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GRADE 12

Life Sciences

SELF STUDY GUIDE 3

GENETICS AND INHERITANCE

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1. INTRODUCTION

The declaration of COVID-19 as a global pandemic by the World Health Organisation led to the disruption of effective teaching and learning in many schools in South Africa. The majority of learners in various grades spent less time in class due to the phased-in approach and rotational/ alternate attendance system that was implemented by various provinces. Consequently, most schools were not able to complete all the relevant content designed for specific grades in accordance with the Curriculum and Assessment Policy Statements in most subjects.

As part of mitigating against the impact of COVID-19 on the current Grade 12, the Department of Basic Education (DBE) worked in collaboration with subject specialists from various Provincial Education Departments (PEDs) developed this Self-Study Guide. The Study Guide covers those topics, skills and concepts that are located in Grade 12, that are critical to lay the foundation for Grade 12. The main aim is to close the pre-existing content gaps to strengthen the mastery of subject knowledge in Grade 12. More importantly, the Study Guide will engender the attitudes in the learners to learning independently while mastering the core cross-cutting concepts.

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2. HOW TO USE THIS SELF-STUDY GUIDE

- ◊ There are five Self-study Guides covering all Grade 12 topics:
  - ◊ Booklet One: DNA: Code of Life and Meiosis
  - ◊ Booklet Two: Reproduction in Vertebrates, Human reproduction, Endocrine System and Homeostasis
  - ◊ **Booklet Three: Genetics and Inheritance**
  - ◊ Booklet Four: Responding to the Environment: Humans and Plants
  - ◊ Booklet Five: Evolution: Natural Selection and Human evolution
- ◊ You must use this Self-study Guide together with the *Life Sciences Mind the Gap Study Guide*.
- ◊ You need to study the content from the *DBE Grade 12 Textbook, DBE Examination Guidelines 2021,* and *Mind the Gap* for all the topics.
- ◊ Ensure you understand all the relevant concepts and content.
- ◊ This Self-study Guide focuses mainly on the skills you will need to answer the questions in examinations.
- ◊ There are exam technique and tips for each topic (*in italics*)
- ◊ These tips will guide you on how to approach certain question types in the Life Sciences Examination papers and tests:
  - How to master the relevant terminology
  - Drawing and interpreting of graphs
  - Interpreting tables
  - Interpreting diagrams
  - Genetics crosses and pedigree diagrams
  - Doing calculations
  - Scientific investigation questions
- ◊ At the end of each booklet, you will find typical examination questions and solutions

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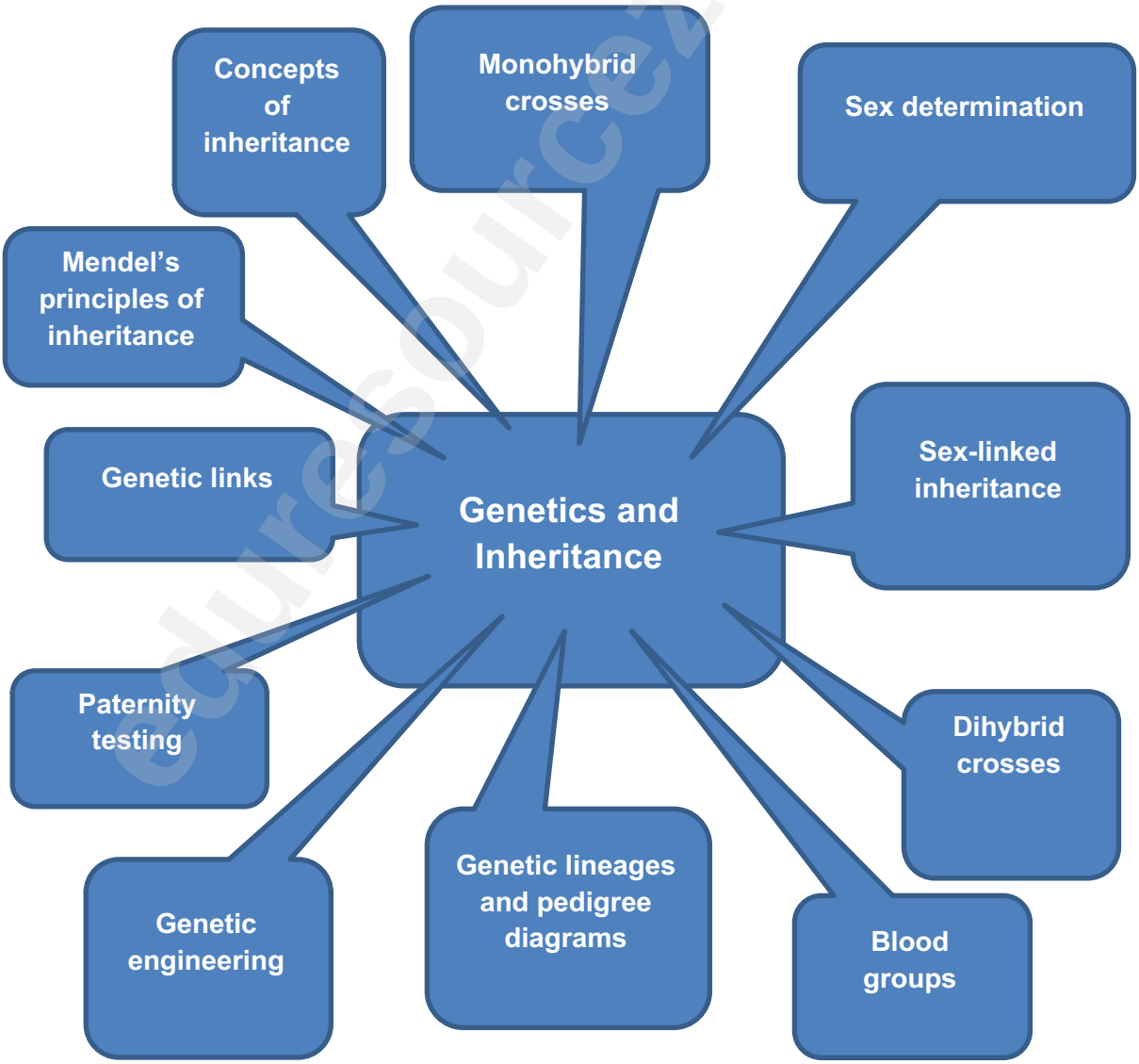
3. GENETICS AND INHERITANCE

Topic: Genetics and Inheritance			
TERM	***1 & 2***	***PAPER***	***2***
DURATION	*14 hours (3½ weeks)*	*WEIGHTING*	*48 marks (32%)*
PRIOR-KNOWLEDGE/BACKGROUND KNOWLEDGE			
DNA replication, Chromosomes, Meiosis			
RESOURCES			
Textbooks, Study Guides, Diagnostic reports, MTG, Past NSC, SC & Provincial Question Papers			

3.1 KEY CONCEPTS



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3.2 TERMINOLOGY

Biological term	Description
Albinism	The condition that results from the absence of skin pigmentation
Alleles	Two or more versions/ forms of a gene which are located at the same position, or genetic locus, on a chromosome
Autosome	Any chromosome that is not a sex chromosome
Biotechnology	The use of biological processes, organisms, or systems to improve the quality of human life
Clone	A copy of an organism that is genetically identical to the original organism
Cloning	The process by which genetically identical organisms are formed using biotechnology
Co-dominance	Both alleles of a gene are equally dominant whereby both alleles express themselves in the phenotype in the heterozygous condition
Complete dominance	One allele is dominant and the other is recessive, such that the effect of the recessive allele is masked by the dominant allele in the heterozygous condition
Chromatin network	Long tangled thread-like structure in the nucleus of an inactive cell made up of DNA
Chromosome	A chromosome is a thread-like structure made up of DNA / that carries hereditary information in the form of genes.
Dihybrid cross	A genetic cross involving two different characteristics e.g. shape and colour of seeds
Dominant allele	An allele that masks or suppresses the expression of the allele partner on the chromosome pair and the dominant characteristic is seen in the homozygous (e.g.: TT) and heterozygous state (e.g.: Tt) in the phenotype.
Gene	A segment of DNA/a chromosome that codes for a particular characteristic
Gene mutation	A change in the sequence of nitrogenous bases or nucleotides in a gene
Genetic variation	This includes a variety of different genes that may differ from maternal and paternal genes resulting in new genotypes and phenotypes.
Genotype	This is the **genetic composition** of an organism. It is the information present in the gene alleles, for example BB, Bb, or bb.
Genome	The complete set of chromosomes in the cell of an organism

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Gonosome	The pair of chromosomes responsible for sex determination.
Haemophilia	A sex-linked genetic disorder characterised by the absence of a blood-clotting factor
Heterozygous	When two alleles that control a single trait(on the same locus) are **different**
Homozygous	When two alleles that control a single trait (on the same locus) are **identical**.
Incomplete dominance	Neither one of the two alleles of a gene is dominant over the other, resulting in an intermediate phenotype in the heterozygous condition
Locus	The exact position or location of a gene on a chromosome.
Mendel's Law of Dominance	When two homozygous organisms with contrasting characteristics are crossed, all the individuals of the F_1 generation will display the dominant trait An individual that is heterozygous for a particular characteristic will have the dominant trait as the phenotype
Mendel's Law of Independent Assortment	The various 'factors' controlling the different characteristics are separate entities, not influencing each other in any way, and sorting themselves out independently during gamete formation
Mendel's Law of Segregation	An organism possesses two 'factors' which separate or segregate so that each gamete contains only one of these 'factors'
Monohybrid cross	A genetic cross involving one characteristic e.g. colour of seeds
Mutation	A sudden change in the sequence/order of nitrogenous bases of a nucleic acid
Multiple alleles	When there are more than two possible alleles for one gene locus. e.g. blood groups
Phenotype	This is the external, physical appearance of an organism. The phenotype is determined by the genotype
Pedigree diagram	A diagram showing the inheritance of genetic disorders over many generations
Population	A group of organisms of the same species living in the same habitat at the same time
Recessive allele:	An allele that is suppressed when the allele partner is dominant. The recessive trait will only be expressed/seen if both alleles for the trait are homozygous recessive e.g. tt
Stem cells/meristematic cells	Undifferentiated cells that can develop into any other cell

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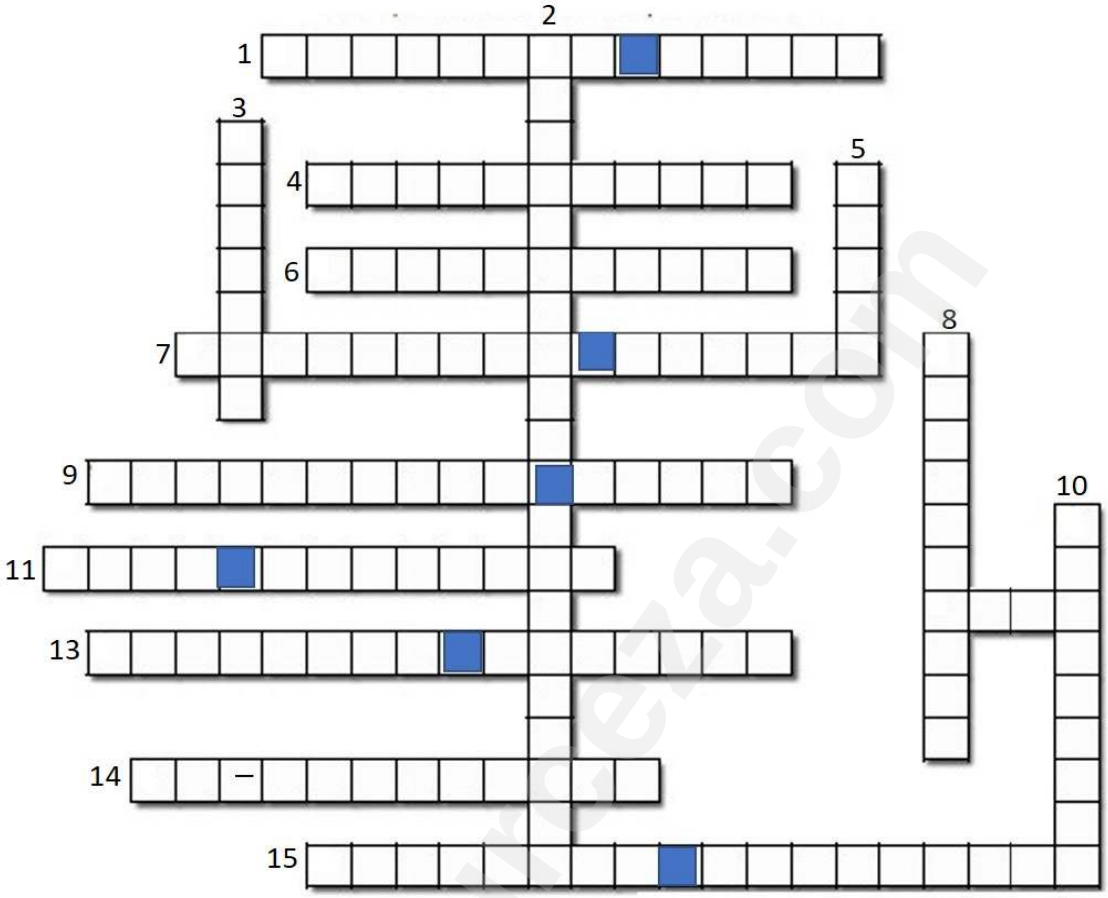
PRACTICE ACTIVITY: GENETICS

Complete the crossword puzzle below



Created using the Crossword Maker on TheTeachersCorner.net

Across

1. A genetic cross involving two different characteristics e.g. shape and colour of seeds
4. A structure made up of two chromatids joined by a centromere that carries the hereditary characteristics within the DNA
6. A sex-linked genetic disorder characterised by the absence of a blood-clotting factor
7. An allele that is suppressed when the allele partner is dominant
9. A genetic cross involving one characteristic e.g. colour of seeds
11. A change of one or more Nitrogen bases in the DNA of an organism.
12. A segment of DNA/a chromosome that codes for a particular characteristic
13. A diagram showing the inheritance of genetic disorders over many generations
14. The type of inheritance where both alleles are equally dominant, and both express themselves equally in the phenotype.
15. The type of inheritance where the dominant allele masks the expression of the recessive allele in the heterozygous condition

