OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

BIOLOGY

2805/02

Applications of Genetics

Thursday **19 JUNE 2003** Afternoon 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers, in blue or black ink, in the spaces on the question paper.
- Read each question carefully before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	15	
2	15	
3	15	
4	13	
5	19	
6	13	
TOTAL	90	

This question paper consists of 18 printed pages and 2 blank pages.

MML 2857 3/02 S32579/5

Answer **all** the questions.

1 Pollen from a pure-bred tomato plant with white flowers and yellow fruit was transferred to the stigmas of a pure-bred plant with yellow flowers and red fruit. All the F_1 generation had yellow flowers and red fruit.

(a) State **three** practical precautions that must be taken by a plant breeder to ensure that the offspring produced are **only** from the desired cross.

1. ....

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2. ....

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3. ....

.... [3]

(b) In a test cross, pollen from the F_1 generation was transferred to pure-bred plants with white flowers and yellow fruit. The ratio of phenotypes **expected** among the offspring of a dihybrid test cross such as this is 1:1:1:1.

Seeds from the test cross were collected and grown, giving plants with the following phenotypes:

yellow flowers and red fruit	87
yellow flowers and yellow fruit	13
white flowers and red fruit	17
white flowers and yellow fruit	83
	200

A chi-squared (χ^2) test can be carried out to check whether the numbers of each phenotype of offspring resulting from the test cross are in agreement with a 1:1:1:1 ratio. Part of the calculation is shown in Table 1.1.

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

Σ = 'sum of...'
O = observed 'value'
E = expected 'value'

Table 1.1

phenotypes	yellow flowers red fruit	yellow flowers yellow fruit	white flowers red fruit	white flowers yellow fruit
observed number (O)	87	13	17	83
expected ratio	1	1	1	1
expected number (E)	50	50	50	50
O – E	37			33
$(O-E)^2$	1369			1089
$(O-E)^2/E$	27.38			21.78

$\Sigma (O-E)^2/E = \chi^2$	

(i) Complete the shaded boxes in Table 1.1 to calculate χ^2 for these results. [3]

(ii) State the number of degrees of freedom applicable to these results.

.... [1]

(iii) Use the calculated value of χ^2 and the table of probabilities provided in Table 1.2 to find the probability of the results of the test cross departing significantly by chance from the expected ratio.

probability (p) .... [1]

Table 1.2

Distribution of χ^2

degrees of freedom	probability, p				
	0.10	0.05	0.02	0.01	0.001
1	2.71	3.84	5.41	6.64	10.83
2	4.61	5.99	7.82	9.21	13.82
3	6.25	7.82	9.84	11.35	16.27
4	7.78	9.49	11.67	13.28	18.47

(iv) State what statistical conclusion may be drawn from the probability found in **(b)(iii)** about the difference between expected and actual results.

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For Examiner's Use

(c) Explain the discrepancy between the expected and the actual results of the test cross.

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[Total: 15]

2 **(a)** The herd of Chillingham cattle lives in isolation in a park in the north of England. The cattle have been studied extensively, including by Charles Darwin, because the herd has remained viable and fertile despite at least 300 years of inbreeding. In October 2000, the herd consisted of 49 individuals. The cattle have never been artificially selected.

Describe briefly the harmful genetic and other effects of inbreeding.

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.... [3]

(b) DNA from 13 Chillingham cattle that died in 1998/99 was analysed at 25 'marker' sites, covering 15 of the 29 autosomal chromosomes. All samples showed identical homozygous genotypes at 24 of the 25 sites. Other breeds of cattle show about 70% heterozygosity at these sites.

Suggest, given their genetic homozygosity at the sites analysed, why the Chillingham cattle continue to be viable and fertile.

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.... [2]

(c) Explain the need to conserve rare breeds, such as Chillingham cattle.

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(d) In this question, one mark is available for the quality of written communication.

One way of conserving rare breeds of mammals is by transplanting embryos of the rare breed into surrogate females.

Describe the techniques used in embryo transplantation.

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Quality of Written Communication [1]

[Total: 15]

For Examiner's Use

3 Using genetically engineered bacteria, a synthetic insulin molecule has been produced which has over 20% of the activity of naturally produced insulin. The gene for the synthetic molecule has been used in an experimental gene therapy for insulin-dependent diabetes.

DNA coding for the synthetic molecule was combined, as shown in Fig. 3.1, with a promoter region taken from a gene for an enzyme found **only** in liver cells. The promoter is sensitive to blood glucose concentration and switches on its associated gene as blood glucose concentration rises above the normal concentration.

