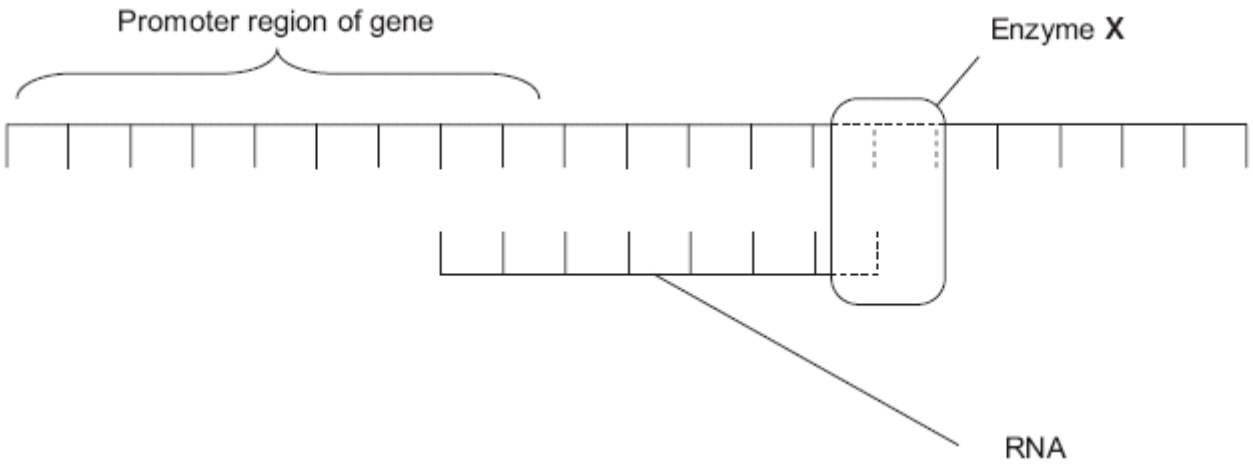
8.1 The control of gene expression (A-Level Only) - Gene expression – Questions

Q1.

Figure 1 shows part of a gene that is being transcribed.

Figure 1



(a) Name enzyme **X**.

_____

(1)

(b) (i) Oestrogen is a hormone that affects transcription. It forms a complex with a receptor in the cytoplasm of target cells. Explain how an activated oestrogen receptor affects the target cell.

_____

_____

_____

_____

(2)

(ii) Oestrogen only affects target cells. Explain why oestrogen does not affect other cells in the body.

_____

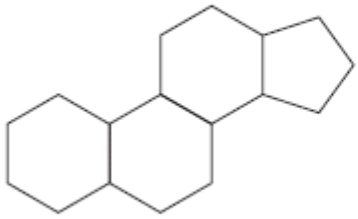
_____

(1)

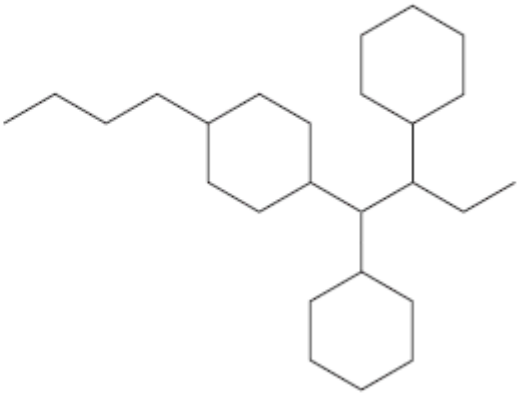
(c) Some breast tumours are stimulated to grow by oestrogen. Tamoxifen is used to treat these breast tumours. In the liver, tamoxifen is converted into an active substance called endoxifen. **Figure 2** shows a molecule of oestrogen and a molecule of endoxifen.

Figure 2

Oestrogen



Endoxifen



Use **Figure 2** to suggest how endoxifen reduces the growth rate of these breast tumours.

_____

_____

_____

_____

(2)

(Total 6 marks)

Q2.

(a) (i) A mutation of a tumour suppressor gene can result in the formation of a tumour.

Explain how.

_____

_____

_____

_____

(2)

(ii) Not all mutations result in a change to the amino acid sequence of the encoded polypeptide.

Explain why.

_____

_____

_____

(1)

(b) Some cancer cells have a receptor protein in their cell-surface membrane that binds to a hormone called **growth factor**. This stimulates the cancer cells to divide.

Scientists have produced a monoclonal antibody that stops this stimulation.

Use your knowledge of monoclonal antibodies to suggest how this antibody stops the growth of a tumour.

_____

_____

_____

_____

_____

_____

[Extra space] _____

_____

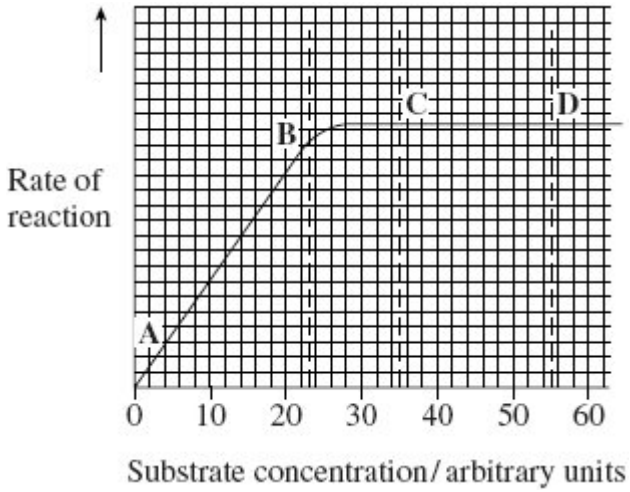
_____

(3)

(Total 6 marks)

Q3.

The graph shows the effect of substrate concentration on the rate of an enzyme-controlled reaction.



(a) (i) Describe what the graph shows about the effect of substrate concentration on the rate of this enzyme-controlled reaction.

_____

_____

_____

_____

(2)

(ii) What limits the rate of this reaction between points **A** and **B**? Give the evidence from the graph for this.

_____

_____

_____

_____

(2)

(iii) Suggest a reason for the shape of the curve between points **C** and **D**.

_____

_____

(1)

(b) Sketch a curve on the graph to show the rate of this reaction in the presence of a competitive inhibitor.

(1)

(c) Methotrexate is a drug used in the treatment of cancer. It is a competitive inhibitor and affects the enzyme folate reductase.

(i) Explain how the drug lowers the rate of reaction controlled by folate reductase.

_____

_____

_____

_____

_____

(2)

(ii) Methotrexate only affects the rate of the reaction controlled by folate reductase.

Explain why this drug does not affect other enzymes.

_____

_____

(1)

(Total 9 marks)

Q4.

(a) Each year, a few people with type I diabetes are given a pancreas transplant. Pancreas transplants are not used to treat people with type II diabetes.

Give **two** reasons why pancreas transplants are not used for the treatment of type II diabetes.

1. _____

_____

_____

2. _____

_____

_____

(2)

(b) The pancreas produces the hormone insulin.

Put a tick (✔) in the box next to the statement which describes **incorrectly** the action of insulin.

Activates enzymes involved in the conversion of glucose to glycogen.	☐
Controls the uptake of glucose by regulating the inclusion of channel proteins in the surface membranes of target cells.	☐
Attaches to receptors on the surfaces of target cells.	☐
Activates enzymes involved in the conversion of glycerol to glucose.	☐

(1)

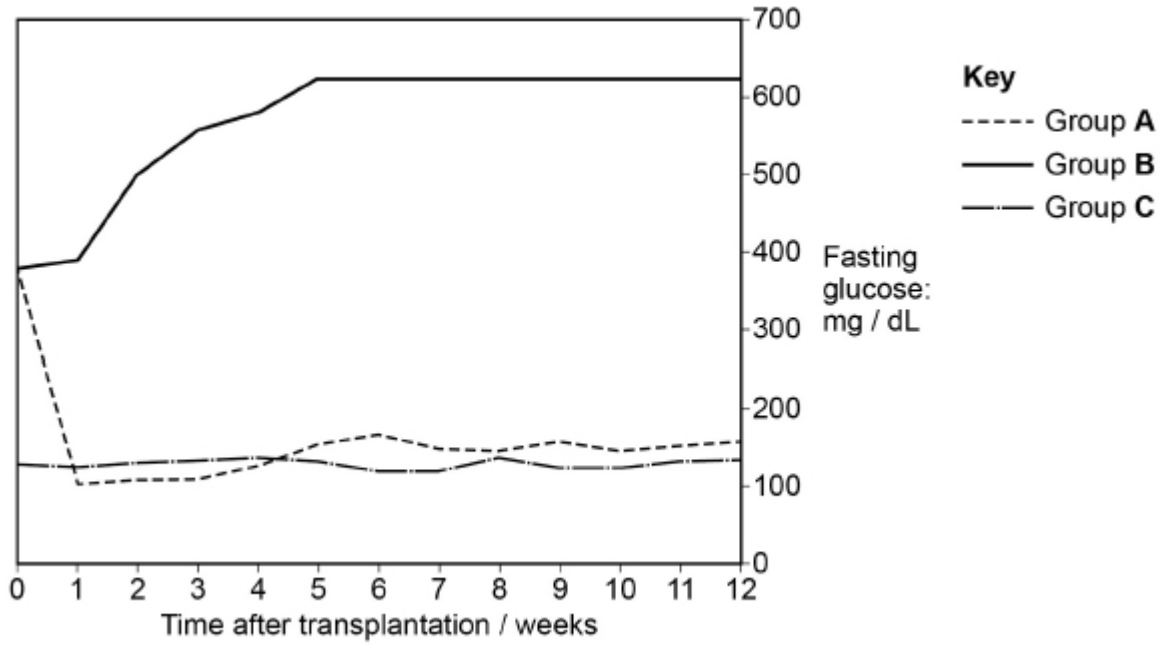
(c) Scientists investigated the use of induced pluripotent stem cells (iPS cells) to treat type I diabetes in mice. The scientists used four transcription factors to reprogramme skin cells to form iPS cells. The scientists then stimulated the *in vitro* differentiation of iPS cells into pancreatic cells.

The scientists set up three experimental groups:

- Group **A** – 30 mice with type I diabetes received pancreatic cell transplants derived from iPS cells.
- Group **B** – 30 mice with type I diabetes were left untreated.
- Group **C** – 30 mice without diabetes were left untreated.

The scientists measured the blood glucose concentration of all the mice on a weekly basis for 12 weeks.

The results the scientists obtained are shown in the graph.



Suggest how transcription factors can **reprogramme** cells to form iPS cells.

(2)

(d) Using all the information provided, evaluate the use of iPS cells to treat type I diabetes in humans.

(4)

(Total 9 marks)

Q5.

Alzheimer's disease (AD) is a non-reversible brain disorder that develops over a number of years. At the start of 2014 the number of Americans with AD was estimated to be 5.4 million. Every 30 seconds another person in America develops AD.

In the brain of a person with AD there is a lower concentration of acetylcholine. This affects communication between nerve cells and initially results in memory loss and confusion. Some of the symptoms of AD that are associated with communication between nerve cells are reduced by taking the drug donepezil. Donepezil inhibits the enzyme acetylcholinesterase.

