Punnett Squares: Incomplete Dominance and Co-dominance

1. If the following genotypes are for traits that exhibit incomplete dominance, state whether the individuals with each genotype will have the dominant, intermediate or recessive phenotype.

    (a) GG <u>dominant</u>   **(b)** nn <u>recessive</u>   **(c)** Mm <u>intermediate</u>

2. In Andalusian chickens, the allele for black feathers (B) exhibits incomplete dominance over the allele for white feathers (b), with heterozygotes having blue-grey feathers.

    Write the genotypes for the following phenotypes.

    (a) black chickens   <u>BB</u>

    (b) blue-grey chickens <u>Bb</u>

    (c) white chickens   <u>bb</u>

3. In mice, the allele for yellow fur (Y) exhibits incomplete dominance over the allele for white fur (y), with heterozygotes having cream fur.

    Write the phenotype for mice with the following genotypes.

    (a) YY <u>yellow fur</u>

    (b) Yy <u>cream fur</u>

    (c) yy <u>white fur</u>

4. In cows, the alleles for red coat (R) and white coat (W) are co-dominant, with heterozygotes having a red and white coat, known as the red roan phenotype.

    Write the genotypes for the following phenotypes.

    (a) pure red cows   <u>RR</u>

    (b) red roan cows   <u>RW</u>
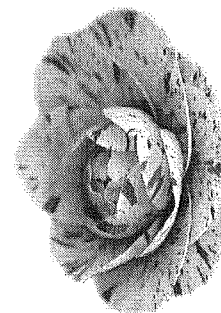
    (c) white cows   <u>WW</u>

5. In some varieties of camellia, the alleles for red flowers (R) and white flowers (W) are co-dominant, with heterozygotes having red and white flowers.

    Write the phenotype for camellias with the following genotypes.

    (a) RR <u>red flowers</u>

    (b) RW <u>red and white flowers</u>

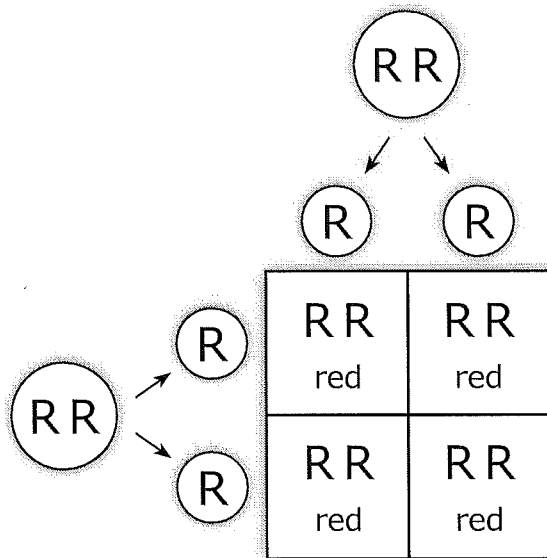   **(c)** WW <u>white flowers</u>

Punnett Squares: Incomplete Dominance and Co-dominance

In snapdragons, the allele for red flowers (R) exhibits incomplete dominance over the allele for white flowers (r), with heterozygotes having pink flowers.

Use this information to answer questions 6-11.

6. **(a)** Complete the Punnett square to show a cross between two red plants.

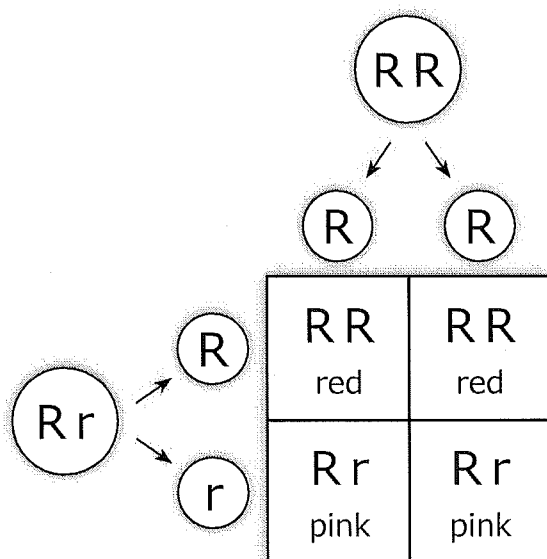Include the genotypes and phenotypes of offspring.

