**Strand 2: Gene Expression**

***Sub-strand 2.5 Gene-gene interactions & Mendellian Inheritance***

**LESSON 1: Mendellian Inheritance with Monohybrid Crosses**

**Key Learning Outcome**:

Students are able to demonstrate understanding of gene-gene interactions and Mendelian inheritance and ways in which these influence DNA functioning

* monohybrid crosses with: complete dominance, incomplete dominance, codominance, multiple allele, test cross (genes, alleles, genotype, phenotype, homozygous, heterozygous) – revision of form 6

The specific learning outcomes targeted in this lesson are provided below:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SLO #** | **Specific Learning Outcomes:***Students are able to*  | **Skill level** | **SLO code** | **√** |
| 1  | Define monohybrid cross, dihybrid cross  | 1 | Bio2.5.1.1 |  |
| 2  | Define complete dominance, incomplete dominance; co-dominance | 1 | Bio2.5.1.2 |  |
| 3  | Define multiple allele/homozygous/heterozygous | 1 | Bio2.5.1.3 |  |
| 4 | Identify/State a feature or example of monohybrid cross/dihybrid coss in a give context. | 1 | Bio2.5.1.4 |  |
| 5 | Identify/State a feature or example of complete dominance/incomplete dominance/co-dominance in a given context. | 1 | Bio2.5.1.5 |  |
| 6 | Identify/State a feature or example of multiple allele/homozygous/heterozygous gene pairs in a given context. | 1 | Bio2.5.1.6 |  |
| 7 | Identify/State a feature of heterozygous gene pair in a given context. | 1 | Bio2.5.1.7 |  |
|  8 | Describe genotypes for monohybrid crosses with complete dominance, Incomplete dominance,Co-dominance,Multiple allele,Test Cross. | 2 | Bio2.5.2.1 |  |
| 9  | Explain the expression of characteristics from monohybrid crosses, complete dominance, incomplete dominance and co-dominance, multiple alleles, test cross and dihybrid crosses (genes, alleles, genotype, phenotype, homozygous, heterozygous) | 3 | Bio2.5.3.1 |  |
| 10  | Discuss the full picture of the inheritance of named characteristics through monohybrid crosses and dihybrid crosses using named plants and or animals  | 4 | Bio2.5.4.1 |  |

**Key Terms:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Term** | **Achieved** |  | **Term** | **Achieved** |
| monohybrid cross |  |  | heterozygous |  |
| complete dominance |  |  | genotypes |  |
| incomplete dominance |  |  | alleles |  |
| co-dominance |  |  | punnet squares |  |
| homozygous |  |  | phenotype |  |
| Multiple alleles |  |  | Test cross |  |
| Dihybrid cross |  |  |  |  |

**Recommended Readings:**

|  |  |  |
| --- | --- | --- |
| **Reading Text** | **Page(s)** | **Achieved** |
| Bradfield, P., Dodds, J., Dodds, J., and Taylor, N. (2002). *A2 Level Biology*. Essex: Pearson Education Limited. | 57 – 73  |  |

**MENDELLIAN INHERITANCE – YEAR 12 REVISION**

**Monohybrid Cross**

A genetic cross that considers only **ONE** characteristic.

Example: Gene that codes for height

 Alleles for this gene are: T – tall, t – short

Genotype of a tall person can be: homozygous dominant (TT) OR heterozygous (Tt)

Genotype of a short person would be: homozygous recessive (tt)

**Homozygous:** having the same alleles in a genotype.

 For example TT (*Homozygous* dominant) or tt.(*homozygous recessive*)

**Heterozygous:** having different alleles in a genotype, for example Tt

**Incomplete Dominance**

|  |  |  |
| --- | --- | --- |
|  | R | R |
| r | Rr | Rr |
| r | Rr | Rr |

When one allele is not completely dominant over the other and the heterozygote produced is a mixture of the two alleles.

Phenotypic ratio = all offspring are **PINK**

Example: R – red r – white

 Parents: RR x rr

*A new phenotype is expressed in the heterozygote = pink (blending of both alleles)*

Phenotypic ration of offspring = All (100%) pink

**Co-dominance**

When both the dominant and recessive alleles share the same dominance and are both expressed in the phenotype of the heterozygote.

|  |  |
| --- | --- |
|  | R |
| r | Rr |

Phenotypic ratio = all offspring are **RED AND WHITE**

Example: R – red, r – white

Parents: Red x white

 RR x rr

**Multiple Alleles** *(Having more than one allele for a gene)*

Many genes have more than two alleles, although only two can occupy the gene locus on a pair of homologous chromosomes at any one time in any one individual.