A gene mutation called E280A found on chromosome 14 causes early-onset AD at a mean age of 49 years. The age at which the E280A mutation is expressed to cause AD varies.
Yaramul is a town in a historically isolated region of the Andes Mountains. The population of this town has the highest frequency of the E280A mutation in the world. The origin of the E280A mutation in this population has been traced back to a common ancestor in the 17th century. Natural selection has not reduced the frequency of the E280A mutation in the population.

This autosomal dominant mutation involves a change in triplet 280 from GAA to GCA. Scientists analysed chromosome 14 from 102 individuals from Yaramul. They recorded a sample size of 204 and detected 75 E280A mutations but only 74 potential AD cases. The scientists identified individuals with the mutation by whole genome sequencing. They had decided that a DNA probe would not be a suitable method to detect the E280A mutation.

(a) Assuming no one with AD died in 2014, calculate the annual percentage increase in AD cases in America for 2014 (lines 2–4).

Answer = _____ %

(2)

(b) Explain how donepezil could improve communication between nerve cells (lines 7–9).

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(c) Suggest and explain **two** reasons why there is a high frequency of the E280A mutation in Yaramul (lines 13–15).

1. _____

_____

_____

2. _____

_____

_____

(2)

(d) Explain why natural selection has **not** reduced the frequency of the E280A mutation in the population (lines 16–17).

_____

_____

_____

_____

(2)

(e) The age at which the E280A mutation is expressed to cause AD can vary (lines 11–12).

Suggest and explain **one** reason for this.

_____

_____

_____

_____

_____

(2)

(f) One scientific study which analysed chromosome 14 involved 102 individuals. The scientists recorded a sample size of 204. In this sample they detected 75 E280A mutations but only 74 potential AD cases (lines 19–21).

Suggest explanations for the figures the scientists recorded.

_____

_____

_____

_____

_____

(2)

(g) Suggest why a DNA probe for the mutated triplet was **not** considered a suitable method for detection of the E280A mutation (lines 22–23).

_____

_____

_____

_____

_____

(2)

(Total 15 marks)

Q6.

(a) Name **two** enzymes involved in the semi-conservative replication of DNA.

1. _____

2. _____

(2)

(b) Sometimes, damage occurs during DNA replication. One enzyme involved in repairing damage to DNA is called ATR.

ATR works as follows.

- ATR phosphorylates other enzymes involved in repairing DNA.
- ATR **also** phosphorylates substrates required to repair DNA.

When ATR phosphorylates other enzymes, these enzymes become able to bind to their substrates.

Use your knowledge of enzyme structure to suggest why.

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(c) The enzyme-catalysed reactions activated by ATR only occur if the substrates have been phosphorylated.

Use your knowledge of energy changes in enzyme-catalysed reactions to suggest why.

(1)

(d) Sometimes, a mutagenic agent causes DNA to break. A different enzyme called ATM binds to the broken DNA. This leads to the activation of a protein coded for by a tumour suppressor gene. The effect of ATM binding is to stop cell division until DNA is repaired.

A mutation could result in a person having non-functional forms of the gene that produces ATM.

What can you predict about the possible effects of having a non-functional form of ATM?

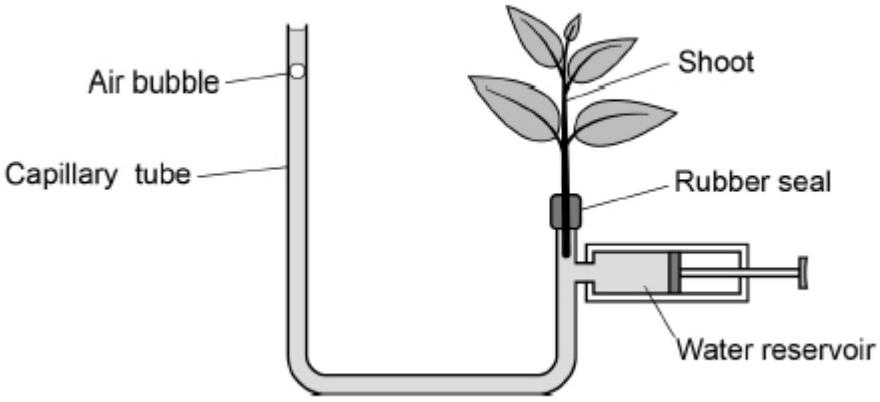
(3)

(Total 8 marks)

Q7.

A student used a potometer to measure the movement of water through the shoot of a plant. The potometer is shown in **Figure 1**. As water is lost from the shoot, it is replaced by water from the capillary tube.

Figure 1



(a) In one experiment, the air bubble moved 7.5 mm in 15 minutes. The diameter of the capillary tube was 1.0 mm.

Calculate the rate of water uptake by the shoot in this experiment.

Give your answer in mm^3 per hour. Show your working. (The area of a circle is found using the formula, area = πr^2)

_____ $mm^3\ hour^{-1}$

(2)

(b) The student wanted to determine the rate of water loss per mm^2 of surface area of the leaves of the shoot in **Figure 1**.

Outline a method she could have used to find this rate. You should assume that all water loss from the shoot is from the leaves.

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(c) The rate of water movement through a shoot in a potometer may not be the same as the rate of water movement through the shoot of a whole plant.

Suggest **one** reason why.

_____

_____

_____

_____

_____

_____

_____

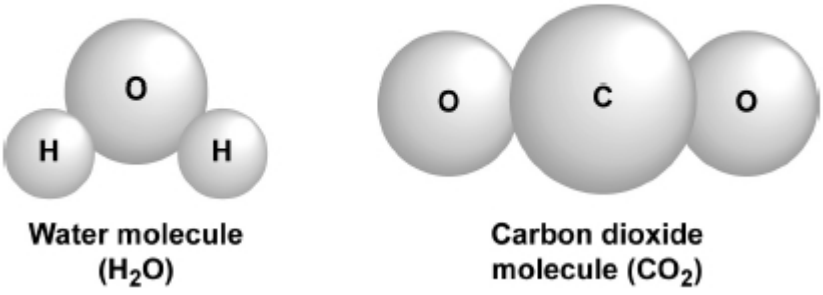
_____

(1)

(d) Aquaporins are channel proteins that allow the diffusion of water across membranes. One type of aquaporin, called PIP1, can also transport carbon dioxide molecules across membranes.

Figure 2 shows the structure of a water molecule and of a carbon dioxide molecule. They are drawn to the same scale.

Figure 2



Water molecule (H_2O)

Carbon dioxide molecule (CO_2)

Suggest **two** reasons why water molecules **and** carbon dioxide molecules can both pass through PIP1.

1. _____

_____

_____

_____

2. _____

_____

_____

(2)

(e) The scientists first produced transgenic poplar trees. These trees all had a length of foreign DNA inserted into them. This DNA led to the production of single-stranded RNA that specifically inhibited expression of the gene for PIP1.

The scientists then measured the difference in the amount of PIP1 in leaves of transgenic poplars and in leaves of wild type poplars without the foreign DNA. The amount of PIP1 in the transgenic poplars was approximately 15% of that in the wild type poplars.

Using this information, what can you conclude about the effect of the foreign DNA in the transgenic poplar trees?

(3)

(f) The transgenic poplars still produced some PIP1.

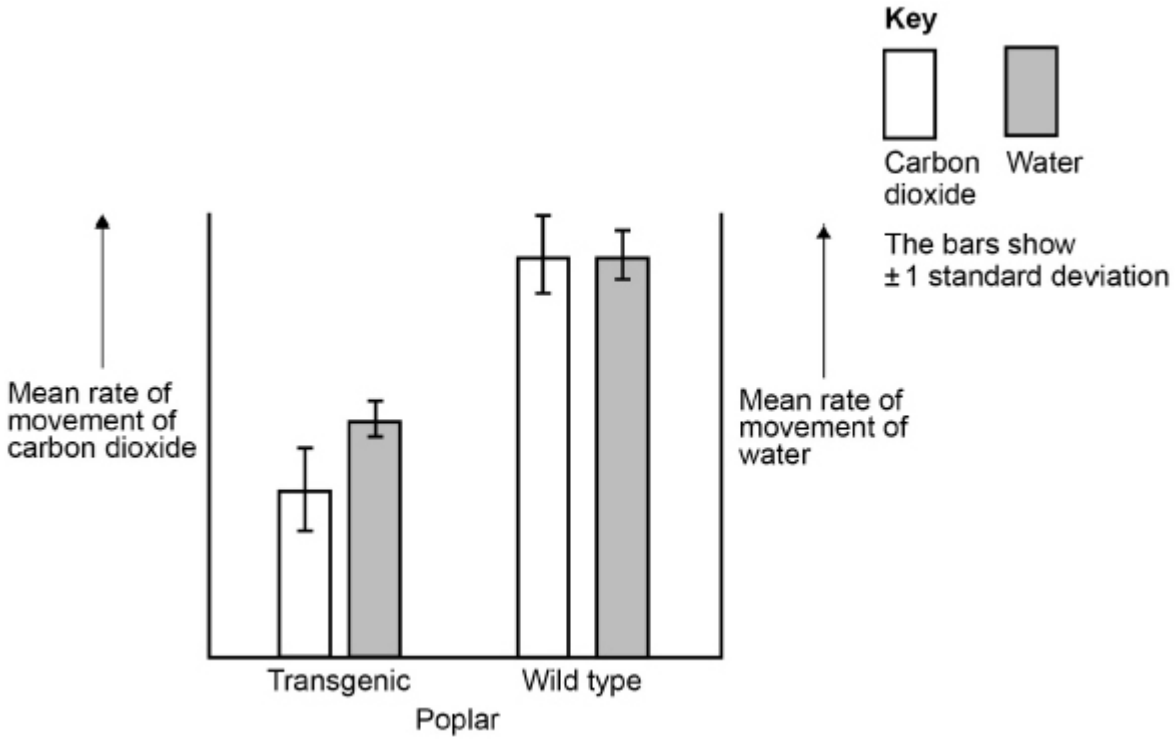
Suggest why.

(1)

(g) The scientists investigated the importance of PIP1 in the movement of water and carbon dioxide through the tissues of leaves of poplar trees.

They measured the mean rates of movement of carbon dioxide and water through the tissues of leaves of transgenic poplars and through the tissues of leaves of wild type poplars.

Their results are shown in the graph below.



Using only the graph above, evaluate the importance of PIP1 in the movement of carbon dioxide and water through leaves of poplar trees.

(3)

(Total 15 marks)

Q8.

(a) Define what is meant by epigenetics.

(2)

(b) In eukaryotes, transcription of target genes can be stimulated or inhibited when specific transcriptional factors move from the cytoplasm into the nucleus.

Oestrogen, methyl groups and acetyl groups are control factors that can play a role in initiating transcription.

Complete the table to show features of these control factors.

Put a tick (✔) in the box if the control factor shows the feature.

	Feature	
Control factor	**Binds with DNA**	**Binds with protein**
Oestrogen		
Methyl groups		
Acetyl groups		

(2)

(c) Explain how increased methylation could lead to cancer.

(3)

(d) Give **one** way in which benign tumours differ from malignant tumours.

(1)

(Total 8 marks)

Q9.

Read the following passage.

