3 Transgenic goats, containing a gene from a spider that codes for spider web silk protein, have been produced by genetic modification. The silk protein can be harvested from the milk of the female transgenic goats.

Spider silk protein is lightweight but has very high tensile strength. It is used to make items such as bullet-proof vests.

(a) A vector containing recombinant DNA is needed to produce transgenic goats.

Define the term *recombinant DNA*.

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..... **[1]**

(b) Complete Table 3.1 by suggesting **one** example of a suitable vector for each of the following applications of genetic modification.

Table 3.1

application of genetic modification	suitable vector
goats making spider silk protein	
somatic gene therapy for a recessive human genetic disorder	
plants that express a bacterial toxin that kills insects feeding on them	
bacteria that produce a human protein for therapeutic use	

[4]

(c) In order to make spider silk protein on a commercial basis, many transgenic goats will be needed.

Outline the process by which an animal, such as the first transgenic goat, may be cloned to produce a population.

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..... **[5]**

(d) An alternative method for producing a population of more transgenic goats is to breed the transgenic goat with normal goats.

Discuss the advantages **and** disadvantages of cloning the transgenic goat compared with breeding the transgenic goat with normal goats.

advantages .....

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disadvantages.....

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..... **[5]**

[Total: 15]

Answer **all** the questions.

1 Fig. 1.1 shows a metabolic pathway involving the amino acid, phenylalanine. One of the products of this pathway is melanin, the pigment that gives a brown colour to hair, skin and the iris of the eyes. This metabolic pathway also produces thyroid hormones.

