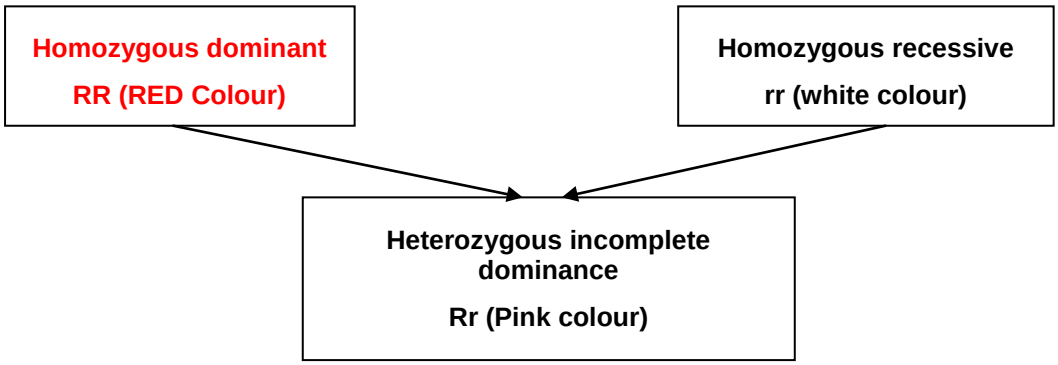
INHERITANCE & VARIATION 22 APRIL 2015

Section A: Summary Content Notes

Monohybrid Crosses – Incomplete Dominance and Co-dominance

- **Incomplete dominance:** when the dominant gene allele is not able to completely dominate over the recessive gene allele, a mix of the two genes results, e.g.: red + white = pink. When the offspring is heterozygous with incomplete dominance, you will be able to see the combination of the two gene alleles traits:



- **Codominance**: the type of dominance where both alleles in a gene pair are expressed fully. An example is human blood groupings.

Blood Group Inheritance

Each human has blood flowing through their blood vessels. Blood is determined by **THREE alleles** and not two as for all other characteristics and traits. The existence of more than two genes for a trait is termed **multiple alleles.** Specific proteins that are present on the surface of the red blood cells determine the blood type. Protein A and protein B are coded by **alleles A and B**. If no protein A or B is present, then these cells will be coded by the **allele O**. Any **two** of these alleles (genes A, B or O) will occur in combination in an individual. The alleles A and B are **co-dominant** (both dominate equally) over O, which is **recessive.**

Phenotype	Genotype
A	I^AI^A
A	I^AI^O / I^Ai
B	I^BI^B
B	I^BI^O / I^Bi
AB	I^AI^B
O	I^OI^O / ii

Monohybrid Crosses – Sex Determination and Sex Linked Genetic Diseases

Sex Determination

In humans, the **somatic cells** are diploid and contain 23 pairs of chromosomes in each nucleus of which:

- 22 pairs of autosomes
- 1 pair of sex chromosomes (gonosomes): females - **XX** sex chromosomes and males - **XY** sex chromosomes

Gametes are formed by **gametogenesis** in the **ovaries** and **testes.** The egg cell (female gamete) can only ever contain one X chromosome, but half the sperm cells will have X and half will have Y chromosomes. When fertilisation occurs, there is a 50 % chance that the zygote is male and a 50 % chance that the zygote is female:

X + **X** = **XX** or

X + **Y** = **XY**

P_1/parent

Phenotype	female	x	male
Genotypes	XX	x	XY

Meiosis

Gametes	X, X	x	X, Y

Fertilisation

gametes	X	X
X	XX	XX
Y	XY	XY

F_1

Genotype: X X 50% X Y 50%)

Phenotype: 50% males and 50% females

Sex-Linked Genetic Diseases

Haemophilia (the inability of the blood to clot) and colour blindness are disorders that are sex-linked characteristics. The alleles of the genes for these disorders are recessive and located on the X chromosome. Females are generally 'carriers' of the gene, with the gene masked by the normal allele gene.

Males have only ONE X chromosome, so if the gene is present, there is NO masking allele and they will inherit and display the trait.

