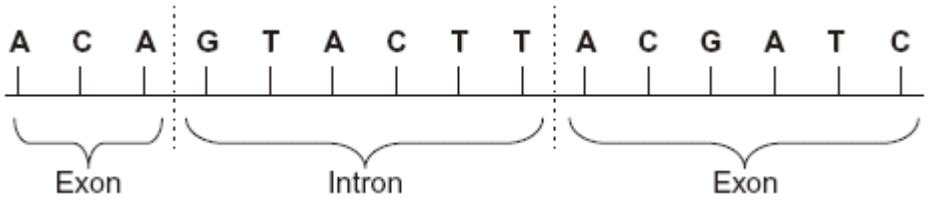
4.2 GENETIC INFORMATION, VARIATION AND RELATIONSHIP – DNA AND PROTEIN SYNTHESIS (2) - QUESTIONS

Q1. (a) Complete the table to show the differences between DNA, mRNA and tRNA.

Type of nucleic acid	Hydrogen bonds present (✓) or not present (✗)	Number of polynucleotide strands in molecule
DNA		
mRNA		
tRNA		

(2)

(b) The diagram shows the bases on one strand of a piece of DNA.



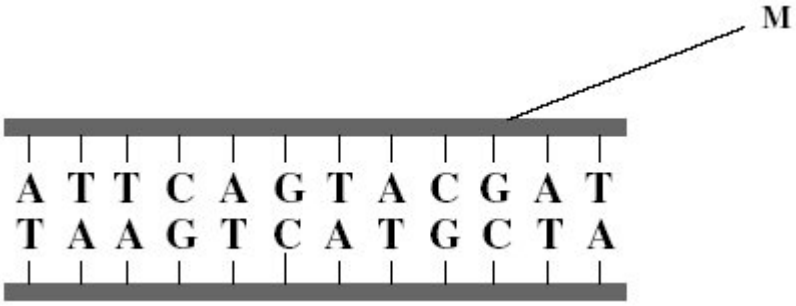
(i) In the space below, give the sequence of bases on the pre-mRNA transcribed from this strand.

(2)

(ii) In the space below, give the sequence of bases on the mRNA produced by splicing this piece of pre-mRNA.

(1)
(Total 5 marks)

Q2. The diagram shows part of a DNA molecule.



(a) Name the **two** components of the part of the DNA molecule labelled **M**.

1. _____

2. _____

(2)

(b) What is the maximum number of amino acids for which this piece of DNA could code?

☐

(1)

(c) Scientists calculated the percentage of different bases in the DNA from a species of bacterium. They found that 14% of the bases were guanine.

(i) What percentage of the bases in this species of bacterium was cytosine?

Answer _____ **(1)**

(ii) What percentage of the bases in this species of bacterium was adenine?

Answer _____ **(1)**

(d) The scientists found that, in a second species of bacterium, 29% of the bases were guanine.

Explain the difference in the percentage of guanine bases in the two species of bacterium.

_____

_____

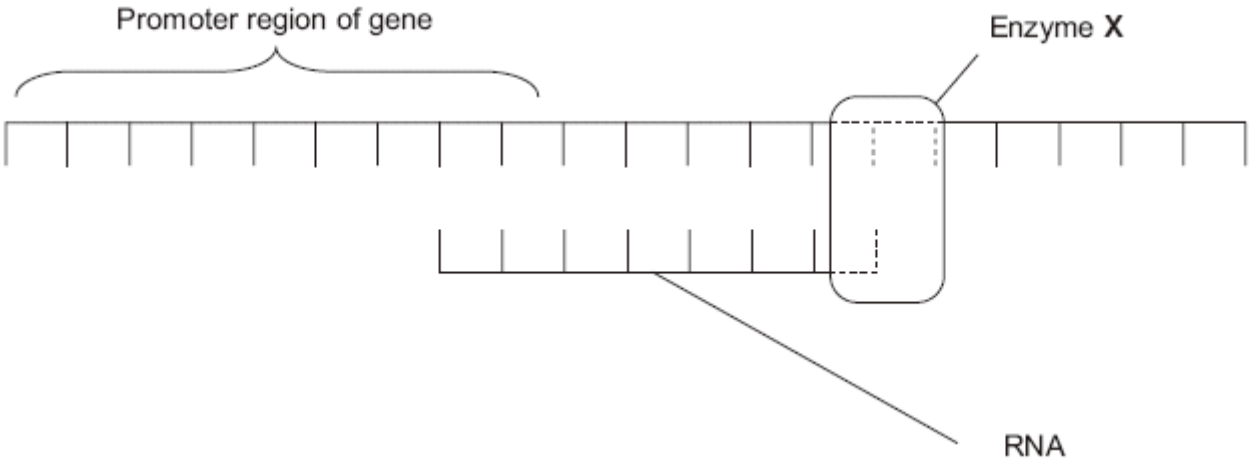
_____

_____ **(2)**

(Total 7 marks)

Q3. **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.