Down

2. The type of inheritance where both alleles express themselves in such a way that an intermediate phenotype is formed
3. Two alternative forms of a gene at the same locus
5. A copy of an organism that is genetically identical to the original organism
8. When two alleles that control a single trait (on the same locus) are identical.
10. This is the external, physical appearance of an organism

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3.3 NOTES/EXAM TIPS/TECHNIQUES

Concepts commonly confused and used interchangeably

Chromatin	Chromosomes
Long tangled thread-like structure in the nucleus of an inactive cell made up of DNA	A *chromosome* is a thread-like structure made up of DNA / that carries hereditary information in the form of genes.
Genes	**Alleles**
A segment of DNA or chromosome that codes for a particular characteristic e.g. height	Two or more versions/ forms of a gene which are located at the same position, or genetic locus, on a chromosome e.g. tall or short
Dominant allele	**Recessive allele**
An allele that masks or suppresses the expression of the allele partner on the chromosome pair and the dominant characteristic is seen in the homozygous (e.g.: TT) and heterozygous state (e.g.: Tt) in the phenotype.	An allele that is suppressed when the allele partner is dominant. The recessive trait will only be expressed/seen if both alleles for the trait are homozygous recessive e.g. tt
Phenotype	**Genotype**
The observable characteristics (physical appearance) or traits of an organism that are produced by the interaction of the genotype and the environment : the physical expression of one or more genes e.g. the plant is either tall or short	The genetic makeup of an organism e.g. TT; Tt or tt
Homozygous	**Heterozygous**
When two alleles that control a single trait (on the same locus) are identical e.g. TT; tt	When two alleles that control a single trait (on the same locus) are different e.g. Tt

CONTENT	POSSIBLE EXAM QUESTIONS
Genetics and Inheritance	• Explain terminology • Solve monohybrid crosses • Explain three types of dominance • Definition of mutation • List causes and effects of mutation • Use genetic crosses to show determination of sex-linked disorders • Use pedigree diagrams to answer questions

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Type of inheritance	Brief description of the mode of inheritance
Monohybrid cross	One characteristic is investigated, so the individuals genotype will consist of two letters **e.g. RR or Rr or rr.** Gametes will have one letter **e.g. R or r**
Complete dominance	One allele masks the expression of the other allele, **e.g. B is dominant over b**
Incomplete dominance	Neither of the alleles are dominant over each other. An intermediate phenotype (form of the gene) is obtained when both alleles are present. **e.g. in flowers RW in the genotype is expressed as pink in the phenotype**
Co-dominance	Both alleles are equally dominant, and both are expressed in the phenotype **e.g. in blood the alleles I^A and I^B result in the blood group AB**
Sex-linked	The allele causing the disorder is found on the X-chromosome **e.g. $X^H X^h$ or $X^h Y$**
Dihybrid cross	Two characteristics are investigated and therefore there will be four letters in the individual's genotype, **e.g. RRYy (two for each characteristics)** Gametes will have two different letters **e.g. Ry**
Gregor Mendel, an Austrian monk, is regarded as the father of genetics for his work on garden pea plants that helped explain how genes are passed from parents to offspring.	

3.3.1 MENDEL'S LAWS OF INHERITANCE

Mendel's first Law of Inheritance: Law (principle) of Segregation
An organism possesses two 'factors' which separate or segregate so that each gamete contains only one of these 'factors'.

Mendel's Second Law of Inheritance: Law of Dominance
When two homozygous organisms with contrasting characteristics are crossed, all the individuals of the F_1 generation will display the dominant trait. An individual that is heterozygous for a particular characteristic will have the dominant trait as the phenotype.

Mendel's Third Law of Inheritance: Law (principle) of Independent Assortment
The various 'factors' controlling the different characteristics are separate entities, not influencing each other in any way, and sorting themselves out independently during gamete formation.

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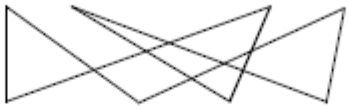
3.3.2 FORMAT OF A GENETIC CROSS

Layout of a genetic diagram	Explanation
P_1 Phenotype ..... x .....✓ Genotype ..... x .....✓ Meiosis Gametes ..... x ..... ✓ Fertilisation  **F_1** Genotype .....✓ Phenotype .....✓ P_1 and F_1 ✓ Meiosis and fertilisation✓	Visible trait is the **phenotype** e.g. tallness, shortness, etc. The genetic make-up of the individual is its **genotype** e.g. TT or Tt or tt The alleles segregate (or separate) during **meiosis** to form gametes. Each gamete has only one copy of each allele During **fertilisation** the individual gets one allele of the gene from each parent The matrix box used to determine the results of fertilisation is called a **Punnet square**
OR	
P_1 Phenotype ..... x .....✓ Genotype ..... x .....✓ Meiosis Gametes ..... x ..... ✓ Fertilisation Gametes | | | **F_1** Phenotype .....✓ Genotype .....✓ P_1 and F_1 ✓ Meiosis and fertilisation✓	

Remember that by writing P_1 and F_1 & meiosis and fertilization in the correct sequence you can get 2 marks

*The maximum marks for a genetic cross is **(6)** so you need to score 6 out of 7 possible marks.*

IMPORTANT: You may also be asked to work out the ratio or % chance of the various phenotypes or genotypes occurring. So, if there are 4 possible genotypes or phenotypes in total and only 1 having a particular phenotype, it will be a 1 in 4 ratio (25% chance)

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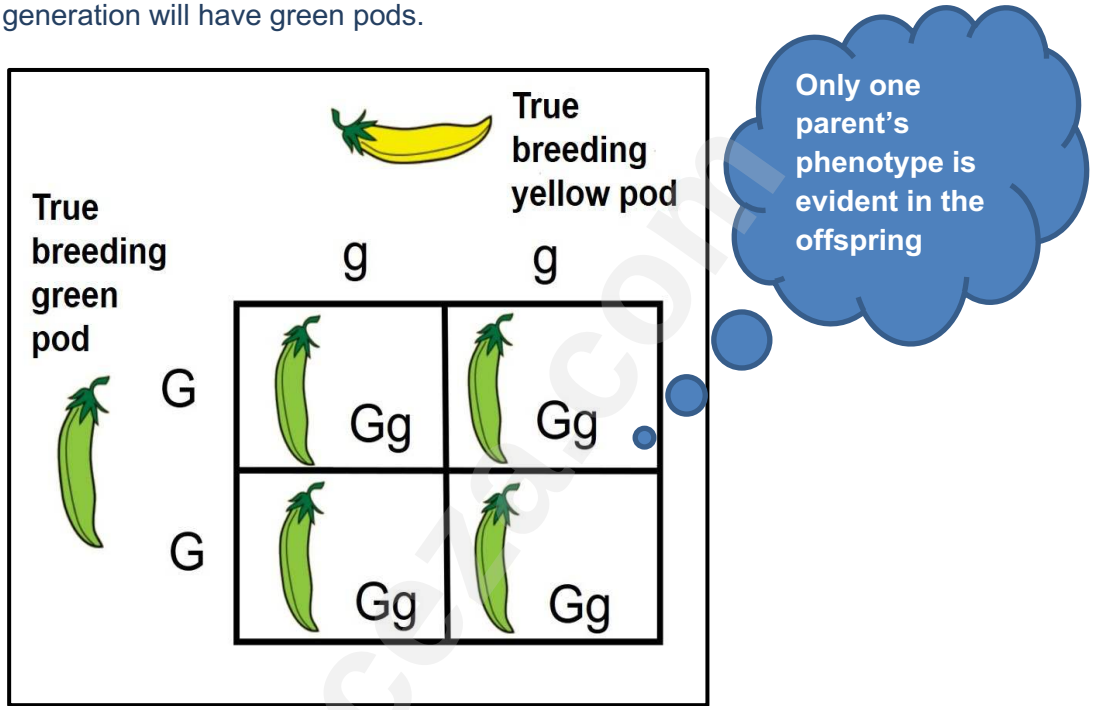
3.3.3 MONOHYBRID CROSSES

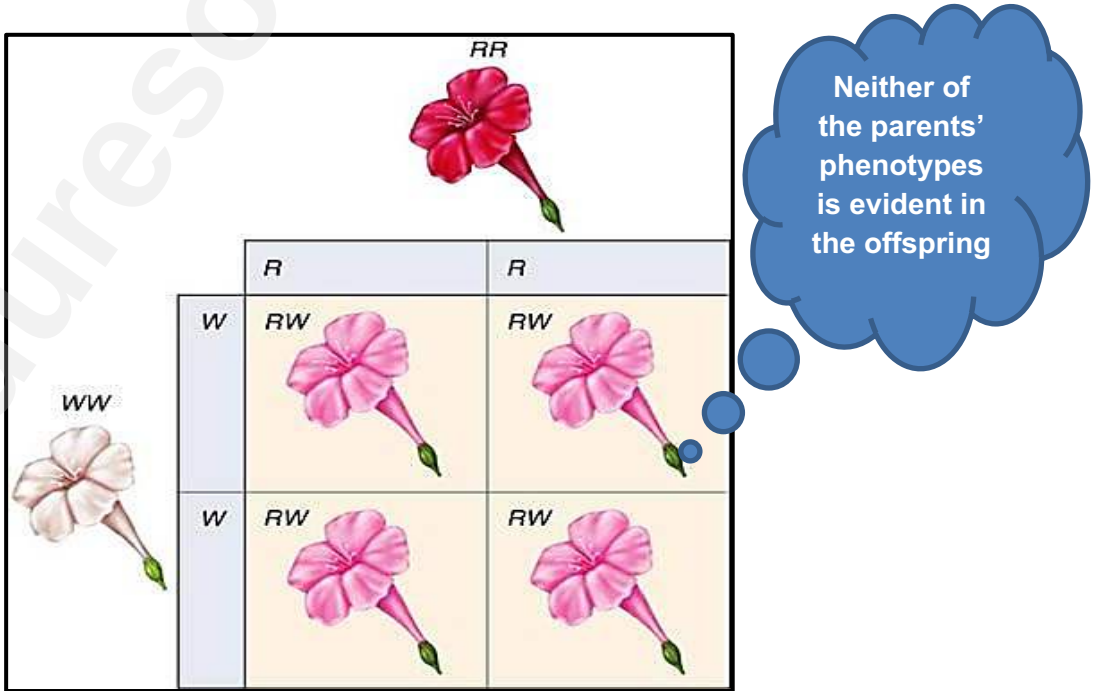
i) Complete dominance

e.g. in pea plants the allele for green pod (G) is dominant over the allele for yellow pod (g), so if you cross two homozygous parents for contrasting traits then the phenotype of all offspring in the F_1 generation will have green pods.



ii) Incomplete dominance

e.g. in flowers neither the allele for red colour (R) nor white colour (W) is dominant, so the offspring in the F_1 generation will have an intermediate or third form of colour – pink.



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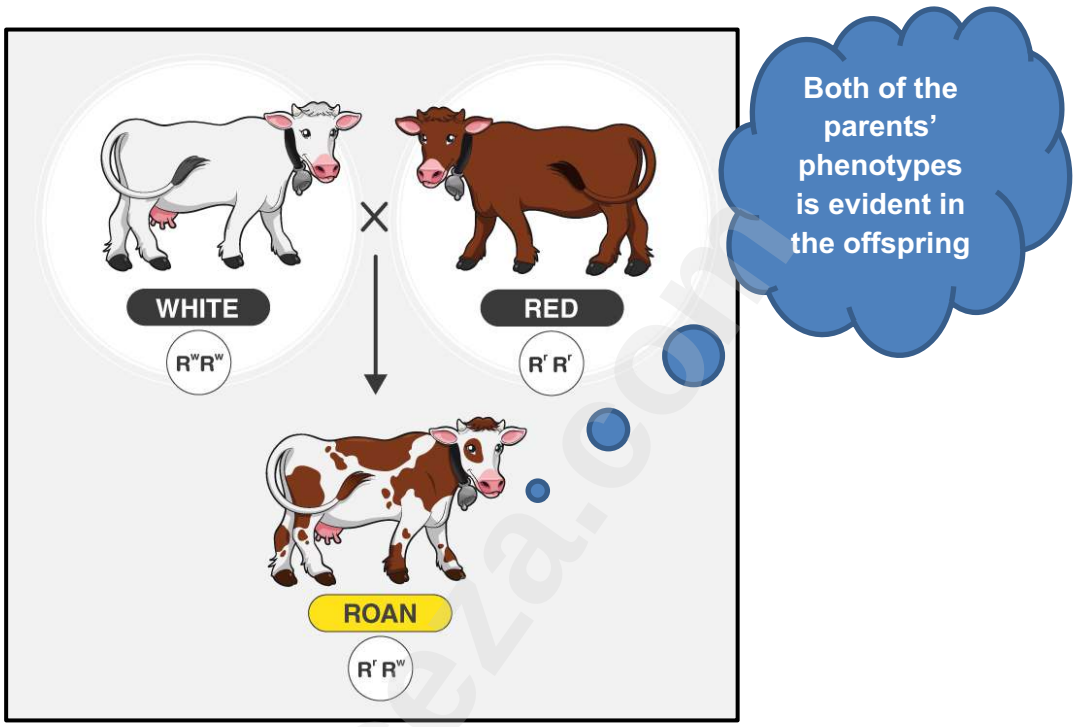
iii) Co-dominance

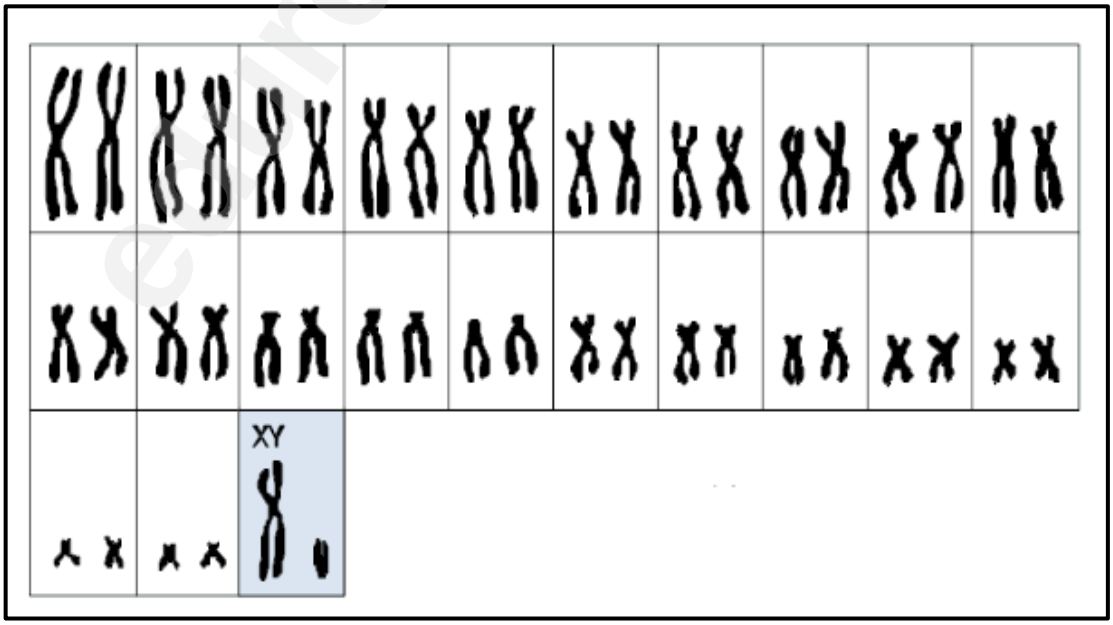
e.g. in cows the allele for red colour (R) and the allele for white colour (W) are equally dominant, so the offspring in the F_1 generation will be red and white in colour.



