DP Biology – D3.2 (HL extension)

Two genes at a time

- What patterns of inheritance are seen in plants and animals?
- What happens at the molecular level to produce these patterns?

HL statements D3.2.16–21. Textbook pp. 747–759.



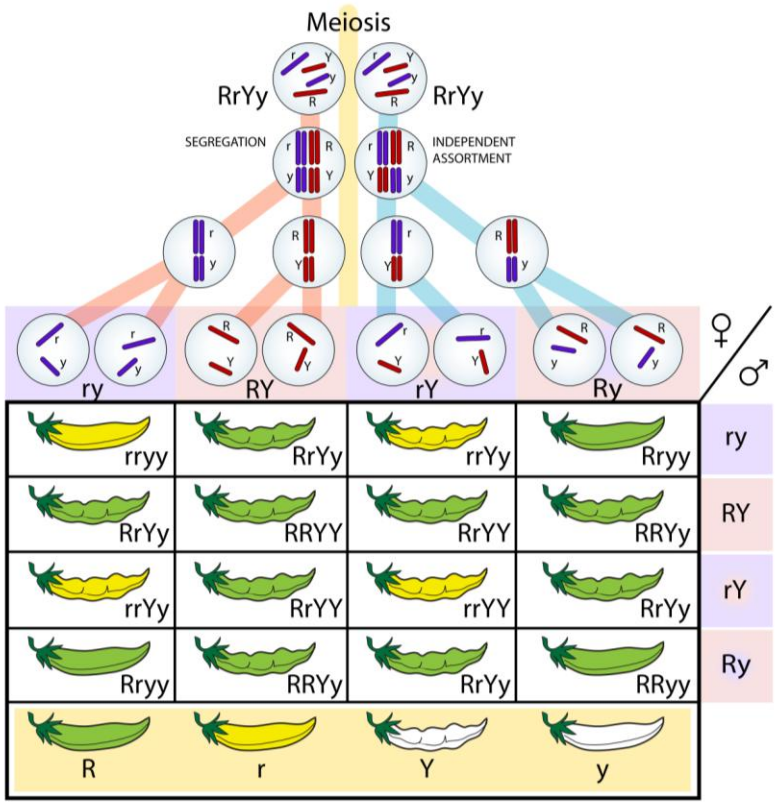
Image: peas in their pods. CC BY-SA 3.0.

Objectives for each class

Class	Statements	By the end of the class, you can...
1	D3.2.16–17	Explain independent assortment in meiosis, and use Punnett grids for dihybrid crosses
2	D3.2.18–19	Locate human genes on chromosomes, and explain why linked genes do not assort independently
3	D3.2.20	Identify recombinants in test crosses with linked and unlinked genes
4	D3.2.21	Use a chi-squared test on the results of a dihybrid cross

Segregation and independent assortment

D3.2.16



Meiosis and a dihybrid cross in peas. LadyofHats, public domain.

- **Segregation**: the two alleles of a gene go into different gametes, because homologous chromosomes separate in meiosis I
- **Independent assortment**: for genes on different chromosomes, each pair of homologues lines up at random in metaphase I
- So a parent RrYy makes four kinds of gamete, RY, Ry, rY and ry, in equal numbers
- This applies only to **unlinked** genes, on different chromosomes

Key idea

The ratios Mendel saw in his crosses are explained by how chromosomes move in meiosis.

The 9:3:3:1 ratio

	SY	Sy	sY	sy
SY	SSYY	SSYy	SsYY	SsYy
Sy	SSYy	SSyy	SsYy	Ssyy
sY	SsYY	SsYy	ssYY	ssYy
sy	SsYy	Ssyy	ssYy	ssyy

- Cross: SsYy × SsYy (S smooth, Y yellow)
- 9 smooth yellow
- 3 smooth green
- 3 wrinkled yellow
- 1 wrinkled green

Test cross: 1:1:1:1

SsYy × ssyy gives four phenotypes in equal numbers, because the double recessive parent only gives sy gametes. The phenotype of each offspring shows which gamete came from the heterozygous parent.