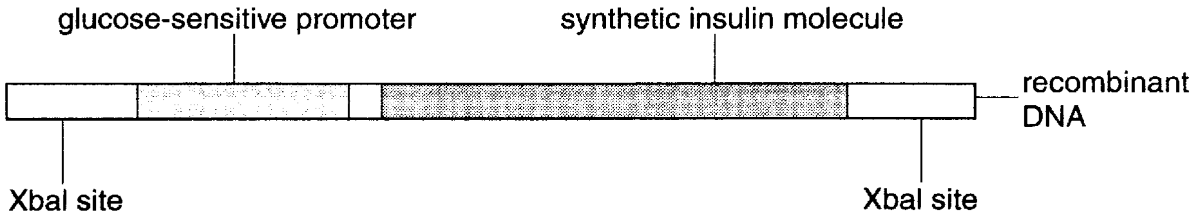

Fig. 3.1

The recombinant DNA shown in Fig. 3.1 was cut with the restriction enzyme, Xbal, at the two sites shown and inserted into a virus. Cloned virus particles were injected into diabetic rats which expressed the gene only in liver cells.

(a) **(i)** State what is meant by *recombinant* DNA.

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.... [1]

(ii) Describe the roles of a restriction enzyme, such as Xbal, in genetic engineering.

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(iii) Explain the advantage of being able to produce the synthetic insulin molecule in response to a rise in blood glucose concentration.

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(b) Four weeks after receiving this gene therapy, the experimental diabetic rats were given a glucose meal. The concentrations of blood glucose and synthetic insulin in their blood were measured at intervals for eight hours.

A control group of non-diabetic rats, which had **not** received gene therapy, were also given a glucose meal and the concentrations of blood glucose and insulin measured at the same time intervals. The results are shown in Figs. 3.2 and 3.3.

