IB · HL · Biology

3 hours 23 questions

Structured Questions

Protein Synthesis

Transcription in Protein Synthesis / Translation in Protein Synthesis / The Genetic Code / Protein Structure & Mutations / Mechanism of Transcription (HL) / Post-Transcriptional Modification (HL) / Translation & the Proteome (HL)

Easy (6 questions)	/44
Medium (11 questions)	/86
Hard (6 questions)	/52
Total Marks	**/182**

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Easy Questions

1 (a) What is the name of the part of the cell where polypeptide synthesis takes place?

.....

(1 mark)

(b) When a polypeptide is synthesised it is important that the amino acids are combined in the correct order to produce a functional protein.

Outline the process that allows the amino acids to be added to the polypeptide in the correct order.

.....

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.....

(3 marks)

(c) After a polypeptide has been synthesised it must undergo a series of changes before it can become a functional protein.

Describe the changes that occur between polypeptide synthesis and the formation of the functional protein.

.....

.....

.....

(3 marks)

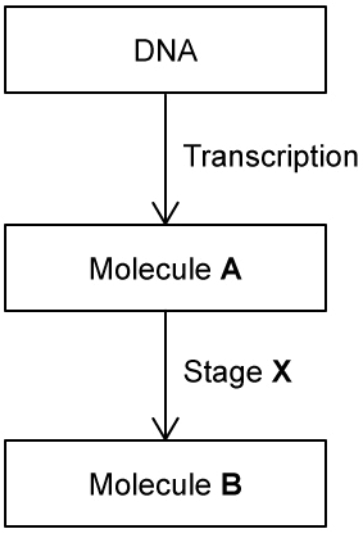
(d) How might a change in the DNA affect the way that the process of protein folding occurs?

.....

.....

(2 marks)

2 (a) The following diagram shows the process of protein synthesis.



(i) Identify stage **X**.

[1]

(ii) State where in the cell stage **X** occurs.

[1]

.....

.....

(2 marks)

(b) Label molecule **A** and **B** in the diagram.

.....

.....

(2 marks)

(c) State **one** difference in structure between DNA and molecule **A** identified at part b).

.....

(1 mark)

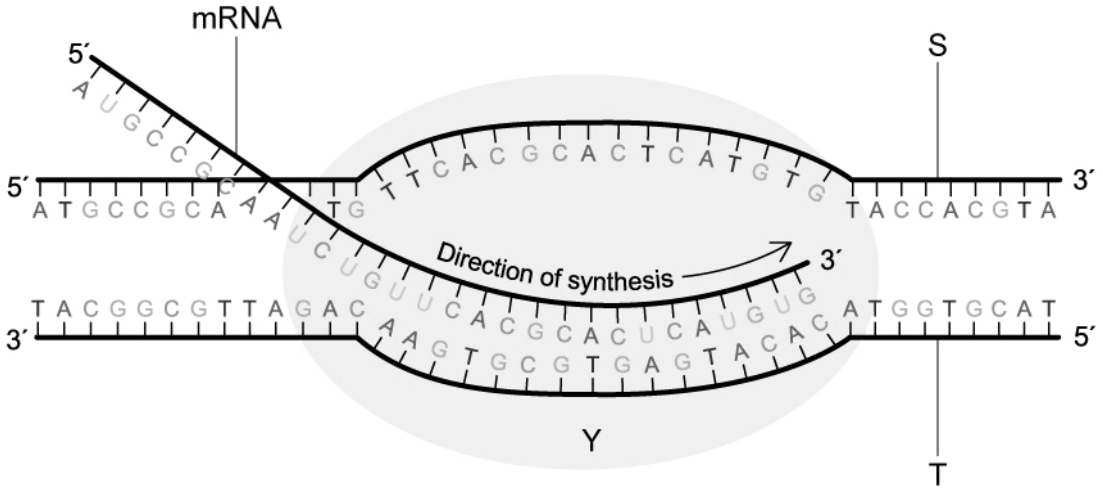
(d) Molecule **B** is synthesised from monomers.

Identify the monomers of molecule **B**.

.....

(1 mark)

3 (a) The diagram below shows one of the stages in protein synthesis.



(i) Identify the stage of protein synthesis represented by the diagram.

[1]

(ii) State **one** reason for your answer in part i).

[1]

.....

.....

(2 marks)

(b) Enzyme **Y** plays an important role during the stage of protein synthesis identified at part a) i).

(i) Identify enzyme **Y**.

[1]

(ii) State the role of this enzyme during protein synthesis.

[1]

.....

.....

(2 marks)

(c) Label strands **S** and **T** of the DNA molecule.

.....

.....

(2 marks)

(d) Explain the purpose of creating an mRNA copy of the genetic code on the DNA molecule.

.....

.....

(2 marks)

4 (a) The following DNA base triplets form part of a gene coding for a polypeptide.

CCC ATA CTT GGA

State the mRNA codons that would be transcribed from this section of the gene.

.....

.....

(2 marks)

(b) The gene mentioned in part a) formed an mRNA molecule that consisted of 180 nucleotides.

