IB · DP · Biology

2 hours 15 questions

Structured Questions: Paper 2

10.2 Inheritance

10.2.1 Unlinked Genes / 10.2.2 Skills: Analysing Dihybrid Crosses / 10.2.3 Gene Linkage / 10.2.4 Skills: Identifying Recombinants / 10.2.5 Skills: Chi-squared Test / 10.2.6 Variation

Easy (5 questions)	/43
Medium (5 questions)	/45
Hard (5 questions)	/55
Total Marks	**/143**

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Easy Questions

1 (a) Define the term 'genotype'.

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(1 mark)

(b) In guinea pigs, the allele for black hair (*B*) is dominant to the allele for white hair (*b*) and the allele for long hair (*L*) is dominant to the allele for short hair (*l*). A double homozygous guinea pig with long, black hair was bred with another double homozygous guinea pig with long, white hair.

State the genotypes of the two parent guinea pigs.

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(2 marks)

(c) Use a genetic diagram to show the ratio of different phenotypes which could result from the cross discussed in part (b).

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(3 marks)

2 (a) In 1905 a group of scientists were investigating Mendelian inheritance by carrying out experiments on sweet pea plants. They were looking at the inheritance of two traits, flower colour and pollen grain shape. Flower colour is determined by two alleles, the dominant *P* for purple and recessive *p* for red. Pollen grain shape is determined by two alleles, the dominant *L* for long and recessive *l* for round.

They started by breeding together a double homozygous dominant plant (*PPLL*) with a double homozygous recessive plant (*ppll*) to produce a generation of plants that were all double heterozygous (*PpLl*).

They then bred together several double heterozygous plants and ended up with 381 offspring.

The outcome of the crosses are as follows:

Phenotype and genotype	Observed	Expected from 9:3:3:1 ratio
Purple flower, long pollen	284	
Purple flower, round pollen	21	
Red flower, long pollen	21	
Red flower, round pollen	55	

Complete the third column of the table above with the expected number of individuals of each phenotype if the expected 9:3:3:1 ratio of offspring traits had occurred.

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(3 marks)

(b) In order to establish whether there was a significant difference between the actual results and the expected results, a statistical test is required.

Identify which statistical test the scientists should use.

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(1 mark)

(c) It was found that there was a significant difference between the expected and observed results from the genetic cross.

The genes are not located on the sex chromosomes.

Suggest a possible reason for the data that was collected in the experiment.

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(1 mark)

(d) The work of these scientists helped to establish the idea that not all dihybrid crosses produce Mendelian ratios and was later expanded on by another scientist through his work with *Drosophila.*

State the name of this scientist.

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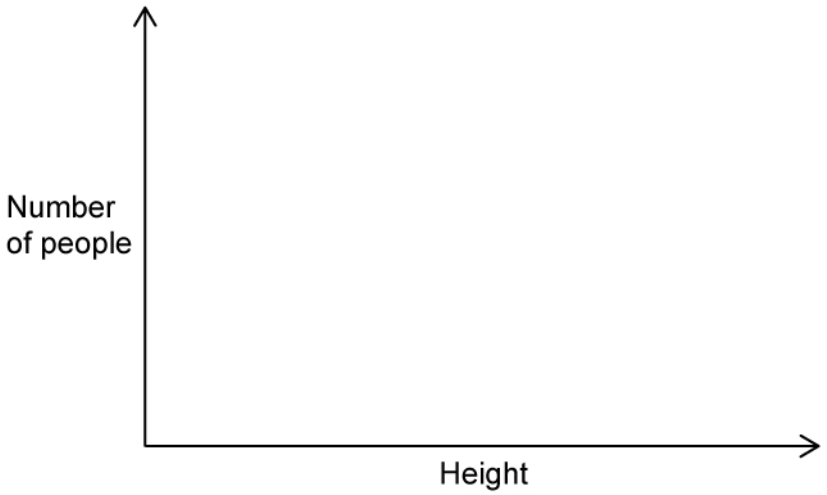
(1 mark)

3 (a) A group of 1000 people were chosen at random and surveyed as part of a population study. The participants were asked about their characteristics.

One characteristic that was surveyed was the participant's height measurements.

Sketch a graph in the space below to predict the distribution of individuals height values.



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(2 marks)

(b) Name the type of variation shown in the example in part (a).

