

Probability in Genetic Crosses

Key rules

Product rule (AND): $P(A \text{ and } B) = P(A) \times P(B)$ · **Sum rule (OR):** $P(A \text{ or } B) = P(A) + P(B)$ when they can't both happen ·

Complement: $P(\text{at least one}) = 1 - P(\text{none})$

From Aa × Aa: $P(AA) = 1/4$, $P(Aa) = 1/2$, $P(aa) = 1/4$, $P(A_) = 3/4$ · **From Aa × aa:** $P(Aa) = 1/2$, $P(aa) = 1/2$

Chi-square: $\chi^2 = \sum (O - E)^2 \div E$. If χ^2 is less than the critical value, the difference is due to chance. Give answers as fractions.

A Probability basics

3 marks

1. An Aa parent makes gametes. What is the probability that a gamete carries the a allele?

2. What is the probability that a baby is a boy?

3. Two coins are tossed. What is the probability of two heads? (Two Aa parents each passing on a works the same way.)

B The product rule (AND)

4 marks

4. Aa × Aa: what is the probability of an aa offspring?

5. AaBb × AaBb: what is the probability of an AABB offspring?

6. AaBbCc × AaBbCc: what is the probability of an aabbcc offspring?

7. AaBb × aabb: what is the probability of an Aabb offspring?

C The sum rule (OR)

3 marks

8. Aa × Aa: what is the probability of a heterozygous offspring?

9. Aa × Aa: what is the probability of an offspring with the dominant phenotype?

10. AaBb × AaBb: what is the probability that an offspring shows *exactly one* recessive trait?

D Crosses without a Punnett square

4 marks

Treat each gene as its own cross, then combine.

11. AaBbCc × AaBbCc: what is the probability of an offspring with all three dominant traits (A_B_C_)?

12. AaBbCc × aaBbcc: what is the probability of an aaB_cc offspring?

13. AaBbCcDd × AaBbCcDd: what is the probability of an AABBCCDD offspring?

14. How many different kinds of gametes can an AaBbCc individual make?

E Probability in families

4 marks

15. Cystic fibrosis is recessive. Two carrier parents (Ff × Ff) plan to have children. What is the probability that their first two children both have cystic fibrosis?

16. What is the probability that all three of their children are unaffected?

17. What is the probability that *at least one* of three children has cystic fibrosis?

18. What is the probability that *exactly one* of three children has cystic fibrosis?

F Challenge: chi-square test

4 marks

A student crosses two RrYy pea plants and counts 160 offspring. Do the results fit the expected 9 : 3 : 3 : 1 ratio?

Phenotype	Observed (O)	Expected (E)	(O - E) ² ÷ E	
Round yellow	95			
Round green	28			
Wrinkled yellow	27			
Wrinkled green	10			
Total $\chi^2 =$				
Degrees of freedom	1	2	3	4
Critical value (p = 0.05)	3.84	5.99	7.81	9.49

19. Calculate the expected number of offspring in each group and record it in the table.

20. Complete the $(O - E)^2 \div E$ column.

21. Calculate χ^2 (the sum of the last column).

22. There are 3 degrees of freedom. Do the results support a 9 : 3 : 3 : 1 ratio? Explain.

G Spot the mistake

2 marks

23. A student says: "A carrier couple has three children without albinism, so their fourth child is certain to have it." Explain the error and correct it.

24. A student calculates $P(A_B_)$ for $AaBb \times AaBb$ as $3/4 + 3/4$. Explain the error and correct it.

Probability in Genetic Crosses**ANSWER KEY****Key rules****Product rule (AND):** $P(A \text{ and } B) = P(A) \times P(B)$ · **Sum rule (OR):** $P(A \text{ or } B) = P(A) + P(B)$ when they can't both happen ·**Complement:** $P(\text{at least one}) = 1 - P(\text{none})$ **From Aa × Aa:** $P(AA) = 1/4$, $P(Aa) = 1/2$, $P(aa) = 1/4$, $P(A_) = 3/4$ · **From Aa × aa:** $P(Aa) = 1/2$, $P(aa) = 1/2$ **Chi-square:** $\chi^2 = \sum (O - E)^2 \div E$. If χ^2 is less than the critical value, the difference is due to chance. Give answers as fractions.**A Probability basics****3 marks**

- 1.**
- An Aa parent makes gametes. What is the probability that a gamete carries the a allele?

Each gamete gets one allele: $P(a) = 1/2$ (50%)

- 2.**
- What is the probability that a baby is a boy?

The father's sperm carries X or Y: $P(\text{boy}) = 1/2$ (50%)

- 3.**
- Two coins are tossed. What is the probability of two heads? (Two Aa parents each passing on a works the same way.)