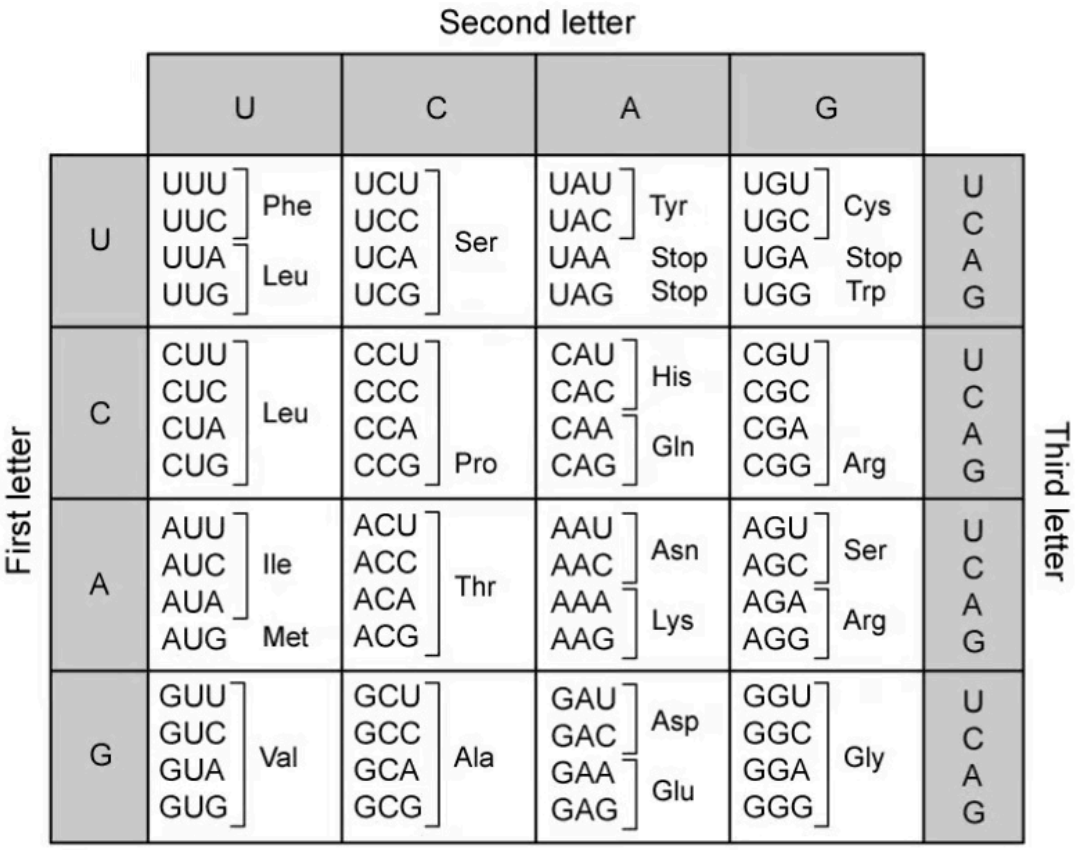
Calculate the number of amino acids that will be coded for by this gene. Show your working.

.....

.....

(2 marks)

(c) The table below shows mRNA codons and their corresponding amino acids.



Use this table to state the amino acid sequence of the section of the gene given in part a).

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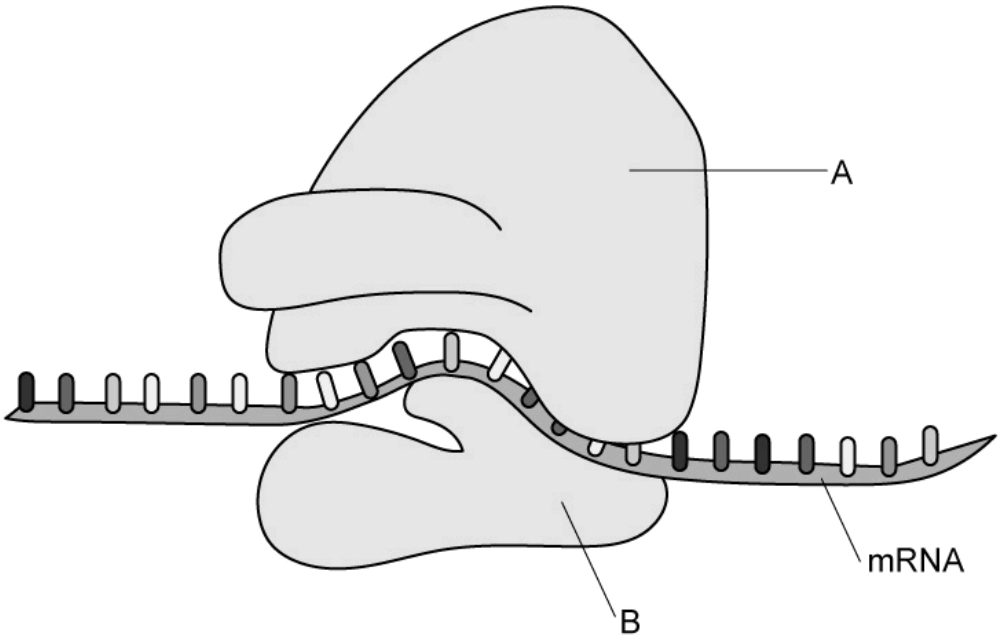
(2 marks)

5 (a) The diagram below shows the structure of a ribosome.



Identify parts **A** and **B** of the ribosome.

.....

.....

(2 marks)

(b) State **one** substance that a ribosome is composed of.

.....

(1 mark)

(c) Describe the role of a ribosome in the process of protein synthesis.

.....

.....

