

Exercise walk-through

17.4.1

Pedigrees, test crosses, blood groups and sex linkage

IGCSE Biology

Inheritance key words

BB → brown eyes

Bb → brown eyes

bb → blue eyes

B (brown) is dominant

b (blue) is recessive

■ **genotype** – the alleles; **phenotype** – what you see

■ **dominant** (B) shows with one copy

■ **recessive** (b) needs two

■ **homozygous**

BB/bb;

heterozygous Bb

Two more words, and a family tree

Pure-breeding

A **homozygous** organism (BB or bb) carries two identical alleles, so it breeds true – it is **pure-breeding**.

Pedigree diagram

A **pedigree diagram** is a family tree of one feature. Work backwards from an affected child to fix the parents' genotypes.

Replication first

Before any division the chromosomes are copied exactly – **replication** – so each **daughter cell** can keep the full number.

On a pedigree, two unaffected parents with an affected child prove the allele is **recessive**, and that both parents are carriers.

Monohybrid crosses

A **Punnett square**

predicts the offspring.

■ $Bb \times Bb \rightarrow 3:1$

■ $Bb \times bb \rightarrow 1:1$

A **test cross** (against bb) reveals an unknown genotype.

$Bb \times Bb$ (both parents)

gametes

	B	b
B	BB	Bb
b	Bb	bb

3 : 1

3 dominant (blue)

1 recessive (orange)

Codominance and sex linkage

codominance

both alleles show: $I^A I^B \rightarrow$
blood group AB

sex linkage

a gene on the X; **colour blindness**
is commoner in boys

Sex chromosomes, sex linkage and blood groups

Sex chromosomes

The 23rd pair are the **sex chromosomes** : XX in a female, XY in a male, so the father's gamete decides the sex.

Sex-linked

A **sex-linked** characteristic is controlled by a gene on a sex chromosome, usually the X.

Red-green colour blindness

Red-green colour blindness is the standard example: the recessive allele sits on the X, so it is far more common in boys – they have no second X to mask it.

Blood groups

The ABO **blood groups** show codominance: I^A and I^B are both expressed in group AB.

Write a sex-linked genotype on the chromosome: $X^B X^b$, not Bb . Half the marks are in the notation.

Exercises 2.1·2.2

2.1 A pea plant is homozygous for tall stems (T). State its genotype, and explain why it is pure-breeding. [2]

2.2 In cats, short hair (S) is dominant to long hair (s). A heterozygous short-haired cat is crossed with a long-haired cat. Draw a genetic diagram for this cross and give the ratio of the offspring phenotypes. [4]

Exercises 2.1·2.2

2.1 A pea plant is homozygous for tall stems (T). State its genotype, and explain why it is pure-breeding. [2]

2.1

- genotype **TT**
- both alleles are the same, so every gamete carries T and all the offspring of a cross with another TT plant are TT – the feature never changes between generations

2.2 In cats, short hair (S) is dominant to long hair (s). A heterozygous short-haired cat is crossed with a long-haired cat. Draw a genetic diagram for this cross and give the ratio of the offspring phenotypes. [4]

2.2

- state the parents: heterozygous short-haired is **Ss**, long-haired is **ss**
- gametes: S or s from the first parent, s or s from the second
- the grid gives **Ss, ss, Ss, ss**
- so **1 short-haired : 1 long-haired**, a **1:1** ratio

Exercises 2.3-2.4

2.3 A short-haired cat may be SS or Ss. Describe a test cross that would show which it is, and state how you would read the result. [3]

2.4 A man has blood group AB. State his genotype, and explain what codominance means in this case. [3]

Exercises 2.3-2.4

2.3 A short-haired cat may be SS or Ss. Describe a test cross that would show which it is, and state how you would read the result. [3]

2.3

- cross the unknown cat with a **long-haired (ss)** cat
- if **any** kitten has long hair, that kitten is ss, so it received an s from the unknown parent, which must therefore be **Ss**
- if every kitten has short hair, the unknown parent is very probably **SS**

2.4 A man has blood group AB. State his genotype, and explain what codominance means in this case. [3]

2.4

- genotype **$I^A I^B$**
- codominance means **both** alleles are expressed in the phenotype
- neither allele masks the other, so this man's blood has **both** the A and the B features, rather than only one of them

Exercises 2.5-2.6

2.5 State the genotype of a person with blood group O, and the two possible genotypes of a person with blood group A. [2]

2.6 Explain why red-green colour blindness is more common in boys than in girls. [3]

Exercises 2.5-2.6

2.5 State the genotype of a person with blood group O, and the two possible genotypes of a person with blood group A. [2]

2.5

- group O: $I^O I^O$
- group A: $I^A I^A$ or $I^A I^O$

2.6 Explain why red-green colour blindness is more common in boys than in girls. [3]

2.6

- the gene is on the **X chromosome**, and the allele for colour blindness is **recessive**
- a boy is $X^? Y$, with only **one** X, so a single copy of the recessive allele always shows
- a girl is $X^? X^?$ and needs **two** copies; with one copy she is a carrier with normal vision, and two copies are far less likely

Exercise 3.1

3.1 A woman of blood group A and a man of blood group B have a child of blood group O. Which row gives the genotypes of the parents? [1]

