

TYPES OF GENE ACTION

The interaction with in alleles of gene controlling a single character may be dominant, incomplete dominance and co-dominance and are called intra allele interaction. When there is a interaction occurs between different pairs of alleles influencing a character of an individual is said to be interallelic interaction or epistatic. The gene that has masking effect is called epistatic gene, and the gene whose effect is masked is known as hypostatic gene. Epistasis leads to modification of normal dihybrid or trihybrid segregation ratio in F₂ generation.

The term epistasis was coined by Bateson in 1909. Various types of epistatic gene interaction are

- 1) Recessive epistasis (9:3:4)
- 2) Dominant epistasis (12:3:1)
- 3) Dominant and recessive (inhibitory) epistasis (13:3)
- 4) Duplicate recessive epistasis (9:7)
- 5) Duplicate dominant epistasis (15:1) and
- 6) Polymeric gene interaction (9:6:1).

Dihybrid ratio (9:3:3:1)

A classical case of two genes affecting the one and the same character and producing in the F₂ four different phenotypes in the ratio of 9:3:3:1 was discovered in fowls by Bateson and Punnett. Each breed of poultry possesses characteristic type of comb. The Wyandotte breed has a comb known as the **rose** comb, the Brahma has a **pea** comb, and the leghorn has a **single** comb and the Malaya **walnut** comb. Each of these breeds true. Cross between rose comb and single combed types show that rose is dominant to single comb and that there is a segregation of 3 rose: 1 single comb in the F₂. In mating between pea combed with single combed and 3:1 ratio appears in F₂. In mating between pea combed with single combed bird, pea combed is found to be dominant over single comb and 3:1 ratio appears in F₂. When a rose combed fowl is crossed with a pea combed one, all the F₁ birds show a new comb known as walnut comb. When the walnut combs are inbred there appears in F₂ walnut 3 rose pea single comb. As well in the ratio of 9:3:3:1. The rose comb is due to the presence of R gene and Pea due to P gene. Walnut comb is due to the presence of the dominant genes. R and P and single comb are due to the presence of recessive of r and p. The ratio expected in F₂ is 9:3:3:1.

Parent RR PP x rrpp
 Rose x rp

Rr pp(Walnut)

♀ \ ♂	RP	Rp	rP	rp
RP	RRPP (W)	RRPp (W)	RrPP (W)	RrPp (W)
Rp	RRPp (W)	RRpp (R)	RrPp (W)	Rrpp (R)
rP	RrPP (W)	RrPp (W)	rrPP (P)	rrpp (P)
rp	RrPp (W)	Rrpp (R)	rrPp (P)	rrPP (S)

9 Walnut: 3 Rose: 3 Pea: 1 Single

Duplicate recessive epistasis (Complimentary gene action) 9:7

When recessive alleles at either of the two loci can mask the expression of dominant alleles at the two loci, it is called duplicate recessive epistasis. This is also known as complementary epistasis. The best example of duplicate recessive epistasis is found for flower colour in sweet pea. The purple colour of flower in sweet pea is governed by two dominant genes say A and B when these genes are in separate individuals (Aabb or aaBB) and white (aabb) they produce white flower. A cross between purple flower (AABB) and white flower (aabb) strains produced purple colour in F1 intermating of F1 plants produced purple and white flower plants in 9:7 ratio in F2 generation. Here the recessive allele 'a' is epistatic to B/b alleles and mask the expression of these alleles, another recessive allele 'b' is epistatic to A/a alleles and mask their expression.

Parents purple x White
 AABB x aabb
 AB ab

AaBb
Purple

♂		AB	Ab	aB	ab
♀	AB	AABB (P)	AABb (P)	AaBB (P)	AaBb (P)
	Ab	AABb (P)	AAbb (W)	AaBb (P)	Aabb (W)
	aB	AaBB (P)	AaBb (P)	aaBB (W)	aaBb (W)
	Ab	AaBb (P)	Aabb (W)	aaBb (W)	aabb (W)

Ratio = 9 Purple : 7 white

Duplicate gene action (15:1) (Duplicate dominant epistasis)

When a dominant allele at either of two loci can mask the expression of recessive alleles at the two loci, it is known as duplicate dominant epistasis. In rice awn character is controlled by two dominant duplicate genes (A and B). Presence of any of these two alleles can produce awn. The awnless condition develops only when both these genes are in homozygous recessive state (aabb). A cross between awned and awnless strains produced awned plants in F1. Intermating of F1 plants produced awned and awnless plants in 15:1 ratio in F2 generation. The allele A is epistatic to a/b alleles and all plants having allele A will develop awn. Another dominant allele B is epistatic to alleles a/b. An individual with these allele also develop awn character.

