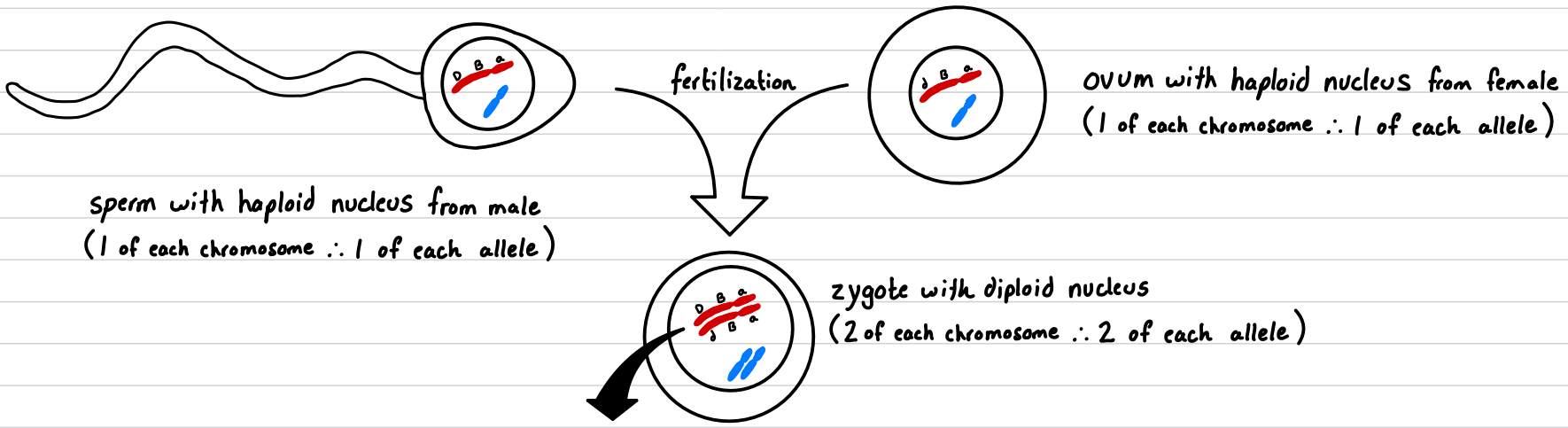
Inheritance

Learning Outcomes

- *17.4.1* – **Describe** inheritance as the transmission of genetic information from generation to generation
- *17.4.2* – **Describe** genotype as the genetic make-up of an organism and in terms of the alleles present
- *17.4.3* – **Describe** phenotype as the observable features of an organism
- *17.4.4* – **Describe** homozygous as having two identical alleles of a particular gene
- *17.4.5* – **State** that two identical homozygous individuals that breed together will be pure-breeding
- *17.4.6* – **Describe** heterozygous as having two different alleles of a particular gene
- *17.4.8* – **Describe** a dominant allele as an allele that is expressed if it is present in the genotype
- *17.4.9* – **Describe** a recessive allele as an allele that is only expressed when there is no dominant allele of the gene present in the genotype
- *17.4.10* – **Interpret** pedigree diagrams for the inheritance of a given characteristic
- *17.4.11* – Use genetic diagrams to **predict** the results of monohybrid crosses and **calculate** phenotypic ratios, limited to 1 : 1 and 3 : 1 ratios
- *17.4.12* – Use Punnett squares in crosses which result in more than one genotype to work out and show the possible different genotypes
- *17.4.13* – **Explain** how to use a test cross to identify an unknown genotype
- *17.4.14* – **Describe** codominance as a situation in which both alleles in heterozygous organisms contribute to the phenotype
- *17.4.15* – **Explain** the inheritance of ABO blood groups: phenotypes are A, B, AB and O blood groups and alleles are I^A, I^B and I^o
- *17.4.16* – **Describe** a sex-linked characteristic as a feature in which the gene responsible is located on a sex chromosome and that this makes the characteristic more common in one sex than in the other
- *17.4.17* – **Describe** red-green colour blindness as an example of sex linkage
- *17.4.18* – Use genetic diagrams to **predict** the results of monohybrid crosses involving codominance or sex linkage and **calculate** phenotypic ratios

