

Inheritance

Five one-hour lesson plans, and three more at higher level

Eight one-hour lessons cover D3.2: five for standard level and three more for higher level (the guide gives D3.2 five hours at SL and three more at HL). The plan follows the chapters, so a class can read the guide for homework and use the lesson for the activities. Every figure plays on a projector: step through each with the arrow keys and stop on each caption, and pause the meiosis film at each stage.

LESSON	COVERS	FOCUS	CHAPTERS
1 Halving, crossing and the genotype	D3.2.1 to D3.2.4	Meiosis as halving and fertilisation as doubling, how a cross in flowering plants is made and described, and the difference between genotype and phenotype	1, 2, 3
2 Dominance, plasticity and PKU	D3.2.5 to D3.2.7	Why a heterozygote can look like one homozygote, how the environment changes which genes are expressed, and phenylketonuria as a disease of a recessive allele	4, 5, 6
3 Many alleles, codominance and sex linkage	D3.2.8 to D3.2.12	Single-nucleotide polymorphisms and multiple alleles, the ABO blood groups, incomplete dominance and codominance, and the inheritance of genes on the sex chromosomes	7, 8, 9
4 Reading a family tree	D3.2.13	Using a pedigree chart to deduce whether a condition is dominant or recessive and autosomal or sex-linked, and reasoning from some cases to a general pattern	10
5 A spread, not a few types	D3.2.14 and D3.2.15	Continuous variation from polygenic inheritance and the environment, and drawing and reading box-and-whisker plots	11, 12
6 Two genes at once HL	D3.2.16 and D3.2.17	Segregation and independent assortment of unlinked genes, and the Punnett grid for a dihybrid cross	13
7 Genes that travel together HL	D3.2.18 to D3.2.20	The loci of human genes, linkage on a chromosome, recombinants made by crossing over, and reading a test cross	14
8 Is it chance? Chi-squared and the dry lab HL	D3.2.21	Using the chi-squared test to decide whether a dihybrid cross matches the expected ratio, and applying it in a simulated experiment	15, lab

The guide, for the class to read and play: biologybybradford.com/guides/ib-biology-d3-2-inheritance

Halving, crossing and the genotype

60 minutes • D3.2.1 to D3.2.4 • Chapters 1, 2, 3

Meiosis as halving and fertilisation as doubling, how a cross in flowering plants is made and described, and the difference between genotype and phenotype

BY THE END, STUDENTS CAN

- ☐ Explain how meiosis halves the chromosome number to make haploid gametes, and how fusion gives a diploid zygote D3.2.1
- ☐ Describe how a genetic cross is made in flowering plants, using the terms P generation, F1 generation, F2 generation and Punnett grid D3.2.2
- ☐ Define genotype, and use homozygous, heterozygous, gene and allele correctly D3.2.3
- ☐ Explain how phenotype comes from genotype and the environment, with examples of each D3.2.4

TIMING

0-6	6 min	Do now: how many chromosomes?	
6-18	12 min	Halve, then fuse	
18-28	10 min	Halve and fuse: the model	
28-40	12 min	Making a cross	
40-55	15 min	Gene, allele, genotype, phenotype	
55-60	5 min	Exit	
	60 min	One lesson	

STARTER

6 min

Do now: how many chromosomes?

Chapter 1's first predict box. Students answer on mini whiteboards before the options appear on the screen: how many chromosomes in a human sperm, and in the zygote? Keep the boards up. Ask what would happen if gametes were made by ordinary division.

ON THE BOARD, FROM THE GUIDE

Open the guide on the projector at each chapter (the links work in this PDF). Every figure plays from its own buttons, and the lesson's slides have the same figures, step by step, in the order of this plan.

01 Halve, then fuse

CHAPTER 01 IN THE SLIDES

Step through the figure (4 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

- Two parents, each with **diploid** body cells ($2n = 46$). Three of the 23 pairs are drawn.
- Meiosis** makes gametes with one chromosome from each pair: an egg and a sperm, each **haploid** ($n = 23$).
- Fusion** of the two gametes makes a zygote. It is diploid again, with one set from each parent.
- In the zygote, a pair of chromosomes carries the **same gene** twice, one copy from each parent.

Play the animation, Watch it happen: halving, then fusing. It loops; pause it on each moment below and ask what is happening (in the lesson slides it is a video).

1. A **diploid** cell of a parent. Its chromosomes are in pairs: one of each pair came from its mother (pink), one from its father (green).
2. First the DNA is copied: each chromosome becomes two identical **sister chromatids**, joined at a **centromere**.
3. The nucleus breaks down and each chromosome lies beside its partner: a **homologous pair**, with the same genes in the same order.
4. **Crossing over**: chromatids of a pair swap matching sections, making new mixes of the mother's and the father's alleles.
5. A spindle forms and the pairs line up across the middle. Which way round each pair lies is down to chance: **random orientation**.
6. **Meiosis I**: one chromosome of each pair is pulled to each end, and the cell divides. Each new cell has half the number of chromosomes.
7. **Meiosis II**: in each cell the sister chromatids are pulled apart, and both cells divide again.
8. Four **haploid** gametes, each with one chromosome of every pair, and no two alike.
9. **Fertilisation**: the gamete fuses with one from another parent (yellow). The **zygote** is diploid again, with one of each pair from each parent.

Predict box: A human body cell has 46 chromosomes. How many chromosomes are in a sperm, and how many in the zygote it helps to form? Hands up or mini whiteboards first.

Answer B: 23 in the sperm and 46 in the zygote

02 How to make a cross

CHAPTER 02 IN THE SLIDES

Step through the figure (5 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. A pea flower makes both kinds of gamete. **Pollen** forms in the anthers and holds the male gametes. The **ovules** in the ovary hold the female gametes.
2. Left alone, a pea flower **pollinates itself**: its pollen reaches its own stigma.
3. For a **cross**, the anthers are removed from the receiving flower, and pollen is carried from the donor to its stigma.
4. Cross two true-breeding parents (the **P generation**). Every seed of the **F1 generation** has one allele from each parent.
5. Let the F1 plants self-pollinate to make the **F2 generation**. The **Punnett grid** shows every way their gametes can combine: 3 yellow seeds for every 1 green.

Predict box: A student wants to cross a purple-flowered pea plant with a white-flowered one, but forgets to remove the anthers from the white plant. What is likely to happen? Hands up or mini whiteboards first.

Answer A: Some seeds will come from self-fertilisation, so not all will be from the cross

Remember it: Parents First Follows (P generation, F1 generation, F2 generation).

03 Genes, alleles and the traits you see

CHAPTER 03 IN THE SLIDES

Step through the figure (3 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. A pair of homologous chromosomes. The **gene** is one place on the chromosome. Each chromosome carries one **allele** of it, here Y and y.
2. The two alleles make the **genotype**. Two the same is **homozygous**. Two different is **heterozygous**.
3. The **phenotype** comes from the genotype, the environment, or both: blood group, a scar and height.