Plants require phosphate ions that they get from soil. These ions are often in poor supply and this results in poor growth of the plants. Most plants have mycorrhizae that help the plants to obtain nitrates. Mycorrhizal networks can connect the roots of plants growing next to each other. The use of fertilisers containing phosphate and nitrates in farming inhibits the growth of mycorrhizae. As a result, intensively farmed crop plants do not have mycorrhizae.

Plants can defend themselves by producing defensive enzymes that destroy pathogens such as bacteria. Some plants express the genes for defensive enzymes in response to signal proteins secreted by other plants that are being attacked by a pathogen. These signal proteins can be released into the air.

Scientists have discovered that tomato plants increase production of defensive enzymes if plants next to them become infected with a pathogen. These tomato plants were connected by a mycorrhizal network that can carry signal proteins between them. The largest increase in defensive enzyme secretion that the scientists found in a tomato plant in response to the signal protein was by 122.6 per cent.

Use the information in the passage and your own knowledge to answer the following questions.

(a) Suggest and explain **two** reasons why a poor supply of phosphate ions results in poor growth of plants (lines 1–2).

1. _____

_____

2. _____

_____

(2)

(b) Suggest how defensive enzymes produced by plants destroy bacteria (lines 8–9).

_____

_____

_____

_____

_____

(2)

(c) The signal proteins secreted into the air by a plant being attacked by a pathogen act as stimuli leading to the expression of genes for defensive enzymes in other plants (lines 9–12).

Suggest how they lead to the expression of these genes.

_____

(3)

(d) Suggest and explain **the** advantage to tomato plants of transmitting signal proteins through mycorrhizal networks, rather than releasing them into the air (line 11–12 and lines 14–16).

(2)

(e) The largest increase in defensive enzyme secretion that the scientists found in a tomato plant in response to the signal protein was by 122.6 percent (lines 16–18).

The rate of secretion of the defensive enzymes before the signal protein was produced was 450 μmol dm^{-3} g^{-1} $hour^{-1}$.

Calculate the rate of secretion **per second** after the response to the signal protein.

Answer = _____ μmol dm^{-3} g^{-1} $second^{-1}$

(2)

(f) A student who read this passage concluded that farmers should **not** use fertilisers to increase yields when growing tomato plants.

Evaluate his conclusion.

(4)
(Total 15 marks)

Q10.

Scientists have investigated the use of different types of stem cell to treat damage to the heart after a myocardial infarction. During a myocardial infarction, a number of different cell types in the heart die. This includes cardiomyocytes which are heart-muscle cells.

Embryonic pluripotent stem cells (ESCs) can divide and differentiate into a wide range of different cell types.

(a) Using the information given, suggest **one** reason why ESCs might be suitable to treat damage to the heart.

(1)

(b) ESCs have not yet been used to treat people who have had a myocardial infarction. This is because of concern that the use of ESCs might lead to more harm to the person. One way that ESCs might lead to more harm is by differentiating into the wrong types of cells.

Suggest **one** other way that putting ESCs into a person's heart might lead to more harm to the person.

(2)

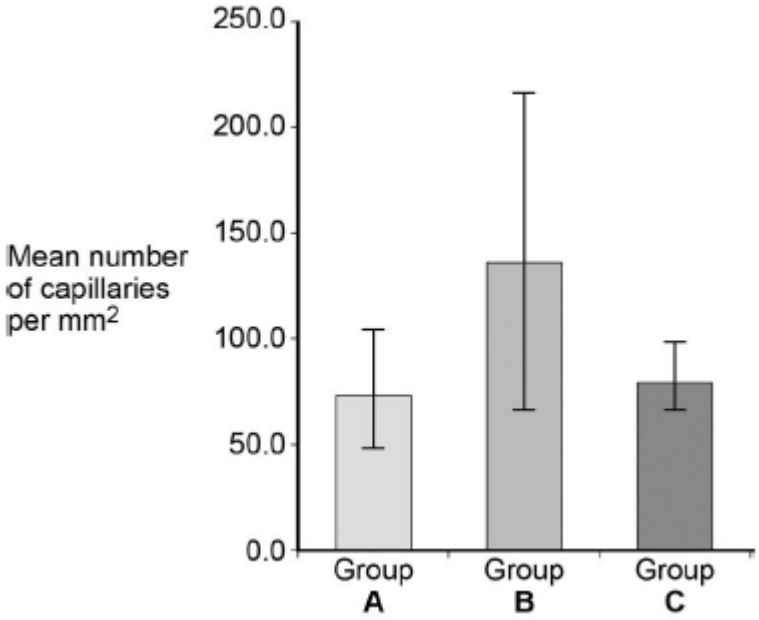
(c) Transplants of cardiomyocytes have been shown to increase the repair of heart tissue damaged by myocardial infarction.

One group of scientists investigated the hypothesis that these transplants work by stimulating growth of new blood vessels into damaged heart tissues. They obtained three groups of mice, **A**, **B** and **C** that had suffered myocardial infarctions.

- **Group A** were operated on but no transplant was given.
- **Group B** were operated on and given transplants containing cardiomyocytes and two other types of heart cell.
- **Group C** were operated on and given transplants containing the two other types of heart cells but no cardiomyocytes.

After a suitable time, the scientists measured the mean number of capillaries per mm^2 in sections taken from areas of the hearts of the mice affected by myocardial infarction.

Their results are shown in the graph below. The bars show ±2 standard deviations, which includes 95.4% of the data.



Group **A** was a control group. Explain **two** ways in which Group **A** acts as a control.

1. _____

_____

_____

2. _____

_____

_____

(2)

(d) What can you conclude from these data about the stimulation by cardiomyocytes on growth of new blood vessels into damaged heart tissues?

_____

_____

(3)

(e) Suggest how the growth of new blood vessels into damaged heart tissues could increase the rate of repair of tissues.

(3)

(f) The scientists used an optical microscope to measure the number of capillaries in thin sections cut from samples of heart muscle.

Describe the method they would have used to find the mean number of capillaries per mm^2.

(4)

(Total 15 marks)

Q11.

(a) Explain how the methylation of tumour suppressor genes can lead to cancer.

(Extra space) _____

(3)

Scientists investigated a possible relationship between the percentage of fat in the diet and the death rate from breast cancer in women from 10 countries.

Their data is shown in the table below.

Percentage of fat in diet of population	Death rate of women from breast cancer per 100 000 women
9.5	1.5
15.0	7.0
20.0	12.0
25.0	9.0
32.0	15.0
35.0	8.0
35.0	20.0
40.5	18.0
43.0	24.0
45.0	26.0

(b) Describe how you would plot a suitable graph of these data. Explain your choice of type of graph.

(Extra space) _____

(3)

(c) What can you conclude from these data?

(2)

(Total 8 marks)

Q12.

Metastatic melanoma (MM) is a type of skin cancer. It is caused by a faulty receptor protein in cell-surface membranes. There have been no very effective treatments for this cancer.

Dacarbazine is a drug that has been used to treat MM because it appears to increase survival time for some people with MM.

Doctors investigated the use of a new drug, called ipilimumab, to treat MM. They compared the median survival time (ST) for two groups of patients treated for MM:

- a control group of patients who had been treated with dacarbazine
- a group of patients who had been treated with dacarbazine and ipilimumab.

The ST is how long a patient lives after diagnosis.

The doctors also recorded the percentage of patients showing a significant reduction in tumours with each treatment.

The total number of patients in the investigation was 502.

The table below shows the doctors' results.

Treatment	Median survival time (ST) / months	Percentage of patients showing significant reduction in tumours

Dacarbazine	9.1	10.3
Dacarbazine and ipilimumab	11.2	15.2

(a) The doctors compared median survival times for patients in each group.

How would you find the median survival time for a group of patients?

(2)

(b) In many trials of new drugs, a control group of patients is given a placebo that does not contain any drug.

The control group in this investigation had been treated with dacarbazine.
Suggest why they had not been given a placebo.

(1)

(c) A journalist who read this investigation concluded that ipilimumab improved the treatment of MM.

Do the data in the table support this conclusion? Give reasons for your answer.

(Extra space)

(4)

(d) MM is caused by a faulty receptor protein in cell-surface membranes. Cells in MM tumours can be destroyed by the immune system.

Suggest why they can be destroyed by the immune system.

_____

_____

_____

_____

_____

_____

(Extra space) _____

_____

_____

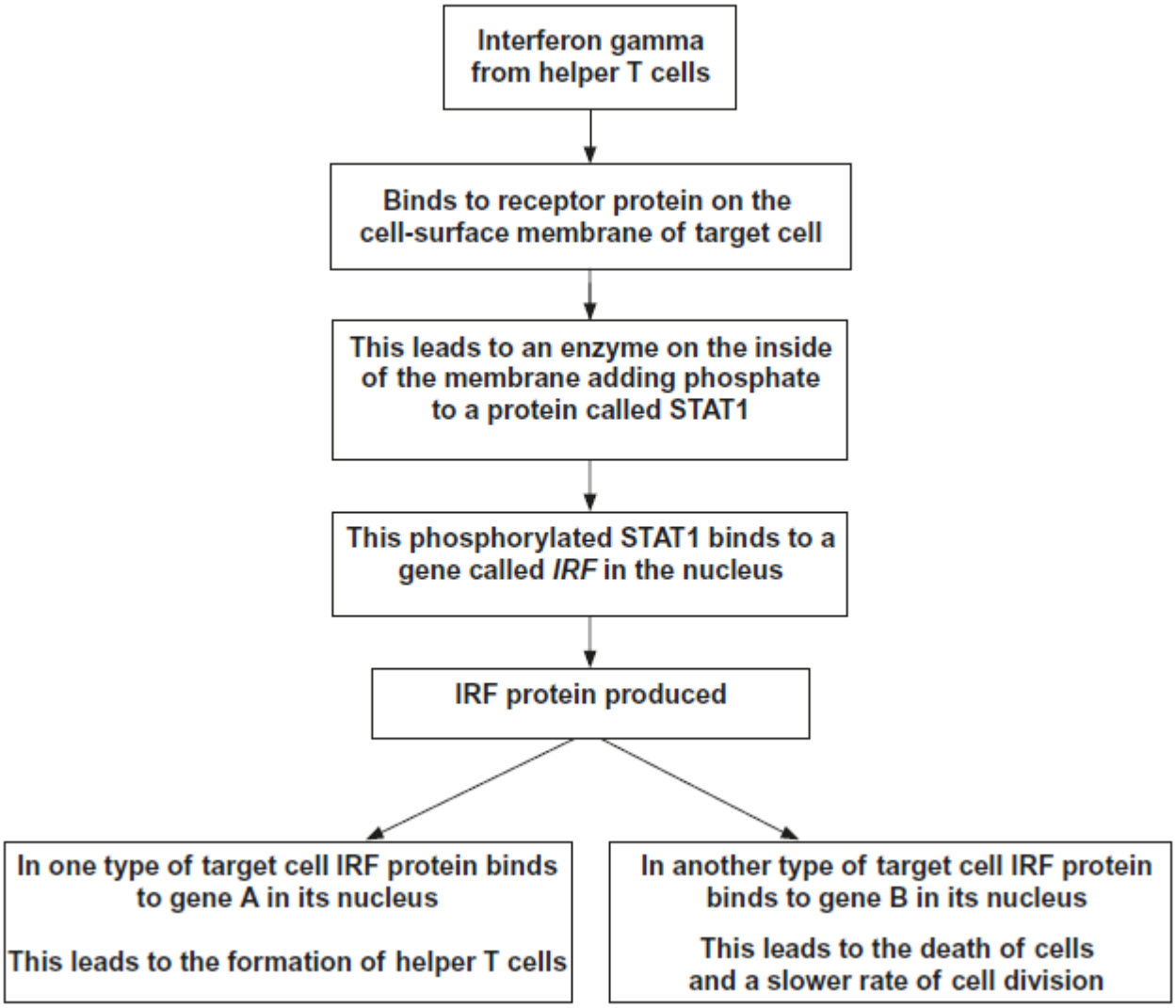
(3)

(Total 10 marks)

Q13.

