Name	Date started	Target end date

GCE A LEVEL — BIOLOGY UNIT 4 QUESTION PACK

1075 (Legacy BY5) · New spec Unit 4 Topic 4 · A2 unit, first sat 2017, 90 marks, 2h paper

REVISE
.wales

BIOLOGY — UNIT 4 · INHERITANCE — DIHYBRID, LINKAGE, EPISTASIS & CHI-SQUARED

4.3 Inheritance — dihybrid crosses, autosomal linkage, epistasis and chi-squared significance testing

Mendel's law of independent assortment, the 9:3:3:1 dihybrid ratio, autosomal linkage groups, epistatic interactions (e.g. coat colour in Labradors, flower pigment in clover), and the use of the chi-squared test to decide whether observed offspring ratios deviate significantly from expectation.

LEGACY 2008 SPECIFICATION

Estimated time for entire question pack: ~1 h 17 min

Derived from the legacy BY5 papers' pace of ~1.6 min/mark, padded for long-prose answers (48 marks over 4 questions).

*You are advised to **not** attempt to complete all of this in one sitting.*

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC BY5 papers (2008 modular spec, 2011–2017) that maps onto new-spec A2 Unit 4 Topic 4 (4.3). Questions are ordered by source paper date.

INSTRUCTIONS

Use black ink or black ball-point pen. Show all working — quality of written communication will affect marks. A calculator is allowed. Diagrams included in answers must be fully annotated.

For Examiner's use only

Q	Source	Max	Mark
1	BY5 Jun 14 Q4	11	
2	BY5 Jun 15 Q2	10	
3	BY5 Jun 16 Q3	16	
4	BY5 Jun 17 Q6	11	
	Total	**48**	

Inheritance — Dihybrid, Linkage, Epistasis & Chi-Squared — what the new spec asks

WJEC GCE A Level Biology (from 2015) · Unit 4: Variation, Inheritance & Options · Topic 4.3.

Law of independent assortment

- Alleles of different genes segregate independently into gametes.
- True only if the genes are on different chromosomes (or far apart).
- Pure-breeding AABB × aabb → F_1 AaBb → F_2 9:3:3:1.

Dihybrid 9:3:3:1

- 9 A_B_ : 3 A_bb : 3 aaB_ : 1 aabb in F_2.
- Confirmed by Mendel's pea experiments and many later studies.
- Test cross (AaBb × aabb) gives 1:1:1:1.

Autosomal linkage

- Two loci on the same chromosome tend to be inherited together.
- Recombinants arise by crossing-over during prophase I.
- Recombination frequency ↔ map distance (centimorgans).

Epistasis

- One gene masks expression of another at a different locus.
- Recessive epistasis: aa hides B locus (e.g. Labrador coat: ee → yellow).
- Dominant epistasis can give 12:3:1 or 9:3:4 ratios.

Chi-squared test

- $\chi^2 = \Sigma\,(O-E)^2/E$ summed over each phenotype class.
- Degrees of freedom = classes − 1.
- $P < 0.05$ ⇒ observed deviates significantly — reject expected ratio.

Pedigree analysis

- Family trees show pattern of trait across generations.
- Use to deduce dominant / recessive, sex-linked or autosomal.
- Carrier deductions critical in genetic counselling.

Inheritance — Dihybrid, Linkage, Epistasis & Chi-Squared in one page

Quick-reference notes — revisit before each question.

Independent assortment

Alleles of separate genes go independently to gametes.

True if on different chromosomes (or far apart).

Dihybrid 9:3:3:1

AaBb × AaBb → 9 A_B_ : 3 A_bb : 3 aaB_ : 1 aabb.

Punnett square 4×4 of gametes AB, Ab, aB, ab.

Test cross 1:1:1:1

AaBb × aabb → 1 AaBb : 1 Aabb : 1 aaBb : 1 aabb.

Recombinants = parental types swap = crossing-over.

Autosomal linkage

Loci on same chromosome — usually inherited together.

Recombinants arise from crossing-over.

Closer loci = fewer recombinants = tighter linkage.

Epistasis (recessive)

One locus masks another.

Labrador coat: ee → yellow regardless of B locus.

F_2 ratio 9 black : 3 chocolate : 4 yellow.

Chi-squared

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

df = classes − 1.

$p < 0.05$ ⇒ reject expected ratio.

Reading x^2 tables

Critical values: df=1 → 3.84; df=3 → 7.82.

If χ^2 > critical → significant deviation.

Pedigree caveats

Combine pedigree with cross data.

Note: incomplete penetrance can blur ratios.

4. 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

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Examiner only

(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** ....

Examiner only

(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]

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

χ^2 = ...

(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

(iii) State whether you would accept or reject the Null Hypothesis, for this cross and explain why. [1]

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(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]

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

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(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]

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

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(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]

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3. In white clover, *Trifolium repens*, one gene determines the production of a cyanide forming substrate. Allele **A** produces the cyanide forming substrate, whilst allele **a** produces no substrate.

A second gene, located on a different chromosome, determines the production of an enzyme which catalyses the release of cyanide from the substrate. Allele **E** produces the enzyme, whilst allele **e** produces no enzyme.

- Clover that has both **A** and **E** alleles gives off cyanide as soon as its leaves are crushed.
- Clover with **A** but not **E** releases cyanide slowly when its leaves are crushed.
- Clover that does not have **A** cannot release cyanide.

