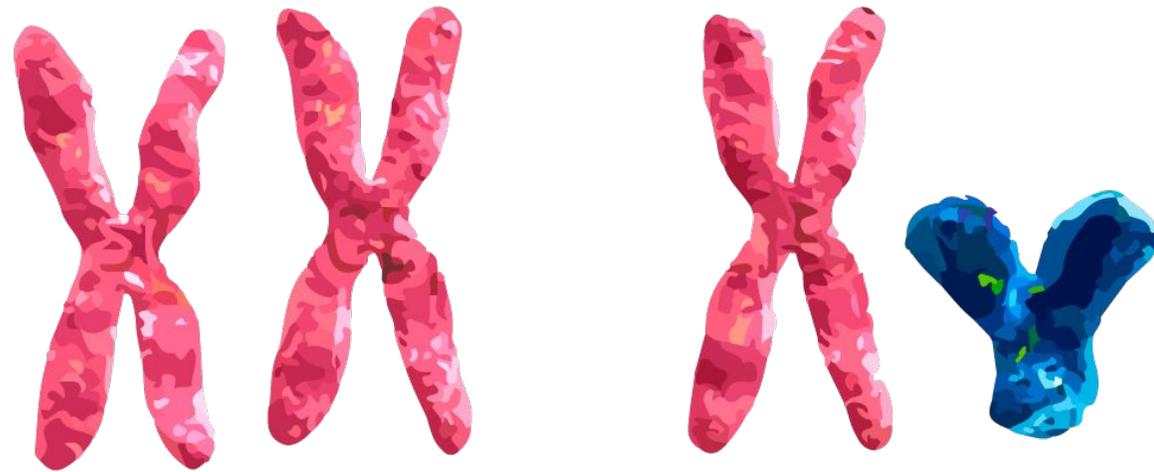


# Inheritance



# Material Covered

## Monohybrid and Dihybrid Crosses

1. Monohybrid Crosses
2. Dihybrid Crosses

## Autosomal Linkage

1. Autosomal Linkage
2. Recombination Frequencies

# Material Covered

## The Chi-squared Test

1. Chi-squared and the Null Hypothesis
2. Applying the Chi-squared Test

## Sex Linkage

1. Sex Linkage in Humans

## Epistasis

1. Epistasis in animals

# Monohybrid and Dihybrid Crosses

	$G$	$g$
$G$	$GG$	$Gg$
$g$	$Gg$	$gg$

# Specification Points

## AQA

### 3.7.1 Inheritance (A-level only)

Content	Opportunities for skills development
<p>The genotype is the genetic constitution of an organism.</p> <p>The phenotype is the expression of this genetic constitution and its interaction with the environment.</p> <p>There may be many alleles of a single gene.</p> <p>Alleles may be dominant, recessive or codominant.</p> <p>In a diploid organism, the alleles at a specific locus may be either homozygous or heterozygous.</p> <p>The use of fully labelled genetic diagrams to interpret, or predict, the results of:</p> <ul style="list-style-type: none"> <li>monohybrid and dihybrid crosses involving dominant, recessive and codominant alleles</li> <li>crosses involving sex-linkage, autosomal linkage, multiple alleles and epistasis.</li> </ul> <p>Use of the chi-squared (<math>X^2</math>) test to compare the goodness of fit of observed phenotypic ratios with expected ratios.</p>	<p><b>AT h</b></p> <p>Students could investigate genetic ratios using crosses of <i>Drosophila</i> or Fast Plant®</p> <p><b>MS 0.3</b></p> <p>Students could use information to represent phenotypic ratios in monohybrid and dihybrid crosses.</p> <p><b>MS 1.4</b></p> <p>Students could show understanding of the probability associated with inheritance.</p> <p><b>MS 1.9</b></p> <p>Students could use the <math>X^2</math> test to investigate the significance of differences between expected and observed phenotypic ratios.</p>

## OCR

### 6.1.2 Patterns of inheritance

Learning outcomes	Additional guidance
<p>(b) (i) genetic diagrams to show patterns of inheritance</p>	<p>To include monogenic inheritance, dihybrid inheritance, multiple alleles, sex linkage and codominance.</p>

# Specification Points

## Edexcel A

### Topic 2: Genes and Health

#### Students should:

- 2.13 i) Know the meaning of the terms: gene, allele, genotype, phenotype, recessive, dominant, incomplete dominance, homozygote and heterozygote.
- 2.13 ii) Understand patterns of inheritance, including the interpretation of genetic pedigree diagrams, in the context of monohybrid inheritance.

## Edexcel B

### Topic 8: Origins of Genetic Variation

#### Students should:

#### 8.2 Transfer of genetic information

- i Understand that mutations are the source of new variations and that the processes of random assortment and crossing over during meiosis give rise to new combinations of alleles in gametes.

#### Students should:

#### 8.2 Transfer of genetic information

- ii Be able to construct genetic crosses and pedigree diagrams.

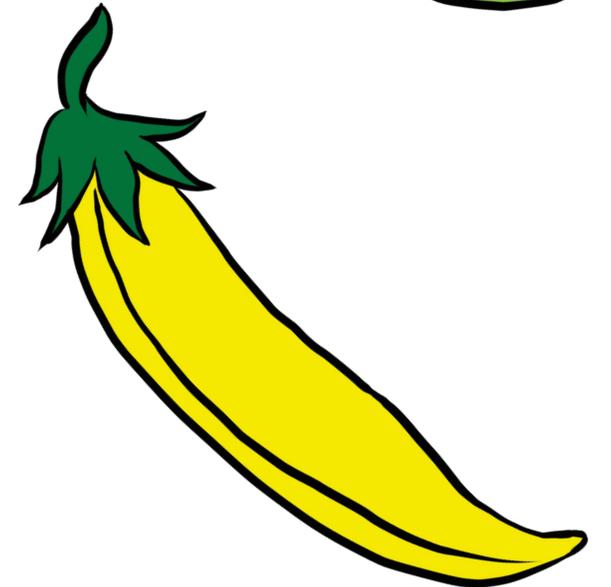
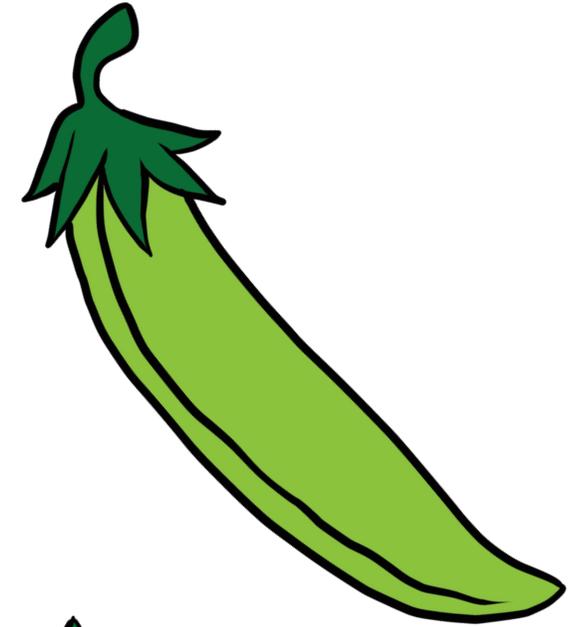
#### Students should:

#### 8.2 Transfer of genetic information

- iii Understand the inheritance of two non-interacting unlinked genes.