3.3.4 SEX DETERMINATION

- **22 pairs** of **chromosomes** in humans are **autosomes**
- **1 pair** of **chromosomes** are sex chromosomes **or gonosomes**
- **Males** have **XY** chromosomes and **females** have **XX** chromosomes at pair 23

NORMAL MALE KARYOTYPE



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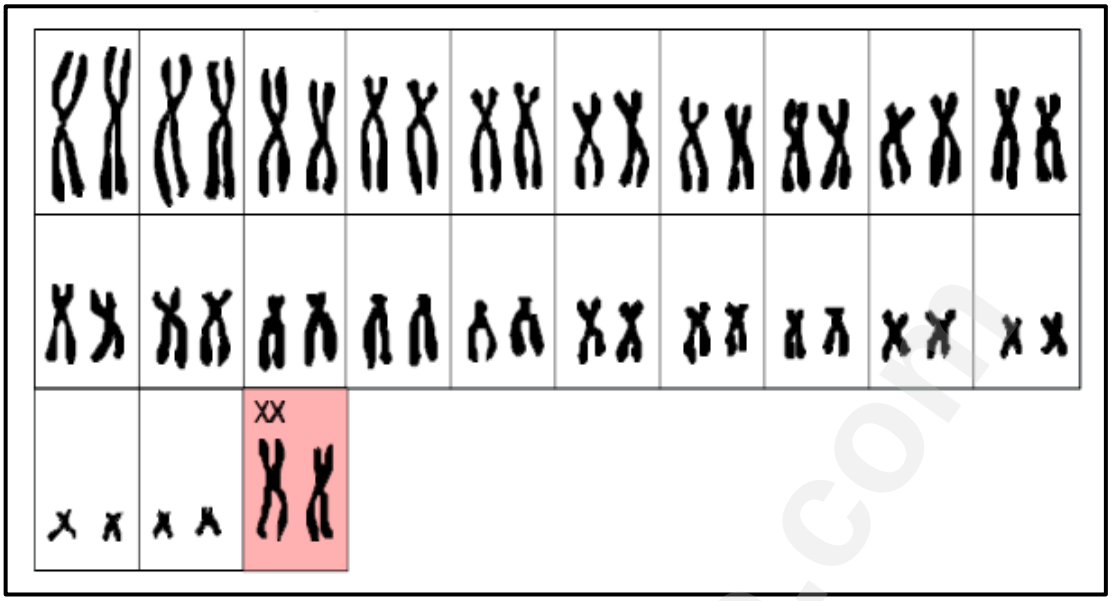
NORMAL FEMALE KARYOTYPE



A genetic cross to show the inheritance of sex

P_1 **Phenotype**: Male x Female ✓

Genotype: XY x XX ✓

Meiosis

Fertilisation

Gametes	**X**	**Y**
X	XX	XY
X	XX	XY

1 mark for correct gametes
1 mark for genotypes

F_1 **Genotype** XX ; XX ; XY ; XY✓

Phenotype 50% female 50% male✓

Ratio 1:1

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3.3.5 SEX-LINKED INHERITANCE

- A genetic disorder caused by or linked to gene(s) located in the sex chromosome.
- In humans, the sex chromosomes are the X chromosome and Y chromosome.
- A female individual possesses two X chromosomes whereas a male has X chromosome and Y chromosome.
- Since the X chromosome carries more genes that are not found in the Y chromosome, the X chromosome is more commonly linked to genetic mutations and disorders.
- Usually, the X-linked traits and disorders are expressed more in males than in females because the males have only one copy of the X chromosome.
- A typical example of this is the genetic disorder, haemophilia, caused by a defect in a gene located in the X chromosome.

Use the genetics cross recipe

PRACTICE QUESTION

Haemophilia is a sex-linked disease caused by the presence of a recessive allele (X^h). A normal father and heterozygous mother have children. Construct a genetic cross to determine the possible genotype and phenotype of the children of the parents. (6)

Remember when you answer this question it is important to identify the letters used to indicate the recessive and dominant alleles for this disorder.

P_1 **Phenotype**: Normal father x Normal mother ✓

Genotype: X^HY x X^HX^h ✓

Meiosis

Fertilisation

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

1 mark for correct gametes
1 mark for genotypes

F_1 **Genotype** X^HX^H ; X^HX^h ; X^HY ; X^hY ✓

Phenotype 50% Normal female; 25% Normal male ; 25% Affected male✓

P_1 and F_1✓
Meiosis and Fertilisation✓ **(any 6)**

IMPORTANT:
In an exam you may be asked to do other sex-linked disorders other than haemophilia and colour-blindness. Unless stated otherwise, follow the same format as in haemophilia and colour-blindness.

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3.3.6 BLOOD GROUPS

- The inheritance of blood groups is an example of multiple alleles
- The notation for alleles indicating blood groups is only I^A; I^B and i
- different combinations of the alleles result in four blood groups

1-2-3-4 Rule of blood

1. An individual has **ONE blood group**

2. An individual has **TWO alleles** for their blood group

3. There are **THREE different alleles** controlling blood groups

4. There are **FOUR blood groups**

- the inheritance of blood groups displays both co-dominance and complete dominance, it is important to understand the difference.
- **NOTE: the only acceptable notation for blood groups are I^A/I^B and i (I^A / I^B and I^O are not acceptable)**

Phenotype (Blood group)	Genotype	Type of Dominance
A	Homozygous – (I^A I^A) Heterozygous – (I^A i)	Complete dominance of I^A over i
B	Homozygous – (I^B I^B) Heterozygous – (I^B i)	Complete dominance of I^B over i
AB	Heterozygous – (I^A I^B)	Co-dominance between I^A and I^B
O	Homozygous – (ii)	Complete dominance of I^A and I^B over i

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PRACTICE QUESTION DBE P2 NOV 2020

A man with blood group AB and a woman who is heterozygous for blood group B plan to have children.

1. **How many alleles control the inheritance of blood groups?** **(1)**

   REMEMBER the 1-2-3-4 rule of blood

   3✓/Three

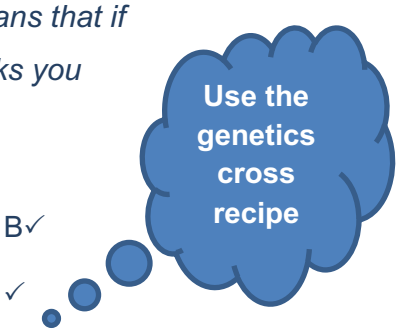
2. **Describe the type of dominance that occurs in the inheritance of blood group *B* in the woman.** **(3)**

   Some alleles in blood groups are dominant and some are recessive, so read the question carefully to see which blood group is mentioned in the question.

   – complete dominance✓
   – the allele for blood group B/I^B is dominant✓and
   – the allele for blood group O/i is
   – recessive✓

3. **Use a genetic cross to show all the possible genotypes and phenotypes of their children.** (6)

   The question asks for the possible genotypes and phenotypes of the children so these will be linked to compulsory marks. This means that if you do not answer this part of the question the maximum marks you can get is 4/6. **(10)**



P_1 **Phenotype** Blood group AB x Blood group B✓

Genotype $I^A I^B$ x $I^B i$ ✓

Meiosis

G/gametes I^A , I^B x I^B , i ✓

Fertilization

F_1 **Genotype** $I^A I^B$; $I^A i$; $I^B I^B$; ii ✓*

Phenotype Blood group:

AB; A; B✓*

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P_1 and F_1✓

Meiosis and fertilization ✓

2 compulsory* + Any 4

OR

P_1 **Phenotype** Blood group AB x Blood group B✓

Genotype $I^A I^B$ x $I^B i$ ✓

Meiosis

Fertilization

Gametes	**I^A**	**I^B**
I^B	$I^A I^B$	$I^B I^B$
i	$I^A i$	$I^B i$

1 mark for correct gametes✓

1 mark for correct genotypes ✓*

F_1 **Phenotype** Blood group:

AB; A; B✓*

P_1 and F_1✓

Meiosis and fertilization✓

2 compulsory* + Any 4

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3.3.7 DIHYBRID CROSSES

- Dihybrid crosses involve **two pairs** of alleles representing **two different** characteristics, e.g., the height of a plant and the colour of its seeds.
- According to the Law of Independent Assortment, alleles of different genes move (segregate) independently of each other into the gamete. They therefore appear on the gametes in different combinations.

Steps to follow when solving a dihybrid cross

<table>
<tr><th>STEPS</th><th>WHAT TO DO</th></tr>
<tr><td>1</td><td>Identify the phenotypes of the two organisms for each of the two characteristics:
tall yellow flowers x short orange flowers</td></tr>
<tr><td>2</td><td>Choose letters to represent the alleles for the gene responsible for each characteristic: Tall (T); Short (t) ; Yellow (Y); Orange (y)</td></tr>
<tr><td>3</td><td>Write the genotype of each parent: TtYy x Ttyy</td></tr>
<tr><td>4</td><td>Determine the possible gametes that each parent can produce
Remember that each parent will have two alleles for each gene
the gametes of each parent will have only one allele for each gene because of segregation during meiosis
<table>
<tr><th></th><th>T</th><th>t</th></tr>
<tr><td>Y</td><td>TY</td><td>tY</td></tr>
<tr><td>y</td><td>Ty</td><td>ty</td></tr>
</table>
<table>
<tr><th></th><th>T</th><th>t</th></tr>
<tr><td>y</td><td>Ty</td><td>ty</td></tr>
<tr><td>y</td><td>Ty</td><td>ty</td></tr>
</table></td></tr>
<tr><td>5</td><td>Enter possible gametes on the side and top of the Punnet square
<table>
<tr><th></th><th>TY</th><th>Ty</th><th>tY</th><th>ty</th></tr>
<tr><td>Ty</td><td></td><td></td><td></td><td></td></tr>
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<tr><td>ty</td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>6</td><td>Because of random fertilization, gametes from both parents could fuse in different combinations to form the offspring
In the Punnet square, write down the genotypes of the offspring that will result from each possible combination of gametes
<table>
<tr><th></th><th>TY</th><th>Ty</th><th>tY</th><th>ty</th></tr>
<tr><td>Ty</td><td>TTYy</td><td>TTyy</td><td>TtYy</td><td>Ttyy</td></tr>
<tr><td>Ty</td><td>TTYy</td><td>TTyy</td><td>TtYy</td><td>Ttyy</td></tr>
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</table></td></tr>
<tr><td>7</td><td>Determine the phenotypes of the offspring from the genotypes obtained in the Punnet square</td></tr>
</table>

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EXAM TIPS

DBE Diagnostic report 2020

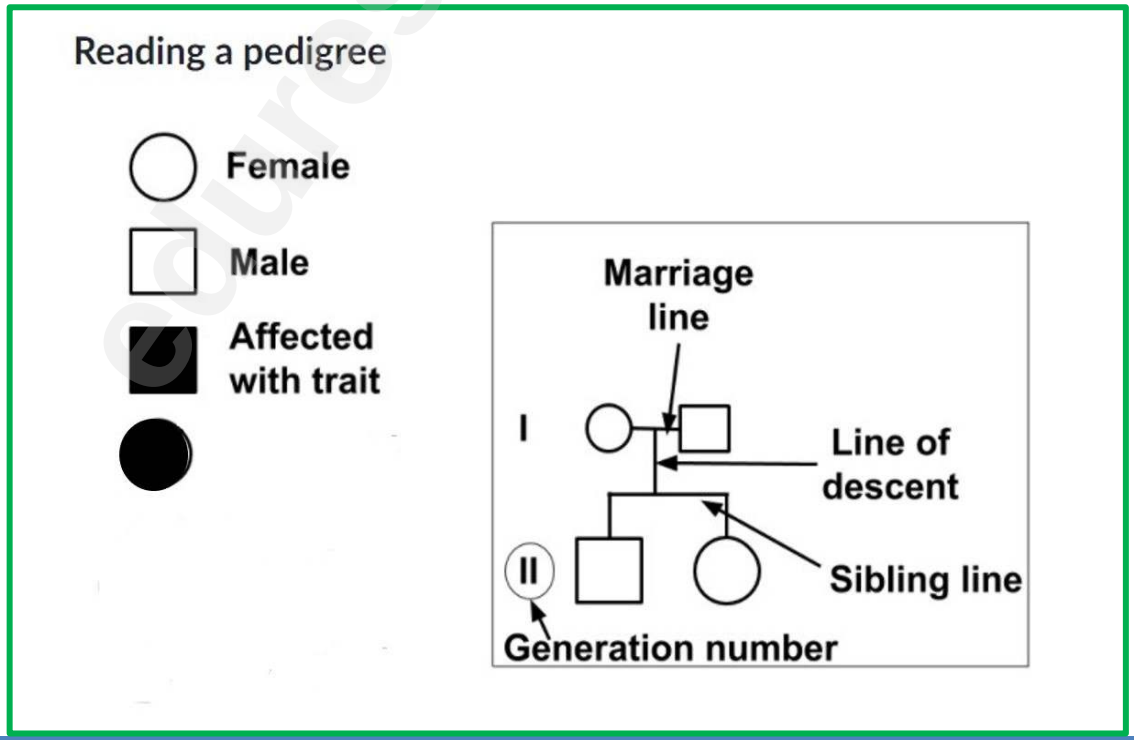
Phenotypes are written as a cross, e.g., white x rough instead of White fur and rough texture.

