WJEC EDUQAS A-LEVEL BIOLOGY · COMPONENT 2

BIOLOGY



EXAM QUESTION PACK

2.5 INHERITANCE

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1. The fruit fly Drosophila melanogaster is extensively used to study genetics because it is relatively easy to cause mutations in the flies.

Some mutant flies have very small (vestigial) wings:



normal wings



vestigial wings

Other mutants have very dark (ebony) bodies instead of the normal grey body.



grey body



ebony body

In a dihybrid cross, when flies with normal wings and grey bodies were crossed with flies with vestigial wings and ebony bodies all the offspring had normal wings and grey bodies.

(a) The F_1 hybrid flies (heterozygous for both traits) were allowed to interbreed freely. The F_2 flies were sorted and counted. The results are shown below.

Phenotype		**Number of flies**
Wings	**Body**	
Normal	Grey	75
Normal	Ebony	23
Vestigial	Grey	21
Vestigial	Ebony	9

(i) Draw a genetic diagram, in the space provided below, to show the expected F_2 phenotype ratio. [5]
Use the letters given

Allele for normal wings = N Allele for vestigial wings = n

Allele for grey body = G Allele for ebony body = g

F_1 phenotypes	Normal wing, grey body	X	Normal wing, grey body
F_1 genotypes	.....	X	.....
Gametes	.....	X	.....

F_2 phenotype **ratio** .....

(ii) Using the F_2 phenotype ratio from part (i) calculate the **expected** number of each phenotype in the F_2 generation from a total of 128 offspring, and enter the values in the table below. [1]

Phenotype		Observed number (O)	Expected number (E)	(O – E)	$(O - E)^2$	$\frac{(O - E)^2}{E}$
Normal wings	Grey body	75				
Normal wings	Ebony body	23				
Vestigial wings	Grey body	21				
Vestigial wings	Ebony body	9				

(b) Complete the other columns in the table and carry out a Chi square test, testing the Null Hypothesis – that there is no significant difference between the observed and expected results.

(i) Use the last column in the table to calculate χ^2. [1]

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

(ii) Use the 5% probability level and the correct number of degrees of freedom to **circle** the critical value of χ^2 in the table below. [1]

Degrees of freedom	Probability								
	0.9	0.8	0.7	0.5	0.2	0.1	0.05	0.02	0.01
1	0.016	0.064	0.15	0.46	1.64	2.71	3.84	5.41	6.64
2	0.21	0.45	0.71	1.39	3.22	4.60	5.99	7.82	9.21
3	0.58	1.00	1.42	2.37	4.64	6.25	7.82	9.84	11.34
4	1.06	1.65	2.20	3.36	5.99	7.78	9.49	11.67	13.28

.....

.....

(c) In another cross, flies with ebony bodies and scarlet eyes were crossed with flies homozygous for grey body and red eyes. All the F_1 flies had grey bodies and red eyes. When the F_1 hybrid flies were crossed the following results were obtained:

Phenotype		Number of flies
Eyes	**Body**	
Red	Grey	91
Red	Ebony	3
Scarlet	Grey	2
Scarlet	Ebony	32

The table shows that some of the offspring were far more common than expected and some phenotypes were very rare. Explain both of these observations.

[2]

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2. There are three varieties of Labrador dogs; black, chocolate, and yellow. A student noticed that some yellow Labradors have black noses and some have brown noses. She proposed the hypothesis that the overall appearance is determined by fur colour **and** skin colour, as follows:

Variety	Fur colour	Skin colour
black	black	black
chocolate	black	brown
yellow (black nose)	brown	black
yellow (brown nose)	brown	brown

(a) The alleles for black fur (**B**) and black skin (**R**) are both dominant.

(i) Draw a genetic diagram to illustrate a cross between two heterozygous black Labradors. [4]

Parental phenotypes	black fur, black skin	X	black fur, black skin
Parental genotypes	.....	X	.....
Gametes	.....	X	.....

(ii) State the proportion of the offspring which would be, [1]

chocolate .....

yellow .....

(iii) State the proportion of the yellow offspring which would have brown noses. [1]

.....

(iv) Suggest what simple observation of the chocolate Labradors could be used to support her hypothesis. [1]

.....

.....