(2 marks)

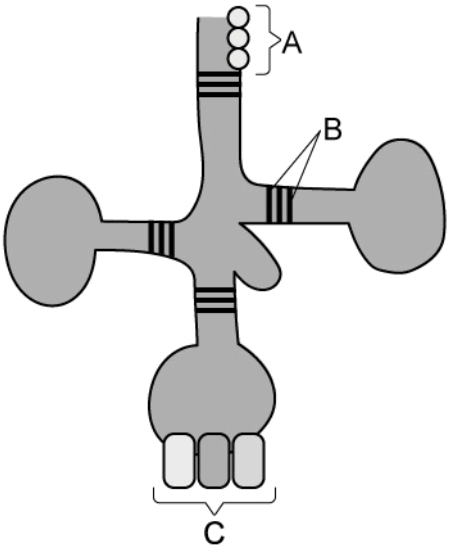
(d) The mRNA molecule that is shown in the diagram at part a) carries the genetic code in the form of codons.

Define the term 'codon'.

.....

(1 mark)

6 (a) The diagram below shows the structure of a tRNA molecule.



Identify the type of molecule that would bind to site **A**.

.....

(1 mark)

(b) (i) Identify the type of bond present at **B**.

[1]

(ii) State the purpose of these bonds in a tRNA molecule.

[1]

.....

.....

(2 marks)

(c) Describe the role of **C** in the process of translation.

.....

.....

(2 marks)

(d) Before tRNA molecules can partake in translation, they bind to tRNA-activating enzymes.

State the purpose of tRNA-activating enzymes.

.....

(1 mark)

(e) Outline the steps involved in the initiation of translation.

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.....

.....

(3 marks)

Medium Questions

1 (a) The following base sequences represent sections of two different alleles of the gene which determines an individual's ability to roll their tongue.

Allele A (tongue roller): GCCGTAAC
Allele B (non-tongue roller): GCGCTTAC

Outline why two different alleles result in different expressions of a gene.

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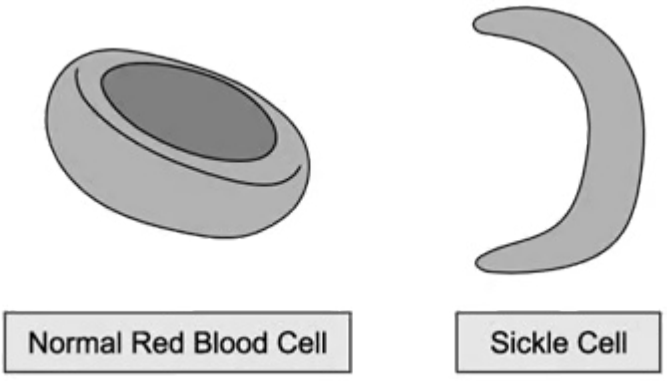
(3 marks)

(b) Sickle cell anemia is a genetic disorder with symptoms such as dizziness, a rapid heart rate and fatigue. It is caused by an allele that leads to altered haemoglobin proteins. These altered proteins undergo aggregation (sticking together), an event which changes the shape of red blood cells. This can be seen in the image below.



Suggest how sickled red blood cells may result in the symptoms noted above.

.....

.....

.....

(3 marks)

(c) Suggest why the shape of white blood cells is not affected by sickle cell anaemia.

.....

(1 mark)

(d) Mutations such as the one seen in sickle cell patients are usually caused by an error during DNA replication.

Identify the enzyme that is responsible for catalysing the process of DNA replication.

.....

(1 mark)

2 (a) Myoglobin is a eukaryotic protein consisting of a single polypeptide chain of 153 amino acids.

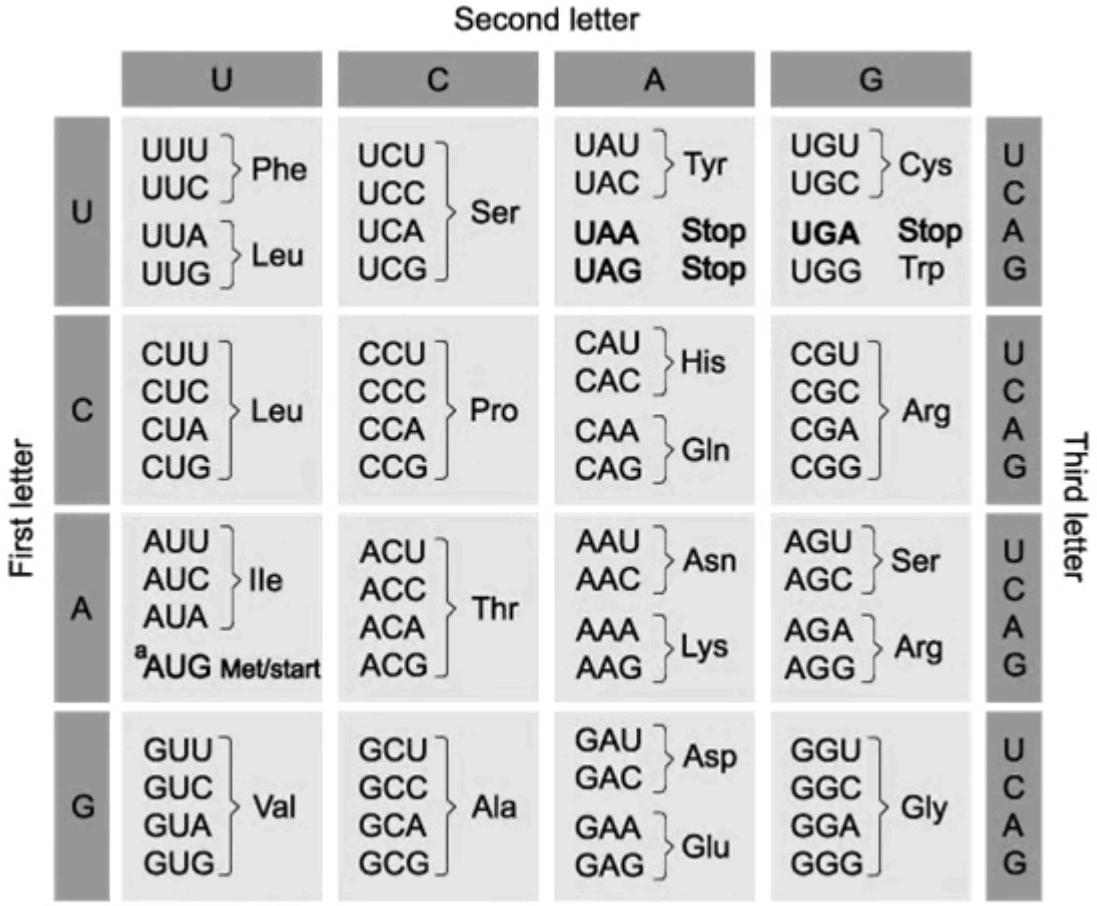
Calculate the minimum number of DNA bases needed to code for Myoglobin.