Sex-Linked Genetic Crosses

H = normal (dominant) h = haemophilia (recessive)

Carrier female: $X^H X^h$ where H = normal (dominant) and h = haemophilia (recessive)

Normal male: X^HY there is no 'arm' on the chromosome to carry the allele

P_1/parents

phenotype	normal male	x	carrier female
genotype	X^HY	x	X^HX^h -

Meiosis

Gametes	X^H, Y	x	X^H, X^h

Fertilisation

Gametes	X^H	X^h
X^H	X^HX^H	X^HX^h
Y	X^HY	X^hY

F_1/offspring

Genotype: 25% X^HX^H, 25% X^HY, 25% X^HX^h, 25% X^hY

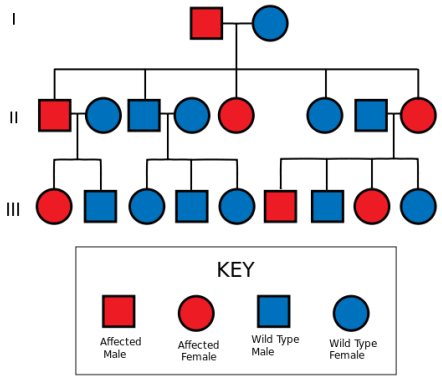
Phenotype: 25% normal female (X^HX^H)

25% normal male (X^HY)

25% carrier female (X^HX^h)

25% male with haemophilia (X^hY)

Pedigree charts are a popular way to express family history. In a pedigree chart, first establish which of the individuals is **homozygous recessive** for a gene combination as this is always a surety and can be see easily on the chart. There are basically **FOUR crosses**. If you know these crosses, you should not have a problem.



Dihybrid Crosses

Mendel's Second Law can be difficult to grasp. Ensure that you are comfortable with monohybrid crosses before you begin to do dihybrid crosses. A dihybrid cross works with TWO characteristic at a time (di = two). The process is the same as for a monohybrid crosses, it is just that the two characteristics are passed to the offspring in **different possible combinations**. If one characteristic has 4 possible outcomes, then two characteristics will be 4 x 4 = 16 possible outcomes/combinations. You MUST know Mendel's pea plant crosses. Follow each step and look at WHY each step is done.

Mendel's Law of Independent Assortment

You have learned that each trait is controlled by **allele genes**, located on a separate pair of chromosomes. Mendel stated that different pairs of genes **segregate independently** of the members of other pairs, when two or more characteristics (traits) are involved in a dihybrid cross. This means that each characteristic separates on its own during meiosis. (provided they are on different chromosomes)

For example: hair colour and eye colour are two characteristics. The following are possible examples of the combinations if B = brown hair, b = blonde hair, N = brown eye colour and n = blue eye colour:

BB, NN – Homozygous brown hair, Homozygous brown eyes

BB, Nn – Homozygous brown hair, Heterozygous brown eyes

BB, nn – Homozygous brown hair, Homozygous blue eyes

Bb, NN – Heterozygous brown hair, Homozygous brown eyes

Bb, Nn – Heterozygous brown hair, Heterozygous brown eyes

Bb, nn – Heterozygous brown hair, Homozygous blue eyes

bb, NN – Homozygous blonde hair, Homozygous brown eyes

bb, Nn – Homozygous blonde hair, Heterozygous brown eyes

bb, nn – Homozygous blonde hair, Homozygous blue eyes

This means that each characteristic can combine with any number of other combinations. Remember that ONE characteristic presents FOUR possible combinations when fertilisation takes place between TWO parents.

Male parent = 2 allele genes and Female = 2 allele genes. During meiosis, **each gene** from the allele pair will **separate independently** in the male and the same will take place in the female. Mother (2) x Father (2) = 4

In a **dihybrid cross** (di = two) - **two parents** will each have **two characteristic** that are passed to their offspring. Each parent will therefore present **4 sets** of possibilities in the genotype. Mother (4) x Father (4) = 16 possible combinations of the genotype.

Mendel used peas to explain a dihybrid cross where two traits/characteristics were crossed. A genetic trait for a round seed versus a wrinkled seed will be **independent** of the combinations for a yellow versus green colour of the seeds. This means that seeds can be round and yellow, round and green, wrinkled and yellow or wrinkled and green – so, there will be 16 combinations.

