Full Name:	Civics group: 21S	Index no.:	Date:

Core Idea 2: Genetics and Inheritance

Dihybrid cross & Test Cross
Tutorial 13

QUESTION 1

A homozygous white-flowered, long-stemmed tobacco plant, *Nicotiana affinis*, was crossed with homozygous pink flowered, short-stemmed plant. The alleles for white flower and long stem are dominant to those for pink flower and short stem.

Tip: When 2 homozygous parents of contrasting traits are crossed, traits observed in F1 are dominant traits.

The above cross gave rise to the F1 generation. The F1 plants were selfed to produce the F2 generation. Using suitable symbols, construct a genetic diagram to illustrate the outcome of the above crosses.

F1 x F1 cross

……[6]

Key:
Let W represent the allele for white flowers.
Let w reresent the allele for pink flowers.
Let L represent the allele for long stems.
Let l represent the allele for short stems.

The allele for white flowers (W) is dominant to allele for pink flowers (w).
The allele for long stems (L) is dominant to allele for short stems (l).

Parental phenotypes: white flowers, long stems x pink flowers, short stems
Parental genotype: WWLL wwll
Parental gametes: WL wl

F1 genotypes: WwLl
F1 phenotypes: All white flowers, long stems

Selfing F1: WwLl x WwLl
F1 gametes: WL Wl wL wl WL Wl wL wl

F1 genotype, determined by Punnett square:

Punnett square showing fusion of F1 gametes:

	WL	Wl	wL	wl
WL	WWLL White, long stem	WWLl White, long stem	WwLL White, long stem	WwLl White, long stem
Wl	WWLl White, long stem	WWll White, short stem	WwLl White, long stem	Wwll White, short stem
wL	WwLL White, long stem	WwLl White, long stem	wwLL Pink, long stem	wwLl Pink, long stem
wl	WwLl White, long stem	Wwll White, short stem	wwLl Pink, long stem	wwll Pink, short stem

If no punnett sq:

1 WWLL	1 WWll	1wwLL	1wwll
2 WWLl	2 Wwll	2 wwLl	
4 WwLl			
2 WwLL			

F2 phenotypes: White, long stem: White, short stem : pink, long stem: pink, short stem

F2 phenotypic ratio: 9 : 3 : 3 : 1

[Total: 6]

Mark scheme:

1 Key
2 Parental genotypes
3 Parental gametes – (Gametes **must** be circled)
4 F1 genotype
5 F1 phenotypic ratio

Tip: Points in yellow are likely areas awarded marks. Always provide a full presentation of answers.

Selfing:

6 F1 genotypes (both heterozygous)
7 F1 gametes – (Gametes **must** be circled)
8 F2 genotypes / Punnett square
9 Genotypes correspond to phenotypes / legend for Punnett square
10 F2 phenotypic ratio
11 Correct presentation of genetic diagram (correct sequence of presentation)

QUESTION 2

In rumbunnies, facial warts (W) is dominant to smooth face (w) and freckled face (F) is dominant to freckle-less face (f). Rumbunnies that are heterozygous for both facial warts and freckles were crossed with smooth-faced and freckle-less rumbunnies.

The resultant offspring were as follows:

Phenotype	No. of rumbunnies
Wild phenotype (facial warts, facial freckles)	45
Facial warts, freckle-less	48
Smooth face, freckle-less face	46
Smooth face, Facial freckles	51

Question: What kind of cross involves crossing a Rumbunny showing dominant phenotypes with another which is homozygous recessive?

(a) Draw a genetic diagram to show the cross described.

……[5]

Key: (Given for this question)
Let W represent the allele for facial warts.
Let w represent the allele for smooth face.
Let F represent the allele for facial freckles.
Let f represent the allele for freckle-less face.

*If symbols are provided in the question, students do **not** need to write out the key*

The allele for freckled face (F) is dominant to allele for freckle-less face (f).
The allele for facial warts (W) is dominant to allele for smooth face (w).

Parental phenotypes: Facial Warts, Freckled face x Smooth face, Freckle-less

Parental genotype: WwFf wwff

Parental gametes: (WF) (Wf) (wF) (wf) (wf)

F1 genotype, determined by Punnett square:

	(WF)	(Wf)	(wF)	(wf)
(wf)	WwFf Facial Warts, Facial Freckles	Wwff Facial Warts, Freckleless	wwFf Smooth face, Facial Freckles	wwff Smooth face, Freckle-less

F_1 phenotypes: Facial Warts, Facial Freckles ; Facial Warts, Freckleless ; Smooth face, Facial Freckles ; Smooth face, Freckleless

F_1 phenotypic ratio: 1 : 1 : 1 : 1

Mark scheme:

1 Parental phenotype
2 Parental genotypes
3 Parental gametes – (Gametes **must** be circled)
4 Progeny genotypes / Punnett square
Genotypes correspond to phenotypes / legend for Punnett square
5 F_1 phenotypic ratio

(b) If you are given a Rumbunny with Facial Warts and Facial Freckles, explain how you would derive its actual genotype.