.....

(1 mark)

(b) Haemoglobin is another eukaryotic protein; it contains both α and β polypeptide chains. Some of the first seven amino acids of an α chain of haemoglobin, along with the corresponding bases in the sequence are shown below. An mRNA codon and amino acid table is also provided.

Amino acid sequence	Met	(i)	Leu	(ii)	(iii)	Ala	Asp
Base sequence in DNA antisense strand (3'→5')	TAC	CAC	GAC	AGA	GGA	CGG	CTG



Use the information provided to identify the missing amino acids from the sequence of seven shown above.

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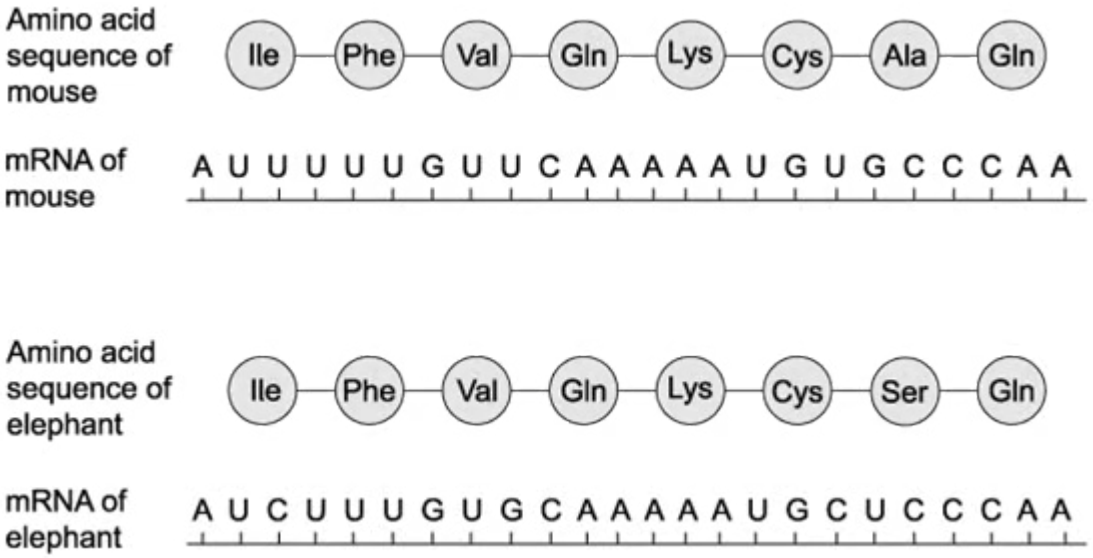
.....

.....

(3 marks)

(c) A third eukaryotic protein, cytochrome c, is involved in the process of aerobic respiration. The diagram below shows part of the mRNA sequence and its corresponding amino acid sequence for cytochrome c in *Mus musculus* (house mouse) and *Loxodonta africana* (African elephant).



Identify the tRNA anticodon that corresponds to the amino acid serine (Ser).

.....

(1 mark)

(d) The triplet codes for the amino acid Ile in part (c) demonstrate a property of the genetic code known as degeneracy, or redundancy.

Use the information in part (c) to:

(i) Suggest what is meant when we say that the genetic code is degenerate/redundant.