 $1/2 \times 1/2 = 1/4$ (25%)**B The product rule (AND)****4 marks**

- 4.**
- Aa × Aa: what is the probability of an aa offspring?

 $1/2 \times 1/2 = 1/4$ (25%)

- 5.**
- AaBb × AaBb: what is the probability of an AABB offspring?

 $P(AA) \times P(BB) = 1/4 \times 1/4 = 1/16$ (6.25%)

- 6.**
- AaBbCc × AaBbCc: what is the probability of an aabbcc offspring?

 $1/4 \times 1/4 \times 1/4 = 1/64$ (1.56%)

- 7.**
- AaBb × aabb: what is the probability of an Aabb offspring?

 $P(Aa) \times P(bb) = 1/2 \times 1/2 = 1/4$ (25%)**C The sum rule (OR)****3 marks**

- 8.**
- Aa × Aa: what is the probability of a heterozygous offspring?

Aa can form two ways (A from mother, a from father or the reverse): $1/4 + 1/4 = 1/2$ (50%)

- 9.**
- Aa × Aa: what is the probability of an offspring with the dominant phenotype?

 $P(AA) + P(Aa) = 1/4 + 1/2 = 3/4$ (75%)

- 10.**
- AaBb × AaBb: what is the probability that an offspring shows
- exactly one*
- recessive trait?

 $P(A_bb) + P(aaB_) = 3/16 + 3/16 = 3/8$ (37.5%)

D Crosses without a Punnett square

4 marks

Treat each gene as its own cross, then combine.

11. AaBbCc × AaBbCc: what is the probability of an offspring with all three dominant traits (A_B_C_)?
 $3/4 \times 3/4 \times 3/4 = 27/64$ (42.19%)
12. AaBbCc × aaBbcc: what is the probability of an aaB_cc offspring?
 $P(aa) \times P(B_) \times P(cc) = 1/2 \times 3/4 \times 1/2 = 3/16$ (18.75%)
13. AaBbCcDd × AaBbCcDd: what is the probability of an AABBCCDD offspring?
 $(1/4)^4 = 1/256$ (0.39%)
14. How many different kinds of gametes can an AaBbCc individual make?
 $2^3 = 8$ kinds

E Probability in families

4 marks

15. Cystic fibrosis is recessive. Two carrier parents (Ff × Ff) plan to have children. What is the probability that their first two children both have cystic fibrosis?
 $1/4 \times 1/4 = 1/16$ (6.25%)
16. What is the probability that all three of their children are unaffected?
 $3/4 \times 3/4 \times 3/4 = 27/64$ (42.19%)
17. What is the probability that *at least one* of three children has cystic fibrosis?
Use the complement: $1 - 27/64 = 37/64$ (57.81%)
18. What is the probability that *exactly one* of three children has cystic fibrosis?
The affected child could be 1st, 2nd or 3rd: $3 \times (1/4 \times 3/4 \times 3/4) = 27/64$ (42.19%)

F Challenge: chi-square test

4 marks

A student crosses two RrYy pea plants and counts 160 offspring. Do the results fit the expected 9 : 3 : 3 : 1 ratio?

Phenotype	Observed (O)	Expected (E)	(O - E) ² ÷ E
Round yellow	95	90	0.28
Round green	28	30	0.13
Wrinkled yellow	27	30	0.30
Wrinkled green	10	10	0.00
Total $\chi^2 =$			0.71

Degrees of freedom	1	2	3	4
Critical value (p = 0.05)	3.84	5.99	7.81	9.49

19. Calculate the expected number of offspring in each group and record it in the table.
90, 30, 30 and 10 ($160 \times 9/16, 3/16, 3/16, 1/16$)
20. Complete the (O - E)² ÷ E column.
0.28, 0.13, 0.30, 0.00
21. Calculate χ^2 (the sum of the last column).
 $\chi^2 = 0.71$
22. There are 3 degrees of freedom. Do the results support a 9 : 3 : 3 : 1 ratio? Explain.
Yes. 0.71 is less than the critical value 7.81, so the differences are due to chance and the 9 : 3 : 3 : 1 hypothesis is accepted.

G Spot the mistake

2 marks

23. A student says: "A carrier couple has three children without albinism, so their fourth child is certain to have it." Explain the error and correct it.

Each child is an independent event. The fourth child still has a 1/4 chance of albinism.

24. A student calculates $P(A_B_)$ for $AaBb \times AaBb$ as $3/4 + 3/4$. Explain the error and correct it.

"A and B" needs the product rule: $3/4 \times 3/4 = 9/16$. (Adding gives 1.5, which is impossible.)