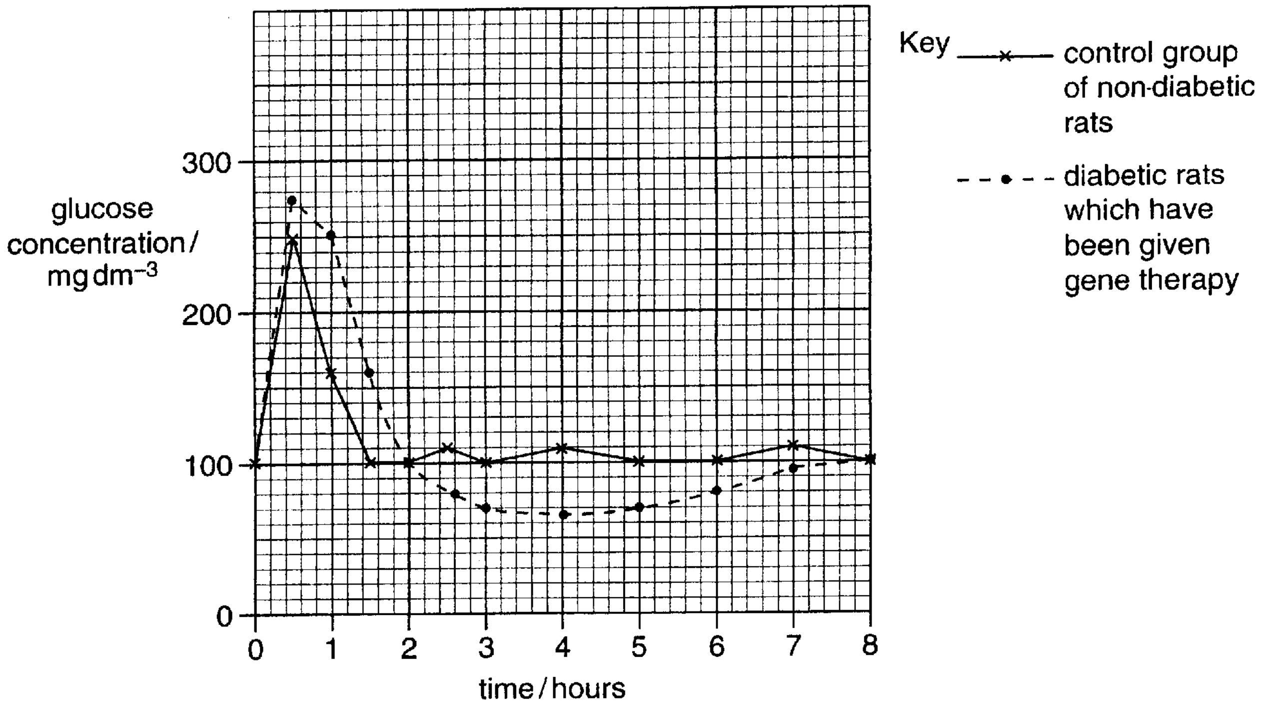

Fig. 3.2

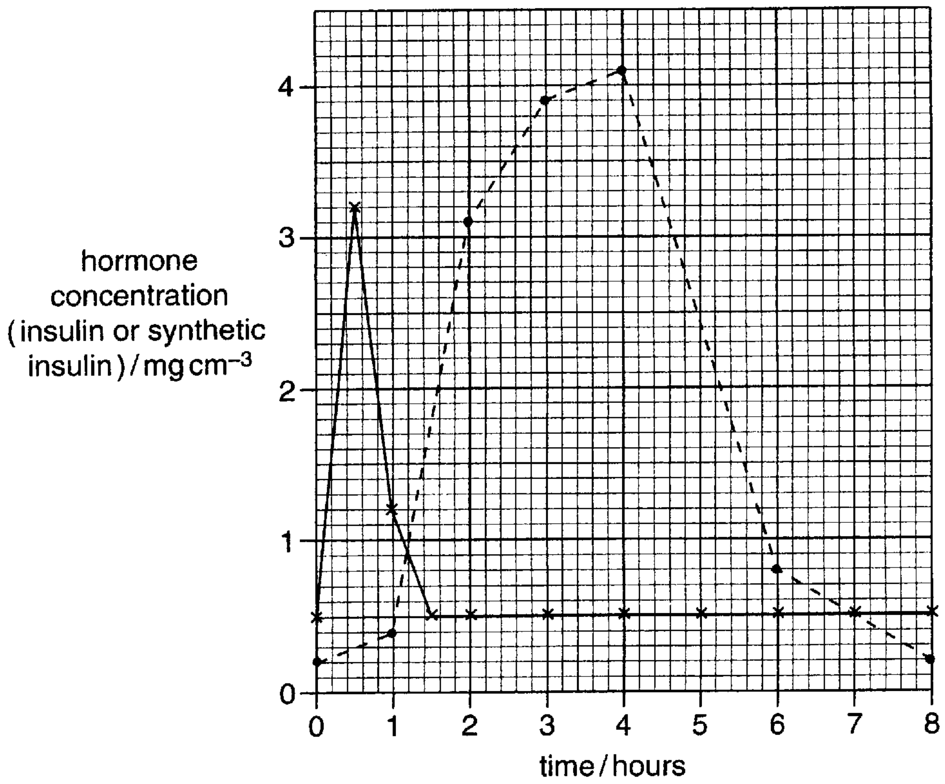

Fig. 3.3

For Examiner's Use

With reference to Figs. 3.2 and 3.3,

(i) compare the concentrations of glucose and hormone in the blood of experimental and control rats;

glucose ....

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hormone ....

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(ii) discuss the potential benefits and problems of using this gene therapy for the treatment of diabetes.

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[Total: 15]

4 *Bt* maize has been genetically modified to express an insecticidal toxin (*Bt* toxin), derived from the bacterium *Bacillus thuringiensis*, to kill insect pests feeding on the plants. The gene for *Bt* toxin was inserted into maize cells in tissue culture.

(a) Describe briefly the technique of cloning plants from tissue culture.

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It has been suggested that *Bt* toxin may kill soil organisms such as insects, worms, bacteria and fungi.

An experiment was performed to investigate the potential danger to soil organisms of growing *Bt* maize. Seeds of *Bt* maize were surface-sterilised and germinated on sterile agar. After germination the seedlings were grown at constant temperature in sterile soil-free nutrient medium in closed containers. After 20 days the containers were left open.

After 7, 15 and 25 days growth the plants were placed in fresh medium. The medium that the plants had been growing in was analysed for the presence of *Bt* toxin and samples of it placed in contact with insect larvae of a species known to be susceptible to *Bt* toxin. The results are shown in Table 4.1.

Table 4.1

time / days	7	15	25
sterility of medium	sterile	sterile	non-sterile
presence of *Bt* toxin in medium	present	present	not present
effect of medium on insect larvae	95% dead after 5 days	95% dead after 5 days	no larval death

(b) Describe the control experiment that should have been performed for the investigation described above.

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(c) With reference to Table 4.1,

(i) explain the results found at 25 days;

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(ii) discuss whether the results of this investigation show that growing *Bt* maize could damage the soil organisms of the fields in which it is grown.

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[Total: 13]

For Examiner's Use

5 In Sri Lanka, mosquito breeding sites are sprayed with the insecticide Fenthion. This is the main means of controlling the spread of the disease filariasis. The mosquito *Culex quinquefasciatus* developed resistance to the insecticide in one population, and resistance is now spreading rapidly.