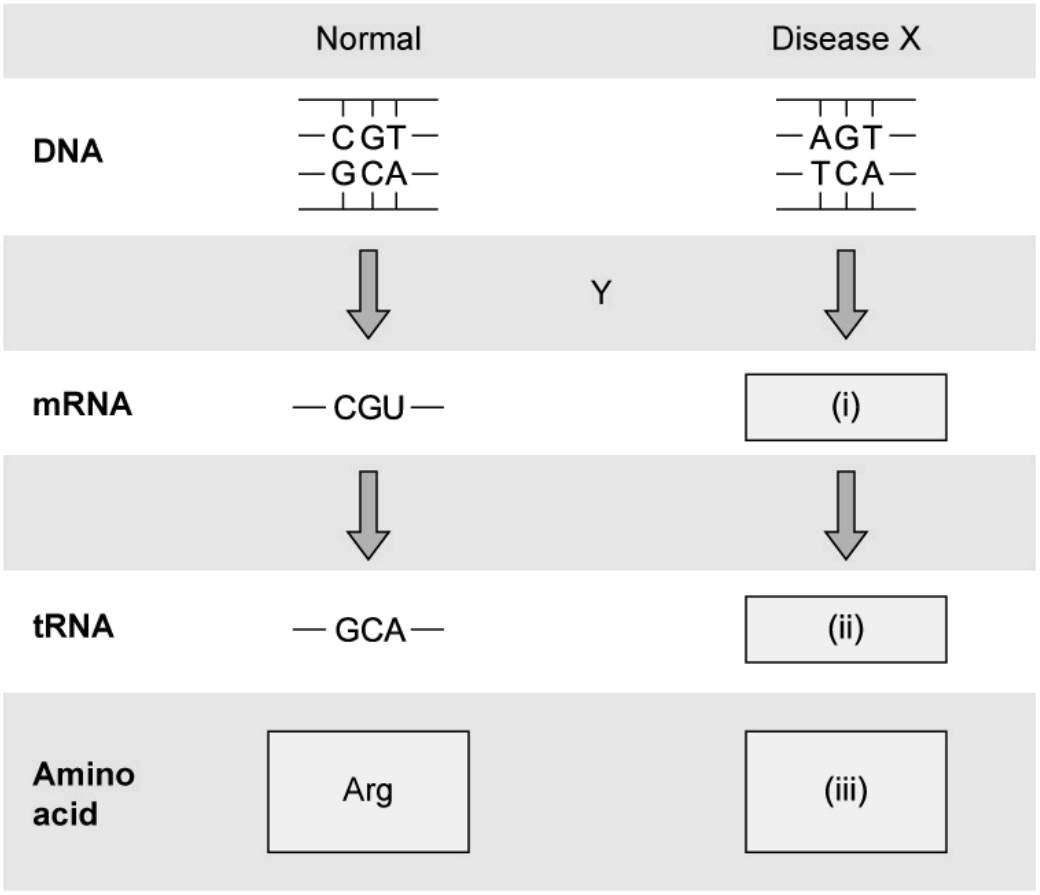
(ii) Identify one **other** amino acid that demonstrates this property.

.....

.....

(2 marks)

3 (a) Disease X is a genetic condition. It is caused by various mutations, one of which is shown in the diagram below.

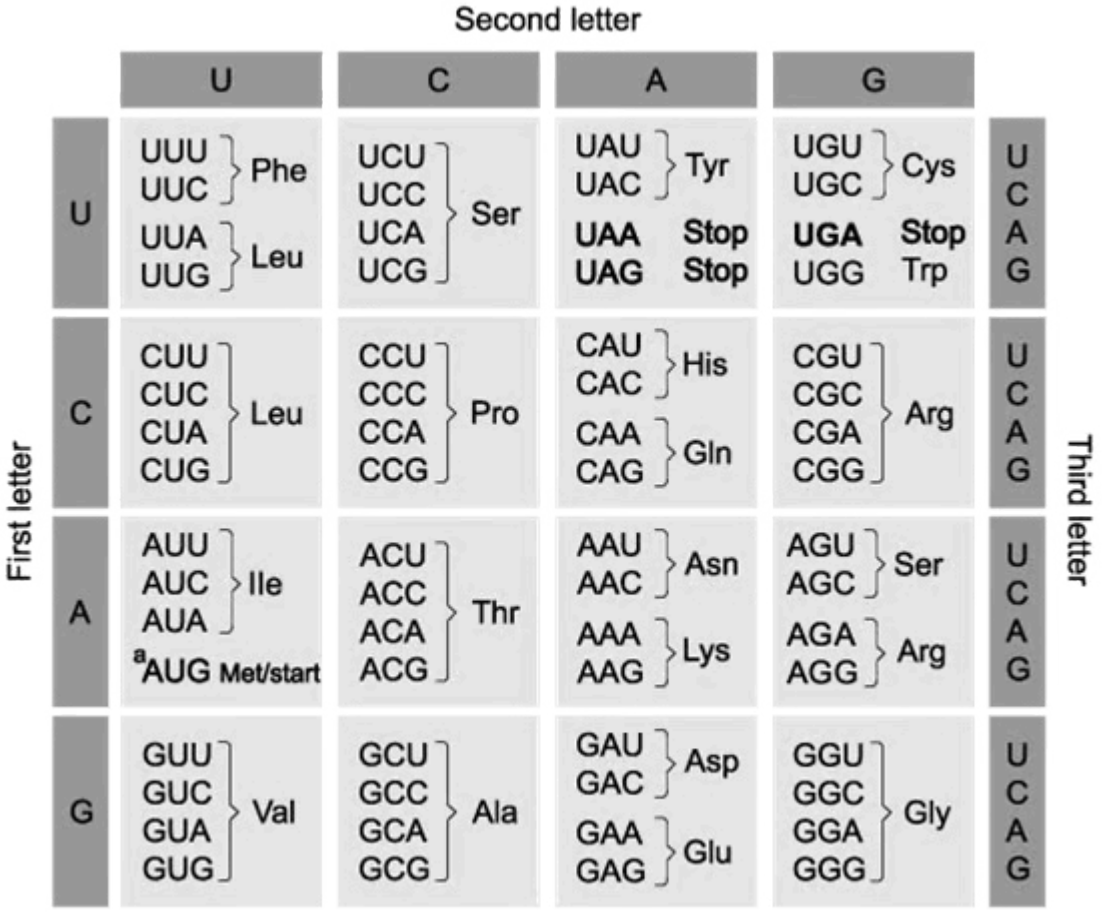


Identify the process marked **Y** in the diagram.

