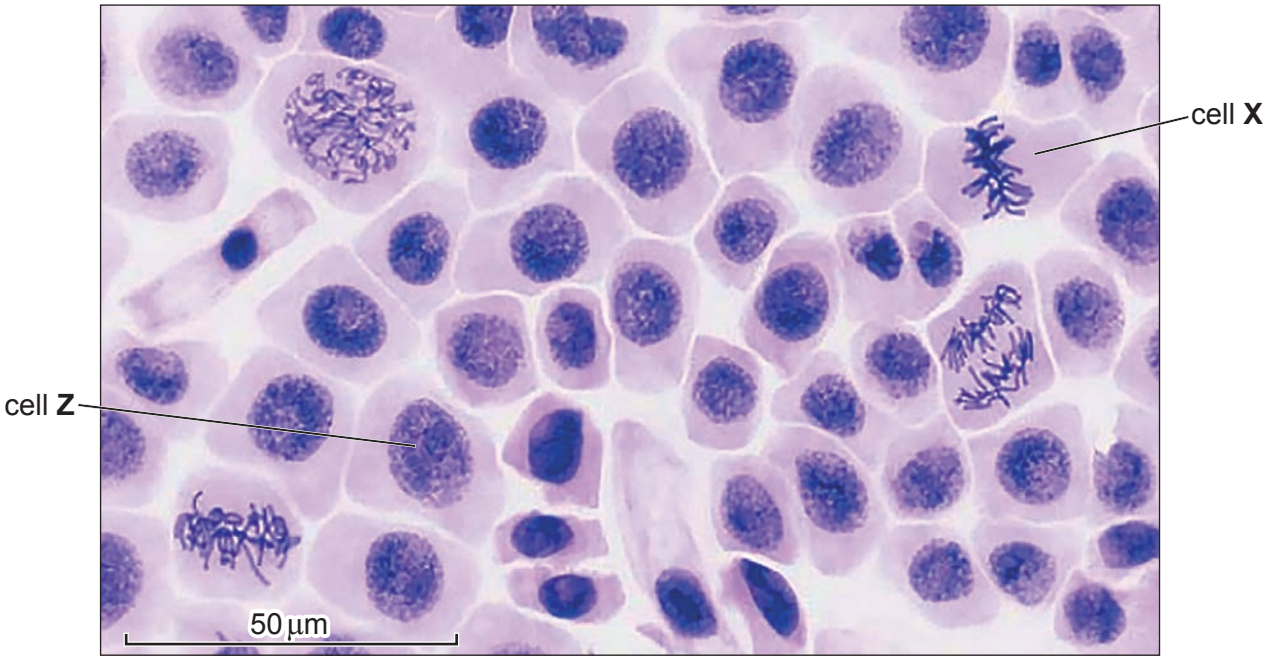
6. Mast cell tumours (MCTs) are a type of cancer found in the skin of dogs.

(a) A sample of the tumour can be removed and stained to allow the DNA in the cells to be seen using a light microscope.

Image 6.1 shows a sample of an MCT taken from the skin of a dog.

Image 6.1



(i) Name the phase of mitosis shown by cell **X**. [1]

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(ii) Cell **Z** is in interphase.
State **three** events that must occur during interphase before mitosis can take place. [3]

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(b) A group of vets gathered data from 160 dogs with MCTs.

The MCTs were classified as one of three different grades, which have different effects on the survival of dogs. These are shown in **Table 6.2**.

Table 6.2

MCT grade	Effect of MCT
I	long term survival and most were cured with surgical removal
II	may survive a long time but the tumour could potentially start growing faster and spread throughout the body
III	median survival time of 6 months as they are faster-growing tumours

It has been proposed that MCTs could be classified according to the number of cells in different stages of mitosis. This is done by examining samples of tumour tissues under a light microscope.

(i) Describe and explain what should have been done when counting cells to make sure that the data obtained for each sample was reliable and accurate. [4]

Reliable:

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Accurate:

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Table 6.3 shows the data for a tissue sample from a grade I MCT.

Table 6.3

Stage of cell cycle	Number of cells in stage
interphase	497
prophase	12
metaphase	6
anaphase	3
telophase	4

The mitotic index (MI) is a measure of the growth activity of a tissue. The mitotic index of a sample can be calculated using the formula:

$$\text{Mitotic Index} = \frac{\text{number of cells in mitosis} \times 100}{\text{total number of cells}}$$

(ii) Calculate the mitotic index of the tumour sample in **Table 6.3** to **two decimal places**. Show your working. [2]

MI = ...

