SENIOR SIX BIOLOGY (MR. ABIB AMIR)

GENE INTERACTIONS.

Sometimes a single characteristic is controlled by the alleles of two or more genes interacting with one another. A characteristic which is controlled by more than one gene is known as polygenic character and its transmission is called polygenic inheritance. There are many situations when genes interact to control phenotypic characteristics of organisms, these include,

- Incomplete dominance.
- Multiple alleles.
- Lethal genes.
- Gene complex/simple gene interactions/ complementary genes.
- Epistasis.

MULTIPLE ALLELE

This is where a phenotypic characteristic of an individuals is controlled by many alleles occurring at a specific gene locus, however, only two of such alleles may occupy the same gene loci of homologous chromosomes.

Characteristics controlled by multiple alleles include; eye color and coat color in mice and blood group in humans

Multiple alleles can result in offsprings with characteristics which differ from both parents.

INHERITANCE OF A, B, O BLOOD GROUPS

A good example of such multiple alleles is provided by the alleles controlling the ABO blood group system in humans. Blood group is controlled by an autosomal gene. The gene locus is represented by the symbol I, which stands isohaemoglutinogen. Blood group in individuals is determined by the types of mucopolysaccharides that function as antigens (agglutinogens) on the plasma membrane of blood red blood cells. There are 3 alleles represented by the symbols A, B, and 0. The alleles A and B are dominant to O which is recessive to both alleles A and B. Alleles A (I^A) and B (I^B) codes for the enzymes that are involved in the formation of the antigens A and B respectively and allele O (I^O) does not code for any known proteins. Individuals of blood group A have antigens A only, those of blood group B has antigens B, The AB blood groups have both antigens A and antigen B and group O has neither antigens A nor antigens B. The genotypes for different blood groups are shown below,

A person whose genotype is I^AI^A or I^AI^o will belong to blood group A
A person with genotype I^BI^B or I^BI^0 will belong to blood group B
Genotype I^AI^B belongs to blood group AB
Genotype I^0I^0 belongs to blood group O.

NOTE:

When both allele **A** and **B** occur together they show equal dominance with respect to one another called co-dominance.

The A, B, 0 blood group system Can be inherited in the normal mendelian fashion.

EXERCISE

Explain using appropriate genetic symbols the possible blood groups of children whose parents are both heterozygous, the father being blood group A and the mother blood group B.

If these parents have non-identical twins what is the probability that both twins will have blood group A.

LETHAL ALLELES

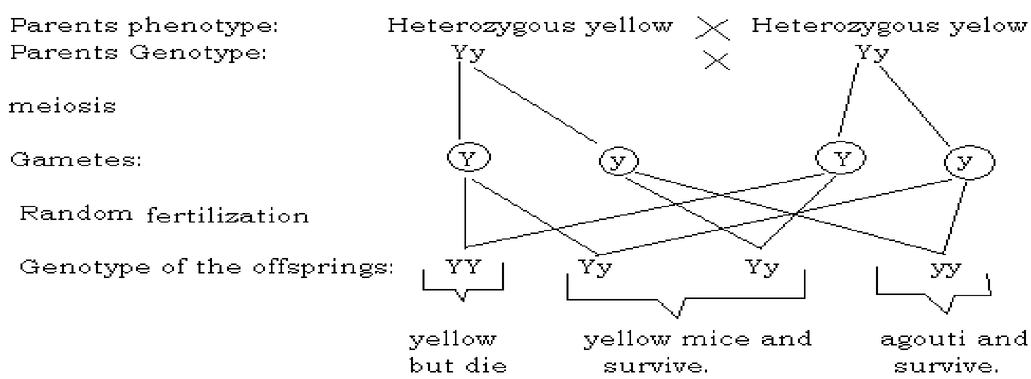
This is a condition where a single gene determines several characteristics that includes mortality or death of an individual.

EXAMPLES.

The effects of a lethal gene are clearly shown by the inheritance of fur color in mice, wild mice have grey colored fur a condition known as agouti. The grey color is determined by recessive alleles. Some mice have yellow fur. The yellow color is controlled by the dominant alleles. Cross breeding heterozygous yellow mice produces offsprings in the ratio of 2 heterozygous yellow and 1 agouti fur mice. In this case the homozygous dominant yellow fur mice die. Examination of the uteri of heterozygous yellow mice in the above cross revealed dead yellow fetuses.

Let,

Y represents an allele for yellow fur.
y represents an allele for agouti fur.



EXERCISE.