.....

(1 mark)

(b) The table below shows mRNA codons and their corresponding amino acids.



Use the table above and your knowledge of protein synthesis to identify the contents of boxes (i)-(iii) in the diagram in part (a).

.....

.....

.....

(3 marks)

(c) Outline the role of transfer RNA in the process of protein synthesis.

.....

.....

(2 marks)

(d) Explain why the protein produced as a result of the disease **X** mutation shown in part (a) does not function as it should.

.....

.....

(2 marks)

4 (a) The table below shows the exposed bases of two tRNA molecules involved in the synthesis of a protein.

Bases of tRNA anticodon	UAU	GAC
Bases of corresponding DNA antisense strand	(i)	(ii)

Identify the base sequences found on the corresponding sections of the DNA antisense strands.

.....

.....

(2 marks)

(b) Outline how a gene codes for a polypeptide.

.....

.....

.....

(3 marks)

(c) A polypeptide is formed when a series of amino acids join to form a chain.

Identify the following:

(i) The chemical reaction that joins two amino acids together in a polypeptide.

(ii) The type of bond that joins two amino acids together in a polypeptide.

.....

.....

(2 marks)

5 (a) Draw an annotated diagram to illustrate the structure of a DNA double helix. You do not have to show the helical shape in your diagram.

(5 marks)

(b) Describe the process of transcription in eukaryotic cells.

(6 marks)

6 (a) The human genome is approximately 3 billion, or 3 000 000 000, base pairs long. A DNA sequencing machine allows for 5.5×10^8 base pairs to be sequenced per hour.

Using this information calculate the number of days it would take to sequence 1500 genomes of hospital patients using this machine. Give your answer to the nearest day.

.....

.....

(2 marks)

(b) The table below shows part of the DNA base sequence coding for β-haemoglobin and two mutations of this sequence detected in a sickle cell sufferer.

DNA base sequence coding for β-haemoglobin												
mRNA sequence for β-haemoglobin	A	C	U	C	C	U	G	A	G	G	A	G
DNA base sequence with mutation 1												
mRNA base sequence with mutation 1	A	C	U	C	C	U	G	U	G	G	A	G
DNA base sequence with mutation 2												
mRNA base sequence with mutation 2	A	C	U	C	C	U	G	A	A	G	A	G

Complete the table with the DNA sequences that will undergo transcription to produce β-haemoglobin, mutated protein **1,** and mutated protein **2**.

.....

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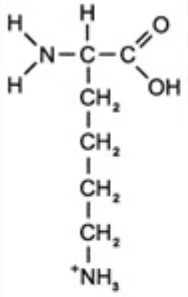
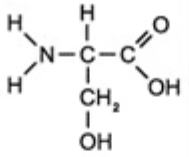
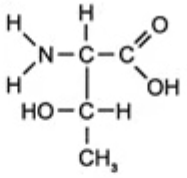
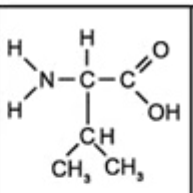
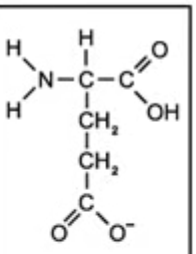
(3 marks)

(c) The table below shows some examples of amino acids, their structures, and the mRNA codons that code for them.

Amino Acid	 Lys	 Ser	 Thr	 Val	 Glu
mRNA codons	AAA AAG	AGU AGC	ACU ACG ACA ACC	GUU GUG GUC GUA	GAA GAG

Suggest why mutation **2** from part (b) is of no concern to the scientists studying this patient's DNA

(2 marks)

(d) A karyogram, such as the one shown in the image below, can be used to detect some Mutations

State why this karyogram could not be used to detect sickle cell anaemia.

.....

(1 mark)

7 (a) Messenger RNA (mRNA) and transfer RNA (tRNA) are important molecules required for the transcription and translation of proteins.

Contrast the structures of mRNA and tRNA.

.....

.....

(2 marks)

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

.....

.....

.....

(3 marks)

(c) Tobacco plants have been genetically modified to produce human haemoglobin. The first three triplets of the non-coding (template) strand of the human haemoglobin gene are:

ATG GTG CAT

Deduce the anticodons of the corresponding tRNA molecule.

.....

(1 mark)

(d) The base sequence below is found in a section of the mRNA strand used to synthesise an enzyme found in tobacco plants.

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

Using the diagram, deduce how many different **types** of tRNA molecules would attach to the section of mRNA shown in the diagram?

.....

(1 mark)

8 (a) Describe the function of ribosomes in protein synthesis.

(4 marks)

(b) Within a cell ribosomes can be found free or bound to structures.

Contrast free ribosomes with bound ribosomes.

(2 marks)

(c) Ribosomes are made of ribosomal RNA (rRNA). Messenger RNA (mRNA), transfer RNA (tRNA) and DNA are all involved in the synthesis of proteins.

Complete the table to show the differences between DNA, mRNA and tRNA.

Type of nucleic acid	Number of polynucleotide strands in the molecule	The nitrogenous base uracil present (✓) or not present (X)
DNA		
mRNA		
tRNA		

(2 marks)

9 (a) Enzymes play an important role during transcription and translation.

Discuss the importance of enzyme-substrate specificity in the activation of tRNA molecules.

(4 marks)

(b) The tRNA-activating enzyme relies on phosphorylation.

Outline the role of phosphorylation during translation.