• Double letters are used for the genotype of gametes for a single characteristic

Know the difference between the genotype of an individual (BBhh) and the genotype of a gamete (Bh) in a dihybrid cross.

3.3.8 PEDIGREE DIAGRAMS/GENETIC LINEAGES

- A genetic lineage/pedigree traces the inheritance of characteristics over many generations.
- Not **ALL** questions on pedigree diagrams are related to **sex-linked** disorders.
- Learners should be able to interpret pedigree diagrams with or without a key.
- ***The only sex-linked disorders you will be required to know are:***
    - ***Haemophilia***
    - ***Colour-blindness***
- ***if any other sex-linked disorder is examined more information will be given in the stem of the question***
- ***Reasons why males have a greater chance of having a sex-linked disorder:***
    - *Males have only one X chromosome (XY)*
    - *If they inherit the affected allele on the X chromosome, then they will have the disorder*
    - *As they do not have another X chromosome to mask it*



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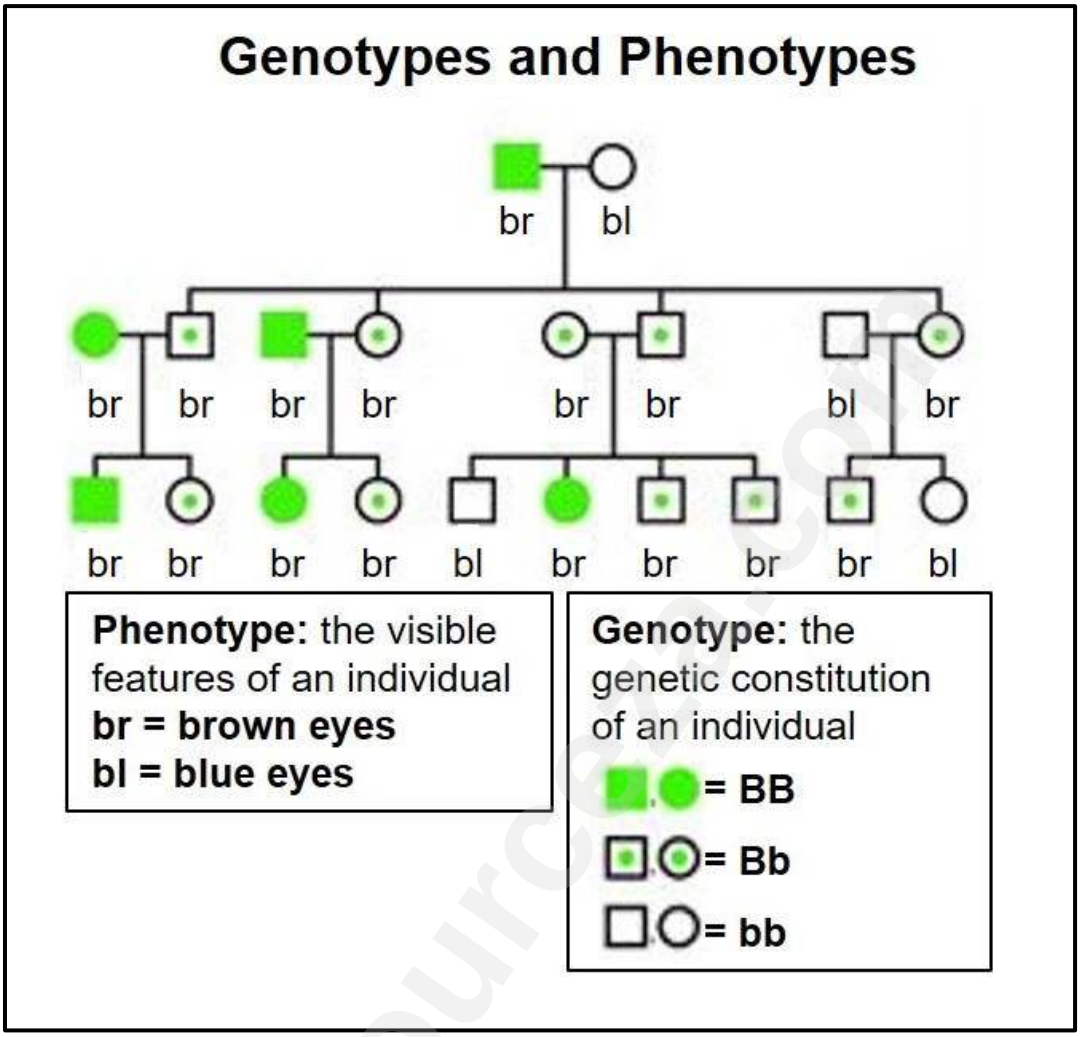

Steps in solving a pedigree

- Study any **key and opening statement/s** and look for **dominant characteristics** and phenotypes.
- Fill in the **genotype of all the individuals with the recessive condition-** it must have 2 **lower case** letters e.g. bb
- For every individual in the diagram that has the recessive condition, it means that each gene was obtained from each of the parents. **Work backwards** and fill **in one recessive gene for each parent.**
- If the **parents showed the dominant characteristic** fill in the **second letter** which must be a **capital letter**.
- Any other individual showing the dominant characteristic will most likely be **homozygous dominant** – two capital letters.

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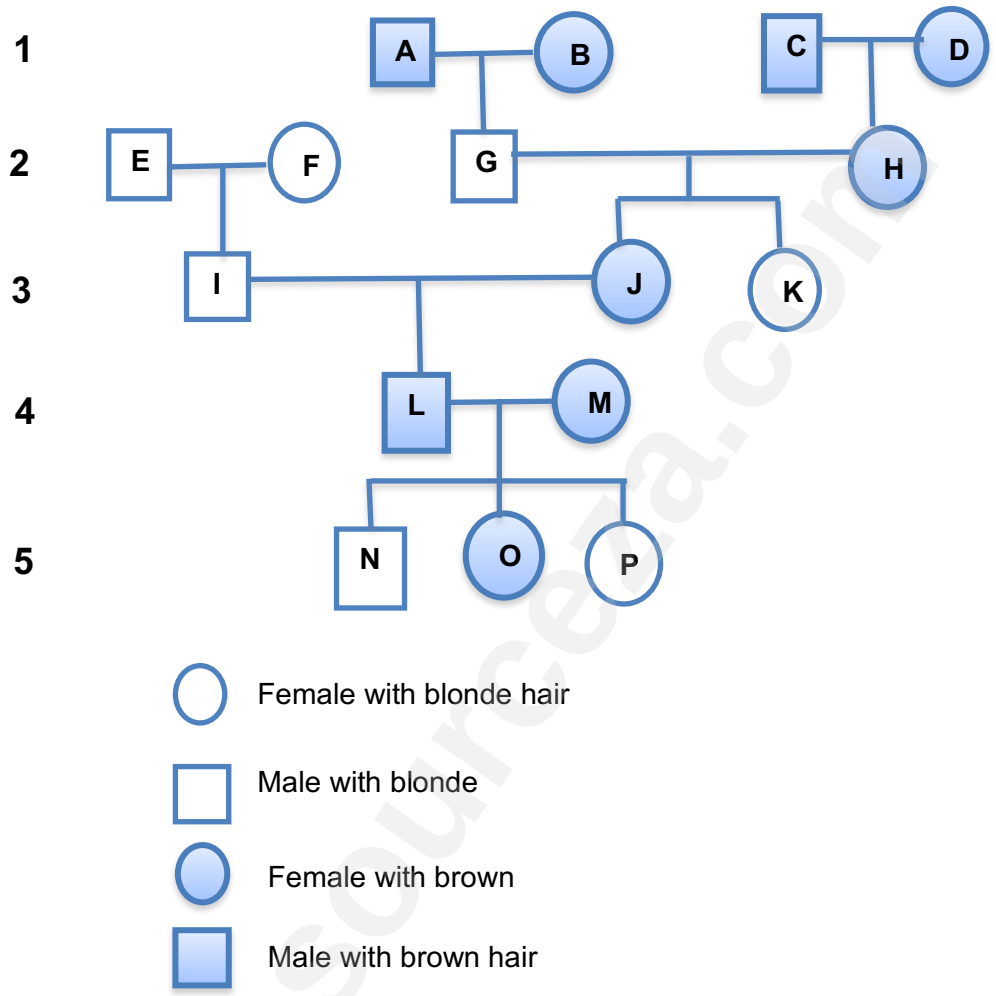
How to approach answering pedigree diagram questions:

Generation



Analysing the genetic lineage in a pedigree diagram above:

Step 1: Mark all the **homozygous recessive** individuals with blonde hair. This will be all the white shapes: E, F, G, I, K, N and P as **bb** on the pedigree chart.

Step 2: Work from the generation line 5 up towards the generation line 1 so that you start with the last offspring on the pedigree diagram. To produce an offspring with **bb**, BOTH parents must have at least one homozygous recessive gene (**b**).

If the parent is a white shape – then the parent is **bb** and already marked. If the parent is a blue shape and produced a **bb** offspring, then the parent must be heterozygous **Bb**. Mark the **Bb** parents on the pedigree diagram.

Step 3: Parents that are blue shapes and produce only blue shape offspring, can be homozygous **BB** or heterozygous **Bb**. Look to the next generation and then work backwards. Mark the parents on the pedigree diagram.

Step 4: Answer the questions that relate to the pedigree diagram.

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ACTIVITY

Try to work out the genotype of A, B, C, D, H, J, L, M and O on your own first.

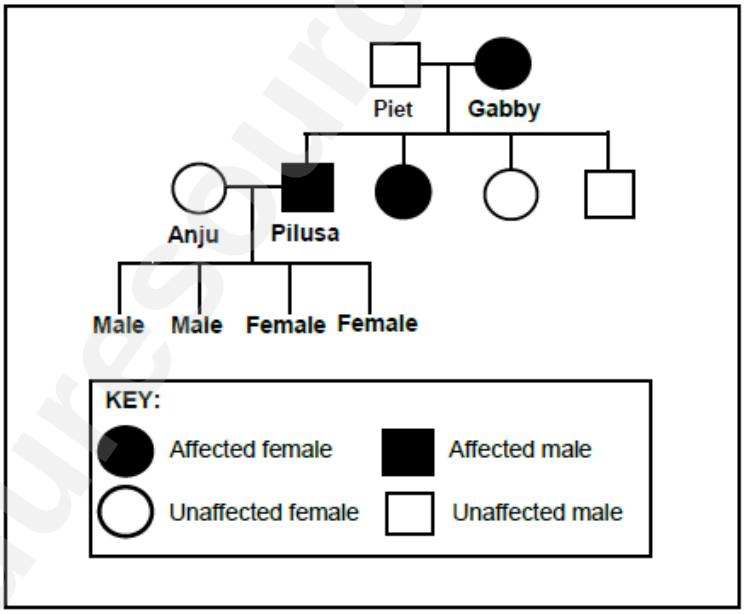
ANSWER

Let us see if you were right:

- A and B are **Bb** because they produce G (**bb**)
- If C is **BB,** then D must be **Bb** or C is **Bb** then D is **BB** because H must be **Bb** to produce K (**bb**)
- J is **Bb** because G is **bb** and H is **Bb** (produced sister K - **bb**)
- L and M are both **Bb** because parent J is **Bb** and I is **bb** so they cannot be homozygous **BB** and L and M produce a son (N) and daughter (P) that are both homozygous **bb**
- Offspring O can be either **BB** or **Bb** because both parents are heterozygous **Bb**

PRACTICE QUESTION *DBE P2 NOV 2020*

Goltz syndrome is a sex-linked genetic disorder. It is caused by a dominant allele X^G. The diagram below shows the inheritance of Goltz syndrome in a family.



1. **Name the type of diagram shown.** **(1)**

REMEMBER it is important to know the difference between a pedigree diagram, genetics cross and a phylogenetic tree.

Pedigree✓ diagram

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2. How many:

(a) Females are in this family? **(1)**

Look at the key to determine the shape used to represent females as well as the labels in the third generation.

6✓

(b) Males in the F_1-generation have Goltz syndrome? **(1)**

*In this question you need to look for the shape representing males and at a specific generation in the family lineage. Here they are not asking for a generation, but specifically the **F_1** generation*

1✓

3. Give Gabby's genotype. **(2)**

Genotype is the genetic make-up of the individual. REMEMBER this disorder is X-linked so the gender of the individual mentioned in the question is important.

$X^G X^g$✓✓

4. Anju and Pilusa have four children. Give the phenotype of their sons. **(2)**

In this question it is important to look at the key for the phenotype.

Unaffected✓✓/without Goltz syndrome

5. Explain your answer to QUESTION 2.5.4. **(4)**

When a question asks you to 'explain' you need to give the answer in a cause-effect or statement and reason sequence. This question is not asking you to say what the genotype of the sons is, but rather why their genotype is what it is.

