

Inheritance revision notes

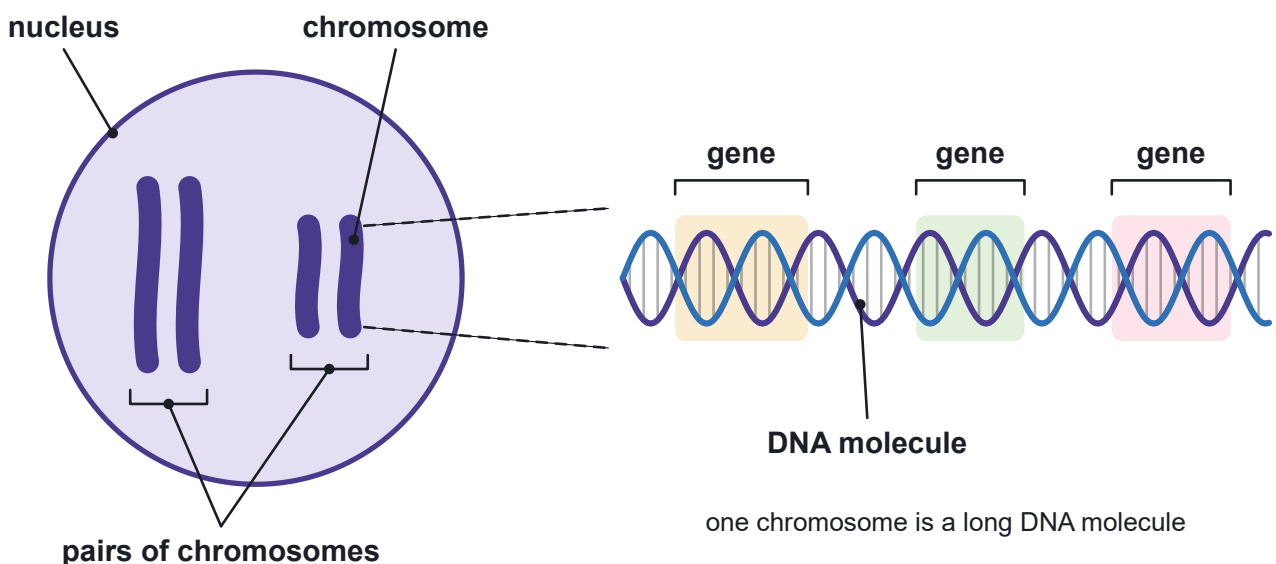
Inheritance is how genetic information is passed from cells to daughter cells and from parents to offspring. This topic covers chromosomes, genes and the proteins they code for, the two types of cell division (mitosis and meiosis), and how characteristics are inherited, including dominance, codominance and sex linkage.

For Cambridge IGCSE Biology 0610 (and 0970, which has the same content). **Supplement** is Extended content, only examined on Papers 2 and 4.

1 Chromosomes, genes and proteins Spec 17.1

Chromosomes, genes and alleles Spec 17.1.1, 17.1.2, 17.1.3

The nucleus of a cell contains **chromosomes**. Chromosomes are made of **DNA**, and the DNA contains genetic information in the form of **genes**.



A nucleus contains **chromosomes** in pairs. Each chromosome is a long DNA molecule carrying many **genes**.

Gene	A length of DNA that codes for a protein.
Allele	An alternative form of a gene.

Every gene has a fixed position on a chromosome. Many genes exist in more than one form. For example, the gene for flower colour may have an allele for red flowers and a different allele for white flowers. Different alleles of the same gene have slightly different DNA, so they can code for slightly different proteins.

Chromosome, DNA, gene and allele

Term	What it is
Chromosome	a structure in the nucleus made of DNA
DNA	the molecule that contains the genetic information
Gene	a length of DNA that codes for a protein
Allele	an alternative form of a gene

Common mistake: A gene is not the same as an allele. Write that an allele is an alternative form of a gene. Do not say a gene is a 'section of a chromosome' without saying it codes for a protein.

Inheritance of sex Spec 17.1.4

Human body cells contain one pair of **sex chromosomes**, which decide whether a person is male or female. There are two types, called X and Y.

- Females have two X chromosomes (XX).
- Males have one X chromosome and one Y chromosome (XY).

Gametes (sex cells) carry only one sex chromosome. All eggs carry an X chromosome. Half of the sperm carry an X chromosome and half carry a Y chromosome. The sex of a baby depends on which sperm fertilises the egg.