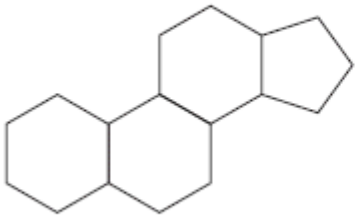
_____

_____ **(1)**

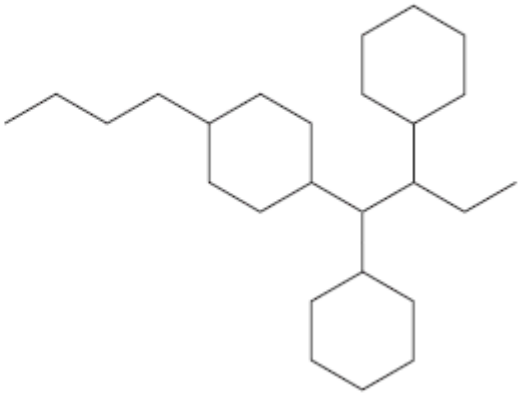
(c) Some breast tumours are stimulated to grow by oestrogen. Tamoxifen is used to treat these breast tumours. In the liver, tamoxifen is converted into an active substance called endoxifen. **Figure 2** shows a molecule of oestrogen and a molecule of endoxifen.

Figure 2

Oestrogen



Endoxifen



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

_____

_____

_____

_____ **(2)**

(Total 6 marks)

Q4. (a) The table shows the mRNA codons for some amino acids.

Codon	Amino acid
CUA	Leucine
GUC	Valine
ACG	Threonine
UGC	Cysteine
GCU	Alanine
AGU	Serine

(i) Give the DNA sequence coding for cysteine.

_____

(1)

(ii) Name the amino acid coded by the tRNA anticodon UCA.

_____

(1)

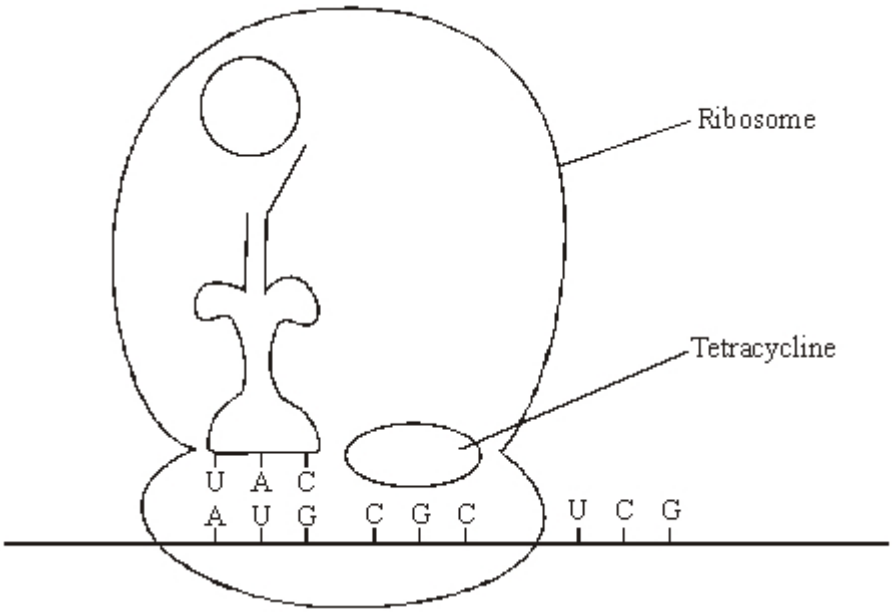
(b) A particular gene is 562 base-pairs long. However, the resulting mRNA is only 441 nucleotides long. Explain this difference.

_____

_____

(1)

(c) Tetracycline binds to bacterial ribosomes. This is shown in the diagram.



Protein synthesis in bacteria is similar to that in eukaryotic cells. Explain how tetracycline stops protein synthesis.

_____

_____

_____

_____

(2)

(Total 5 marks)

Q5. The table shows the sequence of bases on part of the coding strand of DNA.

Base sequence on coding strand of DNA	**C**	**G**	**T**	**T**	**A**	**C**
Base sequence of mRNA						

(a) Complete the table to show the base sequence of the mRNA transcribed from this DNA strand.

(2)

(b) A piece of mRNA is 660 nucleotides long but the DNA coding strand from which it was transcribed is 870 nucleotides long.

(i) Explain this difference in the number of nucleotides.

_____

_____

(1)

(ii) What is the maximum number of amino acids in the protein translated from this piece of mRNA? Explain your answer.

Number of amino acids _____

Explanation _____

_____

(2)

(c) Complete the table to give **two** differences between the structure of mRNA and the structure of tRNA.

mRNA	tRNA

(2)

(Total 7 marks)

Q6. Read the following passage.

The sequence of bases in a molecule of DNA codes for proteins. Different sequences of bases code for different proteins. The genetic code, however, is degenerate. Although the base sequence AGT codes for serine, other sequences may also code for this same amino acid. There are four base sequences which code for the amino acid glycine. These are CCA, CCC, CCG and CCT. There are also four base sequences coding for the amino acid proline. These are GGA, GGC, GGG and GGT.

Pieces of DNA which have a sequence where the same base is repeated many times are called "slippery". When "slippery" DNA is copied during replication, errors may occur in copying. Individual bases may be copied more than once. This may give rise to differences in the protein which is produced by the piece of DNA containing the errors.

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

(a) Different sequences of bases code for different proteins (lines 1 – 2). Explain how.

_____

(2)

(b) The base sequence AGT codes for serine (lines 2 – 3). Give the mRNA codon transcribed from this base sequence.

(2)

(c) Glycine-proline-proline is a series of amino acids found in a particular protein. Give the sequence of DNA bases for these three amino acids which contains the longest "slippery" sequence.

(2)

(d) (i) Explain how copying bases more than once may give rise to a difference in the protein (lines 9 – 10).

(2)

(ii) At what stage in the cell cycle would these errors in copying DNA bases occur?

(1)

(e) Starting with mRNA in the nucleus of a cell, describe how a molecule of protein is synthesised.