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(1 mark)

(c) Another characteristic that was surveyed was hair colour.

It was found that most individuals had black, brown, blonde, or red hair, but a small number of individuals had hair colours like pink, blue and green.

Describe the factors that can cause variation in hair colour.

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(2 marks)

(d) Some characteristics that are more likely to be examples of continuous variation are those that are coded for by several genes that work in combination to produce the phenotype.

State the scientific term used for this type of characteristic.

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(1 mark)

4 (a) Describe autosomal linkage.

(3 marks)

(b) In tomato plants, the genes for height and for the type of leaf are autosomally linked.

The allele *T*, for a tall plant, is dominant to the allele *t*, for a dwarf plant. The allele *M*, for normal leaves, is dominant to the allele *m*, for mottled leaves.

A tomato plant is heterozygous, with both dominant alleles located on one chromosome and both recessive alleles located on the other.

Draw the correct notation to represent the genotype of this plant.

(2 marks)

(c) The plant from part (b) was crossed with another plant with the same genetic composition.

By drawing a genetic diagram, predict the genotypes and phenotypes of the offspring produced by this cross.

(3 marks)

(d) A small number of offspring from the cross possess phenotypes that were different to the ones predicted in part (c).

Suggest how it is possible for some plants to have different combinations of phenotypes than expected.

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(2 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

Describe the purpose of a test cross as well as the steps involved in carrying it out.

(4 marks)

(b) Outline the causes of variation.

(7 marks)

(c) Explain how an understanding of inheritance would allow farmers to selectively breed their livestock for specific characteristics.

(4 marks)

Medium Questions

1 (a) Hair colour and eye colour are traits controlled by genes. Many people with blonde hair also have blue eyes.

Suggest a reason for this occurrence.

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(1 mark)

(b) In the common pea plant (*Pisum sativum*), the allele **P**, for purple flowers, is dominant to the allele **p**, for white flowers. The allele **I**, for inflated seed pods, is dominant to the allele **i**, for constricted seed pods. Two pea plants, heterozygous for both characteristics are crossed.

State the possible genotypes of the offspring by completing the Punnett Square table below.

		Gametes from parent 2			
Gametes from parent 1					

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(4 marks)

(c) The result of this genetic cross was 112 seeds being produced by the parent plants.

Calculate the expected number of offspring that would have white flowers and constricted seed pods.

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(2 marks)

2 (a) The gene for body colour and antennal shape in the fruit fly (*Drosophila melanogaster*) are close together on the same chromosome. These genes are therefore said to be linked.

Allele **E** for a striped body is dominant over allele **e** for an ebony body. Allele **A** codes for the dominant normal antennae, whereas allele **a** codes for an aristopedia antennae. Aristopedia antennae resemble a *Drosophila* leg rather than an antennae.

A male that is heterozygous for striped body and normal antennae is crossed with female that has an ebony body and aristopedia antennae.

State the possible allele combinations in the gametes of these flies. Use the correct notation in your answer.

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(2 marks)

(b) State the possible phenotypes of the offspring of this genetic cross, along with the predicted ratios of each.

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(2 marks)

(c) Explain why it may still be possible for recombinant offspring to appear in this genetic cross, even though the genes are linked.

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(2 marks)

(d) Describe the idea that Thomas Hunt Morgan proposed to explain the variation observed in the number of recombinants that resulted from crossing linked genes.

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(2 marks)

3 (a) Describe the early events that lead scientists to discover exceptions to Mendel's predicted phenotypic ratios for dihybrid crosses.

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(2 marks)

(b) Recombinant offspring are those that have a different allele combination to their parents.

Explain how test crosses can be used to identify recombinant individuals in offspring.

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(2 marks)

(c) A set of identical twins were raised in similar conditions by the same parents. One of the twins fell off a swing, which left a permanent scar on his chin.

State the impact this would have on the phenotypic variation between the twins.

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(1 mark)

(d) Shepherd's purse (*Capsella bursa*) is a flowering plant which belongs to the mustard family. Fruit shape in this plant is determined by two alleles, namely allele **T** for a triangular fruit shape, which is dominant over allele **t** for top-shaped fruit.
A plant with triangular shaped fruit was crossed with a plant that has top-shaped fruit.
All 30 offspring of this cross had triangular shaped fruit.