(iii) Using the information given, explain why a tissue sample from a grade III MCT would have a higher mitotic index. [1]

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(iv) Apart from the grade of MCT, suggest **three** other factors that could have led to a variety of survival times for the dogs studied. [3]

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(c) (i) To predict the increase in the number of cancer cells over time, the following equation can be used:

$$N_t = N_c e^{rt}$$

Where:

N_t = number of cancer cells after a given time

N_c = number of cancer cells at the start

e = 2.72 (base of natural log)

r = growth rate

t = time period in hours over which r applies

A group of 150 cancer cells were grown on nutrient gel in a Petri dish.

Use the equation above to calculate the predicted number of cancer cells that would be present after 24 hours if the growth rate is 0.05 (5%). [2]

Predicted number of cancer cells = ...

(ii) If the 150 cancer cells were part of a mast cell tumour in a dog rather than on nutrient gel the actual number of cancer cells after 24 hours may be less than predicted in (c)(i).

Suggest **one** explanation for this. [1]

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(d) It has been suggested that the rate of mitosis in a tumour could be estimated by measuring the uptake of radioactive thymine. A sample of the tumour is added to a nutrient solution containing radioactive thymine. After three days the tumour is removed and the level of radioactivity of the tumour is measured.

(i) Use the information given and **Table 6.2** to explain why grade II tumours would have a higher level of radioactivity than grade I tumours after being removed from the nutrient solution. [2]

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(ii) Explain why **radioactive thymine** would be used to measure the rate of mitosis and **not radioactive guanine**. [2]

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(e) Suggest **one** reason why the mitotic index method of estimating the rate of mitosis would be preferred by vets rather than the radioactive thymine method. [1]

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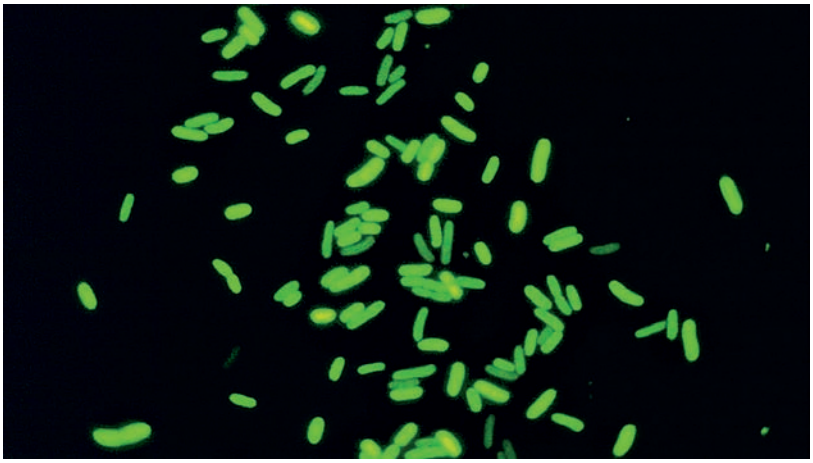
7. Bioluminescence is the natural ability to produce light through a chemical reaction. This property is possessed by certain marine animals, such as jellyfish. *Aequorea victoria* is a jellyfish that produces a protein called green fluorescent protein (GFP) that confers the ability to glow. These are shown in **Image 7.1A**.

The gene for GFP was taken from the jellyfish and introduced into different organisms leading to the development of genetically engineered glow-in-the-dark organisms such as bacteria. These are shown in **Image 7.1B**.

Image 7.1A

Jellyfish

Image 7.1B



Bacteria

Bacteria can be genetically modified to contain functioning human genes. Previously, genetic modification of bacteria has relied on the introduction of antibiotic resistance marker genes. These identify genetically modified cells that contain a functioning human gene. The use of the GFP gene has been trialled as an alternative marker gene in human gene therapy.

Describe how scientists can use mRNA from the jellyfish to synthesise a DNA molecule coding for GFP.

Explain how this method overcomes the problems of removing the GFP gene directly from the jellyfish chromosomes.

Suggest how the GFP marker could be used in gene therapy and why it is more useful than the antibiotic resistance marker. [9 QER]

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Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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