Single-Factor Inheritance

Inheritance : the transmission of genetic information from generation to generation (i.e. from parent to offspring)



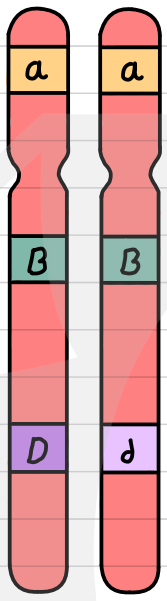
Genotype : genetic make-up of an organism in terms of alleles present

Phenotype : observable features of an organism the expression of the genotype

Dominant alleles are always expressed in the phenotype - they mask the expression of recessive alleles

recessive alleles are only expressed in phenotype in the absence of a dominant allele

homologous chromosomes



homozygous recessive : two identical recessive alleles of a particular gene
↳ as there is no Dominant allele, recessive allele is not masked and is expressed in the phenotype

homozygous Dominant : two identical Dominant alleles of a particular gene
↳ Dominant allele expressed in phenotype

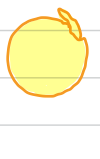
heterozygous : two different alleles of a particular gene
↳ Dominant allele masks expression of recessive allele and only Dominant allele expressed in phenotype

Notes:
- ↳ alleles are typically represented by single letters of dominant allele
- ↳ alleles controlling the same characteristic are given the same letter
- ↳ dominant allele is given the capital letter, recessive lower case

ex: in rabbits, the allele for black fur is dominant to the allele for white fur for the gene controlling fur colouration
- ✓ Black - B × Black - Bl this implies two genes
- ✓ white - b × white - w this implies different gene

Example: A pea plant produces peas that are smooth. Another plant produces peas that are wrinkled When the gene responsible for pea shape was analyzed in both, it was found that the allele for wrinkled was found in both. Deduce the genotype for both plants

Because the allele for wrinkled was found in both but only expressed in one the plants, it must be recessive to smooth.
Since the smooth pea plant has different alleles for the same gene, it is heterozygous (Ss)
Since the wrinkled pea plant is expressing a recessive allele, it must be homozygous recessive (ss)

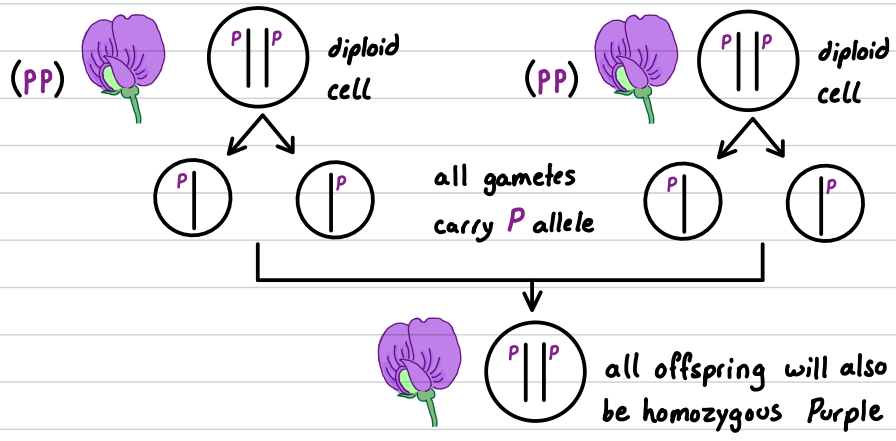


* The genotypes above are examples of <u>single-factor inheritance</u>, where the expression of a trait is controlled by a single gene. It is worth noting that most characteristics are not like this but controlled by many genes