State, with a reason, whether there can be certainty that the original parent plant with triangular shaped fruit had a genotype of **TT**.

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(2 marks)

4 (a) In fruit flies (*Drosophila melanogaster*) wing length and body colour are each controlled by a single gene with two alleles. Allele **L** for long wings is dominant over allele **l** for vestigial wings, while allele **G** for grey body colour is dominant over allele **g** coding for ebony body colour.

Two homozygous fruit flies were crossed, one had a grey body colour and long wings while the other had an ebony body colour and vestigial wings.

State, with a reason, the number of offspring that would display a grey body colour and vestigial wings if 350 offspring were produced from this cross.

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(2 marks)

(b) Two fruit flies from this cross, heterozygous for both body colour and wing length, were crossed and 3 200 offspring were produced.

Calculate the expected number of offspring that would display the following phenotypes, assuming that the genes for body colour and wing length are not linked.

Phenotype	Expected number of offspring
Grey body, long wings	
Grey body, vestigial wings	
Ebony body, long wings	
Ebony body, vestigial wings	

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(1 mark)

(c) The results for the cross were different from what was expected. Scientists decide to perform a chi-squared test to determine if the difference is significant.

Calculate the value of χ^2 by completing the following table:

Phenotype of offspring	**Observed (O)**	**Expected (E)**	$(O-E)$	$(O-E)^2$	$\frac{(O-E)^2}{E}$
Grey body, long wings	1 650				
Grey body, vestigial wings	600				
Ebony body, long wings	690				
Ebony body, vestigial wings	260				

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

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(2 marks)

(d) The table shows values for?^{2} at different levels of probability and for different degrees of freedom.

Degrees of freedom	Probability, p				
	0.2	0.1	0.05	0.02	0.01
1	1.64	2.71	3.84	5.41	6.64
2	3.22	4.61	5.99	7.82	9.21
3	4.64	6.25	7.82	9.84	11.35
4	5.99	7.78	9.49	11.67	13.28
5	7.29	9.24	11.07	13.39	15.09

State the conclusion the scientists should make about the significance of their results and explain your answer.

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(3 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

Contrast continuous and discontinuous variation.

(7 marks)

(b) Explain the use of a chi-squared test on data from a dihybrid cross.

(4 marks)

(c) Describe sex linkage and autosomal linkage in genes.

(4 marks)

Hard Questions

1 (a) An investigation on fruit flies, *Drosophila melanogaster*, was carried out to determine the relationship between body colour and wing length.

Scientists found the genes controlling these characteristics are inherited on different autosomal chromosomes. Fruit flies are either black or grey and have either long or short wings.

A homozygous fruit fly with a black body and long wings was crossed with a homozygous grey fruit fly with short wings. All of the offspring produced had black bodies with long wings.

Using this information and a genetic diagram, show how these offspring were produced. Use **B/b** and **L/l** to represent the alleles.

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(3 marks)

(b) The offspring from part (a) were crossed with grey bodied fruit flies with short wings. Use a genetic diagram to show the expected ratios of the phenotypes expected from this cross.

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(3 marks)

(c) The scientists determined the offspring phenotypes from the cross in part (b) and the data collected is shown in the table below:

Phenotype	Observed Numbers	Expected Numbers
Black body and long wings	83	
Grey body and long wings	78	
Black body and short wings	85	
Grey body and short wings	74	

Complete the table to show the expected number of offspring for each phenotype.

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(1 mark)

(d) The scientists claimed that independent segregation had taken place. The chi-squared test can be used to determine the significance of the data. The critical value for this data is 7.82.

The formula below can be used to determine the value of chi-squared.

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

(i) Calculate the value of chi-squared (χ^2), using the above formula.

[2]

(ii) Comment on the scientists claims, using the chi-squared value calculated at part (d)(i).

[3]

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(5 marks)

2 (a) When investigating variation scientists often study sets of twins, both identical and non-identical.

Suggest the advantages of studying twins when investigating variation.

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(3 marks)

(b) A scientific study in 2013 investigated whether academic achievement was influenced by genetics or the environment.

11,117 pairs of twins participated in the study, which found that around 55% of the outcomes in core GCSE subjects (English, maths, and science) were explained by genetic influence, 25% by shared environmental influences, such as parental support, and the remaining 20% by environmental influences that were not shared between the two twins, such as teacher quality and class grouping.