(3 marks)

(c) Enzymes, such as the tRNA-activating enzyme, are proteins.

State, with named examples, **two** functions of proteins.

(2 marks)

10 (a) Describe how the process of translation leads to the production of a polypeptide.

(6 marks)

(b) Contrast protein synthesis in eukaryotes with protein synthesis in prokaryotes.

(4 marks)

11 Radiation and mutagenic chemicals can cause mutations in DNA that result in new alleles.

Explain how mutations in DNA can affect the final protein product.

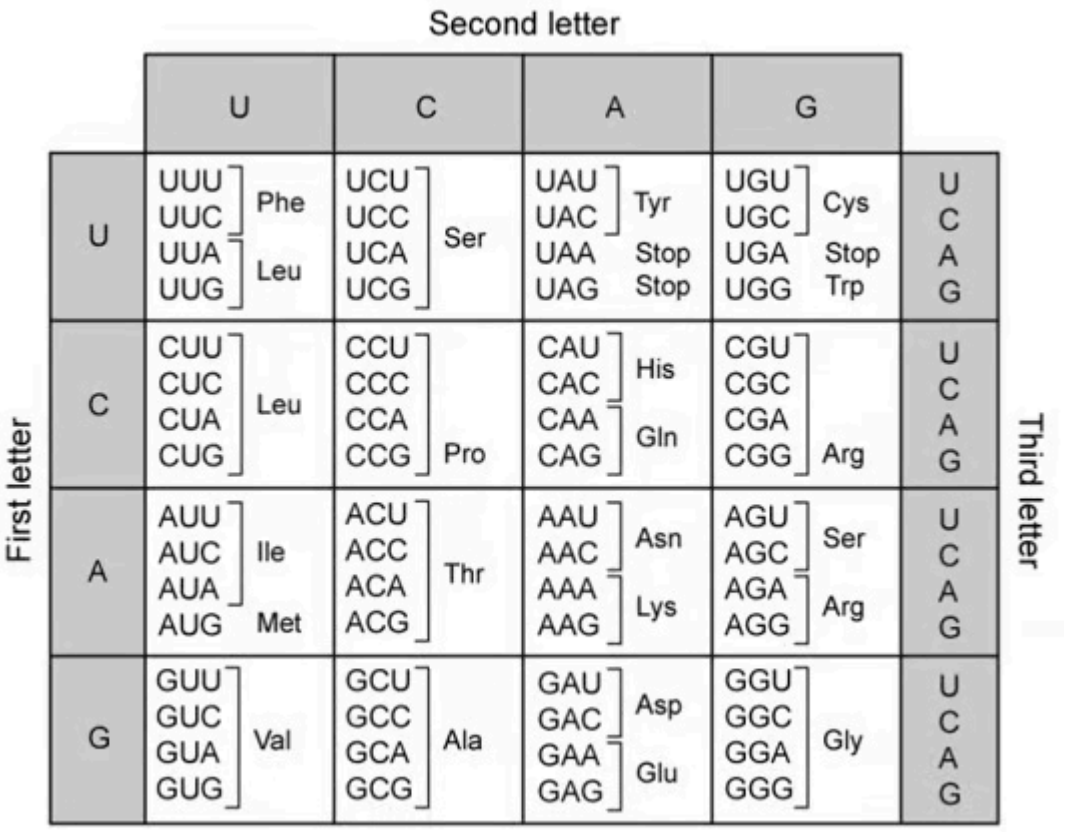
(3 marks)

Hard Questions

1 (a) The sequence below shows the DNA bases coding for seven amino acids in the enzyme papain. Note that the sequence shown is from the **sense** strand.

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

The image shows the genetic code (mRNA codons).



First letter	Second letter: U	Second letter: C	Second letter: A	Second letter: G	Third letter
U	UUU, UUC: Phe; UUA, UUG: Leu	UCU, UCC, UCA, UCG: Ser	UAU, UAC: Tyr; UAA: Stop; UAG: Stop	UGU, UGC: Cys; UGA: Stop; UGG: Trp	U C A G
C	CUU, CUC, CUA, CUG: Leu	CCU, CCC, CCA, CCG: Pro	CAU, CAC: His; CAA, CAG: Gln	CGU, CGC, CGA, CGG: Arg	U C A G
A	AUU, AUC, AUA: Ile; AUG: Met	ACU, ACC, ACA, ACG: Thr	AAU, AAC: Asn; AAA, AAG: Lys	AGU, AGC: Ser; AGA, AGG: Arg	U C A G
G	GUU, GUC, GUA, GUG: Val	GCU, GCC, GCA, GCG: Ala	GAU, GAC: Asp; GAA, GAG: Glu	GGU, GGC, GGA, GGG: Gly	U C A G

Use the image to identify the sequence of amino acids in this part of the enzyme.

.....

(1 mark)

(b) **Table 1** below shows some mRNA codons and the amino acids for which they code.

Table 1

Codon	Amino Acid
ACG	Threonine
UUA	Leucine
CCA	Proline
GUA	Valine
GCU	Alanine
AAU	Asparagine

(i) Identify the DNA coding strand sequence for leucine.

[1]

(ii) Identify the amino acid carried by the tRNA with the anticodon CAU.

[1]

.....

.....

(2 marks)

(c) Ricin is a protein produced by castor beans. In animal cells, ricin acts as an enzyme. This enzyme removes the adenine molecule from one of the nucleotides in the RNA that makes up the structure of ribosomes. As a result, the ribosome changes shape. Ricin causes the death of cells and is highly toxic to many animals.