Interferon gamma is a substance secreted by some types of white blood cells, including helper T cells. It regulates the production of a number of proteins by target cells. Which protein is produced depends on the type of target cell.

The diagram shows how interferon gamma regulates three genes.



(a) Use information in the diagram to suggest how the binding of interferon gamma to its receptor protein leads to the production of phosphorylated STAT1.

_____

_____

_____

_____

(2)

(b) Name the **two** transcription factors in the diagram.

1. _____

2. _____

(2)

(c) The regulation of the formation of helper T cells by interferon gamma is an example of positive feedback.

Explain why it is an example of positive feedback.

_____

_____

_____

_____

(2)

(d) The *IRF* gene can be a tumour suppressor gene.

Use the information in the diagram to explain how the *IRF* gene acts as a tumour suppressor gene.

_____

_____

_____

_____

_____

_____

(3)

(Total 9 marks)

Q14.

Oestrogen is a substance produced by the enzyme aromatase. In females, the main source of oestrogen is the ovaries but aromatase is produced by many other organs in the body, including the lungs. Oestrogen can stimulate the development of some lung tumours. In these tumours, binding of oestrogen to cell-surface receptors stimulates cell division.

Scientists investigated whether two drugs could prevent lung tumours in female mice. First, they removed the ovaries from these mice. They then injected the mice with a tumour-causing chemical found in tobacco twice a day for 4 weeks. The mice were then randomly allocated to one of four groups. Each group contained 10 mice.

- Group **Q** was given a placebo. This placebo did not contain either drug.
- Group **R** was given the drug anastrozole. This inhibits the enzyme aromatase.
- Group **S** was given the drug fulvestrant. This binds to oestrogen receptors.
- Group **T** was given both anastrozole and fulvestrant.

The mice were given these drugs each week during weeks 5−15 of the investigation.

(a) The scientists removed the ovaries from the mice for the investigation. They also gave the mice injections of the substrate of aromatase each day.

Explain why these steps were necessary.

_____

_____

(2)

(b) The scientists predicted that fulvestrant would be more effective when given with anastrozole than when given alone.

Use the information provided to suggest why they predicted this.

(2)

At week 15, the lungs of the mice were removed and examined. The scientists then determined the number of tumours present and the mean tumour area for each group.

Figure 1 and **Figure 2** show the scientists' results.

Figure 1

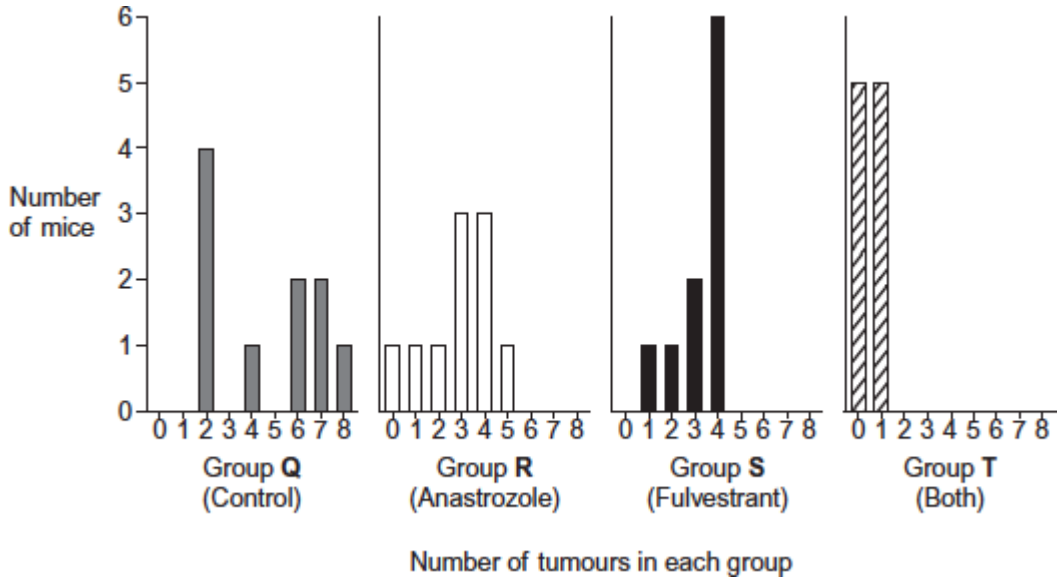
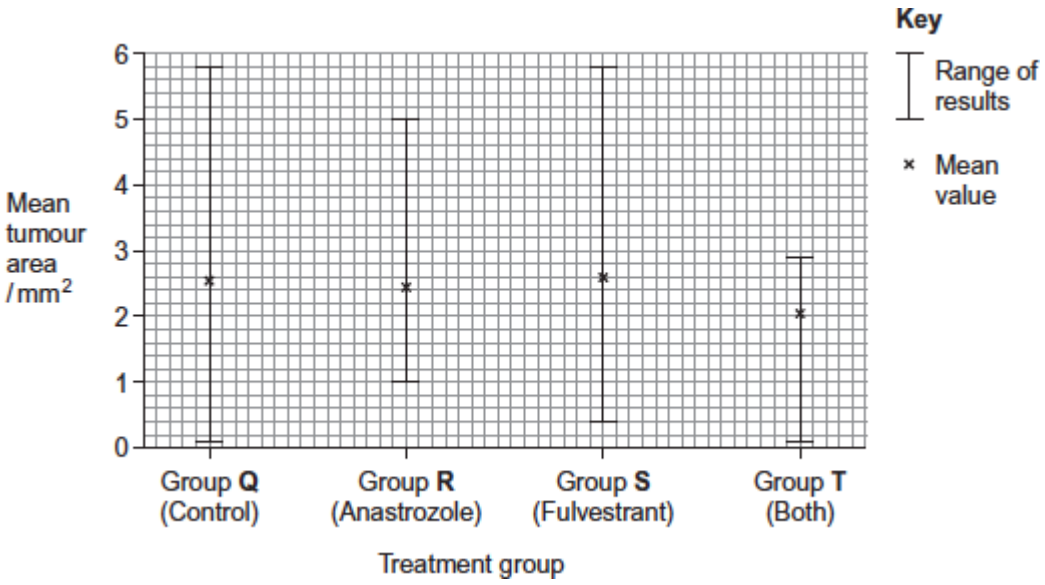


Figure 2



(c) The scientists concluded that both drugs should be used together to reduce the risk of lung cancer in women exposed to tobacco products.

Do you agree? Explain your answer.

(5)

(d) The scientists used tumour area as an indicator of tumour size.

Explain why tumour area may **not** be the best indicator of tumour size and suggest a more reliable measurement.

(2)

(e) The scientists repeated the investigation but this time they did not give the drugs until week 9.

Suggest why they gave the drugs at week 9, rather than at week 5.

(2)

(f) Another group of scientists is currently using these drugs in human trials. However,

the control group is **not** being given a placebo.

Suggest why a placebo is **not** being given and what is being given to this group instead.

(2)
(Total 15 marks)

Q15.

(a) Explain how the structure of DNA is related to its functions.

(Extra space)

(6)

Scientists investigated three genes, **C**, **D** and **E**, involved in controlling cell division. They studied the effect of mutations in these genes on the risk of developing lung cancer.

The scientists analysed genes **C**, **D** and **E** from healthy people and people with lung cancer.

- If a person had a normal allele for a gene, they used the symbol N.
- If a person had two mutant alleles for a gene, they used the symbol M.

They used their data to calculate the risk of developing lung cancer for people with different combinations of N and M alleles of the genes. A risk value of 1.00 indicates no increased risk. The following table shows the scientists' results.

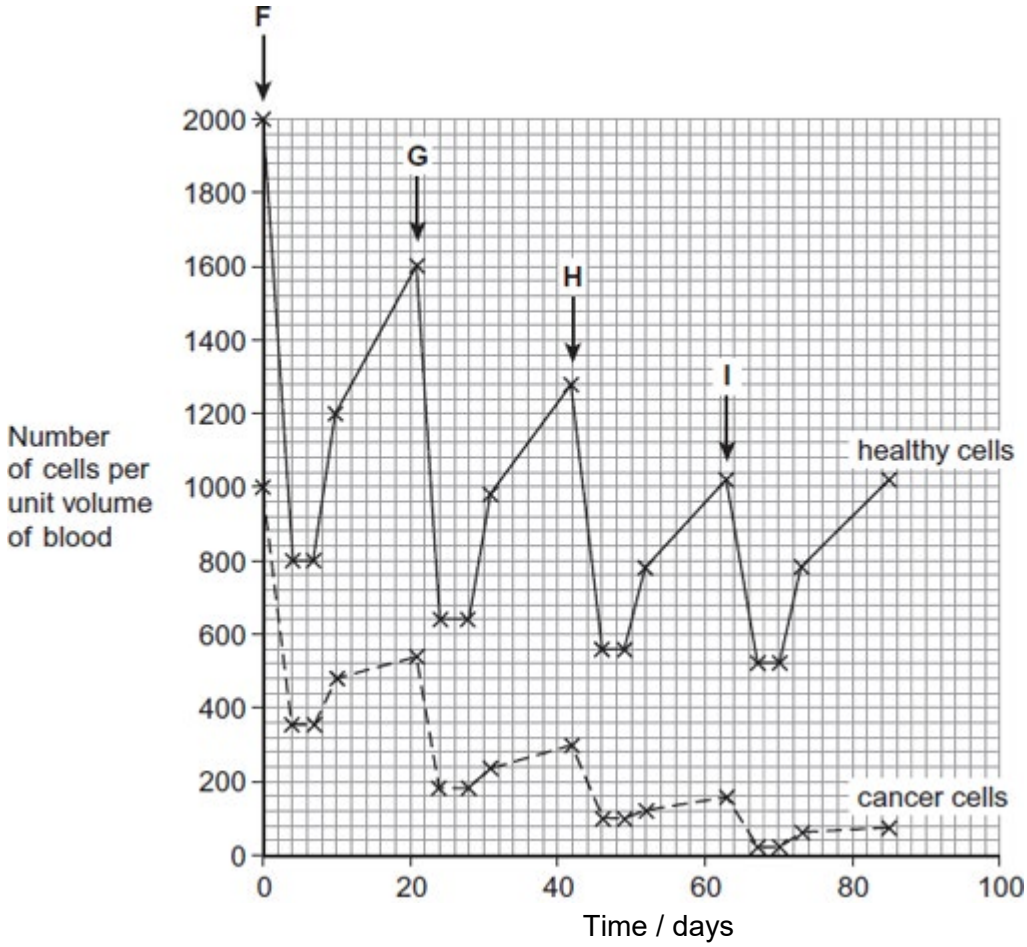
Gene C	Gene D	Gene E	Risk of developing lung cancer
N	N	N	1.00
M	N	N	1.30
N	N	M	1.78
N	M	N	1.45

N = at least one copy of the normal allele is present
M = two copies of the mutant allele are present

(b) What do these data suggest about the relative importance of the mutant alleles of genes **C**, **D** and **E** on **increasing** the risk of developing lung cancer? Explain your answer.