- Pilusa is affected✓/X^G Y – *statement*
- Anju is unaffected✓/X^g X^g – *statement*
- Males inherit the Y chromosome from Pilusa✓ – *reason*
- and inherit X^g from Anju✓ – *reason*

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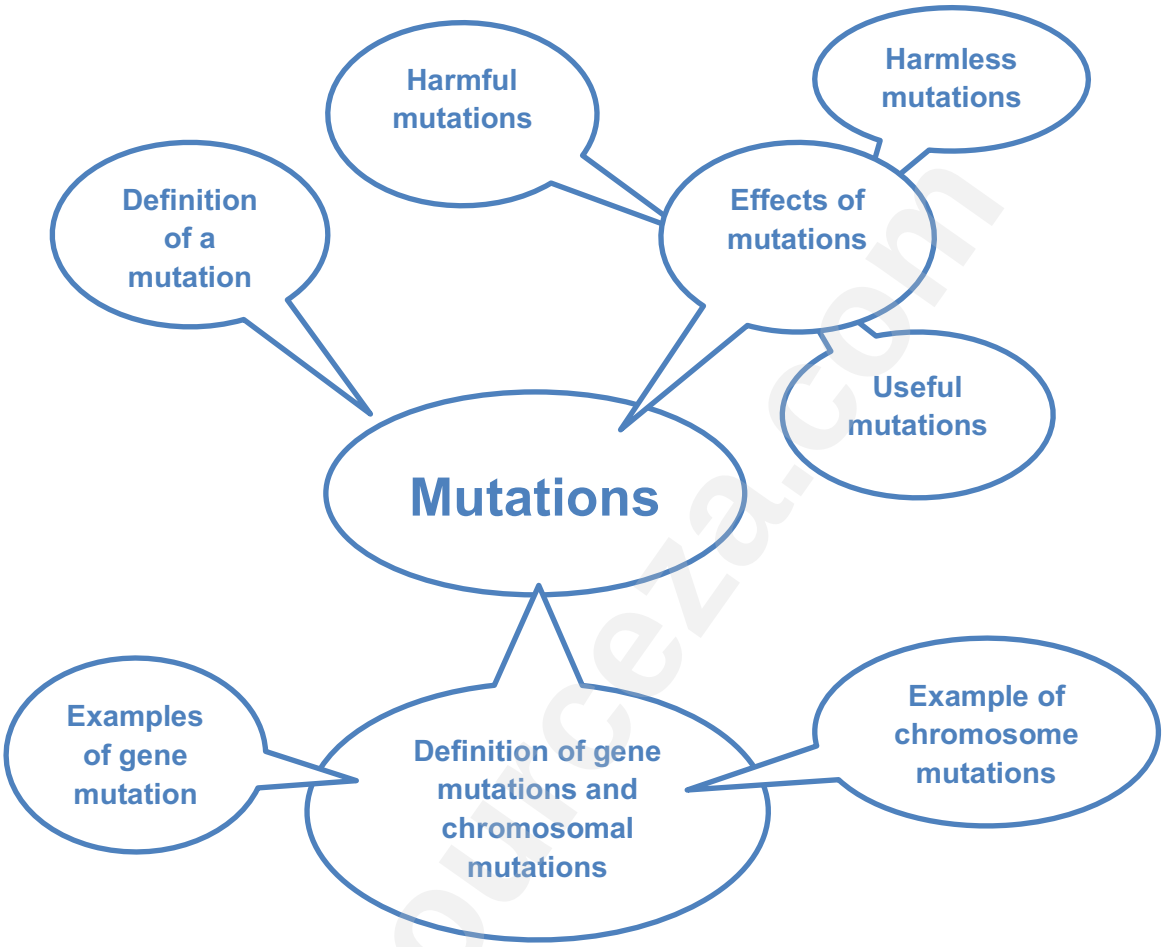
3.3.9 MUTATIONS



EXAM TIPS

*Know the difference between the terms **mutation, gene mutation,** and **chromosome mutation.***
The definition of a mutation is more general than the definitions of a gene or chromosome mutation, which are more specific.
NOTE:** a description of point and frameshift mutations are **not required!

- **Mutation** – a sudden change in the genetic composition of an organism
- **Gene mutation** – a change in the sequence of nitrogenous bases or nucleotides in DNA
- **Chromosomal mutation** – a change in the normal structure or number of Chromosomes

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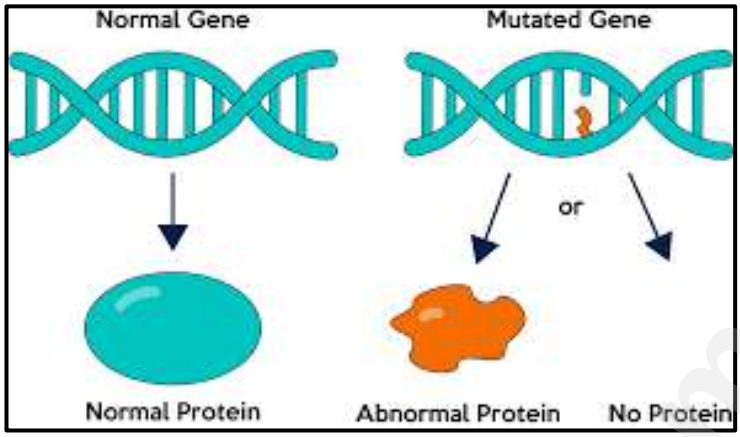


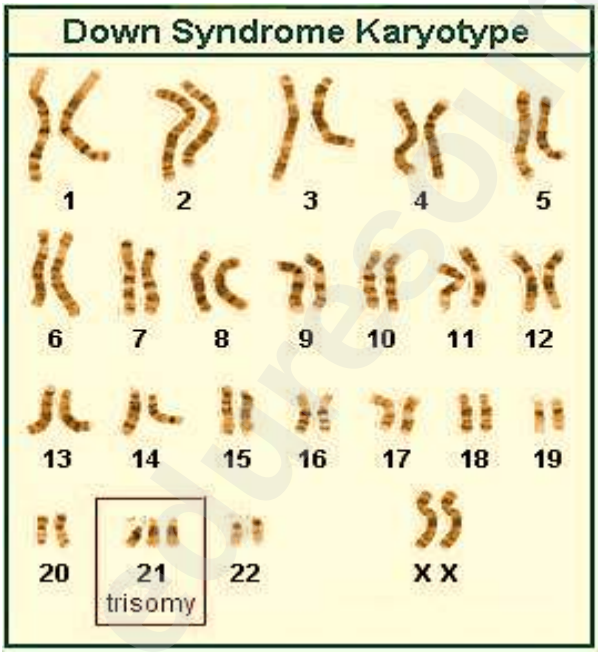
Examples of gene mutations

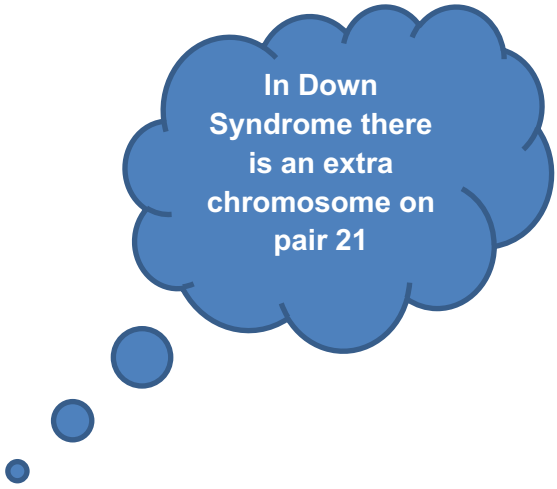
Know these examples:

- *Haemophilia – absence of blood clotting factors*
- *Colour-blindness – due to the absence of the protein that comprise either the red or green cones/photoreceptors in the guide*

Example of chromosomal mutations

- *Down syndrome – due to an extra copy of chromosomes 21 as a result of non-disjunction during meiosis*





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3.3.10 GENETIC ENGINEERING

Biotechnology is the manipulation of biological processes to satisfy human needs

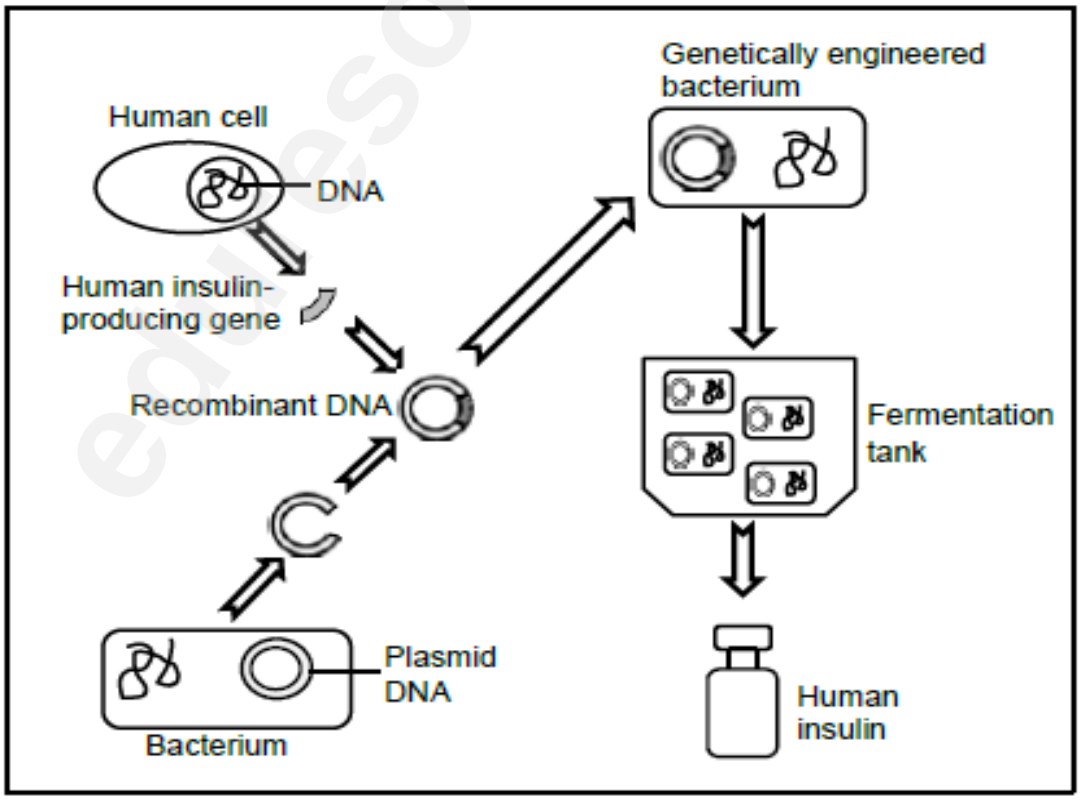
Advantages of Genetic engineering	Disadvantages of Genetic engineering
• Production of medication/ resources cheaply • Control pests with specific genes inserted into a crop • Uses specific genes to increase crop yields/ food security • Selecting genes to increase shelf-life of plant products	• Expensive/ research money could be used for other needs • Interfering with nature or immoral • Potential health impacts • Unsure of long-term effects

Why people might be against genetic engineering:

- **The long-term effects of genetic engineering on the environment are not known so it could lead to health problems in the future**
- **It is morally wrong to engage in genetic engineering since it is interfering with nature**

Practice question *DBE P2 MAY-JUNE 2019*

3.3 Synthetic insulin is used to treat diabetes and is produced by genetic engineering technology.
The diagram below represents the process.



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1. Define *genetic engineering*. **(2)**

Genetic engineering is an aspect of biotechnology which includes genetically modifying organisms

- The manipulation of genetic material✓
- to produce a genetically different✓/identical organism/repair tissues and organs

OR

- The manipulation of genetic material ✓
- to produce something of benefit to humans✓/society

2. Describe the steps involved in producing the recombinant DNA. **(4)**

You need to look at the diagram to get the steps for the answer to this question. The only relevant part to answer is how the recombinant DNA is formed. There is no need to mention the rest of the process in the diagram.

- A plasmid/ circular DNA is removed from the bacterial cell✓
- It is cut✓ using enzymes
- The insulin gene is removed from the human cell✓ and
- Inserted into the plasmid✓ to form recombinant DNA

3. Explain why bacteria are most suitable for genetic engineering. **(2)**

For this question you need to recall grade 11 knowledge on Bacteria

- Bacteria reproduce very rapidly✓
- forming many copies of the gene✓ in a short period of time

OR

- Bacteria reproduce asexually✓/by mitosis
- forming identical copies of itself✓

OR

- The bacterial DNA is in the form of a plasmid✓,
- for easy insertion of genes✓

OR

- Bacteria exist everywhere✓
- so, they can be obtained with no difficulty✓/expense

OR

- Bacteria are simple organisms✓
- so, their use is unlikely to raise ethical issues✓ (any 1 x 2)

4. Suggest THREE objections that some people might have to genetic engineering. **(3)**

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The examiners are asking for THREE objections, so no more than three are required. Marking principles of Life Sciences require that when marking this question only your first three answers will be marked, whether they are correct or not. Any further answers you give will not be marked.

- Expensive✓/research money could be used for other needs
- Interfering with nature ✓/ immoral
- Potential health impacts✓
- Unsure of long-term effects✓

Mark first THREE only

i) Stem cell research

Sources:

- embryonic stem cells
- bone marrow

Uses:

- treat cancers of the blood e.g., leukaemia,
- replacing dead cells in the heart after a heart attack
- growing skin tissue to treat burn victims
- growing nerve cells to treat spinal cord injuries and Parkinson's
- disease
- growing pancreatic cells to treat diabetes

However, a great deal more research is needed before these procedures are perfected. Parents who believe that there will be success in the future, are able to collect umbilical cord blood from their babies at birth. This blood can now be frozen and stored for future use. Although such facilities are available in South Africa, it is an expensive option.