1. Chickens with shortened wings and legs are called creepers.

(i) When creepers are mated to normal birds they produce creepers and normal birds with equal frequency.
(ii) When creepers are mated to creepers, they produce two creepers to one normal.
(iii) Crosses between normal birds produce only normal progeny.
(a) Explain these results using your knowledge of genetics.

(b) Using suitable symbols work out the genotypes and phenotypes of the offsprings of the first, second and third crosses.
(c) State the genotypes of the parents in the third cross and explain your answer.

GENE COMPLEX/ COMPLEMENTARY GENES.

This is a condition where a single characteristic is controlled by the interaction of two or more genes occupying different gene loci on different chromosomes. It is also referred to as simple gene interaction. Example of gene complex is the inheritance of shapes of the comb in poultry (Domestic fowl).

There are two genes located at different gene loci on different chromosomes. One gene has a dominant allele P and a recessive allele p. whereas the other gene has a dominant allele R and a recessive allele r. The two genes interact and give rise to four distinct phenotypes (comb shapes in poultry) and these,

- Pea comb.
- Rose comb.
- Walnut.
- A single.

• Pea comb is determined when atleast its one dominant allele P is present, in absence of the dominant allele R, other alleles being recessive in the genotype. Possible genotypes for pea comb, PPrr or Pprr.

• Rose comb arises when atleast its dominant allele R is present, in absence of the other dominant allele P, other alleles being recessive in the genotype. Possible genotypes for the Rose comb, ppRR, or ppRr.

• Walnut comb is determined if atleast both dominant alleles P and R are present in the genotype. Possible genotype for the walnut comb, PPRR, PpRR, PPRr or PpRr.

• A single comb is determined only when both alleles exist in their homozygous recessive state. A possible genotype for the single comb type is, pprr.

Let,

R represents an allele for rose type comb
P represents the allele for pea type comb.

Parents :	♂ (male)	×	♀ (female)
Parents phenotype:	Rose comb		Pea comb
Parents Genotype :	RRpp		rrPP
Meosis			
Gametes	Rp Rp		rP rP
Random fertization.			
F1 Genotype:	All RrPp		
F1 phenotype	Walnut comb.		

SELFING FI OFFSPRINGS.

Parents phenotype:	Walnut comb	×	Walnut comb.
Parents Genotype;	RrPp	×	RrPp
meiosis			
F1 gametes.	all RP Rp rP rp		

Random fertilization of the F1 gametes as shown by the punnet square below.

Male gametes

		RP	Rp	rP	rp
Female Gametes	RP	RRPP	RRPp	RrPP	RrPp
	Rp	RRPp	RRpp	RrPp	Rrpp
	rP	RrPP	RRPp	rrPP	rrPp
	rp	RrPp	Rrpp	rrPp	rrpp

The F_2 phenotypes;

9 walnut type combs (R - P)

3 rose type comb (R – pp)

3 pea type comb (rr – P)

1 single (rrpp)

EXERCISE.

1. In poultry, the allele for white feather (W) is dominant over the allele for black feather (w) the allele for pea comb is P and rose comb is R, they are both dominant alleles. The alleles P and R produce phenotypes called walnut comb if at least both alleles are present together in a genotype. But if both alleles are present in a genotype in a homozygous recessive condition, they produce a phenotype called single comb.

A cross between a black rose comb cock (a homozygous black, heterozygous rose comb) and a heterozygous white walnut comb hen produced variety of phenotypes. Assuming random and independent assortment occurred during gamete formation.

(i) State the genotypes of the parents.

(ii) State the possible male and female gametes that will be formed.

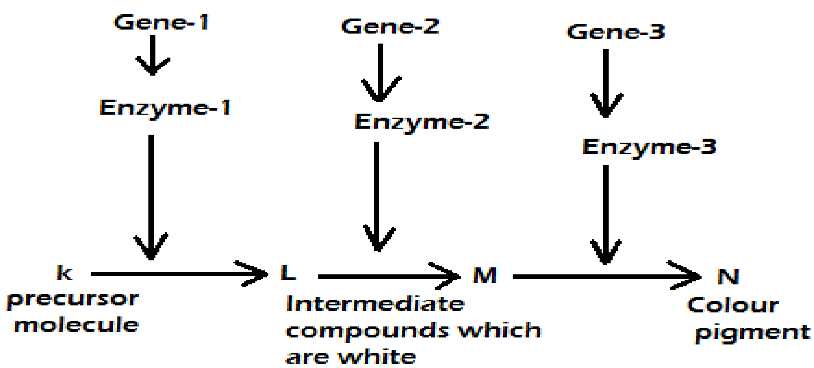
(iii) Determine the Genotypes and phenotypes of the F1 offsprings after random fusion of the parental gametes.