(3)

Chemotherapy is the use of a drug to treat cancer. The drug kills dividing cells.
The figure below shows the number of healthy cells and cancer cells in the blood of a patient receiving chemotherapy. The arrows labelled **F** to **I** show when the drug was given to the patient.



(c) Calculate the rate at which healthy cells were killed between days 42 and 46.

_____ cells killed per unit volume of blood per day

(1)

(d) Describe similarities and differences in the response of healthy cells and cancer cells to the drug between times **F** and **G**.

_____

_____

_____

_____

_____

_____

(Extra space) _____

_____

_____

(3)

(e) More cancer cells could be destroyed if the drug was given more frequently.

Suggest why the drug was **not** given more frequently.

_____

_____

_____

_____

(2)

(Total 15 marks)

Q16.

Imatinib is a drug used to treat a type of cancer that affects white blood cells. Scientists investigated the rate of uptake of imatinib by white blood cells. They measured the rate of uptake at 4°C and at 37°C.
Their results are shown in the table.

	Mean rate of uptake of imatinib into cells / µg per million cells per hour	
Concentration of imatinib outside cells / µmol dm^{-3}	**4°C**	**37°C**
0.5	4.0	10.5
1.0	10.7	32.5
5.0	40.4	420.5
10.0	51.9	794.6
50.0	249.9	3156.1
100.0	606.9	3173.0

(a) The scientists measured the rate of uptake of imatinib in µg per million cells per hour. Explain the advantage of using this unit of rate in this investigation.

_____

_____

_____

_____

_____

(2)

(b) Calculate the percentage increase in the mean rate of uptake of imatinib when the temperature is increased from 4°C to 37°C at a concentration of imatinib outside the cells of 1.0 μmol dm^{-3} .

Give your answer to one decimal place.

Answer _____

(2)

(c) Imatinib is taken up by blood cells by active transport.

(i) Explain how the data for the two different temperatures support this statement.

_____

_____

_____

_____

_____

(2)

(ii) Explain how the data for concentrations of imatinib outside the blood cells at 50 and 100 μmol dm^{-3} at 37°C support the statement that imatinib is taken up by active transport.

_____

_____

_____

_____

_____

(2)

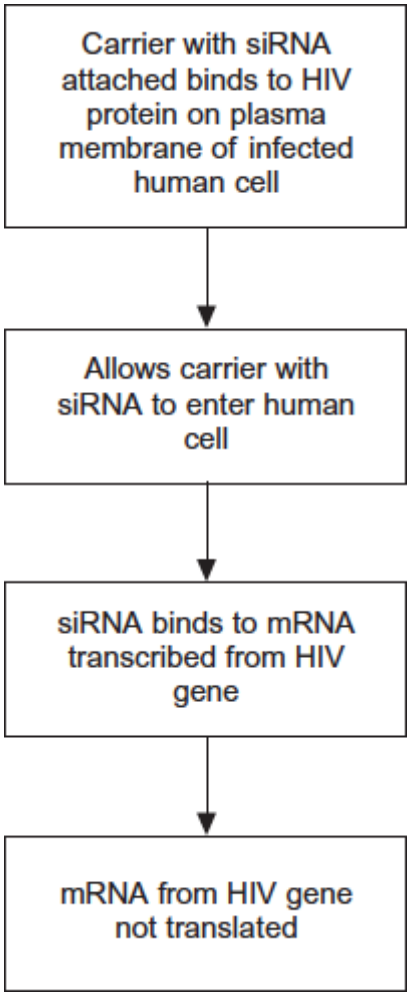
(Total 8 marks)

Q17.

Human immunodeficiency virus (HIV) particles have a specific protein on their

surface.This protein binds to a receptor on the plasma membrane of a human cell and allows HIV to enter. This HIV protein is found on the surface of human cells after they have become infected with HIV.

Scientists made siRNA to inhibit expression of a specific HIV gene inside a human cell. They attached this siRNA to a carrier molecule. The flow chart shows what happens when this carrier molecule reaches a human cell infected with HIV.



(a) When siRNA binds to mRNA, name the complementary base pairs holding the siRNA and mRNA together. One of the bases is named for you.

_____with_____

_____**Adenine**_____with_____

(1)

(b) This siRNA would **only** affect gene expression in cells infected with HIV.

Suggest **two** reasons why.

1. _____

_____

_____

_____

2. _____

_____

_____

_____

(4)

(c) The carrier molecule on its own may be able to prevent the infection of cells by HIV.

Explain how.

_____

_____

_____

_____

_____

(2)

(Total 7 marks)

Q18.

Scientists investigated the effect of drinking tea and coffee on reducing the risk of developing one type of brain cancer. The investigation involved 410 000 volunteers and was conducted in 10 European countries over a period of 8.5 years.

(a) (i) Apart from age, suggest **two** factors that the scientists should have considered when selecting volunteers for this trial.

1. _____

2. _____

(2)

(ii) Give **two** features of the design of this investigation that would ensure the reliability ofthe results obtained.

1. _____

_____

2. _____

_____

(2)

(b) The incidence for this type of brain cancer is 6 cases per 100 000 per year.
Use this information to calculate the expected number of volunteers developing this cancer during the 8.5 year period of this investigation. Show your working.

Answer_____

(2)

(c) In analysing the results of this investigation, the scientists took into account the age of the volunteers. Suggest why.

_____

_____

_____

(1)

(d) During the investigation, the volunteers were asked to estimate the volume of tea and/or coffee that they drank each day. The types of tea and coffee consumed in different countries varied. When the data from all the countries were collected there was a correlation between drinking more than 100 cm^3 of tea or coffee each day and a reduced risk of developing this type of brain cancer.

Tea and coffee contain caffeine. A newspaper reported the results of this investigation under the headline 'Caffeine helps cut cancer risk'. Explain why scientists could **not** support this view solely on the basis of this investigation.

_____

_____

_____

_____

_____

_____

_____

_____

*(Extra space)*_____

_____

_____

_____

(4)

(e) Another group of scientists investigated the effect of caffeine on blood flow to certain parts of the brain. Volunteers were given different concentrations of caffeine solution to drink. A control group was also set up.

(i) Describe how the control group should have been treated.

_____

_____

_____

_____

_____

(2)

(ii) Volunteers who drank the same concentration of caffeine solution often had different concentrations of caffeine in their blood. Suggest **one** reason for the difference in concentration of caffeine in the blood of volunteers.

_____

_____

_____

(1)

(iii) The investigation showed that caffeine reduces the blood flow to certain parts of the brain. Suggest **one** way in which this could lead to a reduced risk of brain cancers.

_____

_____

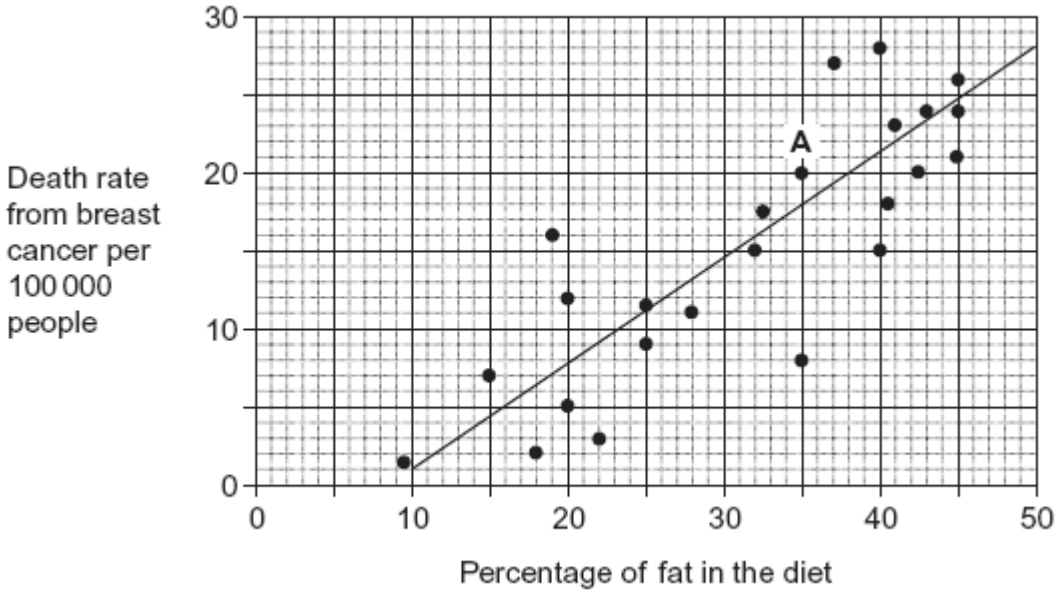
_____

(1)

(Total 15 marks)

Q19.

Scientists investigated the relationship between the percentage of fat in the diet and the death rate from breast cancer in 24 different countries. They plotted the data from each country on the graph below.



(a) Describe the information given by point **A** on the graph.

_____

_____

_____

(1)

(b) Describe how the scientists calculated the death rate from breast cancer for each country.

_____

_____

_____

(1)

(c) Some people have used the graph to conclude that a high percentage of fat in the diet causes breast cancer. Evaluate this conclusion.

_____

_____

_____

_____

_____

_____

*(Extra space)*_____

_____

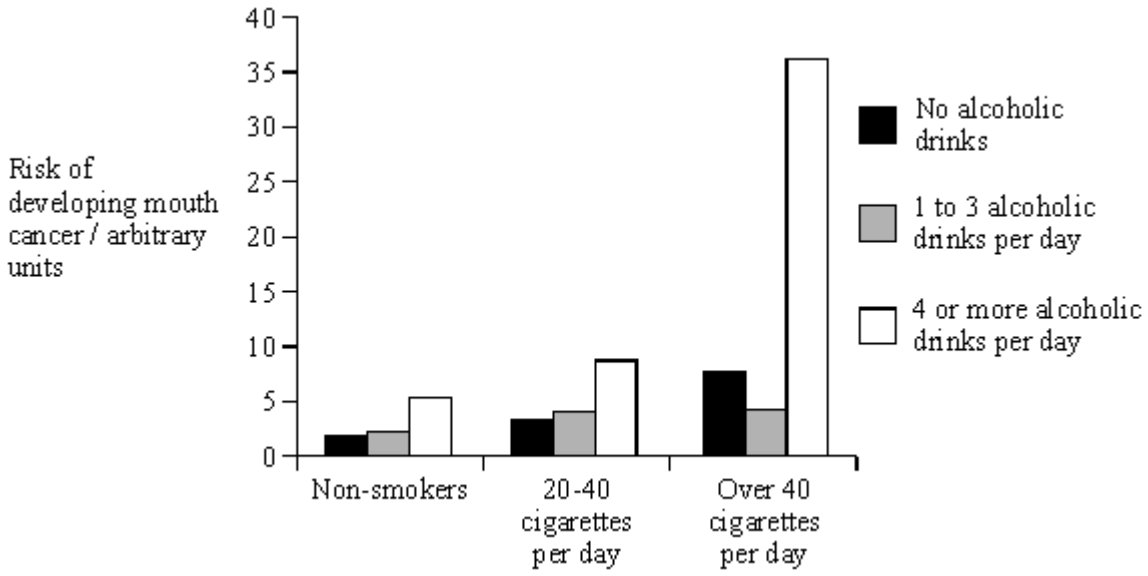
_____

(3)

(Total 5 marks)

Q20.