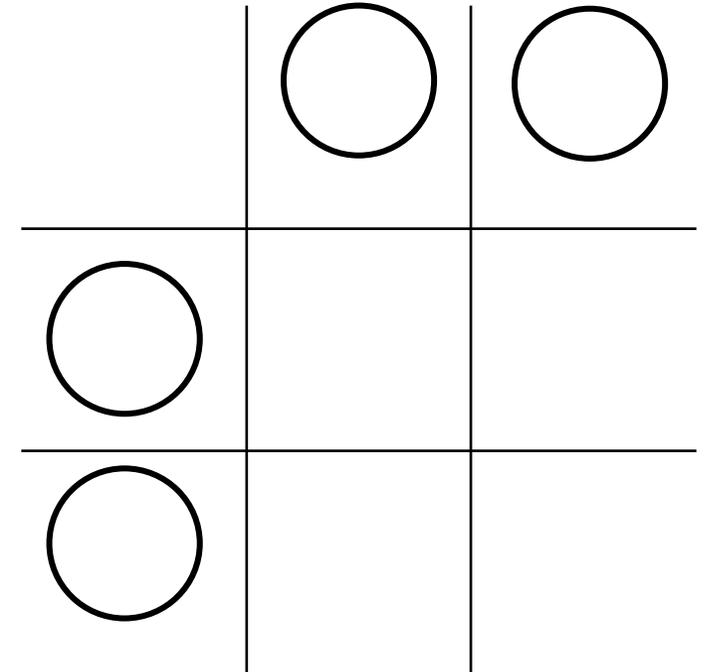
# Monohybrid Crosses

- A **monohybrid inheritance** is the **inheritance** of a **characteristic controlled** by **one gene** with two **alleles**
- **Dominant alleles** of a gene are given a **capital letter** (e.g. G) whereas **recessive alleles** are **lower case** (e.g. g)
- The **genotype** of an organism is the total **combination** of the **alleles** (e.g. Gg, gg or GG)
- The **phenotype** is what is expressed and is affected by the environment too (e.g. Gg will have the G phenotype)



# Calculating Monohybrid Crosses

- **Punnett squares** are used to **calculate** the **genotypes** of the **offspring** in a **monohybrid cross**
- The **parental genotypes** are determined first and the **gamete genotypes** inserted into the **Punnett square**
- The **offspring genotypes** and **phenotypes** can then be determined
- The **ratio** of **offspring phenotypes** can then be determined



# Codominance and Multiple Alleles

- Codominance is where two **alleles** can be expressed in the phenotype at the same time, without either trait being **dominant**.
- The gene is given a **letter** with **superscript alleles**
- So **flower colour** could be determined by the following alleles  **$P^W$  &  $P^R$**
- **Multiple alleles** similarly have more than **2 alleles** where the **gene** has a **letter** with **superscript alleles e.g  $I^A$   $I^B$   $I^O$**

	$P^W$	$P^R$
$P^R$		
$P^W$		
	$I^A$	$I^O$
$I^B$		
$I^O$		

**Edexcel A:** Don't need to know about codominance & multiple alleles

## Exemplar Exam Question – Statement

1) In a monohybrid cross, what is the expected ratio of the various phenotypes when heterozygous parents are crossed?

**[2 marks]**

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**Command:** only requires a ratio

**Direction:** need to determine genotype before phenotype

**Context:** phenotypic ratios of monohybrid crosses

## Exemplar Exam Question – Statement

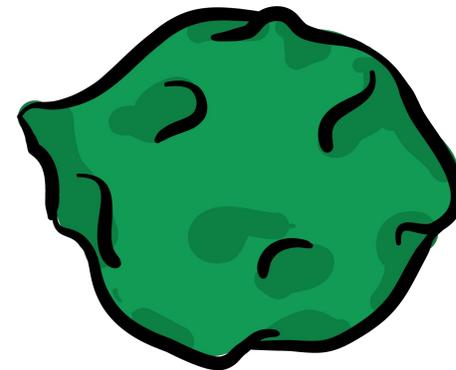
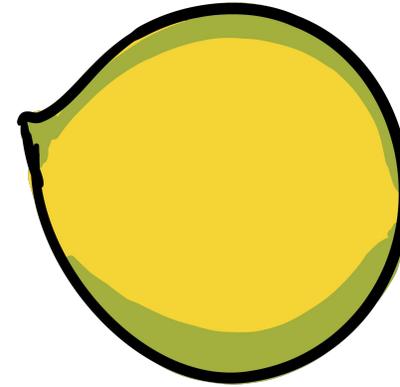
1) In a monohybrid cross, what is the expected ratio of the various phenotypes when heterozygous parents are crossed?

**[2 marks]**

---

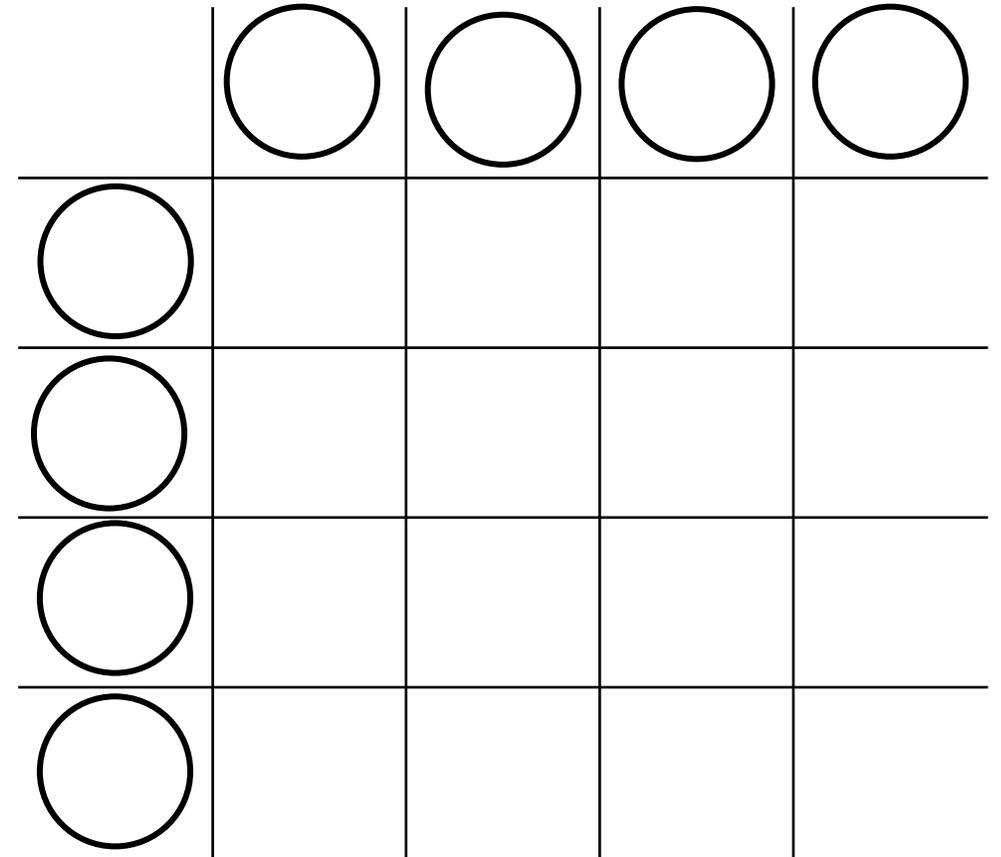
# Dihybrid Crosses

- **Dihybrid inheritance** is the **inheritance** of **2 characteristics controlled** by **2 genes** each with two **alleles**
- A common example for characteristics which can be inherited simultaneously are **seed colour** and **seed shape** in **pea plants**



# Calculating Dihybrid Crosses

- Parental genotypes:
  
- Parental gametes:



## Exemplar Exam Question – Calculation

2) A scientist has two pea plants. One plant produces round, green seeds, the other wrinkled, yellow seeds. The yellow seed colour and the round seed shape are dominant. Both plants are heterozygotes for the dominant trait.