*The human ABO blood group*

* The phenotype is determined by alleles A, B and O
* Allele A and B are co-dominant; allele O is recessive

|  |  |  |
| --- | --- | --- |
| **Blood group phenotype** | **Blood group type** | **Possible Genotypes** |
| A | AA, AO | IAIA and IAIO (or IAi) |
| B | BB, BO | IBIB and IBIO (or IBi) |
| AB | AB | IAIB |
| O | OO | IOIO (or ii) |

When working with multiple alleles problems, follow the same steps used for monohybrid crosses.

For example:

A man with blood group AB marries a woman with blood group AO. Determine the blood types of their offspring.

Phenotype AB x AO

Genotype IAIB IAi

Gametes IA and IB IA and i

|  |  |  |
| --- | --- | --- |
|  | IA | i |
| IA | IAIA | IAi |
| IB | IAIB | IBi |

Punnet cross:

Phenotypic ratio of offspring: 2 blood group A : 1 blood group AB : 1 blood group B

**Test Cross**

This is a cross (mating) between an individual showing dominance for a given trait (but whose genotype is unknown) with an individual who is homozygous recessive for the same trait. The phenotypes of the offspring produced are used to determine the genotype of the parent with the dominant trait.

For example:

A man has black hair. Black hair is a dominant trait (B), brown hair is recessive (b). Determine the genotype of the man.

You would perform a test cross by mating the man with a brown haired woman (bb). If any of their children have brown hair, the man is heterozygous for black hair (Bb). If all the children have black hair, the man is homozygous dominant for black hair (BB).

|  |  |  |
| --- | --- | --- |
|  | B | b |
| b | Bb | bb |

|  |  |
| --- | --- |
|  | B |
| b | IAIA |

Bb x bb BB x bb

Phenotypes of offspring: Phenotypes of offspring:

 1 black-haired : 1 brown haired all have black hair

**Dihybrid Cross**

This is a genetic cross that considers two different characteristics.

**How to solve dihybrid cross problems**

Example:

Gene for bean texture and gene for bean colour

Bean texture: Alleles S – smooth coat; s – wrinkled coat

Bean color: Alleles Y – yellow; y – green

A bean plant, heterozygous for both traits, is cross pollinated with a bean plant, homozygous recessive for both traits. Determine the phenotypic ratio of the progeny.

Phenotype of parent plants: heterozygous for homozygous

 bean color and texture recessive for bean

color and texture

Genotypes of parents: SsYy x ssyy

Gametes: SY, Sy, sY, sy sy

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | SY | Sy | sY | sy |
| sy | SsYy | Ssyy | ssYy | ssyy |

Punnet cross:

Phenotypic ratio of progeny: 1 smooth, yellow beans : 1 smooth, green beans ; 1 wrinkled, yellow beans: 1 wrinkled, green beans

***IMPORTANT PHENOTYPIC RATIOS***

|  |  |  |
| --- | --- | --- |
| **Cross between parents** | **Genotypic ratio of offspring** | **Phenotypic ratio of offspring** |
| Heterozygotes (dihybrid) AsBb x AaBb | 9 A\_B\_ : 3 A\_bb : 3 aaB\_ : 1 aabb | 9 dominant for both traits : 3 dominant for one trait : 3 dominant for the other trait : 1 recessive for both traits |
| Heterozygotes (monohybrid)Aa x Aa | 1 AA : 2 Aa : 1 aa | 3 dominant : 1 recessive |

**LESSON ACTIVITY**

**Question One**

Define the following mendelian terms: **(L1) (Bio2.5.1.1) (Bio2.5.1.2)(Bio2.5.1.3)**

(i) **Monohybrid cross:**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(ii)**dihybrid cross:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(iii)**complete dominance:**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(iv)**Incomplete dominance**:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(v)**Co-dominance**: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(vi)**Multiple allele**: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(vii) **Homozygous**:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(viii)**Heterozygous**:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question Two**

The pedigree shows the pattern of inheritance of black fur in one family of guinea pigs. This involves a single gene only. Circles indicate females, squares indicate males, black symbols represent black fur (B), and white symbols represent white fur (b).