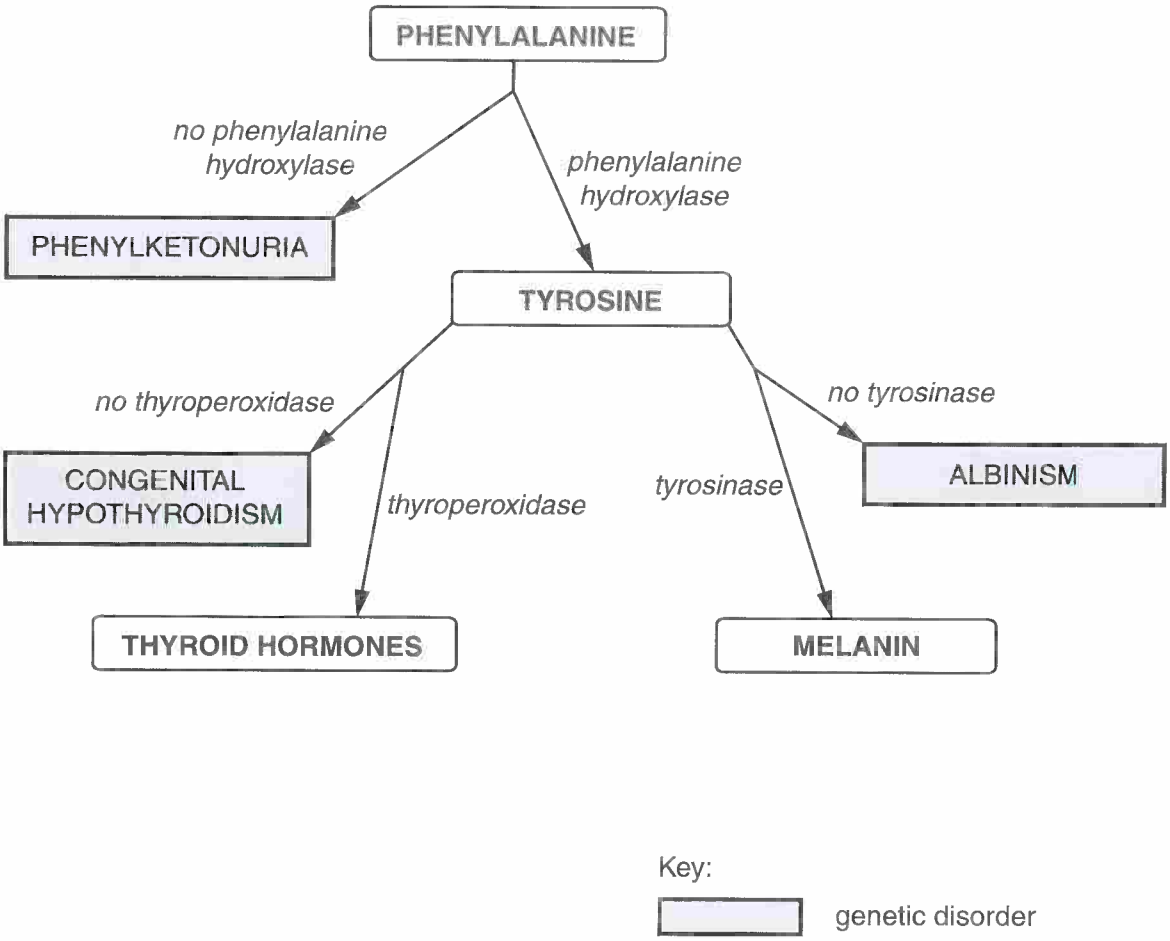

Fig. 1.1

(a) Use Fig. 1.1 to name:

(i) the **enzyme** that catalyses the last step in melanin production

..... [1]

(ii) the **genetic disorder** resulting from the absence of the enzyme at the start of the metabolic pathway for melanin production.

..... [1]

(b) Phenylalanine and tyrosine are both amino acids.

Explain why phenylalanine and tyrosine are classified as amino acids.

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..... **[2]**

(c) One effect of thyroid hormones is to increase the activity of mitochondria within cells. Suggest how the metabolism of a person with the condition congenital hypothyroidism might differ from that of a person who does not have this condition.

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..... **[3]**

(d) Albinism is a genetic disorder in which a person lacks melanin pigment in their skin, hair and the iris of their eyes. A person with this disorder is called an albino. The genotype of an albino has two copies of a recessive allele of the gene for an enzyme involved in melanin production.

(i) State the term used to describe a genotype that has two copies of the same allele at a particular gene locus.

..... **[1]**

(ii) Explain what is meant by the following terms:

genotype .....

.....

.....

allele .....

.....

..... **[4]**

(e) The Hardy-Weinberg principle can be used to predict the expected frequencies of albino and non-albino alleles in a population. However, this principle can only be applied to populations which fulfil all of the following criteria:

- sexually reproducing organisms
- diploid organisms
- large populations
- randomly-mating populations.

The tiger, an endangered species of mammal, is undergoing a worldwide captive breeding programme in zoos.

Suggest why the Hardy-Weinberg principle cannot be used to predict the expected frequencies of albino and non-albino alleles in the worldwide zoo population of tigers.

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..... **[2]**

(f) A change in allele frequencies in a population is described as an evolutionary change.

List **two** factors that might cause allele frequencies to change from generation to generation in a population that meets the Hardy-Weinberg criteria.

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..... **[2]**

[Total: 16]

4 **(a)** Genetic modification of organisms uses a "toolkit" that includes:

- enzymes that cut DNA
- enzymes that join sections of DNA together
- vectors that introduce DNA into new host cells.

Some of the enzymes and vectors that are important in genetic modification are given an identifying letter in Table 4.1.

Table 4.1

	enzymes
A	reverse transcriptase
B	DNA polymerase
C	DNA ligase
D	restriction endonuclease
E	RNA polymerase

	vectors
J	plasmid
K	virus
L	*Agrobacterium tumefaciens*
M	BAC
N	bacteriophage

Select **one** correct letter from Table 4.1 to fit each of the following statements.

An enzyme that cuts DNA .....

An enzyme that joins sections of DNA together .....

A vector to introduce foreign DNA into bacteria .....

A vector to introduce foreign DNA into plant cells .....

A vector to introduce foreign DNA into animal cells ..... **[5]**

(b) Discuss the **potential benefits** to mankind and the **ethical concerns** raised by the following examples of genetically modified organisms:

- rice modified for increased vitamin A content ('Golden Rice™')
- humans having somatic gene therapy treatment for a genetic disease.

In your answer you should give a balanced account of the benefits and concerns for each example of genetic modification.

..... [9]

[Total: 14]

6 A long-term breeding experiment to investigate the **genetic** basis of tame (friendly) behaviour was carried out in a population of silver foxes. The foxes were bred each year and the resulting young foxes assessed each month between the ages of 1 and 8 months to see how tame they were.

Table 6.1 shows how the foxes were put into categories according to their tameness.