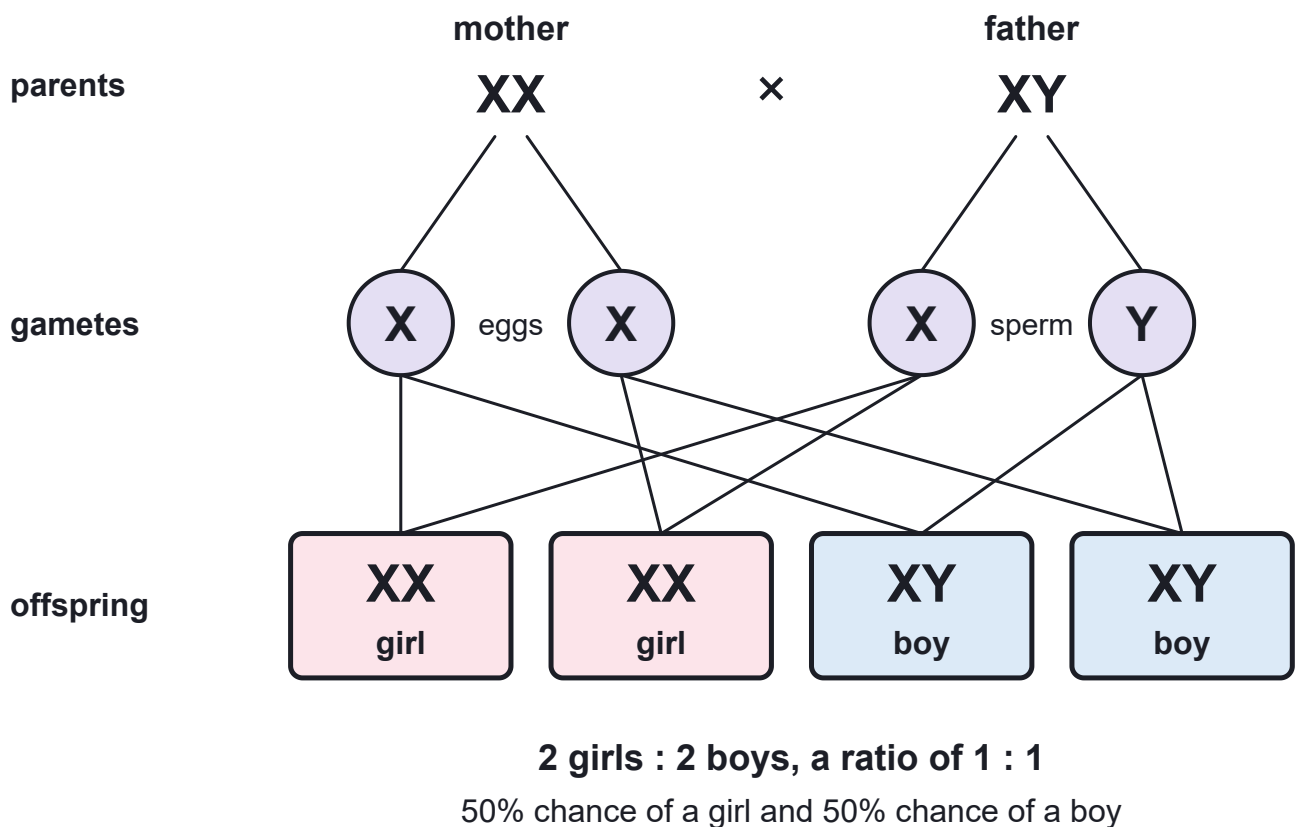
Genetic diagram: inheritance of sex

	Mother (female)	Father (male)
Parental genotypes	XX	XY
Gametes	X and X (every egg carries X)	X and Y (half the sperm carry X, half carry Y)

Punnett square: eggs across the top, sperm down the side

Sperm ↓ Eggs →	X	X
X	XX (girl)	XX (girl)
Y	XY (boy)	XY (boy)

Offspring: 2 XX (girls) : 2 XY (boys). The chance of a baby being a boy is the same as the chance of it being a girl: **1:1**, or 50% each.



Every egg carries X; half the sperm carry X and half carry Y, so the chance of a girl or a boy is **1:1**.

Exam tip: The father decides the sex of the baby, because only his gametes can carry either X or Y. State this in your answer and show the gametes in a genetic diagram.

How genes control proteins Spec 17.1.5, 17.1.6, 17.1.7, 17.1.8 Supplement

Supplement

A gene is a length of DNA. DNA contains a sequence of bases. The **sequence of bases** in a gene determines the **sequence of amino acids** used to make a specific protein.

Supplement

Amino acid sequence and protein shape

Supplement

A protein is a chain of amino acids. Different sequences of amino acids make chains that fold into different **shapes**. Each protein has a shape that suits its job. If the sequence changes, the shape may change, and the protein may no longer work.

Supplement

DNA controls cell function

Supplement

DNA controls cell function by controlling the production of proteins. Examples of proteins include:

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- enzymes, which control the chemical reactions in a cell
- membrane carriers, which move substances across the cell membrane
- receptors for neurotransmitters, which detect chemicals released at synapses

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How a protein is made

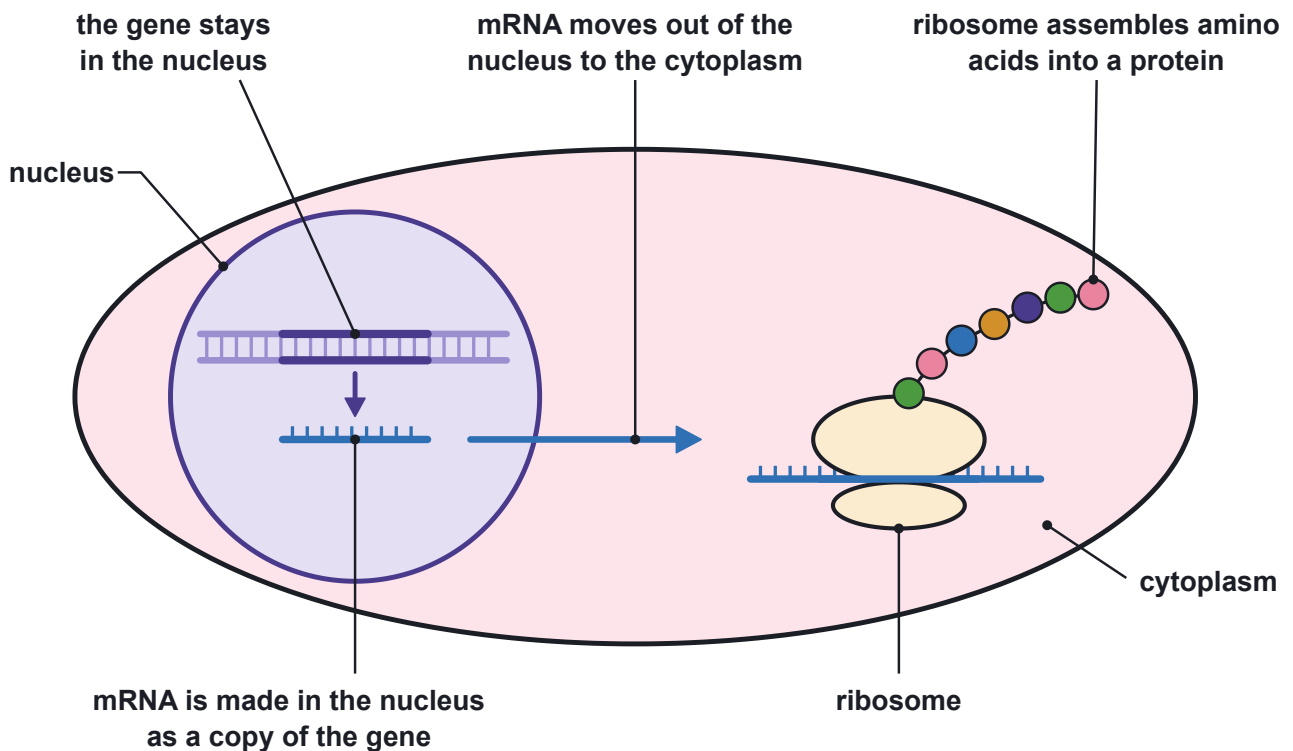
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The gene for a protein stays in the **nucleus**. A copy of the gene is made instead. This copy is called **messenger RNA** (mRNA).

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1. The gene coding for the protein remains in the nucleus.
2. mRNA is made in the nucleus as a copy of the gene.
3. The mRNA molecule moves out of the nucleus to the cytoplasm.
4. The mRNA passes through a ribosome.
5. The ribosome assembles amino acids into a protein molecule.
6. The specific sequence of amino acids is determined by the sequence of bases in the mRNA.

