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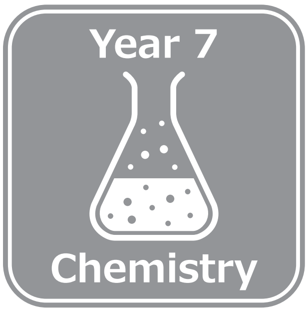

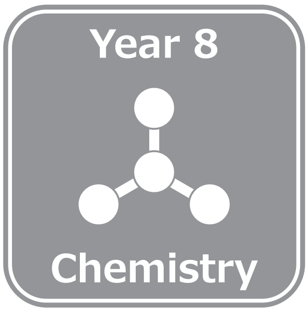

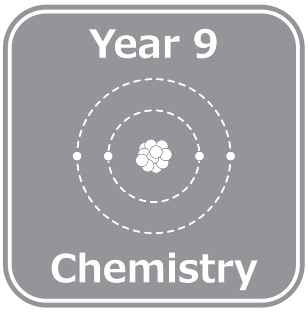

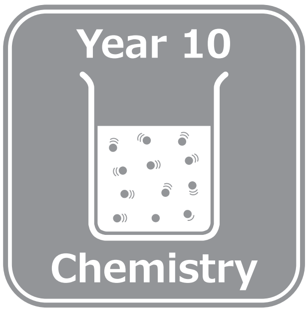

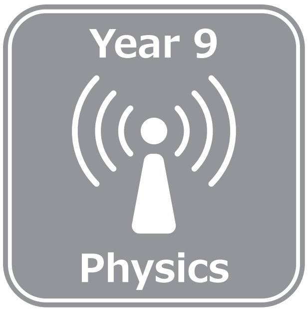

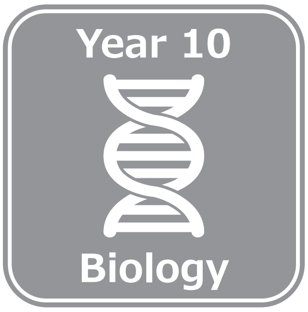

Written and illustrated by Greg Good, except for credited images.

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2.3c Punnett Squares – Sex-Linked Inheritance

Key Learning Idea

➤ Punnett squares can be used to predict genotypes and phenotypes of offspring for traits that are sex-linked.

Content

- Constructing Punnett squares for traits that are: (i) X-linked with dominant and recessive inheritance, and (ii) X-linked with codominant inheritance.
  - Determining parental alleles.
  - Determining possible genotypes of male and female offspring.
  - Determining possible phenotypes of male and female offspring.
  - Determining probabilities of different genotypes and phenotypes in male and female offspring.
- Determining genotypes of parents based on phenotypes observed in male and female offspring.

Learning Checklist

By the end of this worksheet students will be able to:

✓ Use a Punnett square to determine the possible genotypes and phenotypes of male and female offspring for traits that are X-linked.

✓ Use a Punnett square to determine the probabilities of different genotypes and phenotypes in male and female offspring for traits that are X-linked.

✓ Determine genotypes of parents based on the numbers of different phenotypes observed in male and female offspring for traits that are X-linked.