Practise dihybrid crosses

D3.2.17

1. In rabbits, brown coat (B) is dominant to white (b) and a normal tail (T) is dominant to no tail (t). A BbTt male is crossed with a bbtt female. Give the gametes and the expected phenotype ratio.
2. Two pea plants SsTt (S smooth, T tall) are crossed and 320 seeds grown. How many tall plants with wrinkled seeds are expected?
3. In fruit flies, Wwgg is crossed with wwGg (W normal wings, G normal body). Predict the ratio of phenotypes.

Answers

1. 1:1:1:1; 2. 3/16 of 320 = 60; 3. 1:1:1:1.

Where human genes are



Human male karyotype. NHGRI, public domain.

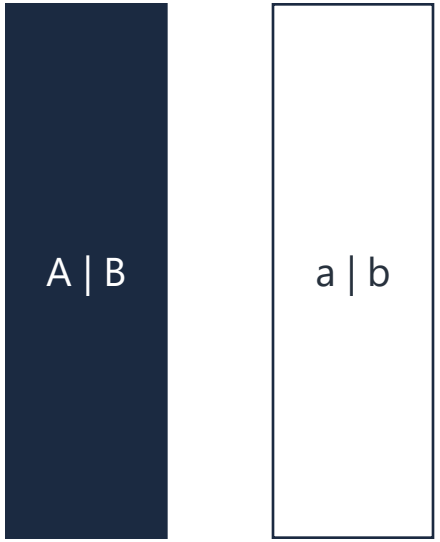
Gene	Locus	Polypeptide
HBB	11p15	Beta globin of haemoglobin
HBD	11p15	Delta globin, next to HBB
HBA1	16p13	Alpha globin
CFTR	7q31	Chloride channel in cell membranes
F8	Xq28	Clotting factor VIII

Activity

Use an online gene database (such as NCBI Gene or Ensembl) to find the locus and polypeptide of three genes. Find one pair of genes on different chromosomes and one pair close together on the same chromosome. Which pair would you expect to be inherited together?

Linked genes

- Genes with loci on the same chromosome are **linked**
- They tend to be inherited together, so they do not assort independently
- Alleles are shown beside vertical lines, one line for each homologous chromosome
- The closer two loci are, the more strongly they are linked

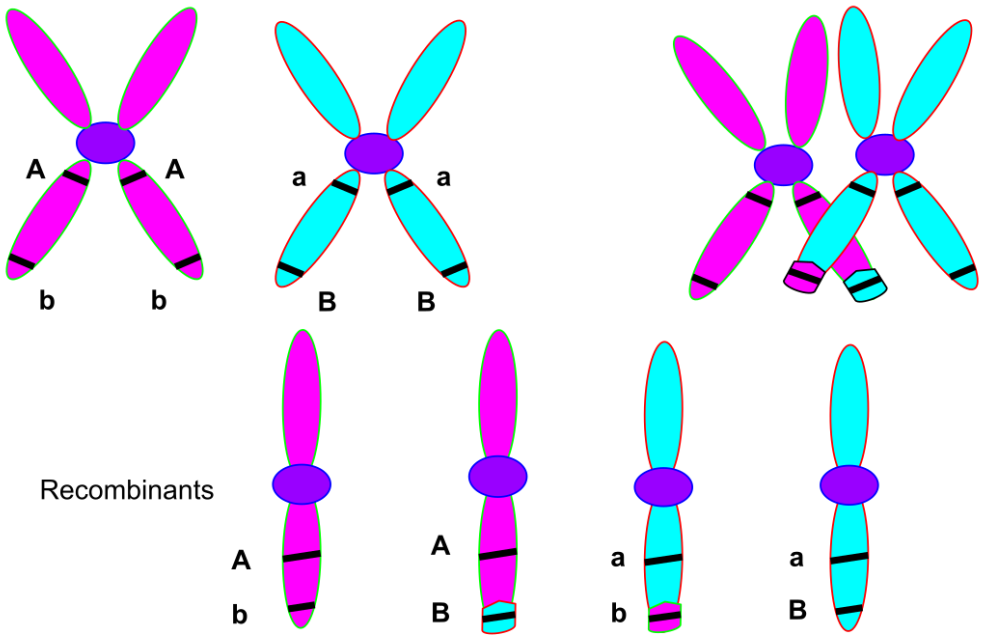


Notation for a heterozygote, AB on one chromosome and ab on the other

Why not always together?

Crossing over in prophase I can swap sections between homologues, giving new combinations.