Suggest how the effect of ricin on ribosomes could cause the death of cells.

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.....

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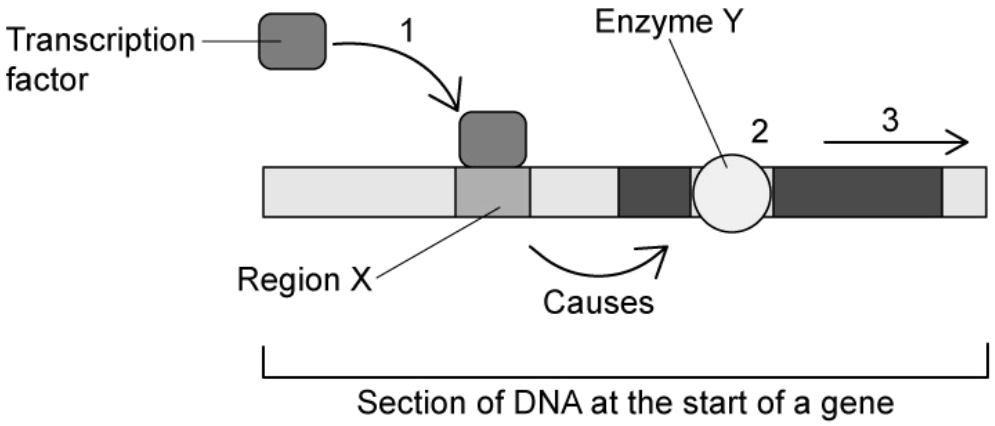
(3 marks)

2 (a) Transcription factors are proteins that influence the process of transcription. One mechanism by which transcription factors affect transcription is illustrated and described below.



1. The transcription factor binds to region **X** at the start of a gene, also known as a promoter region.
2. This causes enzyme **Y** to bind to the DNA.
3. Transcription is initiated and enzyme **Y** moves along the DNA in the direction shown.

(i) Identify enzyme **Y**.

[1]

(ii) State the precise role of enzyme **Y**.

[1]

.....

.....

(2 marks)

(b) As enzyme **Y** in part a) moves along the DNA, the base sequence on the **template** strand is as follows:

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

Identify the **tRNA anticodons** that would bind with the mRNA produced from this section of DNA.

.....

.....

(2 marks)

(c) The transcription factor shown in part a) is a protein.

Suggest, with a reason, how a mutation in the gene that codes for the transcription factor protein might affect the expression of the gene shown in part a).

.....

.....

(2 marks)

(d) The transcription factor shown in part a) is an example of a type of transcription factor known as an activator. This means that it initiates transcription or increases the rate at which transcription takes place.

Use the illustration in part a) to suggest how a transcription factor might have the opposite effect and function as a repressor.

.....

.....

(2 marks)

3 (a) *One mark is available for clarity of communication throughout this question.*

Compare and contrast the processes of DNA replication and transcription.

(8 marks)

(b) Explain the relationship between the genetic code and proteins.

(6 marks)

4 (a) Ricin is a protein produced by castor beans. In animal cells, ricin acts as an enzyme which removes the adenine base from one of the nucleotides in the RNA of ribosomes. As a result, the ribosome changes shape. Ricin causes the death of cells and is very poisonous to certain animals.

Suggest how the action of ricin on ribosomes could cause the death of cells.

.....

.....

(2 marks)

(b) The image below shows the structure of ricin.

Discuss the level(s) of protein structure visible in the diagram.

.....

(2 marks)

(c) The Flavr Savr tomato plant was genetically engineered to ripen and soften more slowly than a normal tomato. The inserted gene prevents the enzyme *Beta polygalacturonase* from breaking down pectin which softens the tomatoes.

The diagram below shows the matching parts of the base sequences for the mRNA produced from the transcription of the softening gene in a normal tomato and that of the inserted gene.

Softening gene	....AAUCGGAAU....
Inserted gene	....UUAGCCUUA....

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

(3 marks)

5 (a) Discuss the importance of hydrogen bonds in the process of translation.

(4 marks)

(b) Draw labelled diagrams contrasting the structure of an mRNA and tRNA molecule.

(4 marks)

6 (a) Part of the gene coding for a specific polypeptide contains the following base sequence:

CATAGTTGGCCA

The following table contains some of the codons on messenger RNA and the amino acids that they code for:

Codons	Amino acid coded for by codons
AUU / AUC / AUA	Isoleucine (Ile)
UUA / UUG / CUU / CUC / CUA / CUG	Leucine (Leu)
GGU / GGC / GGA / GGG	Glycine (Gly)
ACU / ACC / ACA / ACG	Threonine (Thr)
UCU / UCC / UCA / UCG	Serine (Ser)
GUU / GUC / GUA / GUG	Valine (Val)
UAA / UAG / UGA	STOP

Using the information provided, identify the amino acid sequence for this part of the polypeptide.

.....

.....

.....

(3 marks)

(b) The cells that synthesise this polypeptide was exposed to a mutagen that caused a substitution mutation that changed the DNA base sequence in the following way:

CATACTTGGCCA

Using the table from part a), explain the effect this mutation will have on the polypeptide produced.

.....

.....

.....

(3 marks)

(c) This polypeptide forms part of the active site of an enzyme that catalyses a metabolic reaction.

Suggest the effect that the mutation mentioned in part b) would have on the enzyme.

.....

.....

(2 marks)

(d) Based on the information provided in part a), explain how it could be possible for a mutation to have no effect on the polypeptide.

.....

(1 mark)