

Name: \_\_\_\_\_ Per: \_\_\_\_\_

## AICE Biology: Meiosis and Genetic Control Problem Set

Answer the following AICE practice questions in complete sentences. All questions come from AICE Paper 4 (A2 Level topics) and are all essay based. This problem set will be due the day of the genetics test **and is worth 40 points**.

1.

(a) Outline the symptoms of cystic fibrosis (CF).

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..... [4]

(b) CF is caused by a recessive mutation, **b**, on an autosome.

Draw a genetic diagram to show, for parents with genotypes **BbXX** and **BbXY**, the **probability** of having a daughter who suffers from CF.

In your genetic diagram, show the genotypes of the gametes and the genotypes and phenotypes of the offspring.

genetic diagram

*parental genotypes*                      **BbXX**                      x                      **BbXY**

*genotypes  
of gametes*

*genotypes and  
phenotypes  
of offspring*

1 continued...

- (c) One of the many mutations for CF results in the amino acid arginine being replaced by histidine in the polypeptide encoded by the CF gene.

Explain how a mutation may cause such a change in the amino acid sequence of a polypeptide.

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..... [4]

- (d) A genetic test was performed on two individuals, **D** and **E**, to find the base sequences of a small part of the CF gene. The different base sequences are shown diagrammatically in Fig. 3.1. Individual **E** has CF.

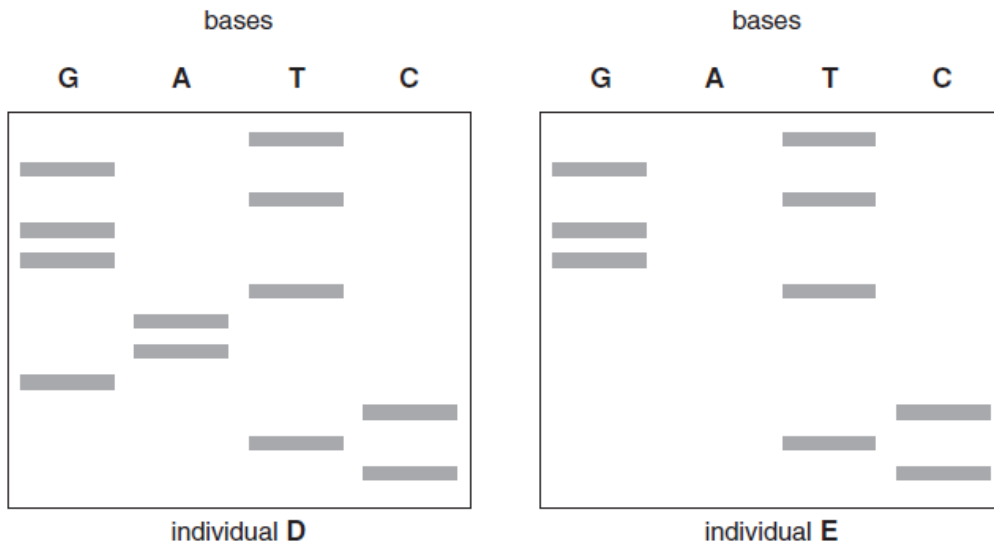


Fig. 3.1

With reference to Fig. 3.1, state,

- (i) how the base sequence of **E** differs from that of **D**

.....

..... [1]

1 continued...

(ii) the effect of this difference in the polypeptide produced by the two individuals.

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

[Total: 15]

2.

(a) A husband and wife who already have a child with cystic fibrosis (CF) elected to have their second child tested for the condition while still a fetus in very early pregnancy. The results of the test, a DNA banding pattern, were discussed with a genetic counsellor.

The relevant DNA banding pattern produced by electrophoresis is shown in Fig. 6.1.

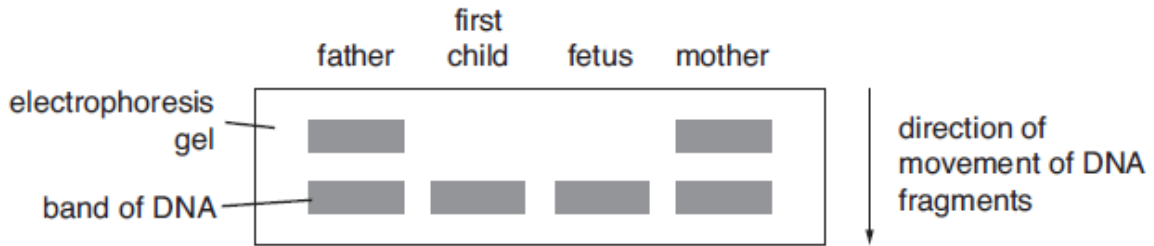


Fig. 6.1

With reference to Fig. 6.1, explain why,

(i) the fetus will develop CF,

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

(ii) the positions of the bands of DNA of the first child and of the fetus indicate that the mutant allele for CF has a deletion in comparison with the normal allele.