Construct a Punnett square and calculate the phenotypic ratio of the offspring if the scientist's two plants are crossed.

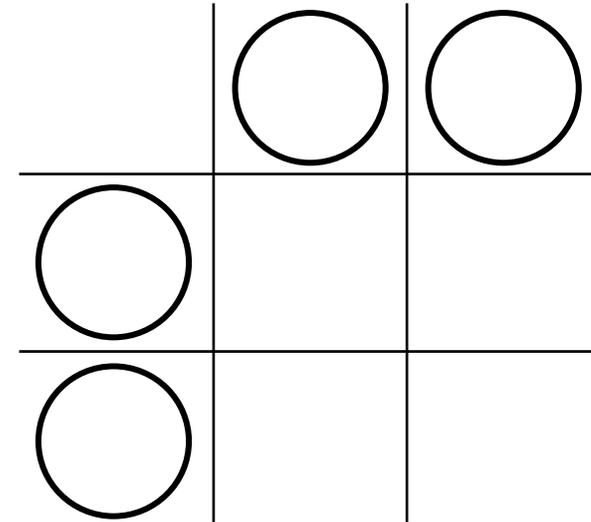
**[4 marks]**

**Command:** draw and calculate, give answer as a ratio

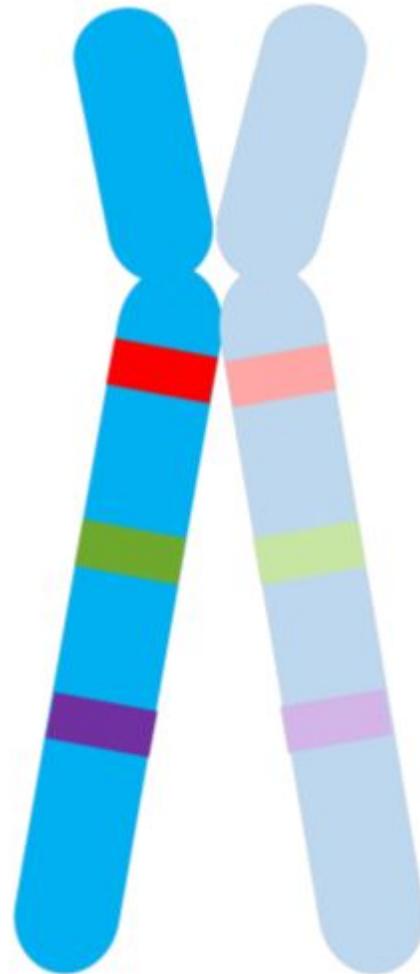
**Direction** – use punnet square to determine phenotypic ratio

**Context:** find genotypes of two plants

## Exemplar Exam Question – Calculation



# Autosomal Linkage



# Specification Points

## AQA

### 3.7.1 Inheritance (A-level only)

Content	Opportunities for skills development
<p>The genotype is the genetic constitution of an organism.</p> <p>The phenotype is the expression of this genetic constitution and its interaction with the environment.</p> <p>There may be many alleles of a single gene.</p> <p>Alleles may be dominant, recessive or codominant.</p> <p>In a diploid organism, the alleles at a specific locus may be either homozygous or heterozygous.</p> <p>The use of fully labelled genetic diagrams to interpret, or predict, the results of:</p> <ul style="list-style-type: none"> <li>monohybrid and dihybrid crosses involving dominant, recessive and codominant alleles</li> <li>crosses involving sex-linkage, autosomal linkage, multiple alleles and epistasis.</li> </ul> <p>Use of the chi-squared (<math>\chi^2</math>) test to compare the goodness of fit of observed phenotypic ratios with expected ratios.</p>	<p><b>AT h</b></p> <p>Students could investigate genetic ratios using crosses of <i>Drosophila</i> or Fast Plant®</p> <p><b>MS 0.3</b></p> <p>Students could use information to represent phenotypic ratios in monohybrid and dihybrid crosses.</p> <p><b>MS 1.4</b></p> <p>Students could show understanding of the probability associated with inheritance.</p> <p><b>MS 1.9</b></p> <p>Students could use the <math>\chi^2</math> test to investigate the significance of differences between expected and observed phenotypic ratios.</p>

## OCR

### 6.1.2 Patterns of inheritance

Learning outcomes	Additional guidance
<p>(b) (ii) the use of phenotypic ratios to identify linkage (autosomal and sex linkage) and epistasis</p>	<p>To include explanations of linkage and epistasis.</p> <p><i>M0.3, M1.4</i> HSW2, HSW8</p>

# Specification Points

## Edexcel A

### Topic 3: Voice of the Genome

#### Students should:

- 3.8 i) Know that a locus (plural = loci) is the location of genes on a chromosome.  
ii) Understand the linkage of genes on a chromosome and sex linkage.

## Edexcel B

### Topic 8: Origins of Genetic Variation

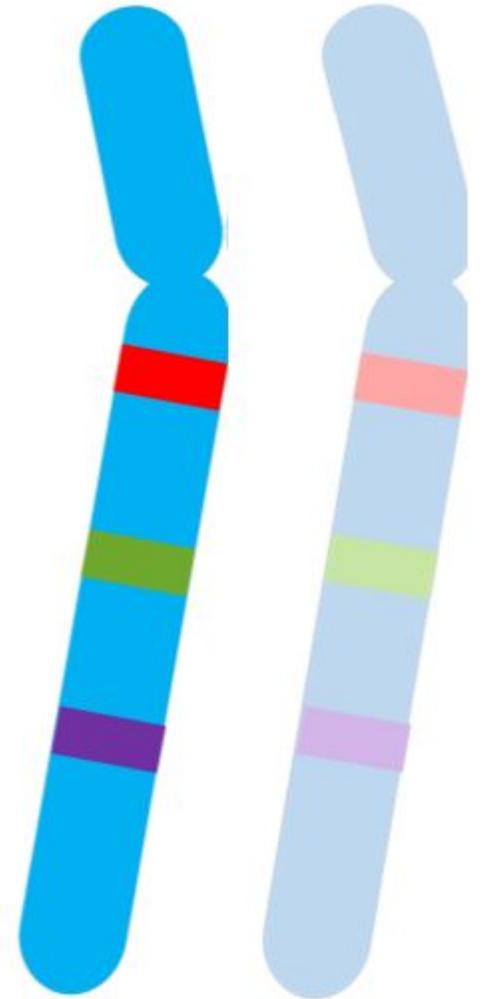
#### Students should:

#### 8.2 Transfer of genetic information

- iv Understand that autosomal linkage results from the presence of alleles on the same chromosome and that the results of crosses can be explained by the events of meiosis, including black/grey body and long/vestigial wing in *Drosophila*.