Table 6.1

tameness class	description of behaviour towards humans
3	Not tame – these foxes run away from humans or bite when handled.
2	Neutral – these foxes allow handling by humans but show no emotionally friendly response.
1	Tame – these foxes are friendly to humans. They wag their tails and whine for attention.
elite	Very tame – these foxes are eager for human contact. They whimper to attract attention and sniff and lick humans.

The tamest 5% of the male foxes and the tamest 20% of the female foxes in each generation were used for breeding to produce the next generation. This was repeated for over forty generations.

(a) (i) State the name given to the process in which only a certain percentage of adult foxes were chosen by humans to breed in each generation.

..... **[1]**

(ii) Suggest why 20% of the female foxes were used for breeding but only 5% of the male foxes.

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..... **[2]**

(b) Table 6.2 shows the number of foxes in the elite tameness class during the long-term experiment.

Table 6.2

number of generations	foxes in elite class (%)
10	18
20	35
35	75

Discuss what the results shown in Table 6.2 suggest about the **causes of the variation** in tameness behaviour in silver foxes.

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..... **[3]**

QUESTION 6(c) STARTS ON PAGE 18

(c) As tameness increased in the silver fox population over the years, it was noticed that other phenotypic traits also became more common.

Table 6.3 compares the frequency of these traits in a control group of silver foxes that had not been used in this long-term breeding experiment and in the tame population of foxes.

Table 6.3

phenotypic trait	animals showing trait (per 100 000)		percentage increase in trait
	control population	tame population	
white patch of fur on head	710	12 400	1 646
floppy ears	170	230	35
short tail	2	140	6 900
curly tail	830	9 400	1 033

Students were asked to suggest a variety of genetic hypotheses to explain why these traits become more common in tame foxes. Their suggestions were:

linkage **epistasis** **inbreeding** **genetic drift**

Select **one** hypothesis from the list and explain how it could account for the data in Table 6.3.

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..... **[2]**

(d) Similar changes in tameness, colour and body shape are believed to have occurred in the 11 000 year period during which the grey wolf species, *Canis lupus*, evolved into the domesticated dog species, *Canis familiaris*.

Suggest how different types of isolating mechanism allowed dogs to evolve separately to wolves.

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..... **[3]**

(e) Interbreeding between members of the wolf species and some dogs has been reported. However, there are some large breeds of dogs that cannot breed successfully with small dog breeds.

Use this information and your own knowledge to explain the problems of classifying wolves and different dog breeds according to:

- the biological species concept
  and
- the phylogenetic species concept.

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..... **[4]**

[Total:15]

7 Homeobox genes show astonishing similarity across widely different species of animal, from fruit flies, which are insects, to mice and humans, which are mammals. The sequences of these genes have remained relatively unchanged throughout evolutionary history and the same genes control embryonic development in flies and mammals.

(a) State what is meant by a homeobox gene.

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..... **[2]**

(b) Homeobox genes show 'astonishing similarity across widely different species of animal'.

Explain why there has been very little change by mutation in these genes.

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..... **[2]**

(c) Frogs reproduce by laying eggs in water. Each egg develops into a tadpole, which has external gills to extract oxygen from the water, and a tail to help it swim. The tadpole gradually changes into an adult frog as it grows. During this time its gills and tail disappear.

List **two** cellular processes that must occur during the development of a tadpole into a frog.

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..... **[2]**

(d) Name another kingdom of organisms, other than animals, that have similar homeotic genes.

..... **[1]**

[Total: 7]

END OF QUESTION PAPER

3 Molecular evidence has shown that all specimens of the English Elm tree, *Ulmus procera*, form a genetically isolated clone. English Elms developed from a variety of elm brought to Britain from Rome in the first century A.D.

Although English Elm trees make pollen, they rarely produce seeds. Instead they spread by developing structures known as suckers from their roots. Each sucker can grow into a new tree.

This tendency of elms to create suckers has been exploited by humans, who have separated the suckers, with roots attached, and used them to plant hedges and establish new woodlands.

(a) (i) Suggest a technique that could be used to provide **molecular** evidence that all English Elm trees form a clone.

.....[1]

(ii) State why the English Elm clone is genetically isolated from other varieties of elm.

.....