(6)
(Total 15 marks)

Q7. In a hospital laboratory, a sterile Petri dish of nutrient agar was inoculated with bacteria from a patient with a throat infection. Four discs, each of which had been soaked in a different antibiotic, were placed on top of the bacteria. The dish was incubated at 37 °C. **Figure 1** shows the appearance of the dish after incubation.

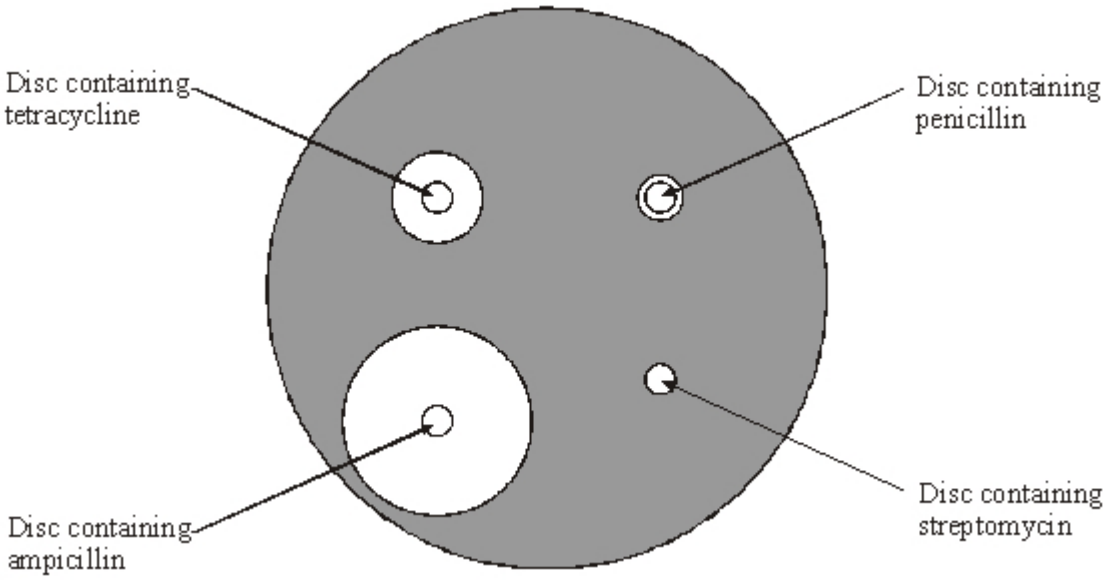


Figure 1

(a) Explain why there are clear zones around some of the discs containing antibiotic.

(2)

(b) It was suggested that ampicillin might be the best antibiotic to treat the patient's throat infection. Give the evidence from the laboratory test to support this suggestion.

(1)

(c) Tetracycline binds to bacterial ribosomes. This is shown in **Figure 2**.

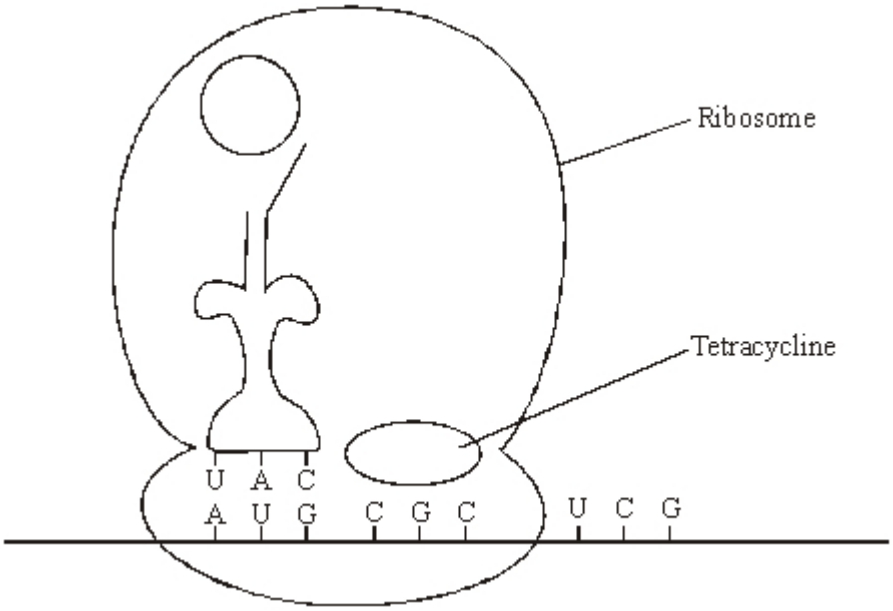


Figure 2

Tetracycline prevents bacterial growth by preventing protein synthesis. Give **two** other ways in which antibiotics can prevent bacterial growth.

1. _____

_____

2. _____

_____

(2)

(Total 5 marks)

Q8. (a) **Table 1** shows some of the events which take place in protein synthesis.

A	tRNA molecules bring specific amino acids to the mRNA molecule
B	mRNA nucleotides join with exposed DNA bases and form a molecule of mRNA
C	The two strands of a DNA molecule separate
D	Peptide bonds form between the amino acids
E	The mRNA molecule leaves the nucleus
F	A ribosome attaches to the mRNA molecule

Table 1

(i) Write the letters in the correct order to show the sequence of events during protein synthesis, starting with the earliest.

_____ _____ _____ _____ _____ _____

(2)

(ii) In which part of a cell does **C** take place?

_____

(1)

(iii) Which of **A - F** are involved in translation?