(b) A dog breeder has a chocolate bitch which she would like to use to produce only chocolate pups.

(i) State the genotype of bitch the breeder should use to produce only chocolate pups. [1]

.....

(ii) Describe the cross the breeder should carry out to test whether the bitch has the correct genotype. [1]

.....

.....

.....

(iii) Which is the only variety of Labrador, if bred with the same variety, will always produce pups with the same phenotype as both parents? [1]

.....

10

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3. The image below shows sweet peas which can be a number of different colours including white and purple.



Pollen was transferred from the anthers of white flowers onto the stigmas of purple flowers. In the F1, some plants produced purple flowers and some produced white flowers.

Two hypotheses have been suggested to explain this result.

(a) The **first hypothesis** is that the purple variety is caused by a dominant allele of a single gene.

(i) Construct a genetic diagram to show the genotypes and phenotypes of the parents of this cross. Use the letters **A** and **a** to represent the alleles of this gene. [2]

(ii) Based on the first hypothesis, the F1 would be expected to contain equal numbers of plants producing purple flowers compared to white flowers. When the cross was carried out, the resulting seeds were planted and 32 plants produced white flowers and 18 produced purple flowers.

State the null hypothesis and complete the table below. [4]

Null hypothesis

.....

.....

Phenotype	Observed numbers *(O)*	Expected numbers *(E)*	$O-E$	$(O-E)^2$	$\frac{(O-E)^2}{E}$
White	32				
Purple	18				

Use the formula below to calculate the value of chi-squared (χ^2).

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

χ^2 = ...

(iii) Use the table of chi-squared values below to state whether you would accept or reject the null hypothesis stated in *(a)*(ii). Explain your answer. [4]

Degrees of freedom	Probability								
	0.9	0.8	0.7	0.5	0.2	0.1	0.05	0.02	0.01
1	0.016	0.064	0.15	0.46	1.64	2.71	3.84	5.41	6.64
2	0.21	0.45	0.71	1.39	3.22	4.60	5.99	7.82	9.21
3	0.58	1.00	1.42	2.37	4.64	6.25	7.82	9.84	11.34
4	1.06	1.65	2.20	3.36	5.99	7.78	9.49	11.67	13.28

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(b) The **second hypothesis** is that the purple variety is produced by an interaction between two unlinked genes **A** and **B**. The presence of at least one dominant allele for both genes results in purple flowers. If the plant is homozygous recessive for either gene, the phenotype will be white.

(i) Complete the Punnett square to determine the phenotype ratios expected on the basis of this second hypothesis, given that the genotype of the purple flower is **AaBb** and the genotype of the white flower is **aaBb**. The gametes for the white flowering plant have been done for you. [3]

aB				
ab				

Phenotype ratio .....

(ii) The value of chi-squared for the second hypothesis was calculated as 0.044. Using the data conclude which hypothesis is more likely to be correct, the first or the second. Explain your answer. [1]

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(c) Explain how a cross between two white flowered parents which produced purple flowered offspring would confirm that hypothesis 2 is correct. [1]

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4. Haemophilia is caused by a sex linked gene.

(a) (i) What is meant by the term '*sex linkage*'?

[1]

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.....

.....

(ii) Complete the following genetic diagram to show how parents who did not suffer from haemophilia, could have a son with haemophilia but also other children who did not suffer from haemophilia. Use the symbols $\mathbf{X^H}$ for the normal allele and $\mathbf{X^h}$ for the allele which causes haemophilia. [4]

Phenotype of parents	Normal male		Normal female	
Genotype of parents	.....		.....	
Genotype of gametes	.....	.....	.....	.....

Genotype of offspring	.....	.....	.....	.....
Phenotype of offspring	.....	.....	.....	.....

(iii) What is the probability of the couple having a daughter with haemophilia?

[1]

.....

(iv) What is the probability of the couple having another son with haemophilia?

[1]

(b) An organism has two genes A and B which are found on the same chromosome.

Complete the following genetic diagram for a cross between two individuals with genotype Aa Bb but where no crossing over occurs (complete linkage). [3]

Genotype	AaBb		AaBb	
Genotype of gametes	.....	.....	.....	.....
Genotype of offspring	.....	.....	.....	.....
Ratio of Phenotype	.....			