Supplement



The gene stays in the nucleus; an **mRNA** copy carries the code to a **ribosome** in the cytoplasm.

Supplement

Exam tip: Learn the order: gene in nucleus, mRNA copy made, mRNA to cytoplasm, ribosome assembles amino acids. You do not need the details of transcription or translation.

Gene expression, haploid and diploid

Spec 17.1.9, 17.1.10, 17.1.11, 17.1.12

Supplement

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Gene expression

Supplement

Most body cells in an organism contain the **same genes**. However, a cell only makes the specific proteins it needs. Many genes in a particular cell are therefore **not expressed**. For example, a cell in the pancreas makes the protein insulin, but a skin cell has the gene for insulin and does not make it.

Supplement

This is why cells can be different shapes and do different jobs, although they have the same genes.

Supplement

Haploid and diploid nuclei

Supplement

Haploid nucleus	A nucleus containing a single set of chromosomes.
Diploid nucleus	A nucleus containing two sets of chromosomes.

Supplement

In a diploid cell there is a **pair of each type of chromosome**. One chromosome in each pair came from the mother and one came from the father. In a human diploid cell there are **23 pairs** of chromosomes, which is 46 in total. Human gametes are haploid and have 23 chromosomes.

Supplement

Haploid and diploid human cells

	Haploid	Diploid
Sets of chromosomes	one	two
Number of chromosomes in a human cell	23	46 (23 pairs)
Example	sperm cell, egg cell	skin cell, muscle cell

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Common mistake: Say 23 pairs for a diploid cell and 23 chromosomes for a haploid cell. '23 chromosomes' on its own does not tell the examiner whether you mean pairs or a single set.

Quick check

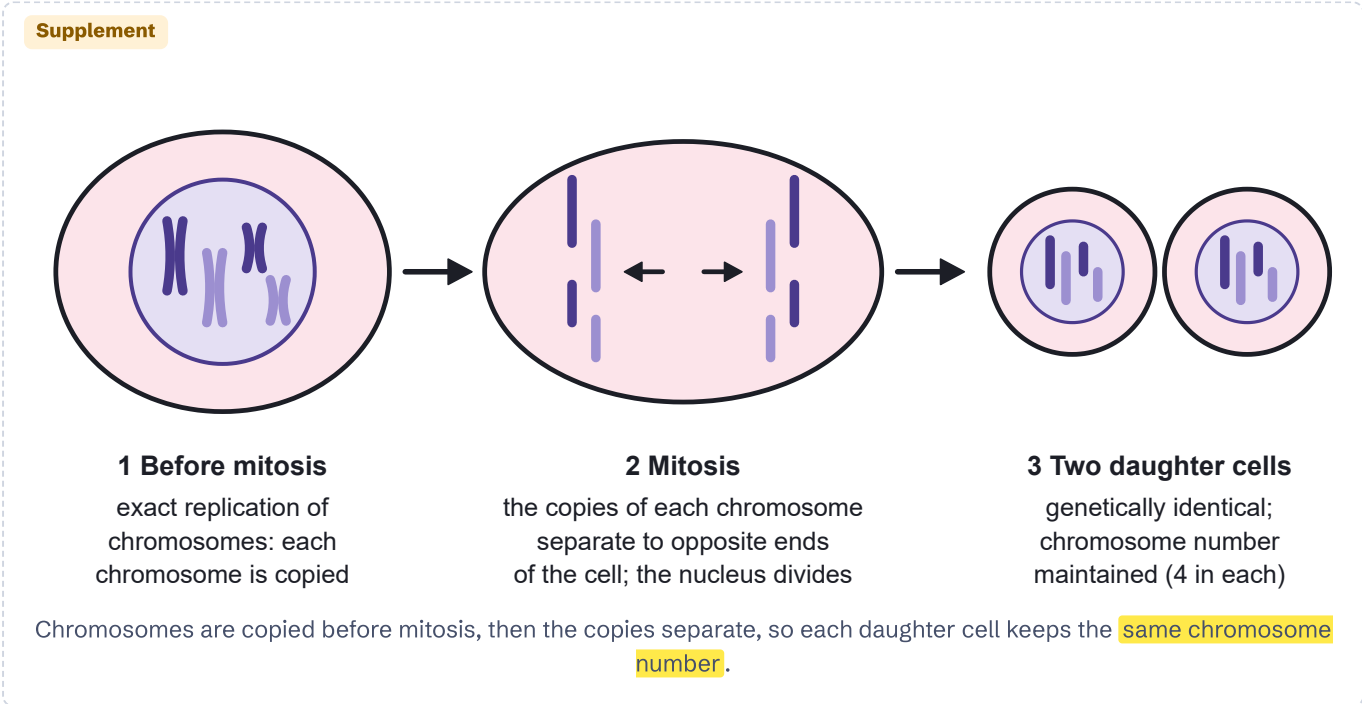
1. Define a gene.
2. Define an allele.
3. Which sex chromosomes do males and females have?
4. **Supplement** What determines the sequence of amino acids in a protein?
5. **Supplement** How many pairs of chromosomes are in a human diploid cell?

2 Mitosis and meiosis Spec 17.2, 17.3 Supplement

Mitosis Spec 17.2.1, 17.2.2, 17.2.3, 17.2.4

Mitosis Nuclear division giving rise to genetically identical cells.

Before a cell divides by mitosis, the chromosomes are copied. The **exact replication of chromosomes** occurs before mitosis, so each chromosome is made of two identical copies. During mitosis the **copies of chromosomes separate**, and one copy goes into each new nucleus. This maintains the **chromosome number** in each daughter cell.



The two daughter cells have the same number of chromosomes and the same genes as the parent cell. A diploid cell divides to make two diploid cells.

The role of mitosis

Roles of mitosis	
Role	Explanation
Growth	more cells are made so that the organism gets bigger
Repair of damaged tissues	new cells replace those that are damaged
Replacement of cells	cells such as skin cells are lost and replaced all the time
Asexual reproduction	one parent makes offspring that are genetically identical to it

Exam tip: Use the phrase 'genetically identical' for mitosis. You do not need the names of the stages of mitosis.

Stem cells Spec 17.2.5

Stem cell An unspecialised cell that divides by mitosis to produce daughter cells that can become specialised for specific functions.

Stem cells are **unspecialised**. They divide by **mitosis** to make daughter cells. Some of these daughter cells stay as stem cells, so the supply is not used up. Others become **specialised** for specific functions,

such as a red blood cell or a nerve cell.