_____

(1)

(b) **Table 2** shows some mRNA codons and the amino acids for which they code.

mRNA codon	Amino acid
GUU	Valine
CUU	Leucine
GCC	Alanine
AUU	Isoleucine
ACC	Threonine

Table 2

(i) A tRNA molecule has the anticodon UAA. Which amino acid does the tRNA molecule carry?

_____

(1)

(ii) Give the DNA base sequence that codes for threonine.

_____

(1)

(Total 6 marks)

Q9. Lysozyme is an enzyme consisting of a single polypeptide chain of 129 amino acids.

(a) What is the minimum number of nucleotide bases needed to code for this enzyme?

_____

(1)

(b) The diagram shows the sequence of bases in a section of the mRNA strand used to synthesise this enzyme.

G G U C U U U C U U A U G G U A G A U A U

(i) Give the DNA sequence which would be complementary to the first four bases in this section of mRNA.

_____

(1)

(ii) How many different types of tRNA molecule would attach to the section of mRNA shown in the diagram?

_____

(1)

(c) Give **two** factors which might increase the frequency at which a mutation in DNA occurs.

1. _____

2. _____

(2)

(d) Two single base mutations occurred in the DNA coding for this section of mRNA. These mutations caused an alteration in the sequence of amino acids in the enzyme. The diagram shows the original and altered sequences of amino acids.

Original amino acid sequence	Gly	Leu	Ser	Tyr	Gly	Arg	Tyr
Original mRNA base sequence	GGU	CUU	UCU	UAU	GGU	AGA	UAU

Altered amino acid sequence	Gly	Leu	Tyr	Leu	Trp	Arg	Tyr
Altered mRNA base sequence	GGU	CUU				AGA	UAU

(i) Use the mRNA codons provided in the table to complete the altered mRNA base sequence in the diagram.

Amino acid	**mRNA codons which can be used**
Arg	AGA
Gly	GGU
Leu	CUU or UUA
Ser	UCU
Trp	UGG
Tyr	UAU or UAC

(1)

(ii) Use the information provided to determine the precise nature of the **two** single base mutations in the DNA.

_____

_____

_____

_____

_____

_____

(3)

(Total 9 marks)

Q10. (a) Changes to the protein coat of the influenza virus cause antigenic variability. Explain how antigenic variability has caused some people to become infected more than once with influenza viruses.

_____

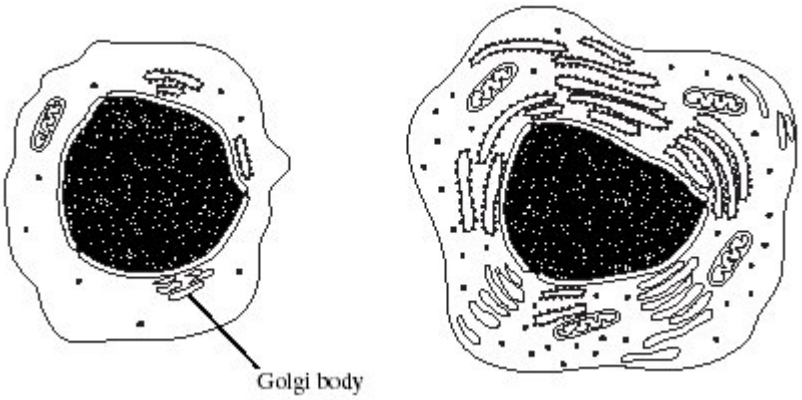
_____

_____

_____

(2)

(b) The drawings show the changes in a B lymphocyte after stimulation by specific antigens.



B lymphocyte before stimulation B lymphocyte after stimulation

(i) Describe the role of macrophages in stimulating B lymphocytes.

_____

_____

(1)

(ii) Explain how the changes shown in the drawings are related to the function of B lymphocytes.

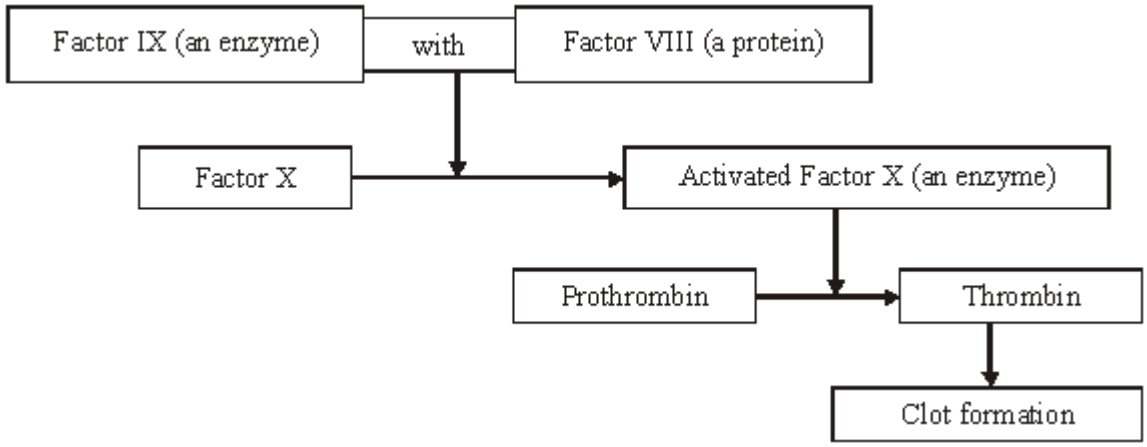
_____

_____

_____

(4)
(Total 7 marks)

Q11. The diagram shows part of the metabolic pathway involved in the clotting of blood in response to an injury.