……[5]

Tip: Suggest a method, and provide what's expected to be observed in phenotypic ratios. This allows a way to deduce the genotype clearly.

1 Perform a test cross between this Rumbunny with unknown genotype (W_F_) with one that is **homozygous recessive** for both traits (wwff) ;
2 Obtain a large number of progeny *(explanation of large number : Use of large sample size for reliability of results*);
to determine the **offspring phenotypic ratio** ;

3 Deduce the genotype of the rumbunny based on the phenotypic ratio according to the predicted results in the table below:

4 (2 marks) list all possible genotype and phenotypic ratio

Case	Possible Genotype	Phenotypic ratio of test cross
1	**WWFF**	All Facial warts and freckled face
2	**WWFf**	1 facial warts and freckled face : 1 facial warts and freckle-less face
3	**WwFF**	1 facial warts and freckled face : 1 smooth and freckled face
4	**WwFf**	1 facial warts and freckled face : 1 facial warts and freckle-less face : 1 smooth and freckled face : 1 smooth and freckles face

[Total: 10]

QUESTION 3

Fruit flies (*Drosophila melanogaster*) have been used extensively in investigation of inheritance. They are particularly suited to study because of their short life cycle and many different mutant forms. In one investigation, red-eyed females with grey bodies were crossed with brown-eyed males with black bodies. All the F1 generation had red eyes and black bodies.

Tip: When 2 homozygous parents of contrasting traits are crossed, traits observed in F1 are dominant traits

When these F1 flies were crossed, the following offspring were produced:

Phenotype	No. of flies
Red-eyed, black-bodied	110
Red-eyed, grey-bodied	39
Brown-eyed, black-bodied	37
Brown-eyed, grey-bodied	13

Tip: The observed F2 numbers seemed like 9:3:3:1 phenotypic ratio.
What genotype should F1 flies have, so that after selfing, gives rise to F2 generation of this phenotypic ratio?

(a) State the dominant characters for eye color and body color.

……..[1]

1 Red eyes and black body ;

(b) State the genotypes of the parent flies, using suitable symbols.

……..[3]

Key :

1 Let R represent the allele for red eyes.
Let r represent the allele for brown eyes.
Let B represent the allele for black body.
Let b represent the allele for grey body.

The allele for red eyes (R) is dominant to allele for brown eyes (r).
The allele for black body (B) is dominant to allele for grey body (b).

2 Genotype of red-eyed female with grey bodies - RRbb ;
3 Genotype of brown-eyed males with black bodies - rrBB.

Tip: Work backwards, by observing the results of the F2 generation, can you deduce about F1 genotype? To give rise to F1 genotype, what genotype will the parent flies have?

Thought process:
1) Red eyed and grey bodied parental flies have minimum 1 copy of allele R and 2 copies of allele b (Genotype: R_bb).
2) Brown eyed and black bodied parental flies are having 2 copies of allele r, minimum 1 copy of allele B (genotype of rrB_)
3) In order for **all** F1 flies to be red eyed and black bodied, there must **not** be any recessive allele for both gene for eye color and gene for body color.

c) Draw a genetic diagram to show how the F2 offsprings were produced.

……[6]

F1 phenotype: Red-eyed and black-bodied X Red-eyed and black-bodied

F1 genotype: RrBb RrBb

F1 gametes: (RB) (Rb) (rB) (rb) (RB) (Rb) (rB) (rb)

F2 genotype, determined by Punnett Square:

	RB	Rb	rB	rb
RB	RRBB **Red eyed, black bodied**	RRBb **Red eyed, black bodied**	RrBB **Red eyed, black bodied**	RrBb **Red eyed, black bodied**
Rb	RRBb **Red eyed, black bodied**	RRbb **Red eyed, Grey bodied**	RrBb **Red eyed, black bodied**	Rrbb **Red eyed, Grey bodied**
rB	RrBB **Red eyed, black bodied**	RrBb **Red eyed, black bodied**	rrBB **Brown eyed, black bodied**	rrBb **Brown eyed, black bodied**
rb	RrBb **Red eyed, black bodied**	Rrbb **Red eyed, Grey bodied**	rrBb **Brown eyed, black bodied**	rrbb **Brown eyed, Grey bodied**

F2 phenotypes: Red-eyed Black-bodied ; Brown-eyed Black-bodied ; Red-eyed Grey-bodied ; Brown-eyed Grey-bodied

F2 phenotypic ratio: **9 : 3 : 3 : 1**

Mark scheme:

1 F1 genotypes (both are RrBb)
2 F1 gametes – RB, Rb, rB, rb (Gametes must be circled)
3 F2 genotypes / Punnett square
4 corresponding genotypes to phenotypes / legend for Punnett square
5 F2 phenotypic ratio – 9:3:3:1
6 Correct presentation of genetic diagram

d) Determine the results of a test cross conducted on the F1 offsprings.

Tip: What is a test cross?