Dihybrid Cross of Homozygous Parents

R = round seeds (dominant) r = wrinkled seeds (recessive)

Y = yellow seeds (dominant) y = green seeds (recessive)

The parents are as follows:

'Parent 1': **RRYY** – homozygous round AND homozygous yellow and

'Parent 2': **rryy** – homozygous wrinkled AND homozygous green

Step 1: **RRYY xrryy**- we need to find the combination of gametes for each of the parents

'Parent 1': **RR x YY - Meiosis**

Gametes	**R**	**R**
Y	RY	RY
Y	RY	RY

'Parent 2': **rr x yy - Meiosis**

Gametes	**r**	**r**
y	ry	ry
y	ry	ry

Step 2: **The Dihybrid cross**

Now take the 4 combinations for 'parent 1' and the 4 combinations for 'parent 2'

P_1

Gametes	**RY**	**RY**	**RY**	**RY**
ry	RrYy	RrYy	RrYy	RrYy
ry	RrYy	RrYy	RrYy	RrYy
ry	RrYy	RrYy	RrYy	RrYy
ry	RrYy	RrYy	RrYy	RrYy

Fertilisation

F_1

Genotype: 100% Heterozygous RrYy

Phenotype: 100% round and yellow

HINT: Choose one letter as the letter to be written **first** in each case. Here we chose R. Always write the **capital letters** before the small letters so write RR or Rr or rr first and then the Y, either YY or Yy or yy.

Now if we cross these F_1 seeds (offspring of the P_1) we must follow **Step 1** again:

So, to find the **P_2** we need to find the combinations of:

'Parent 1': RrYy and **'Parent 2'**: RrYy (both parents are heterozygous round and heterozygous yellow)
RrYy x RrYy (to find the combination of gametes for each parent)

Rr x Yy - Meiosis

Gametes	R	r
Y	RY	rY
y	Ry	ry

Rr x Yy - Meiosis

Gametes	R	r
Y	RY	rY
y	Ry	ry

P_2

Gametes	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

Fertilisation
F_2
Genotype: 1/16 RRYY, 2/16 RRYy, 1/16 RRyy, 2/16RrYY, 4/16 RrYy, 2/16 Rryy, 1/16 rrYY, 2/16 rrYy and 1/16 rryy
Phenotype: 9 round and yellow, 3 round and green, 3 wrinkled and yellow, 1 wrinkled and green. (There will always be a total of 16 combinations in a dihybrid cross)

Section B: Practice Questions

Question 1

Blood typing can be used to identify a parent in that the blood type can prove that a person is not the parent of a child rather than determine without question who the parent is. A, B, AB and O blood groups are the result of three alleles. Allele A and B are co-dominantand O is recessive to both A and B. Should the discrepancy continue, tissue typing and DNA fingerprinting will be used. Read through the following information and answer the questions below:

In a maternity ward of a hospital, two newly born babies were mixed up. One baby isblood type O and the other is type A. Both mothers believe the baby with blood type O is their baby. Can you sort it out?

On testing the parents' blood it was found that:

1. Mr. Xhosa is blood group AB and his wife is blood group B
2. Mr. Mbundwini is type A.

Wo does baby 'O' belong to and who does baby 'A' belong to? Explain / show your reasoning. [6]

Question 2

Study the diagram below which shows three generations of snapdragon plants and answer the questions which follow. Use the following symbols for the contrasting alleles:

W – for white flowers

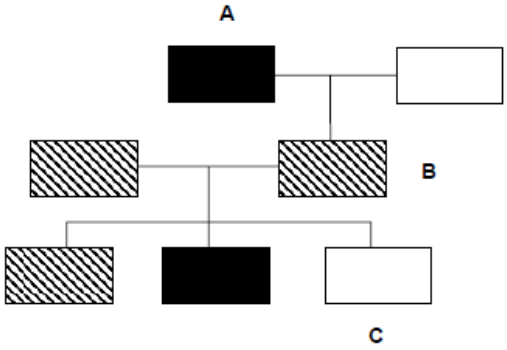
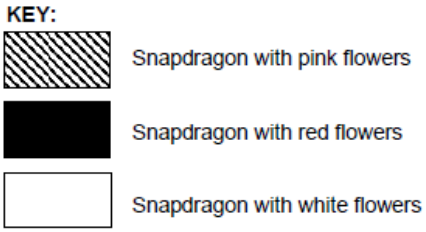


Diagram showing inheritance of colour of snapdragon flowers



R – for red flowers

2.1. State the kind of dominance shown in the diagram above. (1)

2.2. Use the symbols **R** and **W** and write down the genotypes of each of the following snapdragon plants.

a) A (2)

b) B (2)

c) C (2)

Question 3

Haemophilia is a sex-linked disease caused by the presence of a recessive allele (X^h). A normal father and heterozygous mother have children.