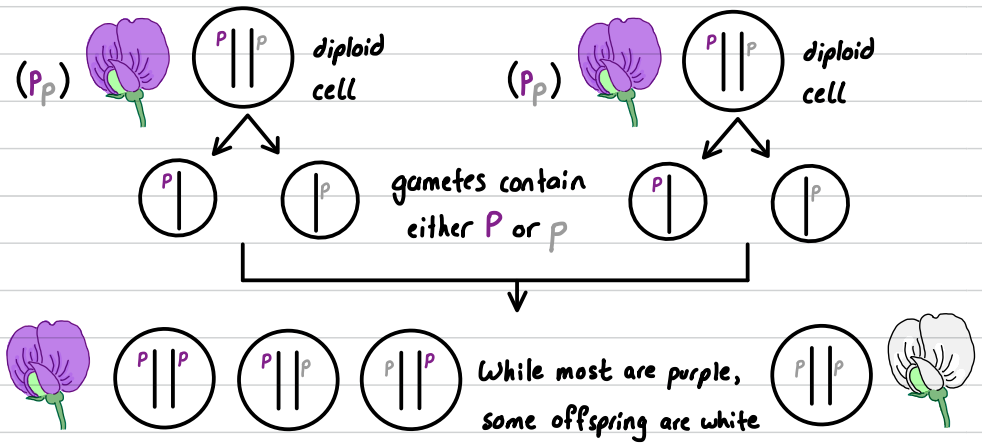
Pure breeds : refers to individuals that are homozygous for a gene as they will always pass down the same allele to their offspring thus the offspring will always express the same phenotype as their parents

ex: In pea plants, flower colour is controlled by one gene where the allele for purple is dominant (P) to white (p)

If two pure-breed purple plants were crossed all the offspring will be purple



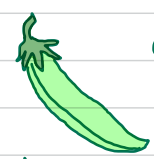
If two non-pure bred purple plants were crossed the offspring may inherit P allele or p allele



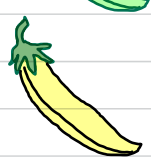
Monohybrid Crosses

Monohybrid cross: cross between two organisms with different genotypes for <u>one</u> particular gene
<u>ex</u>: AA × aa AA × Aa Aa × aa

Punnett square: (named after geneticist Reginald C. Punnett) is a diagram used to predict genotypes of a cross



Green pod colour is Dominant (G)



Yellow pod colour is recessive (g)

Heterozygous green pea plant (Gg)

×

homozygous white pea plant (gg)

	G	g
g	Gg	gg
g	Gg	gg

each square represents 25% chance of an offspring having that genotype

parent's genotype

50% chance of having green pods

50% chance of having yellow pods

1:1 ratio

<u>How to predict the probability of genotypes</u>

Example

In squirrels, grey fur is dominant and brown fur is recessive. A brown female is crossed with a homozygous grey male
Deduce the phenotypic and genotypic ratio of potential offspring as well as the likelihood their offspring will be brown.

① write the given information

male ♂ phenotype: grey
genotype: GG

female ♀ phenotype: brown
genotype: gg

② draw Punnett square with parent genotypes

	G	G
g		
g		

③ Drop down the alleles to each box

	G	G
g		
g		

④ Each box represents 25%

	G	G
g	Gg	Gg
g	Gg	Gg

100% chance of grey

0% chance of brown

phenotypic ratio Grey : brown = 1:0
genotypic ratio GG : Gg : gg = 0 : 1 : 0

Example

Brown eyes is dominant to blue eyes. A brown eyed man, whose mother has blue eyes marries a blue eyed woman.
Deduce the probability that their offspring will have blue eyes.

male ♂ phenotype: brown
genotype: BB or Bb → mother: bb, must pass b allele to son, ∴ Bb
female ♀ phenotype: blue
genotype: bb

	B	b
b	Bb	bb
b	Bb	bb

50% chance of brown
50% chance of blue
phenotypic ratio brown : blue = 1 : 1
genotypic ratio BB : Bb : bb = 0 : 1 : 1

Test Crosses

Example

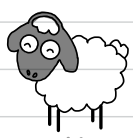
In sheep, black wool is dominant to white wool.
If you see a white sheep, it is easy to deduce its genotype: as it's expressing the recessive allele, it must be homozygous recessive (bb)
<u>but</u> if you see a black sheep, its genotype is not certain.