(c) In another cross between two individuals with the genotype DdEe, where the genes D and E are on the same chromosome, the offspring showed four different types of phenotype.

The phenotype of some of the offspring were far more common than expected and some phenotypes were very rare. Explain these observations.

[2]

5. A species of mouse *Peromyscus polionotus* found in Florida, USA, has a number of different coat colours. Coat colour in mice is controlled by several genes. Dark fur is produced when the hair producing cells secrete a pigment called eumelanin. A high level of eumelanin is produced when a transmembrane protein called MC1R is stimulated by a hormone.

(a) The diagram below shows part of the amino acid sequence of MC1R, part of the sequence of nucleotides in the gene for MC1R and how it might change to produce light fur:

Original

Amino acid sequence: Ile – Thr – Lys – Asn – Arg – Asn – Leu – His – Ser

Nucleotide sequence (allele R): ATCACCAAAAACCGCAACCTGCACTCG

Changed to produce light fur

Amino acid sequence: Ile – Thr – Lys – Asn – Cys – Asn – Leu – His – Ser

Nucleotide sequence (allele C): ATCACCAAAAACTGCAACCTGCACTCG

(i) Describe the change in the gene and the subsequent change in the MC1R molecule. [2]

(ii) Using the information provided, explain how this change results in mice with light fur. [2]

6. *(a)* Cattle can have coats which are white, red or an even distribution of white and red hair (Roan). Roan is caused by incomplete dominance between the alleles for red and white hair (heterozygous condition).
Cattle can have horns or be hornless. Horns are a result of a double recessive allele and hornless is caused by a dominant allele.

Key:	
WW = white	H = hornless
RW = roan	h = horned
RR = red	

The genetic diagram shows the cross between a hornless white animal with a horned red animal.

parental phenotype:	hornless white	×	horned red
parental genotype:	HH WW		hh RR
genotype gametes:	HW		h R
genotype offspring:		Hh W R	
phenotype offspring:		hornless roan	

(i) The offspring were then bred together. Complete the Punnett square to show the possible genotypes of the offspring. [4]

Gametes				

(ii) Complete the following table to show the different phenotypes you would expect and the ratio. [6]

Phenotype	*Ratio*

(Total 10 marks)

1.

Question			Marking details	Marks Available
1	(a)	(i)	NnGg for both; NG Ng nG ng for both; correct completion of punnet square; correct ratio 9:3:3:1; correct phenotypes matched to ratio;	5
		(ii)	Correct expected number column 72 : 24 : 24 : 8;	1
	(b)	(i)	0.667 / 0.67 / ⅔;	1
		(ii)	7.82 circled;	1
		(iii)	Accept because χ^2 value is to left of {critical value / 7.82} / Accept because χ^2 value has probability higher than {0.05/5%} / Accept because χ^2 value falls between {0.9/90%} and {0.8/80%} probability / Accept because the probability lies between 80-90% that it is due to chance alone; *If not circled any answer for (ii) must refer to 7.82 in (iii)* ECF from chi squared table	1
	(c)		{Common phenotypes/red grey and scarlet ebony} are due to linkage / description of linkage; {Rare phenotypes/red ebony and scarlet grey} due to {crossing over / recombinants};	2
			Question 1 Total	**[11]**

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2.

Question			Marking details	Marks Available
2	*(a)*	(i)	Correct parental genotypes: BbRr BbRr; Correct gametes: BR Br bR br; Correct headings on punnet square: BR Br bR br; Correct completion of genotypes in punnet square;(ecf)	4
		(ii)	Chocolate $^{3}/_{16}$ / 18.75% **and** yellow $^{4}/_{16}$ / ¼ / 25%; **both** for 1(ecf)	1
		(iii)	¼ /25%;	1
		(iv)	All the noses should be brown; Accept fur is black and skin is brown	1
	(b)	(i)	BBrr;	1
		(ii)	Cross with {yellow, brown nose dog / homozygous recessive / bbrr} / back cross / test cross;	1
		(iii)	Yellow with a brown nose;	1
			Question 2 Total	**[10]**

3.