☐

A $I^A I^A$ and $I^B I^B$

B $I^A I^o$ and $I^B I^o$

C $I^A I^B$ and $I^o I^o$

D $I^A I^o$ and $I^B I^B$

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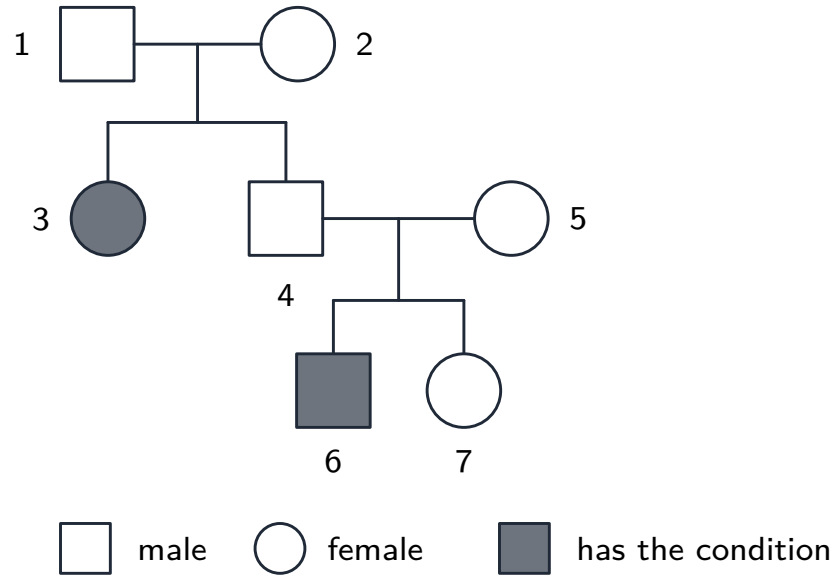
D $I^A I^o$ and $I^B I^B$

3.1 B

- the child is group O, so its genotype is $I^o I^o$ and it received an I^o from **each** parent
- so each parent carries an I^o as well as the allele for their own group: $I^A I^o$ and $I^B I^o$
- **A** and **D** give no I^o to pass on; **C** gives the wrong blood groups for the parents themselves

Setup for exercise 3.2

3.2 The pedigree diagram shows how an inherited condition passes through one family.



Exercise 3.2 (a)

(a) State whether the allele for the condition is dominant or recessive, and give the evidence from the diagram. [2]

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(a)

- the allele is **recessive**
- individuals 1 and 2 do not have the condition, but their daughter 3 does, so the allele must have been carried without showing

Exercise 3.2 (b)

(b) Explain how the diagram shows that the gene is **not** on the X chromosome. [2]

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(b)

- individual 3 is an **affected female**, so she has the recessive allele on **both** of her X chromosomes, one of them from her father, individual 1
- individual 1 has only one X, so he would then have the condition himself – and he does not, so the gene cannot be on the X chromosome

Exercise 3.2 (c)

(c) Using the symbols A and a, give the genotypes of individuals 4 and 5, and explain how you worked them out. [2]

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(c)

- individual 6 has the condition, so he is **aa**, with one a from each parent
- individuals 4 and 5 do not have the condition, so each also carries an A: both are **Aa**

Exercise 3.2 (d)

(d) Calculate the probability that the next child of individuals 4 and 5 has the condition.^[1]

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(d)

- $Aa \times Aa$ gives AA , Aa , Aa , aa , so the probability is $\frac{1}{4}$, or **25%**

Exercise 3.3 (a)

3.3 A woman with normal colour vision has a father who is red-green colour-blind. She marries a man who is red-green colour-blind.

(a) Explain why the woman must be a carrier of the colour-blindness allele. [2]

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(a) Explain why the woman must be a carrier of the colour-blindness allele. [2]

(a)

- her father is colour-blind, so his genotype is X^bY , and his only X carries X^b
- every daughter receives that X, so she has X^b ; she has normal vision, so her other X must carry X^B , making her $X^B X^b$ – a carrier

Exercise 3.3 (b)

3.3 A woman with normal colour vision has a father who is red-green colour-blind. She marries a man who is red-green colour-blind.

(b) Draw a genetic diagram for this couple. Show the parents' genotypes, their gametes, and all the possible children with their phenotypes. [4]

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(b)

- parents: mother $X^B X^b$, father $X^b Y$
- gametes: X^B or X^b from the mother, X^b or Y from the father
- the grid gives $X^B X^b$, $X^b X^b$, $X^B Y$ and $X^b Y$
- phenotypes: a **carrier daughter** with normal vision, a **colour-blind daughter**, a **son with normal vision** and a **colour-blind son**

Exercise 3.3 (c)

3.3 A woman with normal colour vision has a father who is red-green colour-blind. She marries a man who is red-green colour-blind.

(c) State the probability that a daughter of this couple is colour-blind, and the probability that a son is colour-blind. [2]

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(c) State the probability that a daughter of this couple is colour-blind, and the probability that a son is colour-blind. [2]

(c)

- a daughter: $\frac{1}{2}$, or **50%**
- a son: $\frac{1}{2}$, or **50%**

Exercise 3.3 (d)

3.3 A woman with normal colour vision has a father who is red-green colour-blind. She marries a man who is red-green colour-blind.

(d) The couple have three children, none of them colour-blind. State the probability that a fourth child is colour-blind, and explain your answer. [2]

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(d)

- **50%**, the same as for every other child
- each fertilisation is independent of the ones before it, so the three earlier children do not change the chance

Exercise 3.3 (e)

3.3 A woman with normal colour vision has a father who is red-green colour-blind. She marries a man who is red-green colour-blind.

(e) The couple have a daughter with normal colour vision. State her genotype and explain how you know it exactly. [2]

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3.3 A woman with normal colour vision has a father who is red-green colour-blind. She marries a man who is red-green colour-blind.

(e) The couple have a daughter with normal colour vision. State her genotype and explain how you know it exactly. [2]

(e)

- $X^B X^b$, a carrier
- her father is $X^b Y$, so his only X gave her X^b ; she has normal vision, so her mother's X must have carried X^B – no other genotype is possible