↳ <u>solution</u> **test cross**: crossing unknown genotype with a homozygous recessive in order to see if recessive allele becomes expressed in offspring

① cross the unknown dominant genotype with homozygous recessive

BB or Bb

×



bb

will always be masked
· phenotype of offspring reflect other parent

if unknown is BB

	B	B
b	Bb	Bb
b	Bb	Bb

100% of offspring black

if unknown is Bb

	B	b
b	Bb	bb
b	Bb	bb

50% Black
50% white

② Repeat cross many times and examine large number of offspring

<u>note</u>: probabilities are random independent events
50% black could still mean out of 4 offspring all are black. Unlikely, but possible

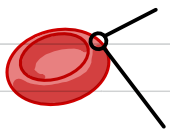
ex: coin flips are ~50/50 but it's possible to flip heads 5 times in a row

Co-Dominance

Co-dominance: both alleles in heterozygous genotypes are expressed in the phenotype. Neither is dominant or masks the other

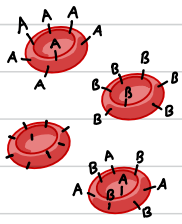
↳ **ABO blood groups**

the ABO gene codes for red blood cell antigens



3 types:

		coded by 3 alleles:	
A	A antigen	I^A	I^A and I^B are co-dominant
B	B antigen	I^B	
O	O antigen	I^O (also shown as i)	I^O is recessive to I^A and I^B

Blood group	Phenotype	RBC antibody	Genotype
A	 A antigen	anti-B	I^AI^A or I^AI^O
B	B antigen	anti-A	I^BI^B or I^BI^O
O	O antigen	anti-B and anti-A	I^OI^O
AB	A and B antigens	none	I^AI^B

Example: A man is type AB and his wife is heterozygous B. What is the phenotypic and genotypic ratio of their potential offspring?

male phenotype: AB
♂ genotype: I^AI^B
female phenotype: B
♀ genotype: I^BI^O

	I^A	I^B
I^B	I^AI^B	I^BI^B
I^O	I^AI^O	I^BI^O

25% type A
50% type B
25% type AB

phenotypic ratio A:B:O:AB = 1:2:0:1
genotypic ratio I^AI^O:I^BI^B.I^BI^O:I^AI^B = 1:1:1:1

Example: Alice has blood type A blood and her husband has blood type B blood. Their first child, Amanda, has type O blood. Their second child has type AB blood. Deduce the genotype of both Alice and her husband

Alice phenotype: Type A
genotype: I^AI^A or I^AI^O
husband phenotype: Type B
genotype: I^BI^B or I^BI^O

Amanda phenotype: Type O
genotype: I^OI^O

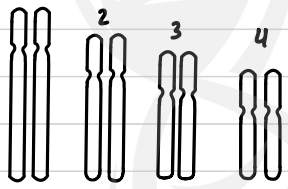
must recieve a recessive I^O allele from each parent

	I^A	I^O
I^B	I^AI^B	I^BI^O
I^O	I^AI^O	I^OI^O ← Amanda

Alice's genotype: I^AI^O
husband's genotype: I^BI^O

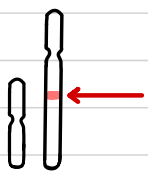
Sex-Linkage

Both males and females have the same amount of **autosomes**, in humans it's 22 pairs



Sex chromosomes differ in males  and females 

Sex linkage: gene located on a sex chromosome (X or y) thus, the pattern of inheritance differs between males and females



X-linked means gene found on X chromosome

females have homologous X chromosomes → two copies of allele → inheritance pattern similar to autosomal traits
males only have 1 X chromosome → single copy of allele → if allele present, always expressed
∴ recessive phenotype more common