R R	R R
red	red
R R	R R
red	red

(b) What is the probability of offspring with:

(i) red flowers?

_4_ in _4_ or _100_ %

(ii) pink flowers?

_0_ in _4_ or _0_ %

(iii) white flowers?

_0_ in _4_ or _0_ %

7. **(a)** Complete the Punnett square to show a cross between a red plant and a pink plant.

Include the genotypes and phenotypes of offspring.

R R	R R
red	red
R r	R r
pink	pink

(b) What is the probability of offspring with:

(i) red flowers?

_2_ in _4_ or _50_ %

(ii) pink flowers?

_2_ in _4_ or _50_ %

(iii) white flowers?

_0_ in _4_ or _0_ %

Punnett Squares: Incomplete Dominance and Co-dominance

8. **(a)** Complete the Punnett square to show a cross between a red plant and a white plant.

Include the genotypes and phenotypes of offspring.

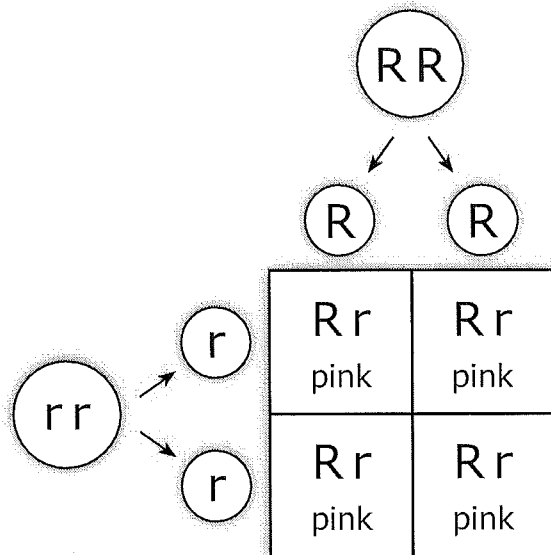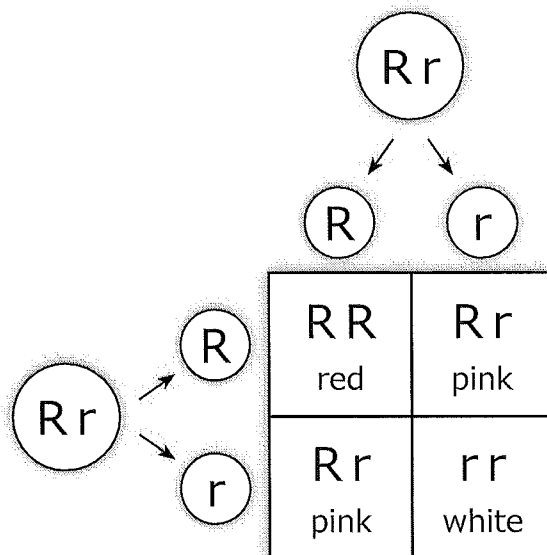|	R	R
r	R r pink	R r pink
r	R r pink	R r pink

Parents: RR × rr

(b) What is the probability of offspring with:

(i) red flowers?
0 in 4 or 0 %

(ii) pink flowers?
4 in 4 or 100 %

(iii) white flowers?
0 in 4 or 0 %

9. **(a)** Complete the Punnett square to show a cross between two pink plants.

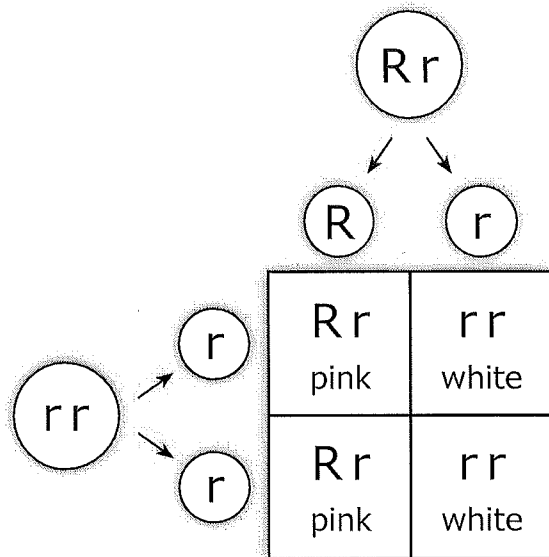Include the genotypes and phenotypes of offspring.