Predict box: Two plants have the same genotype for every gene, but one grows much taller because it was given more water and fertiliser. What does this show? Hands up or mini whiteboards first.

Answer B: The environment affects the phenotype as well as the genotype

THE LESSON

12
min

Halve, then fuse

Chapter 1's film, paused at each stage. Students sketch a cell with two chromosome pairs, then the four gametes it can make, then the zygote. Land on the linking question: what processes involve doubling and halving? Meiosis halves the number, fertilisation doubles it.

10

min

Halve and fuse: the model

The activity below. Each pair makes gametes by flipping a coin for each chromosome pair, then fuses with another pair. Tally the zygotes on the board and ask why two gametes from the same parent are never quite the same.

12

min

Making a cross

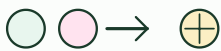
Chapter 2's figure, one step at a time, then its predict box on the forgotten anthers. Students write the words pollen, anther, stigma, ovary, P, F1 and F2 on a flower outline. Turn over the Remember it tiles for the generations.

15

min

Gene, allele, genotype, phenotype

Chapter 3's figure and predict boxes. Then the card sort below: is each trait set by genotype only, environment only, or both? Ask students to defend any card the class splits on. Do not rush the gene against allele distinction: say "versions of a gene".

ACTIVITIES**MODEL****Halve and fuse**

Each student has two cards for one chromosome pair, one pink (from the mother) and one green (from the father), and a coin. Heads, the pink card goes into the gamete; tails, the green one. Two students then bring their gametes together to make a zygote. Repeat with two pairs, using two coins. Tally on the board how many zygotes have both pink, both green, or one of each. Ask why a parent never passes both cards.

Needs: coins, pink and green cards (two for each pair of chromosomes), a tally table on the board.

**CARD SORT****Genes, environment or both?**

Twelve trait cards for pairs, sorted into three piles: set by genotype only, by environment only, and by both. Use blood group, a scar, a tattoo, height, the shape of earlobes, a tan, speaking a language, body mass, the colour of eyes and a broken arm, with two of your own. Some cards invite argument; that is the point. For each card in the third pile, name the gene and name the environmental factor. Expect disagreement over height and body mass; both belong in the third pile.

Needs: printed cards, one set per pair.

PLENARY**5**

min

Exit

Write a sentence using homozygous and a sentence using heterozygous, each for the pea seed shape gene. Collect on the way out.

WHAT STUDENTS GET WRONG

"Dominant means common or strong." A dominant allele is one that shows in the heterozygote. Many dominant alleles are rare, and some harmful ones are dominant.

Gene and allele are the same. A gene is a stretch of DNA that codes for a polypeptide; alleles are its versions. Ask "which gene, and which allele of it?".

"A Punnett grid predicts exactly." It gives a probability for each child. Four children from Yy by Yy need not include a green one. Use the coins.

STRETCH AND SUPPORT

Support: give each figure's captions as a cut-up storyboard to put in order, and let students tap the dotted words as a glossary.

Stretch: a pea plant has 7 pairs of chromosomes. How many different gametes can one plant make from the way the pairs line up, ignoring crossing over? *2 to the power 7, which is 128.*

IN THE GUIDE

- 1 [Halve, then fuse](#)
- 2 [How to make a cross](#)
- 3 [Genes, alleles and the traits you see](#)
- All [The whole guide, with the figures that play](#)
- PPTX [This lesson's slides, in the order of this plan](#)

PRACTISE AND REVISE

BUILD FOR YOUR CLASS

- [Tarsia puzzle, dominoes and picture reveal](#) on D3.2, built from its key terms and ready to print
- A [pub quiz](#) with rounds on D3.2, to present or run with no projector
- An [escape room](#) built from the [question bank](#) on D3.2

ALREADY ON THE SITE FOR D3.2

- Lesson: [Linked Genes & Chi-Squared](#)
- Lesson: [Dihybrid Crosses & Test Crosses](#)
- Lesson: [Inheritance](#)
- Summary doodle: [Inheritance](#)
- Quiz: [Inheritance \(HL\)](#)
- Quiz: [Inheritance](#)
- Revision map: [D3.2 Inheritance](#), to fill in
- Exam questions: [D3.2 in the exam maker](#), a paper with its markscheme

CARD SETS ON SPLYCR

- Open a set to host it as a class game, or make a copy to edit.
- [D3.2 Inheritance](#)

EXAM PRACTICE

Check yourself

Set it for homework: a fresh paper of exam-bank questions on D3.2 at standard level each time, marked as students go and saved to their Exam practice when they are signed in.

biologybybradford.com/exam-maker/sit?topics=D3.2&level=SL&paper=quiz&marks=15&src=ep



Dominance, plasticity and PKU

60 minutes • D3.2.5 to D3.2.7 • Chapters 4, 5, 6

Why a heterozygote can look like one homozygote, how the environment changes which genes are expressed, and phenylketonuria as a disease of a recessive allele

BY THE END, STUDENTS CAN

- ☐ Predict the effects of dominant and recessive alleles on phenotype D3.2.5
- ☐ Explain phenotypic plasticity as a change in gene expression, not in the genes themselves D3.2.6
- ☐ Explain phenylketonuria as a disease caused by a recessive allele D3.2.7

TIMING

0-5	5 min	Do now	
5-20	15 min	Dominant and recessive, and the grid	
20-32	12 min	Same genes, different outcomes	
32-52	20 min	One faulty enzyme: PKU	
52-60	8 min	Exit	
	60 min	One lesson	

STARTER

- 5 min** **Do now**
- Chapter 4's first predict box. Vote with fingers (1, 2 or 3) for the option, then reveal. Leave the votes on the board for the figure.

ON THE BOARD, FROM THE GUIDE

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04 Dominant and recessive alleles

CHAPTER 04 IN THE SLIDES

Step through the figure (3 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

- Three genotypes of the seed colour gene: two **homozygous** and one **heterozygous**.
- Each gene makes a protein. A **Y** allele makes a working one, and one working copy makes **enough** to give the trait. With no working copy, the trait changes.
- The phenotypes: **YY** and **Yy** are both yellow, so the dominant allele shows in a heterozygote. Only **yy** is green.

Step through the figure (2 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

- Each parent makes gametes by meiosis, one allele of each gene in each. The female parent's go down the side of the **Punnett grid**, the male parent's along the top.
- Each cell joins one gamete from each parent: a possible offspring, every cell as likely as the next. The F1: genotypes all Yy; phenotypes all yellow.

Predict box: Two yellow-seeded pea plants are crossed, and some of their offspring have green seeds. What must be true of both parents? Hands up or mini whiteboards first.