……[5]

Test cross on F1 offsprings

Parental phenotypes:	Red-eyed and black-bodied	x	Brown-eyed and grey-bodied
Parental genotype:	RrBb		rrbb
Parental gametes:	(RB) (Rb) (rB) (rb)		(rb)

F2 genotypes, determined by Punnett square:

	(RB)	(Rb)	(rB)	(rb)
(rb)	RrBb Red-eyed and black-bodied	Rrbb Red-eyed and grey-bodied	rrBb Brown-eyed and black-bodied	rrbb Brown-eyed and grey-bodied

F_2 phenotypes: Red-eyed and black-bodied ; Red-eyed and grey-bodied ; Brown-eyed and black-bodied ; Brown-eyed and grey-bodied

F_2 phenotypic ratio: **1 : 1 : 1 : 1**

Mark scheme:

1 Parental phenotype
2 Parental genotypes
3 Parental gametes – (Gametes **must** be circled)
4 Progeny genotypes / Punnett square
Genotypes correspond to phenotypes / legend for Punnett square
5 F_1 phenotypic ratio

[Total: 15]

Genetics & Inheritance

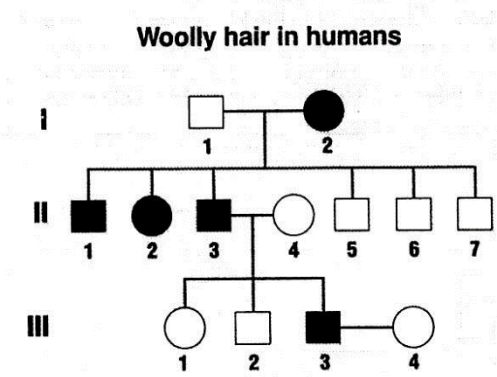
Codominance, incomplete dominance, multiple alleles, sex-linked genes

STUDY AID

Pedigree trees, based on their traits, can be classified into 4 inheritance patterns:

1 Autosomal recessive traits
2 Autosomal dominant traits
3 X-linked recessive traits
4 X-linked dominant traits

*(Important ! The following table has been compiled to assist you to quickly identify the mode of inheritance in pedigrees but you will **still need to perform a genetic analysis to confirm your prediction**)*



Autosomal dominant trait

E.g. woolly hair.

Some info

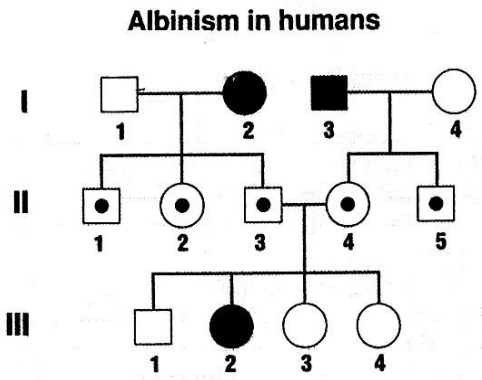
(a) A relatively large proportion of the members in the family will be affected with the disease because all it requires is just one copy of the disease allele for manifestation of the disease.

(b) Each affected individual will have at least one affected parent.

(c) Equal chance of disease manifestation for both females and males.

NO Skipping of generation

Generic reason. Try to state exact evidence why it is NOT X-linked instead



Autosomal recessive trait

E.g. albinism – affected person lacks pigment in the hair, skin and eyes.

Recessive: Diseased parent can have offspring without disease (skips generation)

Some info

(a) Lower proportion of the members in the family will be affected with the disease because two copies of the disease allele are required for manifestation of the disease.

(b) Equal chance of disease manifestation for both females and males.

Generic reason. Try to state exact evidence why it is NOT X-linked instead.

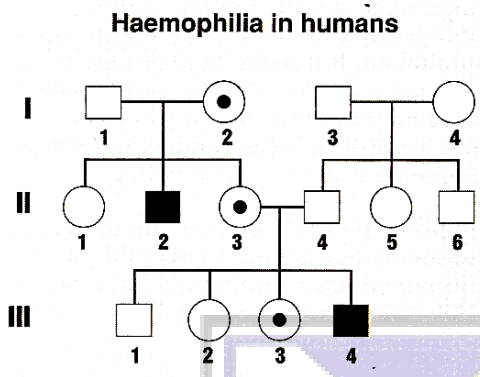
e.g. If it is X-linked, all diseased mothers e.g. I2, must have affected sons, but II1 is normal

(c) Offspring of I-1 and I-2 (as well as I-3 and I-4) are not affected with the disease although I-2 (and I-3) has the disease.

(d) Offspring of II-3 and II-4 (ie. III-2) has the disease, suggesting carrier status of both parents. Both II-3 and II-4 inherited a copy of the disease allele from one of their parents.

Alternative clue: If it is X-linked, all diseased mothers must have affected sons

Recessive: Diseased parent can have offspring without disease (skips generation)



X-linked recessive trait

E.g. Haemophilia – blood clotting disease where a person can die from a simple bruise which results in internal bleeding.