	R	r
R	R R red	R r pink
r	R r pink	r r white

Parents: Rr × Rr

(b) What is the probability of offspring with:

(i) red flowers?
1 in 4 or 25 %

(ii) pink flowers?
2 in 4 or 50 %

(iii) white flowers?
1 in 4 or 25 %

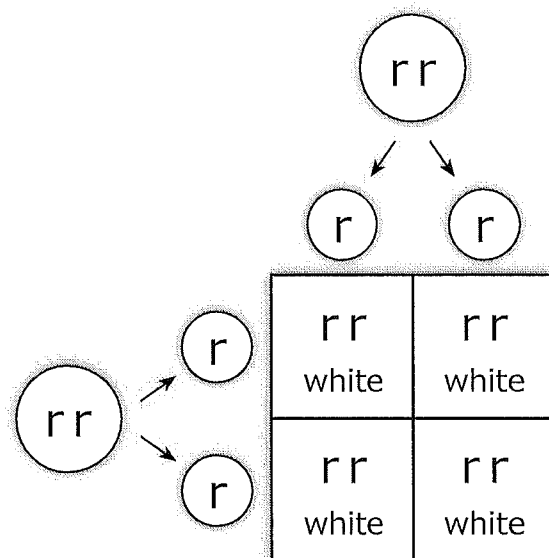# Punnett Squares: Incomplete Dominance and Co-dominance

10. **(a)** Complete the Punnett square to show a cross between a pink plant and a white plant.

Include the genotypes and phenotypes of offspring.

	R	r
r	R r pink	r r white
r	R r pink	r r white

Parent: R r → R, r

Parent: r r → r, r

(b) What is the probability of offspring with:

(i) red flowers?

   0 in 4 or 0 %

(ii) pink flowers?

   2 in 4 or 50 %

(iii) white flowers?

   2 in 4 or 50 %

11. **(a)** Complete the Punnett square to show a cross between two white plants.

Include the genotypes and phenotypes of offspring.

	r	r
r	r r white	r r white
r	r r white	r r white

Parent: r r → r, r

Parent: r r → r, r

(b) What is the probability of offspring with:

(i) red flowers?

   0 in 4 or 0 %

(ii) pink flowers?

   0 in 4 or 0 %

**(iii)** white flowers?

   4 in 4 or 100 %

Punnett Squares: Incomplete Dominance and Co-dominance

In horses, the alleles for black coat (B) and white coat (W) are co-dominant, with heterozygotes having a black and white coat, known as the blue roan phenotype.

Use this information to answer questions 12-17.

12. **(a)** Complete the Punnett square to show a cross between two black horses.
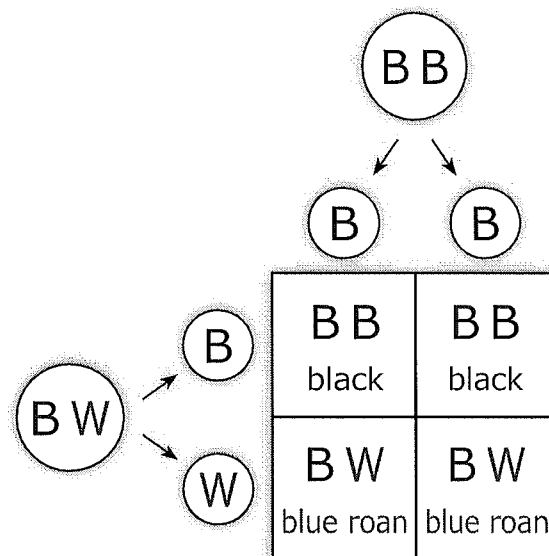
Include the genotypes and phenotypes of offspring.
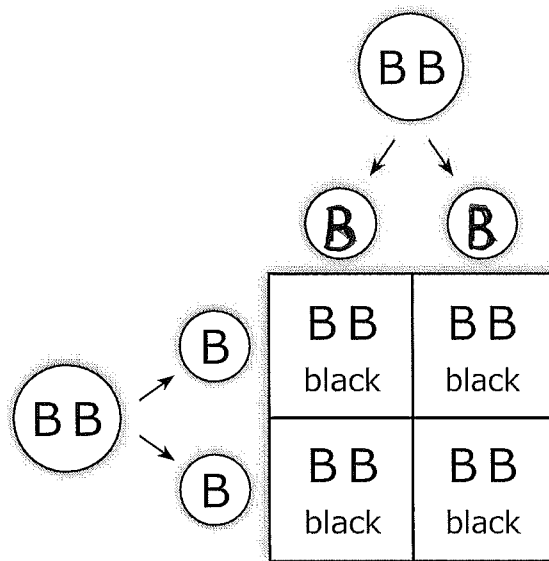
(b) What is the probability of offspring with:

(i) black coat?
_4_ in _4_ or _100_ %

(ii) blue roan coat?
_0_ in _4_ or _0_ %

(iii) white coat?
_0_ in _4_ or _0_ %

13. **(a)** Complete the Punnett square to show a cross between a black horse and a blue roan horse.
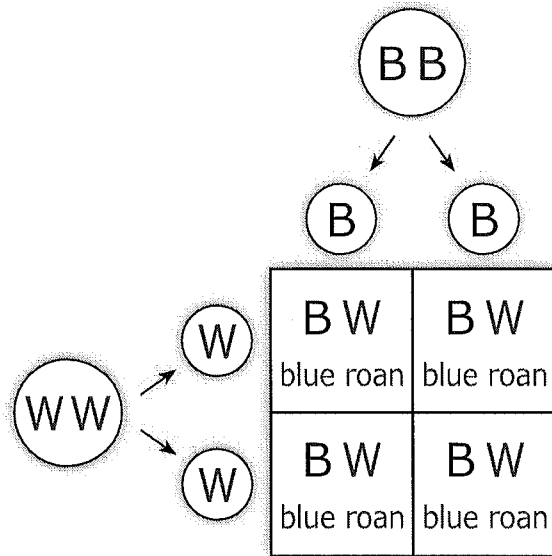
Include the genotypes and phenotypes of offspring.

(b) What is the probability of offspring with:

(i) black coat?
_2_ in _4_ or _50_ %

(ii) blue roan coat?
_2_ in _4_ or _50_ %

(iii) white coat?
_0_ in _4_ or _0_ %

Punnett Squares: Incomplete Dominance and Co-dominance

14. **(a)** Complete the Punnett square to show a cross between a black horse and a white horse.

Include the genotypes and phenotypes of offspring.

B B

B   B

	B W	B W
W W / W	B W blue roan	B W blue roan
W	B W blue roan	B W blue roan

(b) What is the probability of offspring with:

(i) black coat?

_0_ in _4_ or _0_ %

(ii) blue roan coat?

_4_ in _4_ or _100_ %

(iii) white coat?

_0_ in _4_ or _0_ %

15. **(a)** Complete the Punnett square to show a cross between two blue roan horses.

Include the genotypes and phenotypes of offspring.

B W

B   W

	B	W
B W / B	B B black	B W blue roan
W	B W blue roan	W W white

(b) What is the probability of offspring with:

(i) black coat?

_1_ in _4_ or _25_ %

(ii) blue roan coat?

_2_ in _4_ or _50_ %

(iii) white coat?

_1_ in _4_ or _25_ %

Punnett Squares: Incomplete Dominance and Co-dominance

16. **(a)** Complete the Punnett square to show a cross between a blue roan horse and a white horse.
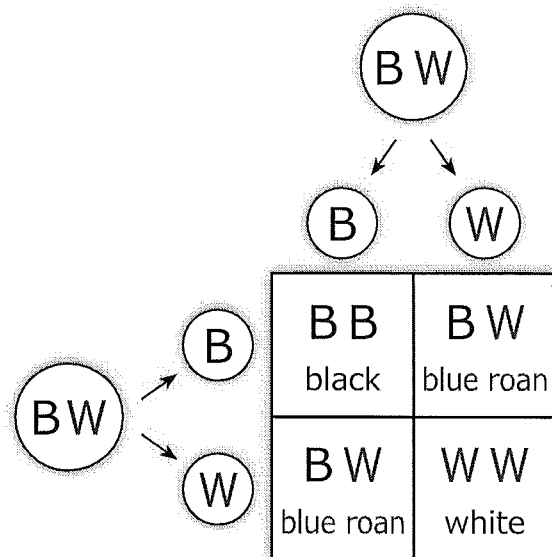
Include the genotypes and phenotypes of offspring.