Punnett Squares – Sex-Linked Inheritance

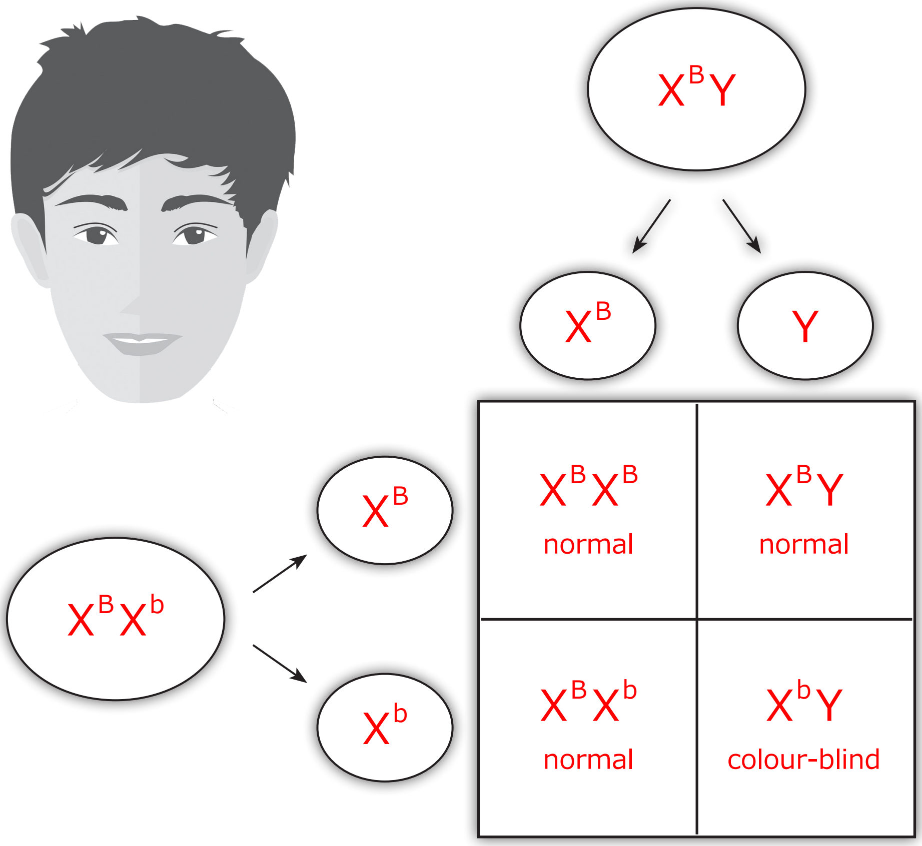
Sex Linkage and Dominance

In humans, the gene associated with red-green colour blindness is located on the X chromosome. The allele for normal vision (X^B) is dominant over the allele for red-green colour blindness (X^b).

Use this information to answer questions 1-4.

1. **(a)** Complete the Punnett square to show the offspring of a hemizygous dominant male and a heterozygous female.

Include the genotypes and phenotypes of offspring.



	X^B	Y
X^B	X^BX^B normal	X^BY normal
X^b	X^BX^b normal	X^bY colour-blind

(b) For sons, what is the probability of:

(i) Normal vision?
1 in 2 or 50 %

(ii) Colour blindness?
1 in 2 or 50 %

(c) For daughters, what is the probability of:

(i) Normal vision?
2 in 2 or 100 %

(ii) Colour blindness?
0 in 2 or 0 %

(d) What is the probability of daughters being carriers (unaffected heterozygotes)?

1 in 2 or 50 %

Punnett Squares – Sex-Linked Inheritance

2. **(a)** Complete the Punnett square to show the offspring of a hemizygous dominant male and a homozygous recessive female.

Include the genotypes and phenotypes of offspring.

X^BY

X^bX^b

	X^B	Y
X^b	X^BX^b normal	X^bY colour-blind
X^b	X^BX^b normal	X^bY colour-blind

(b) For sons, what is the probability of:

(i) Normal vision?
0 in 2 or 0 %

(ii) Colour blindness?
2 in 2 or 100 %

(c) For daughters, what is the probability of:

(i) Normal vision?
2 in 2 or 100 %

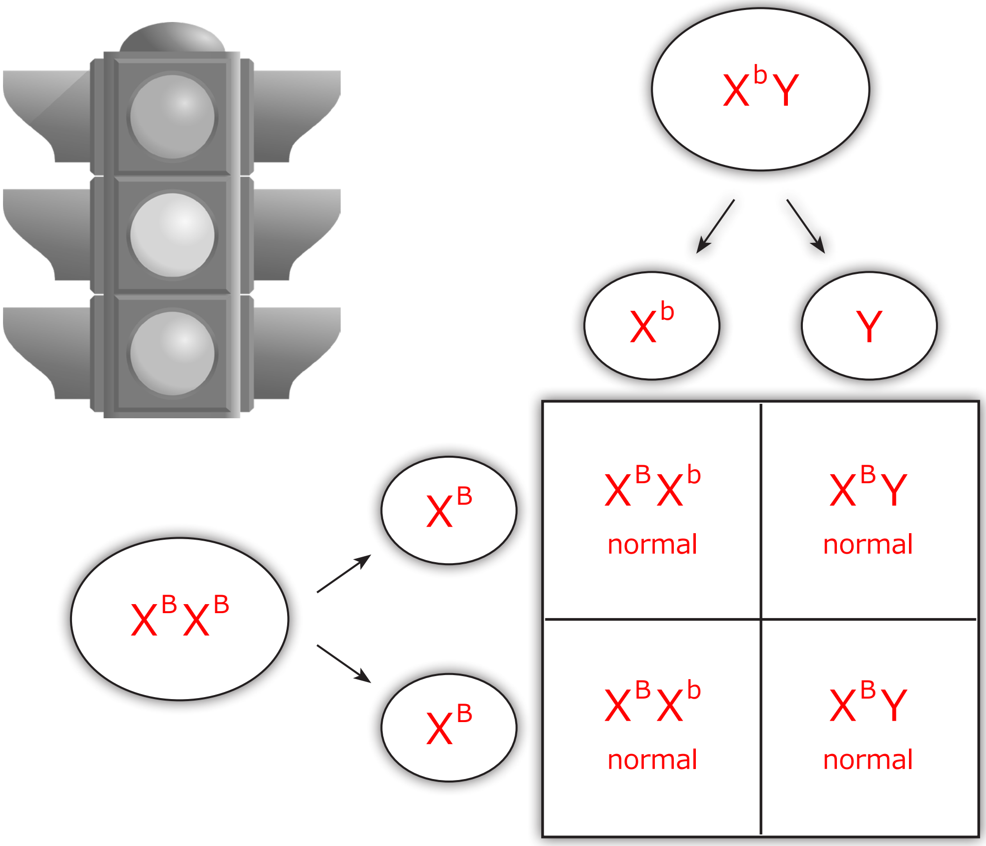
(ii) Colour blindness?
0 in 2 or 0 %

(d) What is the probability of daughters being carriers?

2 in 2 or 100 %

3. **(a)** Complete the Punnett square to show the offspring of a hemizygous recessive male and a homozygous dominant female.

Include the genotypes and phenotypes of offspring.



	X^b	Y
X^B	X^BX^b normal	X^BY normal
X^B	X^BX^b normal	X^BY normal

(b) For sons, what is the probability of:

(i) Normal vision?
2 in 2 or 100 %

(ii) Colour blindness?
0 in 2 or 0 %

(c) For daughters, what is the probability of:

(i) Normal vision?
2 in 2 or 100 %

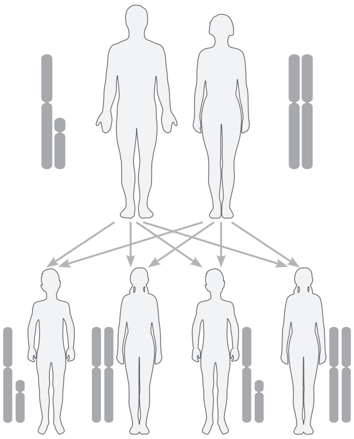
(ii) Colour blindness?
0 in 2 or 0 %

(d) What is the probability of daughters being carriers?

2 in 2 or 100 %

4. **(a)** Complete the Punnett square to show the offspring of a hemizygous recessive male and a heterozygous female.

Include the genotypes and phenotypes of offspring.



X^bY

X^BX^b

	X^b	Y
X^B	X^BX^b normal	X^BY normal
X^b	X^bX^b colour-blind	X^bY colour-blind

(b) For sons, what is the probability of:

(i) Normal vision?
1 in 2 or 50 %

(ii) Colour blindness?
1 in 2 or 50 %

(c) For daughters, what is the probability of:

(i) Normal vision?
1 in 2 or 50 %

(ii) Colour blindness?
1 in 2 or 50 %

(d) What is the probability of daughters being carriers?

1 in 2 or 50 %

2.3c Punnett Squares – Sex-Linked Inheritance

Sex Linkage and Codominance

In cats, the gene associated with orange fur colour is located on the X chromosome. The allele for black fur (X^B) and the allele for orange fur (X^O) exhibit codominance, with heterozygotes having black and tan fur, known as the 'calico' phenotype.