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..... [2]

2 continued...

(b) Explain briefly the need to discuss the result of the test with a genetic counsellor.

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[4]

[Total: 7]

3.

(a) The fruit fly, *Drosophila melanogaster*, feeds on sugars found in damaged fruits. A fly with normal features is called a wild type. It has a striped body and its wings are longer than its abdomen. There are mutant variations such as an ebony coloured body or vestigial wings. These three types of fly are shown in Fig. 7.1.

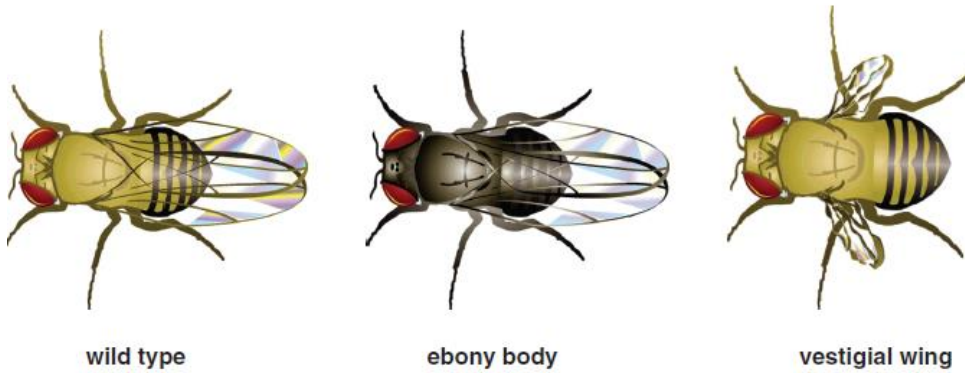


Fig. 7.1

Wild type features are coded for by dominant alleles, **A** for wild type body and **B** for wild type wings.

Explain what is meant by the terms *allele* and *dominant*.

allele .....

.....

dominant .....

.....

[2]

3 continued...

- (b) Two wild type fruit flies were crossed. Each had alleles **A** and **B** and carried alleles for ebony body and vestigial wings.

Draw a genetic diagram to show the possible offspring of this cross.

- (c) When the two heterozygous fruit flies in (b) were crossed, 384 eggs hatched and developed into adult flies.

A chi-squared ( $\chi^2$ ) test was carried out to test the significance of the differences between observed and expected results.

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

where  $\Sigma$  = sum of  
 O = observed value  
 E = expected value

Table 7.1

	phenotypes of <i>Drosophila melanogaster</i>			
	grey body long wing	grey body vestigial wing	ebony body long wing	ebony body vestigial wing
observed number (O)	207	79	68	30
expected ratio	9	3	3	1
expected number (E)	216	72	72	24
O – E	-9	.....	-4	6
(O – E) <sup>2</sup>	81	.....	16	36
$\frac{(O - E)^2}{E}$	0.38	.....	0.22	1.50

[3]

- (ii) Calculate the value for  $\chi^2$ .

$$\chi^2 = \dots\dots\dots [1]$$

3 continued...

Table 7.2 relates  $\chi^2$  values to probability values.

As four classes of data were counted the number of degrees of freedom was  $4 - 1 = 3$ . Table 7.2 gives values of  $\chi^2$  where there are three degrees of freedom.

**Table 7.2**

probability greater than	<i>0.50</i>	<i>0.20</i>	<i>0.10</i>	<i>0.05</i>	<i>0.01</i>	<i>0.001</i>
values for $\chi^2$	2.37	4.64	6.25	7.82	11.34	16.27

(iii) Using your value for  $\chi^2$ , and Table 7.2, explain whether or not the observed results were significantly different from the expected results.

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..... [2]

[Total: 14]

4.

Pompe disease is a rare neuromuscular disease caused by an autosomal recessive allele. This allele prevents the production of an enzyme called acid alpha-glucosidase (AG), which breaks down glycogen in muscle cells. Glycogen can build up in muscle cells causing damage to the cells. This damage leads to muscle weakness which gets worse with time.

(a) Explain how two parents, both of whom produce normal amounts of AG, can produce a child with Pompe disease.