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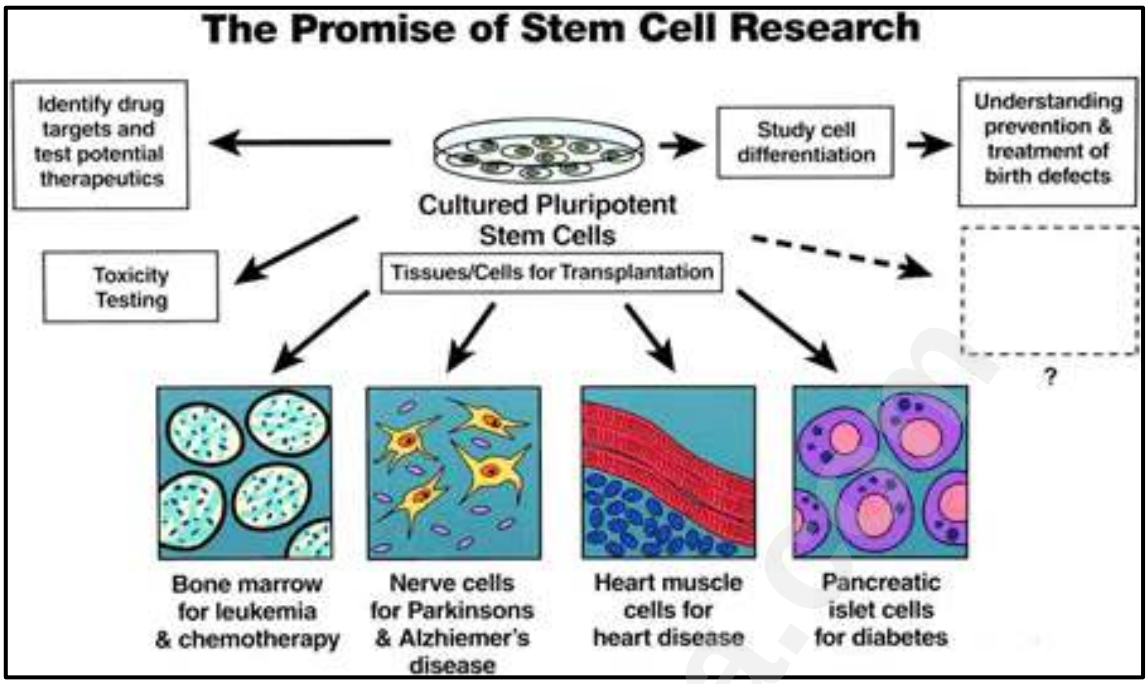

Practice question *DBE P2 MAY-JUNE 2018*

Read the extract below.

> Stem cell surgery has been performed for the first time in South Africa at a Cape Town hospital. A patient became paralysed in a diving accident. He had no movement or feeling in any of his limbs because his nerve cells were damaged. Embryonic stem cells were used in an attempt to correct a defect in the spinal cord of the patient. He has now developed partial sensation throughout the body.

1. **Explain why stem cells are suitable cells to use for the treatment of this patient.** **(3)**

   In this question you are required to apply your knowledge of stem cells and give the answer in a statement – reason sequence.

   - Stem cells are undifferentiated✓
   - and have the potential to develop into any type of cell✓
   - to replace the nerve cells that are damaged✓

2. **Explain why some people prefer the use of umbilical cords as a source of stem cells rather than the use of human embryos.** **(2)**

   In this question you are required to apply your knowledge of stem cells and give the answer in a statement – reason sequence

   - An embryo is a potential life✓/could develop into a baby
   - It poses moral or ethical issues✓

   OR

   - Umbilical cords are discarded✓
   - Do not pose a moral or ethical issue✓

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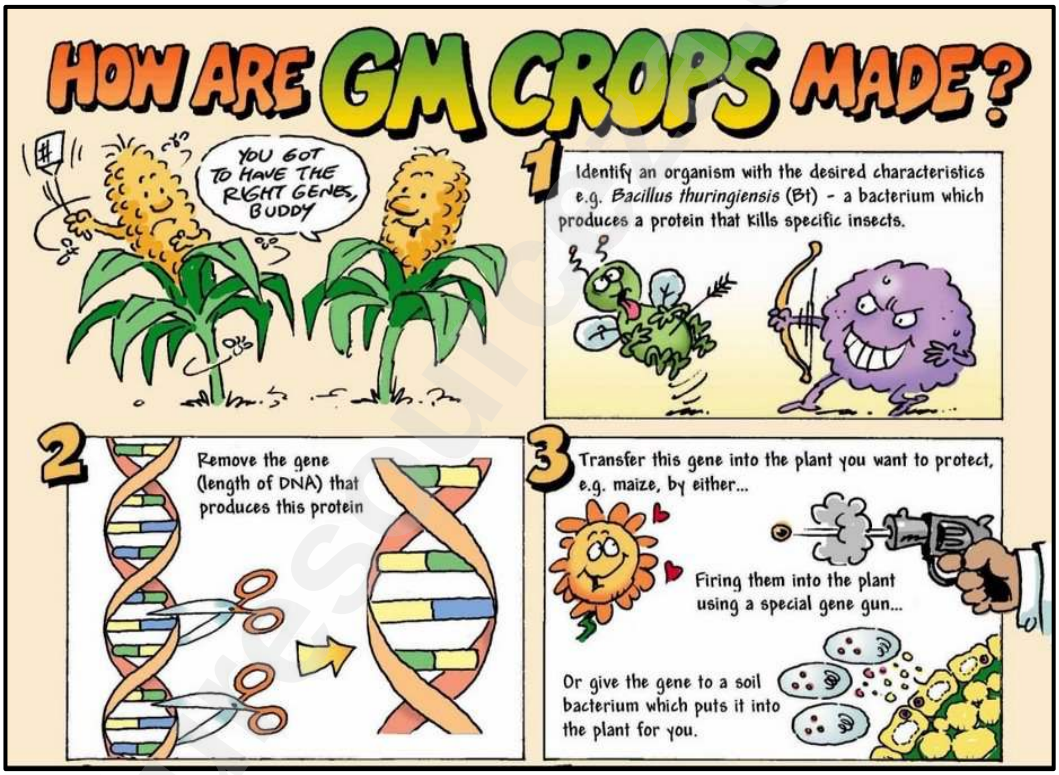
ii) Genetically modified organisms

- Genetic engineering is used to alter the genome of a living cell for medical, industrial, or agricultural purposes.
- This results in a **genetically modified organism** (GMO) or transgenic animal (animal with DNA from more than one species).

GMO's are used …

- to breed more productive crops or animals so that more food can be made
- to produce drugs or hormones (e.g., insulin) which have fewer side-effects and is cheaper.
- to 'infect' cells to cure diseases (gene therapy) such as brain tumors and cystic fibrosis.



Practice question *DBE P2 MAY-JUNE 2017*

3.4 Farmers use insecticides to kill insects that damage their crops. In this way they are able to increase their crop yield.

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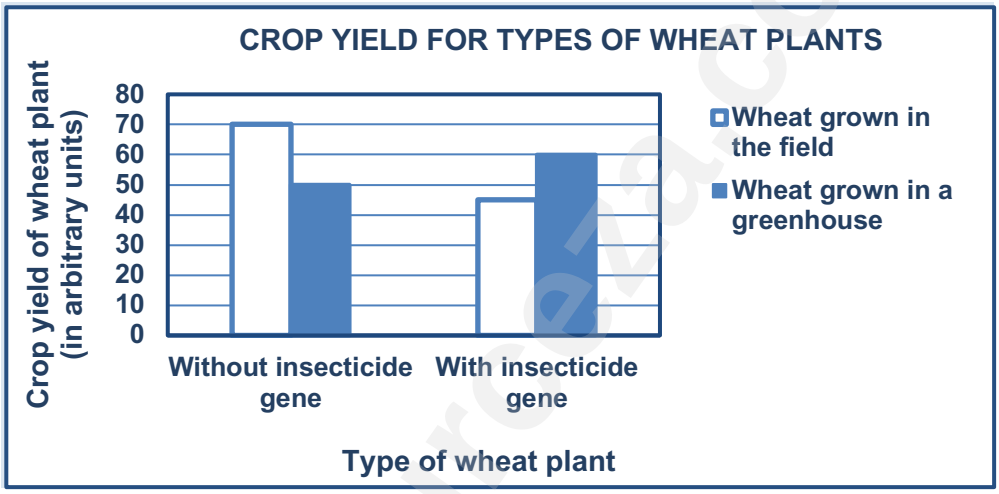
They found a bacterium which contains a gene that produces insecticides. Scientists transferred the insecticide gene to wheat plants and wanted to investigate the effectiveness of this process in increasing crop yield. Below are some of the steps they followed.

- Wheat plants with the insecticide gene were grown in a field and in a greenhouse.
- Wheat plants without the insecticide gene were grown in a field and in a greenhouse.
- The crop yield of the wheat plants was measured.

The results are shown in the graph below.



3.4.1 What is the process called where wheat plants are altered by the insertion of genes? **(1)**

Note in this question they are asking for the name of the process and not the product

Genetic engineering✓/modification/recombinant DNA technology

3.4.2 Insecticides are expensive and add to the cost of produce.

State ONE other disadvantage of using insecticides. **(1)**

In this question the examiners have given one disadvantage of insecticide use, they want you to mention a different one. Once again, only your first answer will be marked according to the marking principles in Life Sciences.

– Can kill other useful insects✓
– Can cause pollution✓
– May cause harm to consumers of the produce✓ Any 1

(Mark first ONE only)

3.4.3 State TWO ways in which scientists could have improved the validity of this investigation. **(2)**

Validity refers to the experimental method and how appropriate it is in addressing the aim of the investigation. For example, keeping

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all other factors constant/identifying the controlled variables helps in making an investigation valid.

- Use the same field✓/greenhouse
- Use the same number of plants✓
- Use the same species of wheat✓
- Measure the crop yield over the same period✓
- Use same techniques of measuring the crop yield✓ Any 2

3.4.4 Describe the difference in results for the wheat with the insecticide gene grown in a greenhouse and the wheat grown in a field. (2)

In this question the examiners want you to describe the difference in the results and not calculate them.

- In the greenhouses high yield✓
- In the fields low yield✓

iii) Cloning

Benefits of cloning:

- Therapeutic cloning can replace damaged tissue e.g. skin, heart cells and bone marrow, so helping to save human lives.
- Genetic diseases could be prevented.
- Superior animals may be bred to improve food supply and quality.
- Research in any form improves skills and could open other avenues due to spin-off technologies which could help mankind in the future.

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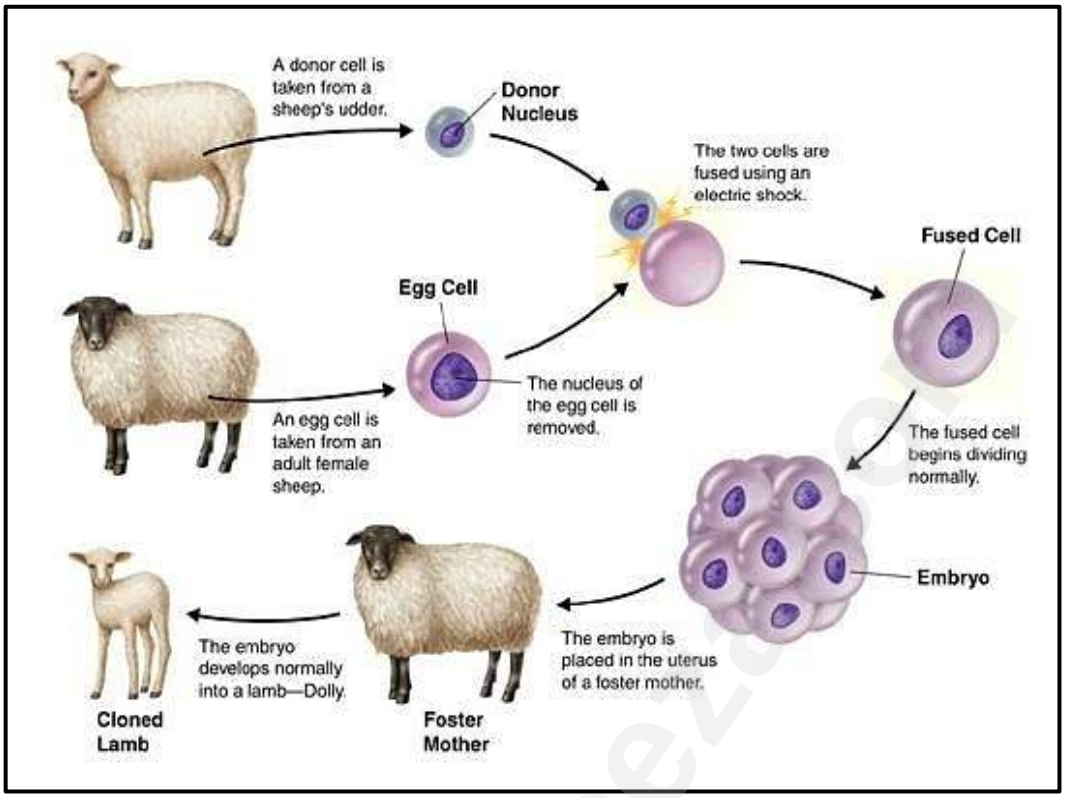
PROCESS OF CLONING



EXAM TIPS

Practice question: ***DBE P2 NOV 2020***

It is important for learners to know a brief outline of the process and benefits of cloning. In this question the process was given in the stem of the question step by step, in some questions in the past the process was described in a diagram.

1. **What is *cloning*?** **(1)**

   In this question a simple definition is required. This is part of the terminology that should be learnt well.

   The production of (genetically) identical organisms✓

2. **Explain why the nucleus of a muscle cell was used and not the nucleus of a sperm cell.** **(2)**

   For this question you need to recall grade 11 knowledge on chromosome number of somatic cells and gametes i.e. diploid number and haploid number, and apply to the example given

   – A muscle cell contains all the genetic material✓ of the bull/is diploid whereas
   – a sperm cell has only half the genetic material✓/ is haploid

3. **Explain why the nucleus of the ovum was removed.** **(2)**

   In this question you are required to apply your knowledge of cloning and give the answer in a statement – reason sequence

   – to remove the genetic material of the cow✓

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– so that only the genetic material from the (best meat producing) bull is present✓

4. State ONE benefit of cloning. **(1)**

In this question you are required to write down information without discussion. Only one answer will be marked according to the Marking principles.

– to produce organisms with desired traits✓ e.g., health; appearance; nutritious; yield; shelf-life; etc.

