Nucleic acids and Protein Synthesis

(Past Year Topical Questions 2010-2015)

May/June 2010 (21)

5 **(a)** Name the stage during the mitotic cell cycle when replication of DNA occurs.

.....[1]

(b) Fig. 5.1 shows details of DNA replication.

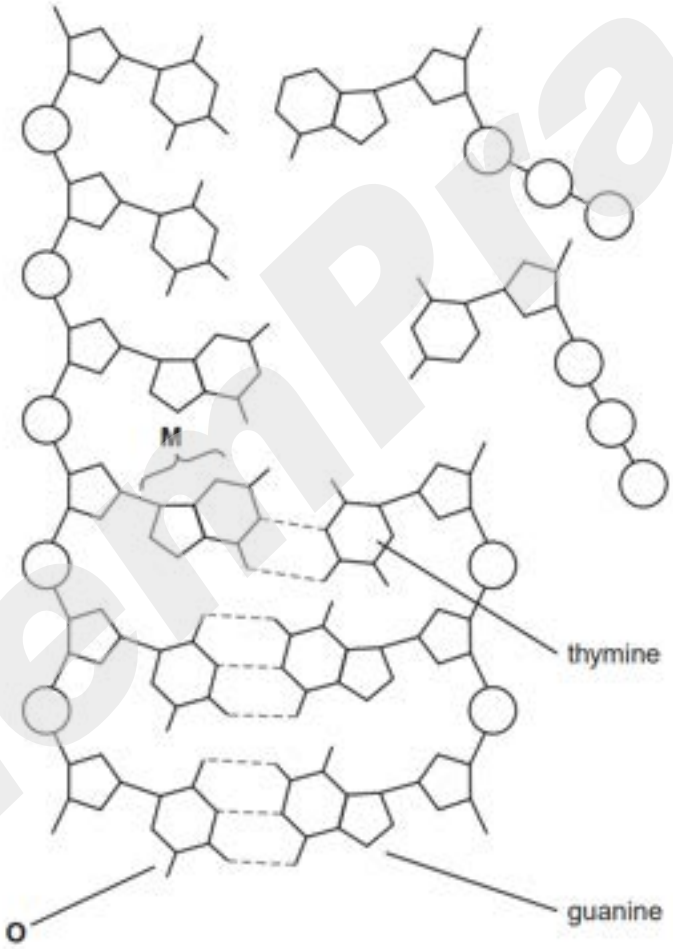

Fig. 5.1

(i) Name the bonds shown by the dashed lines on Fig. 5.1.

.....[1]

(ii) Name the nitrogenous bases, **M** and **O**.

M .....

O .....[1]

(c) Explain why DNA replication is described as *semi-conservative*.

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.....[2]

(d) The enzyme that catalyses the replication of DNA checks for errors in the process and corrects them. This makes sure that the cells produced in mitosis are genetically identical.

Explain why checking for errors and correcting them is necessary.

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.....[2]

Oct/Nov 2010 (22)

1 Protein production involves a complex sequence of events and a number of cell structures.

(a) The first column in Table 1.1 shows some of the events that occur in the production of a protein in a cell and its eventual release from the cell.

Table 1.1

event	sequence of events (numbers)	cell location (letters)
exocytosis		
protein modification		
secretory vesicle formation		
transcription		
translation		

(i) In Table 1.1, write the sequence in which the events occur, using **1** as the **first** process in the sequence. [2]

(ii) From the list **A** to **F** below, choose **one** cell location for each event and write the letter in Table 1.1. Each letter may be used once, more than once, or not at all.

A Golgi apparatus
B lysosome
C nucleus
D rough endoplasmic reticulum
E smooth endoplasmic reticulum
F plasma (cell surface) membrane [3]

(c) One example of protein modification is the removal of the first amino acid, methionine, from a newly formed polypeptide chain to make a functioning protein.

(i) The DNA nucleotide sequence that specifies the amino acid methionine is TAC.

State the mRNA nucleotide sequence that is complementary to the DNA sequence for methionine.

..... [1]

(ii) Suggest **two** other ways in which the polypeptide chain is modified to produce the functioning protein.

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..... [2]

Oct/Nov 2010 (23)

(c) Structure **E** is a protein composed of 588 amino acids.