Answer B: Both are heterozygous Yy: each carries a hidden y allele

05 Same genes, different outcomes

CHAPTER 05 IN THE SLIDES

Step through the figure (4 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. One parent plant, with its alleles.
2. Two **cuttings** from it carry exactly the same alleles.
3. One cutting grows in **sun** and one in **shade**. Same alleles, but different gene expression makes a short, sturdy plant and a tall one with broad leaves.
4. Move the shaded plant into the sun, and its **new growth** comes in like the sun plant's. The change is reversible, and the alleles never changed.

Predict box: Two clones grow differently, one in sun and one in shade. What explains the difference? Hands up or mini whiteboards first.

Answer B: The light changed how their genes were expressed

06 One faulty enzyme: PKU

CHAPTER 06 IN THE SLIDES

Step through the figure (4 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. In a person with a working allele, the **enzyme** converts phenylalanine to tyrosine, which has one extra OH group.
2. In a person with two faulty alleles the enzyme does not work. Little tyrosine is made and **phenylalanine builds up**.
3. A **diet low in phenylalanine** gives the body less to build up. The genotype is the same, and the phenotype changes.
4. Two **carrier** parents (Nn): each child has a 1 in 4 chance of nn, so of PKU.

Predict box: Two parents do not have PKU, but their first child does. What is the chance that their second child has PKU? Hands up or mini whiteboards first.

Answer C: 1 in 4, because both parents must be carriers

THE LESSON

15

min

Dominant and recessive, and the grid

Chapter 4's figure and the cross builder under it. Students predict each result before the grid fills in. Then the practice below, in pairs: six crosses, each set out with gametes, grid, genotype ratio and phenotype ratio.

12

min

Same genes, different outcomes

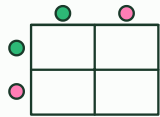
Chapter 5's figure. Show the cress seedlings, or photographs of them, from the practical below (set up the week before, or use the photographs on the card). Ask: do the two trays have the same genes? Land on "the genes were the same; what differed was which were expressed".

20

min

One faulty enzyme: PKU

Chapter 6's figure, step by step, then the two-carrier cross at the board. Then the case cards below, in groups: each card describes a family and asks for the chance that a child has PKU. Finish with screening and diet.



PRACTICE

Six crosses

Six crosses, each with two parents, the gametes, a Punnett grid, the genotype ratio and the phenotype ratio. Use pea seed colour (Y yellow dominant, y green): (1) YY by yy. *All Yy, all yellow.* (2) Yy by yy. *1 Yy : 1 yy, 1 yellow : 1 green.* (3) Yy by Yy. *1 YY : 2 Yy : 1 yy, 3 yellow : 1 green.* (4) yy by yy. *All green.* (5) A yellow plant by a green gave 18 yellow and 20 green offspring: what was the yellow parent? *Yy.* (6) Two yellow plants gave some green offspring: give the genotypes of both parents and the chance of a green seed. *Both Yy; one in four.* Finish by asking what would be different if you counted 8 offspring instead of 800.

Needs: mini whiteboards or squared paper.

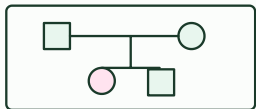


PRACTICAL

Cress in the dark and the light

Sow cress seeds in two trays of damp cotton wool. Put one on a windowsill and the other in a cupboard, and water both. After a week, students record height, colour and leaf size, then answer: the seeds were from one packet, so why do the trays differ? Move the pale tray into the light and watch it for three days. Which parts of the seedling change, and which parts do not? Link to [chapter 5](#): expression changes, the alleles do not. Photographs on the board are an acceptable substitute if no cupboard is free.

Needs: cress seeds, trays, cotton wool, a dark cupboard and a windowsill, a ruler; set up a week ahead.



CASE CARDS

PKU in the family

Six cards, each a short invented family: two unaffected parents and a child with PKU; two parents who both have PKU; one parent who is a carrier and one who has two normal alleles; and so on. Groups set out the genotype of each parent with N for the normal allele and n for the PKU allele, draw the cross, and give the chance of a child with PKU. Add a question about how the disease would be found at birth and what a family does about it. Keep every card invented and avoid naming real people.

Needs: printed cards, one set per group.

PLENARY

8

min

Exit

On a slip: the chance that the child of two carriers is a carrier, and the chance that it has PKU. Then one sentence on why a low phenylalanine diet helps.

WHAT STUDENTS GET WRONG

"Dominant means common or strong." A dominant allele is one that shows in the heterozygote. Many dominant alleles are rare, and some harmful ones are dominant.

"Recessive alleles disappear." A recessive allele stays in a heterozygote, hidden, and can come back in a later generation. Return to PKU carriers.

"A Punnett grid predicts exactly." It gives a probability for each child. Four children from Yy by Yy need not include a green one. Use the coins.

Plasticity is inheritance of acquired characteristics. A plant that grows tall in the shade does not give its seeds taller genes. The same alleles are expressed differently in a different environment.

STRETCH AND SUPPORT

Support: give each figure's captions as a cut-up storyboard to put in order, and let students tap the dotted words as a glossary.

Support: a Punnett grid with the gametes already written in for the first two crosses.

Stretch: why can a recessive disease stay common in a population even though the affected cannot easily have children? Link to the carriers in [chapter 6](#).

IN THE GUIDE

- 4 [Dominant and recessive alleles](#)
- 5 [Same genes, different outcomes](#)
- 6 [One faulty enzyme: PKU](#)
- A11 [The whole guide, with the figures that play](#)
- PPTX [This lesson's slides, in the order of this plan](#)

PRACTISE AND REVISE

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EXAM PRACTICE

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biologybybradford.com/exam-maker/sit?topics=D3.2&level=SL&paper=quiz&marks=15&src=ep



Many alleles, codominance and sex linkage

60 minutes • D3.2.8 to D3.2.12 • Chapters 7, 8, 9

Single-nucleotide polymorphisms and multiple alleles, the ABO blood groups, incomplete dominance and codominance, and the inheritance of genes on the sex chromosomes

BY THE END, STUDENTS CAN

- ☐ Describe single-nucleotide polymorphisms and multiple alleles in a gene pool D3.2.8
- ☐ Use the ABO blood groups to show how multiple alleles are inherited D3.2.9
- ☐ Distinguish incomplete dominance from codominance D3.2.10
- ☐ Explain sex determination in humans and the inheritance of genes on the sex chromosomes D3.2.11
- ☐ Use haemophilia to explain a sex-linked genetic disorder D3.2.12

TIMING

0–5	5 min	Do now	
5–15	10 min	Spot the SNP	
15–27	12 min	ABO and the baby swap	
27–37	10 min	Neither wins, or both do	
37–55	18 min	X, Y and sex	
55–60	5 min	Exit	
	60 min	One lesson	

STARTER

- 5 min** **Do now**
- Chapter 7's first predict box. Ask students to write down what they think determines their blood group, then compare to the figure.