(b) What is the probability of offspring with:

(i) black coat?
0 in 4 or 0 %

(ii) blue roan coat?
2 in 4 or 50 %

(iii) white coat?
2 in 4 or 50 %

17. **(a)** Complete the Punnett square to show a cross between two white horses.

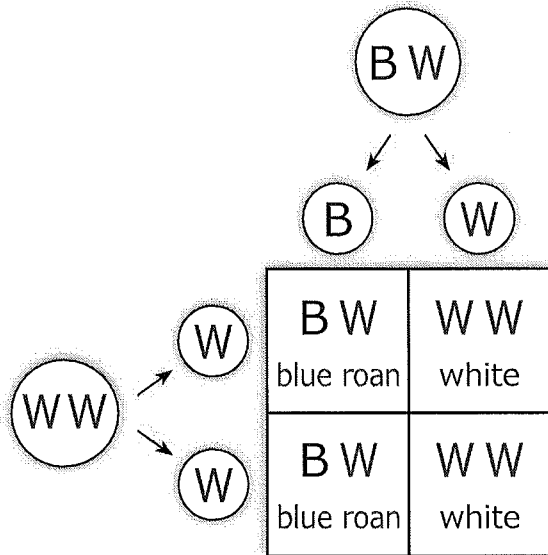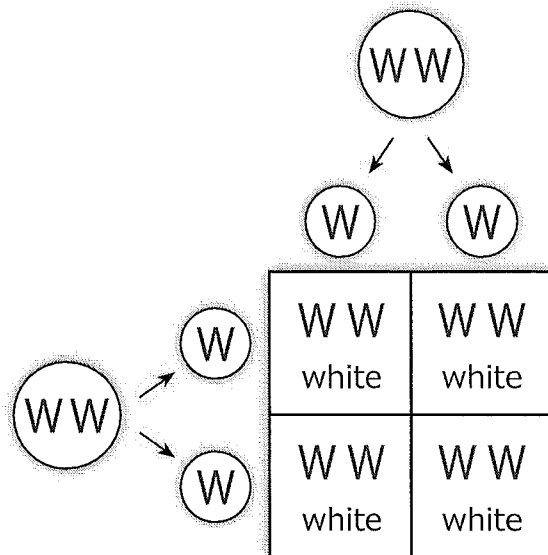Include the genotypes and phenotypes of offspring.

(b) What is the probability of offspring with:

(i) black coat?
0 in 4 or 0 %

(ii) blue roan coat?
0 in 4 or 0 %

**(iii)** white coat?
4 in 4 or 100 %

Punnett Squares: Incomplete Dominance and Co-dominance

In cats, the gene associated with orange fur colour is located on the X-chromosome.
The alleles for black fur (X^B) and orange fur (X^O) are co-dominant, with heterozygotes having black and tan fur, known as the calico phenotype.

Use this information to answer questions 18-23.