Use the information contained in the pedigree to answer the following questions.

(i) Does the above pedigree show a dihybrid or monohybrid cross**? (L1) (Bio2.5.1.4)**

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(b) Determine the genotypes of their offspring: II1, II3, II4 and II6. Show your working out.

 **(L2)(Bio2.5.2.1)**

Working out:

Genotypes: II1 \_\_\_\_\_\_\_\_\_, II3 \_\_\_\_\_\_\_\_\_\_, II4 \_\_\_\_\_\_\_\_\_\_, II6 \_\_\_\_\_\_\_\_\_\_

**Question Three**

Mary has blood group AB. She has a daughter Sally who has blood group AO. Mary claims that she slept with Mark and Tom on two separate occasions but within the same week which led to her conception of Sally. Mary wishes to know who the real father is so she asks both Mark and Tom to take a blood test to prove paternity. Results show that Mark has blood group AO and Tom has blood group OO.

(i)Identify the type of inheritance of shown by Blood Group. **(L1) (Bio2.5.1.6)**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(ii)Determine who Sally’s father from the two is. **Show your working out**.

 **(L2) (Bio2.5.2.1)**

Sally’s father is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question Four**

A plant breeder crossed a red-flowered plant (R) with a white-flowered plant (r) of the same species. He obtained all pink flowered plants from the cross.

(i)State the type of inheritance seen in the production of pink flowers. **(L1) (Bio2.5.1.5)**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(ii)Identify the genotype of the pink flowers. **(L1) (Bio2.5.1.7)**

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(iii)One of the pink flowered plants from the above cross was cross-pollinated with a

 red-flowered plant. Determine the genotypic ratio of their plant progeny. (**L2) (Bio2.5.2.1)**

*Show your working out.*

Phenotypic ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question Five**

Using an example, explain the expression of characteristics involving the following types of inheritance: **(L3) (Bio2.5.3.1)**

(i)Incomplete Dominance:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(ii)Complete Dominance:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(iii)Co-dominace:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Question Six**

Discuss the full picture of the inheritance of named characteristics through monohybrid crosses using named plants or animals. **(L4)(Bio2.5.4.1)**

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**LESSON 2: Gene-gene interactions (Collaboration & Epistasis)**

**Key Learning Outcome**:

Students are able to demonstrate understanding of gene-gene interactions and Mendelian inheritance and ways in which these influence DNA functioning

* gene – gene interactions : collaboration, epistasis (complementary; supplementary genes)
* polygenes (eg height and skin colour in humans); pleiotrophy (eg sickle cell disease)

The **specific learning outcomes** targeted in this lesson are provided below:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SLO #** | **Specific Learning Outcomes:***Students are able to*  | **Skill level** | **SLO code** | **√** |
| 11 | Define the term epistasis | 1 | Bio2.5.1.8 |  |
| 12 | Define the term complementary gene | 1 | Bio2.5.1.9 |  |
| 13 | Define the term supplementary gene | 1 | Bio2.5.1.10 |  |
| 14 | Define the term pleiotropy/polygene | 1 | Bio2.5.1.11 |  |
| 15  | Identify/State a feature or example of gene interactions in collaboration, epistasis (complementary, supplementary genes); polygenes and pleiotropy in a given context  | 1 | Bio2.5.1.12 |  |
| 16 | Describe the process of gene – gene interactions with complementary genes  | 2 | Bio2.5.2.2 |  |
| 17 | Describe the process of gene – gene interactions with supplementary genes  | 2 | Bio2.5.2.3 |  |
| 18 | Describe the process of gene – gene interactions involving polygenes genes  | 2 | Bio2.5.2.4 |  |
| 19 | Describe the process of gene – gene interactions involving pleiotropy  | 2 | Bio2.5.2.5 |  |
| 20 | Explain height and skin colour in humans in terms of gene – gene interactions  | 3 | Bio2.5.3.2 |  |
| 21 | Explain sickle-cell disease in humans in terms of gene-gene interaction | 3 | Bio2.5.3.3 |  |
| 22 | Explain the difference between complementary gene and supplementary gene using appropriate examples | 3 | Bio2.5.3.4 |  |
| 23 | Discuss the types of epistasis shown using the phenotypic ratio from a dihybrid cross. | 4 | Bio2.5.4.2 |  |
| 24 | Discuss the inter-relationship between gene-gene interaction in determining various characteristics in humans and the impact of these characteristics on survival | 4 | Bio2.5.4.3 |  |