EPISTASIS

This is a condition where the presence of one gene suppresses the effect of another gene at another gene locus. The term “epi” means over, while “hypo” means under. Epistatic genes are the ones suppressing the effects of others and also called inhibiting genes. While the gene, whose effects are suppressed is called hypostatic genes. In addition, epistatic and hypostatic genes occur at different gene loci on homologous chromosomes. Epistasis does not always result in the blending of features to produce intermediates. It may instead create entirely new features. It can also result into variety of phenotypic ratios depending on the genotype of the mating pairs.

EXPLANATION OF EPISTASIS.

Epistasis arises when different genes control production of different enzymes that catalyse series of bio-chemical reactions that determine expression of a single character in an individual. Production of each enzyme depends on specific gene. For example, consider the gene pathway shown below for the synthesis of sweet pea plant pigment.



Production of enzyme-1, enzyme-2 and enzyme-3 are controlled by specific gene-1, gene-2 and gene-3 respectively. Compounds L and M are white intermediate compounds. Compound N is a coloured end product pigment.

Gene-1 initiates production of enzyme-1 which catalyses conversion of precursor molecule to the intermediate compound L while gene-2 stimulates production of enzyme-2 which catalyses production of enzyme-2 which catalyses conversion of L to another intermediate compound M. Then finally enzyme-3 catalyses convertion of M to final colored pigment N. Production of enzyme-3 is controlled by gene-3.

If gene-2 mutates or fail to stimulate production of enzyme-2, compound M would not be formed and final colored pigment N will not be formed. Intermediate compound L will accumulate and gene-3 will have no effect on the phenotype. In this case gene-2 is epistatic while gene-3 is the hypostatic.

TYPES OF EPISTASIS.

- Supplementary gene interactions.
- Complementary gene interactions.
- Dominant gene epistasis.

SUPPLEMENTARY GENE INTERACTIONS.

This is where a particular gene will have no effect on a phenotype on their own but do so in combination with another different gene. For example, in the inheritance of fur color in mice.

• In the Inheritance of fur color in mice. There are three possible phenotypes, Agouti (grey), Black fur and Albino (white fur). They are controlled by a pair of genes occupying different loci. The Epistatic gene determines the presence of color and has two alleles, the dominant allele determines colored (C) and its recessive allele c, that controls white color (albino). The hypostatic gene that controls the nature of the color, has a dominant allele (A) that controls grey color or agouti and the recessive allele that controls black color.

The dominant allele (A) for grey (Agouti) color or recessive allele (a) for black color only express themselves when they are accompanied by the dominant allele (C) that controls colored fur in the genotype.

Albino conditions appear in mice when the alleles controlling colored fur are homozygous recessive even when the alleles controlling agouti and black fur are present in the genotype.

Phenotypes. Possible Genotypes.

(i) Agouti (grey)	AaCc, AACc or AaCC.
(ii) Black	aaCc or aaCC.
(ii) Albino	AAcc, Aacc or aacc.

Using the above ways in which the above alleles of the two genes interact,

(a) Determine the phenotype ratios of the following crosses
(i) AaCc X AaCc.   (ii)   AaCc X   Aacc.

Assuming no linkage.

• Another example of such epistasis is provided by color differences in onion bulb, fur color in mice. Skin pigmentation in humans (albinism) and comb shape in poultry.

In onion bulbs, the red color is obtained if at least both dominant allele C and R are present in the genotype. The color is yellow if dominant allele C is only present without the dominant allele R in the genotype and white color obtained if recessive allele c is present in homozygous recessive condition without its dominant allele C, either allele R or r being present in the genotype. This indicates that the dominant allele C and recessive allele c are epistatic.

PHENOTYPES AND SOME POSSIBLE GENOTYPES OF THE ONION BULB

Phenotypes:	**Possible genotypes:**
Red	CCRR , CCRr , CCRR or CcRr
Yellow.	CCrr or Ccrr
White	ccRR, ccRr, ccrr.

COMPLEMENTARY GENE EPISTASIS.

Is where presence of one gene affects another gene at another gene locus in such away that when the two alleles of the genes are at least dominant, they interact and produce a single identical and specific phenotype and in absence of dominant allele of at least one gene, its alleles being homozygous recessive, the phenotype is inhibited.

For example, flower color in sweet pea plant is determined by two genes with their dominant and recessive alleles (R, r and W, w). If at least one dominant allele of one gene is present in the genotype, it determines purple color of the flower while homozygous recessive state of alleles of any one gene determines white color in flowers.