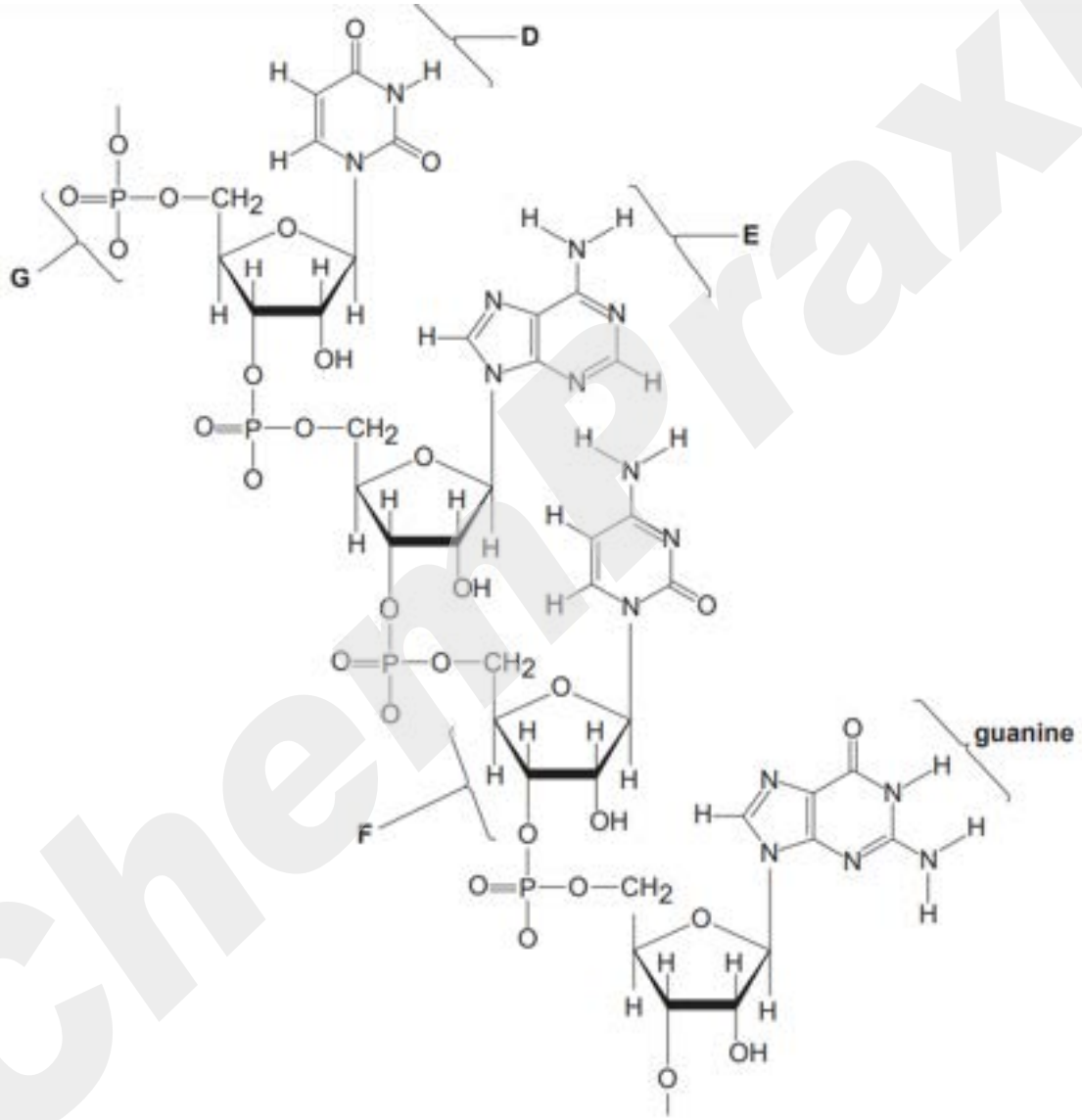
Calculate the minimum number of nucleotide base pairs required in the gene coding for this protein. Show your working.

Answer = ...[2]

May/June 2011 (21)

3 A molecule of messenger RNA (mRNA) was produced during the transcription of a gene. Part of the template sequence of DNA was ATGC.

Fig. 3.1 shows the part of the molecule of messenger RNA corresponding to that sequence of four bases.



(a) Name the parts of the mRNA molecule shown in Fig. 3.1 labelled **D**, **E**, **F** and **G**.

D .....

E .....

F .....

G ..... [4]

(b) Complete the table to show **three** ways in which mRNA differs from DNA.

	mRNA	DNA
1		
2		
3		

[3]

(c) Describe the role of mRNA after it leaves the nucleus and enters the cytoplasm of a eukaryotic cell.

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.....[4]

May/June 2011 (23)

2 **(a)** Complete the table to show **three** ways in which the **structure** of DNA differs from RNA.

	DNA	RNA
1		
2		
3		

[3]

(b) Table 2.1 shows two messenger RNA (mRNA) codons. Fill in the complementary transfer RNA (tRNA) anticodons in the spaces provided.

Table 2.1

mRNA codons	GCG	ACA
complementary tRNA anticodons		

[2]

(c) Calculate the minimum number of DNA nucleotides necessary to code for a polypeptide with 238 amino acids.

Show your working.

answer ..... nucleotides [2]

(d) Describe the role played by tRNA in polypeptide synthesis.

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..... [4]

Oct/Nov 2011 (21)/Q3

There are many different variants of haemoglobin. The sequence of bases in DNA that code for the first seven amino acids in two variants of the β-globin polypeptide are shown in Fig. 3.2.