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

(b) One form of treatment is enzyme replacement therapy where AG is given through regular injections.

(i) Suggest how AG may be manufactured.

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

(ii) Name the hormone that stimulates the breakdown of glycogen in liver cells.

.....[1]

(c) The MN blood group system is based on the presence of glycoproteins M and N, on the surface membrane of red blood cells, which act as *antigens*.

State what is meant by the term *antigen*.

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



- (d) The type of MN antigen on the surface membrane of red blood cells is controlled by a single gene with two alleles,  $L^M$  and  $L^N$ . The phenotypes of the MN blood group system are MM, MN and NN.

Complete the genetic diagram to show how the MN blood group is inherited.

parental phenotypes                      MN                      x                      MN

parental genotypes                      .....                      .....

gametes                      .....

offspring genotypes                      .....

offspring phenotypes                      ..... [3]

- (e) Allele frequencies for  $L^M$  and  $L^N$  vary in different human populations throughout the world.

Table 7.1 shows the  $L^M$  and  $L^N$  allele frequencies from five populations.

**Table 7.1**

population	allele frequency / %	
	$L^M$	$L^N$
Canadian Inuit	91	9
Egyptian	52	48
German	55	45
Chinese	57	43
Nigerian	55	45

Discuss the data shown in Table 7.1.

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..... [3]

5.

Canavan disease is a non sex-linked inherited condition that causes progressive damage to neurones of the brain. Symptoms of the condition include a loss of motor skills and mental retardation. The symptoms appear in early infancy and many children with this condition die by the age of four years.

People with Canavan disease lack an enzyme called aspartoacylase which breaks down N-acetyl aspartate. The build up of N-acetyl aspartate can interfere with the formation of the myelin sheath, particularly in neurones of the brain.

(a) Enzymes such as aspartoacylase display specificity.

Outline what is meant by *specificity* of an enzyme.

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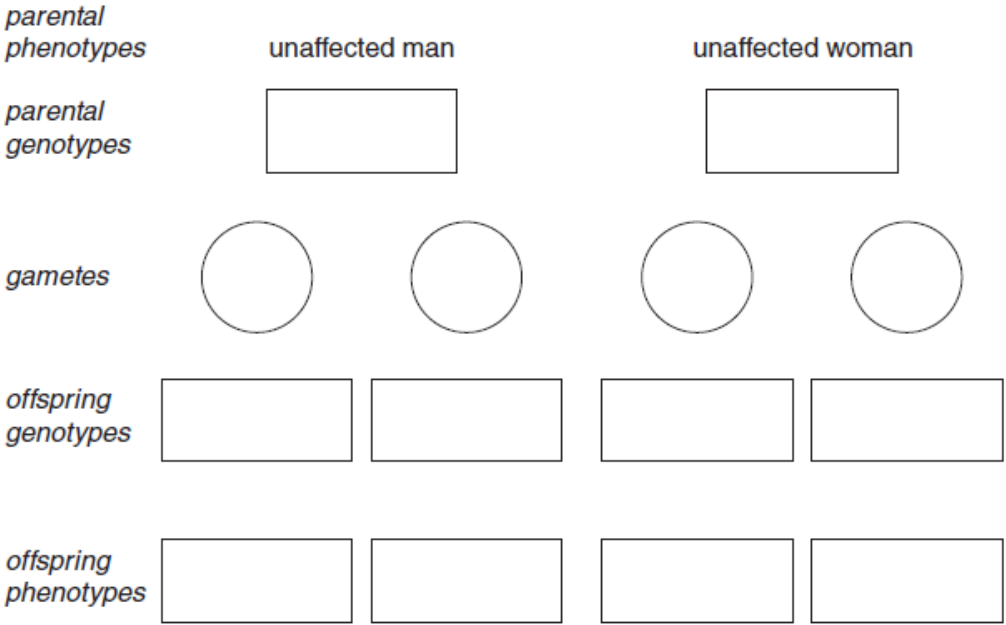
..... [2]

(b) Complete the genetic diagram below to show how an unaffected man and an unaffected woman could produce a child with Canavan disease.

*key to symbols*

.....

.....



[3]

6.

Meiosis is a type of nuclear division, which produces gametes for sexual reproduction.

(a) Fig. 7.1 shows diagrams of the stages of meiosis, A to J, but they are not in the correct order.