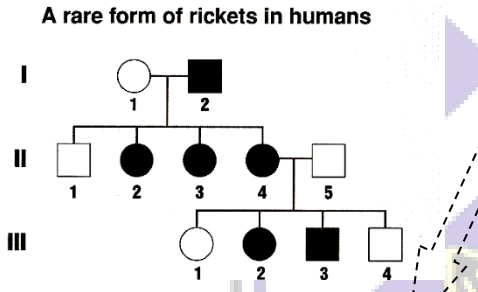
Some info

(a) More males affected than females in the pedigree

(b) Scenario 1 - If both parents are normal and yet child (son) is affected, female parent must be a carrier of the disease allele.

(c) Scenario 2 - If male parent is affected and female parent a carrier, both male and female offspring have 50% chance of having the disease.

(d) Scenario 3 – If male parent is normal and female parent has the disease, all female offspring will are carriers of the disease allele while all male offspring will have the disease.



X-linked dominant trait

E.g. A rare form of rickets

Some info

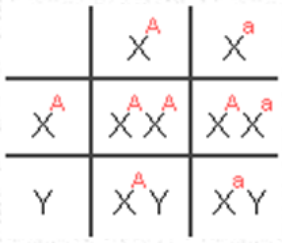
(a) Each affected individual will have at least one affected parent.

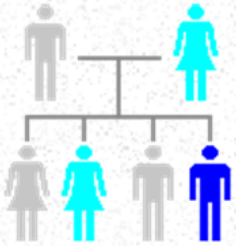
(b) Higher probability for female to be affected than males.

NO Skipping of generation

Alternative clue: If it is X-linked, all diseased fathers must have affected

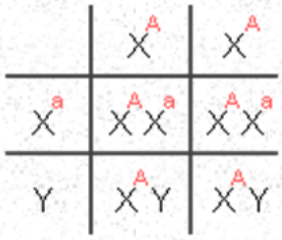
If a woman is a carrier of an X-linked recessive allele for a disorder and her mate does not have it, their boys will have a 50% chance of inheriting the disorder. None of their girls will have it, but half of them are likely to be carriers.

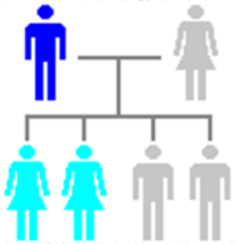




dominant allele = A
recessive allele = a

If a man has an X-linked recessive disorder and his mate does not carry the allele for it, all of their girls will be carriers. None of their boys will inherit the harmful allele. Only girls receive X chromosomes from their fathers.





Revision on Symbol Representation:

Scenario	Representation	Example
Co-dominance	*Allelic symbols (B vs P vs Y) should be superscripted against a base gene alphabet e.g. C*	C^B , C^P, C^Y
Incomplete dominance	*Allelic symbols (B vs b) should be superscripted against a base gene alphabet e.g. C*	C^B, C^b
X-linked condition (with one allele dominant to another)	*Allelic symbols (e.g. N, n) should be superscripted against the letter X (representing X chromosome).* *Y chromosome has no corresponding allele for the same gene*	X^N, X^n, Y
X-linked condition with 2 co-dominant alleles	*Allelic symbols (e.g. B, G) should be superscripted against the letter X (representing X chromosome).* *Different allelic symbols are used instead of capital letter vs small letter, because of co-dominance.* *Y chromosome has no corresponding allele for the same gene*	X^B, X^G, Y

QUESTION 4 [MULTIPLE ALLELES] [Time : 12min]

The background colour of the shell of the snail *Cepaea nemoralis* may be brown, pink or yellow. The colour is controlled by a **single gene locus with three alleles**.

If one gene locus has more than 2 possible types of alleles, the gene is considered to have multiple alleles.

C^B codes for brown and is dominant to C^P which codes for pink. C^Y codes for yellow and is recessive to both of the other alleles. What will be the expected phenotypic ratios in the offspring of the following crosses?

Establish the dominance relationship between the 3 alleles: $C^B > C^P > C^Y$ (where > = dominant to)

Recall the symbol representation of multiple alleles. Allelic symbols (B vs P vs Y) should be superscripted against a base gene alphabet e.g. C

(a) Heterozygous pink X yellow

……..….[3]

Parental phenotypes:	Pink shell	X	Yellow shell
Parental genotype:	C^PC^Y	X	C^YC^Y
Parental gametes:	C^P, C^Y	X	C^Y

Since yellow allele is recessive to C^B and C^P alleles, yellow shell phenotype can only have C^YC^Y genotype

F1 genotypes:	$C^P C^Y$		$C^Y C^Y$
F1 phenotypes:	Pink shell		Yellow shell
F1 phenotypic ratio:	1	:	1

Mark scheme:

1 Parental genotypes ;
2 Parental gametes (circled) ;
3 F1 genotypes ;
4 Genotype correspond to phenotype ;
5 F1 phenotypic ratio ;

To earn the "genotype correspond to phenotype" mark, all genotypes are to be properly aligned with the correct phenotype

(b) C^BC^Y X heterozygous pink

……..…[3]