The genetic dictionary for some of the amino acids is in Table 3.1.

Variant 1

1	2	3	4	5	6	7
CAC	GTG	GAC	TGA	GGA	CTC	CTC

Variant 2

1	2	3	4	5	6	7
CAC	GTG	GAC	TGA	GGA	CAC	CTC

Fig. 3.2

Table 3.1

amino acid	abbreviation	DNA triplets on the coding polynucleotide
valine	val	CAA, CAC, CAG, CAT
proline	pro	GGA, GGC, GGG, GGT
threonine	thr	TGA, TGC, TGG, TGT
histidine	his	GTA, GTG
glutamic acid	glu	CTC, CTT
leucine	leu	AAC, AAT, GAA, GAC, GAG, GAT

(b) Use the genetic dictionary to describe the similarities and differences between the two variants of haemoglobin.

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.....[3]

Oct/Nov 2011 (22)/Q4

Semi-conservative replication of DNA and transcription involve the formation of polynucleotide chains.

(c) State the type of reaction that occurs in the formation of a polynucleotide chain.

.....[1]

(d) Complete Table 4.1 to show **four** differences between DNA replication and DNA transcription.

Table 4.1

	replication	transcription
1		
2		
3		
4		

[4]

Oct/Nov 2011 (23)

5 Fig. 5.1 represents part of a DNA molecule.

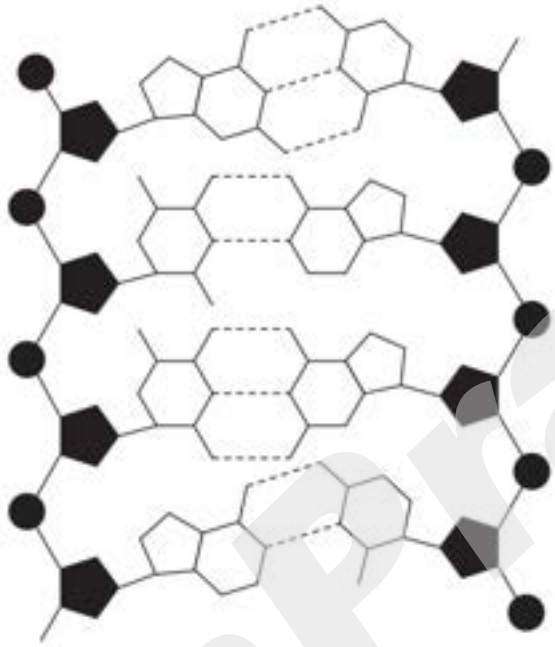

Fig. 5.1

(a) On Fig. 5.1

(i) draw a box around a nucleotide [1]

(ii) label, with the letter **P**, a phosphate group. [1]

(b) Describe how a DNA molecule replicates.

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..... [5]

(c) DNA codes for polypeptides in cells. Transfer RNA (tRNA) is involved in this process.

Describe the role of tRNA in the production of polypeptides in cells.

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..... [3]

May/June 2012 (21)