ON THE BOARD, FROM THE GUIDE

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07 Many alleles, not just two

CHAPTER 07 IN THE SLIDES

Step through the figure (4 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

- DNA from four people at one place. They differ at a single base: a **SNP**.
- Across a whole population a gene can have many **alleles**. The **gene pool** holds them all.
- Each person inherits just **two** of them.
- ABO: three alleles in the pool give six genotypes and four blood groups.

Predict box: A man with blood group AB ($I^A I^B$) and a woman with group O (ii) have children. Which groups are possible? Hands up or mini whiteboards first.

Answer C: A and B only

Remember it: Apple Banana Both Orange (Group A, Group B, Group AB, Group O).

08 Neither wins, or both do

CHAPTER 08 IN THE SLIDES

Step through the figure (3 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. **Incomplete dominance** in four o'clocks: red ($C^R C^R$), pink ($C^R C^W$) and white ($C^W C^W$). The heterozygote is intermediate.
2. Cross two pink plants and the offspring are **1 red : 2 pink : 1 white**. The phenotype ratio matches the genotype ratio, and red and white reappear.
3. **Codominance** in blood: a red blood cell of group AB carries both markers, so the heterozygote has a dual phenotype.

Predict box: A red four o'clock plant is crossed with a white one. What colour are the F1 flowers? Hands up or mini whiteboards first.

Answer C: All pink

09 X, Y and sex

CHAPTER 09 IN THE SLIDES

Step through the figure (3 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. The **X** is big and carries many genes. The **Y** is small and carries far fewer. Two Xs develop female, an X and a Y develop male.
2. Every egg carries an X. A sperm carries X or Y, so the **sperm decides** the sex: half girls, half boys.
3. **Haemophilia**: a carrier mother ($X^H X^h$) and an unaffected father ($X^H Y$). Half the sons have haemophilia and half the daughters are carriers. No daughter is affected.

Predict box: A man with haemophilia ($X^h Y$) and a woman who is not a carrier ($X^H X^H$) have children. What are the children like? Hands up or mini whiteboards first.

Answer C: All daughters are carriers; all sons are unaffected

THE LESSON

10 Spot the SNP

min

Chapter 7's figure on SNPs, then the DNA strip activity below. Students find the single-letter differences and say which differences change the polypeptide and which do not.

12 ABO and the baby swap

min

The ABO table in [chapter 7](#) and the Remember it tiles. Then the hospital cases below: could this baby belong to these parents? Insist on genotypes written out with the I and i symbols.

10 Neither wins, or both do

min

[Chapter 8's](#) figure. Students put the two flower crosses side by side and name the pattern in each. Ask: what is the difference between the heterozygote that is a blend and the one that shows both?

18 X, Y and sex

min

[Chapter 9's](#) figure and the crosses below. Students set out X and Y with their superscripts, read the sons and daughters of each cross, and say what fraction of each sex is affected.

ACTIVITIES



PUZZLE

Spot the SNP

Three strips of invented DNA, about 30 letters each, from three people. Pairs lay them over each other, ring the letters that differ, and count them. Ask: what is a single-nucleotide polymorphism? Then, for each difference: does it change a codon, and does the change alter the amino acid? Use the codon table. Close with the point that a SNP is a difference found in at least 1 percent of the population, and so is not simply any mutation.

Needs: printed strips, a codon table.



CASE CARDS

The baby swap

Six hospital cases: one baby, two possible parents, and their blood groups. Could the baby belong to them? (1) Mother A, father B, baby O. *Possible, if both are heterozygous.* (2) Mother O, father O, baby AB. *Not possible.* (3) Mother AB, father O, baby A. *Possible.* (4) Mother AB, father AB, baby O. *Not possible.* (5) Mother B, father A, baby AB. *Possible.* (6) Mother O, father AB, baby O. *Not possible.* Students write each possible genotype pair and the cross before they answer, and say which result would rule out a pair for certain.

Needs: printed cards, one set per pair.



PRACTICE

Colour blindness and haemophilia

Four crosses. Use X with a superscript for each allele: X^H and X^h for haemophilia. (1) A carrier mother by an unaffected father. *Half the sons affected, no daughters affected, half the daughters carriers.* (2) An affected father by a mother who is not a carrier. *No sons affected, all daughters carriers.* (3) An affected father by a carrier mother. *Half the sons and half the daughters affected.* (4) An unaffected father by a mother who is not a carrier. *No affected children and no carriers.* Repeat (1) and (2) for red-green colour blindness, which is also carried on the X chromosome. Ask why a son cannot inherit an X-linked condition from his father.

Needs: mini whiteboards.

PLENARY

5
min

Exit

A father with haemophilia and a mother who is not a carrier: write the cross and the chance that a son or a daughter is affected. Collect.

WHAT STUDENTS GET WRONG

Incomplete dominance is "blending". The red and white alleles are not mixed up or lost: they come apart again in the next generation, so red and white can reappear.

"An individual has three ABO alleles." A person has two of the three alleles in the population, one from each parent. Three is the number in the gene pool.

A son can inherit an X-linked condition from his father. A father gives his son a Y chromosome. The son's X comes from his mother.

"Every X-linked condition affects only boys." Daughters can be affected, but need two copies of the recessive allele.

STRETCH AND SUPPORT

Support: give each figure's captions as a cut-up storyboard to put in order, and let students tap the dotted words as a glossary.

Support: a table of the four ABO phenotypes and their genotypes on the desk.

Stretch: a woman has blood group A and a child with blood group O. What can you say for certain about her genotype, and about the father's?

IN THE GUIDE

- 7 [Many alleles, not just two](#)
- 8 [Neither wins, or both do](#)
- 9 [X, Y and sex](#)
- A11 [The whole guide, with the figures that play](#)
- PPTX [This lesson's slides, in the order of this plan](#)

PRACTISE AND REVISE

BUILD FOR YOUR CLASS

- [Tarsia puzzle, dominoes and picture reveal](#) on D3.2, built from its key terms and ready to print
- A [pub quiz](#) with rounds on D3.2, to present or run with no projector
- An [escape room built from the question bank](#) on D3.2

ALREADY ON THE SITE FOR D3.2

- Lesson: [Linked Genes & Chi-Squared](#)
- Lesson: [Dihybrid Crosses & Test Crosses](#)
- Lesson: [Inheritance](#)
- Summary doodle: [Inheritance](#)
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- Quiz: [Inheritance](#)
- Revision map: [D3.2 Inheritance](#), to fill in
- Exam questions: [D3.2 in the exam maker](#), a paper with its markscheme

CARD SETS ON SPLYCR

Open a set to host it as a class game, or make a copy to edit.

