Lecture 8, 9 and 10

Deviation from Mendelian inheritance – Non allelic interaction without modification in Mendelian ratio – EPISTASIS

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- 8. Deviation from Mendelian inheritance – Non allelic interaction without modification in Mendelian ratio – Batson and Punnet's experiment on fowl comb shape. Non allelic interaction with modification in Mendelian ratio – i.) Dominant epistasis (12:3:1)
- 9. ii.) Recessive epistasis(9:3:4) iii.) Duplicate and additive epistasis((9:6:1). iv.) Duplicate dominant epistasis(15:1)
- 10. v) Duplicate recessive epistasis (9:7) vi.) Dominant and recessive epistasis(13:3) Summary of epistatic ratios (i)to (vi).

- **Gene interaction:** For the determination of single phenotypic character, two alleles of a single gene interacted in various way.
- Eg: complete dominance, incomplete dominance or codominance.
- These kind of genetic interactions occur in between the two alleles of a single gene is referred as **Allelic interaction or intra genic interaction.**

When different pairs of alleles influence the same character of an individual, it is likely that the expressions of these genes interact.

As two different genes interact and affect the same character, such a genetic interaction is said to be intergenic or nonallelic.

In nonallelic interactions different genes located on the same or different chromosomes interact with one another for the expression of a single phenotypic trait of an organism.

Intergenic or nonallelic interactions may suppress or mask the action of a gene at another locus or modify partially or completely the effect of another gene.

This nonallelic interaction is otherwise called *epistasis.*

Definition- epistasis(non –allelic interaction)

E**xpression of one gene masks the expression of the other** is **called epistasis**

A kind of interaction between genes belonging to different pairs of alleles, the dominant allele in one of the pairs preventing the dominant allele in the other pair from expressing itself.

.A gene that prevents the expression of another gene is said to be **epistatic** to it, and the gene that is suppressed is hypostatic.

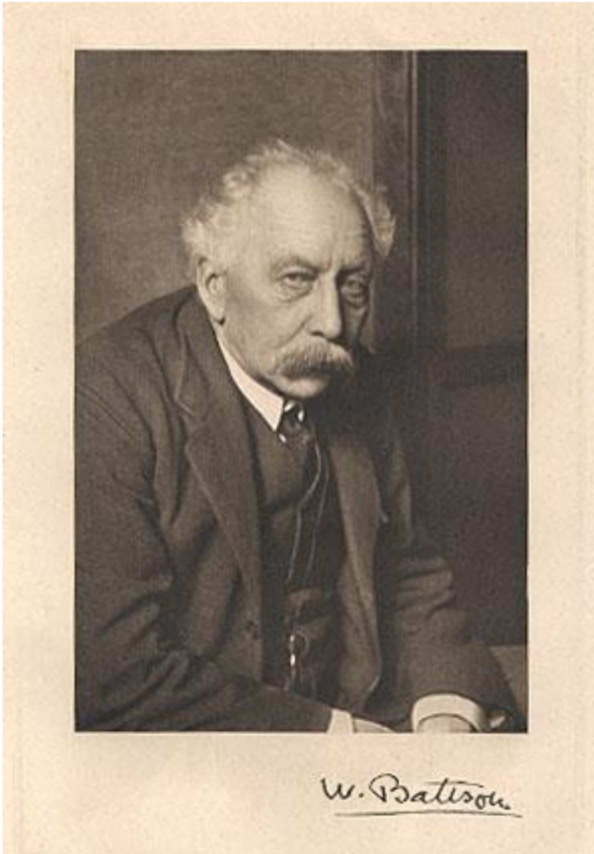
Thus,

the gene A is epistatic over B.

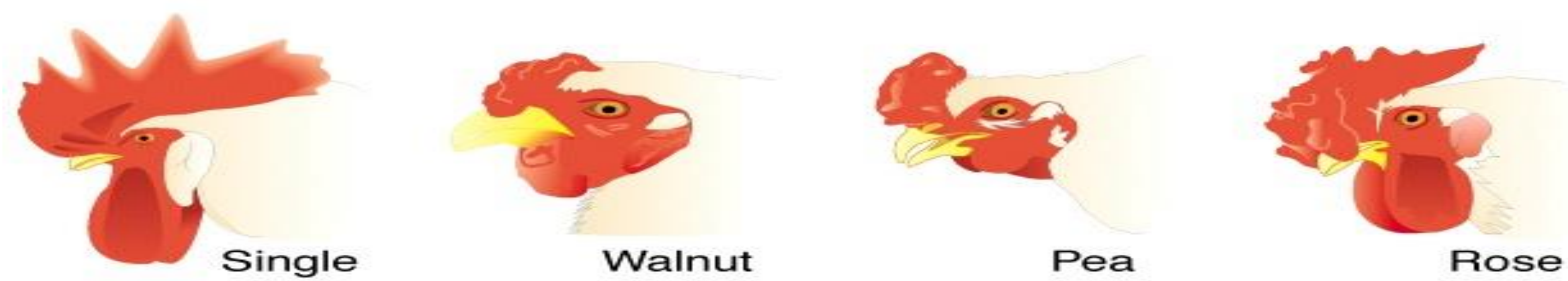
B is then said to be hypostatic to A.