– Conservation of threatened species✓

– To create tissues/organs for transplant✓

Mark first ONE only Any 1

3.11 PATERNITY TESTING

Blood grouping and DNA profiles are used to determine paternity

Blood grouping

- The child received an **allele for blood group** from the **mother** and an allele from the **father**.
- If the blood group of the mother and the possible father cannot lead to the blood group of the child, then the man is not the father.
- If it can lead to the blood group of the child, then the man might be the father, **but this is not conclusive as many men have the same blood group.**

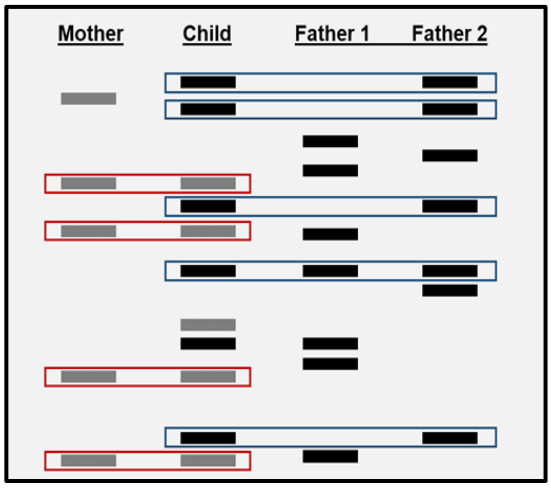
DNA profiles

- The **mother's bands** are compared to the **child's bands** to see which bands correlate.
- The **remaining bands** of the **child** are compared to the bands of the **possible father**.

Blood groups

Mother's Blood Type	Father's Blood Type: A	B	AB	O	Child's Blood Type
A	A or O	A, B, AB, or O	A, B, or AB	A or O	
B	A, B, AB, or O	B or O	A, B, or AB	B or O	
AB	A, B, or AB	A, B, or AB	A, B, or AB	A or B	
O	A or O	B or O	A or B	O	

DNA profile



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Practice question *DBE P2 NOV 2015*

The father of a child can be determined by analysing blood groups.

1. Explain how an analysis of blood groups can be used to determine paternity. (5)

In this question you are required to apply your knowledge of inheritance of blood groups and how this can be used to test paternity. The answer must be given in a statement – reason sequence.

- The blood groups of the mother, possible father and the child must be compared✓
- If this shows that it is not possible that these parents can produce a child with his/her blood group✓
- Then the man is not the father✓
- If it shows that it is possible that these parents can produce a child with his /her blood group✓
- The he may/may not be the father✓
- Because other males may have the same blood group

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4. TYPICAL EXAM QUESTIONS

QUESTION 1 *(Questions taken from various sources)*

Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A to D) next to the question number (1.1 to 1.6) in your ANSWER BOOK, for example 1.7 D.

1.1 In humans, light hair colour is recessive to dark hair colour. In one family, the mother has dark hair, the father has light hair, one daughter has light hair and the other daughter has dark hair.

Which ONE of the following combinations best represents the genotypes for the mother and the daughter with dark hair?

A mother DD, daughter DD
B mother Dd, daughter Dd
C mother DD, daughter Dd
D mother Dd, daughter DD

1.2 Ultraviolet radiation causes mutations, which sometimes leads to antibiotic resistance in bacteria. To investigate this, bacteria were first exposed to ultraviolet radiation and then their resistance to different antibiotics was measured. The results are shown in the table below.

✓ = resistant **X = non-resistant**

	Antibiotic resistance		
Treatment	**Antibiotic P**	**Antibiotic R**	**Antibiotic S**
Before exposure to ultraviolet radiation	✓	X	X
After exposure to ultraviolet radiation	✓	X	✓

A suitable conclusion for the investigation would be that a mutation in bacteria led to a resistance to antibiotic …

A R only.
B P and R.
C S only.
D R and S.

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1.3 In the tobacco plant, albinism (the inability to make chlorophyll) is a recessive trait. Two heterozygous tobacco plants were crossed, and 300 seedlings were produced. What is the percentage chance that the seedlings will have albinism?

A 75%

B 300%

C 50%

D 25%

1.4 An autosomal genetic disorder is caused by a dominant allele **R**.

Consider the following crosses.

(i) rr x Rr

(ii) rr x RR

(iii) Rr x Rr

(iv) Rr x RR

Which ONE of the following combinations of crosses can result in offspring without the disorder?

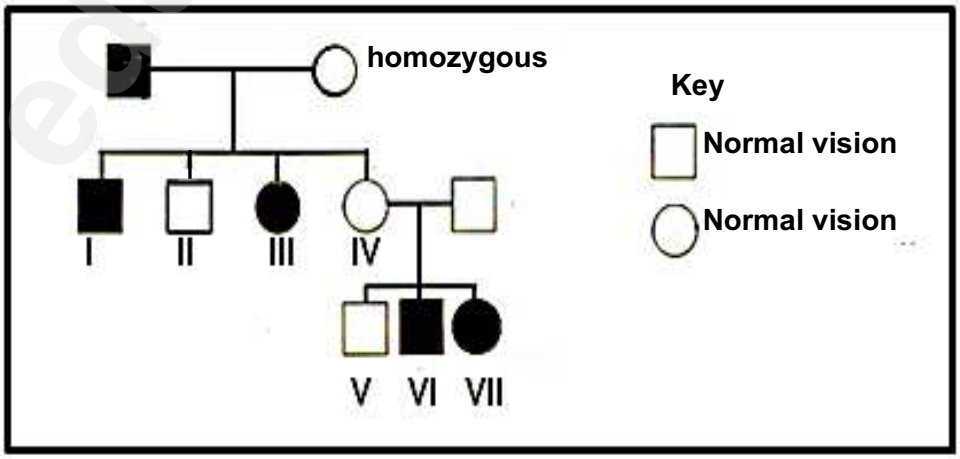
A (i) and (ii) only

B (i) and (iii) only

C (i) only

D (ii) and (iv) only

1.5 Study the pedigree diagram below which shows the inheritance of colour-blindness caused by a recessive allele in humans.



Which offspring show the INCORRECT representation of the inherited trait?

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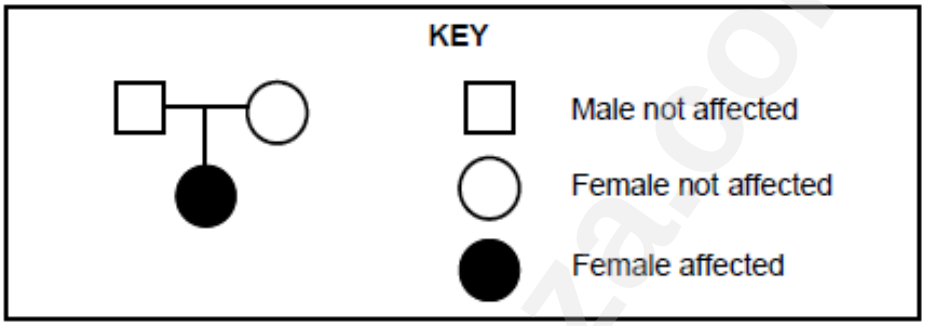
A I, II and III
B I, IV and V
C I, III and VII
D I, II, III, VI and VII

1.6 The diagram below shows the pattern of inheritance of a disorder



One can conclude that the disorder is caused by a …

A recessive allele, with both parents heterozygous.
B dominant allele, with both parents heterozygous.
C recessive allele, with one parent homozygous recessive while the other is heterozygous.
D dominant allele, with one parent heterozygous while the other is homozygous recessive.

(6 x 2) **(12)**

QUESTION 2 *(Questions taken from various sources)*

Give the correct **biological term** for each of the following descriptions. Write only the term next to the question number (2.1 to 2.5) in your ANSWER BOOK.

2.1 The type of inheritance where two different alleles of a gene are expressed in the phenotype
2.2 A genetic cross involving only one characteristic
2.3 The position of a gene on a chromosome
2.4 A sex-linked disorder that affects the photoreceptors in the eye
2.5 More than two alleles for the same gene **(5)**

QUESTION 3 *(Questions taken from various sources)*

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Indicate whether each of the statements in COLUMN I applies to **A ONLY**, **B ONLY**, **BOTH A AND B or NONE** of the items in COLUMN II. Write **A only**, **B only**, **both A and B,** or **none** next to the question number (3.1 and 3.2) in the ANSWER BOOK.

COLUMN I	COLUMN II
3.1 Cause of Down syndrome	**A: Gene mutation** **B: Extra copy of chromosome number 23**
3.2 An allele for one gene could appear in the same gamete with any of the alleles of another gene	**A: Dihybrid cross** **B: Mendel's law of independent assortment**

(2 x 2) **(4)**

QUESTION 4 (*DBE, Nov 2017 Paper 2)*

Mendel observed some characteristics of the pea plant (*Pisum sativum)* which he suggested were controlled by inherited factors. He conducted a series of experiments in which he crossed pea plants with contrasting phenotypes to obtain the offspring of the **F_1** generation. At first his crosses were simple and involved only one pair of characteristics.

Mendel counted the number of offspring showing each of the variations.

His results are shown in the table below.

PLANT PART	CHARACTERISTIC	P_1 GENERATION	F_1 GENERATION
Seed	Seed texture	Round x wrinkled	All round
	Seed colour	Yellow x green	All yellow
Pod	Pod texture	Full x constricted	All full
	Pod colour	Green x yellow	All green
Flowers	Flower colour	Violet x white	All violet
Stem	Location of flower of the stem	Axial x terminal	All axial
	Height of stem	Tall x short	All tall

4.1 Give the term for:

(a) The *inherited factors* that Mendel referred to (1)

(b) A cross involving only ONE characteristic (1)

4.2 Name the female structure of the flower where meiosis occurs. (1)

4.3 Use the information in the table above to give the NUMBER of EACH of the following:

(a) Characteristics of pods (1)

(b) Alleles for seed characteristics (1)

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4.4 Give the characteristic that is:

(a) Dominant for flower colour (1)

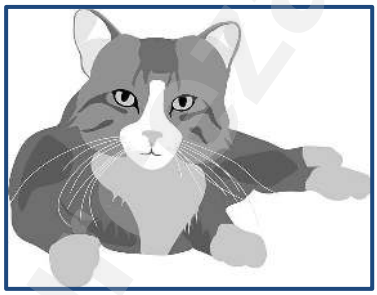
(b) Recessive for stem height (1)

4.5 If the individuals of the F_1 generation are crossed, how many phenotypes for seed colour would be expected in the $\mathbf{F_2}$ generation? (1)

(8)

QUESTION 5 *(FS, Sept. 2019, Paper 2)*

The inheritance of fur colour in cats is sex-linked. The tortoise-shell colour of cats is a combination of black and orange fur. The allele for black fur is represented by X^B and the allele for orange fur is represented by X^O.



HINT: The sex chromosomes/gonosomes in cats are inherited in the same way as in humans.

5.1 A female cat with a tortoise-shell colour is crossed with an orange male cat. Show the genetic cross between the two cats and determine the phenotype ratio of the F_1 generation. (Use X^B, X^o and Y.) (7)

5.2 Explain why male kittens can never have the tortoise-shell colour. (3)

(10)

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QUESTION 6 *(GDE, Sept. 2019, Paper 2)*

For flower colour in sweet-pea plants, the allele **(A)** for purple flowers is dominant over the allele **(a)** for white flowers.

For the shape of the pollen grains, the allele **(B)** for long pollen grains is dominant over the allele **(b)** for round pollen grains.

Plant **X** with the genotype **AABb** was crossed with plant **Y** that had white flowers and round pollen grains.

6.1 Identify the phenotype of plant **X**. (1)

6.2 Write down all the possible gametes of plant **Y**. (2)

6.3 Write down all the expected phenotypes of the offspring in a cross between plant **X** and **Y**. (2)

(5)

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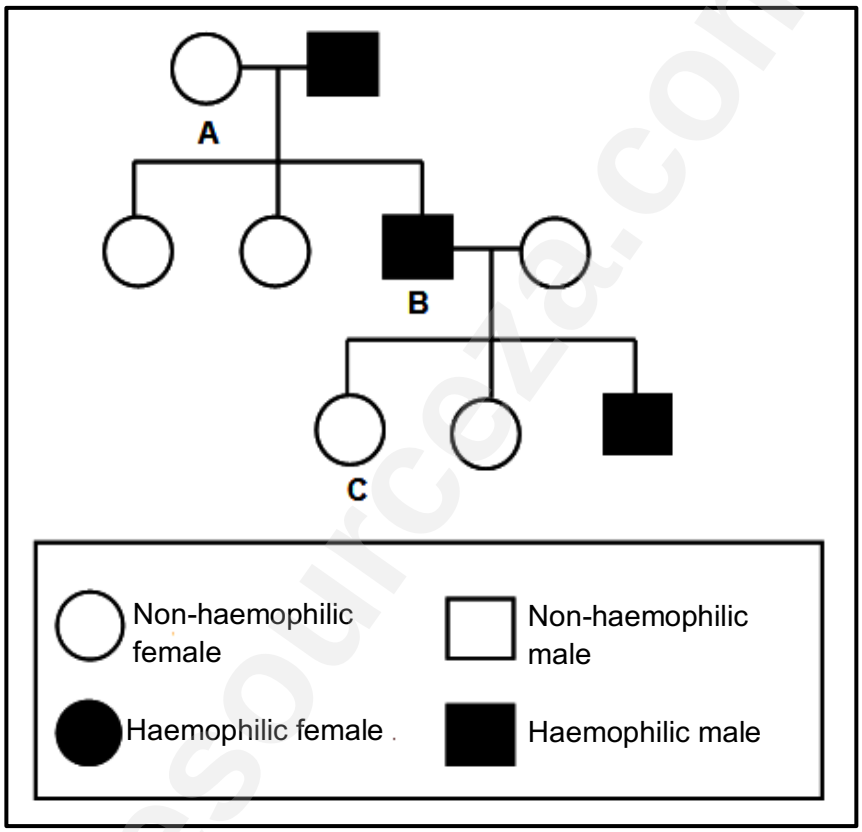
QUESTION 7 (*DBE, May-June 2017 Paper 2*)

Haemophilia is a genetic disorder resulting in the abnormal clotting of blood. It is caused by a recessive allele that is carried on the **X**-chromosome. The allele for normal clotting is $\mathbf{X^H}$ and the allele for haemophilia is $\mathbf{X^h}$.

The inheritance of haemophilia in a family is shown in the diagram below.