Haemophilia is a condition in which blood fails to clot. This is usually because of a mutant allele of the gene for Factor VIII.

(a) Explain how mutation could lead to faulty Factor VIII.

(2)

(b) Use information in the diagram to explain how faulty Factor VIII causes haemophilia.

(2)

(c) A boy had haemophilia caused by faulty Factor IX. When his blood was mixed with blood from a haemophiliac with faulty Factor VIII, the mixture clotted. Suggest an explanation for

clotting of the mixture.

_____

_____

_____

_____

(2)

(Total 6 marks)

Q12. Mitochondria contain the genes needed for the synthesis of the enzymes involved in the electron transport chain. One of these enzymes is cytochrome oxidase. If a mutation occurs during replication of the mitochondrial genes, functional cytochrome oxidase may not be produced.

Explain why mutation of a mitochondrial gene might result in no functional cytochrome oxidase being produced.

_____

_____

_____

_____

_____

_____

_____

_____

(Total 5 marks)

Q13. (a) (i) What is the role of RNA polymerase in transcription?

_____

_____

(1)

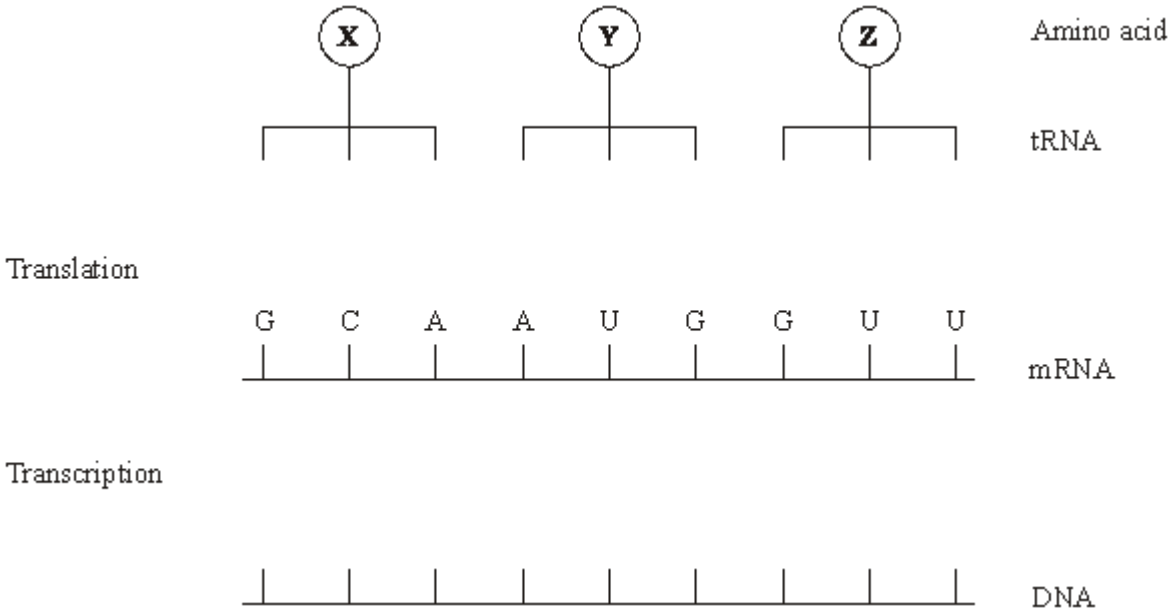
(ii) Name the organelle involved in translation.

_____

(1)

(b) **Figure 1** shows some molecules involved in protein synthesis.

Figure 1



Complete **Figure 1** to show

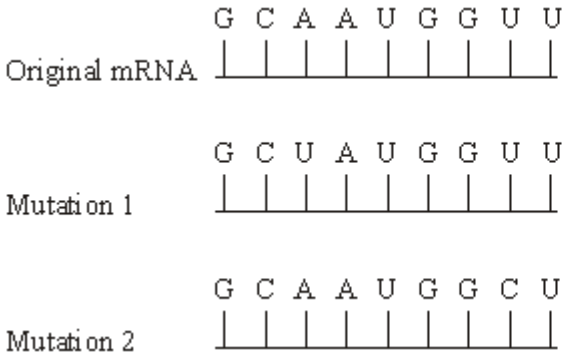
(i) the bases on the DNA strand from which the mRNA was transcribed;

(ii) the bases forming the anticodons of the tRNA molecules.

(2)

Figure 2 shows the effects of two different mutations of the DNA on the base sequence of the mRNA. The table shows the mRNA codons for three amino acids.

Figure 2



Amino acid	mRNA codon
methionine	AUG
valine	GUC GUU
alanine	GCA GCC GCU

(c) Name the type of mutation represented by mutation 1.

_____

(1)

(d) Use the information in the table to

(i) identify amino acid **X** in **Figure 1**;

_____

(1)

(ii) explain how each mutation may affect the polypeptide for which this section of DNA is part of the code.

Mutation 1 _____

_____

_____

_____

(2)

Mutation 2 _____

_____

_____

_____

(2)

(Total 10 marks)

Q14. (a) CFTR is a transmembrane regulator protein. Its molecules have 1480 amino acids. People with cystic fibrosis produce defective CFTR protein which is missing one amino acid from its structure.

(i) What is the minimum number of bases on DNA which would code for the normal CFTR protein? Explain your answer.

Number of bases _____

_____

_____

_____

_____

(2)

(ii) Which type of gene mutation produced the cystic fibrosis allele? Explain your answer.