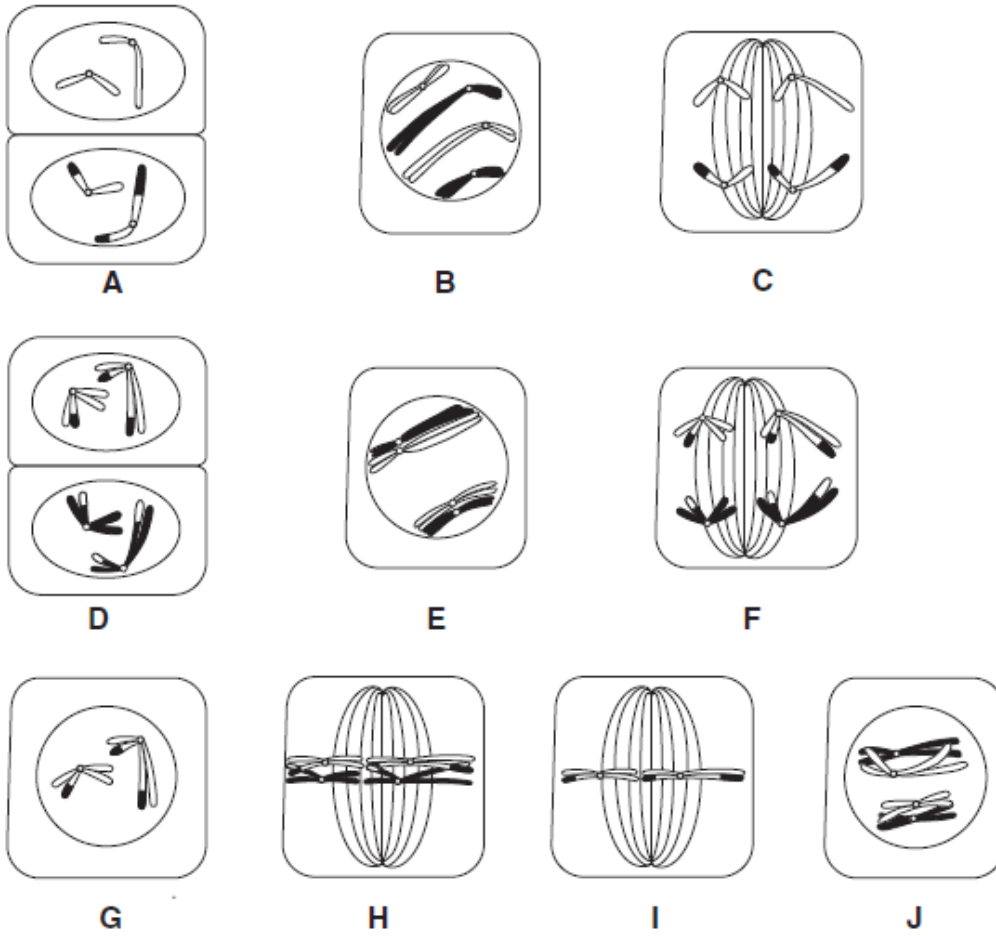


Fig. 7.1

Complete the table below by writing the stages of meiosis in the correct order.

Some of the stages have already been written in the table.

nuclear division	letter of stage
meiosis I	B
	D
meiosis II	

[4]

(b) Explain how meiosis can result in genetic variation amongst offspring.

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..... [5]

[Total: 9]

7.

Huntington's Disease (HD) is a severe neurological disorder in which symptoms usually appear after the person has reached sexual maturity. Symptoms include memory loss and changes in personality and mood.

HD is caused by a gene mutation on chromosome 4 in which the triplet code CAG is repeated many times. The resulting allele is dominant.

(a) Explain what is meant by the terms gene mutation and triplet code.

*gene mutation*.....  
 .....  
 .....  
 .....  
 .....  
*triplet code*.....  
 .....  
 .....  
 .....[4]

(b) A couple wish to start a family. The man does not have HD but the woman does have the disease. The woman's father does not have the disease.

Complete the genetic diagram below to show the probability of the couple's first child having HD.

*key*  
*Huntington allele = T*  
*normal allele = t*

<i>parental phenotypes</i>	man without HD	woman with HD
<i>parental genotypes</i>	.....	.....
<i>gametes</i>	.....	.....
<i>offspring genotypes</i>	.....	
<i>offspring phenotypes</i>	.....	
<i>probability of first child having HD</i>	..... [3]	

[Total: 7]

8.

In mice there are several alleles of the gene that controls the intensity of pigmentation of the fur.

The alleles are listed below in order of dominance with **C** as the most dominant.