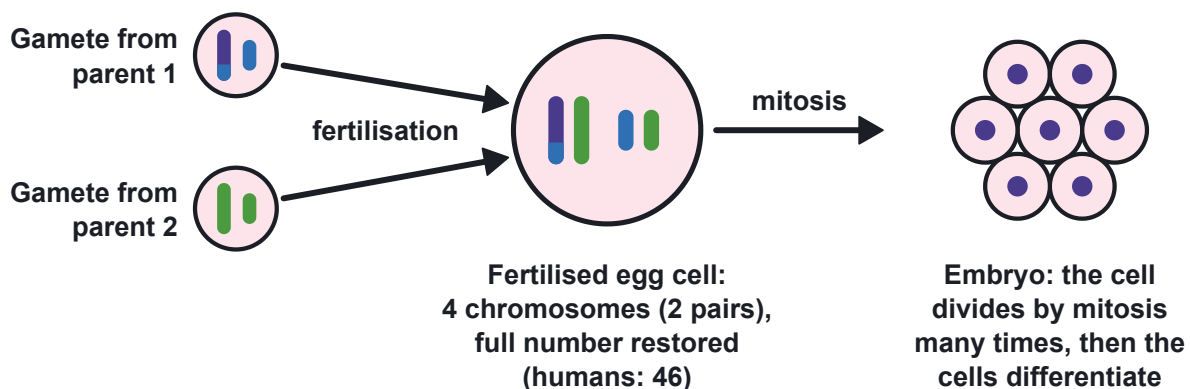
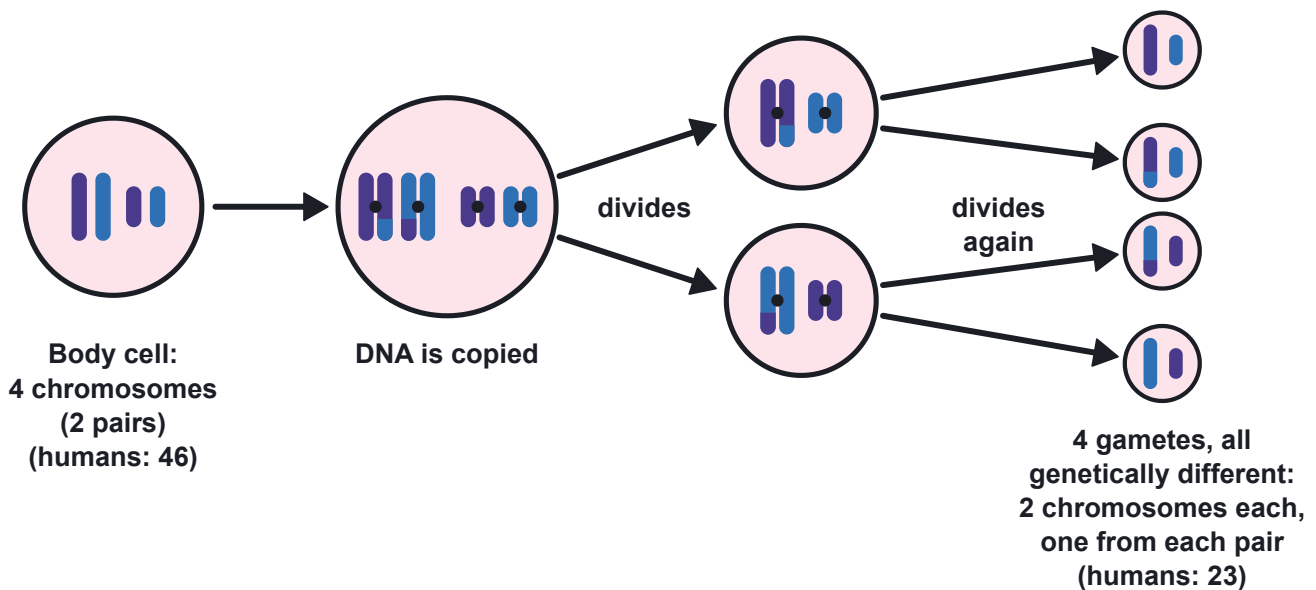
Cells become specialised because only some of their genes are expressed. This links to gene expression: the genes that are switched on decide which proteins the cell makes, and so what the cell can do.

Common mistake: Do not say that stem cells 'turn into' any cell. Say that stem cells divide by mitosis and the daughter cells can become specialised.

Meiosis Spec 17.3.1, 17.3.2

Meiosis is involved in the production of gametes. It takes place in the reproductive organs (the testes and ovaries in humans).

Meiosis is a **reduction division**. The chromosome number is **halved from diploid to haploid**. It results in cells that are **genetically different** from each other and from the parent cell.



Meiosis **halves** the chromosome number in gametes; fertilisation **restores** the full number, then mitosis builds the embryo.

In humans, meiosis makes gametes with 23 chromosomes from a cell with 46 chromosomes. When a sperm fertilises an egg, the full number of 46 chromosomes is restored in the zygote. If gametes were diploid, the chromosome number would double in every generation.

Mitosis compared with meiosis

	Mitosis	Meiosis
Number of daughter cells	2	4
Chromosome number in daughter cells	same as parent (diploid)	half of parent (haploid)
Genetically	identical to the parent	different from each other and the parent
Used for	growth, repair, replacement, asexual reproduction	production of gametes

Exam tip: You do not need the stages of meiosis. Learn the keywords: gametes, reduction division, diploid to haploid, genetically different.

Quick check

1. **Supplement** Define mitosis.
2. **Supplement** State four roles of mitosis.
3. **Supplement** What happens to the chromosomes before mitosis?
4. **Supplement** What is a stem cell?
5. **Supplement** What happens to the chromosome number in meiosis?

3 Monohybrid inheritance Spec 17.4

Key genetic terms Spec 17.4.1, 17.4.2, 17.4.3, 17.4.4, 17.4.5, 17.4.6, 17.4.7, 17.4.8, 17.4.9

Inheritance is the transmission of genetic information from generation to generation. Parents pass genes to their offspring in their gametes, so offspring have features like their parents.

Inheritance	The transmission of genetic information from generation to generation.
Genotype	The genetic make-up of an organism and in terms of the alleles present.
Phenotype	The observable features of an organism.
Homozygous	Having two identical alleles of a particular gene. Example: TT or tt.
Heterozygous	Having two different alleles of a particular gene. Example: Tt.
Dominant allele	An allele that is expressed if it is present in the genotype.
Recessive allele	An allele that is only expressed when there is no dominant allele of the gene present in the genotype.