Parental phenotypes:	Brown shell	X	Pink shell	
Parental genotype:	C^BC^Y	X	$C^P C^Y$	
Parental gametes:	C^B, C^Y	x	C^P, C^Y	
F1 genotypes:	$C^B C^P$	$C^B C^Y$	$C^P C^Y$	$C^Y C^Y$
F1 phenotypes:	Brown shell	Brown shell	Pink shell	Yellow shell
F1 phenotypic ratio:	2	:	1:	1

Use a bracket to combine 2 phenotypes into 1 category

To earn the "genotype correspond to phenotype" mark, all genotypes are to be properly aligned with the correct phenotype

Mark scheme:

1 Parental gametes (circled) ;
2 F1 genotypes ;
3 Genotype correspond to phenotype
4 F1 phenotypic ratio ;

[Total: /6]

QUESTION 5 [SEX-LINKAGE AND CO-DOMINANCE]

Recall the symbol representation of X-linked genes. Allelic symbols (e.g. B, G) should be superscripted against the letter X (representing X chromosome). Different allelic symbols are used instead of capital letter vs small letter, because of co-dominance

Coat colour in cats is determined by a **sex-linked gene** with two alleles, black and ginger. In a particular colony of cats, the coats of the males were either black or ginger and those of females black, ginger or **tortoiseshell** (a patchwork pattern of black and ginger).

Recall: What scenario gives rise to both alleles equally expressed in the phenotype, e.g. in tortoiseshall coat?
Ans: co-dominance

Marks will be awarded for the key in this case.

(a) Using appropriate symbols, state the genotypes and phenotypes of the observations.

……..….[4]

Key:
Let X^B represent the X chromosome with the allele for black coat colour
Let X^G represent the X chromosome with the allele for ginger coat colour
Let Y represent the Y chromosome
Alleles X^B and X^G are co-dominant.

Genotypes of males: X^BY or X^GY
Phenotypes of males: black coat or ginger coat

Genotypes of females: X^BX^B or X^BX^G or X^GX^G
Phenotypes of females: black coat or tortoiseshell coat or ginger coat

Mark scheme:
1 Key ;
2 Both alleles are co-dominant ;
3 Male genotypes ;
Male phenotypes ;
4 Females genotypes ;
Females phenotypes ;

(b) In a litter of kittens, half the number of females was tortoiseshell and the other half were black; half the number of males was black and the other half were ginger.

Thought process: What did we know about the genotypes of the kittens in the pre-amble so far?

The phenotypic ratio for females is 1 tortoiseshell (with $X^B X^G$ genoptype) : 1 black (with $X^B X^B$ genotype)

The phenotypic ratio for males is 1 black (with $X^B Y$ genotype): 1 ginger (with $X^G Y$ genoptype)

What were the colours of the parental male and female? Explain your answer with the help of a genetic diagram.

……[3]

	Female			Male
Parental phenotypes:	Tortoise- shell coat		x	Black coat
Parental genotype:	$X^B X^G$		x	$X^B Y$
Parental gametes:	X^B, X^G		x	X^B, Y
F1 genotypes:	$X^B X^B$	$X^B X^G$	$X^B Y$	$X^G Y$
F1 phenotypes:	Black female	Tortoise-shell female	Black male	Ginger male
F1 phenotypic ratio:	1 :	1 :	1 :	1

***Working backwards / reasoning**:*

Males always inherit a copy of the X chromosome (carrying the allele for fur coat colour) from their mothers and a Y chromosome from their fathers.

Since the male offsprings are either black or ginger, their genotypes are $X^B Y$ or $X^G Y$, and their mother would have both X^B and X^G alleles. Her genotype is thus $X^B X^G$, corresponding to tortoiseshell phenotype.

Mark scheme:

1 Parental phenotypes and gender ;
2 Parental genotypes ;
3 Parental gametes (circled) ;
4 F1 genotypes ;
5 Genotypes correspond to phenotypes ;
6 F1 phenotypic ratio ;

[Total: /7]

QUESTION 6 [SEX-LINKAGE]

Red-green colour blindness is the inability to distinguish between the colours red and green. The genes that determine colour vision is located on the **X chromosome**. The allele for normal vision is dominant to that for colour blindness.

Recall the symbol representation of X-linked genes. Allelic symbols (e.g. N, n) should be superscripted against the letter X (representing X chromosome).

(a) A woman with normal colour vision, whose father was red-green colour blind, married a red-green colour blind man.

Thought process:
The woman has normal color vision, her genotype should be X^NX_-.
The woman's father is color blind, with genotype X^nY.
Thus, the father must pass down the X^n allele to the woman. The woman's genotype is X^NX^n.

(i) Show with the help of genetic diagram, the **probability** that a girl born to this couple being red-green colour blind.