Y X

↳ **Red-green colour blindness**

The gene that codes for red-green colour-detecting pigments for photoreceptors in the eye is located on the X chromosome The recessive allele is a mutant, which does not properly produce the pigments, causing red and green to look similar

2 alleles: X^N normal colour vision - Dominant
X^n red-green colour blindness - recessive

Genotype	X^Ny	X^ny	X^NX^N	X^nX^n	X^NX^n → carrier: has the mutant recessive allele but does not express it
Phenotype	normal ♂	colour-blind ♂	normal ♀	colour-blind ♀	normal ♀

Example: A colour-blind woman and normal vision man want to have children What is the probability of:
a) having a colour-blind child b) colour blind girl c) colour-blind boy

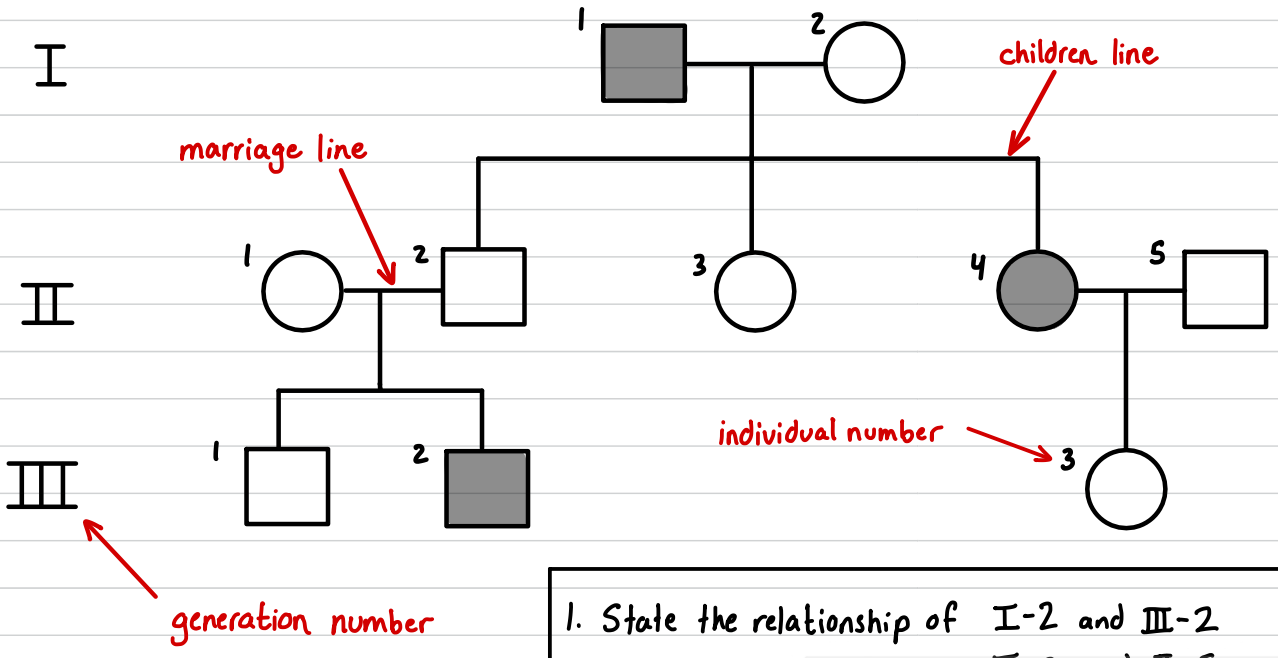
male phenotype: normal
♂ genotype: X^Ny
female phenotype: colour-blind
♀ genotype: X^nX^n