Dominant alleles are written as capital letters (T) and recessive alleles as lower case letters (t). A heterozygous individual (Tt) shows the dominant feature, because the dominant allele is expressed.

Pure-breeding

Two identical **homozygous** individuals that breed together will be **pure-breeding**. For example, $TT \times TT$ can only give TT offspring, and $tt \times tt$ can only give tt offspring, so every generation looks the same.

A **heterozygous** individual will **not** be pure-breeding. A Tt parent makes two types of gamete (T and t), so its offspring can have different genotypes and different phenotypes.

Exam tip: Genotype is the alleles, such as Tt. Phenotype is what you can see, such as tall. Do not swap them, and do not say a recessive allele is 'weaker'.

Common mistake: Heterozygous and homozygous describe genotypes only. Do not use them for phenotypes.

Genetic diagrams, Punnett squares and pedigrees Spec 17.4.10, 17.4.11, 17.4.12

A **monohybrid cross** looks at the inheritance of one characteristic controlled by a single gene. You show the result using a genetic diagram or a **Punnett square**, which lists the possible gametes and the genotypes they can make.

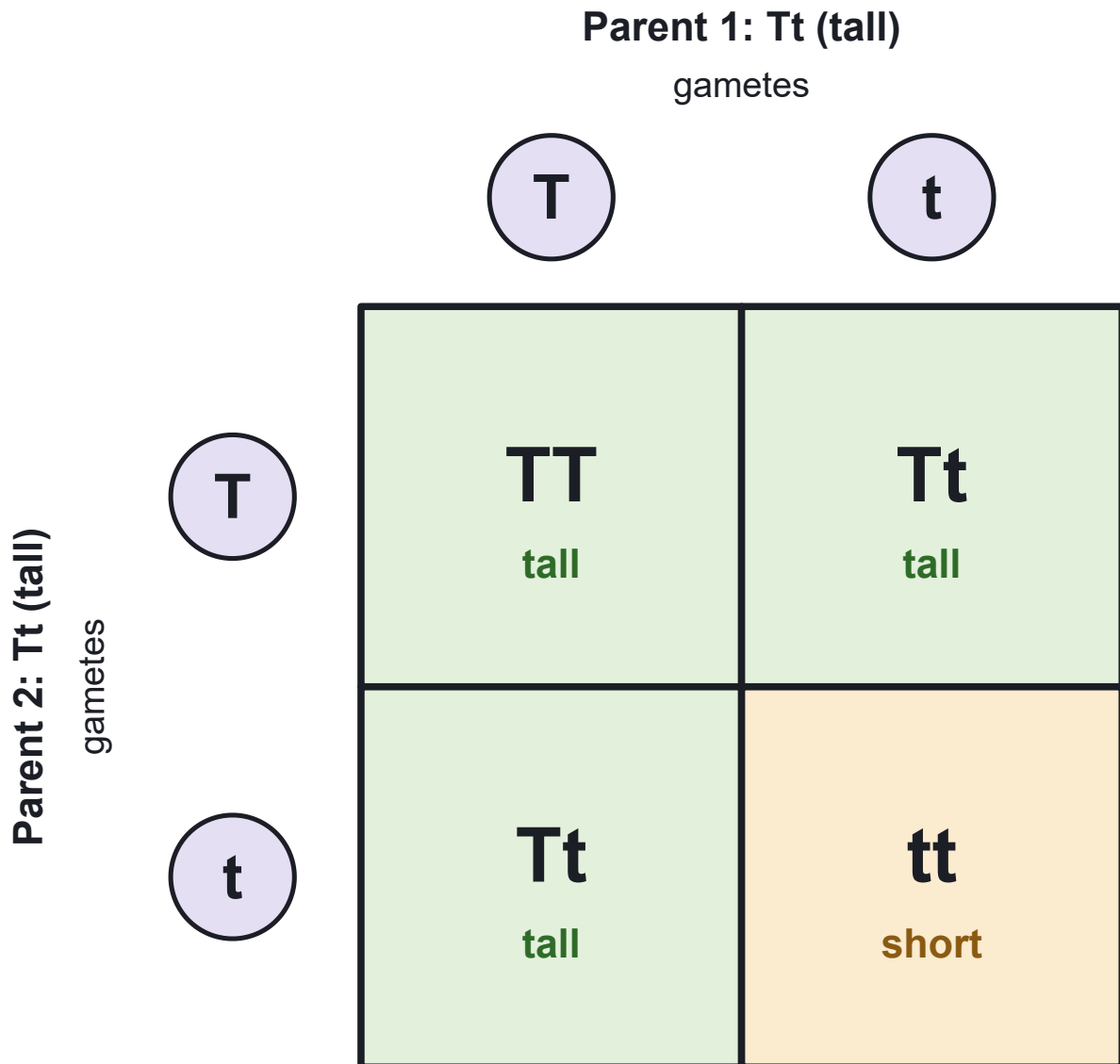
1. Choose letters for the alleles: a capital letter for the dominant allele and the same letter in lower case for the recessive allele.
2. Write the genotypes of the parents.
3. Write the gametes each parent can make. Each gamete has only one allele.
4. Put the gametes along the top and side of a Punnett square and fill in the boxes to show the possible offspring genotypes.
5. Write the phenotype for each genotype and work out the ratio.

Two heterozygous parents (3 : 1)

Tall (T) is dominant to short (t) in pea plants. Two heterozygous tall plants are crossed. Show the possible offspring and the phenotypic ratio.

1. Parents: Tt × Tt.
2. Gametes: T or t from each parent.
3. Punnett square boxes: TT, Tt, Tt, tt.
4. TT and Tt are tall. tt is short.

Answer: Genotypes 1 TT : 2 Tt : 1 tt. Phenotypes 3 tall : 1 short.



Heterozygous × homozygous recessive (1 : 1)

Black fur (B) is dominant to brown fur (b) in guinea pigs. A heterozygous black guinea pig is crossed with a brown one. Show the possible offspring and the phenotypic ratio.

1. Parents: Bb × bb.
2. Gametes: B or b from the first parent; only b from the second.
3. Punnett square boxes: Bb, Bb, bb, bb.
4. Bb is black. bb is brown.