Parents awned rice x awnless rice
 AAbb x aaBB

AaBb
Awned rice

♀ ♂	AB	Ab	aB	ab
AB	AABB (A)	AABb (A)	AaBB (A)	AaBb (A)
Ab	AABb (A)	AAbb (A)	AaBb (A)	Aabb (A)
aB	AaBB (A)	AaBb (A)	aaBB (A)	aaBb (A)
ab	AABb (A)	AAbb (A)	AaBb (A)	Aabb (a)

Ratio = 15 awned : 1 awnless

Inhibitory gene action (13:3)

In this type of epistasis, a dominant allele at one locus can mask the expression of both (dominant and recessive) alleles at second locus. This is also known as inhibitory gene interaction. An example of this type of gene interaction is found for anthocyanin pigmentation in rice. The green colour of plants is governed by the gene I which is dominant over purple colour. The purple colour is controlled by a dominant gene P. when a cross was made between green (IiPp) and (iiPP) colour plants, the F1 was green. Intimating of F1 plants produced green and purple plants in 13:3 ratio in F2.

Parents awned rice x awnless rice
 AAbb x aaBB
 AaBb
 Awned rice

♀ ♂	IP	Ip	iP	ip
IP	IIPP (G)	IIPp (G)	IiPP (G)	IiPP (G)
Ip	IIPp (G)	Ippp (G)	IiPp (G)	Iipp (G)
iP	IiPP (G)	IiPp (G)	IiPP (P)	IiPp (P)
ip	IiPp (G)	Iipp (G)	IiPp (P)	Iipp (G)

Ratio = 13 Green : 3 Purple

Supplementary gene action. (Recessive epistasis) 9:3:4

Here one dominant gene has its own phenotypic effect and other dominant gene has no effect of its own but its presence with the first gene modified the phenotypic expression. Thus in supplementary gene action the dominant allele of one gene is necessary for the development of the concerned phenotype, while the other gene modifies the expression of the first gene.

Parents RR PP x rr pp
 Purple Red
 RP rp
 Rr Pp
 Purple

♀ \ ♂	RP	Rp	rP	rp
RP	RRPP (P)	RRPp (P)	RrPP (P)	RrPp (P)
Rp	RRPp (P)	RRpp (W)	RrPp (P)	Rrpp (W)
rP	RrPp (P)	RrPp (P)	RrPP (R)	RrPp (R)
rp	RrPp (G)	Rrpp (W)	rrPp (RP)	rrpp (W)

Ratio = 9 Purple : 3 Red : 4 White

Additive factors (9:6:1) (Polymeric gene action)

In these two genes controlling a character produces identical phenotype when they are alone i.e. with the homozygous recessive condition of the other gene. But when both the genes are present together, their phenotype effect is enhanced as if the effect of the two genes were cumulative or additives. It should be noted that in this case both the genes show complete dominance. If the two genes showing polymeric gene action, what will be the consequence. In barley two completely dominant genes A and B affect the length of awns, the thin needle like extension of lemma genes A and B alone (e.g. Aabb and aaBB give gives rise to awn of medium length, the effect of A is the same as that of B. But when both the genes A and B are present together they produce long awn indicating the effect of A and B genes of awn length are added together. Individual homozygous recessive for both these genes are awn less.

♀ ♂	WG	Wg	wG	wg
Wg	WWGG (W)	WWGg (W)	WwGG (W)	WwGG (W)
Wg	WWGg (W)	WWgg (W)	WwGg (W)	Wwgg (W)
WG	WwGG (W)	WwGg (W)	wwGG (Y)	WwGg (Y)
Wg	WwGg (W)	Wwgg (W)	wwGg (Y)	wwgg (G)

Ratio = 12 White: 3 Yellow: 1 Green

Modifying genes

These are group of genes, which enhances or reduce the phenotypic effect of a major gene. Such genes have small and cumulative effect on the expression of the major genes. As a result continuous variation is generated in the phenotype governed by a single major gene, which converts qualitative character into a quantitative one. In rats, guinea pigs and rabbits, piebald spotting is produced by recessive genes when present in a homozygous state (ss). The degree of spotting depends upon the modifying factors, designed as S1, S2, S3 etc. which enhances or reduces the expression of this spotting gene with cumulative on spotting. Most quantitative characters of crop plants may be determined in a similar fashion. Some modifying genes affect more than one character.