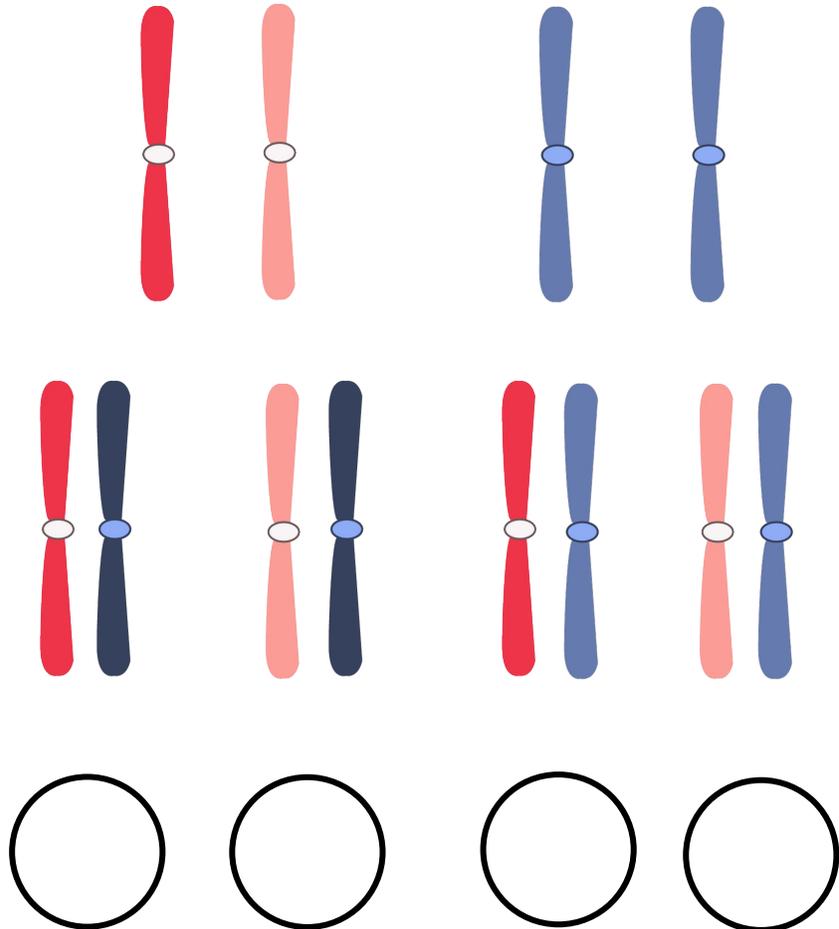
# Autosomal Linkage

- Of the **23 pairs of chromosomes** in humans, 22 are **autosomes** and the final pair are **sex chromosomes**
- **Genes** which are located on the **same chromosome** are described as being **linked**
- Therefore if **two** or more genes are located on the **same autosome** – this is called **autosomal linkage**

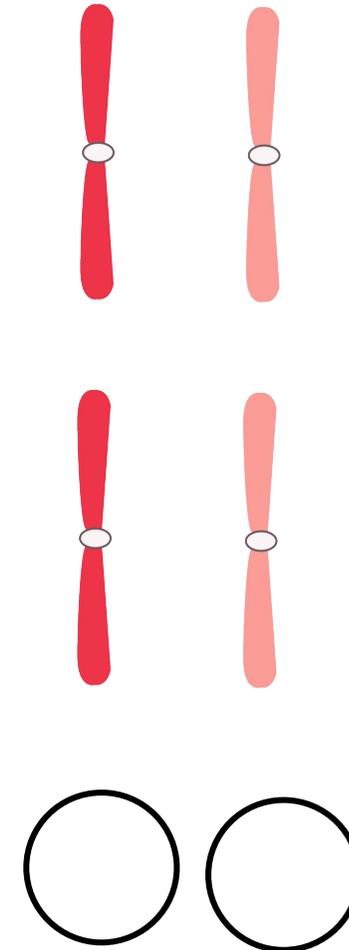


# Autosomal Linkage - Gamete Combinations

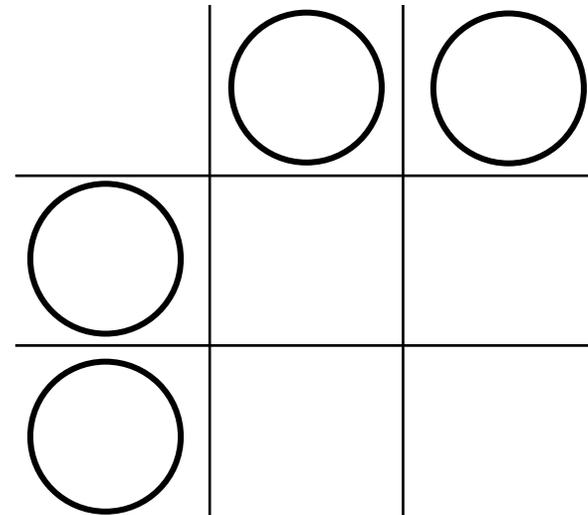
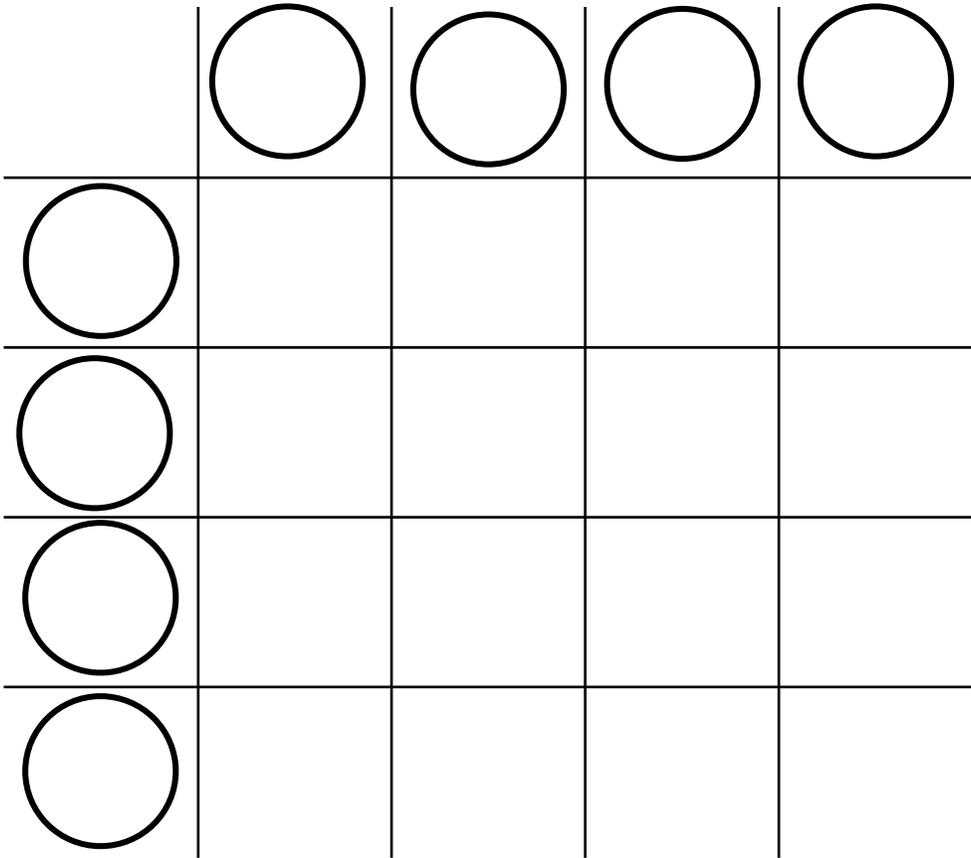
AaBb individual when genes unlinked