_____

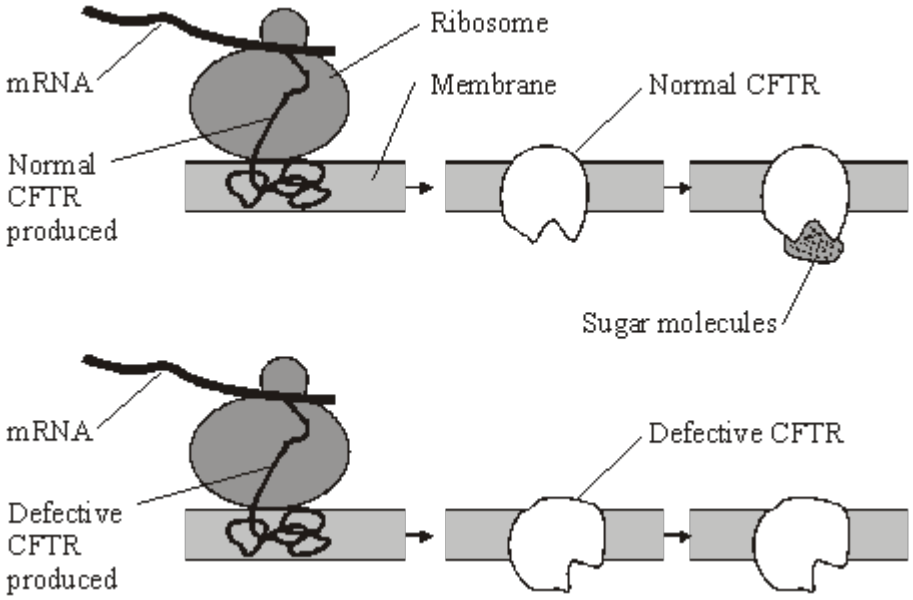
_____

_____

_____

(2)

(b) The diagram shows part of the process of making normal and defective CFTR in a cell. A normal CFTR protein molecule has sugar molecules attached to it which make it functional.



Describe how the information on mRNA is translated into CFTR at the ribosome.

(4)

(Total 8 marks)

Q15. (a) Give **two** factors, other than cost, that should be considered when selecting an antibiotic to treat a bacterial disease.

1. _____

2. _____

(2)

(b) The table describes the effects of two antibiotics on bacteria.

Antibiotic	Effect

Tetracycline	prevents tRNA binding
Chloramphenicol	prevents peptide bonds forming

(i) Explain how each of these antibiotics slows down the rate of growth of bacteria.

Tetracycline _____

_____

_____

_____

Chloramphenicol _____

_____

_____

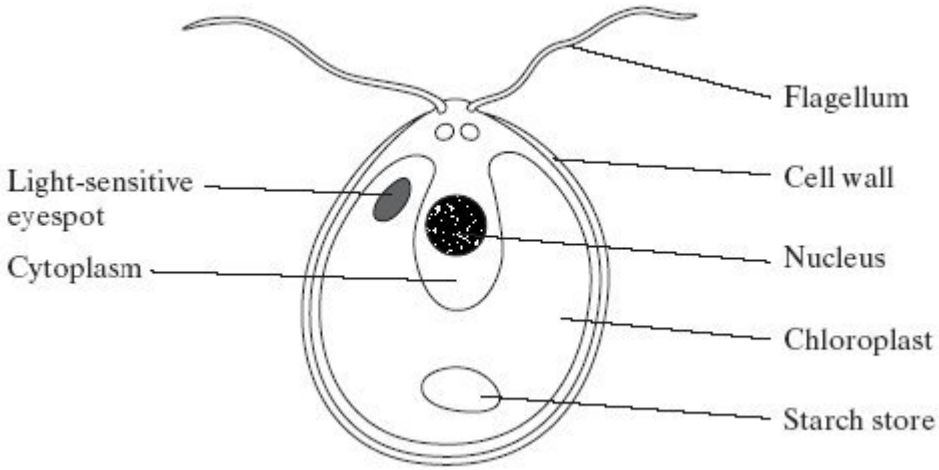
_____ **(4)**

(ii) Suggest why tetracycline has no effect on human cells.

_____ **(1)**

(Total 7 marks)

Q16. The diagram shows a single-celled organism called *Chlamydomonas*.



(a) *Chlamydomonas* lives in fresh-water ponds. It uses its flagella to swim towards light of moderate intensity but away from very bright light. Using information in the diagram, explain the advantage of this behaviour.

_____

_____

_____

_____ **(2)**

(b) A *Chlamydomonas* cell has two flagella. These flagella contain a single sort of protein. A flagellum consists of a bundle of 242 filaments. Each filament consists of 7500 protein molecules. Each protein molecule contains 900 amino acid units.

(i) What would be the minimum number of nucleotides in the coding region of the mRNA used to synthesise this protein?

_____

(1)

(ii) In an investigation, a culture of *Chlamydomonas* was treated in a way that caused them to lose their flagella without any other damage to the cells. The flagella grew back to their original length in 60 minutes.

How many amino acid molecules would be incorporated into each growing flagellum per minute? Show your working.