The bar chart shows the effects of smoking and alcoholic drinks on the risk of developing mouth cancer.



(i) Describe the effects of smoking and drinking on the risk of developing mouth cancer.

_____

_____

_____

_____

_____

_____

(3)

(ii) Suggest **one** reason why people who neither drink nor smoke sometimes develop mouth cancer.

_____

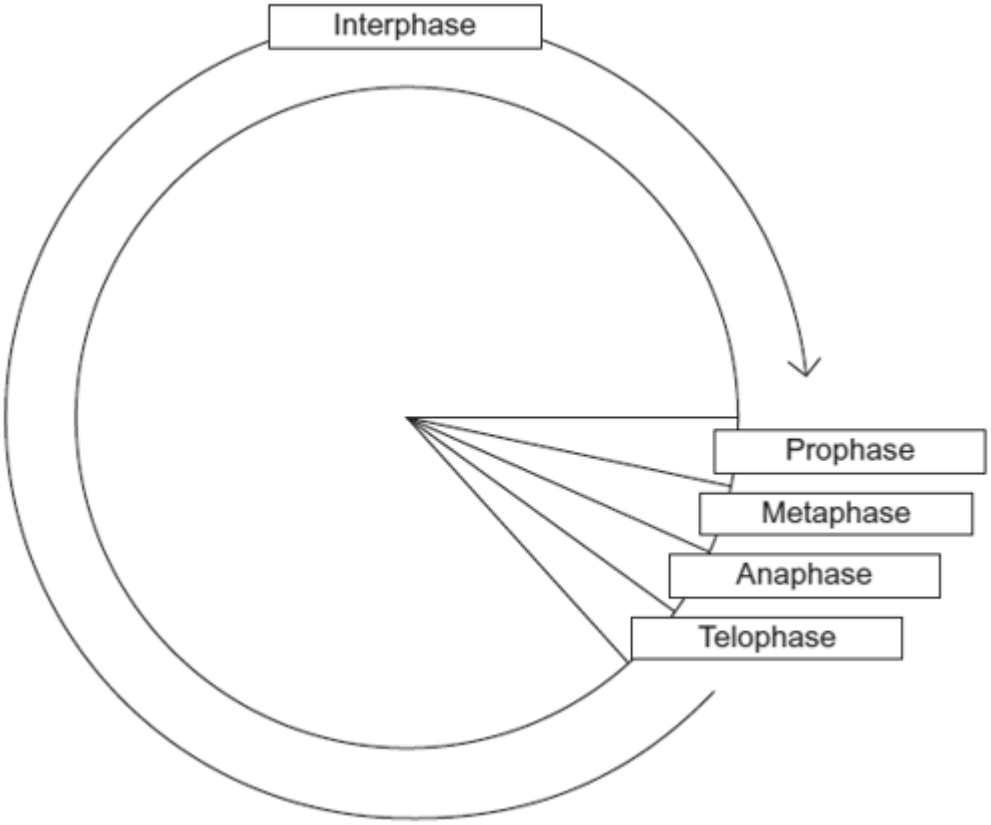
_____

(1)

(Total 4 marks)

Q21.

The diagram shows a cell cycle.



(a) In prophase of mitosis, the chromosomes become visible. Describe what happens in

(i) metaphase

_____

_____

_____

_____

_____

(2)

(ii) anaphase.

_____

_____

_____

_____

_____

(2)

(b) (i) Cells lining the human intestine complete the cell cycle in a short time. Explain the advantage of these cells completing the cell cycle in a short time.

_____

_____

_____

(1)

(ii) The time required for a cell to complete the cell cycle was 4 hours 18 minutes.

Calculate the time required in minutes for this cell to multiply to produce eight cells.
Show your working.

Answer _____

(2)

(c) Mikanolide is a drug that inhibits the enzyme DNA polymerase. Explain why this drug may be effective against some types of cancer.

_____

_____

_____

_____

_____

(2)

(Total 9 marks)

Q22.

Plant physiologists attempted to produce papaya plants using tissue culture. They investigated the effects of different concentrations of two plant growth factors on small pieces of the stem tip from a papaya plant. Their results are shown in the table.

Concentration of auxin / µmol dm^{-3}	**Concentration of cytokinin / µmol dm^{-3}**		
	5	25	50
0	No effect	No effect	Leaves produced

1	No effect	Leaves produced	Leaves produced
5	No effect	Leaves produced	Leaves and some plantlets produced
10	Callus produced	Leaves and some plantlets produced	Plantlets produced
15	Callus produced	Callus and some leaves produced	Callus and some leaves produced

Callus is a mass of undifferentiated plant cells. Plantlets are small plants.

(a) Explain the evidence from the table that cells from the stem tip are totipotent.

_____

_____

_____

_____

_____

(2)

(b) Calculate the ratio of cytokinin : auxin that you would recommend to grow papaya plants by this method.

Answer _____

(2)

(c) (i) Papaya plants reproduce sexually by means of seeds. Papaya plants grown from seeds are very variable in their yield. Explain why.

_____

_____

_____

_____

_____

(2)

(ii) Explain the advantage of growing papaya plants from tissue culture rather than from seeds.

_____

_____

_____

(1)

(Total 7 marks)

Q23.

Essay

You should write your essay in continuous prose.

Your essay will be marked for its scientific accuracy.

It will also be marked for your selection of relevant material from different parts of the specification and for the quality of your written communication.

The maximum number of marks that can be awarded is

Scientific	16
Breadth of knowledge	3
Relevance	3
Quality of written communication	3

Write an essay on the following topic:

Using DNA in science and technology

(Total 25 marks)

Q24.

SCID is a severe inherited disease. People who are affected have no immunity. Doctors carried out a trial using gene therapy to treat children with SCID. The doctors who carried out the trial obtained stem cells from each child's umbilical cord.

(a) Give **two** characteristic features of stem cells.

1. _____

_____

2. _____

_____

(2)

The doctors mixed the stem cells with viruses. The viruses had been genetically modified to contain alleles of a gene producing full immunity. The doctors then injected this mixture into the child's bone marrow.

The viruses that the doctors used had RNA as their genetic material. When these viruses infect cells, they pass their RNA and two viral enzymes into the host cells.

(b) One of the viral enzymes makes a DNA copy of the virus RNA. Name this enzyme.

_____

(1)

The other viral enzyme is called integrase. Integrase inserts the DNA copy anywhere in the DNA of the host cell. It may even insert the DNA copy in one of the host cell's genes.

(c) (i) The insertion of the DNA copy in one of the host cell's genes may cause the cell to make a non-functional protein. Explain how.

_____

_____

_____

_____

(2)

(ii) Some of the children in the trial developed cancer. How might the insertion of the DNA have caused cancer?

_____

_____

_____

_____

(2)

(d) Five out of the 20 children in the trial developed cancer. Although the cancer was treated successfully, the doctors decided to stop the trial in its early stages. They then reviewed the situation and decided to continue. Do you agree with their decision to continue? Explain your answer.

_____

_____

_____

_____

(2)

(Total 9 marks)

Q25.

Taxol is a drug used to treat cancer. Research scientists investigated the effect of injecting taxol on the growth of tumours in mice. Some of the results are shown in **Figure 1**.

Figure 1

Number of days of treatment	Mean volume of tumour / mm^3	
	Control group	Group injected with taxol in saline
1	1	1
10	7	2
20	21	11
30	43	20
40	114	48
50	372	87

(a) Suggest how the scientists should have treated the control group.

_____

_____

_____

_____

(2)

(b) Suggest and explain **two** factors which should be considered when deciding the number of mice to be used in this investigation.

1. _____

_____

2. _____

_____

(2)

(c) The scientists measured the volume of the tumours. Explain the advantage of using volume rather than length to measure the growth of tumours.

_____

_____

(1)

(d) The scientists concluded that taxol was effective in reducing the growth rate of the tumours over the 50 days of treatment. Use suitable calculations to support this conclusion.

(2)

(e) In cells, taxol disrupts spindle activity. Use this information to explain the results in the group that has been treated with taxol.

_____

_____

_____

_____

_____

_____

(3)

(f) The research scientists then investigated the effect of a drug called OGF on the growth of tumours in mice. OGF and taxol were injected into different mice as separate treatments or as a combined treatment. **Figure 2** and **Figure 3** show the results from this second investigation.

Figure 2

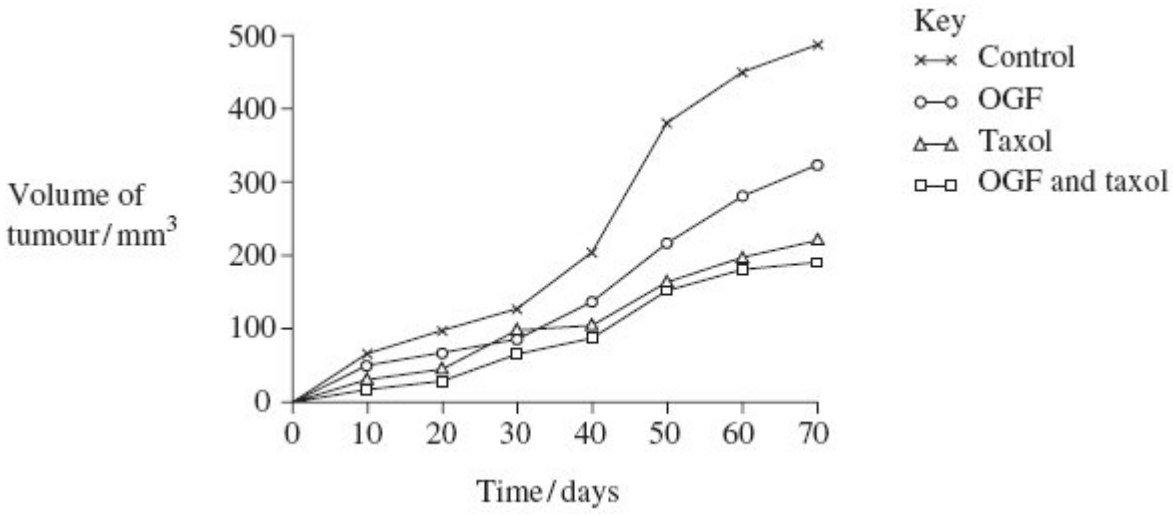


Figure 3

Treatment	Mean volume of tumour following 70 days treatment /mm³ (± standard deviation)
OGF	322 (± 28.3)
Taxol	207 (± 22.5)

OGF and taxol	190 (± 25.7)
Control	488 (± 32.4)

(i) What information does standard deviation give about the volume of the tumours in this investigation?