AaBb individual when genes linked



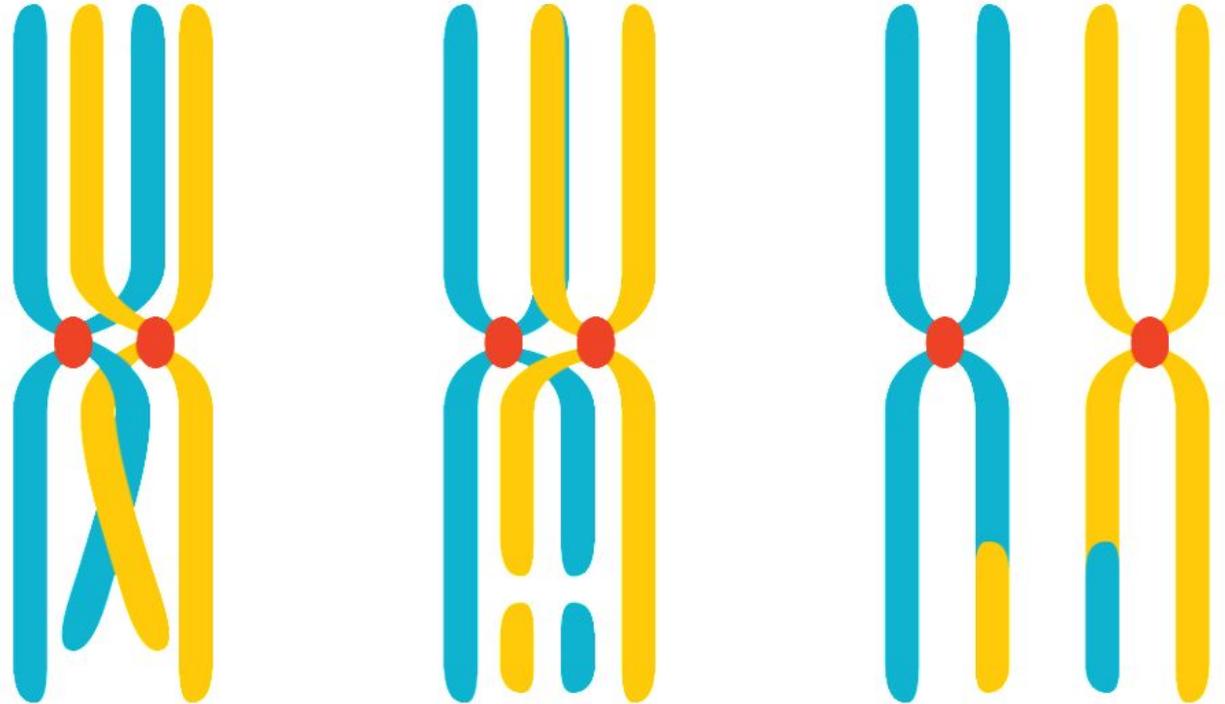
# Linkage – Phenotypic Ratios



- But is this 3:1 ratio really the case?

# Recombinant Gametes

- When **genes** are **linked**, the **gametes** will usually only have **two** possible combinations of **alleles** – rather than **four**
- However, **other allele combinations** can sometimes be formed by **crossing over** – these are **recombinants**



## Exemplar Exam Question – Explanatory

3) Explain why autosomal linkage of genes results in a lower frequency of certain gamete genotypes than seen with unlinked genes.

**[3 marks]**

**Command:** detailed, complex response

**Direction:** how linkage affects gamete allele combinations

**Context:** linkage during meiosis

## Exemplar Exam Question – Explanatory

3) Explain why autosomal linkage of genes results in a lower frequency of certain gametes.

**[3 marks]**

Autosomal linkage occurs when genes are situated on the same chromosome. This means they cannot be separated by independent assortment and can only separate during crossing over. Separation during crossing over occurs with low frequency, therefore resulting in a lower frequency of recombinant gametes.

# Recombination Frequencies

- **Recombination frequency** is a measure of the **amount** of **crossing over** that occurs and can be used to **estimate genetic linkage**
- The **closer** the **genes** are on a **chromosome**, the **tighter** the **linkage** and the **less crossing over**
- **Recombination frequencies** can therefore be used to **estimate** how **close two genes** are on a **chromosome**

$$\text{Recombination frequency (\%)} = \frac{\text{Number of recombinant offspring}}{\text{Number of total offspring}} \times 100$$

**Edexcel B:** This is just for Edexcel B

## Exemplar Exam Question – Data Analysis

4) A student was investigating the inheritance of two characteristics in fruit flies.

**Body colour:** Grey (G) is dominant to black (g)

**Wing length:** Normal (N) is dominant to vestigial (n)

After performing a dihybrid cross with two homozygous parents (GGNN, ggnn), he then interbred their offspring. This produced the offspring ratios shown in table 1.

Table 1

Phenotype	Count
Grey and normal	304
Grey and vestigial	3
Black and normal	2
Black and vestigial	101

## Exemplar Exam Question – Data Analysis

4) Using the offspring ratio and provided experimental information, state how the body colour and wing size genes interact, and explain how you reached your conclusion.

**[5 marks]**

**Command:** critical thinking, use bullet points to simplify

**Direction:** focus on the interaction between the genes

**Context:** linkage between genes, dihybrid crosses

4) Using the offspring ratio and provided experimental information. State how the body colour and wing size genes interact, and explain how you reached your conclusion. **[5 marks]**

- Body colour and wing size genes exhibit autosomal linkage
- The F2 generation phenotypic ratio is roughly 3:1, if unlinked would expect 9:3:3:1
- Homozygous parents have genotype GGNN, ggnn – gametes GN from GGNN parent and gn from ggnn parent. All offspring GgNn.
- 3:1 ratio seen in F2 offspring as the majority of gametes formed are GN and gn as these alleles are inherited together on same chromosome
- Small proportion of recombinants seen due to crossing over allowing formation of gametes gN and Gn
- Some organisms therefore are ggNn and Gggn

# The Chi-squared Test

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

## AQA

### 3.7.1 Inheritance (A-level only)

Content	Opportunities for skills development
<p>The genotype is the genetic constitution of an organism.</p> <p>The phenotype is the expression of this genetic constitution and its interaction with the environment.</p> <p>There may be many alleles of a single gene.</p> <p>Alleles may be dominant, recessive or codominant.</p> <p>In a diploid organism, the alleles at a specific locus may be either homozygous or heterozygous.</p> <p>The use of fully labelled genetic diagrams to interpret, or predict, the results of:</p> <ul style="list-style-type: none"> <li>monohybrid and dihybrid crosses involving dominant, recessive and codominant alleles</li> <li>crosses involving sex-linkage, autosomal linkage, multiple alleles and epistasis.</li> </ul> <p>Use of the chi-squared (<math>\chi^2</math>) test to compare the goodness of fit of observed phenotypic ratios with expected ratios.</p>	<p><b>AT h</b></p> <p>Students could investigate genetic ratios using crosses of <i>Drosophila</i> or Fast Plant®</p> <p><b>MS 0.3</b></p> <p>Students could use information to represent phenotypic ratios in monohybrid and dihybrid crosses.</p> <p><b>MS 1.4</b></p> <p>Students could show understanding of the probability associated with inheritance.</p> <p><b>MS 1.9</b></p> <p>Students could use the <math>\chi^2</math> test to investigate the significance of differences between expected and observed phenotypic ratios.</p>