18. **(a)** Complete the Punnett square to show a cross between two black cats.
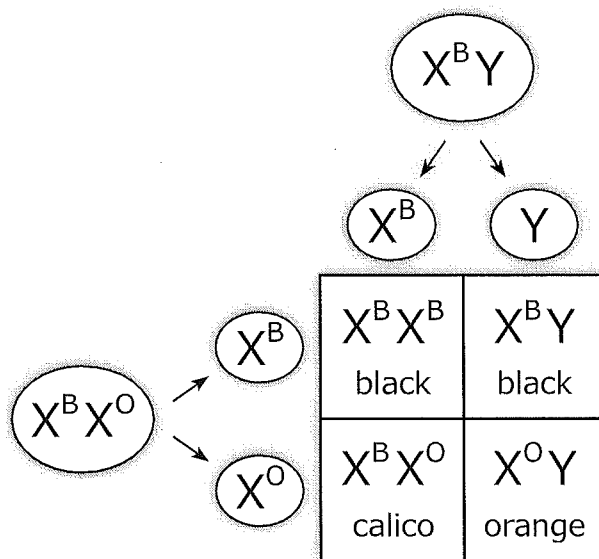
Include the genotypes and phenotypes of offspring.
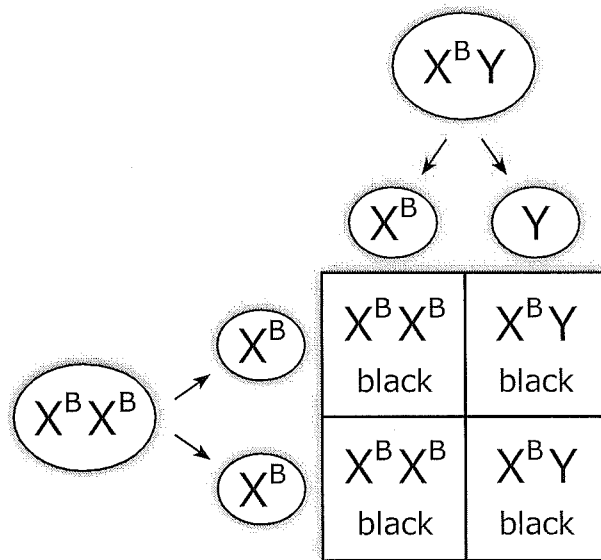
$X^B Y$

X^B Y

	X^B	Y
X^B	$X^B X^B$ black	$X^B Y$ black
X^B	$X^B X^B$ black	$X^B Y$ black

$X^B X^B$

(b) What is the probability of:

(i) black males?
　2　in　4　or　50　%

(ii) orange males?
　0　in　4　or　0　%

(iii) black females?
　2　in　4　or　50　%

(iv) calico females?
　0　in　4　or　0　%

(v) orange females?
　0　in　4　or　0　%

19. **(a)** Complete the Punnett square to show a cross between a black male and calico female.

Include the genotypes and phenotypes of offspring.

$X^B Y$

X^B Y

	X^B	Y
X^B	$X^B X^B$ black	$X^B Y$ black
X^O	$X^B X^O$ calico	$X^O Y$ orange

$X^B X^O$

(b) What is the probability of:

(i) black males?
　1　in　4　or　25　%

(ii) orange males?
　1　in　4　or　25　%

(iii) black females?
　1　in　4　or　25　%

(iv) calico females?
　1　in　4　or　25　%

(v) orange females?
　0　in　4　or　0　%

Punnett Squares: Incomplete Dominance and Co-dominance

20. (a) Complete the Punnett square to show a cross between a black male and orange female. Include the genotypes and phenotypes of offspring.
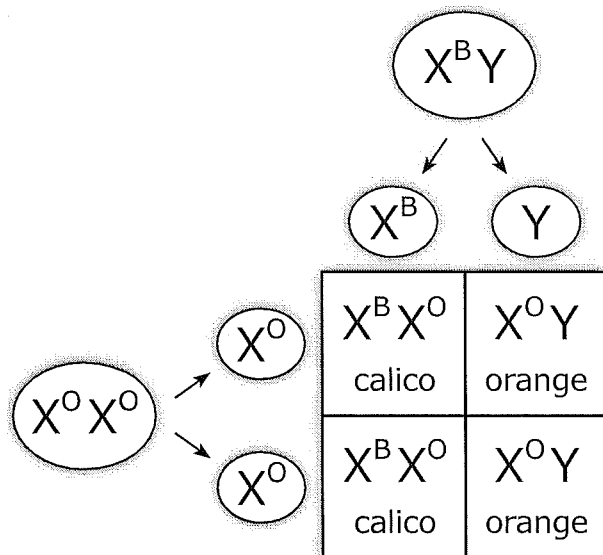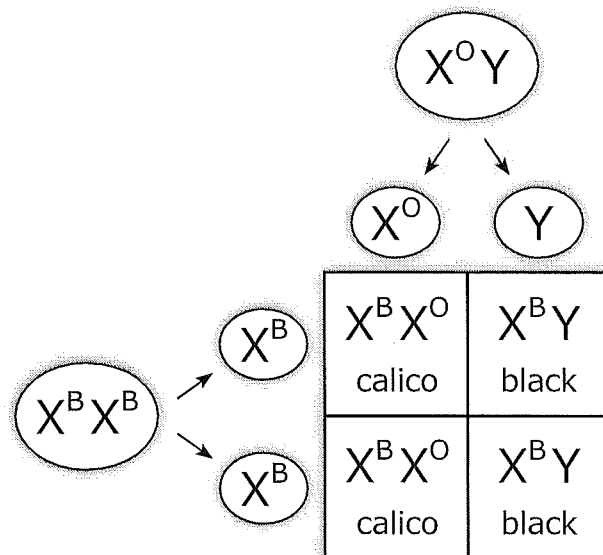
X^BY