Use this information to answer questions 5-8.

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

Include the genotypes and phenotypes of offspring.

X^BY → X^B, Y

X^BX^O → X^B, X^O

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

(b) For male offspring, what is the probability of:

(i) Black fur?
1 in 2 or 50 %

(ii) Calico fur?
0 in 2 or 0 %

(iii) Orange fur?
1 in 2 or 50 %

(c) For female offspring, what is the probability of:

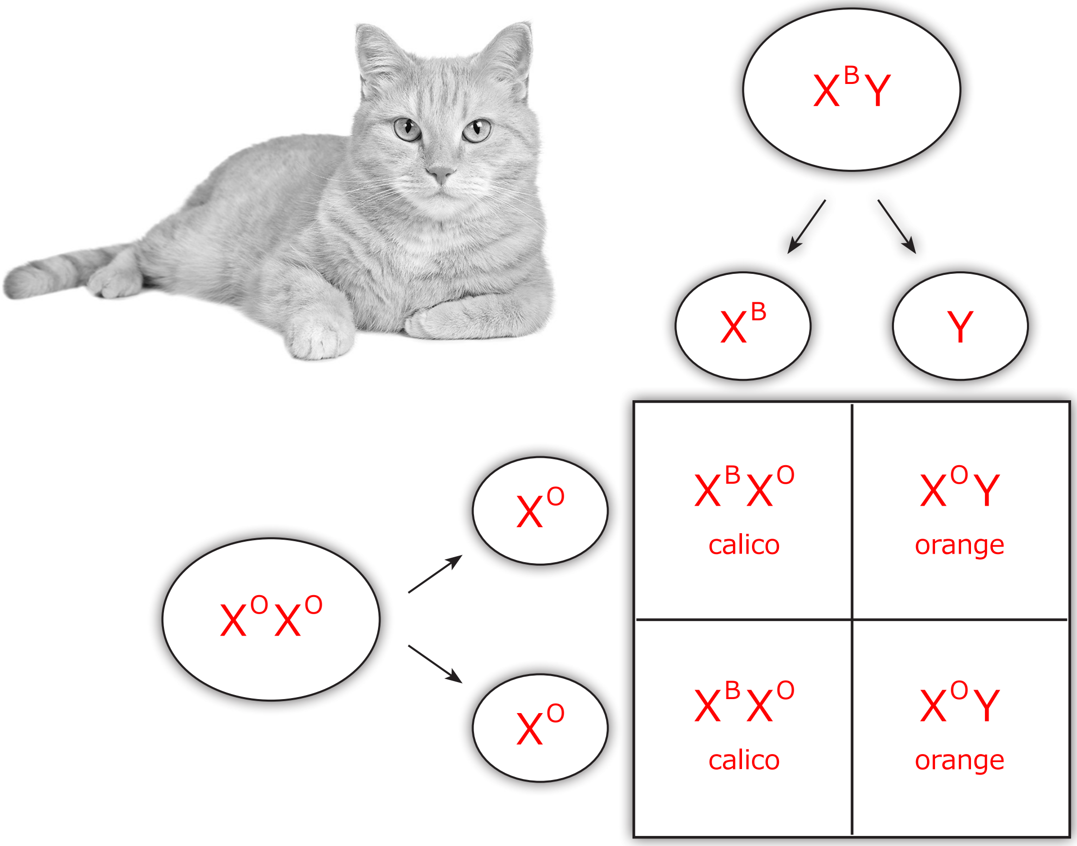
(i) Black fur?
1 in 2 or 50 %

(ii) Calico fur?
1 in 2 or 50 %

(iii) Orange fur?
0 in 2 or 0 %

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

Include the genotypes and phenotypes of offspring.