Answer _____

(2)

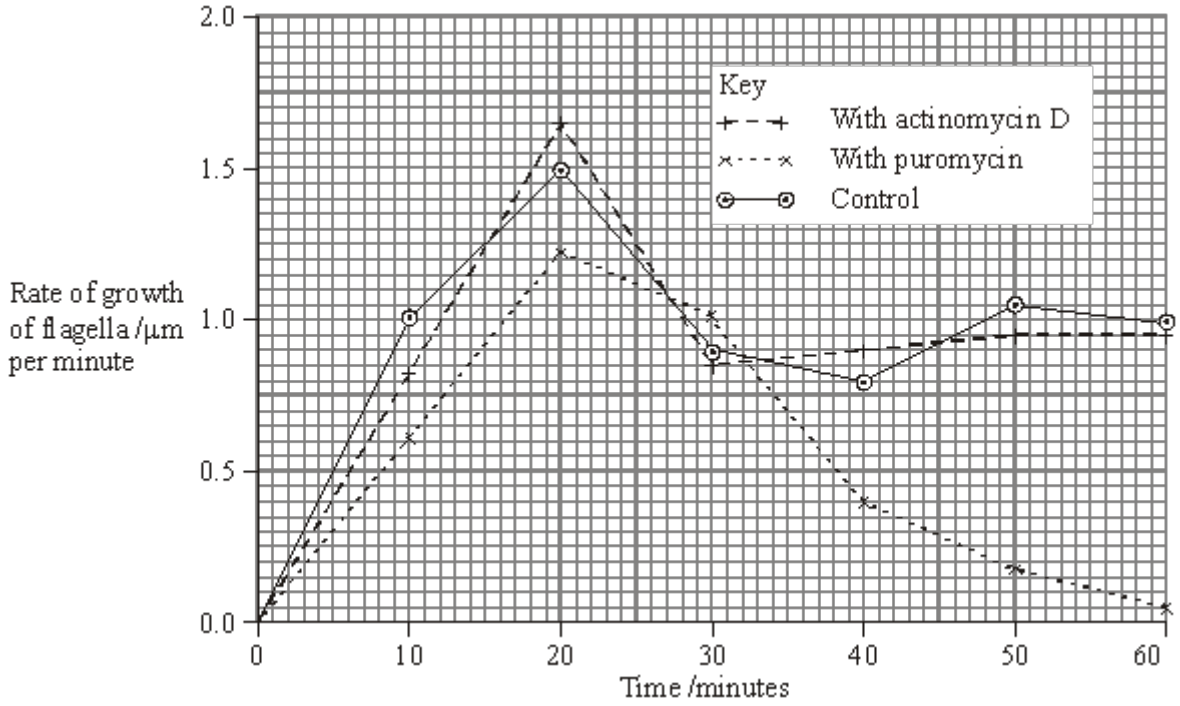
(c) The researchers investigated the rate at which the flagella grew in three different media.

1. A medium containing actinomycin D, which prevents transcription by binding to the guanine in DNA

2. A medium containing puromycin, which prevents translation by attaching to ribosomes

3. A control medium

The results are shown in the graph.



(i) Describe how the rate of growth was affected by puromycin.

_____

_____

_____

_____

(2)

(ii) The researchers concluded

1. that the cells used mRNA that is already present in the cytoplasm for the regrowth of the flagella;

2. that some of the regrowth uses protein molecules already present in the cell.

Explain the evidence for each of these conclusions.

1. _____

_____

_____

_____

2. _____

_____

_____

_____ **(4)**

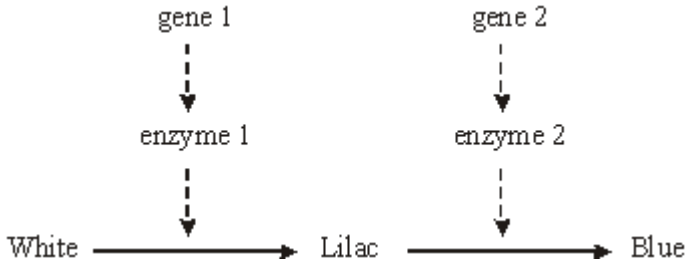
(Total 11 marks)

Q17. (a) Name **one** mutagenic agent.

_____

(1)

(b) In flax plants the flowers are white, lilac or blue. The diagram shows the pathway by which the flower cells produce coloured pigments.



(i) A deletion mutation occurs in gene 1. Describe how a deletion mutation alters the structure of a gene.

_____

_____

_____

_____

(2)

(ii) Describe and explain how the altered gene could result in flax plants with white-coloured flowers.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(iii) Electrophoresis was used to separate the enzymes involved in this pathway. When extracts of the differently coloured flax petals were analysed, four different patterns of bands were produced. In the table, only bands that contain functional enzymes are shown.

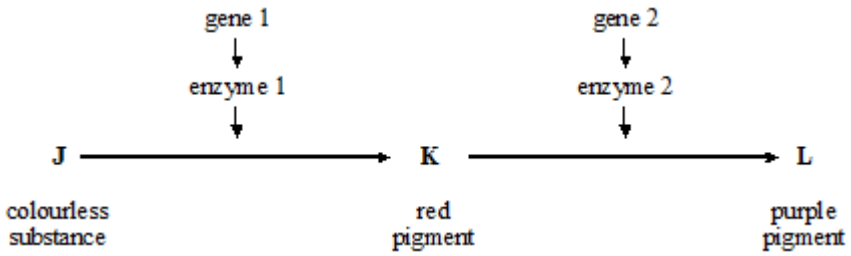
Result of electrophoresis	Colour of petal
	White
	
	
	

Complete the table to give the colour of the petal from which each extract was taken.