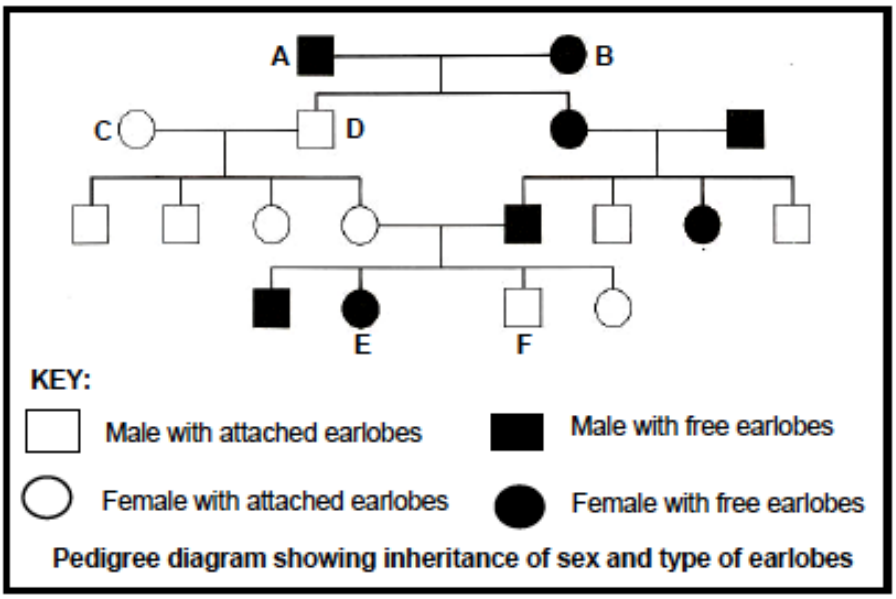
3.1 Represent a genetic cross to determine the possible genotypes and phenotypes of the children of the parents mentioned above. (6)

3.2 What are the chances of the parents having a child that will be a haemophiliac male? (2)

3.3 Explain why the father is not a carrier for haemophilia. (2)

Question 4

Study the family tree on below, which shows the inheritance of sex and type of earlobes over four generations of a family. In humans, free earlobes (F) is dominant over attached earlobes (f).



Pedigree diagram showing inheritance of sex and type of earlobes

4.1. How many members of the family have free earlobes? (1)

4.2. What proportion of offspring in the fourth generation are females with attached earlobes? (2)

4.3. If the genotype of person A is Ff what will be the genotype of person B? (2)

4.4. Give a reason for your answer to QUESTION 4.3. (2)

4.5. Persons E and F are twins. Were they produced from a single fertilised egg cell or from two separately fertilised egg cells? (1)

4.6. Explain your answer to QUESTION 4.5. (2)

4.7. Is it possible for individuals C and D to have a child with free earlobes? (1)

4.8. Explain your answer to QUESTION 4.7. (2)

Question 5

In guinea-pigs, black fur (B) is dominant over albino (b) and course hair (R) is dominant over smooth hair (r).

5.1 Supply the genotypes and phenotypes of a cross between homozygous black animal with course hair and an albino animal with smooth hair in the F1 generation. (10)

5.2 Supply the genotypes and phenotypes of the F2 generation if two of the offspring from the F1 generation are crossed. (15)

5.3 Explain Mendel's Law of Independent Assortment (4)

Section C: Solutions

Question 1

1.1

P_1/parent

Phenotype Mr. Xhosa – blood type AB **x** Mrs Xhosa blood type BGenotype

I^AI^B x I^BI^B or I^B**i**

Meiosis

Gametes I^A,I^B x I^B,I^B or I^B,i

Fertilisation

Gametes	I^A	I^B
I^B	I^AI^B	I^BI^B
i	I^Ai	I^Bi

F_1/offspring

Genotype 25% I^AI^B, 25% I^BI^B, 25% I^Ai, 25% I^Bi

Phenotype 25% AB, 50% B and 25% A

Baby A is the only possible blood group to belong to Mr and Mrs Xhosa

(Remember that in blood groups there are three alleles A, B and O. A and B are co-dominant over O which is recessive. There must be two of the same alleles if a recessive trait is present in the individual.)