Using this information, evaluate the statement "intelligence is caused by genetics".

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(3 marks)

(c) Twin studies tend to be run using two main assumptions:

- That the identical twins in the study share 100% of their DNA
- That all twins are raised in exactly equal environments at home

Suggest whether it is correct to make these assumptions about twin studies.

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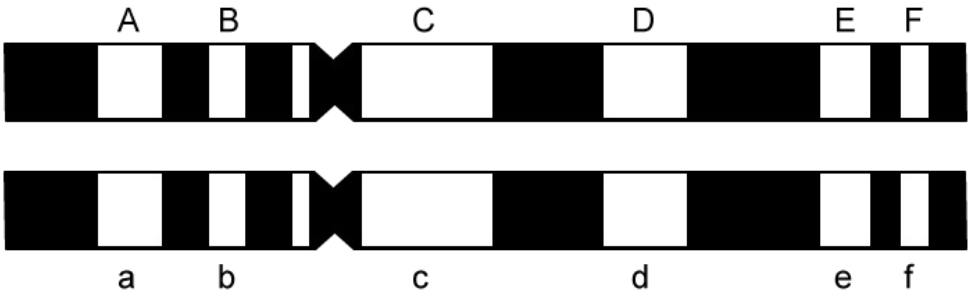
(2 marks)

3 (a) The diagram below shows two homologous chromosomes of the fruit fly *Drosophila melanogaster*.



The white regions are the loci of seven genes involved in different phenotypic traits.

The letters A-F and a-f represent the alleles present at each locus.

Discuss the relative chances of this fly's gametes containing these combinations of alleles:

- A and F
- A and f
- c and d
- c and D

(4 marks)

(b) In a potential scenario where crossing over does not occur between the two genes, the fly in part (a) reproduces with another fly who is homozygous for the dominant A and B alleles.

Predict the genotypes of the offspring, with relation to these two genes.

(2 marks)

(c) *Drosophila melanogaster* is a useful organism to use in studies on inheritance patterns. Female fruit flies can lay up to 400 eggs, developing into adults between 7 and 14 days. They have simple nutrient requirements.

Using the information provided, explain **two** reasons why *Drosophila melanogaster* is a useful organism to use in studies of inheritance patterns

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(2 marks)

4 (a) Mendel studied many characteristics of pea plants during his time investigating inheritance. Two such characteristics were seed colour and flower colour. Seed colour can either be yellow, encoded by the dominant allele *Y,* or green encoded by the recessive allele *y.* Flower colour can either be purple, encoded by the dominant allele *P,* or white encoded by the recessive allele *p.*

A student is unsure whether the two genes are linked. In order to try and work it out they decided to do some breeding experiments.

Outline a method they could use to determine whether the two genes are linked.

(6 marks)

(b) As part of this process, the student bred together two plants that were heterozygous for both traits.

Draw a genetic diagram of the expected results from this cross, using the correct notation as if the two genes are located on the same chromosome.

(3 marks)

(c) On the genetic diagram you produced in part (b), highlight all the recombinants.

(1 mark)

(d) Upon further research, the student found that the two genes are located on the same chromosome, chromosome one of the pea plant.

When Mendel was researching these traits he found that all of his crosses produced a 9:3:3:1 ratio of phenotypes, and there was no evidence of any 'non-Mendelian' inheritance ratios.

Suggest a possible reason for this.

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(2 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

When looking at buildings built over 100 years ago it is often a notable feature that the door frames are a lot shorter than modern day doors.

A student observed this and made the conclusion that humans must have evolved to become taller over the years since the door frames were built.

Suggest some reasons explaining why the student is most likely incorrect with their conclusion.

(4 marks)

(b) Describe how Morgan and his associates were able to produce a genetic map of a chromosome using breeding experiments in *Drosophila.*

(4 marks)

(c) 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.

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 plants were collected and grown, giving plants with the following phenotypes:

- Yellow flowers and red fruit: 59
- Yellow flowers and yellow fruit: 56
- White flowers and red fruit: 40
- White flowers and yellow fruit: 45
- Total number of plants in the four categories: 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.

The chi-squared (χ^2) equation and distribution is as follows:

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

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

Use this information to produce a statistical conclusion about the difference between the expected and actual results in the tomato breeding experiment.

You must show your working in your answer.

(7 marks)