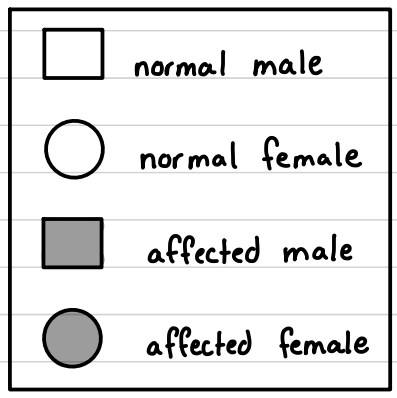
	X^N	y
X^n	X^NX^n	X^ny
X^n	X^NX^n	X^ny

50% chance of child with colour-blindness
0% chance of girl with colour-blindness → girls are carriers but dont express it
100% chance of boy with colour-blindness → boys guaranteed to have it as they inherited X^n from mother

Pedigrees

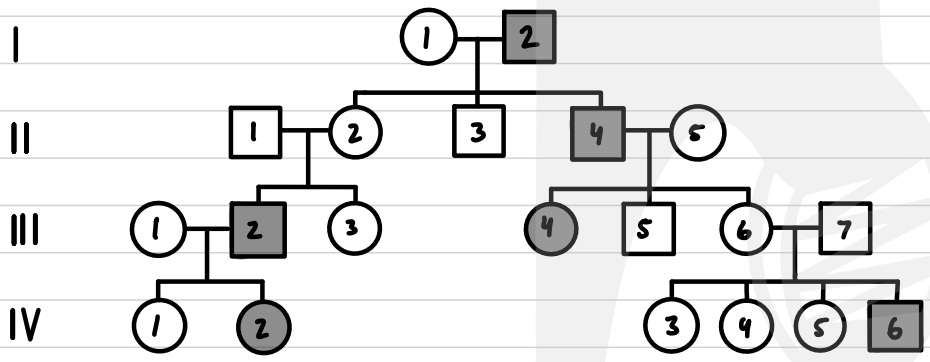
Pedigree: a chart visually showing a pattern of inheritance across generations





1. State the relationship of I-2 and III-2 — grandmother and grandson
   II-2 and II-5 — brother-in-law
   III-1 and III-3 — 1st cousins
2. How many children did I-1 and I-2 have? — 3
3. The disorder is autosomal recessive.
   Deduce all genotypes of I and II generation
   I-1 ee I-2 Ee, as if EE nobody in II would be affected
   II-1 Ee II-2 Ee II-3 Ee II-4 ee II-5 EE or Ee
   III-1 EE or Ee III-2 ee III-3 Ee

Deducing the type of inheritance of a condition can be done through analysis



Is the shaded trait autosomal dominant or recessive?

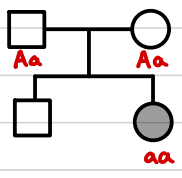
the trait is recessive

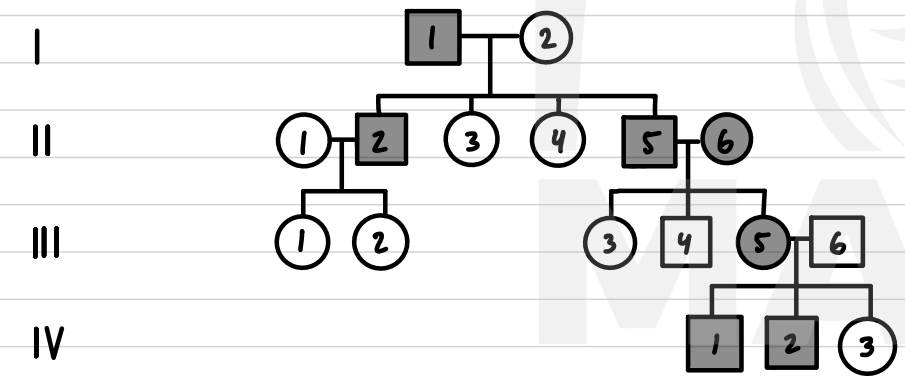
If it was dominant, II-1 and II-2 would be aa

and it would be impossible to have a child affected (III-2)

autosomal recessive patterns

- if both parents of an affected individual are unaffected, they must be heterozygous
- if both parents are affected, all offspring must be affected (aa)





Is the shaded trait autosomal dominant or recessive?