Recombinants



Crossing over makes recombinant chromosomes. CC BY-SA 3.0.

- A **recombinant** has a new combination of alleles, not found in either parent
- In unlinked genes, recombinants come from independent assortment
- In linked genes, recombinants come only from crossing over between the loci
- So linked genes give fewer recombinants

Test cross with linked genes

AaBb (AB on one chromosome) × aabb. Most offspring are the parental types, AaBb and aabb. A few are recombinant, Aabb and aaBb. Two large classes and two small classes suggest linkage; four equal classes suggest independent assortment.

An example: sweet peas

D3.2.20



Sweet pea. Acabashi, CC BY-SA 4.0.

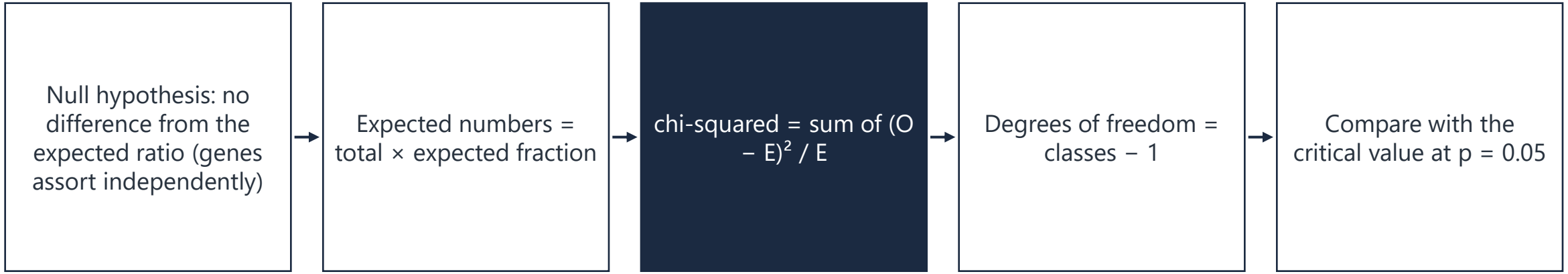
Offspring of test cross	Number	Type
Purple, long	430	Parental
White, short	420	Parental
Purple, short	75	Recombinant
White, long	75	Recombinant

Activity

Invented data. Calculate the percentage of recombinants (15%). Explain why it is far from 50%, and suggest what a higher percentage would tell you about the distance between the loci.

The chi-squared test

D3.2.21



Decision

If the calculated value is greater than the critical value, the difference is significant: reject the null hypothesis (for example, the genes may be linked). If it is smaller, the difference could be due to chance: do not reject it. For four classes (3 degrees of freedom) the critical value at p = 0.05 is 7.81.

A worked example: Bateson's chickens

D3.2.21

Phenotype (F2)	White, pea comb	White, single	Dark, pea	Dark, single
Observed (O)	111	37	34	8
Expected (E), 9:3:3:1	106.9	35.6	35.6	11.9
$(O - E)^2 / E$	0.16	0.05	0.07	1.26

Result

Chi-squared = 1.55, with 3 degrees of freedom. This is less than 7.81, so the difference from 9:3:3:1 is not significant: the data fit independent assortment. Data reported by W. Bateson in the early 1900s (190 chickens).

Check that you can explain

1. How meiosis causes segregation and independent assortment
2. Where the 9:3:3:1 and 1:1:1:1 ratios come from
3. How to find the locus and product of a human gene
4. Why linked genes do not assort independently, and how to show them
5. How to identify recombinants in a test cross
6. How to carry out and interpret a chi-squared test

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. State the expected phenotype ratio when two double heterozygotes for unlinked genes are crossed.
2. Explain why linked genes produce few recombinants.
3. State the null hypothesis in a chi-squared test of a dihybrid cross.

Image credits

Peas in pods – Studio.jpg – Bill Ebbesen – CC BY-SA 3.0

Independent assortment & segregation.svg – LadyofHats – Public domain

NHGRI human male karyotype.png – Courtesy: National Human Genome Research Institute – Public domain

Chromosomal Crossover.svg – Abbyprovenzano – CC BY-SA 3.0

Sweet pea 'Lathyrus odoratus' violet flower at Boreham, Essex, England 1.jpg – Acabashi – CC BY-SA 4.0

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