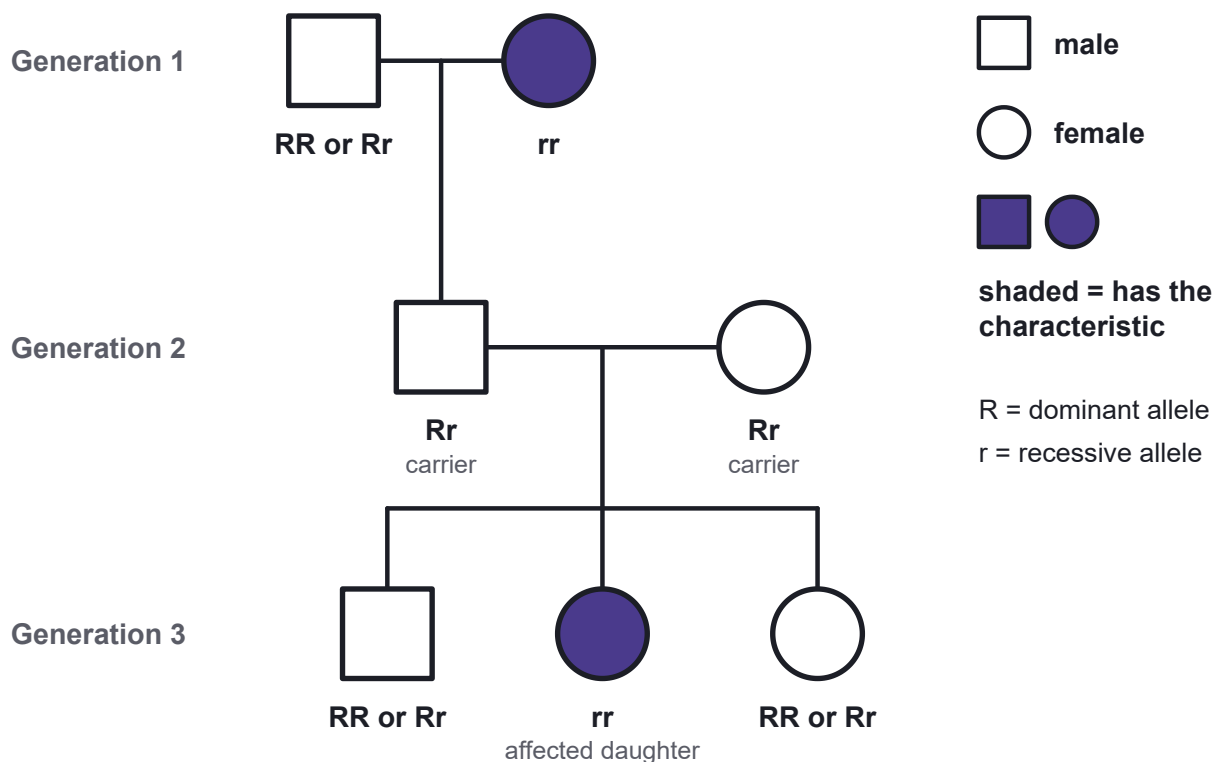
Answer: Genotypes 1 Bb : 1 bb. Phenotypes 1 black : 1 brown.

Exam tip: The ratios you need are 3 : 1 and 1 : 1. Circle the gametes, show every Punnett box, and write the phenotype beside each genotype.

Pedigree diagrams

A **pedigree diagram** (family tree) shows how a characteristic is inherited through a family. Squares are usually males and circles are females. Shaded shapes show people with the characteristic. A horizontal line joins parents and a vertical line leads to their children.

- Two parents **without** a characteristic who have a child **with** it: the characteristic is **recessive**, and both parents are heterozygous (carriers).
- Two parents **with** a characteristic who have a child **without** it: the characteristic is **dominant**, and both parents are heterozygous.



Two unaffected parents with an affected daughter: the characteristic is recessive and both parents are carriers (Rr).

Exam tip: In a pedigree question, find two parents with the same phenotype who have a child with the other phenotype. That tells you which allele is dominant.

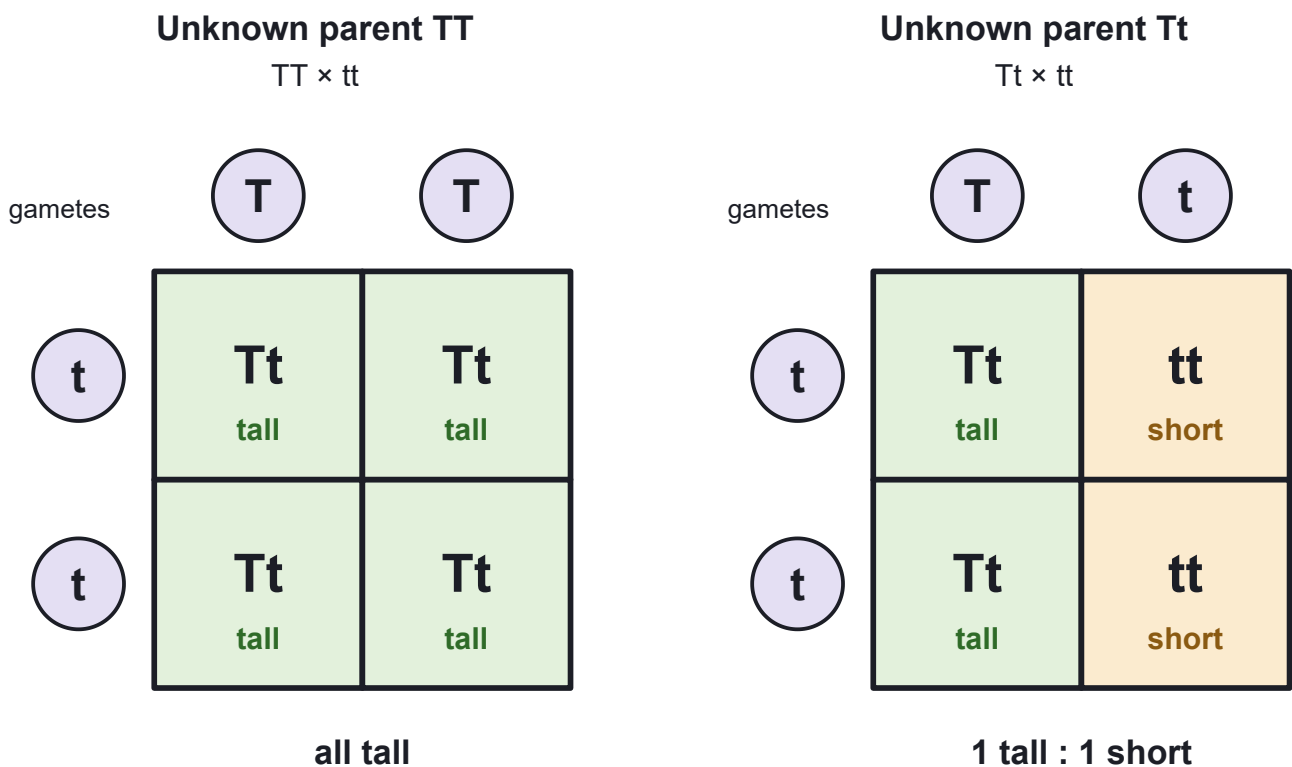
The test cross Spec 17.4.13 Supplement

An organism with the dominant phenotype can be homozygous dominant (TT) or heterozygous (Tt). You cannot tell which by looking at it. A **test cross** finds out the unknown genotype.