6 Fig. 6.1 shows part of a DNA molecule.

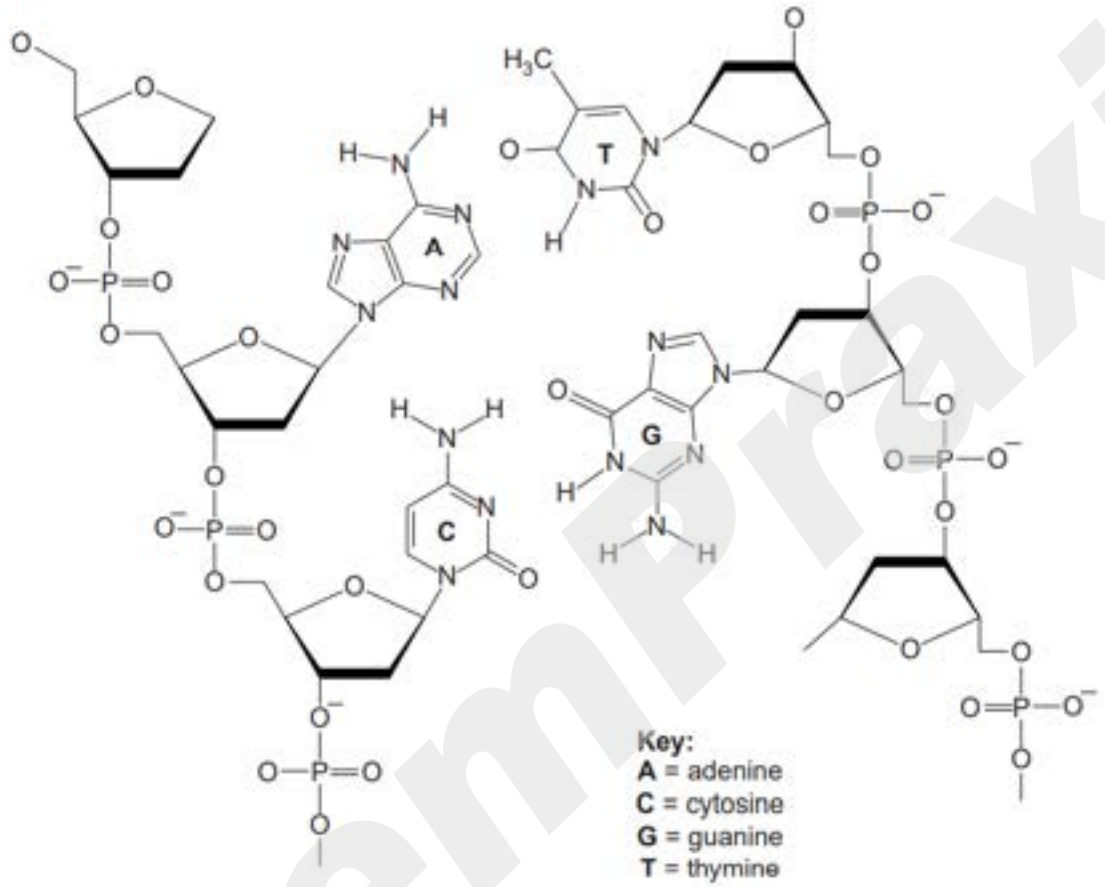

Fig. 6.1

(a) (i) Complete Fig. 6.1 by drawing on the hydrogen bonds between the two base pairs shown. [2]

(ii) State the importance of hydrogen bonding in DNA structure.

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..... [2]

In the 1950s, Erwin Chargaff determined the relative quantities of the four bases in DNA in different organisms. His results provided important evidence for the model of DNA proposed by James Watson and Francis Crick in 1953. Some of Chargaff's data is shown in Table 6.1.

Table 6.1

organism	percentage of adenine	percentage of thymine	percentage of guanine	percentage of cytosine
Escherichia coli (bacterium)	24.7	23.6	26.0	25.7
a yeast	31.3	32.9	18.7	17.1
wheat	27.3	27.1	22.7	22.8
octopus	33.2	31.6	17.6	17.6
sea urchin	32.8	32.1	17.7	17.3
chicken	28.0	28.4	22.0	21.6
human	29.3	30.0	20.7	20.0

(b) With reference to Fig. 6.1, explain how the data in Table 6.1 helps to confirm the arrangement of bases in DNA.

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.....[3]

(c) Table 6.2 shows Chargaff's data for a virus.

Table 6.2

organism	percentage of adenine	percentage of thymine	percentage of guanine	percentage of cytosine
a virus	24.0	31.2	23.3	21.5

(i) State how the result for the virus differs from the results for all the organisms given in Table 6.1.

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.....[1]

(ii) Suggest why the results for the virus are different from all the other organisms.

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.....[1]

May/June 2012 (22)

4 DNA and RNA are important biological molecules that are involved in the production of polypeptides.

(a) Fig. 4.1 shows two nucleotides joined by a covalent bond.

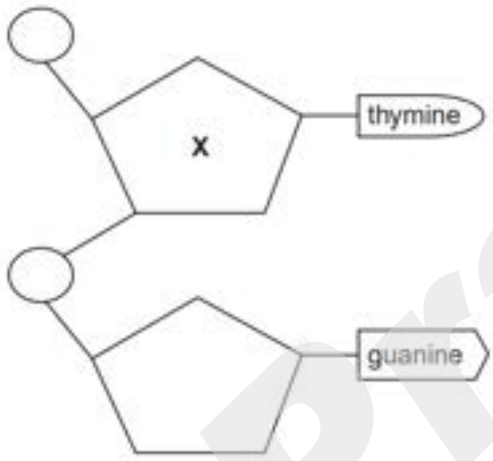

Fig. 4.1

(i) Fig. 4.1 represents part of a DNA molecule, **not** part of an RNA molecule.

Explain why.

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..... [1]

(ii) Name the covalent bond between the two nucleotides.

..... [1]

(iii) Name component **X**.

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..... [1]

(b) Outline the role of transfer RNA (tRNA) in the production of a polypeptide.

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..... [2]

May/June 2012 (23)

4 The two strands of a DNA molecule are held together by hydrogen bonds between complementary base pairs.

(a) Explain why the hydrogen bonding between the two strands of DNA is important for it to carry out its functions.

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..... [4]

Switching genes on and off allows proteins to be synthesised only when required.

Processes **P** and **Q** occur when a gene is switched on, as shown in Fig. 4.1.

Fig. 4.1

(b) Name processes **P** and **Q**.

P .....

Q ..... [1]

DNA is a very stable molecule. This means that it is not broken down either chemically or by enzymes during the normal life of the cell.

In contrast, mRNA is described as being highly labile. This means that most mRNA molecules are broken down in the cytoplasm within a few hours of their release from the nucleus.