X^B Y

X^OX^O → X^O, X^O

	X^B	Y
X^O	X^BX^O calico	X^OY orange
X^O	X^BX^O calico	X^OY orange

(b) What is the probability of:

(i) black males?
_0_ in _4_ or _0_ %

(ii) orange males?
_2_ in _4_ or _50_ %

(iii) black females?
_0_ in _4_ or _0_ %

(iv) calico females?
_2_ in _4_ or _50_ %

(v) orange females?
_0_ in _4_ or _0_ %

21. (a) Complete the Punnett square to show a cross between an orange male and black female. Include the genotypes and phenotypes of offspring.

X^OY

X^O Y

X^BX^B → X^B, X^B

	X^O	Y
X^B	X^BX^O calico	X^BY black
X^B	X^BX^O calico	X^BY black

(b) What is the probability of:

(i) black males?
_2_ in _4_ or _50_ %

(ii) orange males?
_0_ in _4_ or _0_ %

(iii) black females?
_0_ in _4_ or _0_ %

(iv) calico females?
_2_ in _4_ or _50_ %

(v) orange females?
_0_ in _4_ or _0_ %

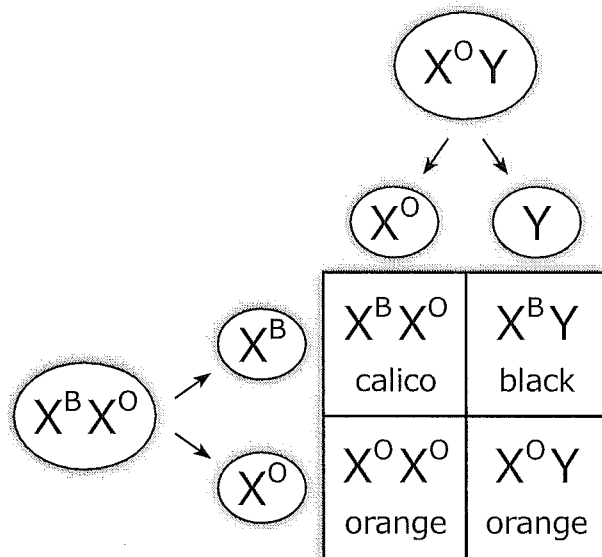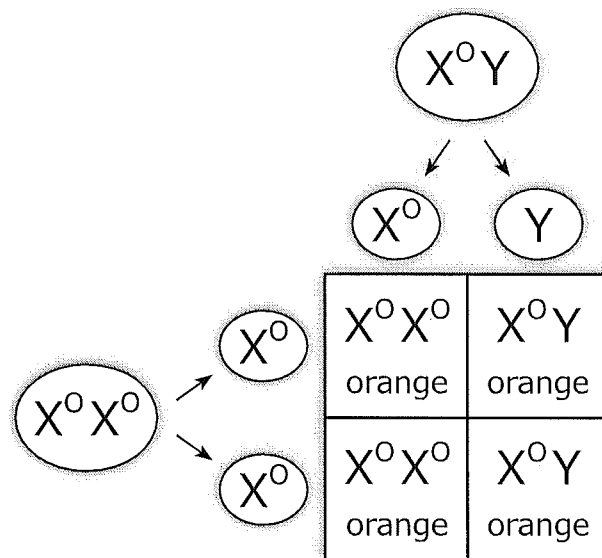# Punnett Squares: Incomplete Dominance and Co-dominance

22. **(a)** Complete the Punnett square to show a cross between an orange male and calico female.