Consider two plants producing purple flowers, each having the genotype RrWw are crossed. What will be phenotype ratio of the resulting offsprings. Assuming that each allele is located on its own chromosome.

Parents phenotype : Heterozygous Purple flower producing plant X Heterozygous purple flower producing plant.

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Parent, Genotype : RrWw RrWw.

Meiosis.

Gametes : all RW , Rw , rW , rw

Show Random fusion of gametes formed above by the purnett square. What phenotype ratio have you obtained. It should be similar to 9:3:3:1. How is it different from the Mendel's Dihybrid phenotype ratio.

- Determine possible genotypes of parents which when crossed will produce all offsprings with purple flowers.
- What will be the phenotype ratio of the F2 offsprings when RrWw is crossed with RRww.

In **dominant gene epistasis**, the presence of at least two dominant genes at different gene loci, will inhibit production of the phenotype while in a homozygous recessive state of one of the genes, a specific phenotype is produced. The dominant gene is epistatic while the recessive one is hypostatic.

For example, In white leghorn fowl, plumage color is controlled by two sets of genes including the following, **W** (white) dominant over **w** (colored) **B** (black) dominant over **b** (brown). The Heterozygous F_1 genotype **WwBb** is white while wwBB, wwBb are black and wwbb is brown.

PLEIOTROPY.

This is the condition in which a single gene controls two or more unrelated characteristics. It arises when the gene codes for an enzyme which affects more than one phenotype. In pleiotropy a single gene affects several phenotypic traits. If it affects a vital function of the body it may become lethal.

Examples of pleiotropy include,

- A mutation in certain gene for chloride ion secretion in epithelial cells gives rise to phenotype known as cystic fibrosis. The patients have problems with breathing and digestion.
- Sickle cell anemia.
- Coat color in mice.

ADVANTGES OF STUYDYING GENETICS

(i) Enable humans to choose partners with good characteristics for reproduction.
(ii) Used in legal profession to determine the paternity of a child.
(iii) enables elimination of harmful and fatal characteristics diseases from human population
(iv) Enables farmers to produced crops and breed animals with desired qualities such as increased crop yields, diseases resistance and drought resistance.

used in techniques of artificial insemination or artificial breeding where the closely related varieties of organisms are crossed so that their characteristics become combined in one individual.

EXERCISE.

1. Flower color in sweet pea plant is determined by two allelomorphic pairs of genes (R, r and W, w). If at least one dominant gene from each allelomorphic pair is present, it determines purple color of the flowers, all other genotypes where at least one dominant allele is absent determine white color in flowers.

(a) Explain each one of the following results,

(i) A cross between white flower producing plants, produced all offsprings with purple flowers.
(ii) A cross between a white flower producing plant and purple flower producing plant, produced offsprings producing white and purple flowers in the ration of 1 : 1.
(b)If two plants producing purple flowers, each having the genotype RrWw are crossed. State the phenotype ratio of the resulting offsprings, assuming the genes are linked.

2. In white leghorn fowl, plumage color is controlled by two sets of genes including the following,

W (white) dominant over **w** (colored)
B (black) dominant over **b** (brown).

The Heterozygous F_1 genotype **WwBb** is white. Account for this type of gene interaction and show the phenotypic ratio of the F_2 generation when the heterozygous white F_1 offsprings are selfed. Assuming no linkage.

3. (a) List down any four features of epistasis.
(b) In an animal species, individuals that are homozygous for gene A or its allele die. Another independent gene B in the homozygous state, blocks this lethal effect, otherwise gene B has no other effect on the organism.
Work out the expected phenotypic ratio of the viable offsprings in a cross of individuals of AaBb and AaBB genotypes.

4. Maize cobs may have purple or red grains. This character is controlled by a single pair of alleles.The dominant allele **R** gives red color. The color appearance is affected by another gene.
(a) In an experiment, a heterozygous plant is crossed with a maize plant homozygous for allele **r**. State genotypes of these two plants.

(b) Grain color is affected by a second pair of alleles. The presence of dominant allele E allows purple or red color to develop but in a homozygous recessive **(ee)** no color will develop despite the presence of alleles **R** or **r** and the grain will be white.
(i) When a plant of genotype RREE is crossed with plant of genotype rree. What will be the phenotypes of the offsprings.
(ii) What phenotypes of the offsprings will be produced when the offsprings in a (i) above interbreed.
State the phenotypic ratio.
(iii) What genotypes if allowed to self fertilize would produce pure breeding lines containing white grains.