- [D3.2 Inheritance](#)

EXAM PRACTICE

Check yourself

Set it for homework: a fresh paper of exam-bank questions on D3.2 at standard level each time, marked as students go and saved to their Exam practice when they are signed in.

biologybybradford.com/exam-maker/sit?topics=D3.2&level=SL&paper=quiz&marks=15&src=ep



Reading a family tree

60 minutes • D3.2.13 • Chapter 10

Using a pedigree chart to deduce whether a condition is dominant or recessive and autosomal or sex-linked, and reasoning from some cases to a general pattern

BY THE END, STUDENTS CAN

☐ Use pedigree charts to deduce patterns of inheritance of genetic disorders D3.2.13

TIMING

0-5	5 min	Do now: the symbols	
5-17	12 min	The rules of thumb	
17-25	8 min	Test your hunch	
25-45	20 min	Pedigree puzzles	
45-55	10 min	Why close relatives?	
55-60	5 min	Exit	
	60 min	One lesson	

STARTER

5 Do now: the symbols

min Draw squares, circles, shading and the lines for mating and children on the board for a made-up family of three generations. Students write what each symbol means, then the carrier status you can be sure of.

ON THE BOARD, FROM THE GUIDE

Open the guide on the projector at each chapter (the links work in this PDF). Every figure plays from its own buttons, and the lesson's slides have the same figures, step by step, in the order of this plan.

10 Reading a family tree

CHAPTER 10 IN THE SLIDES

Step through the figure (3 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. The key: **squares** are males, **circles** are females, filled symbols are affected. A line across joins a couple, and lines down lead to their children.
2. Two unaffected parents (generation I) have an affected daughter (generation II). The condition was **hidden** in both parents.
3. **Deducing** the genotypes: a recessive condition needs **nn** in the daughter and one **n** from each parent, so both parents are **Nn**.

Step through the figure (2 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. A condition no one in the family had heard of appears in a daughter. Her parents are first cousins. Squares are men, circles women; a filled symbol is **affected**. Roman numerals number the generations.
2. Look first at I-1, I-2 and II-4, ringed: they rule out at least one way of inheriting. Which patterns could give this tree, and which are **ruled out**?

Predict box: In a pedigree, two unaffected parents have an affected daughter. Which statement is correct? Hands up or mini whiteboards first.

Answer C: It is recessive and autosomal, so both parents carry it

Remember it: Quiet Loud Dad Boys (Unaffected parents, affected child, Affected parents, unaffected child, Affected daughter, unaffected father, Mostly sons, skipping generations).

THE LESSON

12

min

The rules of thumb

Chapter 10's figure and the Remember it tiles. Ask students to say each rule aloud as a sentence ("two parents without it have a child with it, so it is recessive").

8

min

Test your hunch

The pedigree tool in chapter 10, the first two families. Students choose a pattern, then see which are ruled out and why. Do not move on until each pair can say the reason.

20

min

Pedigree puzzles

The puzzles below in pairs, then the card sort of inductive and deductive steps. Walk round for the common slip: calling a recessive condition dominant because the family is large.

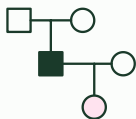
10

min

Why close relatives?

The genetic basis only: relatives are more likely to carry the same rare recessive allele, so a child of cousins has a higher chance of two copies. Return to the PKU cross. Keep the discussion on the genetics and treat the social reasons as outside the course.

ACTIVITIES



PUZZLE

Pedigree puzzles

Five invented pedigrees of increasing difficulty, each with a condition and a question: which patterns of inheritance are possible, and which can you rule out? Start with one where two unaffected parents have an affected child (recessive for certain, but autosomal or X-linked?), and finish with one that supports only one pattern. Students must give the line of reasoning in a sentence. Add a version with a deliberately ambiguous pedigree, and ask what extra information would settle it.

Needs: printed pedigrees, coloured pencils.

CARD SORT

Inductive or deductive?

Eight statements from a pedigree investigation, for pairs to sort. Inductive, from particular cases to a general rule: "Every affected child so far has unaffected parents, so the condition is probably recessive." Deductive, from the rule to a particular case: "The condition is recessive, so the unaffected mother of an affected child must be a carrier." Ask which kind is more certain and why a rule reached by induction is only a theory until tested.

Needs: printed cards, one set per pair.

PLENARY

5

min

Exit

The one pedigree rule that is most useful to you, and a pedigree on which it works. Collect.

WHAT STUDENTS GET WRONG

"A carrier shows the condition." A carrier of a recessive allele has the normal phenotype. Ask what a pedigree can and cannot tell you about the carriers.

"A big family with a condition means it is dominant." Check the rule of thumb about unaffected parents with an affected child first.

STRETCH AND SUPPORT

Support: a pedigree with the rules of thumb already ticked against it, to be copied for the next.

Stretch: why can a pedigree never prove that a condition is X-linked, though it can rule it out? Ask for an example.

IN THE GUIDE

- 10** [Reading a family tree](#)
- A11** [The whole guide, with the figures that play](#)
- PPTX** [This lesson's slides, in the order of this plan](#)

EXAM PRACTICE

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biologybybradford.com/exam-maker/sit?topics=D3.2&level=SL&paper=quiz&marks=15&src=ep



PRACTISE AND REVISE

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CARD SETS ON SPLYCR

Open a set to host it as a class game, or make a copy to edit.

- [D3.2 Inheritance](#)

A spread, not a few types

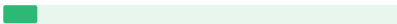
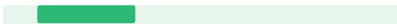
60 minutes • D3.2.14 and D3.2.15 • Chapters 11, 12

Continuous variation from polygenic inheritance and the environment, and drawing and reading box-and-whisker plots

BY THE END, STUDENTS CAN

- ☐ Explain continuous variation as the result of polygenic inheritance and the environment D3.2.14
- ☐ Draw and read box-and-whisker plots for a continuous variable such as student height D3.2.15

TIMING

0–5	5 min	Do now	
5–20	15 min	The six-coin model	
20–30	10 min	Discrete and continuous	
30–52	22 min	Box-and-whisker plots	
52–60	8 min	Exit and linking question	
60 min		One lesson	

STARTER

5
min

Do now

Where does your height fall, compared with the class? Students put a sticky note on an anonymous number line. Do they sit in two groups or form a hill? Why?

ON THE BOARD, FROM THE GUIDE

Open the guide on the projector at each chapter (the links work in this PDF). Every figure plays from its own buttons, and the lesson's slides have the same figures, step by step, in the order of this plan.

11 A spread, not a few types

CHAPTER 11 IN THE SLIDES

Step through the figure (3 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

- Discrete** variation: the bars are separate, because nobody is halfway between two blood groups.
- A simple model of a **polygenic** trait: six alleles, each lighter or darker. Combinations with three darker alleles are commonest, and the extremes are rare.
- Add the **environment** and the steps blur into a smooth, **continuous** spread.

Predict box: Which of these shows discrete variation? Hands up or mini whiteboards first.

Answer B: The blood groups of students in a class

12 Showing a spread with a box plot

CHAPTER 12 IN THE SLIDES

Step through the figure (4 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

- 25 student heights, one dot each (made up). Where is the middle, and how spread out are they?
- The box runs from **Q1** to **Q3** with the **median** marked. The whiskers run to the smallest and largest values that are not outliers.
- IQR** = $172 - 160 = 12$. The fences lie $1.5 \times \text{IQR}$ beyond the box, at 142 and 190.
- A value beyond a fence is an **outlier**: 194 is above 190, so it is plotted on its own.

Step through the figure (2 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. Heights of 25 students in one class (made-up data). Height varies **continuously**: each dot is one student, and the values spread out with most near the middle.
2. The **box** runs from Q_1 (160) to Q_3 (172) with the **median** (166) inside; the whiskers reach the furthest values within $1.5 \times IQR$ of the box (the dashed fences, 142 and 190). Beyond them, 194 is an **outlier**.

Predict box: In a box plot, what fraction of the data lie inside the box? Hands up or mini whiteboards first.

Answer B: One half

THE LESSON

15

min

The six-coin model

The activity below. Each student flips six coins to build a "genotype" for a polygenic trait and the class builds the bar chart of totals. Compare with one coin and the two groups it gives.

10

min

Discrete and continuous

Chapter 11's figure. Students sort the traits on the card: blood group, tongue rolling, height, skin colour, hand span, number of petals. Ask what skin colour needs, besides several genes, to give a smooth spread.

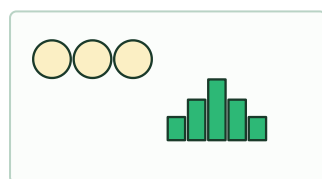
22

min

Box-and-whisker plots

Chapter 12's figure and the box plot tool. Then the hand span task below: collect anonymous measurements, find the median and quartiles, draw the plot by hand and check it with the tool. Ask which values are outliers and what the 1.5 times IQR rule says.

ACTIVITIES

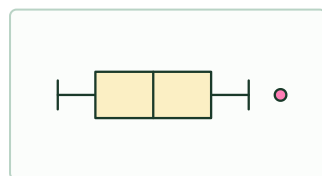


MODEL

The six-coin model

Each student has six coins, one for each of six genes. Heads is an allele that adds one unit of pigment, tails adds none. Flip all six, count the heads, and add a mark to the class bar chart (0 to 6). Then try again with one coin, and with the six coins plus a second round in which "sun" adds or removes one unit for a random half of the students. What shape does the chart have each time? Link to skin colour: many genes, each with a small effect, plus the environment.

Needs: six coins per student, a class tally chart.



DATA TASK

Hand spans and box plots

Students measure their hand span in centimetres and write the number on a slip, with no names. Pool the numbers on the board, then in groups find the median and the quartiles, work out the interquartile range, and set the fences at 1.5 times the range above Q_3 and below Q_1 . Draw the box-and-whisker plot by hand, mark any outlier, and check against the box plot tool. Ask what a plot tells you that a mean does not. Offer a second data set (an invented one of 25 heights) to test the rule on a clear outlier.

Needs: rulers, squared paper, a pooled table on the board.

PLENARY

8

min

Exit and linking question

What are the principles of effective sampling? Ask for two: a large enough sample, and one chosen so it represents the population. Then one sentence on why a class is a poor sample of all students.

WHAT STUDENTS GET WRONG

Continuous variation is only caused by the environment. Several genes, each with a small effect, give a smooth spread even before the environment adds to it.

Outliers should be deleted. A box plot marks them so the reader can see them. Remove one only if you can show it was a mistake.

STRETCH AND SUPPORT

Support: step-by-step boxes for finding the median and quartiles, with a worked example.

Stretch: how might you tell a hill-shaped spread caused by the environment from one caused by several genes? Think about family data.

IN THE GUIDE

- 11** [A spread, not a few types](#)
- 12** [Showing a spread with a box plot](#)
- A11** [The whole guide, with the figures that play](#)
- PPTX** [This lesson's slides, in the order of this plan](#)

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biologybybradford.com/exam-maker/sit?topics=D3.2&level=SL&paper=quiz&marks=15&src=ep



PRACTISE AND REVISE

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CARD SETS ON SPLYCR

Open a set to host it as a class game, or make a copy to edit.

- [D3.2 Inheritance](#)

Two genes at once HL

60 minutes • D3.2.16 and D3.2.17 • Chapter 13

Segregation and independent assortment of unlinked genes, and the Punnett grid for a dihybrid cross

BY THE END, STUDENTS CAN

- ☐ Explain segregation and independent assortment of unlinked genes in meiosis D3.2.16
- ☐ Use Punnett grids to predict genotypic and phenotypic ratios in dihybrid crosses of unlinked autosomal genes D3.2.17

TIMING

0-6	6 min	Do now	
6-18	12 min	Watch the line-up	
18-30	12 min	Gametes with two coins	
30-50	20 min	The grid	
50-60	10 min	Exam practice	
	60 min	One lesson	

STARTER

6
min

Do now

A pea plant is heterozygous for seed colour and seed shape. List every kind of gamete it could make. Students get 2 or 4; take a vote and keep it up.

ON THE BOARD, FROM THE GUIDE

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13 Two genes at once

CHAPTER 13 IN THE SLIDES

Step through the figure (5 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

- In meiosis I each pair of **homologous chromosomes** lines up at the equator, and the partners go to opposite poles.
- The pairs line up either way round, independently. Two equally likely ways give **four kinds of gamete**: YR, yr, Yr and yR.
- A YyRr × YyRr cross: put each parent's four kinds of gamete along the sides of a 4 × 4 grid.
- Fill in the **16 genotypes**, each equally likely.
- Read off the phenotypes: **9 : 3 : 3 : 1**.

Play the animation, Watch it happen: two genes line up independently. It loops; pause it on each moment below and ask what is happening (in the lesson slides it is a video).

1. One cell of an **YyRr** parent, its DNA already copied. Gene Y is on one pair of chromosomes and gene R on another: capitals from its mother (pink), lower case from its father (green).
2. Each chromosome pairs with its homologue, so the two alleles of each gene lie side by side.
3. The pairs line up. In this cell both pink chromosomes face the same end, so Y will go with R, and y with r.
4. **Segregation:** in meiosis I the alleles of each gene separate, Y from y and R from r.
5. Meiosis II separates the sister chromatids, which carry the same alleles.
6. This cell makes two kinds of gamete: YR and yr.
7. In another cell the pairs line up the other way round: now Y goes with r, and y with R.
8. That cell makes Yr and yR gametes.
9. Both line-ups are equally likely, so the four types are made in equal numbers, **1:1:1:1**. This is **independent assortment**.

Step through the figure (2 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

1. Each parent makes gametes by meiosis, one allele of each gene in each. The female parent's go down the side of the **Punnett grid**, the male parent's along the top.
2. Each cell joins one gamete from each parent: a possible offspring, every cell as likely as the next. The F₁: genotypes all YyRr; phenotypes all yellow round.

Predict box: A plant YyRr is crossed with a plant yyrr. What proportion of the offspring are yellow and round?
Hands up or mini whiteboards first.

Answer B: One quarter

THE LESSON

12

min

Watch the line-up

Chapter 13's meiosis film at higher level. Pause at the line-up and show both ways the pairs can face. Define segregation and independent assortment, and note the nature of science point: the second law holds only for unlinked genes.

12

min

Gametes with two coins

The activity below. Two coins make a gamete from a double heterozygote. Fill in the four gamete types and their frequencies, then the grid.

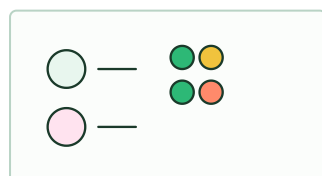
20

min

The grid

Chapter 13's figure and the cross builder in dihybrid mode. Students predict before the grid fills. Then the ratio sort below: match each cross to 9:3:3:1, 1:1:1:1 or all one type.

ACTIVITIES



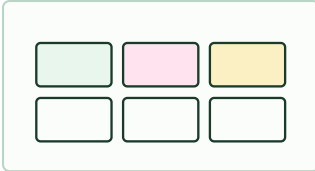
MODEL

Gametes with two coins

Each student plays a plant heterozygous for two genes, YyRr. One coin chooses Y or y, the other chooses R or r. Flip both, write the gamete, and make 40 gametes. Tally the four types on the board. Compare with the grid and with a plant of genotype YyRR. Then two students fuse a gamete each, ten times, to make F₂ plants, and the class counts the phenotypes. Is it close to 9:3:3:1?

Needs: two coins per student, a tally table.

CARD SORT



Sort the ratios

Eight cross cards and three ratio cards ($9:3:3:1$, $1:1:1:1$, one type only). Match each cross to its ratio without drawing a grid when you can: YyRr by YyRr, YyRr by yyrr, YYRR by yyrr, YyRr by YyRR and so on. Then draw grids for the two you were least sure of. Ask students to say why a test cross gives the ratio that it does, and what the F₂ of a cross between true-breeding parents looks like.

Needs: printed cards, one set per pair.

PLENARY

10

min

Exam practice

A dihybrid question from the exam maker (in Practise and revise, below). Students write gametes, grid and ratio in 8 minutes and peer-mark against the scheme.

WHAT STUDENTS GET WRONG

"Two genes always assort independently." Only genes on different chromosomes, or far apart on one, do.

STRETCH AND SUPPORT

Support: the four gametes of a double heterozygote written out for the first two examples.

Stretch: in an F₂ of $9:3:3:1$, count seed colour on its own and then seed shape on its own. What ratio does each gene give, and what does that tell you? *Each gives 3:1: the genes are sorted independently, so each still behaves as in a one-gene cross.*

IN THE GUIDE

13 [Two genes at once](#)

A11 [The whole guide, with the figures that play](#)

PPTX [This lesson's slides, in the order of this plan](#)

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CARD SETS ON SPLYCR

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- [D3.2 Inheritance](#)

Genes that travel together HL

60 minutes • D3.2.18 to D3.2.20 • Chapter 14

The loci of human genes, linkage on a chromosome, recombinants made by crossing over, and reading a test cross

BY THE END, STUDENTS CAN

- ☐ Find the loci of human genes and their polypeptide products in a database D3.2.18
- ☐ Explain autosomal gene linkage D3.2.19
- ☐ Identify recombinants in crosses involving two linked or unlinked genes D3.2.20

TIMING

0-6	6 min	Do now	
6-21	15 min	Where are the genes?	
21-33	12 min	Linkage and the vertical line	
33-50	17 min	Crossing over by hand	
50-60	10 min	Counting recombinants	
	60 min	One lesson	

STARTER

- 6 min** **Do now**
- A chromosome carries many genes. If two genes sit on the same chromosome, will they be passed on together? Students write a one-line prediction and a reason.

ON THE BOARD, FROM THE GUIDE

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14 Genes that travel together

CHAPTER 14 IN THE SLIDES

Step through the figure (4 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

- Unlinked** genes sit on different chromosome pairs, so all four kinds of gamete are equally likely.
- Linked** genes sit on the same chromosome. With no crossing over, only the two **parental** gametes, AB and ab, are made.
- Crossing over** between the genes swaps the ends of two chromatids and makes the **recombinant** gametes Ab and aB. The other two chromatids are unchanged, so recombinants are few.
- A **test cross** ($AaBb \times aabb$) shows it: mostly parental types and a few recombinants. Recombinant frequency = $30 \div 200 = 15\%$.

Predict box: A test cross $AaBb \times aabb$ gives 48 AB, 47 ab, 3 Ab and 2 aB. What does this suggest? Hands up or mini whiteboards first.

Answer C: The genes are linked, and crossovers are rare between them

THE LESSON

15

min

Where are the genes?

The gene database task below. Students look up two genes from the card, write each locus and polypeptide, and say whether the pair could assort independently.

12

min

Linkage and the vertical line

Chapter 14's figure. Students rewrite one genotype with the vertical line notation and name which alleles travel together. Then the predict box on the test cross.

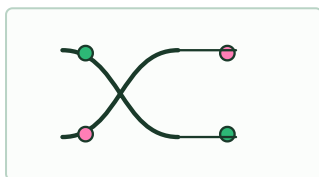
17

min

Crossing over by hand

The pipe-cleaner model below. Pairs cross over once between two loci, read off the gametes and say which are recombinants. Repeat with the loci close together, then far apart.

ACTIVITIES

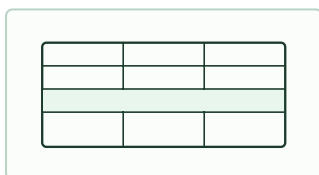


MODEL

Crossing over with pipe cleaners

Pairs take two pipe cleaners (green and pink) with two beads on each, one near each end, to stand for the alleles of two genes. Twist the two cleaners together at one point and cut at the twist, then swap the cut ends. Read off the two new chromosomes. Which combinations are parental and which are recombinant? Do it once with the twist between the beads, once with it outside them. Repeat with beads close together and far apart, and tally how often the twist falls between them.

Needs: pipe cleaners in two colours, beads, scissors.



DATA TASK

Gene loci database

Students open a human gene database that your school can reach (the NCBI Gene and Ensembl databases are two) and look up the genes for the haemoglobin subunits. For each, record the chromosome, the position and the polypeptide it codes for. The beta globin gene (HBB) and the alpha globin genes (HBA1 and HBA2) are on different chromosomes, and a related gene (HBD) lies next to HBB. Ask which pairs could assort independently and which would be linked. If you cannot use the database, give the table from the card and ask the same questions.

Needs: devices with internet access, a recording sheet.

PLENARY

10

min

Counting recombinants

A test cross gave 86, 84, 16 and 14 offspring in the four classes. Students pick out the recombinants and give the recombinant percentage (15 percent). Discuss what a result near 50 percent would mean.

WHAT STUDENTS GET WRONG

Recombinants are mutants. A recombinant has a new combination of existing alleles, made by crossing over, not a new allele.

STRETCH AND SUPPORT

Support: a pre-drawn chromosome pair with the loci marked, to colour in when crossing over.

Stretch: in the test cross above, what would the four classes look like if the recombinants were half of all the offspring? *Close to 1:1:1:1, as if the genes were unlinked.*

IN THE GUIDE

- 14** [Genes that travel together](#)
- A11** [The whole guide, with the figures that play](#)
- PPTX** [This lesson's slides, in the order of this plan](#)

PRACTISE AND REVISE

BUILD FOR YOUR CLASS

- [Tarsia puzzle, dominoes and picture reveal](#) on D3.2, built from its key terms and ready to print
- A [pub quiz](#) with rounds on D3.2, to present or run with no projector
- An [escape room built from the question bank](#) on D3.2

ALREADY ON THE SITE FOR D3.2

- Lesson: [Linked Genes & Chi-Squared](#)
- Lesson: [Dihybrid Crosses & Test Crosses](#)
- Lesson: [Inheritance](#)
- Summary doodle: [Inheritance](#)
- Quiz: [Inheritance \(HL\)](#)
- Quiz: [Inheritance](#)
- Revision map: [D3.2 Inheritance](#), to fill in
- Exam questions: [D3.2 in the exam maker](#), a paper with its markscheme

CARD SETS ON SPLYCR

- Open a set to host it as a class game, or make a copy to edit.
- [D3.2 Inheritance](#)

EXAM PRACTICE

Check yourself

Set it for homework: a fresh paper of exam-bank questions on D3.2 at higher level each time, marked as students go and saved to their Exam practice when they are signed in.

biologybybradford.com/exam-maker/sit?topics=D3.2&level=HL&paper=quiz&marks=15&src=ep



Is it chance? Chi-squared and the dry lab HL

60 minutes • D3.2.21 • Chapter 15 • The dry lab

Using the chi-squared test to decide whether a dihybrid cross matches the expected ratio, and applying it in a simulated experiment

BY THE END, STUDENTS CAN

☐ Use a chi-squared test on data from a dihybrid cross D3.2.21

TIMING

0-5	5 min	Do now	
5-17	12 min	The five steps	
17-32	15 min	The bead bag	
32-55	23 min	The dry lab	
55-60	5 min	Plenary: the decision	
	60 min	One lesson	

STARTER

5 min **Do now**

Flip a coin 10 times. Heads and tails 5 and 5 is expected. What if you get 7 and 3? 9 and 1? Write where you would start to doubt the coin.

ON THE BOARD, FROM THE GUIDE

Open the guide on the projector at each chapter (the links work in this PDF). Every figure plays from its own buttons, and the lesson's slides have the same figures, step by step, in the order of this plan.

15 Is it chance? The chi-squared test

CHAPTER 15 IN THE SLIDES

Step through the figure (4 steps, the arrow keys on a projector). Stop on each caption and ask what changed before you go on.

- 160 F2 plants: the **expected** counts from 9 : 3 : 3 : 1 (90, 30, 30 and 10) against **observed** counts (made up).
- χ^2 is the sum of $(O - E)^2 \div E$ over the four classes: **2.13**.
- With 3 degrees of freedom and $p = 0.05$ the **critical value** is 7.81. 2.13 is below it, so you do not reject the null hypothesis: chance can explain the difference.
- A test cross of linked genes (made-up counts 112, 21, 18 and 109 from 260 offspring) gives $\chi^2 = \mathbf{127.5}$, far past 7.81. Reject the null: the genes are probably linked.

Predict box: A chi-squared value of 2.1 with 3 degrees of freedom is compared with a critical value of 7.81. What do you conclude? Hands up or mini whiteboards first.

Answer B: Do not reject the null: chance could explain it

Remember it: Hungry Elves Cook Delicious Cakes (Hypotheses, Expected, Calculate, Degrees of freedom, Compare).

THE LESSON

12

min

The five steps

Chapter 15's figure and the Remember it tiles. Work the worked example together: say the null and alternative hypotheses, find the expected numbers, total $(O - E)^2 \div E$, find the degrees of freedom and compare with the critical value.

15

min

The bead bag

The activity below. Each group samples from a bag of beads in a 9 : 3 : 3 : 1 ratio and tests its sample. How many groups reject the null hypothesis, and what should that number be?

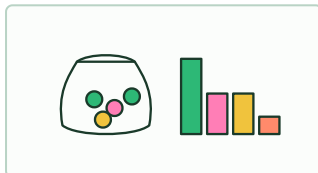
23

min

The dry lab

The dry lab, in pairs. Students choose unlinked or linked genes, make a test cross and test the brood against 1 : 1 : 1 : 1. Then the mystery: breed as many broods as needed and give a verdict. The coach under the bench covers repeats and evaluation.

ACTIVITIES



MODEL

The bead bag

Each group has a bag with 9 parts green round, 3 green wrinkled, 3 yellow round and 1 yellow wrinkled (for example 90, 30, 30 and 10 beads, or a proportion of it). Draw 80 beads with replacement, shaking between draws, tally the four colours, and work out chi-squared against the 9 : 3 : 3 : 1 expectation. Compare it with the critical value for 3 degrees of freedom. Pool the class results on the board: about 1 group in 20 should reject the null hypothesis even though the bag is right. Ask what this tells you about what a rejection means.

Needs: bags of four colours of beads, a calculator, the critical value table.

DRY LAB

Fly crosses: linked or not?

The dry lab above, with the tasks and questions under it. It works on a phone as well as a laptop, and the results download as a CSV for pooling. The genes are invented and the fly is made up, so say so in the debrief. The coach under the bench takes students through variables, repeats and evaluation.

Needs: one device per pair.

PLENARY

5

min

Plenary: the decision

Each pair states one decision in a full sentence: "The value of ... is ... than the critical value, so we ... the null hypothesis, so ...". Take two and correct the wording together.

WHAT STUDENTS GET WRONG

"Not rejecting the null hypothesis proves it." It means the data are consistent with chance, not that the genes are unlinked.

"Any difference under 5 percent is chance." The 0.05 probability level is not a percentage difference in the counts. It is the chance of a value this large if the null hypothesis is true.

STRETCH AND SUPPORT

Support: a table with the observed, expected, difference, squared and divided columns ready to fill in.

Stretch: why does a very large brood make it easier to reject the null hypothesis, even for a tiny departure from the ratio?

IN THE GUIDE

- 15** [Is it chance? The chi-squared test](#)
- Lab** [Dry lab: Fly crosses: linked or not?](#)
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How this was made. The course structure, the activities and the teaching choices come from my own classroom, my presentations and my years of teaching IB and AP Biology. I use Claude, an AI, to help write and build the interactive guides, lesson plans, slides and practice questions, and to draw the diagrams and code the interactives. I direct the work and review it against the IB and AP specifications before it goes live.