Genes and protein synthesis

Question Paper

Level	Pre U
Subject	Biology
Exam Board	Cambridge International Examinations
Topic	The Cell
Sub Topic	Genes and protein synthesis
Booklet	Question Paper

Time Allowed: **110 minutes**

Score: **/91**

Percentage: **/100**

Part - A

1 The gene for colour vision in humans is sex-linked and has two alleles, **Ch** and **ch**. The recessive allele, **ch**, causes red-green colour blindness.

The gene for the ABO blood group system is on chromosome 9. There are three alleles:

$\mathbf{I^A}$ – leads to A antigens on red blood cells

$\mathbf{I^B}$ – leads to B antigens on red blood cells

$\mathbf{I^o}$ – leads to neither A nor B antigens on red blood cells.

These three alleles give four possible phenotypes:

- blood group A (A antigens on red blood cells)
- blood group B (B antigens on red blood cells)
- blood group AB (A and B antigens on red blood cells)
- blood group O (neither A nor B antigens on red blood cells)

Fig. 26.1 shows the inheritance of these two genes in a family.

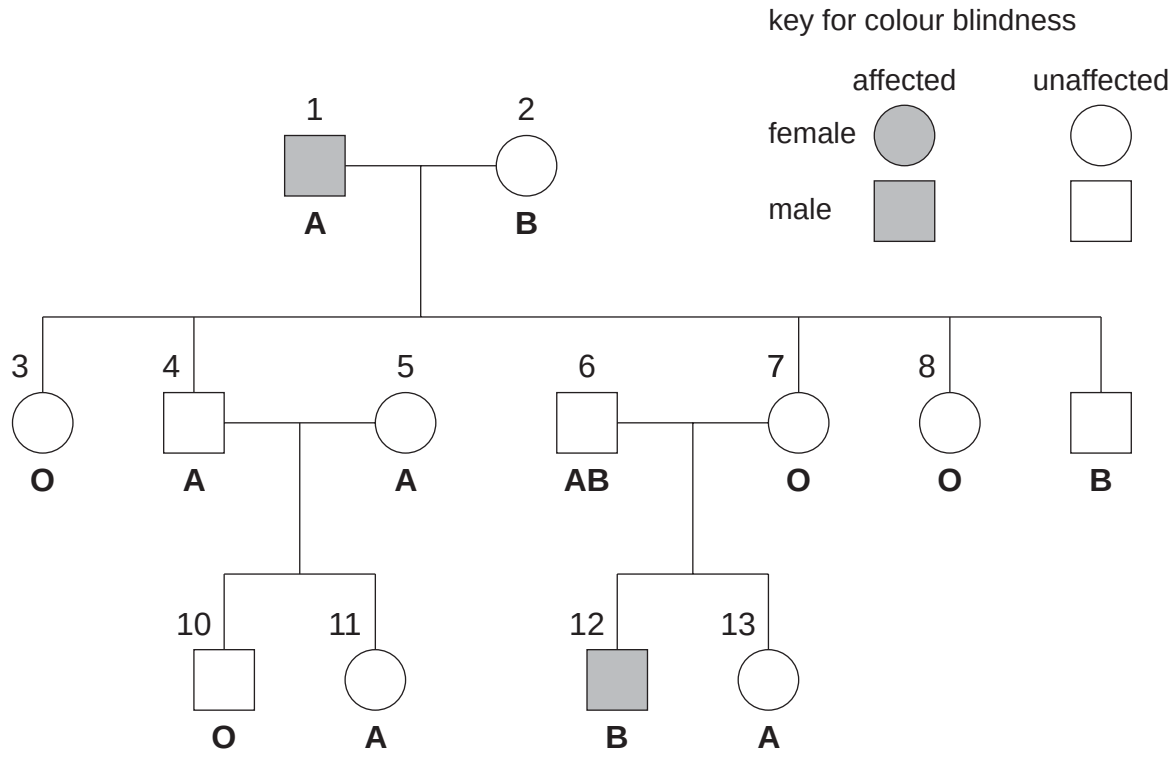

Fig. 26.1

(a) State a possible genotype for each of the following people in the family shown in Fig. 26.1.