……[4]

Key :

Let X^N represent the X chromosome with the allele for normal vision
Let X^n represent the X chromosome with the allele for red-green colour blindness
Let Y represent the Y chromosome
The allele for normal vision (N) is dominant to allele for red-green colour blindness(n)

	Mother		Father
Parental phenotypes:	Normal	x	Colour blind
Parental genotype:	$X^N X^n$	x	X^nY
Parental gametes:	X^N, X^n	x	X^n, Y

F1 genotypes:	$X^N Y$	$X^N X^n$	$X^n Y$	$X^n X^n$
F1 phenotypes:	Normal male	Normal female	Colour – blind male	Colour – blind female
F1 phenotypic ratio:	1 :	1 :	1 :	1

Probability that a F1 female will be colour-blind = 0.5

Thought process:
***Conditions are usually stressed in front** of the question phrase e.g. **girl** who is colourblind instead of "colourblind girl". There is a condition in this question: which is GIRL. Thus, only focus on the females in the results of the cross. Since there is 1 normal female and 1 colourblind female, the prob of girl being normal is 1 out of 2)*

Mark scheme:

1 Parental genotypes ;
2 Parental gametes (circled) ;
3 F1 genotypes ;
4 Genotypes correspond to phenotypes ;
5 F1 phenotypic ratio ;
6 Probability = 0.5.

Additional Questions:

(ii) What is the probability that this couple give birth to a child who is a red-green colour blind girl?

……[1]

Probability that the child is a female and colour-blind = 0.25

Thought process:
There is NO condition stressed at the front of this question phrase. Thus we have to consider all 4 scenarios in the offspring.. Since there is 1 colourblind female out of the 4 possible offspring scenarios, the prob getting a colourblind girl is 1 out of 4.

(iii) What is the probability that their first son will be colour blind?

……[1]

Probability that a F1 male will be colour-blind = 0.5

Thought process:
Conditions are usually stressed in front of the question phrase. There is a condition in this question: which is SON. Thus, only focus on the males in the results of the cross. Since there is 1 normal male and 1 colourblind male, the prob of son being colorblind is 1 out of 2

(iv) What is the probability that this couple give birth to a **second child** who is a **colour blind boy**?

……[1]

Probability = 0.25

Thought process:
There is NO condition stressed at the front of this question phrase. Thus we have to consider all 4 scenarios in the offspring.. Since there is 1 colourblind male out of the 4 possible offspring scenarios, the prob getting a colourblind male is 1 out of 4.

(v) The couple has 4 sons. What is the probability that **all four sons** will be **colour blind**?

……[1]

Probability for one son to be a colour blind = 0.5

Probability that all 4 sons are colour blind = $0.5^4 = 0.0625$

Thought process:
Conditions are usually stressed in front of the question phrase. There is a condition in this question: which is BOY. Thus, only focus on the males in the results of the cross. Since there is 1 normal male and 1 colourblind male, the prob of boy being colorblind is 1 out of 2.

To get all 4 sons who are colourblind = son #1 is colourblind AND son #2 is colourblind AND son #3 is colourblind AND son #4 is colourblind ➔ we need to ***multiply*** *all the 4 probabilities together*

(vii) What is the probability that this couple give birth to 4 colour blind sons?

……[1]

Probability for a child to be a colour blind boy = 0.25
Probability that all 4 sons are colour blind = 0.25^4 = 0.00391

Thought process:
There is NO condition stressed at the front of this question phrase. Thus we have to consider all 4 scenarios in the offspring.. Since there is 1 colourblind male out of the 4 possible offspring scenarios, the prob getting a colourblind male is 1 out of 4

Need to quote data from table

(viii) With reference to the following table, explain the occurrence of female sufferers of red-green colour blindness.

Condition	*Details*	*% male sufferers*	*% female sufferers*
Red-green colour blindness	Inability to distinguish between red and green	8.0	0.70
Haemophilia	Blood fails to clot properly	0.10	Less than 0.01
Duchenne muscular dystrophy	Poor muscular development	0.25	Less than 0.01

……[3]

[**Data**]

1 Female sufferers of colour blindness occur at a low**er** percentage of 0.7% compared to a high**er** 8.0% in male sufferers ;

There is need to contrast between male and female % sufferers to highlight how low female % is.

[**Explanation**]

2 Red-green colour blindness is an X-linked recessive disease ;
Females have 2 copies of X chromosomes, when one recessive allele is inherited, there is a chance that the other X chromosome may carry a dominant allele to mask the expression of the recessive allele ;

3 Female sufferers of red-green colour blindness will have to receive one X^n from the father and another X^n from the carrier mother ;
Males only have one X chromosome and there are **no corresponding alleles in Y chromosome** to mask the recessive allele. Hence there is a lower probability of female inheriting the disease from both parents compared to the male inheriting the disease from one parent.

(b) Explain why the incidence of red-green colour-blindness, in both males and females, is higher than that of the other 2 conditions.