**Key Terms:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Term** | **Achieved** |  |  | **Achieved** |
| Gene-gene interaction |  |  | Polygenes |  |
| Collaborative genes |  |  | Supplementary genes |  |
| Epistasis |  |  | Complementary genes |  |
| Pleiotropy |  |  |  |  |

**GENE-GENE INTERACTIONS**

* Epistasis refers to any type of gene interaction whereby the expression of a gene on one locus is affected by alleles present at another gene locus.
* There are 3 different types of gene interactions.
	+ **Collaboration**
	+ **Supplementary** (Also sometimes referred to as epistasis as well)
	+ **Complementary**

**Hint:** When working with gene-gene interaction problems, treat the problems similar to that of a dihybrid cross but only pay in mind the following:

* One pair of alleles represents a characteristic that can be expressed.
* The other pair of alleles (the alleles of the epistatic gene) controls how these alleles will be expressed.
* The final phenotyp will depend upon the epistatic genes (the genes that control the expression).
1. **Collaboration**

This is where a specific characteristic is expressed with different combinations of both pairs of alleles from both genes. As a result, four different phenotypes are expressed.

Example:

The shape of the comb of roosters is determined by collaborative genes. Each different allele combinations of two separate genes produce a different comb shape.

A heterozygous cross between a rooster and a chicken will produce roosters with the following genotypes and phenotypes.

AaBb x AaBb

Produces the following offspring:

 **Proportion Genotype Alleles in the genotype Phenotype**

9/16 A\_B\_ (2 dominants) Walnut comb

 3/16 A\_bb (1 dominant + 2 recessives) Pea comb

 3/16 aaB\_ (2 recessives + 1 dominant) Rose comb

 1/16 aabb (all recessives) single comb

1. **Supplementary Genes**

This refers to the **masking** of a characteristic determined by one pair of alleles, by the action of another pair of alleles.

Example:

Gene for mouse fur colour is represented by the alleles: B – Black, b – brown

Another gene controls whether the colour will show up or not (*by controlling the production of melanin*). This gene is represented by the alleles:

 C – colour will show; c – wolour will not show up (no color or white)

So the phenotype will be determined by the supplementary genes.

 B\_C\_ black bbC\_ Brown

 B\_cc no colour (white) bbcc no colour (white)

For a heterozygote cross: BbCc x BbCc

The phenotypic ratio of offspring will therefore be 9 Black : 4 white : 3 brown

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | BC | Bc | bC | bc |
| BC | BBCC (black) | BBCc (black) | BbCC (Black) | BbCc (black) |
| Bc | BBCc (black) | BBcc (white) | BbCc (Black) | Bbcc (white) |
| bC | BbCC (black) | BbCc (black) | bbCC (brown) | bbCc (brown) |
| bc | BbCc (Black) | Bbcc (white) | bbCc (brown) | bbcc (white) |

**Hint:**

* A dominant allele from the epistatic gene must be present in the genotype in order for the phenotype (color) to be expressed. Type of phenotype (color) depends upon which allele is present from the non-epistatic gene.
* A heterozygous cross involving supplementary genes will always produce 3 different phenotypes in the progeny.

9 (one phenotype) : 4 (white) : 3 (other phenotype

**Supplementary Gene Interactions can also be represented in the form of a metabolic pathway:**

**C. Complementary Genes**

The presence of **dominant alleles** from both genes are needed for the characteristic to be expressed.

Example: P – purple colour p – no colour

 C – color will show up c – colour will not show up (white)

For a heterozygous cross AaBb x AaBb

The phenotypic ratio of offspring will be **9 (specific phenotype) : 7 white**

**Only two different phenotypes are possible for complementary gene-gene interactions.**

**Representation of complementary gene interactions in a metabolic pathway would be as follows:**

**POLYGENES**

Some genes may not just control a single characteristic or trait in the phenotype of an organism.