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3 .....

9 .....

[3]

(b) With reference to Fig. 26.1, explain why

(i) the grandfather (1) is colour blind, but neither of his sons is colour blind

[2]

(ii) one grandson (12) has inherited colour blindness but the other (10) has not

[2]

(iii) there are four phenotypes in the ABO blood group system.

[3]

Nail-patella syndrome is a rare autosomal dominant trait that affects fingernails, toenails, elbows and kneecaps. The locus of the gene for nail-patella syndrome, **Np** / **np**, is 10 map units from the ABO locus on chromosome 9.

A man with nail-patella syndrome and blood group AB has a family of five children with his wife who does not have the syndrome and is blood group O.

Three children do not have the nail-patella syndrome and are blood group A.

Two children have nail-patella syndrome and are blood group B.

(c) State the genotypes of the father and the mother.

father .....

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mother .....

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(d) Explain why there is a small probability of these parents having a child with both blood group A and nail-patella syndrome.

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[Total: 15]

2 Lactate dehydrogenase (LDH) is an enzyme found in many organisms. Within the same organism, it can be found in different forms, called isoenzymes. The isoenzymes are structurally different but all catalyse the same reaction.

(a) **(i)** Fig. 21.1 shows a reaction catalysed by lactate dehydrogenase that occurs during anaerobic respiration in muscle tissue.

Complete Fig. 21.1 by identifying the compounds **A**, **B** and **C**.

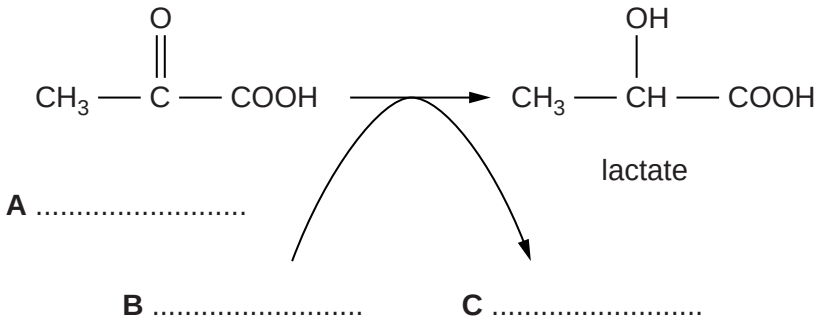

Fig. 21.1

[2]

(ii) State where in the cell this reaction takes place.

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(iii) Explain the importance of this reaction in mammalian muscle tissue.

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Lactate dehydrogenase isoenzymes are globular proteins, each consisting of four polypeptides.

(b) Describe the structure of an enzyme, such as lactate dehydrogenase, and explain how this structure is suited to its role.

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Lactate dehydrogenase isoenzymes are made up of two types of polypeptide: polypeptide M, which is coded for by the *LDH-A* gene and polypeptide H, which is coded for by the *LDH-B* gene.

Table 21.1 shows the composition of different human lactate dehydrogenase isoenzymes and examples of tissues and organs where each can be found.

Table 21.1

isoenzyme	polypeptide composition of enzyme	example of isoenzyme location
LDH-1	HHHH	heart red blood cells
LDH-2	HHHM	heart red blood cells
LDH-3	HHMM	brain lungs
LDH-4	HMMM	kidneys placenta
LDH-5	MMMM	liver skeletal muscles

(c) With reference to Table 21.1, suggest how cells of different tissues of the same individual can produce different isoenzymes.

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(d) LDH can be present in blood plasma as a result of tissue damage.

Blood samples can be taken and tested to measure the concentrations of different LDH isoenzymes.

(i) This test can help in the diagnosis of heart attacks resulting from atheroma formation.

Explain how atheroma can lead to a heart attack.

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(ii) Suggest how a test for LDH isoenzymes can help in the diagnosis of different conditions.

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(e) The base sequences of the *LDH-A* and *LDH-B* genes and the sequences of the amino acids encoded by these genes were determined.