(c) Suggest the significance of:

(i) DNA being very stable

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..... [2]

(ii) mRNA being highly labile.

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..... [2]

Oct/Nov 2012 (22)

5 (a) State the structural features of DNA that make it a stable molecule.

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..... [2]

(b) DNA has been described as a 'carrier of coded information'.

Explain this statement.

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..... [2]

(c) State when, during a cell cycle, DNA replication occurs.

..... [1]

Oct/Nov 2012 (23)

5 **(a)** Describe the role of the ribosome in translation.

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.....[4]

Fig. 5.1 is a diagram of a section of mRNA showing the sequence of three of the codons.

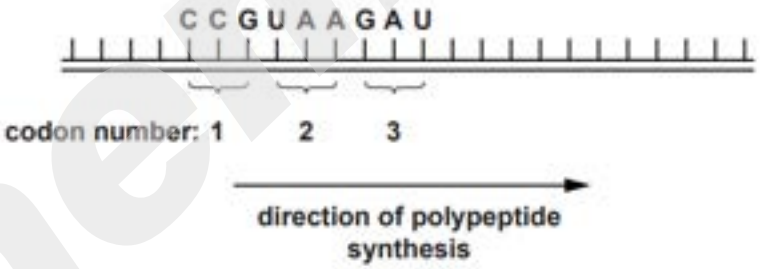

Fig. 5.1

(b) State the base sequences of:

(i) the tRNA anticodon complementary to **codon 1**

.....[1]

(ii) the DNA sequence which coded for **codon 3**.

.....[1]

(c) The three codons in Fig. 5.1 are near the start of the sequence coding for a protein.

Explain the consequence of a mutation which deletes the **U** from **codon 2**.

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.....[3]

May/June 2013 (21)

4 Fig. 4.1 shows the two base pairs in a DNA molecule.

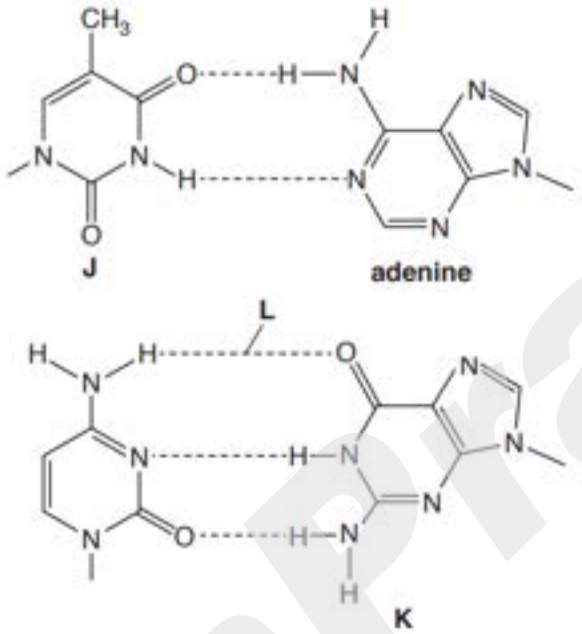

Fig. 4.1

(a) Name the bases labelled J and K and the bond labelled **L**.

J .....

K .....

L ..... [3]

May/June 2013 (22)

5 **(a)** Complete the table to **describe** three differences between DNA replication and DNA transcription.

DNA replication	DNA transcription

[3]

(b) Errors during replication may lead to gene mutations.

Define the term *gene mutation*.

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..... [2]

May/June 2013 (23)

2 Read the following passage.

> A method called *in vitro* translation is often used by scientists to produce proteins in the laboratory. The method uses extracts from animal cells, plant cells or bacteria. These are chosen because they have high levels of protein synthesis. The cells are treated so that the cell walls, if present, and cell membranes are broken down and then treated so that any of the cell's own DNA and mRNA are destroyed. When mRNA from any source is added to these extracts, it will be translated into the corresponding protein.

(a) Explain why:

(i) the cells are chosen on the basis of their high level of protein synthesis

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..... [2]

(ii) the cell walls (if present) and cell membranes need to be broken down

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..... [1]

(iii) the cell's own mRNA needs to be destroyed

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..... [1]

(iv) mRNA from any source can be translated in any type of extract.

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..... [2]

(b) State **two** differences between the cell structures used in translation in prokaryotes and eukaryotes.

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..... [2]

(c) Scientists usually find that the method of *in vitro* translation is less efficient than *in vivo* translation, which occurs in cells.

Suggest a reason for this.

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..... [1]

Oct/Nov 2013 (21)

5 Table 5.1 shows the triplets of bases on the template polynucleotide of DNA for some amino acids.

Table 5.1

amino acid		DNA triplets
glutamic acid	(glu)	CTT CTC
histidine	(his)	GTA GTG
leucine	(leu)	GAA GAG GAT GAC
proline	(pro)	GGA GGG GGT GGC
threonine	(thr)	TGA TGG TGT TGC
valine	(val)	CAA CAG CAT CAC

Fig. 5.1 shows the base sequences in DNA and mRNA for the first seven amino acids of the β chain of haemoglobin.