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

(b) For male offspring, what is the probability of:

(i) Black fur?
0 in 2 or 0 %

(ii) Calico fur?
0 in 2 or 0 %

(iii) Orange fur?
2 in 2 or 100 %

(c) For female offspring, what is the probability of:

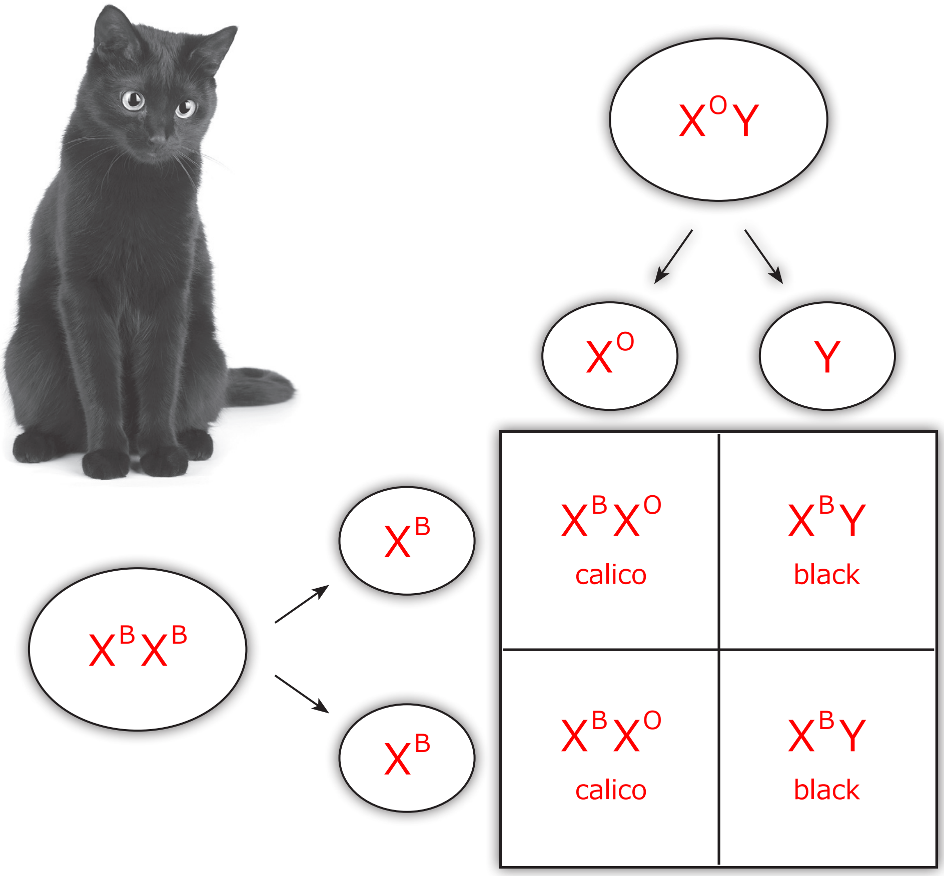
(i) Black fur?
0 in 2 or 0 %

(ii) Calico fur?
2 in 2 or 100 %

(iii) Orange fur?
0 in 2 or 0 %

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

Include the genotypes and phenotypes of offspring.



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

(b) For male offspring, what is the probability of:

(i) Black fur?
2 in 2 or 100 %

(ii) Calico fur?
0 in 2 or 0 %

(iii) Orange fur?
0 in 2 or 0 %

(c) For female offspring, what is the probability of:

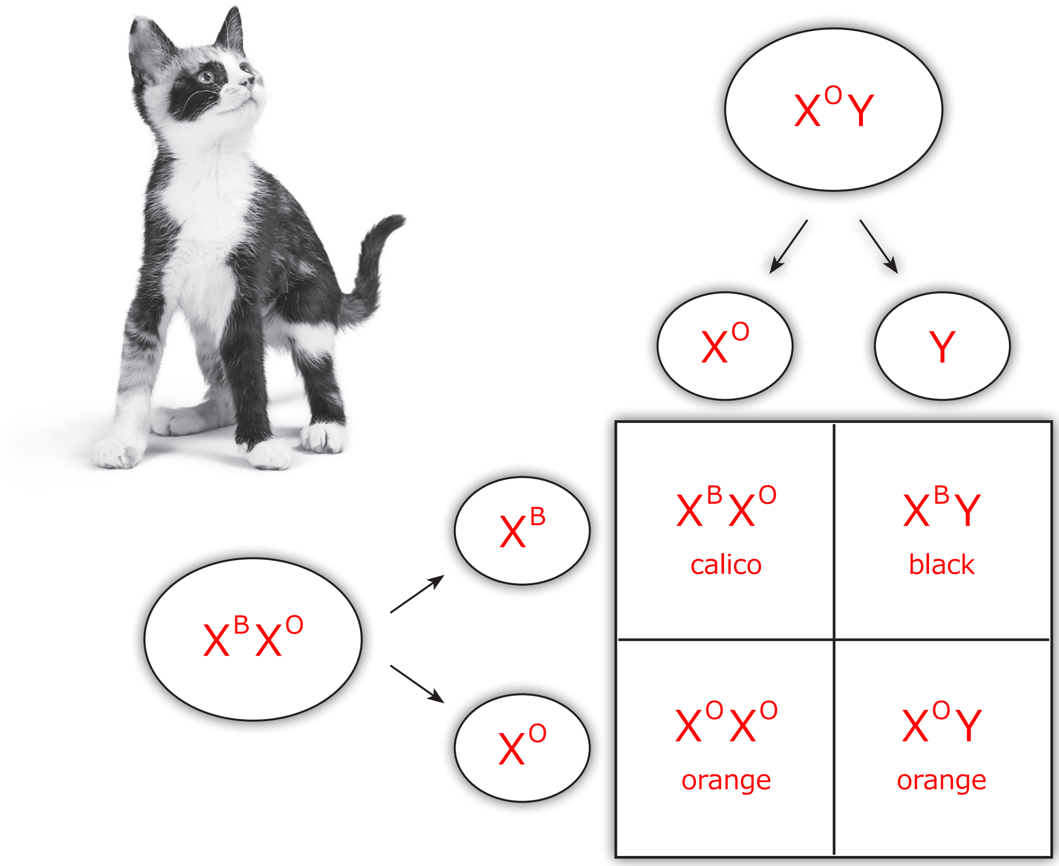
(i) Black fur?
0 in 2 or 0 %

(ii) Calico fur?
2 in 2 or 100 %

(iii) Orange fur?
0 in 2 or 0 %

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

Include the genotypes and phenotypes of offspring.



	X^O	Y
X^B	X^BX^O calico	X^BY black
X^O	X^OX^O orange	X^OY orange

(b) For male offspring, what is the probability of:

(i) Black fur?
1 in 2 or 50 %

(ii) Calico fur?
0 in 2 or 0 %

(iii) Orange fur?
1 in 2 or 50 %

(c) For female offspring, what is the probability of:

(i) Black fur?
0 in 2 or 0 %

(ii) Calico fur?
1 in 2 or 50 %

(iii) Orange fur?
1 in 2 or 50 %

9. In fruit flies, the gene associated with white eye colour is located on the X chromosome. The allele for red eye colour (X^R) is dominant over the allele for white eye colour (X^r).

(a) What is the only possible genotype for red-eyed male fruit flies? X^RY

(b) What is the only possible genotype for white-eyed male fruit flies? X^rY

(c) What are the two possible genotypes for red-eyed female fruit flies? X^RX^R, X^RX^r

(d) What is the only possible genotype for white-eyed female fruit flies? X^rX^r

(e) A red-eyed male fruit fly was mated with a red-eyed female fruit fly, resulting in:

22 red-eyed male offspring
19 white-eyed male offspring
43 red-eyed female offspring

What can you say about the genotype of the female parent? Use a Punnett square to support your answer.

The long answer: The red-eyed male fly can only be hemizygous dominant (X^RY), but the red-eyed female fly could be either homozygous dominant (X^RX^R) or heterozygous (X^RX^r). Therefore, there are two possible crosses – $X^RY \times X^RX^R$ and $X^RY \times X^RX^r$ – which can be represented by the following Punnett squares.

	X^R	Y
X^R	X^RX^R red eyes	X^RY red eyes
X^R	X^RX^R red eyes	X^RY red eyes

(i)

	X^R	Y
X^R	X^RX^R red eyes	X^RY red eyes
X^r	X^RX^r red eyes	X^rY white eyes

(ii)

In scenario (i), it is not possible for any white-eyed male flies to be present in the offspring. In scenario (ii), there is a 50% chance of male offspring being red-eyed and a 50% chance of male offspring being white-eyed. Since the male offspring in question are approximately 1:1 red-eyed and white-eyed, the female parent must have the X^RX^r genotype.