## OCR A

### 6.1.2 Patterns of inheritance

Learning outcomes	Additional guidance
<p>(c) using the chi-squared (<math>\chi^2</math>) test to determine the significance of the difference between observed and expected results</p>	<p>The formula for the chi-squared (<math>\chi^2</math>) test will be provided.</p> <p><i>M0.3, M1.4, M1.9, M2.1</i></p>

## Edexcel A

	Mathematical skills	Exemplification of mathematical skill in the context of A Level biology (assessment is not limited to the examples given below)
A.1.9	Select and use a statistical test	<p>Candidates may be tested on their ability to select and use:</p> <ul style="list-style-type: none"> <li>the Chi squared test to test the significance of the difference between observed and expected results</li> <li>the Student's t-test</li> <li>the correlation coefficient</li> </ul>

## Edexcel B

### Topic 8: Origins of Genetic Variation

#### Students should:

#### 8.2 Transfer of genetic information

- vi Be able to use chi squared tests to test the significance of the difference between observed and expected results.

# The Chi-squared Test

- **Chi-squared** is used to determine whether **observed results** are significantly different to **expected results**
- In particular it checks whether **differences** between **observed** results and **expected** results are due to **chance** or if there is **significant** enough **difference** to suggest a **biological cause**

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

# The Null Hypothesis

Table 1.

Degrees of Freedom	Probability (p)			
	0.5	0.1	0.05	0.01
<b>1</b>	0.46	2.71	3.84	6.64
<b>2</b>	1.39	4.60	5.99	9.21
<b>3</b>	2.37	6.25	7.82	11.34
<b>4</b>	3.36	7.78	9.49	13.28
<b>5</b>	4.35	9.24	11.07	15.09
<b>6</b>	5.35	10.64	12.59	16.81
<b>7</b>	6.35	12.02	14.07	18.48
<b>8</b>	7.34	13.36	15.51	20.09
<b>9</b>	8.34	14.68	16.92	21.67
<b>10</b>	9.34	15.99	18.31	23.21

## Exemplar Exam Question – Simple Explanatory

5) A student conducted genetic crosses with sweet pea plants. He tested his results for statistical significance using the chi-squared test, obtaining a result of 7.61. His experiment had 3 degrees of freedom.

Using table 1, state whether or not the student is able to reject the null hypothesis, and explain why.

**[2 marks]**

**Command:** state and explain

**Direction:** how is the acceptance/rejection of the null hypothesis determined?

**Context:** chi-squared

## Exemplar Exam Question – Simple Explanatory

5) A student conducted genetic crosses with sweet pea plants. He tested his results for statistical significance using the chi-squared test, obtaining a result of 7.61. His experiment had 3 degrees of freedom.

Using Table 1, state whether or not the student is able to reject the null hypothesis, and explain why.

**[2 marks]**

The student cannot reject the null hypothesis, as the value of 7.61 is not greater than the critical value of 7.82. The difference isn't significant and there is more than a 5% probability that any effect is due to chance

# Using the Chi-squared Test

- A student performs cross-breeding experiments with fruit flies - she expects a **phenotypic ratio** of **3:1**
- The **chi-squared test** can be used to determine whether the **actual results fit** the **predicted ratio**

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

	Observed (O)	Expected (E)	(O-E)	(O-E) <sup>2</sup>	
Gray flies (GG, Gg)	82				
Black flies (gg)	18				
				Total:	

# Using the Chi-squared Test

	Observed (O)	Expected (E)	(O-E)	(O-E) <sup>2</sup>	
Gray flies (GG, Gg)	82	75	7	49	0.653
Black flies (gg)	18	25	-7	49	1.960
				Total:	

- After **calculating** the chi-squared value, find the **degrees of freedom** (number of categories – 1) and cross-reference with a table of **critical values**
- In this example the chi-squared value (**2.61**) is **smaller** than the **critical value (3.84 at p=0.05)**, so the **null hypothesis cannot be rejected**

## Exemplar Exam Question – Data Analysis

6) A student performs a dihybrid cross with two heterozygous parents.

The dominant allele for seed shape is round and the dominant allele for seed colour is yellow. The number of offspring produced are shown in the table.

The student expects the usual phenotypic ratios seen in a dihybrid cross and assumes there is no autosomal or sex linkage, co-dominance or epistasis.

Phenotype	Count
Round and yellow	804
Round and green	241
Wrinkled and yellow	264
Wrinkled and green	83

## Exemplar Exam Question – Data Analysis

Perform a statistical analysis to determine if the observed results vary from the expected results.

Phenotype	Count
Round and yellow	804
Round and green	241
Wrinkled and yellow	264
Wrinkled and green	83

- State an appropriate null hypothesis. **[1 mark]**
- Determine the number of degrees of freedom. **[1 mark]**
- Calculate the value of chi-squared. **[3 marks]**
- Conclude as to whether the null hypothesis should be rejected. **[2 Marks]**

## Exemplar Exam Question – Data Analysis

- a) Devise an appropriate null hypothesis. **[1 Mark]**

There is no significant difference between the observed results and the expected results.

---

- b) Determine the number of degrees of freedom. **[1 Mark]**
-

## Exemplar Exam Question – Data Analysis

c) Calculate the value of chi-squared.

**[3 Marks]**

Phenotype	Count (Observed)	Count (Expected)			
Round and yellow	804				
Round and green	241				
Wrinkled and yellow	264				
Wrinkled and green	83				
<b>Total</b>	1392	1392		<b>Total</b>	

## Exemplar Exam Question – Data Analysis

c) Calculate the value of chi-squared.

**[3 Marks]**

Phenotype	Count (Observed)	Count (Expected)			
Round and yellow	804	783 (87 x 9)	21	441	0.563
Round and green	241	261 (87 x 3)	-20	400	1.53
Wrinkled and yellow	264	261	3	9	0.0345
Wrinkled and green	83	87	-4	16	0.184
<b>Total</b>	1392	1392		<b>Total</b>	

## Exemplar Exam Question – Data Analysis

d) Conclude as to whether the null hypothesis should be rejected.

**[2 Marks]**

With 3 degrees of freedom and  $p=0.05$ , we get a critical value of 7.82. Our value of 2.31 is much lower than the critical value of 7.82. Therefore the null hypothesis cannot be rejected as there is no significant difference between observed and expected results. There is a greater than 5% probability that the difference is due to chance.