Fig. 21.2 shows the first ten amino acids of polypeptides M and H and the corresponding base sequences of one of the DNA strands of each gene.

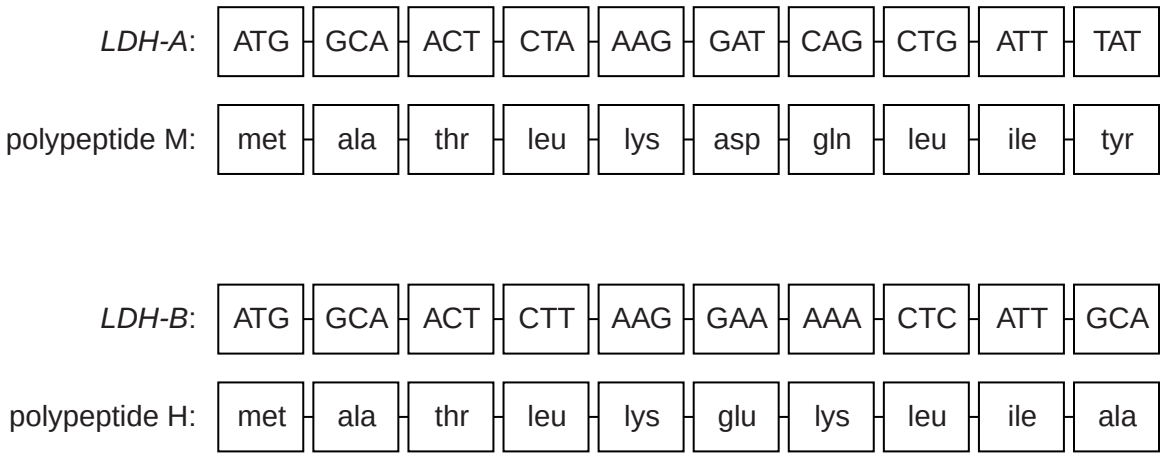

Fig. 21.2

Table 21.2 shows the genetic code (mRNA codons).

Table 21.2

first position	second position				third position
	U	C	A	G	
U	phe	ser	tyr	cys	U
	phe	ser	tyr	cys	C
	leu	ser	STOP	STOP	A
	leu	ser	STOP	trp	G
C	leu	pro	his	arg	U
	leu	pro	his	arg	C
	leu	pro	gln	arg	A
	leu	pro	gln	arg	G
A	ile	thr	asn	ser	U
	ile	thr	asn	ser	C
	ile	thr	lys	arg	A
	met	thr	lys	arg	G
G	val	ala	asp	gly	U
	val	ala	asp	gly	C
	val	ala	glu	gly	A
	val	ala	glu	gly	G

Comment on the sequences shown in Fig. 21.2. You may refer to Table 21.2.

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[Total: 26]

3 T cells (T lymphocytes) differentiate inside the thymus gland. During T cell differentiation, specific cell surface proteins known as CD proteins are produced and inserted into the cell surface membrane.

Fig. 3.1 shows the stages involved in the synthesis of a CD protein in a T cell.