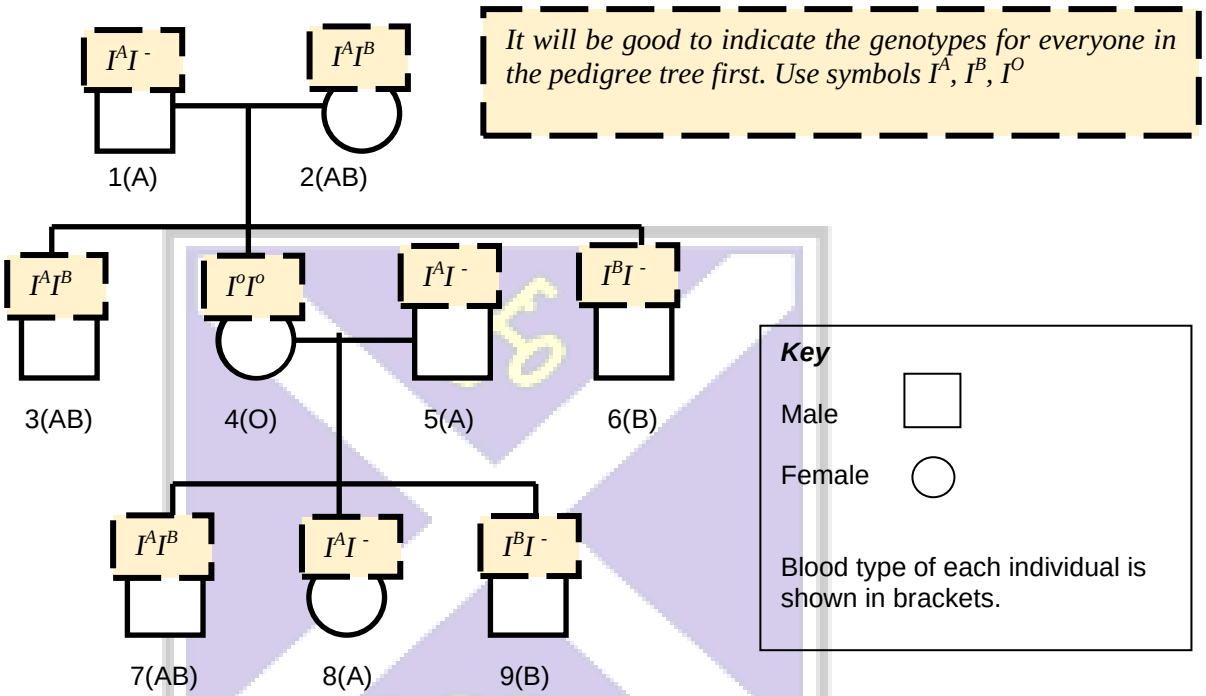
……[1]

1 Most individuals homozygous for haemophilia and muscular dystrophy fail to live to sexual maturity to reproduce ;

[Total: /13]

QUESTION 7 [MULTIPLE ALLELES & PEDIGREE]
Adapted from 2012 SAJC FE

(a) Fig. 7.1 below shows the inheritance of blood group of a family through three generations.



It will be good to indicate the genotypes for everyone in the pedigree tree first. Use symbols I^A, I^B, I^O

Fig. 7.1

The inheritance of the blood type is controlled by a single gene with multiple alleles. Some of these alleles code for antigens on the cell surface membrane of the red blood cells.

Definition questions are popular!

(i) Explain what is meant by multiple alleles.

……[3]

1 The gene has **more than 2**, **REJECT** multiple **AND alternative/ different forms** of **a** gene ;
2 occupy the **same** gene locus on homologous chromosomes ;

Define "multiple" and "alleles" separately

[max 1]

3 causes **slightly different** phenotypes for the same characteristic, due to a **slight difference** in DNA sequence ;

Examiners' comments:

- ***It is required to define "multiple" and "alleles" separately.***
- ***For definition of "multiple", the phrase "more than one allelle" is not acceptable as 2 alleles for a gene is considered normal.***
- ***Students <u>should not reuse the words that are given in question</u> eg. saying that "multiple alleles" means "many alleles" or "multiple alternative forms of a gene" is not fully answering the question / not detailed enough.***

(ii) Use one piece of evidence shown in **Fig. 7.1** to explain clearly which individual's blood group may have been typed wrongly.

.....[3]

1 Individual 4;

Show reasoning by quoting individuals and their genotypes, and stating how observed phenotypes does not correspond to what is expected

Explanation:

1 Mother is blood group AB – can only be I^AI^B;
2 Father is blood group A – can only be I^AI^O;
3 Their children can only have blood groups A(I^AI^O or I^AI^A), AB (I^AI^B) or B(I^BI^O) – correct blood groups with genotypes; / it is impossible to have a child with blood group O (I^OI^O)

OR

1 If individual 4 has blood group O, she can only be I^OI^O;
2 Her husband can be I^AI^O or I^AI^A;
3 Her children can only have blood groups A or O/ it is impossible for her children to have blood groups AB (I^AI^B) or B(I^BI^O) (since the allele I^O is recessive to both I^A and I^B);

Teachers' comments:

- ***OVP includes individual 7 or 9, due to the understanding that individual 4 is blood group O, and cannot produce offspring with I^B allele as husband is A blood group.***
- ***However, the best answer which looked at the whole picture of the entire tree, from generation 1 onwards to younger generations in a top down approach, should still be individual 4.***

Continuous & Discontinuous Variation (not in H1 syllabus)

QUESTION 8 [9648/P2Q5/2010]

A cross was made between two varieties of tobacco, *Nicotiana*, with short-tubed corollas and long-tubed corollas.