.....[1]

(iii) State the name given to the process in which plants reproduce asexually by means such as suckers.

.....[1]

(b) In 1967, a new, virulent strain of an elm disease fungus arrived in Great Britain on imported timber. Beetles that lived under the bark of elm trees spread the fungus.

The saws used to cut down dead branches were not sterilised after use. When the saws were used to prune healthy trees, these trees became infected. Approximately 25 million elm trees, most of the English Elm population, died within a few years of the arrival of this fungus.

Explain why there was such a rapid loss of elm trees in Britain as a result of this elm disease.

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.....[4]

(c) Elm trees respond to fungal infection by plugging their xylem vessels. The leaves on the upper branches of the tree then turn yellow and die. When most of the branches have lost their leaves and died, the roots are weakened and may also die.

(i) Explain why the plugging of xylem vessels will result in the leaves of the upper branches turning yellow.

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..... **[2]**

(ii) Explain why the loss of leaves from the tree may result in the death of the tree's roots.

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..... **[2]**

QUESTION 3(d) STARTS ON PAGE 10

(d) Many ornamental plants for gardens can be cloned by tissue culture.

Describe the process of cloning plants by tissue culture.

In your answer you should make clear the order in which the steps of the process occur.

.... [7]

(e) List **two** advantages and **two** disadvantages of cloning plants by tissue culture.

advantage 1 .....

.....

advantage 2 .....

.....

disadvantage 1 .....

.....

disadvantage 2 .....

..... **[4]**

[Total: 22]

6 Describe the differences between:

(a) somatic cell gene therapy and germ line cell gene therapy

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..... **[2]**

(b) the central nervous system and the peripheral nervous system

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..... **[4]**

(c) prophase 1 of meiosis and prophase 2 of meiosis.

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..... **[2]**

[Total: 8]

Answer **all** the questions.

1 **(a)** Human populations have herded cattle for milk for around 9000 years. Artificial selection over this time has resulted in the modern dairy cow.

(i) State **three** phenotypic traits (characteristics) that have been selected for in dairy cows.

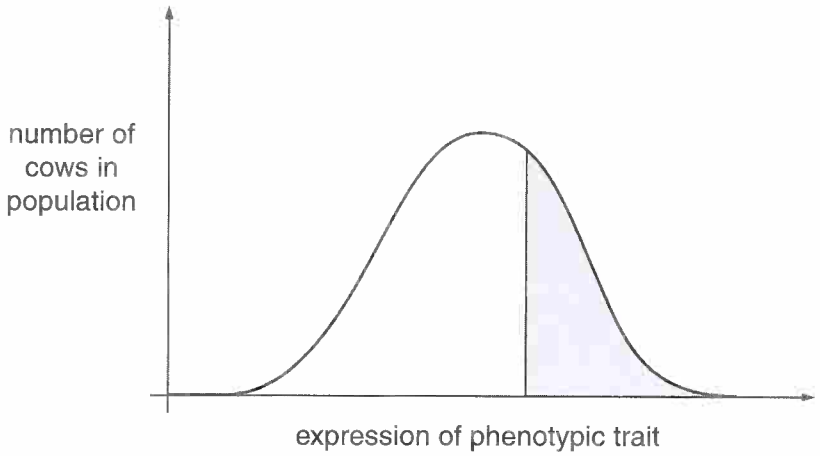
1 .....

2 .....

3 ..... **[3]**

(ii) Fig. 1.1 shows the pattern of variation of a phenotypic trait in a herd of dairy cows. The shaded part of the graph indicates those cows that are chosen to breed.

Draw, **on Fig. 1.1**, a second curve to show the pattern of variation in the next generation.



[2]

Fig. 1.1

(iii) In recent years, artificial selection of dairy cows has been helped by modern reproductive technology.

Name **two** modern techniques or procedures that can be used in the selective breeding of dairy cows.

1 .....

2 ..... **[2]**

(b) Lactase is an enzyme that is necessary to digest lactose sugar in milk.

In some parts of the world, animals are not farmed for milk and no dairy products are eaten. Adult humans that are native to these parts of the world do not produce lactase.

In areas where animals are farmed for milk, native adult humans do produce lactase. In these populations, a new allele has arisen by gene mutation.

(i) State what is meant by gene mutation.

.....