(2)

(Total 9 marks)

Q18. A species of flowering plant can have white, red or purple flowers. The colour of the flowers is controlled by two genes. Each gene is found on a different chromosome, and is responsible for one step in a biosynthetic pathway. The biosynthetic pathway is



Gene 1 has the dominant allele **A** and the recessive allele **a**. Gene 2 has the dominant allele **B** and the recessive allele **b**. In both cases, the dominant allele needs to be present for the production of the associated enzyme.

(a) Explain how the two genes are involved in producing white, red or purple flowers.

_____

_____

_____

_____

(6)

(b) (i) A homozygous red-flowered plant was crossed with a homozygous white-flowered plant. All the flowers of the offspring were purple. What was the genotype of

the red-flowered parent;

_____

the white-flowered parent?

_____

(2)

(ii) The purple-flowered offspring were crossed. What phenotypic ratio would you expect in the next generation? Use a genetic diagram to explain your answer.

(4)

(c) (i) Genetically, there are different types of white-flowered plants of this species. Give their different genotypes.

_____

(1)

(ii) You have samples of fresh petals from the two homozygous types of white flowers, and a pure sample of the red pigment, **K**. Explain, in outline, how you might distinguish the two types of petal from each other.

_____

_____

_____

_____

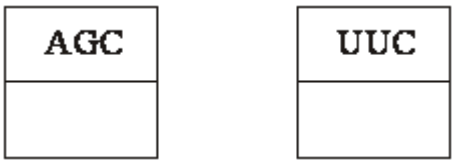
_____

(2)

(Total 15 marks)

Q19. (a) **Figure 1** shows the exposed bases (anticodons) of two tRNA molecules involved in the synthesis of a protein.

Figure 1



Complete the boxes to show the sequence of bases found along the corresponding section of the coding DNA strand.

(2)

(b) Describe the role of tRNA in the process of translation.

_____

_____

_____

_____

_____

_____

(3)

(c) **Figure 2** shows the sequence of bases in a section of DNA coding for a polypeptide of seven amino acids.

Figure 2

TACAAGGTCGTCTTTGTCAAG

The polypeptide was hydrolysed. It contained four different amino acids. The number of each type obtained is shown in the table.

Amino acid	Number present
Phe	2
Met	1
Lys	1
Gln	3

Use the base sequence shown in **Figure 2** to work out the order of amino acids in the polypeptide. Write your answer in the table below.

Met						

(2)

(Total 7 marks)

Q20. (a) Complete the table to give **two** differences between DNA and RNA.

Difference	DNA	RNA
1		
2		

(2)

(b) Describe the part played by RNA in protein synthesis.

(Extra space) _____

(3)

(Total 5 marks)

Q21. This question should be answered in continuous prose.
Quality of Written Communication will be assessed in the answer.

(i) Starting with mRNA, describe how the process of translation leads to the production of a polypeptide.

(4)

(ii) Normal tomato plants have an enzyme that softens tomatoes as they ripen. Genetically engineered tomatoes ripen and soften more slowly. A gene was inserted which reduces the amount of softening enzyme produced.

The diagram shows matching parts of the base sequences for the mRNA produced by the gene for the softening enzyme and that produced by the inserted gene.

Softening gene mRNA …AAUCGGAAU…

Inserted gene mRNA …UUAGCCUUA…

Suggest how the inserted gene reduces the production of the softening enzyme.

_____

_____

_____

_____

(2)

(Total 6 marks)

Q22. (a) Complete the table to show **two** differences between the structure of DNA and RNA.

DNA	RNA

(2)

(b) Explain how a gene codes for a protein.

_____

_____

_____

_____

(2)

(c) What are homologous chromosomes?

_____

_____

_____

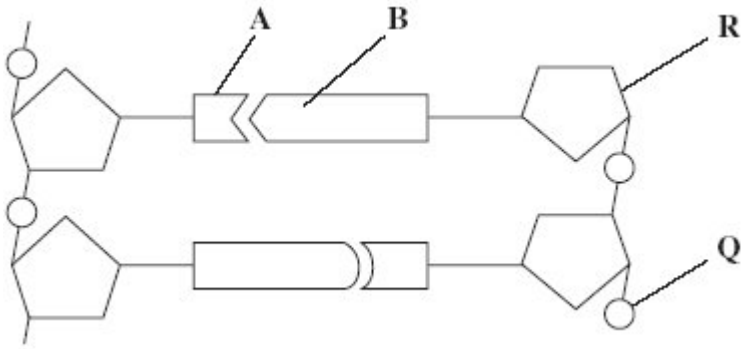
_____

(2)

(Total 6 marks)

Q23. **Figure 1** shows a short section of a DNA molecule.

Figure 1



(a) Name parts **R** and **Q**.

(i) **R** _____

(ii) **Q** _____

(2)

(b) Name the bonds that join **A** and **B**.

_____

(1)

(c) Ribonuclease is an enzyme. It is 127 amino acids long.

What is the minimum number of DNA bases needed to code for ribonuclease?

☐

(1)

(d) **Figure 2** shows the sequence of DNA bases coding for seven amino acids in the enzyme ribonuclease.

Figure 2

G T T T A C T A C T C T T C T T C T T T A

The number of each type of amino acid coded for by this sequence of DNA bases is shown in the table.

Amino acid	Number present
Arg	3
Met	2
Gln	1
Asn	1

Use the table and **Figure 2** to work out the sequence of amino acids in this part of the enzyme. Write your answer in the boxes below.

Gln						

(1)

(e) Explain how a change in a sequence of DNA bases could result in a non-functional enzyme.

_____

_____

_____

_____

_____

_____

(3)

(Total 8 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)