_____

_____

(1)

(ii) Use **Figure 2** and **Figure 3** to evaluate the effectiveness of the two drugs when they are used separately and as a combined treatment.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

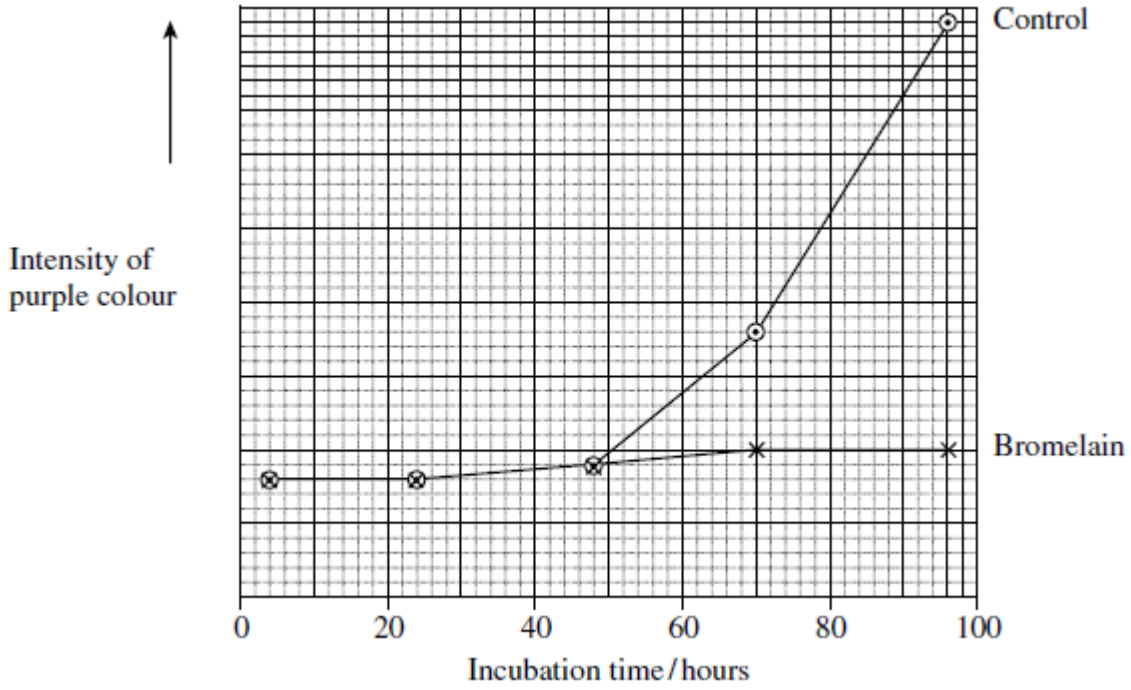
(Total 15 marks)

Q26.

Scientists investigated the effect of bromelain on cancer cells. They took cells from skin cancers in mice and added them to a liquid growth medium in two dishes.

Four hours later they added a solution of bromelain to one of the dishes. They left the other dish as a control. They also added a substance to both dishes that is turned purple by respiring cells.

Both dishes were placed in an incubator. The scientists measured the intensity of the purple colour at intervals over a period of 100 hours.



(a) The scientists put the same number of skin tumour cells in each dish at the start of this investigation. Explain why it was important to put the same number of cells in each dish.

_____

_____

(1)

(b) The scientists concluded that bromelain did not kill cancer cells but stopped them dividing. Does the graph support this conclusion? Explain your answer.

_____

_____

_____

_____

(2)

(c) An article in a newspaper claimed that these data show that bromelain can be used to treat cancer.

Give **three** reasons why we should be careful about accepting this claim.

1. _____

_____

2. _____

_____

3. _____

(3)

(d) The rate of cell division is important in investigations into cancer. Suggest why.

(2)

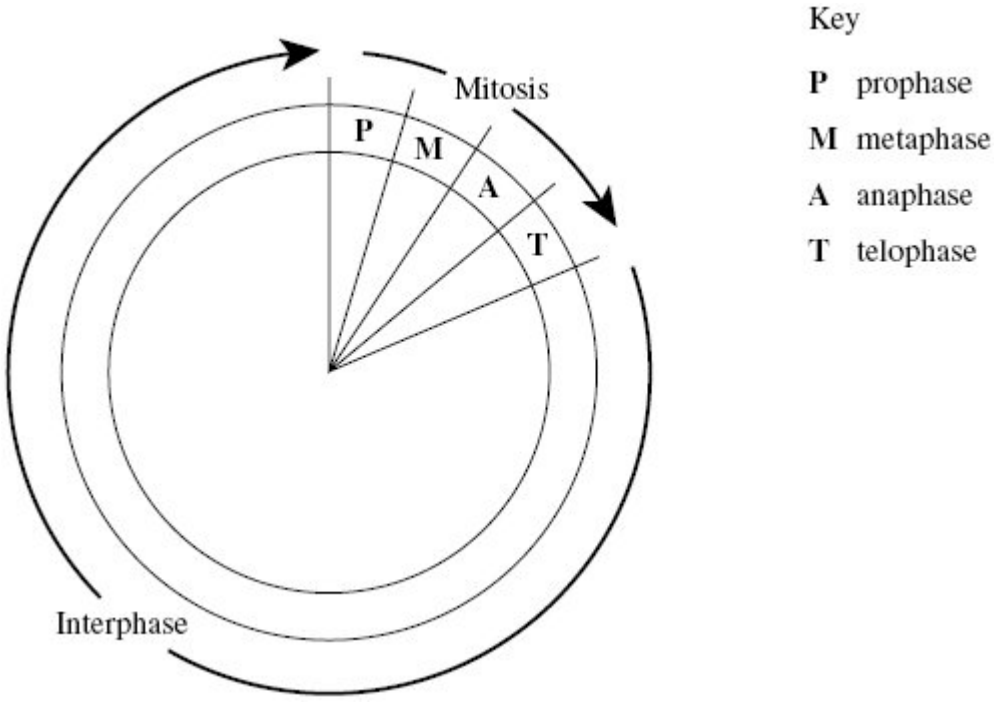
(e) Scientists have investigated the effects of bromelain on cancer growth in humans. Suggest why they gave bromelain in addition to, rather than instead of, the usual treatment.

(2)

(Total 10 marks)

Q27.

The diagram shows a cell cycle.



(a) The table shows the number of chromosomes and the mass of DNA in different nuclei.

All the nuclei come from the same animal. Complete this table.

Nucleus	Number of chromosomes	Mass of DNA / arbitrary units
At prophase of mitosis	26	60
At telophase of mitosis		
From a sperm cell		

(4)

(b) If the DNA of the cell is damaged, a protein called p53 stops the cell cycle.

Mutation in the gene for p53 could cause cancer to develop. Explain how.

_____

_____

_____

_____

_____

_____

(3)

(c) Drugs are used to treat cancer. At what phase in the cell cycle would each of the following drugs act?

(i) A drug that prevents DNA replication

_____

(1)

(ii) A drug that prevents spindle fibres shortening

_____

(1)

(Total 9 marks)

Q28.

Read the following passage.

Soon a single drop of blood might be enough to reveal, at a very early stage, if a patient has cancer. It could also tell us what type of cancer it is and whether it is treatable. Fragments of DNA from body cells are present in blood plasma. Some of these fragments may be from cancer cells. The fragments can be detected by a new test in which a test strip containing nucleic acid binds to sections of altered DNA.

Other cancer-detecting techniques involve removing a tissue sample from a patient. The tissue sample is used to obtain mRNA. By examining the mRNA, scientists can discover whether cancer is present.

Use information from the passage and your own knowledge to answer the questions.

(a) Describe how altered DNA may lead to cancer.

(6)

(b) Explain why fragments of DNA from cancer cells may be present in blood plasma (lines 3-4).

(2)

(c) Explain why the nucleic acid on the test strip will only bind to altered DNA (lines 4-5).

(2)

(d) This test strip will allow cancers to be detected at a very early stage. Explain why cancer is more likely to be treated successfully if the disease is detected at a very early stage.

_____

_____

_____

(2)

(e) Explain how examining mRNA (line 7) enables scientists to discover whether cancer is present.

_____

_____

_____

_____

_____

_____

(3)

(Total 15 marks)

Q29.

(a) Some tumours are benign and some are malignant.

(i) Give **one** way in which a benign tumour differs from a malignant tumour.

_____

(1)

(ii) Describe **two** ways in which both types of tumour may cause harm to the body.

1. _____

_____

2. _____

_____

(2)

(b) (i) Explain the link between sunbathing and skin cancer.

_____

_____

_____

_____

(2)

(ii) Suggest why fair-skinned people are at a greater risk of skin cancer than dark-skinned people when sunbathing.

_____

_____

(1)

(iii) Suggest why people with a family history of cancer are at a greater risk of cancer than those with no family history of cancer.

_____

_____

(1)

(Total 7 marks)

Q30.

Lung cancer, chronic bronchitis and coronary heart disease (CHD) are associated with smoking. **Tables 1** and **2** give the total numbers of deaths from these diseases in the UK in 1974.

Table 1 Men

Age/years	**Number of deaths (in thousands)**		
	lung cancer	chronic bronchitis	coronary heart disease
35 - 64	11.5	4.2	31.7
65 - 74	12.6	8.5	33.3
75+	5.8	8.1	29.1
Total (35 - 75+)	29.9	20.8	94.1

Table 2 Women

Age/years	**Number of deaths (in thousands)**		
	lung cancer	chronic bronchitis	coronary heart disease
35 – 64	3.2	1.3	8.4
65 – 74	2.6	1.9	18.2
75+	1.8	3.5	42.3
Total (35 – 75+)	7.6	6.7	68.9

(i) Using an example from the tables, explain why it is useful to give data for men and women separately.

_____

_____

_____

(2)

(ii) Data like these are often given as percentages of people dying from each cause.

Explain the advantage of giving these data as percentages.

_____

_____

_____

_____

(2)

(Total 4 marks)

Q31.

One hypothesis for the cause of cancer of the colon (large intestine) is that *Clostridium* bacteria present in the gut can convert bile steroids into cancer-causing substances.

(a) Explain the presence of bile in the colon.

_____

_____

_____

_____

(2)

(b) The concentrations of bile steroids and numbers of *Clostridium* bacteria were measured in people with colon cancer and in controls without colon cancer. The table shows the results.

Concentration of bile steroids	Number of *Clostridium* bacteria	Percentage of cancer patients	Percentage of controls	P
high	high	76	9	<0.01
high	low	13	8	<0.01
low	high	7	34	<0.01
low	low	4	49	<0.01

A statistical test showed there was a significant difference between the cancer patients and the controls in each of the four categories.

(i) Explain how the results could be used to support the hypothesis that *Clostridium* bacteria convert bile steroids into substances which cause colon cancer.

_____

_____

_____

_____

(2)

(ii) Explain how the results indicate that other factors may be involved in causing colon cancer.

_____

_____

(1)

(c) Human cells contain genes that control their growth and division. One of these genes codes for a protein that prevents cell division. The substances formed from bile steroids by *Clostridium* bacteria may cause gene mutation. Describe and explain how these substances could cause colon cancer.