Degrees of Freedom	Probability (p)			
	0.5	0.1	0.05	0.01
1	0.46	2.71	3.84	6.64
2	1.39	4.60	5.99	9.21
3	2.37	6.25	7.82	11.34
4	3.36	7.78	9.49	13.28
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7	6.35	12.02	14.07	18.48
8	7.34	13.36	15.51	20.09
9	8.34	14.68	16.92	21.67
10	9.34	15.99	18.31	23.21

# Sex Linkage



# Specification Points

## AQA

### 3.7.1 Inheritance (A-level only)

Content	Opportunities for skills development
<p>The genotype is the genetic constitution of an organism.</p> <p>The phenotype is the expression of this genetic constitution and its interaction with the environment.</p> <p>There may be many alleles of a single gene.</p> <p>Alleles may be dominant, recessive or codominant.</p> <p>In a diploid organism, the alleles at a specific locus may be either homozygous or heterozygous.</p> <p>The use of fully labelled genetic diagrams to interpret, or predict, the results of:</p> <ul style="list-style-type: none"> <li>monohybrid and dihybrid crosses involving dominant, recessive and codominant alleles</li> <li>crosses involving sex-linkage, autosomal linkage, multiple alleles and epistasis.</li> </ul> <p>Use of the chi-squared (<math>X^2</math>) test to compare the goodness of fit of observed phenotypic ratios with expected ratios.</p>	<p><b>AT h</b></p> <p>Students could investigate genetic ratios using crosses of <i>Drosophila</i> or Fast Plant®</p> <p><b>MS 0.3</b></p> <p>Students could use information to represent phenotypic ratios in monohybrid and dihybrid crosses.</p> <p><b>MS 1.4</b></p> <p>Students could show understanding of the probability associated with inheritance.</p> <p><b>MS 1.9</b></p> <p>Students could use the <math>X^2</math> test to investigate the significance of differences between expected and observed phenotypic ratios.</p>

## OCR

### 6.1.2 Patterns of inheritance

Learning outcomes	Additional guidance
(b) (i) genetic diagrams to show patterns of inheritance	To include monogenic inheritance, dihybrid inheritance, multiple alleles, sex linkage and codominance.
(b) (ii) the use of phenotypic ratios to identify linkage (autosomal and sex linkage) and epistasis	To include explanations of linkage and epistasis. <i>M0.3, M1.4</i> HSW2, HSW8

# Specification Points

## Edexcel A

### Topic 3: Voice of the Genome

**Students should:**

3.8 ii) Understand the linkage of genes on a chromosome and sex linkage.

## Edexcel B

### Topic 8: Origins of Genetic Variation

**Students should:**

**8.2 Transfer of genetic information**

ii Be able to construct genetic crosses and pedigree diagrams.

# Sex Linkage

- **Any gene** that is **carried** on the **X** or **Y chromosome** is **said** to be **sex-linked**
- Biological females are **XX** and males are **XY**, so males have a region of their **X chromosome** which does not have a **homologous counterpart**.
- If a **recessive allele** is present on the **X chromosome in males**, it cannot be **silenced** by a **corresponding dominant allele**.



# Sex Linkage in Human Disease

- **Genetic disorders caused by a defective gene on the X chromosome are known as X-linked genetic disorders**
- **Haemophilia is a disorder caused by a defective gene on the X chromosome**
- **Carrier females ( $X^H X^h$ ) that have offspring with unaffected males ( $X^H Y$ ) have a 25% chance of creating another carrier female and a 25% chance of a haemophiliac male**

Maternal Gametes	Paternal Gametes	
	$X^H$	Y
$X^H$		
$X^h$		

Maternal Gametes	Paternal Gametes	
	$X^h$	Y
$X^H$		
$X^h$		

## Exemplar Exam Question – Explanatory

7) Contrast sex linkage and autosomal linkage.

**[3 Marks]**

**Command:** find differences between the two types of linkage

**Context:** sex linkage and autosomal linkage

**Direction:** how each type of linkage is defined and its effects

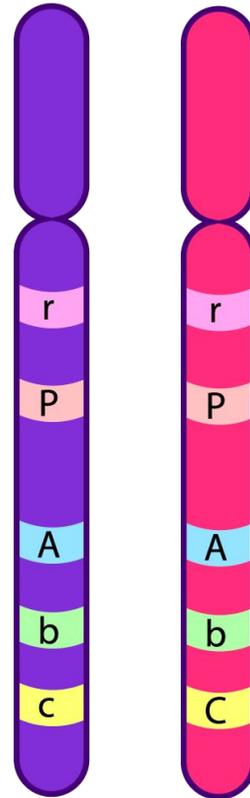
## Exemplar Exam Question – Explanatory

7) Contrast sex linkage and autosomal linkage.

**[3 Marks]**

Sex linkage is when a gene is carried on one of the sex chromosomes (X or Y chromosomes) which means that there is a link between recessive diseases and their prevalence in one gender. Autosomal linkage is when more than one gene is carried on the same non-sex chromosome called an autosome. Autosomally linked genes are more likely to be inherited together.

# Epistasis



# Specification Points

## AQA

### 3.7.1 Inheritance (A-level only)

Content	Opportunities for skills development
<p>The genotype is the genetic constitution of an organism.</p> <p>The phenotype is the expression of this genetic constitution and its interaction with the environment.</p> <p>There may be many alleles of a single gene.</p> <p>Alleles may be dominant, recessive or codominant.</p> <p>In a diploid organism, the alleles at a specific locus may be either homozygous or heterozygous.</p> <p>The use of fully labelled genetic diagrams to interpret, or predict, the results of:</p> <ul style="list-style-type: none"> <li>monohybrid and dihybrid crosses involving dominant, recessive and codominant alleles</li> <li>crosses involving sex-linkage, autosomal linkage, multiple alleles and epistasis.</li> </ul> <p>Use of the chi-squared (<math>X^2</math>) test to compare the goodness of fit of observed phenotypic ratios with expected ratios.</p>	<p><b>AT h</b></p> <p>Students could investigate genetic ratios using crosses of <i>Drosophila</i> or Fast Plant®</p> <p><b>MS 0.3</b></p> <p>Students could use information to represent phenotypic ratios in monohybrid and dihybrid crosses.</p> <p><b>MS 1.4</b></p> <p>Students could show understanding of the probability associated with inheritance.</p> <p><b>MS 1.9</b></p> <p>Students could use the <math>X^2</math> test to investigate the significance of differences between expected and observed phenotypic ratios.</p>

## OCR

### 6.1.2 Patterns of inheritance

Learning outcomes	Additional guidance
<p>(b) (i) genetic diagrams to show patterns of inheritance</p>	<p>To include monogenic inheritance, dihybrid inheritance, multiple alleles, sex linkage and codominance.</p>
<p>(b) (ii) the use of phenotypic ratios to identify linkage (autosomal and sex linkage) and epistasis</p>	<p>To include explanations of linkage and epistasis.</p> <p><i>M0.3, M1.4</i> HSW2, HSW8</p>