DNA	CAC	.....	GAC	TGA	GGA	CTC	CTC
mRNA	GUG	CAC	CUG	.....	CCU	GAG	GAG
β chain	val	his	.....	thr	pro	glu	glu

Fig. 5.1

(a) (i) Use Table 5.1 to complete Fig. 5.1. [3]

(ii) State the term used to describe the sequence of amino acids in a polypeptide.

..... [1]

(b) In sickle cell anaemia, the amino acid at position 6 in the β chain is valine and not glutamic acid.

Explain how a single change in the DNA triplet for the sixth amino acid of the gene coding for the β chain leads to the production of a different amino acid sequence.

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.....[5]

Oct/Nov 2013 (23)/Q2

(b) Fig. 2.1 shows the base sequence of a DNA triplet code used to produce mRNA. Fill in the corresponding tRNA anticodon in the space provided.

DNA triplet	T A C
tRNA anticodon	

[1]

Fig. 2.1

(c) More mRNA molecules than tRNA molecules are synthesised in cells.

Suggest a reason for this.

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..... [1]

(d) Describe the role of ribosomes in protein synthesis.

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..... [3]

May/June 2014 (22)/Q3

(e) People with sickle cell anaemia have a form of haemoglobin that is unable to bind to oxygen efficiently. The cause of the condition is a mutation in the gene coding for the β-globin polypeptide of haemoglobin.

Outline how this mutation can lead to an altered amino acid sequence of the β-globin polypeptide.

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.....[3]

May/June 2014 (22)/Q4

(c) HIV infects cells of the immune system, particularly helper T-lymphocytes (T_h cells). HIV can infect both non-dividing and dividing helper T-lymphocytes, including memory cells.

The onset of disease, which can occur many years later, coincides with a severely lowered primary and secondary immune response, owing to greatly reduced numbers of T_h cells in the body.

(i) An infected T_h cell can still carry out a normal cell cycle and divide to produce two cells.

The following processes occur during one cell cycle:

DNA replication **mitosis** **growth** **cytokinesis**

List the processes in a correct sequence.

1. .....

2. .....

3. .....

4. .....

[1]

May/June 2014 (23)/Q5

(c) Some people who move to live at high altitudes can develop chronic mountain sickness. One feature of this condition makes it difficult for the heart to pump blood around the body owing to the increased production of red blood cells.

The *EPAS*1 gene codes for a type of protein called a transcription factor, which helps to regulate the transcription of genes involved in red blood cell production. Some people have a mutated version of this gene that prevents the over-production of red blood cells.

(i) Explain what is meant by *transcription*.

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.....[3]

(ii) Describe how a mutated version of the *EPAS*1 gene can cause a change in the transcription factor protein produced.

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.....[3]

(iii) Some transcription factors may prevent transcription.

Suggest two ways in which they may do this.

1. .....

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2. .....

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[2]

Oct/Nov 2014 (21)/Q3

(c) Angiotensinogen is an inactive protein molecule. When blood pressure decreases, part of angiotensinogen is removed to form a short polypeptide, angiotensin that stimulates an increase in blood pressure.

Fig. 3.2 shows the base sequence within the gene for angiotensinogen that codes for this short polypeptide, the RNA codons and the primary structure of angiotensin.

DNA base sequence	CTA	GCA	CAA	ATG	TAG	GTG	GGG	.....
RNA codons	.....	CGU	.....	UAC	AUC	CAC	CCC	UUC
polypeptide primary structure	Asp	Arg	Val	Tyr	Ile	His	Pro	Phe

Fig. 3.2

(i) Complete Fig. 3.2 to show the missing DNA triplet and the RNA codons. [1]

(ii) State the full name of the type of RNA shown in Fig. 3.2.

..... [1]

Oct/Nov 2014 (23)/Q1

(ii) Mutations can sometimes occur in cells which are rapidly dividing.

Outline how a mutation can cause an altered polypeptide to be produced.

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..... [2]

May/June 2015 (21)

6 Red blood cells are formed from cells called reticulocytes. Stem cells in the bone marrow produce reticulocytes which differentiate into red blood cells. During differentiation haemoglobin is produced.

Fig. 6.1 shows the structure of small sections of DNA and messenger RNA (mRNA) in the nucleus of a reticulocyte during transcription.