(a) In this question, one mark is available for the quality of written communication.

Explain how insecticide resistance may arise in an insect population and then spread rapidly.

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Quality of Written Communication [1]

For Examiner's Use

(b) The genetic basis of the insecticide resistance is an amplification of the gene for an esterase enzyme which breaks down the insecticide. There may be up to 80 copies of the gene for the enzyme in every cell of insecticide-resistant mosquitoes.

Explain how the presence of many copies of the gene could lead to increased insecticide resistance.

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.... [3]

(c) Filariasis is caused by a parasitic worm whose larvae are transmitted by female mosquitoes. Female mosquitoes were collected in seven districts of Sri Lanka and analysed for the presence of parasite DNA.

Outline a method by which the presence of parasite DNA in an organism could be detected.

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.... [3]

(d) Almost 80% of the mosquitoes collected carried the parasitic worm. Fig. 5.1 shows the relationship between concentration of parasite DNA per mosquito and the esterase activity in the mosquito. The same relationship was found in all seven districts investigated.

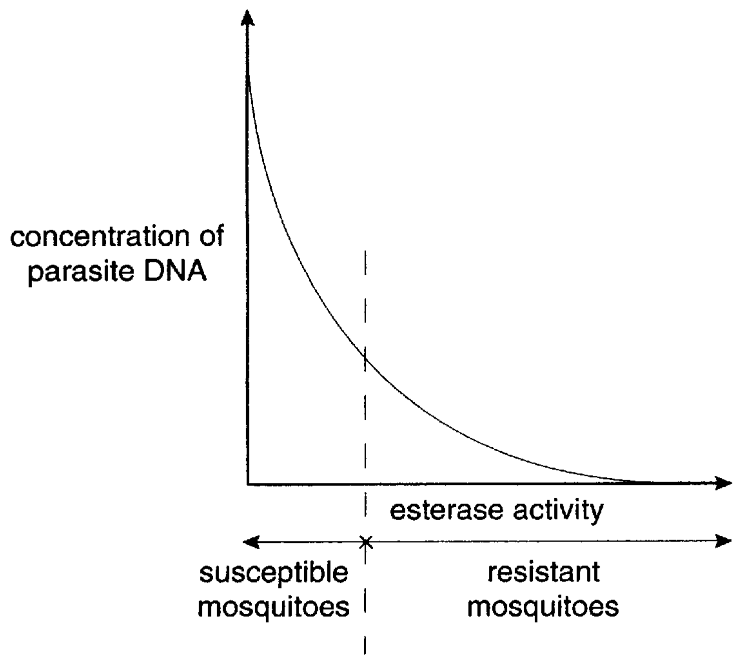

Fig. 5.1

Laboratory colonies of insecticide resistant and susceptible mosquitoes were fed on blood infected with filaria worms. After a few days, the percentage of female mosquitoes from each colony who produced infective larvae of the parasites was found. The results are shown in Table 5.1.

Table 5.1

mosquito colony	percentage of females producing parasite larvae
resistant to insecticide	0
susceptible to insecticide	76

With reference to Fig. 5.1 and Table 5.1,

(i) describe the relationship between a mosquito's resistance to insecticide and its ability to transmit filariasis;

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.... [3]

(ii) explain whether or not the spread of insecticide resistance and resulting changes in mosquito populations would increase the risk of filariasis in humans.

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.... [3]

[Total: 19]

For Examiner's Use

6 Women with an uncommon mutation in the gene BRCA1 on chromosome 17 have an increased risk of developing breast and ovarian cancers. Over a hundred different mutations are known and most of the mutations prevent the gene from producing the protein for which it codes. The role of the normal allele of BRCA1 is to suppress the formation of cancers.

(a) Explain briefly

(i) how a mutation of a gene may **prevent the production** of the protein for which it codes;

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.... [3]

(ii) why cancers are more likely in cells that usually divide frequently;

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(iii) how a mutation in a gene that normally slows mitosis might increase the chances of a cancerous growth occurring.

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(b) Fig. 6.1 shows a family's history of breast and/or ovarian cancer. Women **A**, **B** and **E** are known to have the same mutation of BRCA1.