**C** = full colour  
**C<sup>ch</sup>** = chinchilla  
**C<sup>h</sup>** = himalayan  
**C<sup>p</sup>** = platinum  
**C<sup>a</sup>** = albino

The gene for eye colour has two alleles. The allele for black eyes, **B**, is dominant, while the allele for red eyes, **b**, is recessive.

A mouse with full colour and black eyes was crossed with a himalayan mouse with black eyes. One of the offspring was albino with red eyes.

Using the symbols above, draw a genetic diagram to show the genotypes and phenotypes of the offspring of this cross.

9.

The fruit fly, *Drosophila melanogaster*, is widely used in genetic research. It has many phenotypic variants in features such as body colour, wing shape and eye colour.

Two variations from the normal-winged, grey-bodied phenotype are:

- vestigial (very short) wings, coded for by the recessive allele of the gene **N/n**
- ebony (black) body colour, coded for by the recessive allele of the gene **G/g**.

(a) Using the symbols given, state the possible genotypes of normal-winged, grey-bodied fruit flies.

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.....[2]

(b) Describe how you would determine the genotype of a normal-winged, grey-bodied fly.

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

9 continued...

(c) One of the genes for eye colour is carried on the X chromosome. This gene has different alleles coding for:

- red eyes
- orange eyes
- white eyes.

The allele for red eyes (R) is dominant to the allele for orange eyes (o) and dominant to the allele for white eyes (w). The allele for orange eyes is dominant to that for white eyes.

Using these symbols, draw a genetic diagram to show how a cross between a white-eyed male fruit fly with a red-eyed female fruit fly will produce male and female offspring that are either red-eyed or orange-eyed.

[4]

[Total: 9]



10.

The Labrador retriever is a modern breed of dog that can have yellow, black or brown fur and pale, black or brown noses. The inheritance of fur and nose colour is the result of the interaction between genes at two different loci, the B locus and the E locus.

Fig. 1.1 shows a Labrador retriever.



Fig. 1.1

Table 1.1 shows how gene interaction results in different phenotypes.

Table 1.1

alleles at B locus	alleles at E locus	phenotype
B <sub>-</sub>	ee	yellow fur black nose
bb	ee	yellow fur pale nose
B <sub>-</sub>	E <sub>-</sub>	black fur black nose
bb	E <sub>-</sub>	brown fur brown nose

A male Labrador retriever, heterozygous at the B locus and homozygous recessive at the E locus, was mated with a female Labrador retriever heterozygous at both loci.

(a) Explain the terms *locus* and *homozygous*.

*locus* .....

.....

*homozygous* .....

..... [2]

10 continued...

- (b) Use a genetic diagram to show the possible genotypes and phenotypes of the offspring from the mating between the two Labrador retrievers.

*parental phenotypes*

*parental genotypes*

*gametes*

*offspring genotypes and phenotypes*

[6]

[Total: 8]

11. In mice, the intensity of pigmentation of the fur is controlled by multiple alleles of a single gene.  
The alleles are listed below in order of dominance, with **C** as the most dominant.

- **C** = full colour
- **C<sup>ch</sup>** = chinchilla
- **C<sup>h</sup>** = himalayan
- **C<sup>P</sup>** = platinum
- **C<sup>a</sup>** = albino

(a) Explain how multiple alleles arise.

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..... [2]

(b) Eye colour in mice is controlled by two alleles of a single gene, **B/b**:

- allele **B** codes for black eyes
- allele **b** codes for red eyes.

A mouse with full colour fur and black eyes was crossed with a mouse with himalayan fur and black eyes. One of the offspring was albino with red eyes.

Using the symbols above, draw a genetic diagram to show the genotypes and phenotypes of the offspring of this cross.

### Part B: Extended Essays

On Paper 4, you will be required to write an extended essay on your choice of two topics. For practice, please complete **ALL** of the following essays on a spare sheet of paper and attach it to the back of this problem set.

12. (a) Explain how changes in the nucleotide sequence of DNA may affect the amino acid sequence in a protein. [8]

(b) Explain how the allele for haemophilia may be passed from a man to his grandchildren. You may use genetic diagrams to support your answer. [7]

[Total: 15]

13. (a) Explain how meiosis and fertilisation may result in genetic variation in offspring. [7]

(b) Explain, using examples, how the environment may affect the phenotype of an organism. [8]

[Total: 15]

14. (a) Explain how the *lac* operon is involved in the metabolism of lactose in *Escherichia coli*. [9]

(b) Describe the role of gibberellin in the germination of barley. [6]

[Total: 15]