(a) (i) Complete the genetic diagram below to show what proportion of the three types would be produced if clover heterozygous for both genes was self-pollinated. Use the letters for the alleles given above. [3]

Parental genotypes .... X ....

Gametes .... X ....

(ii) State the ratio of the offspring which would show: [1]

rapid cyanide release .... : slow cyanide release .... : no cyanide release ....

(b) In an experiment where double heterozygotes were self-pollinated the following numbers of offspring were obtained:

rapid cyanide release – 140
slow cyanide release – 49
no cyanide release – 67

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

Phenotype	**Observed number (O)**	**Expected number (E)**	**(O – E)**	**$(O - E)^2$**	**$\frac{(O-E)^2}{E}$**
Rapid cyanide release	140				
Slow cyanide release	49				
No cyanide release	67				

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

Use the last column in the table and the formula below to calculate χ^2. [1]

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

χ^2 = ...

(iii) Using the 5% probability level and the correct number of degrees of freedom **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

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(iv) State whether you would accept or reject the Null Hypothesis for this cross and explain why. [1]

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(c) (i) What is the term for all the alleles in a population? [1]

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(ii) Cyanide has a taste which discourages cattle from eating clover leaves. How would the proportion of allele **E** in the population of white clover in a field grazed by cattle compare to the proportion of allele **E** in the population of white clover in a hedgerow inaccessible to cattle? [1]

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(iii) Explain how continued grazing would change the frequency of allele **E** in the population. [4]

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Examiner only

(iv) Describe how the cattle grazing might lead to the formation of a new species of clover. [2]

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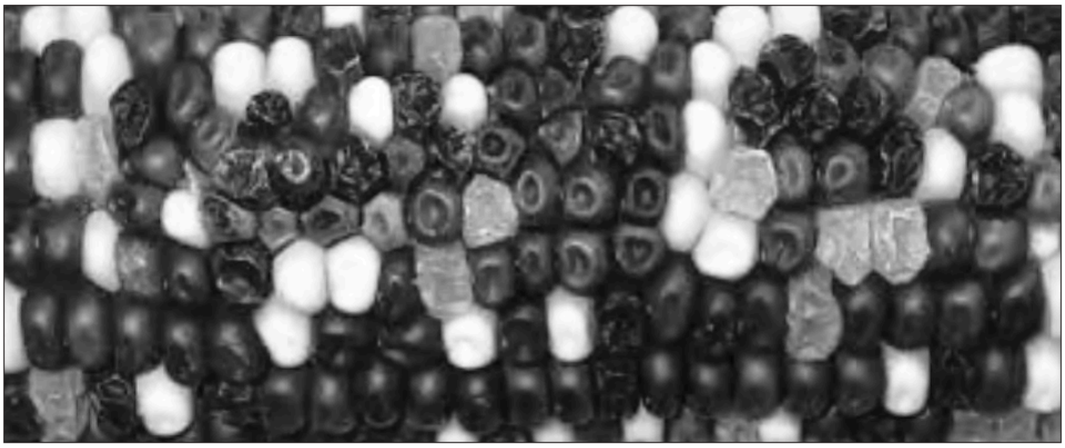
6. The maize plant *Zea mays* is used to study genetics because plants produce groups of fruits called cobs. Each cob contains the results of many fertilisations and each fruit represents the result of a single cross.

The coats of the fruits may be coloured purple or yellow and may be smooth or wrinkled.

The photograph below shows part of a cob from a genetic experiment in which parents heterozygous for both characteristics were crossed.
In the photograph dark fruits are purple and light ones are yellow.



Counting the different kinds of fruits in the photograph gave the following results:

Coat colour	Shape	Number of fruits
purple	round	90
purple	wrinkled	11
yellow	round	23
yellow	wrinkled	20

Purple is dominant to yellow and round is dominant to wrinkled.

Use the following symbols:

Allele for purple fruits = **D** allele for yellow fruits = **d**

Allele for round fruits = **R** allele for wrinkled fruits = **r**

(a) (i) Draw a genetic diagram below, to show the expected phenotypic ratio from the cross described on page 15. Use the symbols provided above. [5]

Phenotype of parents ....

Genotype of parents ....

Gametes ....

Phenotypic ratio = ...

Examiner only

(ii) Enter the ratio from part (i) in the table below and calculate the expected number of each phenotype in the cob. [1]

Kernel colour	Kernel shape	Observed number (*O*)	Expected ratio	Expected number (*E*)	$O - E$	$(O - E)^2$	$\frac{(O - E)^2}{E}$
purple	round	90					
purple	wrinkled	11					
yellow	round	23					
yellow	wrinkled	20					

(b) Carry out a Chi square test to test the null hypothesis that *'there is no significant difference between the observed and expected results'*.

(i) Use the last column in the table to help you calculate χ^2 to two decimal places. [1]

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

(ii) Calculate the degrees of freedom and **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

(iii) State whether you accept or reject the null hypothesis and explain why. [1]

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(c) Explain how the arrangement of genes on chromosomes could have caused all of the phenotypes observed in the offspring. [2]

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END OF QUESTION PACK

4 questions · 48 marks · ~1 h 17 min
Source: WJEC BY5 (2008 modular spec, 2011–2017)
Curated for WJEC Biology 2015 spec A2 Unit 4 — Topic 4 (4.3)