..... **[1]**

(ii) Over time, the frequency of this new allele increased in the gene pool of the human populations whose diet included milk.

Name the process by which this increase occurred.

..... **[1]**

(c) (i) All human babies produce the enzyme lactase. The genetic change that allows adults to produce this enzyme is thought to involve a mutation in a regulatory gene. This mutation causes the structural gene to be expressed in adults.

Distinguish between the terms 'regulatory gene' and 'structural gene'.

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..... **[2]**

(ii) Adult humans who cannot produce the enzyme lactase are described as lactose-intolerant and cannot drink milk without experiencing health problems. However, lactose-intolerant people can safely eat yogurt.

Yogurt is produced from milk that is fermented by bacteria. These bacteria perform anaerobic respiration, using carbohydrate as their respiratory substrate.

Suggest why yogurt is a suitable food for lactose-intolerant people.

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..... **[2]**

(d) The control of the expression of the *lac* operon genes, which allow uptake and digestion of lactose in the bacterium *Escherichia coli*, is well known.

Fig. 1.2 shows the arrangement of the elements of the *lac* operon.

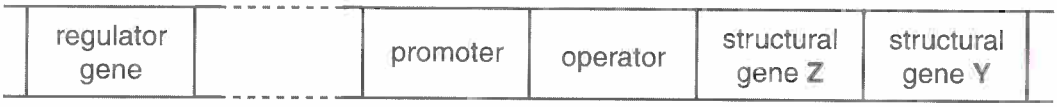

Fig. 1.2

Describe how genes **Z** and **Y** are switched on in bacteria that are moved to a nutrient medium that contains lactose.

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..... **[3]**

[Total: 16]

5 This question is about genetic engineering and the techniques used for making multiple copies of genes (gene cloning).

(a) Genetic engineering uses the following:

A an enzyme that synthesises new DNA
B an enzyme that cuts DNA at specific sequences
C an enzyme that reseals cut ends of DNA
D small circular pieces of DNA found in bacteria; these pieces of DNA have antibiotic resistance genes
E an enzyme found in some viruses with an RNA genome; this enzyme converts RNA into DNA.

Name **A** to **E**.

A .....

B .....

C .....

D .....

E ..... **[5]**

(b) Genes are cloned for a number of reasons. For example,

- one group of research scientists at a hospital wanted to sequence a disease-causing mutation to learn more about a human disease; these scientists started their research using white blood cells;

- another group of scientists at a biotechnology company wanted to clone the insulin gene in order to manufacture its protein product to treat diabetes; these scientists started their research using cells from the pancreas.

Suggest **and** explain the biological reasons why the two groups each started with a different cell.

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..... **[4]**

(c) A gene can be cloned *in vitro* (in a test-tube) by the polymerase chain reaction (PCR). Alternatively, a gene can be cloned *in vivo* (in living cells) by introducing the gene into bacterial host cells.

Table 5.1 identifies some of the key steps in each process.

Table 5.1

in vitro gene cloning (PCR)	*in vivo* gene cloning
At 95 °C, DNA extracted from a cell separates into two strands.	A library of gene fragments is produced and introduced into host bacteria.
At 50 °C, specially-made primer sequences attach to the ends of the desired gene only.	Bacteria are screened for antibiotic resistance to identify those with recombinant DNA.
At 72 °C complementary copies of both DNA strands are made.	A gene probe is used to select the bacterial colony containing the desired gene.
The cycle of temperature changes is repeated and more copies of the gene are made.	This colony is grown on in nutrient broth and the DNA is then purified.

Compare the two processes of gene cloning by explaining the advantages of each.

In your answer you should ensure that clear comparisons between the two processes are made and explained.

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.... **[8]**

[Total: 17]

QUESTION 6 STARTS ON PAGE 18

5 Growth and development in organisms is controlled by a number of mechanisms that operate at the cellular level. The control elements involved in these mechanisms include hormones, the second messenger molecule cyclic AMP and regulatory genes.

- In eukaryotes the most important regulatory genes contain homeobox sequences and are called homeotic genes.
- The regulatory genes of the *lac* operon in prokaryotes are studied to help us to understand how regulatory genes and their products interact to switch structural genes on and off.

(a) Use your understanding of the biochemical identity and interactions of these control elements to complete Table 5.1 by putting a tick (✓) or a cross (✗) **in each box**.