7.1 Give the percentage of the males with haemophilia in this family. (1)

7.2 Give the phenotype for individual **A**. (1)

7.3 Give the genotype for individual:

(a) B (1)

(b) C (2)

(5)

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QUESTION 8 *(DBE, Nov 2016 Paper 2)*

Read the passage below

GENETIC MODIFICATION OF CROPS

Genetic modification (GM) of crops began with the discovery that the soil bacterium Agrobacterium could be used to transfer useful genes from unrelated species into plants.

The gene called Bt, which produces a pesticide toxin that is harmless to humans, but is capable of killing insect pests, is one of the genes most commonly inserted into crop plants. Many new GM crops, such as maize, potatoes and tomatoes, are modified to be pest, disease or weed-killer resistant.

GM foods could have unforeseen effects. Toxic proteins may be produced, or antibiotic-resistance genes may be transferred to human gut bacteria. Modified crops could become weed-killer resistant 'super weeds'. Modified crops could also 'accidentally' breed with wild plants or other crops.

Adapted from GM Organisms www.newscientist.com

8.1 According to the passage, how did genetic modification of crops begin? (1)

8.2 Explain why a plant, which is modified to be weed-killer resistant, could be a problem for farmers. (2)

8.3 Give TWO examples in the passage of the use of GM crops that may be a potential threat to human health. (2)

(5)

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QUESTION 9 *(DBE, May-June 2019 Paper 2)*

A species of fish has three phenotypes for fin length: elongated, short and medium. Heterozygous fish have medium fins.
The characteristic is under the control of one gene with two alleles: elongated (**E**) and short (**S**).

9.1 Name and describe the type of dominance shown here. (3)

9.2 Use a genetic cross to show the percentage chance of two fish with medium fins having offspring with short fins. (6)
(9)

QUESTION 10 *(DBE, Nov 2020 Paper 2)*

Sickle cell disease is caused by a recessive allele and first appeared in humans as a result of a gene mutation.
The table below shows the number of children born with sickle cell disease in some regions in a particular year.

REGION	NUMBER OF CHILDREN BORN WITH SICKLE CELL DISEASE
Democratic Republic of Congo	39 746
United States of America	90 128
Nigeria	91 011
United Kingdom	13 221
Tanzania	11 877
Other	59 750
Worldwide total	**305 733**

10.1 What is a *gene mutation*? (2)

10.2 Which region had the highest number of children born with sickle cell disease in that year? (1)

10.3 What percentage of the worldwide total of children born with sickle cell disease came from the Democratic Republic of Congo? Show ALL calculations. (3)

10.4 Use the letters **D** and **d** to give the genotype of a person who:

(a) Suffers from sickle cell disease (1)

(b) Carries the allele but does not suffer from the disease (1)

(8)

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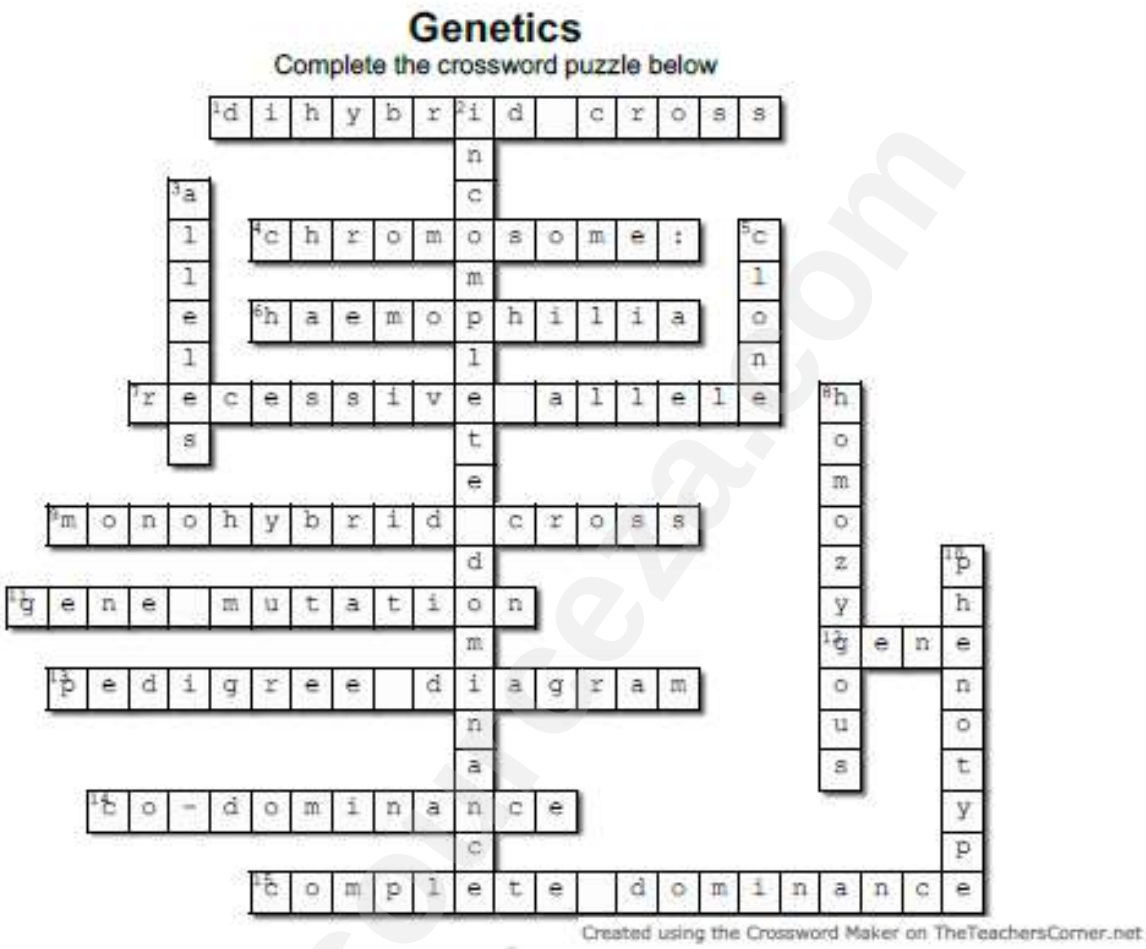
5. SOLUTIONS

Crossword puzzle answer



QUESTION 1

1.1 B✓✓
1.2 C ✓✓
1.3 D ✓✓
1.4 B ✓✓
1.5 C ✓✓ (5 X 2) **(10)**

QUESTION 2

2.1 Co-dominance ✓
2.2 Monohybrid cross ✓
2.3 Locus ✓
2.4 Colour blindness ✓
2.5 Multiple alleles ✓ **(5)**

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QUESTION 3

3.1 B only ✓✓

3.2 Both A and B ✓✓ (2 X 2) **(4)**

QUESTION 4

4.1 The process by which the DNA of a person/organism is analysed✓ to obtain a barcode pattern✓ (2)

4.2
- All the bars/bands of a baby must match the bars of the parents✓
- 3 of the bars/bands of baby 2 does not match✓ (3)
- any bars of Mr and Mrs Taylor✓

4.3
- Mark the samples clearly✓
  to make sure vials are not swopped.✓
- Wear gloves and a mask✓ not to contaminate samples with your own DNA✓
- Use new and clean/sterilised apparatus✓
  not to contaminate samples.✓

(Mark first ONE only) **(Any 1 x 2)** (2)

(7)

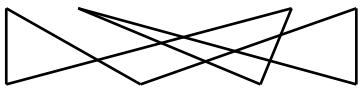
QUESTION 5

5.1 **P**$_1$/parent phenotype: tortoise-shell female x orange male✓

genotype: X^BX^O x X^OY ✓

Meiosis

G/gametes X^B , X^O x X^O, Y ✓



Fertilisation

F$_1$/offspring genotype X^BX^O, X^BY, X^OX^O, X^O Y ✓

phenotype 1 tortoise-shell female, 1 black male, 1 orange female and 1 orange male✓*

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(*1 mark for gender and fur colour with correct proportion)

P_1 and F_1✓

Meiosis and fertilisation✓ *Compulsory 1 + any 6

OR

P_1/parent phenotype tortoise-shell female x orange male✓

genotype X^BX^O x X^OY ✓

Meiosis

Fertilisation

gametes	X^B	X^O
X^O	X^BX^O	X^OX^O
Y	X^BY	X^O Y

1 mark for correct gametes (7)

1 mark for correct genotypes

F_1/offspring phenotype: 1 tortoise-shell female, 1 black male,

1 orange female and 1 orange male✓*

(*1 mark for gender and fur colour with correct proportion)

P_1 and F_1✓

Meiosis and fertilisation✓ *Compulsory 1 + any 6

5.2
- The allele for the fur colour is carried on the X-chromosome✓
- Male have only one X-chromosome✓
- Tortoise shell is only expressed in the heterozygous condition/X^BX^O✓

OR

- If the male is X^BY it is black✓
- if the male is X^OY it is orange✓
- and therefore, can never be tortoise shell as males have one X chromosome only.✓ (3)

(10)

QUESTION 6

6.1 Purple flowers, long pollen grains ✓ (1)

6.2 ab ✓✓ (2)

6.3 Purple flowers, long pollen grains ✓: purple flowers, round pollen grains ✓ (2)

(5)

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QUESTION 7

7.1 100%✓ (1)

7.2 Non-haemophiliac female ✓ /normal female (1)

7.3 (a) X^hY ✓ (1)

(b) $X^H X^h$ ✓✓ (2)

(5)

QUESTION 8

8.1 With the discovery that the soil bacterium *Agrobacterium* could be used to transfer useful genes from unrelated species into plants ✓ (1)

8.2
- modified crops may become super-weeds✓/accidentally breed with other plants to become super-weeds
- they are difficult to kill✓
- and could outcompete the original crop✓/other crops Any (2)

8.3
- toxic proteins might be produced✓
- antibiotic-resistant genes may be transferred to human gut bacteria✓
- **Mark first TWO only**

(2)

(5)

QUESTION 9

9.1
- Incomplete dominance * ✓
- Neither of the alleles are dominant ✓/neither E nor S I dominant
- Leading to an intermediate phenotype ✓/offspring with medium fins

1 compulsory* + 2 (3)

9.2

P_1	**Phenotype**	Medium fins	x	Medium fins ✓	
	Genotype	ES	x	ES ✓	
Meiosis					
	G/gametes	E , S	x	E , S ✓	
Fertilization					
F_1	**Genotype**	EE; ES; ES; SS ✓			
	Phenotype	25% short fins; ✓*			
		50% medium fins; 25% elongated fins			

P_1 and F_1✓

Meiosis and fertilization ✓

1 compulsory* + Any 5

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OR

P_1 OR	**Phenotype**	Medium fins	x	Medium fins ✓
	Genotype	ES	x	ES ✓

Meiosis

Gametes	E	S
E	EE	ES
S	ES	SS

Fertilization

1 mark for correct gametes✓

1 mark for correct genotypes ✓*

F_1 **Phenotype** 25% short fins; ✓*

50% medium fins; 25% elongated fins

P_1 and F_1✓

Meiosis and fertilization✓

1 compulsory* + Any 5

QUESTION 10

10.1 – a change in the sequence ✓of

– nitrogenous bases✓/nucleotides in a gene (2)

10.2 Nigeria✓ (1)

10.3 $\frac{39\ 746}{305\ 733}$ ✓ x 100✓ = 13✓% (3)

10.4 (a) dd✓ (1)

(b) Dd✓ (1)

(8)

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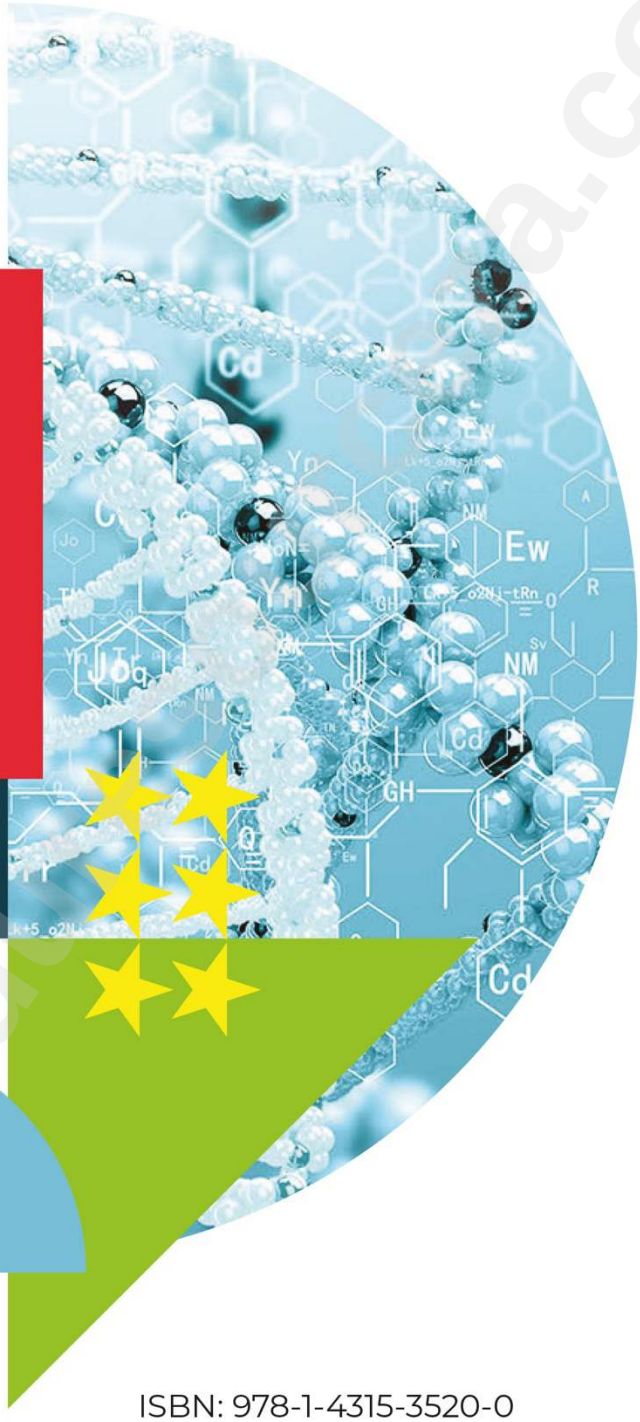

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