Major and minor genes

In the pie bald spotting the modifying factors produce some spotting even in the absence of the spotting genes but their effect is much more pronounced in the presence of s, Obviously the spotting gene s is a major gene controlling spotting, while the modifying genes are minor genes affecting this trait.

Inheritance of quantitative characters

Concept of polygenes

Colour, sex etc which shows distinct categories are known as qualitative characters. They are usually governed by one or major genes or oligogenes. Characters like length of ear in corn, yield of grain, yield of milk, stature etc do not fall into clear cut classes and shown more or less continuous variation and are governed by a large number of minor genes called multiple genes or polygenes. The characteristic feature of quantitative characters is 1) continuous variation and 2) a marked influence of the environment on their expression.

Multiple factor hypothesis (Nilsson - Ehle 1908)

He effected crosses between different true breeding strains of wheat with red kernels and with white kernel and the result of F1 and F2 were obtained. The F1 was (medium) red In F2 15:1 ratio was obtained. Careful examination revealed that the red colour of F1 was not as intense as the red colour of the parent and that in the F2 some red grains were as dark as those of the parent and other only as dark as those of the F1. F2 plants revealed marked difference in the intensity of colour depending upon the ratio of dominant and recessive genes present in them. Thus he obtained 1:4:6:4:1 ratio for dark red, medium dark red medium red, light red and white. It is evident that red colour is due to two pairs of genes. Each gene is capable of producing red colour. Each is incompletely dominant over white and is cumulative in its effect. The intensity of the red color depends upon the number of colour producing genes present. Dark red is due the presence of four genes for red medium dark red to three genes, medium red, to two genes and light red to one gene.

Nilson Ehle from his studies proposed the multiple gene hypothesis for the inheritance of quantitative characters. This assumes that there is a series of independent genes for a given quantitative traits. Dominance is usually incomplete and there is a strength of expression of the character, whereas its alleles do not possess any effect. The F1 essentially uniform but intermediate between the two parents. The F2 shows considerable variability, but is intermediate between the two parents. The F2 mean value being approximately equal to the parental mean and also the F1 mean. Studies on *Nicotiana* (East and Emerson 1916) worked on quantitative characters to explain the inheritance of corolla length in *nicotiana longiflora*. He crossed two inbred with contrasting corolla length of 40 and 93 mm. The F1 was intermediate with mean corolla length of 63 mm. In F2 a much larger variation for corolla length than the parents and F1 was observed. This variation was continuous as well and the F2 mean was close to that of F1 and intermediate between those of the parent. This is precisely what is expected in case of polygenic inheritance.

Transgressive segregation

The appearance in F₂ individuals with higher or lower intensity of characters than the parents is called as transgressive segregation. It is produced when the parents have positive alleles of different genes affecting a quantitative traits and segregation of these genes produce two extreme homozygotes in F₂, which transgress the parental limit for the character. The reappearance of ancestor is called atavism, throw back or reversion.

Expressivity

The degree of phenotypic expression of a penetrant gene is called expressivity. In other words, the ability of a gene to produce identical phenotypes in all the individuals carrying it in the appropriate genotype is known as incomplete expressivity. Many genes have incomplete expressivity, while the wild type (normal) alleles are buffered against such variations.

Penetrance

The frequency with which a gene produces a phenotypic or visible effect in the individuals, which carry it, is known as penetrance. In other words penetrance refers to the proportion of individuals which exhibit phenotypic effect of a specific gene carried by them. In general genes express themselves in all the individuals in which they are present in the appropriate genotype is known as penetrance. It indicates the number of individuals that give the expected phenotype to any degree.

Polydactyly

Polydactyly is a condition with extra fingers and toe or toes in man is due to the presence of dominant gene P. The normal condition is produced by the genotype PP. The genotype and pp produce polydactyly. Some heterozygous individual are not polydactyly. (Pp). Therefore the gene has penetrance of less than 100 per cent and said to be incompletely penetrant. A gene though penetrant, may be quite variable in its expression. The degree of expression produced by a penetrant genotype is termed expressivity. The polydactylous condition may be penetrant in the left hand and not in the right hand or may be penetrant in the feet and not in hands.