Polygenic inheritance is whereby many genes control the expression of a single characteristic. The characteristics produced by polygenes are therefore continuous (i.e. come in different range of varieties). A polygenic characteristic can be plotted on a graph to show a normal distribution curve. The ranges of phenotype therefore range from extremes at one end to the other with fewer individuals showing extreme phenotypes and more showing average phenotypes.

Examples of characteristics controlled by many genes:

Skin color: AABBCC – Very black

 AaBBCC – Dark

 AsBbCC – Mulatto

 AaBbCc – Light

 Aabbcc – very pale (More dominant alleles, the darker the skin color)

Height: AABBCCDDEEFFGGHHII – extremely tall

 AaBbCcDdEeFfGgHhIi – medium height

 Aabbccddeeffgghhii – extremely short.

**PLEIOTROPY**

When a gene has many effects or produces many phenotypic traits this is called **pleiotropy**. The symptoms of many genetic diseases are actually phenotypic traits that can be traced to a single pair of alleles (one gene).

For example: sickle-cell anaemia

* Disease caused by a gene that makes haemoglobin in red blood cells.
* Haemoglobin is round in shape making it most efficient in binding to oxygen.
* If gene is faulty (mutated) then the haemoglobin will be a different shape (sickle-shaped) and will not be efficient in oxygen transportation.
* The person suffering from sickle-cell anaemia will therefore suffer from may different symptoms because of this one faulty gene.

**LESSON ACTIVITY**

**Question One**

Define the term epistasis. **(L1)(Bio2.5.1.8)**

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**Question Two**

Define the term complementary gene. **(L1)(Bio2.5.1.9)**

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**Question Three**

Define the term supplementary gene. **(L1)(Bio2.5.1.10)**

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**Question Four**

Define the term pleiotropy. (L1)(Bio2.5.1.11)

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**Question Five**

The comb shape in chickens is usually caused by the interaction between two different genes. **(L1)(Bio2.5.1.12)**



The type of gene interaction displayed above is known as:

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**Question Six**

Describe the process of gene-gene interaction with complementary genes. (L2)(Bio2.5.2.2)

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**Question Seven**

Describe the process of gene-gene interaction with supplementary genes. (L2)(Bio2.5.2.3)

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**Question Eight**

Describe the process of gene-gene interaction with complementary genes. (L2)(Bio2.5.2.4)

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**Question Nine**

Describe the gene-gene interactions involved in pleiotropy and polygeny.

 (L2)(Bio2.5.2.5)

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**Question Ten**

Explain how height and skin colour in humans are examples of pleotropy.

 **(L3) (Bio2.5.3.2)**

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**Question 11**

Explain how sickle cell disease in humans is a result of gene-gene interaction.

 (**L3) (Bio2.5.3.3)**

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**Question Twelve**

Explain the difference between complementary gene and supplementary gene using appropriate examples. (L3)(Bio2.5.3.4)

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**Question Thirteen**

In guinea pigs, coat colour is determined by two genes. The pigment **melanin** colours the fur of the animal. Without melanin, the fur appears white.

The production of melanin is controlled by a gene whose dominant allele, **A**, will produce **pigment** while its corresponding recessive allele, **a**, produces **no pigment** at all.

A second gene controls how much pigment is deposited in the fur. The dominant allele, **B**, will deposit a lot of melanin resulting in **black fur**. The recessive allele, **b**, will only allow a moderate amount of pigment to be deposited in the fur producing a **brown fur** colour.

If a pure-breeding, brown guinea pig is mated with a pure-breeding white (albino) guinea pig, all of the offspring are black.

(i)From the information given, determine the **genotypes** of the parents and the F1 individuals.

 Genotypes of parents: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Genotypes of F1: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

One of the F1 is then mated with another black individual, **homozygous** for both genes.

(ii)Determine the **genotype** of the black individual mated with the F1?

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(iii)By completing a **Punnet diagram** of the cross between the F1 individual and the homozygous black individual, determine the expected **phenotypic** ratio of the offspring.

Expected phenotypic ratio of the offspring

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(iv)Discuss the type of epistasis shown using the phenotypic ratio from the dihybrid cross above.  **(L4)(Bio2.5.4.2)**

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**Question Fourteen**

Discuss the interrelationship between gene-gene interactions in determining various characteristics in humans and the impact of these characteristics on survival. **(L4)(Bio2.5.4.3)**

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