The phenomenon of non allelic or inter allelic interaction is called Epistais, while dominance involves intra allelic interaction.

Fowls comb shape experiment by Bateson and Punnett.



Reginald Crundall Punnett

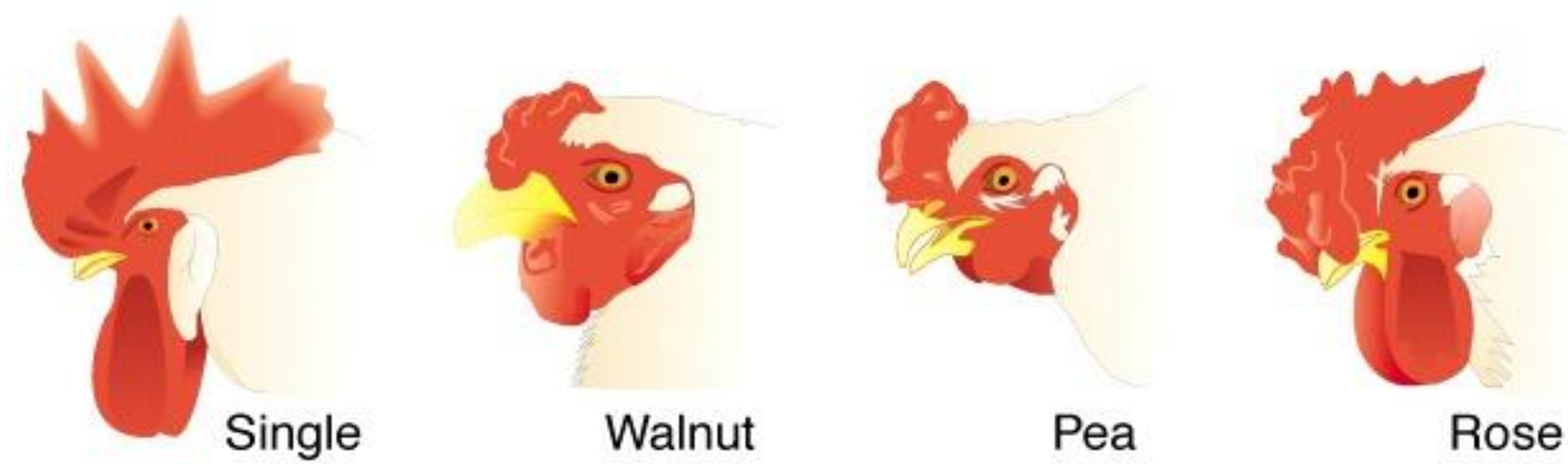


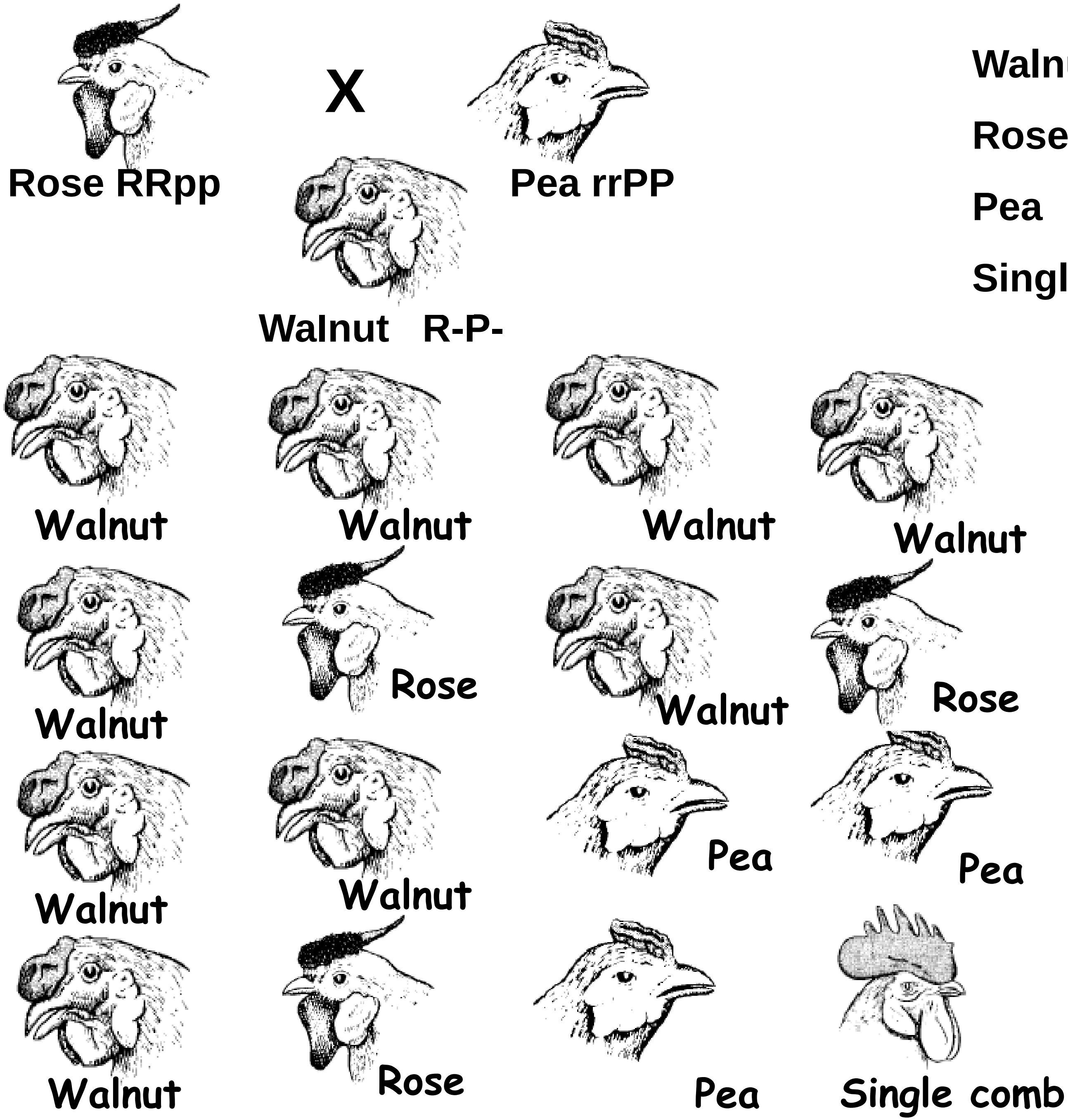
Intergenic / Non-epistatic interaction (9: 3 : 3 : 1 Ratio)

Two pairs of alleles affecting the same characteristic and producing in the F_2 four different phenotypes in the ratio of 9 : 3 : 3 : 1 was discovered in **fowls** by **Bateson and Punnett**.

- Each breed of poultry possesses a characteristic type of comb.
  - **The Wyandotte breed has 'Rose' comb**
  - **The Brahma has a 'Pea' comb**
  - **The Leghorn has a 'Single' comb**
  - **Malay breed has a comb - 'Walnut' comb.**
- Each of these breeds true.

rrpp	rrP_	R_pp	R_P_





Walnut : 9 R – P-

Rose : 3 R – pp

Pea : 3 rr P-

Single : 1 rr pp

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- The differences from normal dihybrid inheritance are that

  1) The F_1 resembles neither parent

  2) Apparently novel characters appeared in F_2

- This leads to the conclusion that WALNUT results from an interaction between two independently inherited dominant genes, and the SINGLE COMB results from the interaction between two recessive alleles.