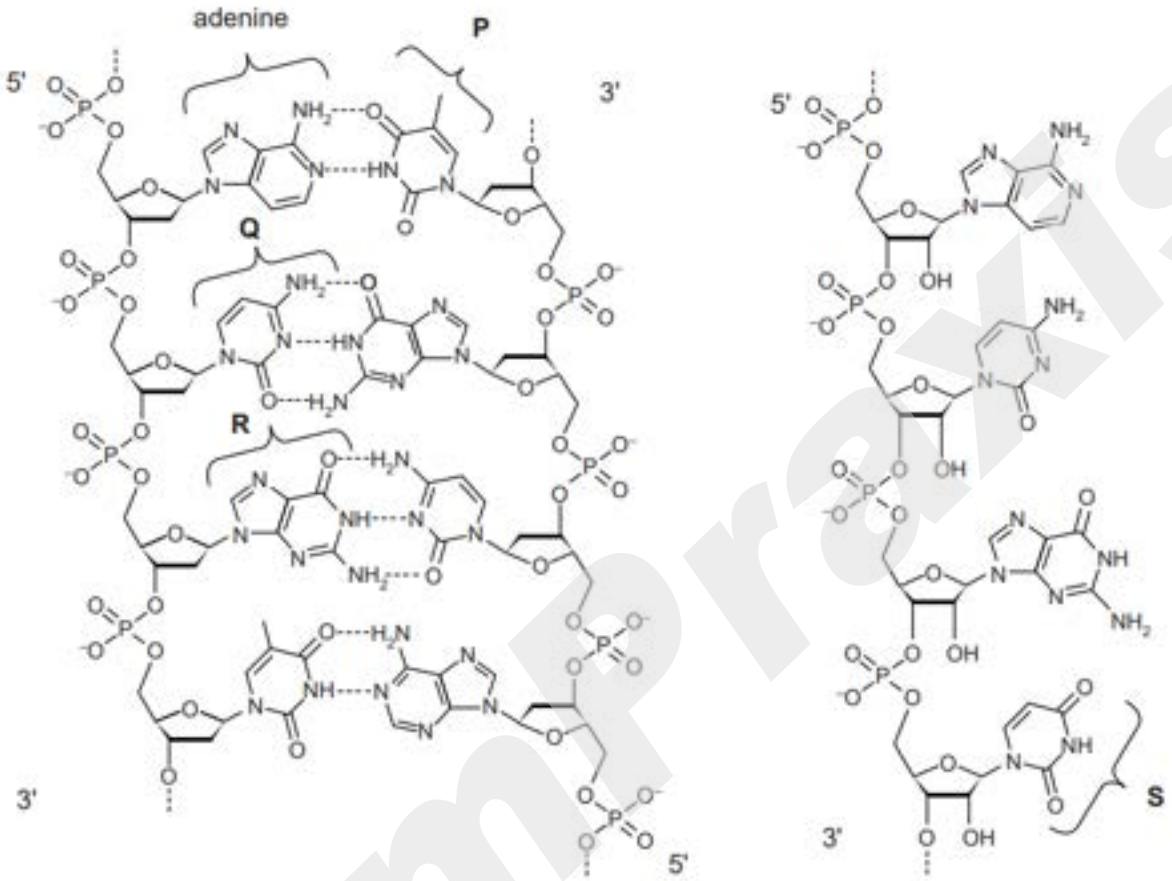

Fig. 6.1

(a) Name the bases **P** to **S**.

P .....

Q .....

R .....

S .....[4]

(b) Describe the role of the mRNA molecule shown in Fig. 6.1.

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.....[3]

May/June 2015 (22)/Q2

(d) The presence of *B. pertussis* stimulates the production of mucin, a gel-like glycoprotein that is the main component of mucus.

The mucin produced by the cell is packaged into vesicles ready for exocytosis.

(i) The first stage in the production of mucin involves transcription of the gene *MUC5AC*.

Outline the stages occurring in transcription.

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.....[4]

May/June 2015 (23)

2 DNA replication is an important event in the cell cycle.

(a) State when, during the cell cycle, DNA replication occurs.

.....[1]

(b) Fig. 2.1 shows pairing between two bases, **X** and **Y**, in a DNA molecule.

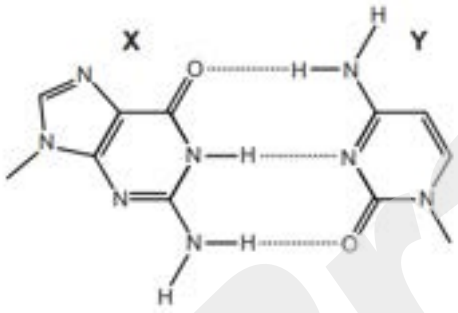

Fig. **2.1**

(i) Name the type of bond shown by the dotted lines between the bases.

.....[1]

(ii) State which base, **X** or Y, is a pyrimidine **and** explain your answer.

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.....[1]

(c) The compound benzopyrene, found in tar from tobacco smoke, can become chemically changed in cells and interferes with DNA replication, causing gene mutations.

(i) State what is meant by the term *gene mutation*.

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.....[2]

May/June 2015 (23)/Q4

(b) Angiotensin is a polypeptide produced in the body to raise blood pressure. Angiotensin converting enzyme (ACE) catalyses the final step in angiotensin production. Fig. 4.2 shows this step.

Fig. 4.2

Describe the step shown in Fig. 4.2.