1. Cross the organism of unknown genotype with a **homozygous recessive** individual (tt).
2. Collect the offspring and record their phenotypes. A large number of offspring gives a more reliable result.
3. Compare the offspring with the expected results.

Results of a test cross (tall is dominant to short)		
Unknown parent	Cross	Offspring
Homozygous dominant (TT)	TT × tt	All Tt: all tall
Heterozygous (Tt)	Tt × tt	1 Tt : 1 tt: about 1 tall : 1 short

If any offspring show the recessive phenotype, the unknown parent must have been heterozygous, because each parent gave the offspring one recessive allele. If all the offspring show the dominant phenotype, the unknown parent is probably homozygous dominant.



A test cross with a homozygous recessive (tt) plant: any short offspring show that the unknown parent is **heterozygous**.

Exam tip: The tester is always homozygous recessive, because its phenotype tells you its genotype. Say that the offspring show whether the unknown parent has a recessive allele.

Codominance and ABO blood groups Spec 17.4.14, 17.4.15 Supplement

In **codominance**, both alleles in heterozygous organisms contribute to the phenotype. Neither allele is hidden and the two do not blend.

The ABO blood group is controlled by one gene with three alleles: I^A , I^B and I^o . Exam papers print the A, B and o as small raised letters after the I. A person inherits two alleles, one from each parent. **I^A and I^B are codominant**. I^o is recessive to both.

ABO blood groups

Phenotype (blood group)	Possible genotypes
A	$I^A I^A$ or $I^A I^o$
B	$I^B I^B$ or $I^B I^o$
AB	$I^A I^B$
O	$I^o I^o$

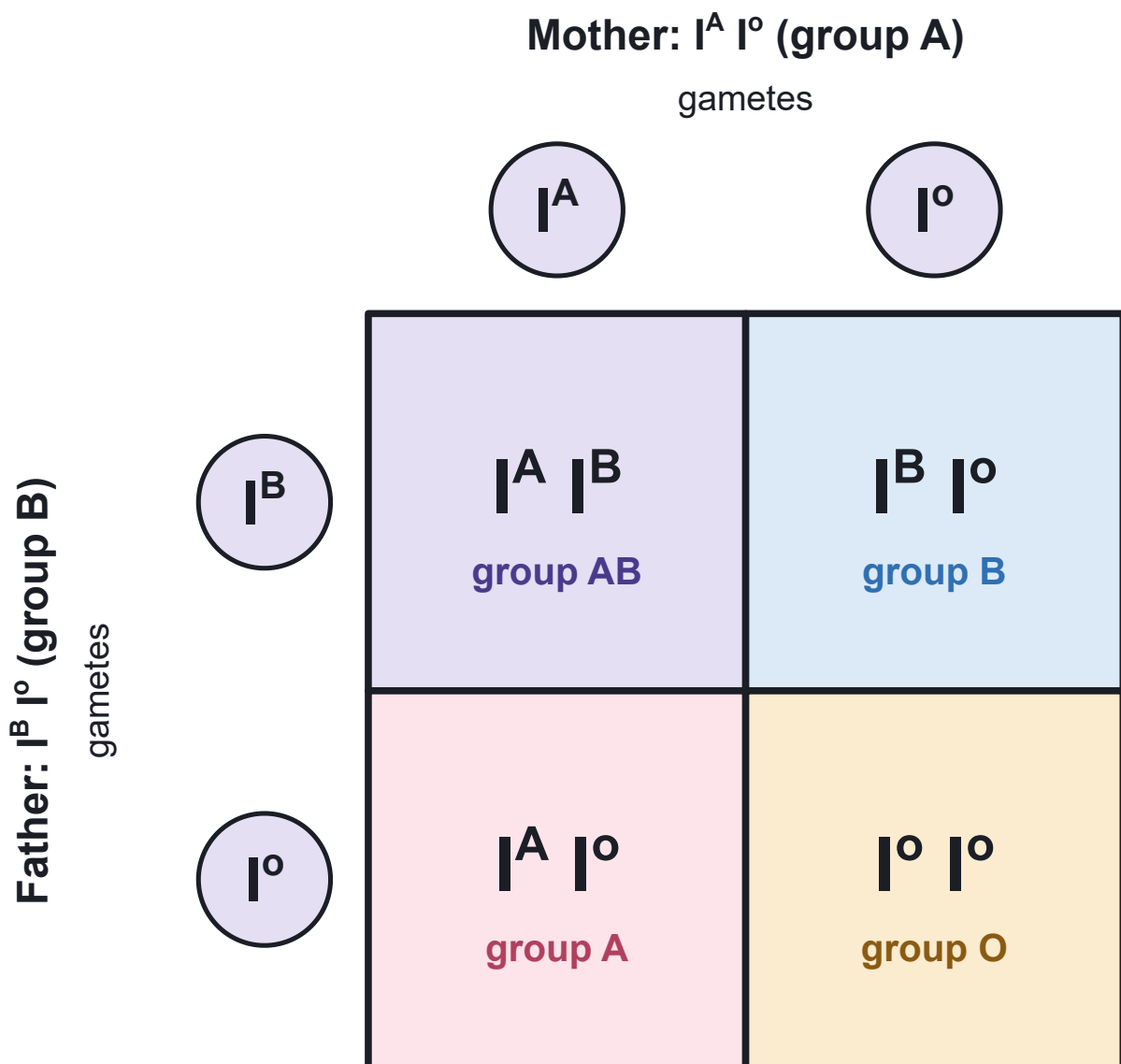
Group A mother and group B father

A mother is $I^A I^o$ and a father is $I^B I^o$. Which blood groups could their children have?

1. Mother's gametes: I^A or I^o . Father's gametes: I^B or I^o .
2. Punnett square boxes: $I^A I^B$, $I^A I^o$, $I^B I^o$, $I^o I^o$.

Answer: Group AB, A, B and O, each with probability 1 in 4 (25%), a ratio of 1 : 1 : 1 : 1.

Exam tip: $I^A I^B$ gives group AB because both alleles are expressed. Group O needs two I^o alleles.



$I^A I^o \times I^B I^o$ can give children of **all four blood groups**, each with a probability of 1 in 4.