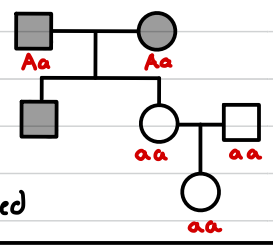
the trait is Dominant

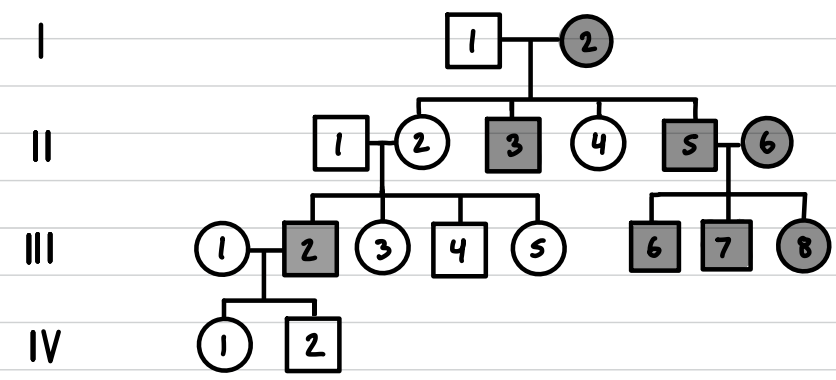
If the trait is recessive, than II-5 and II-6 would be aa

it would be impossible to have a child unaffected (III-3 and III-4)

autosomal Dominant patterns

- every affected individual has at least one affect parent - can't skip generations
- if both parents are affected and offspring is unaffected, parents must be heterozygous
- if both parents unaffected, offspring unaffected





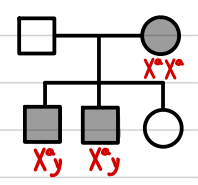
Is the shaded recessive trait autosomal or X-linked?

trait is X-linked recessive

only time female is affected is when both parents carry the recessive allele (X^a) as females need 2 copies to be affected

X-linked recessive patterns

- all sons of affected mothers are affected
- unaffected mother (carrier) can have affected sons
- males tend to be more commonly affected
  * can't be confirmed but suggested



Assessment Tasks

Answer the following questions:

(1) For the following crosses.

i) Determine the phenotype and genotype of the parents
ii) Draw a Punnett square of the cross
iii) Determine the phenotypic ratio of offspring
iv) Determine the genotypic ratio of offspring

a) Hornless (H) in cattle is dominant over horned (h). A horned bull is mated with a homozygous hornless cow

b) In tomatoes, red fruit (R) is dominant over yellow fruit. A heterozygous red is crossed with yellow.

c) In guinea pigs, short hair (S) is dominant over long (s). Two heterozygous short hairs mated

d) In chickens, black feathers (C^B) is co-dominant to white (C^W). A white rooster mated with a white/black chicken

e) Man has type O blood has children with an AB woman.

f) Red-green colour blindness is sex-linked recessive in humans (X^n). A colour blind male and carrier female

(2) Sickle-cell anemia is a co-dominant trait with two different alleles: Hb^A (normal) and Hb^S (sickle cell)

a) Using research, provide all possible phenotypes with their corresponding genotypes

b) In a malaria-prevalent area, which genotype is ideal? Explain.

(3) Using your understanding of antigens and antibodies, explain and justify which blood type is

a) the universal donor

b) the universal recipient

(4) A woman has type B blood and her husband has AB blood. Is it possible for them to have a child with O. Explain

(5) Draw a 3 generation pedigree chart clearly showing the inheritance of a sex-linked recessive disorder. Start with an affected male and unaffected female

(6) Analyze the 3 pedigrees on the previous page. For each, deduce as many of the genotypes as possible

(7) The pedigree below shows the inheritance of fur colour in mice.

a) deduce which characteristic is dominant

b) deduce the genotypes of as many individuals as possible