# Specification Points

**Edexcel A**

**Epistasis is not covered**

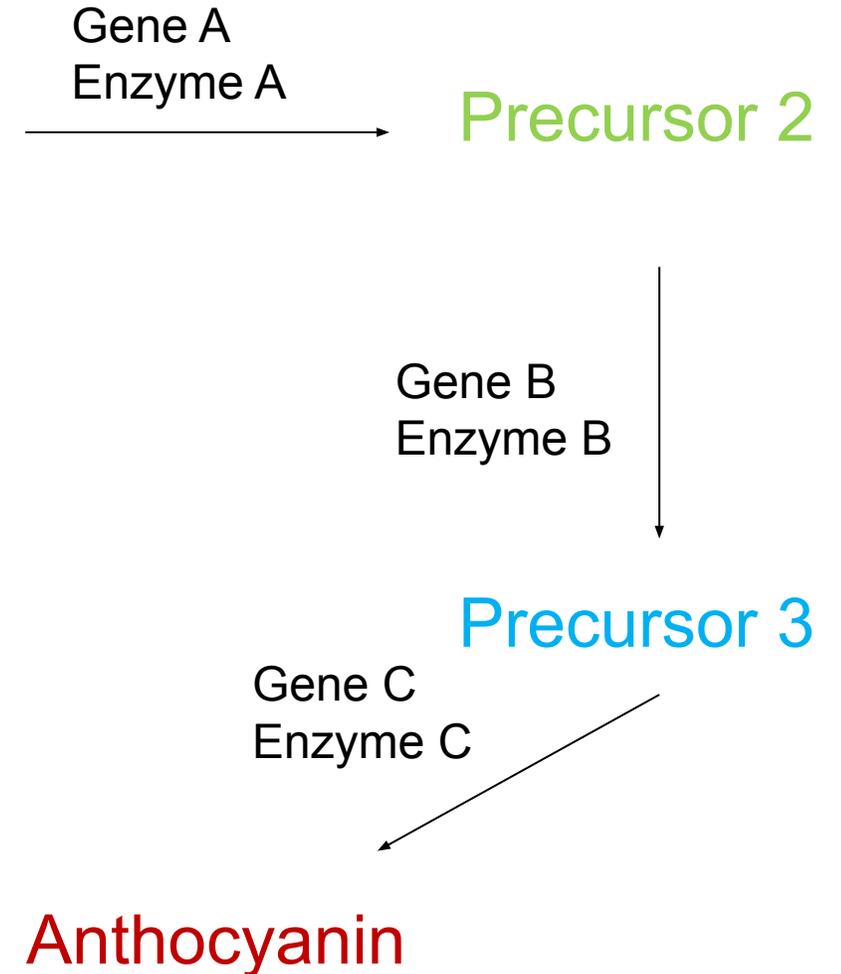
**Edexcel B**

**Epistasis is not covered**

# Epistasis

Precursor 1

- **Different genes** on **different chromosomes** can **interact** to **affect (mask)** a **phenotype**
- These **genes** can work **antagonistically** or in a **complimentary fashion**
- **Recessive epistasis** occurs when a **homozygous recessive genotype** blocks the **expression** of another **gene**. **Dominant epistasis** is when a **dominant genotype** blocks the **expression** of another **gene**



# Epistasis

- **Gene A** determines if a **banding pattern** is present in **mice**. **Allele A** leads to a **banding pattern**, **allele a** leads to a **pure black colour**
- **Gene B** determines if **melanin** is **synthesised**. **Allele B** leads to the **production of melanin**. **Allele b** prevents any **colour formation**
- A **homozygous dominant** and **recessive individual** were **crossed**. Their **offspring** were subsequently **crossed** after.

Maternal Gametes	Paternal Gametes			

## Exemplar Exam Question – Statement

- 8) Alfalfa seed colour is determined by 2 genes which interact in the following way. Precursor 1 is colourless, 2 is orange and xanthophyll is yellow.

Precursor 1  $\xrightarrow{\text{Allele A/Enzyme A}}$  Precursor 2  $\xrightarrow{\text{Allele B/Enzyme B}}$  Xanthophyll

State the phenotypes of the following genotypes:

**[3 marks]**

AABB

aaBB

AAbb

**Command:** only requires a ratio

**Direction:** need to determine genotype before phenotype

**Context:** phenotypic ratios of monohybrid crosses

## Exemplar Exam Question – Statement

- 8) Alfalfa seed colour is determined by 2 genes which interact in the following way. Precursor 1 is colourless, 2 is orange and xanthophyll is yellow.



State the phenotypes of the following genotypes:

**[3 marks]**

AABB - Yellow

aaBB - Colourless

Aabb - Orange

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# Mini Mock Paper



## Mini Mock Paper

a) Define 'allele' and 'homologous chromosomes'.

**[3 marks]**

Allele:

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Homologous chromosomes:

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## Mini Mock Paper

b) A scientist was investigating the inheritance of body colour and wing size genes in *Drosophila*. He crossed two heterozygous flies together. He expected a phenotypic ratio of 9:3:3:1, but observed a different ratio.

Calculate the numbers of each fly phenotype the student expected to find.

Phenotype	Count (observed)	Count (expected)
Grey and normal	805	
Grey and vestigial	16	
Black and normal	14	
Black and vestigial	285	
<b>Total</b>		

**[2 marks]**

## Mini Mock Paper

c) In *Drosophila* the gene for red coloured eyes (R) is dominant to the gene for white coloured eyes (r). A researcher crossed a red-eyed fly with a white-eyed fly, expecting to get an F1 generation of red-eyed flies, instead they obtained the following results:

Fly Phenotype	Number of Offspring
red-eyed female	51
red-eyed male	0
white-eyed female	0
white-eyed male	54

Draw a genetic diagram to show how these results may have been produced.

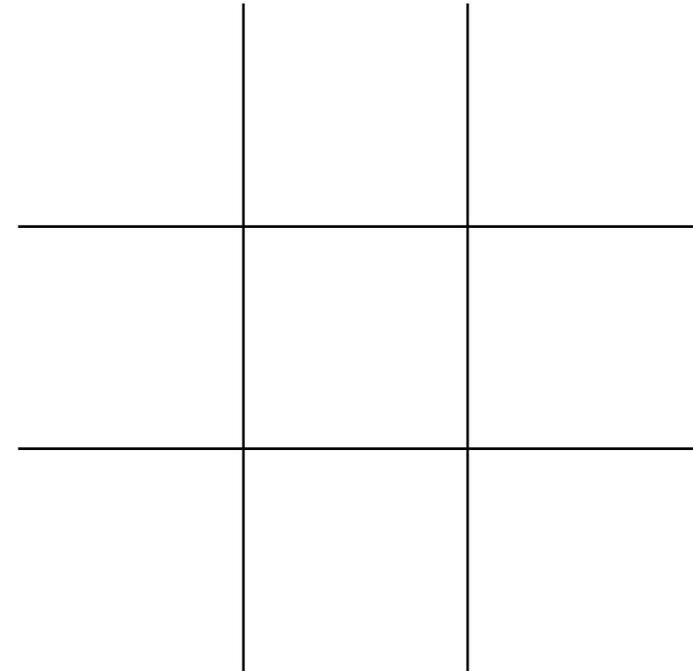
**[3 marks]**

## Mini Mock Paper

Parental genotypes:

Gametes:

F1 genotypes:



# Mini Mock Paper Answers



## Mini Mock Paper

a) Define 'allele' and 'homologous chromosomes'.

**[3 marks]**

Allele: An allele is a different version of a gene.

Homologous chromosomes: Chromosomes which are matched in size and contain the same genes at the same gene loci - one of the homologous pair is paternal and one is maternal

## Mini Mock Paper

b) A scientist was investigating the inheritance of body colour and wing size genes in *Drosophila*. He crossed two heterozygous flies together. He expected a phenotypic ratio of 9:3:3:1, but observed a different ratio.

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## Mini Mock Paper

Parental genotypes:

Gametes:

F1 genotypes:

