Genetic inheritance

4.6.1.6 · Inheritance, variation and evolution · revision notes

The language of genetics and how to use Punnett squares and family trees to predict the outcome of a single-gene cross. It comes up on almost every paper: definitions, Punnett squares, and probability or ratio questions.

Key facts

- Allele = a different form of a gene
- Homozygous = two alleles the same (BB, bb). Heterozygous = two different alleles (Bb)
- Bb × Bb → 1 BB : 2 Bb : 1 bb → 3 : 1 dominant : recessive phenotype
- BB × anything → all offspring show the dominant phenotype
- Dominant: expressed with one copy. Recessive: expressed only with two copies
- Genotype = alleles present. Phenotype = characteristic expressed
- Bb × bb → 1 Bb : 1 bb
- One box out of four = probability 0.25 = 25% = ¼ = 1 in 4

Notes

Key words

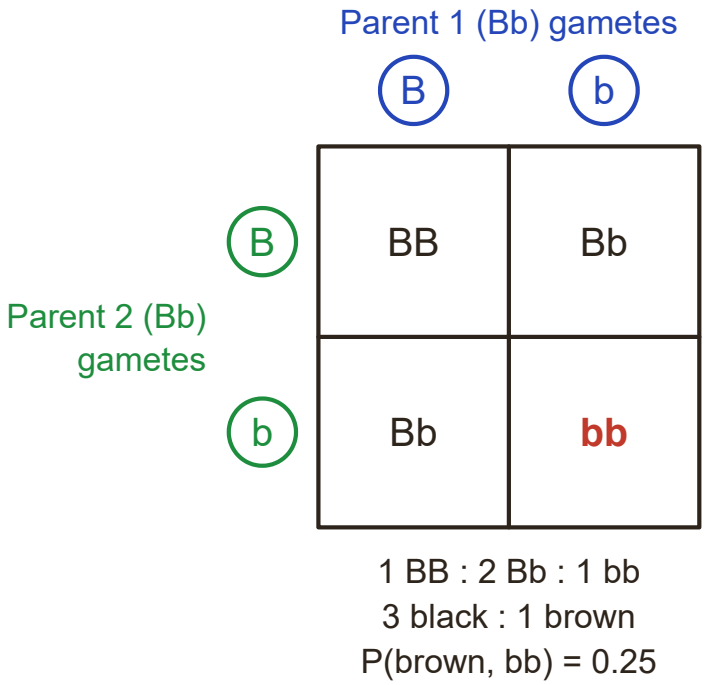
- **Gamete**: a sex cell (e.g. sperm or egg) with a single set of chromosomes.
- **Chromosome**: a structure in the nucleus that contains DNA. **Gene**: a small section of DNA on a chromosome.
- **Allele**: a different form of the same gene.
- **Dominant** allele: always expressed, even if only one copy is present (written as a capital letter, e.g. B).
- **Recessive** allele: only expressed if two copies are present, so there is no dominant allele (lower case, e.g. b).
- **Homozygous**: the two alleles are the same (BB or bb). **Heterozygous**: the two alleles are different (Bb).
- **Genotype**: the alleles present (e.g. Bb). **Phenotype**: the characteristic that is expressed (e.g. black fur).

Single genes and many genes

- Some characteristics are controlled by a **single gene**, e.g. fur colour in mice and red-green colour blindness in humans.
- The alleles present (genotype) work at a molecular level to develop the characteristics that are expressed (phenotype).
- **Most characteristics** are the result of **multiple genes** interacting, not a single gene.

Punnett squares

- Split each parent's genotype into its gametes: Bb makes B gametes and b gametes.
- Put one parent's gametes across the top and the other's down the side, then fill each box with one allele from each parent.
- Each box is an equally likely outcome, so each of the four boxes has a probability of 0.25.
- Bb × Bb gives BB : Bb : bb in the ratio 1 : 2 : 1, so the dominant : recessive phenotype ratio is 3 : 1.

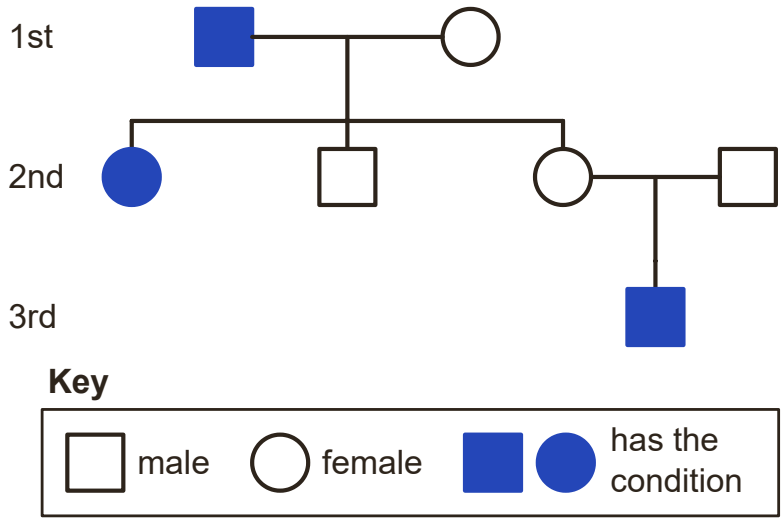


Bb × Bb: each box has a probability of 0.25.

- Bb × bb gives Bb : bb in the ratio 1 : 1.
- The probability is the same for every offspring, because each fertilisation is a separate random event. Real families are small, so actual numbers often differ from the predicted ratio. Grade 7+ only

Family trees

- Squares usually show males and circles females; shaded symbols show the characteristic. Always read the key.



Reading a family tree: a line between two people joins parents; the line below leads to their children.

- If two parents without a characteristic have a child with it, the allele is recessive and both parents must be heterozygous. Grade 7+ only

How to answer each type of question

Use the genetic terms 1 to 3 marks **Grade 4**

1. Learn precise definitions, especially dominant, recessive, homozygous and heterozygous.
2. If asked for a genotype, give letters; if asked for a phenotype, describe the characteristic in words.

Example. In mice, the allele for black fur (B) is dominant to the allele for brown fur (b).
(a) Give the genotype of a mouse that is homozygous recessive.
(b) Give the phenotype of a mouse with the genotype Bb.
(c) What does heterozygous mean? [3 marks]

Model answer.

(a) bb (1)
(b) Black fur (1)
(c) Having two different alleles of a gene (1)

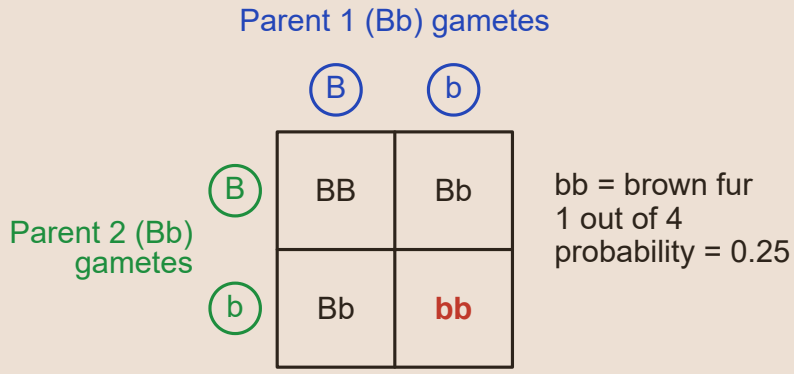
Complete a Punnett square and give a probability

2 to 3 marks | **Grade 5**

1. Write the gametes of each parent on the outside.
2. Fill in each box with one allele from each parent.
3. Count the boxes that give the phenotype asked for, out of 4.
4. Give the answer in the form asked: fraction, decimal, percentage or ratio.

Example. Two heterozygous black-furred mice (Bb) are crossed.
Use a Punnett square to find the probability that an offspring will have brown fur. [3 marks]

Model answer.



Gametes B and b from each parent (1). Offspring BB, Bb, Bb, bb (1). Brown fur = bb = 1 out of 4, so the probability is 0.25 (1).

Construct a genetic cross from the information given

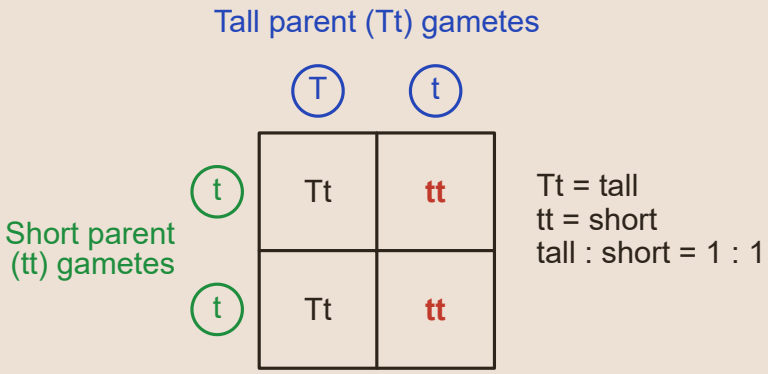
3 to 4 marks | **Grade 7**

1. Work out each parent's genotype (the offspring can give clues).
2. Write the gametes.
3. Draw the Punnett square.
4. Link the genotypes to phenotypes and give the ratio or probability.

Example. In pea plants, the allele for tall stems (T) is dominant to the allele for short stems (t). A tall plant is crossed with a short plant. Some of the offspring are short.
Construct a Punnett square to show this cross, and give the expected ratio of tall to short offspring. [4 marks]

Model answer.

The tall parent must be Tt, because some offspring are short (tt) so it must have passed on a t allele (1). The short parent is tt; gametes are T and t, and t and t (1).



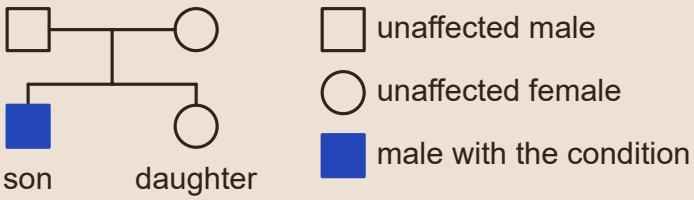
Offspring: Tt, Tt, tt, tt (1). Ratio tall : short = 1 : 1 (1).

Interpret a family tree

2 to 3 marks | **Grade 8**

1. Read the key.
2. Look for two parents without the characteristic who have a child with it: this shows the allele is recessive.
3. Give genotypes: an affected person is homozygous recessive; their unaffected parents are heterozygous.

Example. In a family, neither parent has a particular condition. Their son has the condition, as shown in the family tree.



Explain whether the condition is caused by a dominant allele or a recessive allele. [2 marks]

Model answer. A recessive allele (1). The parents do not have the condition but passed the allele to their son, so each parent must be heterozygous, with the recessive allele hidden by the dominant allele / if the allele were dominant, at least one parent would have the condition (1).

Don’t lose marks

- Turning a 3 : 1 ratio into a probability of ⅓. The recessive phenotype is 1 out of 4 (0.25).
- Writing 1 : 4 or '1 in 3' when asked for a probability. One box out of four is 0.25, 25%, ¼ or 1 in 4.
- Choosing letters that look alike in upper and lower case (such as S and s) and not making them clearly different.
- Saying a dominant allele is 'stronger' or 'more common'. It is simply expressed when only one copy is present.
- Thinking that if a couple's first child has a recessive condition, the next child cannot. The probability is the same for every child.

More tips

Memory tricks

- Homo = same: homozygous means the same alleles. Hetero = different.
- GenoType = the leTTers; PHenotype = the PHysical characteristic.
- Learn the two key crosses: Bb × Bb gives 3 : 1, and Bb × bb gives 1 : 1.
- Check your Punnett square: every box has exactly two letters, one from each parent.

Exam technique

- Show the gametes and the Punnett square even when the question doesn't insist; they often carry marks.
- Give a probability in the form asked. 0.25, 25%, ¼ and '1 in 4' are usually all accepted, but 1 : 4 and '1 in 3' always lose the mark.
- Use the letters given in the question. If you choose your own, give a key.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Define dominant and recessive alleles**
A dominant allele is expressed even with one copy; a recessive allele is expressed only with two copies.

Grade 4 — **Use genotype, phenotype, homozygous and heterozygous correctly**
Genotype is the alleles present, phenotype is the characteristic; homozygous means the same alleles, heterozygous different.

Grade 5 — **Complete a Punnett square**
Put each parent's gametes on the outside and combine one allele from each in every box.

Grade 5 — **Give cross outcomes as ratios or probabilities**
For example 3 : 1, or a probability of 0.25, 25%, ¼ or 1 in 4.

Grade 6 — **Extract information from family trees**
Use the key and the phenotypes of parents and children to work out genotypes.

Grade 7 — **Construct a genetic cross to make predictions**
From the information given, work out the genotypes and gametes, draw the Punnett square and give probabilities.

Grade 8 — **Deduce genotypes from family tree evidence**
For example, two unaffected parents with an affected child must both be heterozygous.

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