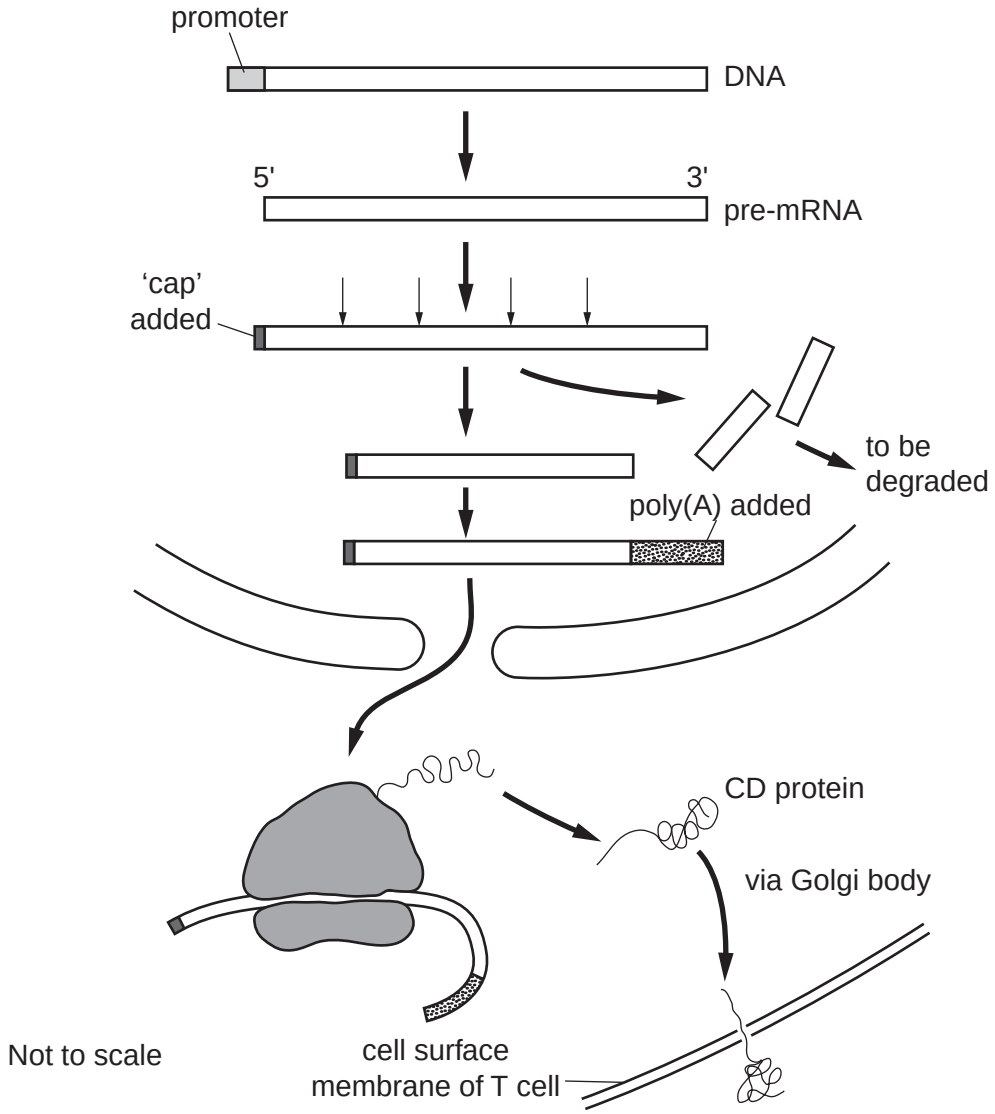

Fig. 3.1

(a) Explain the function of the promoter region of the DNA.

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(b) Using Fig. 3.1 as a guide, describe the events that occur in the nucleus of the T cell to produce a functional molecule of mRNA encoding a CD protein.

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(c) Explain why the cuts made in pre-mRNA are necessary for the T cell to produce a functional CD protein.

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(d) Suggest possible functions for the 'cap' and the poly-A region attached to the mRNA.

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(e) Each clone of fully differentiated T cells expresses a particular set of CD proteins on the cell surface membranes.

Explain how monoclonal antibodies are able to identify different CD proteins.

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(f) Explain why it is necessary to use hybridoma cells, rather than B cells, to produce monoclonal antibodies.

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[Total: 19]

Part - B

4 Once most stem cells differentiate they lose their ability to turn into other types of cells. However, some fully differentiated cells can be stimulated to change back into stem cells in tissue culture. Such cells are called induced pluripotent stem cells (iPS cells).

(a) In experiments with mice it was discovered that the introduction of four genes would cause certain fully differentiated cells to change to iPS cells.

(i) Suggest two possible means by which the four genes were introduced into the cells.

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(ii) Suggest how the researchers identified the cells which had taken up the genes.

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(iii) Suggest how the addition of only a few genes may influence the activity of many other genes.

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(b) There is evidence to suggest that the introduction of the four genes mentioned in **(a)** caused an increase in the production of telomerase reverse transcriptase (TERT) in the fully differentiated cells.

Explain how TERT may help to change the cells back into stem cells.