Fig. 8.1 opposite shows the variation in corolla tube length of the parental forms and the first generation (F_1) and second generation (F_2) of offspring.

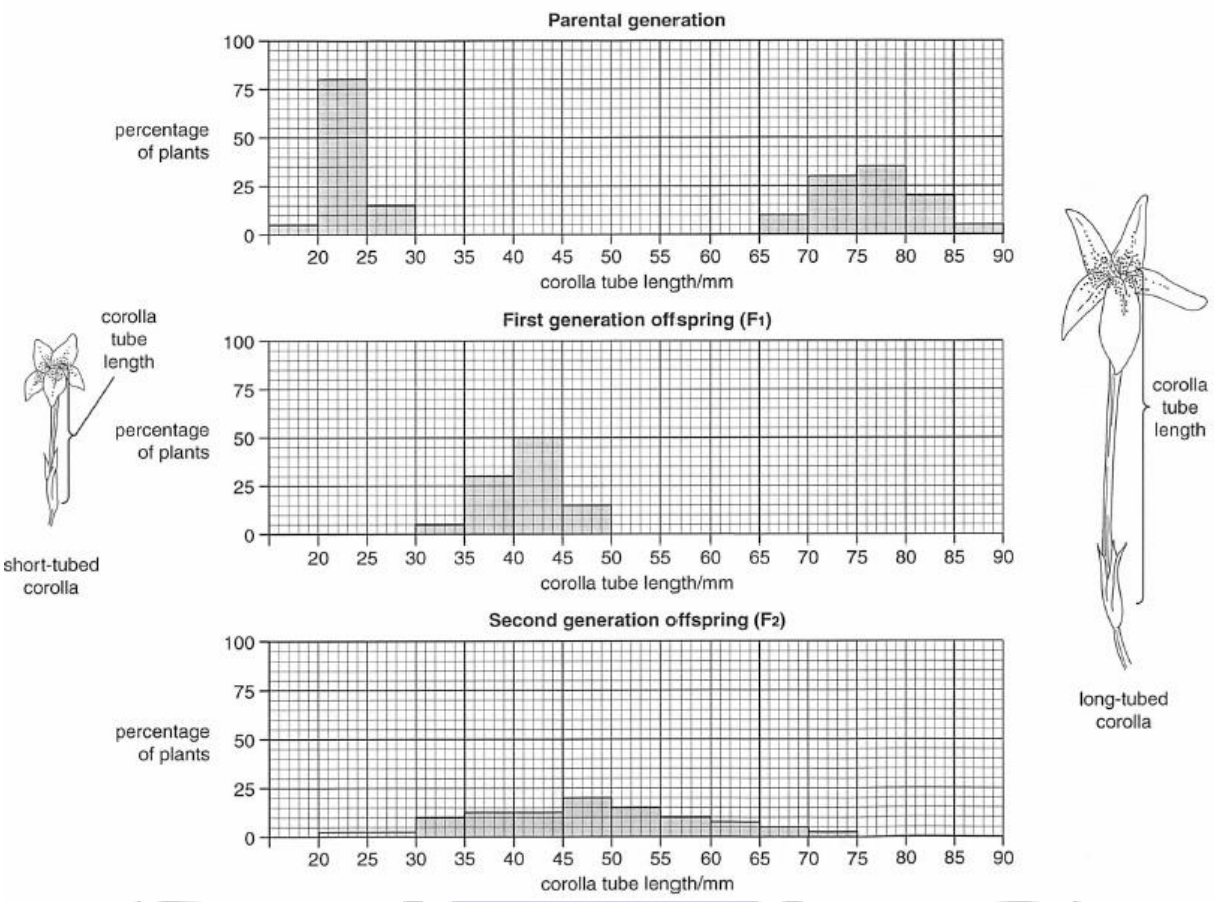


Fig. 8.1

(a) State the term used to describe the range of phenotypes in the second generation (F_2) of offspring.

……[1]

(b) Explain why there is a range of phenotypes for this characteristic.

……[4]

Examiner's comments: Weak candidates tend to address the phenotype range for F_1 and F_2 generation and why its in the middle, referring the parents as homozygous, F_1 being heterozygous/co-dominance of alleles. Question is just asking for reasons for having a range of phenotypes instead of discrete ones.

(c) Suggest why the range of variation is greater in the second generation (F_2) of offspring than in either the first generation of offspring (F_1) or the parental phenotypes.

……[4]

Note: F_1 – variation is due to only environment; individuals all genetically identical / all heterozygous

Examiner's comments: For more able candidates, references to 'independent assortment' and 'crossing over and chiasmata' were common although 'recombination' was infrequently seen and reference to 'multiple alleles' was rare.