1.2. Mr. Mbundwini - I^AI^A or I^Ai√√

Wife – Not given, but assume she is recessive √. Therefore baby 'O' is the possible blood group √as 'O' cannot be the result of Mr. Xhosa and his wife √.

(Each tick = ½ mark) **[6]**

Question 2

2.1 Incomplete ✓ dominance

2.2a. RR or C^RC^R✓✓

2.2b. RW or C^RC^W✓✓

2.2c. WW or C^WC^W✓✓

Question 3

3.1 P_1 / parent phenotype Normal father x Carrier mother ✓

genotype X^HY x X^HX^h✓

Meiosis

Gametes X^H, Y x X^H,X^h✓

Fertilisation

Gametes	X^H	Y
X^H	X^HX^H	X^HY
X^h	X^HX^h	X^HY

F_1 / offspring

Genotype 25% X^HX^H, 25% X^HY, 25% X^HX^h, 25% X^HY ✓

Phenotype 1 normal daughter, 1 carrier carrier, 1 normal son, 1 haemophiliac son✓

3.2 25% or 1 out of 4 or ¼ ✓

3.3 The male has only one X chromosome ✓ Y chromosome does not have the allele for this trait ✓

OR

If he had X^h he would be a sufferer✓, but he does not suffer from haemophilia therefore he must have had X^H. ✓

Question 4

4.1 8 (1)

4.2 25 √% √ (2)

4.3 Ff (2)

4.4 Individual B would have **one dominant gene** since he/she has free earlobes √
and the other gene **must be recessive** since they were able to produce offspring
with attached earlobes/the recessive characteristic √ (2)

4.5 Two separate eggs (1)

4.6 One is male and the other is female √**and one has free earlobes while the other has attached earlobes**
Identical twins are identical in every respect √/from the same sex (2)

4.7 No (1)

4.8 Since C and D have attached earlobes √ they have only recessive genes √
and can, therefore, have no dominant gene/gene for free earlobes to pass to their offspring √.
(Any 2) (2)

Question 5

Dihybrid cross of homozygous parents:

B = black fur (dominant) b = albino (recessive)

R = course hair (dominant) r = smooth hair (recessive)

P_1/ Parents

Phenotype homozygous black AND homozygous course hair x homozygous albino AND homozygous smooth hair ✓

Genotype **BBRR** x **bbrr**✓

Meiosis

Gametes BR, BR, BR, BR x br, br, br, br✓✓

Gametes	**BR**	**Br**	**bR**	**br**	✓✓
BR	**BBRR**	**BBRr**	**BbRR**	**BbRr**	
Br	**BBRr**	**BBrr**	**BbRr**	**Bbrr**	
bR	**BbRR**	**BbRr**	**bbRR**	**bbRr**	
Br	**BbRr**	**Bbrr**	**bbRr**	**bbrr**	
✓✓					

Fertilisation

F_1 / offspring

Genotype: 100% Heterozygous BbRr✓

Gametes	**BR**	**Br**	**bR**	**br**	✓✓
BR	**BBRR**	**BBRr**	**BbRR**	**BbRr**	
Br	**BBRr**	**BBrr**	**BbRr**	**Bbrr**	
bR	**BbRR**	**BbRr**	**bbRR**	**bbRr**	
br	**BbRr**	**Bbrr**	**bbRr**	**bbrr**	
✓✓					

Phenotype: 100% black with course hair ✓ (10)

5.2

P_2/parents

Phenotype black fur, course hair father x black fur course hair mother✓

Genotype BbRr x BbRr✓✓

Meiosis

Gametes BR, Br, bR, br x BR, Br, bR, br✓✓

Fertilisation

F_2/ offspring

Genotype: 1/16 BBRR; 2/16 BBRr; 1/16 BBrr; 2/16 BbRR; 4/16 BbRr; 2/16 Bbrr; 1/16 bbRR; 2/16 bbRr and 1/16 bbrr✓✓

Phenotype: 9 black with course hair ✓; 3 black with smooth hair ✓; 3 albino with course hair ✓; 1 albino with smooth hair ✓ (15)

5.3. Mendel's Law of independent assortment states that different √ pairs of genes **segregate independently**√ of the members of other pairs √, when two or more characteristics √ (traits) are involved in a dihybrid cross. ***(You must know this definition well)*** (4)