The short answer: Males receive their X chromosome from their mother. For there to be both red-eyed and white-eyed male offspring, the mother must have one red-eye allele and one white-eye allele. Therefore, the mother must have the X^RX^r genotype. This is illustrated by the second Punnett square above.

(f) A white-eyed male fruit fly was mated with a red-eyed female fruit fly, resulting in:

27 red-eyed male offspring
26 red-eyed female offspring

What can you say about the genotype of the female parent? Use a Punnett square to support your answer.

The long answer: The white-eyed male fly can only be hemizygous recessive (X^rY), but the red-eyed female fly could be either homozygous dominant (X^RX^R) or heterozygous (X^RX^r). Therefore, there are two possible crosses – $X^rY \times X^RX^R$ and $X^rY \times X^RX^r$ – which can be represented by the following Punnett squares.

	X^r	Y
X^R	X^RX^r red eyes	X^RY red eyes
X^R	X^RX^r red eyes	X^RY red eyes

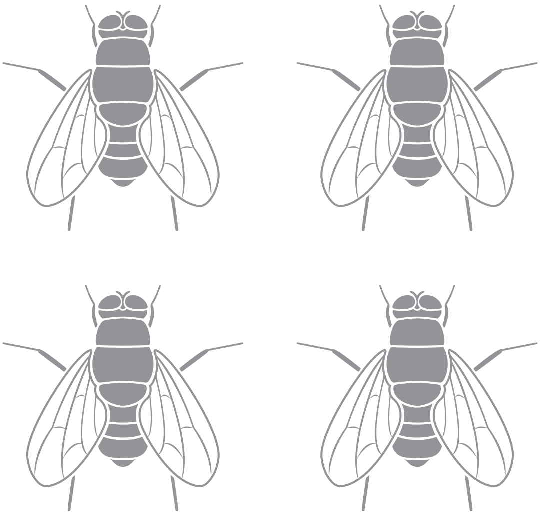
(i)

	X^r	Y
X^R	X^RX^r red eyes	X^RY red eyes
X^r	X^rX^r white eyes	X^rY white eyes

(ii)

In scenario (i), all male and female offspring are red-eyed. In scenario (ii), there is a 50% chance of male and female offspring being red-eyed and a 50% chance of male and female offspring being white-eyed. Since all male and female offspring in question are red-eyed, the female parent must have the X^RX^R genotype.

The short answer: Males receive their X chromosome from their mother. For there to be only red-eyed male offspring, the mother must only have red-eye alleles. Therefore, the mother must have the X^RX^R genotype. This is illustrated by the first Punnett square above.



(g) Two fruit flies were mated, resulting in:

36 white-eyed male offspring
31 red-eyed female offspring

What can you say about the genotype and phenotype of both parents? Use a Punnett square to support your answer.

Males receive their X chromosome from their mother. For there to be only white-eyed male offspring, the mother must have only white-eye alleles. Therefore, the mother must have the X^rX^r genotype and the white-eyed phenotype.

Females receive one X chromosome from each parent. For there to be only red-eyed female offspring, the father must have the red-eye allele. This is because, for daughters to have red eyes, they must have at least on red-eye allele, and they could not receive this from their mother as she has only white-eye alleles. Therefore, the father must have the X^RY genotype and the red-eyed phenotype.

This is illustrated by the following Punnett square.

	X^R	Y
X^r	X^RX^r red eyes	X^rY white eyes
X^r	X^RX^r red eyes	X^rY white eyes

(h) The fruit flies in question (e) went on to produce 76 more offspring. What are the predicted numbers of each phenotype for male and female offspring?

Using Punnett square (ii) from question (e):

Half of the offspring are predicted to be female – all with red eyes. Half of the offspring are predicted to be male – half with red eyes and half with white eyes. Therefore, the predicted phenotypes of offspring are:

38 (½ × 76) red-eyed females
19 (¼ × 76) red-eyed males
19 (¼ × 76) white-eyed males

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