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.....[3]

Oct/Nov 2015 (21)/Q3

(d) DNA replication must occur before cell division.

Describe the process of DNA replication.

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Oct/Nov 2015 (22)/Q2

(e) Tobacco smoke is known to cause increased production of macrophage elastase. *MMP12* is the gene coding for macrophage elastase. Copies of this gene are produced as messenger RNA (mRNA).

Describe how this mRNA is used in translation to produce macrophage elastase.

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Oct/Nov 2015 (23)

1 Antibodies are secreted by activated B-lymphocytes known as plasma cells.

Fig. 1.1 is a diagram showing the cellular processes involved in the production of a polypeptide of an antibody molecule (not drawn to scale).

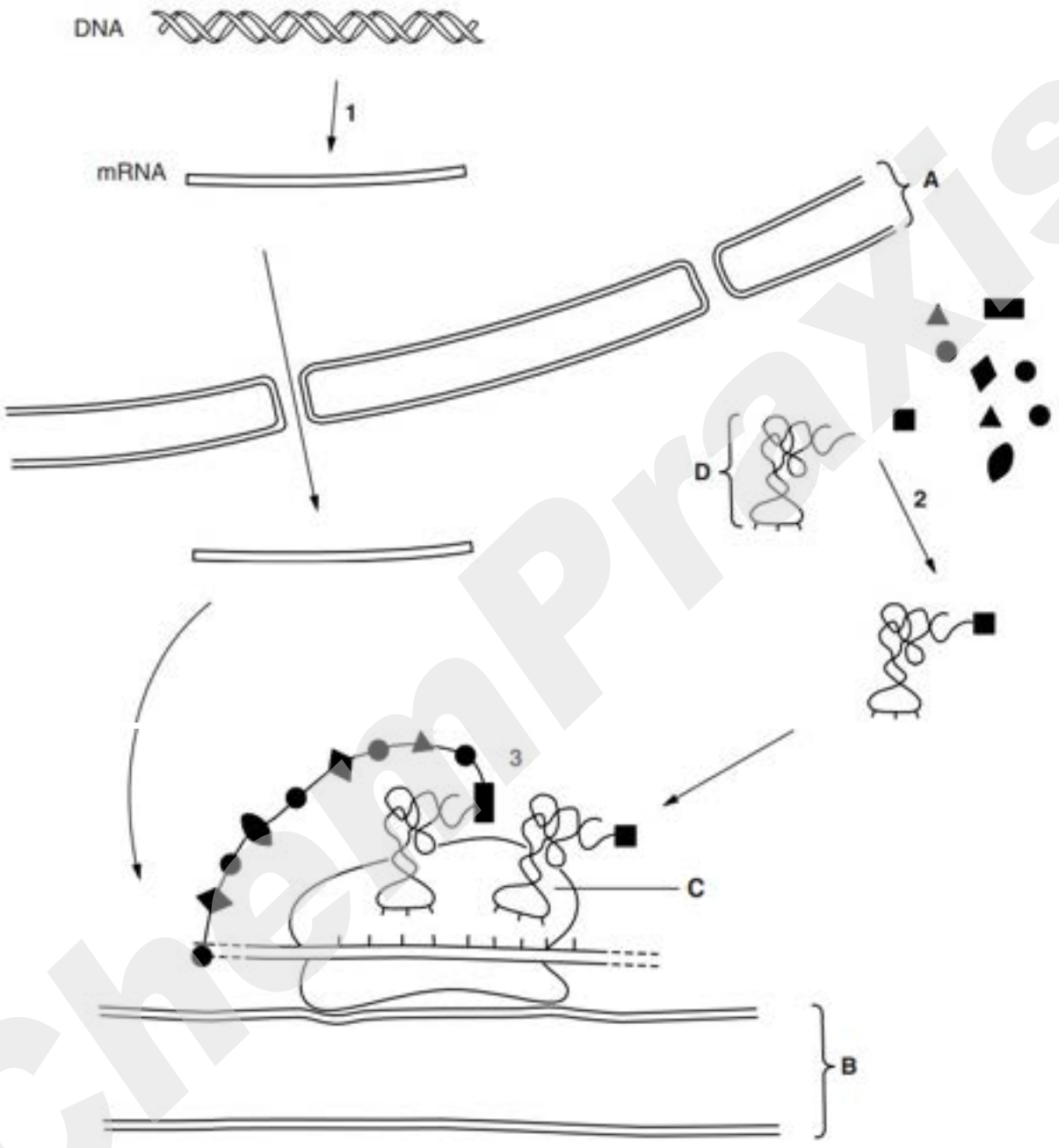

Fig. 1.1

(a) (i) Name structures **A**, **B** and **C**.

A .....

B .....

C ..... [3]

(ii) Name molecule **D**.

D ..... [1]

(iii) State what is occurring at **1**, **2** and **3**.

at 1 .....

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at 2 .....

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at 3 .....

..... [3]