Some of the boxes have been completed for you.

Control element	Made of protein	Binds with a protein	Codes for protein
insulin		✓	
cyclic AMP			✗
lac I (inhibitor) gene		✓	
lac O (operator) gene	✗		
homeotic gene product		✗	

[5]

Table 5.1

(b) RNA polymerase and DNA polymerase are both enzymes. RNA polymerase is involved in the action of some control elements, whereas DNA polymerase is not.

Describe and explain the difference between the **functions** of these two enzymes.

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..... **[4]**

(c) Another mechanism that can act to change the body plan of an organism during its development is **programmed cell death**.

Fill in the gaps in the following passage describing this process and the importance of its regulation.

Programmed cell death is known as ..... . Firstly, the fine network of protein filaments and microtubules known as the ....., which gives structure to the cell, is broken down and digested by ..... .

The plasma (cell surface) membrane then changes, forming small bulges called 'blebs'. The cell breaks into membrane-bound fragments that are removed by the process of ..... so that harmful substances are not released into surrounding tissues.

Programmed cell death is a controlled process. However, mutation in a gene called p53 can prevent programmed cell death. When this occurs, the rate at which somatic cells are produced by the process of ..... becomes greater than the rate at which cells die, resulting in the formation of a mass of cells known as a ..... .

[6]

[Total: 15]

7 **(a)** Fig. 7.1 shows a suggested evolutionary relationship between bears, raccoons and the two species of panda, the giant panda, *Ailuropoda melanoleuca*, and the red panda, *Ailurus fulgens*.

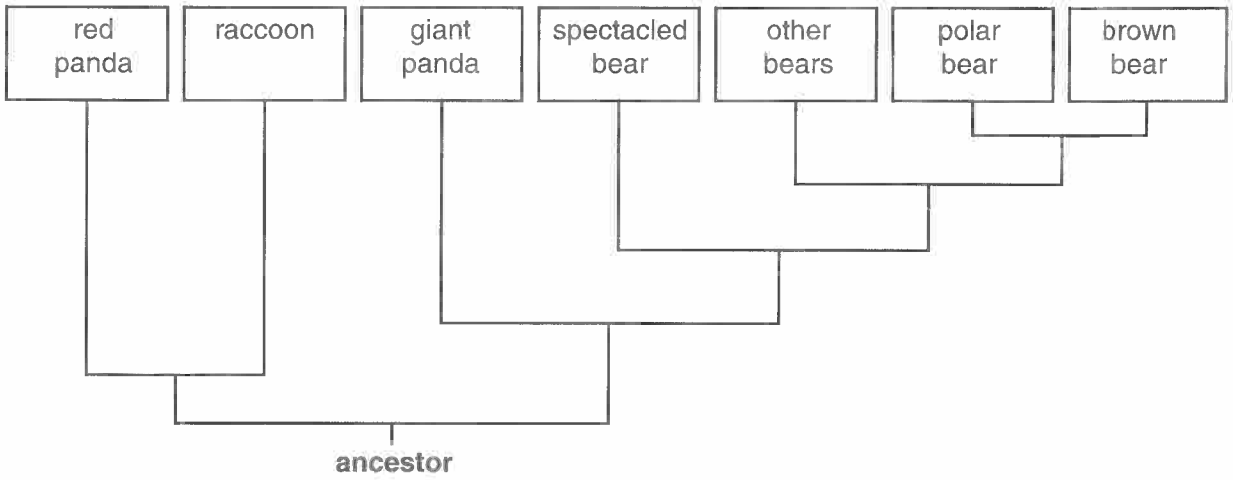

Fig. 7.1

(i) Using Fig. 7.1, name the **two** animals that share the most recent common ancestor.

.....[1]

(ii) State whether pandas form a distinct taxonomic group. Use information from Fig. 7.1 to justify your answer.

.....

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.....[1]

(b) The evolutionary relationship of the giant panda and red panda has been a matter of scientific debate for many years. It was hoped that molecular evidence would provide a definite answer. Some of the results of scientific studies are listed in Table 7.1.