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5 **(a)** Name **and** outline the theory which accounts for the existence of mitochondria in eukaryotic cells.

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(b) Suggest why it is biologically important that mtDNA includes genes for cytochrome c oxidase and NADH dehydrogenase.

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(c) Suggest how all the mitochondria in a male muscle cell derive from the mitochondria of his mother.

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(d) mtDNA is a group of genes which is transmitted to both male and female offspring.

How may a group of genes be transmitted **only** to male offspring?

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[Total: 10]

6 In 2000, Geisert and his co-workers carried out research on mtDNA. They analysed the nucleotide sequence of the mtDNA of

- 994 modern humans (including a range of racial groups)
- one Neanderthal fossil
- nine chimpanzees.

Once they knew the nucleotide sequences of each of these samples of mtDNA they compared each of these sequences with each of the 994 modern human nucleotide sequences. In this way they were able to make human to human, Neanderthal to human and chimpanzee to human comparisons. The number of differences in the nucleotide sequence for each comparison was then recorded. The differences in mtDNA were quite small – no more than a few nucleotide bases – and relatively neutral in terms of evolution.

The results of these comparisons are shown in Fig. 6.1.

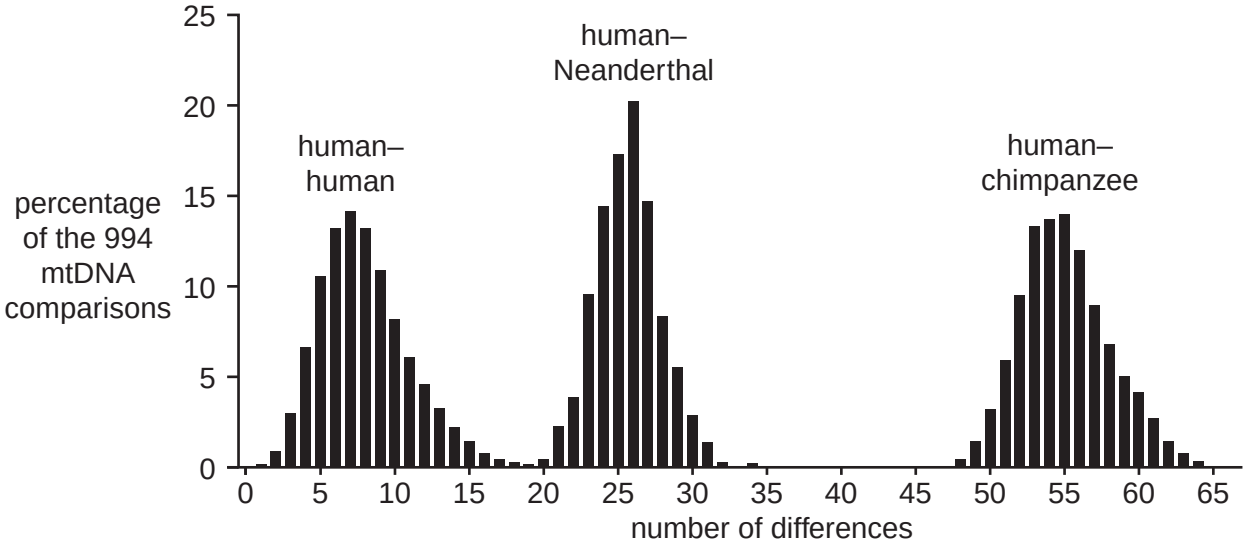

Fig. 6.1

(a) Neanderthal mtDNA is very difficult to obtain. In the case of the specimen referred to in Fig. 6.1, only very small quantities were available.

Suggest how the researchers were able to copy many times the few available Neanderthal mtDNA molecules to provide enough mtDNA to carry out their analyses.

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(b) Suggest why the higher mutation rate and the virtual absence of recombination make mtDNA more useful in tracing ancestry over many generations than the chromosomal DNA of eukaryotic cells.

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(c) Comment on the information given in Fig. 6.1.

You may wish to include potential conclusions, discussion or evaluation in your comments.

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[Total: 11]