Sex linkage and colour blindness Spec 17.4.16, 17.4.17, 17.4.18 Supplement

A **sex-linked characteristic** is a feature in which the gene responsible is located on a sex chromosome. This makes the characteristic more common in one sex than in the other.

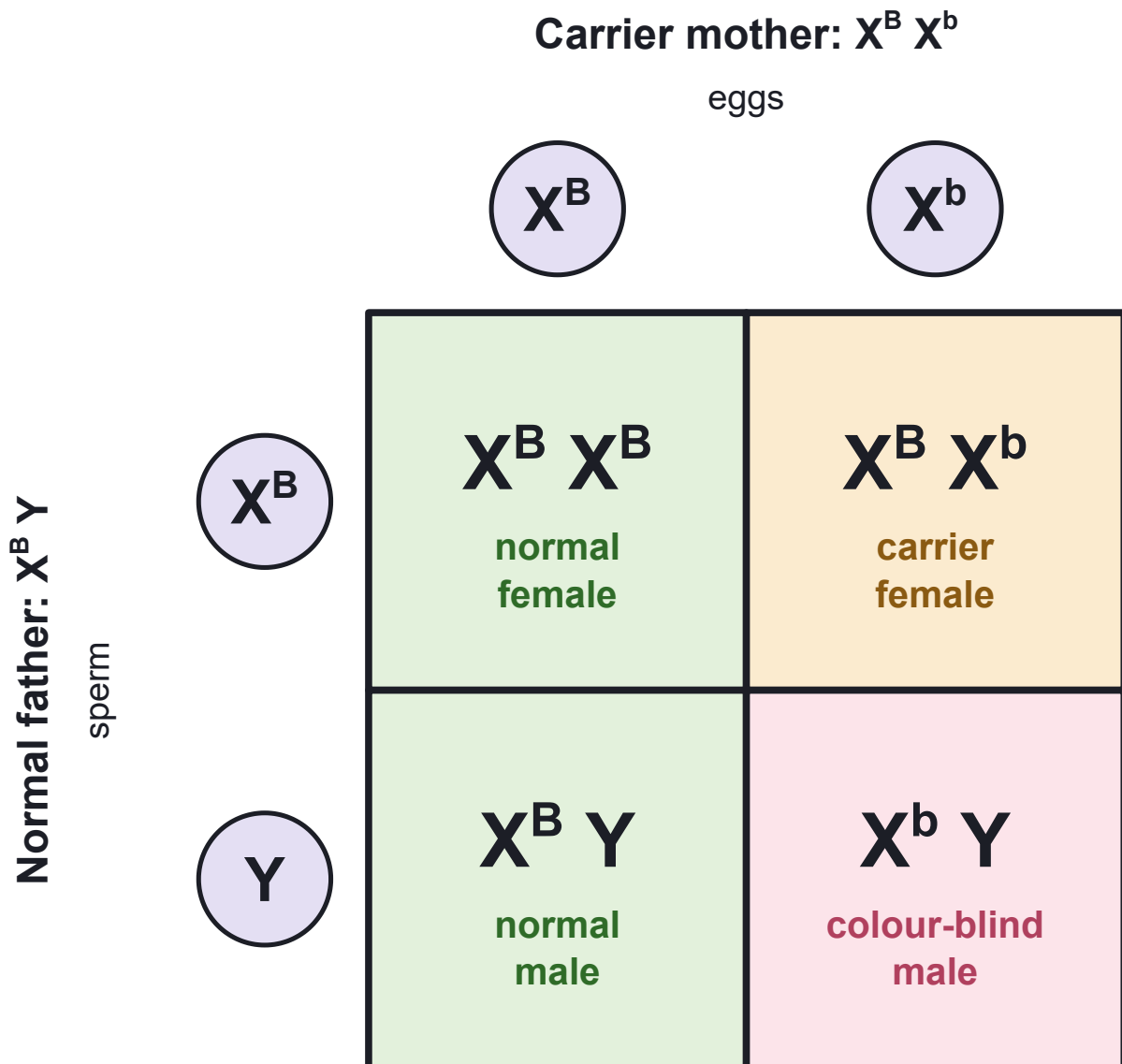
Red-green colour blindness is an example. The gene is on the X chromosome and the allele for colour blindness is recessive. The Y chromosome does not carry this gene.

- Males (XY) have only one X chromosome, so one recessive allele is enough to make them colour blind.
- Females (XX) need two recessive alleles to be colour blind. With one, they are **carriers** and have normal colour vision.
- So colour blindness is more common in males than in females.

Write the allele letter straight after the X: X^B is the normal allele and X^b is the colour blindness allele. Exam papers print the B or b as a small raised letter. The Y has no allele, so a male genotype is $X^B Y$ or $X^b Y$.

Carrier mother ($X^B X^b$) × normal father ($X^B Y$)		
	X^B (egg)	X^b (egg)
X^B (sperm)	$X^B X^B$ normal female	$X^B X^b$ carrier female
Y (sperm)	$X^B Y$ normal male	$X^b Y$ colour-blind male

The probability that a son is colour blind is 1 in 2 (50%). None of the daughters is colour blind, but half are carriers. Phenotypic ratio: 2 normal females : 1 normal male : 1 colour-blind male.



Half of the sons are expected to be **colour blind**; none of the daughters is, but half are carriers.

Exam tip: Always write sex-linked genotypes with X and Y and put the allele letter on the X. Write $X^b Y$, not bb , for a colour-blind male.

Quick check

1. Define phenotype.
2. What is a heterozygous genotype?
3. Two parents without a condition have a child with it. Is the allele dominant or recessive?
4. **Supplement** Which genotype is used as the tester in a test cross?
5. **Supplement** Why is red-green colour blindness more common in males?

Quick check answers

Chromosomes, genes and proteins

1. A length of DNA that codes for a protein.
2. An alternative form of a gene.
3. Males are XY; females are XX.
4. The sequence of bases in the gene.
5. 23 pairs.

Mitosis and meiosis

1. Nuclear division giving rise to genetically identical cells.
2. Growth, repair of damaged tissues, replacement of cells, asexual reproduction.
3. They are copied exactly (replicated).
4. An unspecialised cell that divides by mitosis to produce daughter cells that can become specialised.
5. It is halved, from diploid to haploid.

Monohybrid inheritance

1. The observable features of an organism.
2. Two different alleles of a particular gene, for example Tt.
3. Recessive, and both parents are heterozygous carriers.
4. Homozygous recessive.
5. Males have one X chromosome, so one recessive allele is enough. Females need two.