Table 7.1

year	protein sequenced	conclusion
1985	albumen	Giant panda is more closely related to bears, and red panda is more closely related to raccoons, than pandas are to each other.
1986	haemoglobin	Giant and red panda are more closely related to each other than the giant panda is to bears or the red panda is to raccoons.
1993	cytochrome c	Giant panda is more closely related to bears, and red panda is more closely related to raccoons, than pandas are to each other.

(i) Comment on what the results in Table 7.1 show about the nature of scientific knowledge **and** the role of the scientific community in validating new knowledge.

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..... **[2]**

(ii) The roles of the three proteins sequenced in the studies shown in Table 7.1 are as follows:

- albumen carries molecules such as hormones in the blood
- haemoglobin carries oxygen in the blood
- cytochrome c plays a role in oxidative phosphorylation in mitochondria.

Both the giant and the red panda live in mountain habitats and are physiologically adapted to living at high altitude. Oxygen partial pressure is lower at high altitude than it is at sea level.

Explain how these facts could provide an argument for rejecting the conclusion of the 1986 study.

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..... **[3]**

(c) Research on another protein from the giant panda was carried out in 2008. This protein, called crystallin, is found in the lens of the eye, and has a sequence that has been highly conserved in all mammals.

The steps in the procedure used in the study are summarised in Fig. 7.2.

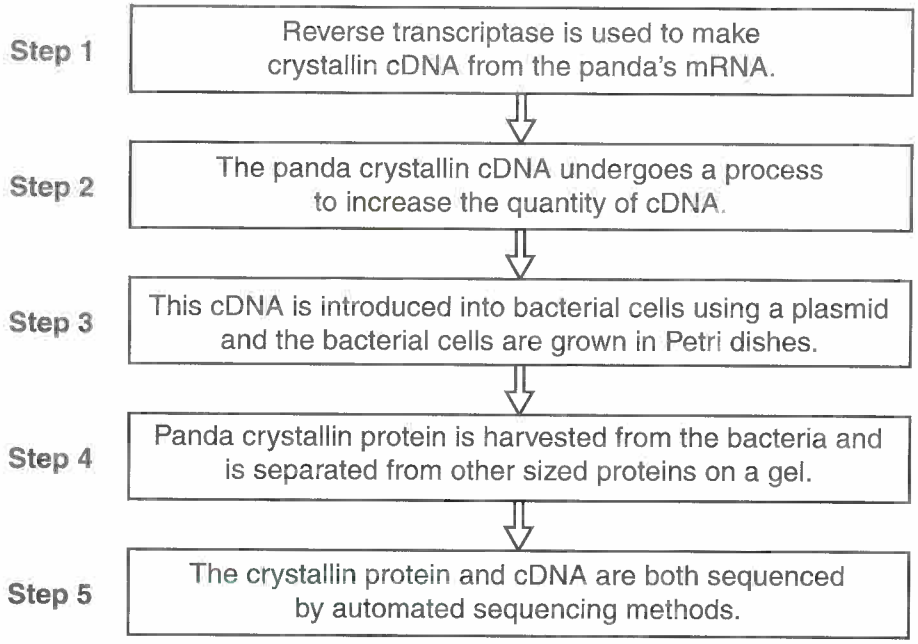

Fig. 7.2

Identify the **technique** used in each case to carry out steps **2**, **3** and **4**.

step **2** .....

step **3** .....

step **4** ..... **[3]**

(d) The panda crystallin protein obtained was 175 amino acids long, corresponding to a 528 base pair cDNA gene.

Explain why a protein that is 175 amino acids long is coded for by 528 base pairs of DNA.

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..... [3]

(e) The crystallin protein and cDNA sequences of the giant panda were compared with those of three other mammals.

The results are shown in Table 7.2.

Table 7.2

	percentage of sequence that is the **same** in the giant panda and other mammal	
mammal	nucleotides in cDNA	amino acids in protein
human	93.9	98.3
mouse	91.5	97.1
ox	95.3	99.4

(i) Using the data in Table 7.2, name the mammal that is the closest relative of the giant panda.

.....

[1]

(ii) Explain why the figures in Table 7.2 are higher for the protein sequences than for the cDNA sequences.