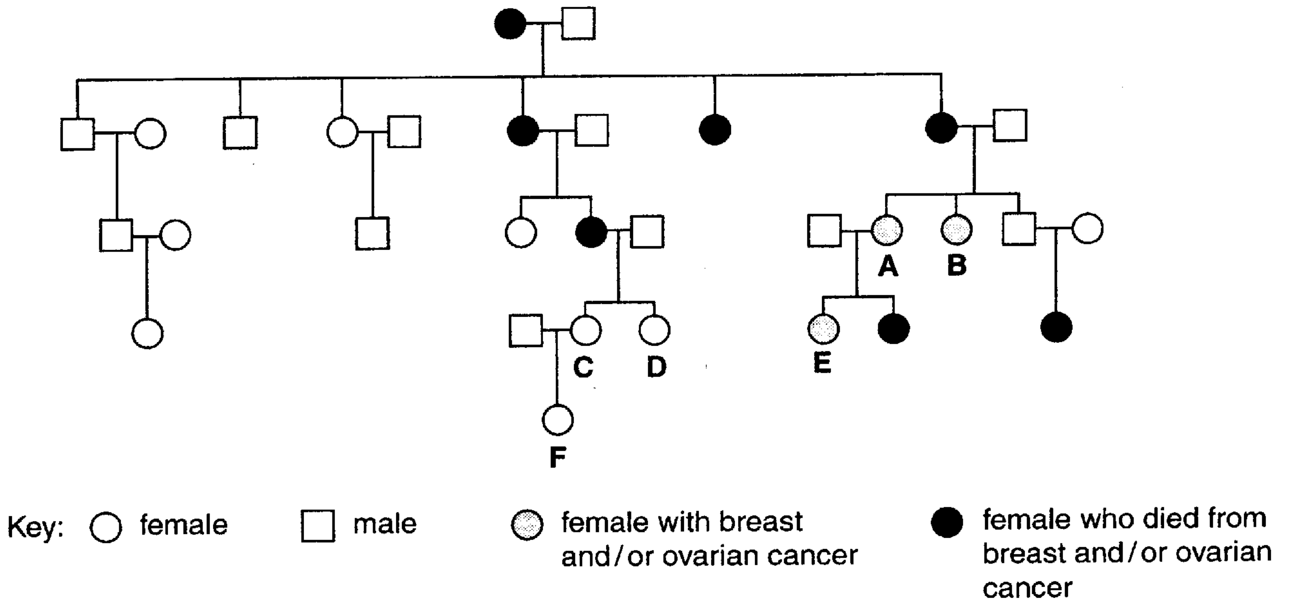

Fig. 6.1

With reference to Fig. 6.1,

(i) explain whether the mutation of BRCA1 found in this family is inherited as a recessive or as a dominant allele;

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.... [2]

(ii) calculate the probability of individual **F** inheriting the mutation.

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.... [1]

For Examiner's Use

(c) Genetic screening for mutations of BRCA1 can be carried out by analysing DNA, using enzymes, in a process similar to genetic fingerprinting. Part of the resulting DNA banding pattern for individuals **A** to **E** is shown in Fig. 6.2.

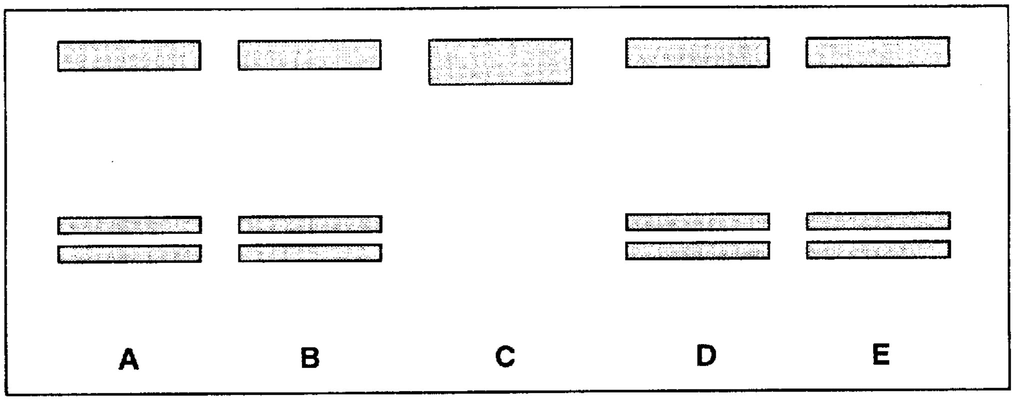

Fig. 6.2

Using the information in Figs. 6.1 and 6.2, explain the advice that a genetic counsellor would give to the sisters **C** and **D**.

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.... [5]

[Total: 13]

Copyright Acknowledgements:

Question 4. Fig. 4.2 and 4.3 reprinted by permission from 'Nature' (No. 408, pp.483 – 487, 23rd Nov. 2000), 'Remission in models type 1 diabetes...' by Hyun Chul Lee et al, © Macmillan Publishers Ltd.