Include the genotypes and phenotypes of offspring.

	X^O	Y
X^B	$X^B X^O$ calico	$X^B Y$ black
X^O	$X^O X^O$ orange	$X^O Y$ orange

Parents: $X^O Y$ → X^O, Y ; $X^B X^O$ → X^B, X^O

(b) What is the probability of:

(i) black males?
__1_ in _4_ or _25_ %

(ii) orange males?
__1_ in _4_ or _25_ %

(iii) black females?
__0_ in _4_ or _0_ %

(iv) calico females?
__1_ in _4_ or _25_ %

(v) orange females?
__1_ in _4_ or _25_ %

23. **(a)** Complete the Punnett square to show a cross between two orange cats.

Include the genotypes and phenotypes of offspring.

	X^O	Y
X^O	$X^O X^O$ orange	$X^O Y$ orange
X^O	$X^O X^O$ orange	$X^O Y$ orange

Parents: $X^O Y$ → X^O, Y ; $X^O X^O$ → X^O, X^O

(b) What is the probability of:

(i) black males?
__0_ in _4_ or _0_ %

(ii) orange males?
__2_ in _4_ or _50_ %

(iii) black females?
__0_ in _4_ or _0_ %

(iv) calico females?
__0_ in _4_ or _0_ %

(v) orange females?
__2_ in _4_ or _50_ %

Punnett Squares: Incomplete Dominance and Co-dominance

24. In your own words, describe the difference between complete dominance, incomplete dominance and co-dominance.

    Include an explanation why heterozygotes have unique phenotypes in traits showing incomplete dominance and co-dominance.

25. In humans, sickle-shaped red blood cells are caused by a mutation in the haemoglobin gene.

    If an individual has one copy of the sickle-cell allele, half of their red blood cells will have the sickle shape and half will have the normal shape. Having one copy of the sickle-cell allele does not cause sickle-cell disease, but it does give the individual resistance to malaria.

    If an individual has two copies of the sickle-cell allele, all of their red blood cells will have the sickle shape. Having two copies of the sickle-cell allele causes sickle-cell disease. (The individual still has resistance to malaria.)

    If an individual has no copies of the sickle-cell allele, all of their blood cells will have the normal shape. They will not have sickle-cell disease and they will not be resistant to malaria.

    The sickle-cell allele therefore has an effect on three different traits: red blood cell shape, sickle-cell disease and malaria resistance. Each of these three traits show a different mode of inheritance.

    Identify whether inheritance for each trait shows complete dominance (including which are the dominant and recessive alleles), incomplete dominance or co-dominance. Draw a separate Punnett square for each trait to illustrate your answer. To avoid confusion, use different letters for each Punnett square, even though they are showing the same two alleles.

normal red blood cell   sickle red blood cell

Answers

24. Complete dominance is when one allele (the dominant allele) completely masks the presence of the other allele (the recessive allele). Heterozygotes will have the dominant phenotype.

Incomplete dominance is when one allele (the dominant allele) only partially masks the presence of the other allele (the recessive allele). Heterozygotes will have a phenotype that is an intermediate or blend of the dominant and recessive phenotypes.

Co-dominance is when neither allele masks the presence of the other allele, so that both phenotypes will be present in heterozygotes.

25. The mode of inheritance of red blood cell shape is co-dominance, with both alleles contributing to the phenotype, as shown in Punnett square (i).

The mode of inheritance of sickle-cell disease is complete dominance, where the allele for sickle-cell disease is the recessive allele, as shown in Punnett square (ii).

The mode of inheritance of malaria resistance is complete dominance, where the allele for malaria resistance is the dominant allele, as shown in Punnett square (iii).

(i)

	O	C
O	O O round only	O C round & sickle
C	O C round & sickle	C C sickle only

(ii)

	N	n
N	N N normal	N n normal
n	N n normal	n n sickle-cell disease

(iii)

	R	r
R	R R resistant	R r resistant
r	R r resistant	r r non-resistant