Question				Marking details	Marks Available					
					AO1	AO2	AO3	Total	Maths	Prac
3	(a)	(i)		Purple White **and** Aa aa (1) Aa Aa aa aa (1) correct completion of punnett square		2		2		
		(ii)		Null hypothesis: There is no significant difference between the observed and expected numbers/ratios **(1)** Phenotype | O | E **(1)** | O-E | $(O-E)^2$ | $\frac{(O-E)^2}{E}$ **(1)** white | 32 | 25 | 7 | 49 | 1.96 purple | 18 | 25 | -7 | 49 | 1.96 $Chi^2 = 3.92$ **(1)**		4		4	4	4
		(iii)		Critical value is 3.84 (1) because chi^2 value {is greater than/to the right of critical value (at 0.05)} (1) reject null hypothesis (1) deviation is not due to chance/there is a significant difference between O and E(1) ECF from (ii)			4	4	4	4
	(b)	(i)		AB | Ab | aB | ab aB | AaBB | AaBb | aaBB | aaBb ab | AaBb | Aabb | aaBb | aabb Gametes (1) Correct completion (1) [from their gametes] Phenotype ratio 3 purple : 5 white (1) [from table]		3		3		
		(ii)		Hypothesis 2 **and** The chi squared value is {to the left/less than} the critical value/no significant difference between O and E/probability is between {0.8-0.9/above 0.8/above 5%}/due to chance alone			1	1	1	
	(c)			Hypothesis 1 white x white could only produce white offspring/hypothesis 2 white x white could give purple/or description with genotypes			1	1		1
				Question 3 total	**0**	**9**	**6**	**15**	**9**	**9**

4.

Question			Marking details	Marks Available
4.	(a)	(i)	(Genes) on the {X/ Y} chromosomes; Reject sex chromosomes Accept (genes) on sex chromosomes not on the autosomes	1
		(ii)	<table><tr><td>Parents</td><td colspan="2">X^hY</td><td colspan="2">X^HX^h ;</td></tr><tr><td>Gametes</td><td>X^H</td><td>Y</td><td>X^H</td><td>X^h ;</td></tr><tr><td>Offspring</td><td>X^HX^H</td><td>X^HX^h</td><td>X^HY</td><td>X^hY;</td></tr><tr><td></td><td>Normal female</td><td>Normal/ Carrier female</td><td>Normal male</td><td>Haemophiliac/ sufferer/ affected} male;</td></tr></table> *Suitable symbols with key eg. X^NX^n max 3* *Suitable symbols with no key max 2* *Reject crosses not involving X and Y chromosomes* *If wrong genotypes ecf apart from phenotype of offspring which must correctly identify a haemophiliac son*	4
		(iii)	None;	1
		(iv)	0.25 / 25%; *Accept 1 in 4/ ¼* *Reject 1:3*	1
	(b)		AB ab AB ab ; AABB AaBb AaBb aabb ; 3:1 ; *Genotypes must show some correct indication of linkage between a and b for ecf* *Award 0 if dihybrid cross is completed*	3

Question			Marking details	Marks Available
	(c)		Incomplete linkage; Genes {further/ far} apart on same chromosome; {Crossing over/ chiasmata} can occur; Four types of gametes produced(but not in equal numbers); Small numbers of recombinants / large numbers parental types; Recombinants equal in numbers / parental equal in numbers;	Max 2
			Question 4 Total	**[12]**

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5.

Question			Marking details	Marks Available
5	(a)	(i)	CGC is replaced by TGC/ C is replaced by T; Amino acid cys has replaced arg;	2
		(ii)	Change in {protein/ tertiary} structure/ different protein is made; MC1R will not be stimulated (by the hormone); {Less/no} eumelanin will be produced;	Max 2
			Question 6 Total	**[4]**

6. **(a) (i)**

Gametes	HW	HR	hW	hR
HW	HW HW	HR HW	hW HW	hR HW
HR	HW HR	HR HR	hW HR	hR HR
hW	HW hW	HR hW	hW hW	hR hW
hR	HW hR	HR hR	hW hR	hR hR

	1 mark per column; if wrong- gametes-1, letters -1;	**4**
(ii)	Phenotypes	
	Horn less roan 6	
	Horn less red 3	
	Horn less white 3	
	Horned roan 2	
	Horned red 1	
	Horned white 1	
	3 marks all phenotypes + 3 for all correct matching ratio -1 per error, no ecf from (i)	**6**