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[3]

[Total: 17]

END OF QUESTION PAPER

5 Fig. 5.1 is a circular representation of the genetic code.

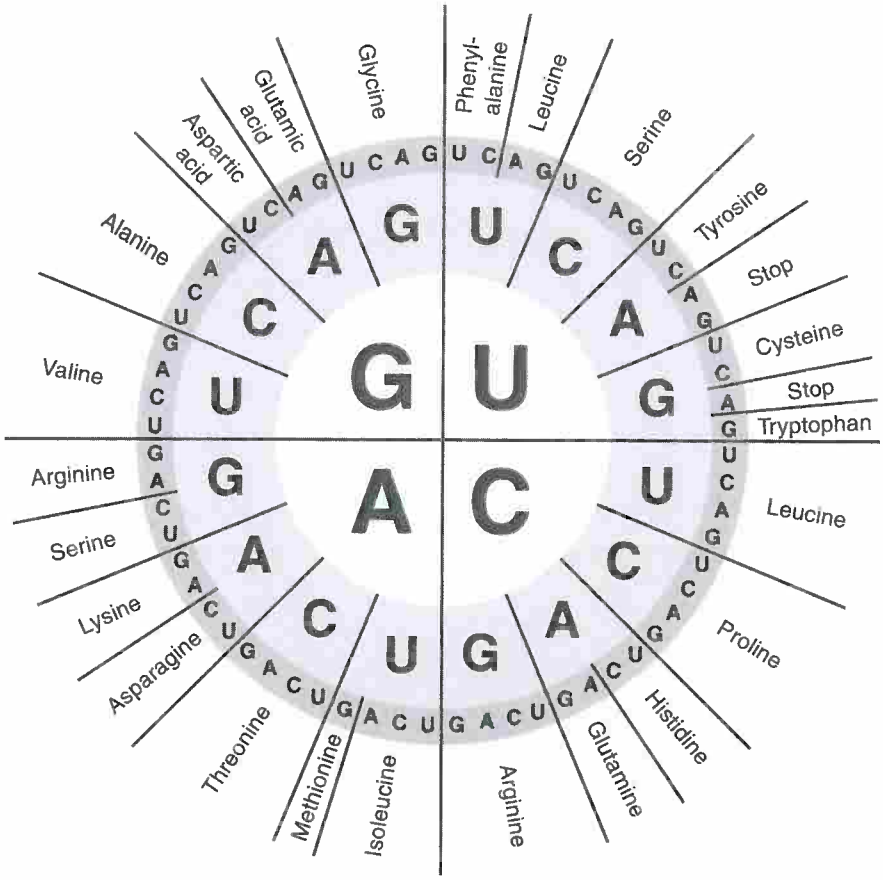

Fig. 5.1

(a) **Fig. 5.2** shows a sequence of bases coding for a sequence of amino acids. The name of the third amino acid in the sequence has been filled in.

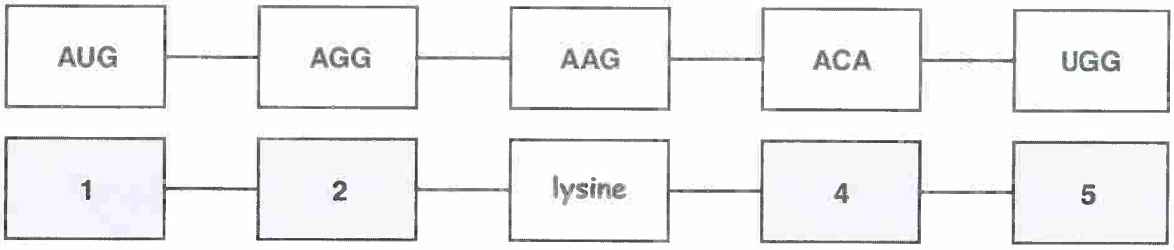

Fig. 5.2

Identify the remaining amino acids in the sequence.

1 .....

2 .....

3 lysine

4 .....

5 ..... [2]

(b) State the name of the stage of protein synthesis represented in Fig.5.2 **and** name the organelle in the cell where this takes place.

.....

..... [2]

(c) Identify the type of nucleic acid that holds the sequence of bases shown in Fig. 5.2.

..... [2]

(d) Using the information in **Fig. 5.1**, list the **three** triplet codons that would cause termination of a polypeptide chain (stop codons) **and** explain why these codons have this effect.

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..... [2]

(e) What name would be given to a mutation that resulted in a change of the codon **UUU** to **UUC**?

..... [1]

[Total: 9]