_____

_____

_____

_____

_____

_____

_____

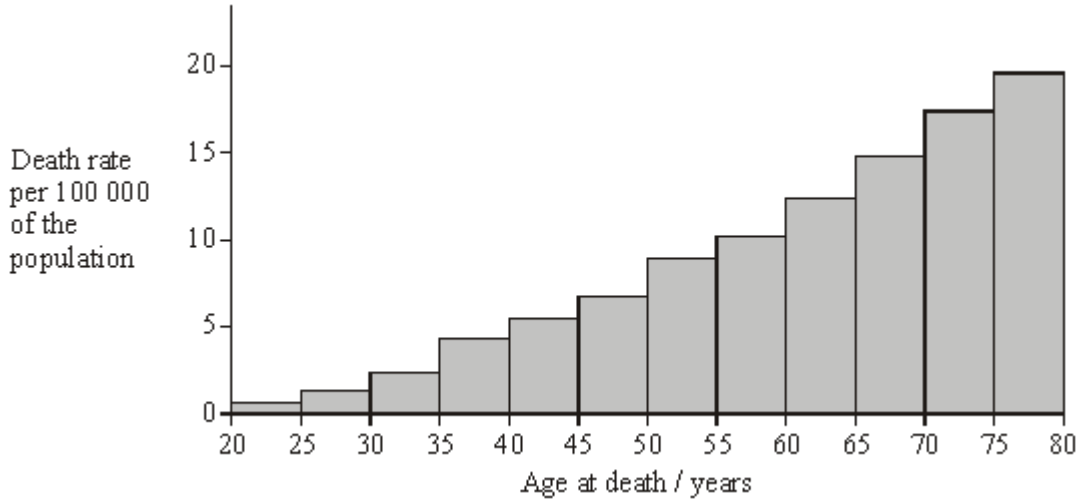
_____

(4)

(Total 9 marks)

Q32.

The death rate from malignant skin tumours was investigated in the USA. The graph shows the results for fair-skinned men in different age groups.



(a) Describe what is meant by a *malignant tumour*.

_____

_____

_____

_____

_____

_____

(3)

(b) Give **one** reason for the change in death rate from malignant skin tumours with increasing age.

_____

_____

(1)

(c) The data for fair-skinned and dark-skinned people were collected separately. Explain why skin colour was a factor likely to affect the death rate.

_____

_____

_____

_____

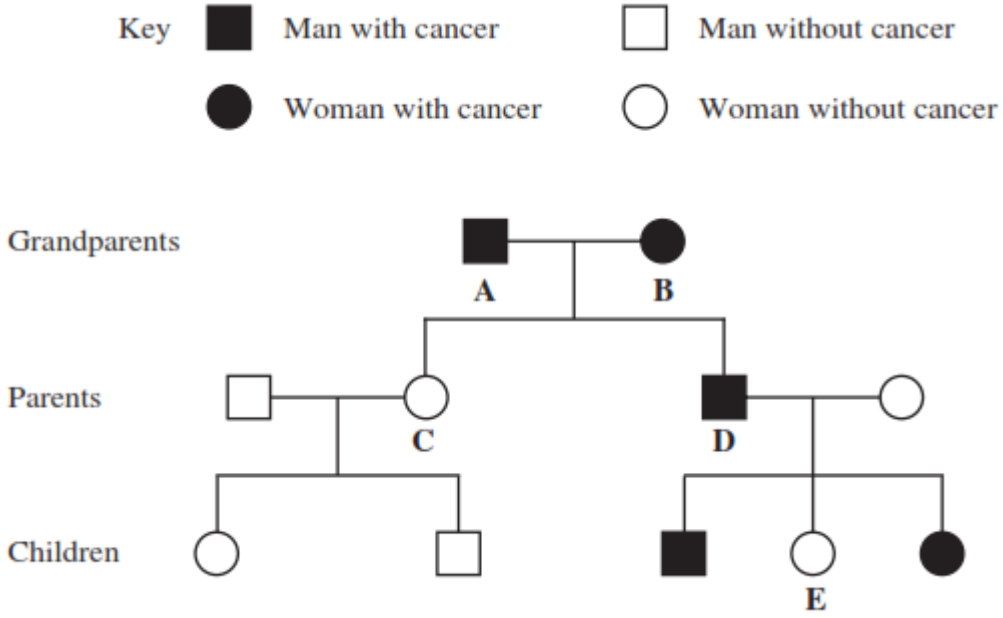
(2)

(Total 6 marks)

Q33.

Li-Fraumeni syndrome is a rare inherited condition. It makes someone much more likely to develop cancer at an early age. The diagram shows part of the family history of a family

affected by Li-Fraumeni syndrome. Li-Fraumeni syndrome is caused by the dominant allele of a gene. The gene is not sex-linked.



The grandparents, **A** and **B**, had two children, girl **C** and boy **D**. Explain how the phenotypes of these children provide evidence that Li-Fraumeni syndrome is

(a) caused by a dominant allele

(2)

(b) **not** sex-linked.

(2)

(c) This family's history of cancer was investigated when person **E** asked for genetic counselling. At the time she was 25 years old. What advice could a genetic counsellor give her about her probability of developing cancer?

(2)

(d) Li-Fraumeni syndrome is caused by a mutation affecting a tumour suppressor gene called TP53. This gene codes for a protein that initiates the death of cells where damaged DNA cannot be repaired. The mutated TP53 gene leads to the production of a non-functional protein. Suggest how the non-functional protein may lead to cancer.

(Extra space)

(3)

(Total 9 marks)

Q34.

Scientists found a correlation between prostate cancer and exposure to cadmium ions.

The scientists investigated the effects of cadmium ions on cells from a human prostate gland.
They grew a culture of these cells in liquid growth medium and removed samples at intervals.

For each sample they measured

- how much DNA was not methylated,
- the activity of the enzyme methyltransferase.

Methyltransferase is an enzyme that adds methyl groups to some of the bases in DNA. The addition of a methyl group is called methylation.

(a) The scientists set up another culture as a control.

Describe how the scientists would have set up a control experiment for this investigation.

_____

(2)

(b) **Figures 1** and **2** show the scientists' results.

Figure 1

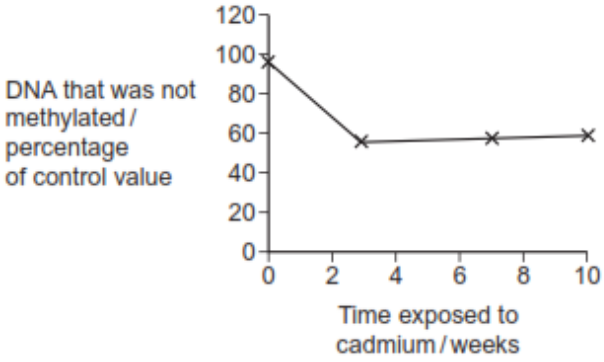
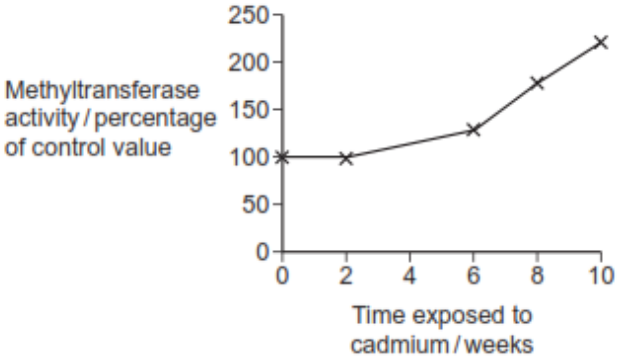


Figure 2



(i) The scientists expressed their results as percentages of the control values. Suggest why.

_____

_____

(1)

(ii) Use information from **Figure 1** to describe how exposure to cadmium ions affected the methylation of DNA.

_____

_____

(1)

(iii) Use information from **Figure 2** to suggest what caused the change to the DNA shown in **Figure 1**.

_____

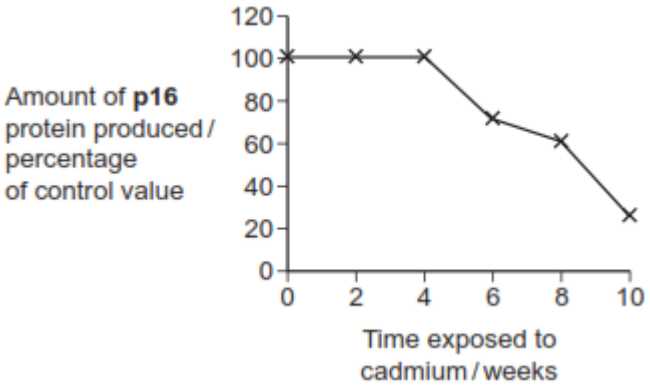
_____

(1)

(c) Prostate gland cells contain a tumour suppressor gene called **p16**.
During the investigation, the scientists also measured the amount of **p16** protein produced.

Figure 3 shows their results.

Figure 3



The scientists found that the promoter DNA of the **p16** gene had become methylated. The promoter is the sequence of bases where the enzyme RNA-polymerase binds to a DNA molecule.

Explain how methylation of the promoter sequence of the **p16** gene could cause the changes shown in **Figure 3**.

_____

_____

_____

_____

(Extra space) _____

_____

(2)

(d) Each week of the investigation, the scientists took samples of the cadmium-treated prostate cells from the laboratory cultures. They injected these cells into mice and monitored the mice for the growth of tumours.

It was only the samples taken in the tenth week that caused tumours to begin to grow in the mice.

Use information from **Figures 1, 2** and **3** to suggest why.

_____

_____

_____

_____

_____

_____

_____

_____

(Extra space) _____

_____

_____

_____

(4)

(Total 11 marks)

Q35.

Read the following passage.

The idea that bacteria could be used as a cancer treatment originated over 100 years ago. A doctor noticed that some cancer patients with bacterial infections showed signs of recovery from the cancer. Attempts to use the bacteria as a treatment were disappointing, however. Experiments showed that the bacteria made an impressive onslaught on tumours, but a ring of cancerous tissue around the edge usually survived.

Bacteria are once again being used in the war on cancer. Scientists have genetically engineered a harmless strain of *Clostridium* to carry the gene for an enzyme. This enzyme converts a harmless "prodrug" into an active drug which acts as a powerful toxin. In people, this strain of *Clostridium* will only grow in tumours. Scientists hope that when they inject the prodrug into a cancer patient's blood, the bacteria will convert it into an active drug. This will destroy tumours from the inside, leaving healthy tissues unharmed.

The idea of converting a harmless prodrug into an active drug that only kills cancer cells is not new. Apart from the use of genetically modified *Clostridium*, other methods have been tried. One of these involved attaching an enzyme to an antibody that binds only to cancer cells. This enzyme then activates the drug. Unfortunately, different types of cancer require different antibodies, making the treatment expensive to develop. Scientists hope their bacterial approach will offer a way of delivering the enzymes to any cancer cell.

(a) Describe how scientists could genetically engineer *Clostridium* bacteria to produce the enzyme which activates the prodrug. (lines 7-8)

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(b) Explain why it is important to destroy all the cancer cells in a tumour.

(2)

(c) Explain how the use of antibodies (lines 16-17) results in a drug only killing cancer cells.

(3)

(d) Cancer drugs usually interfere with DNA replication. Use this information to explain why the cancer drugs are administered as prodrugs and not the active form.

(4)

(Total 15 marks)