- Crosses between rose-combed 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 F_2.
- In matings between pea-combed and single-combed birds, pea comb is found to be dominant over single comb and a 3 : 1 ratio appears in the F_2.

- However, when a rose-combed fowl is crossed with a pea combed one, all the F_1 birds show the walnut comb.
- When the F_1 walnut combed birds are bred together, there appears 9 walnut : 3 rose : 3 pea : 1 single comb in F_2

Results:

the rose comb is due to dominant gene R

the pea comb is due to dominant gene P.

the walnut comb is due to both the dominant genes, R and P

the single comb is due to their recessive alleles, r and p.

The breeding behaviour of the different genotypes of the F_2 is summarised.

F_2			Breeding behaviour
Phenotype	Genotype	Ratio	
Walnut	RRPP	1	All the progeny walnut-combed
	RRPp	2	3 walnut (RP) : 1 rose (Rp)
	RrPP	2	3 walnut (RP) : 1 pea (rP)
	RrPp	4	9 walnut : 3 rose : 3 pea : 1 single
Rose	RRpp	1	All the progeny rose-combed
	Rrpp	2	3 rose (Rp) : 1 single (rp)
Pea	rrPP	1	All the progeny pea-combed
	rrPp	2	3 pea (rP) : 1 single (rp)
Single	rrpp	1	All the progeny single-combed

Types of epistasis

1. Dominant epistasis (12:3:1)
2. Recessive epistasis (9:3:4)
3. Duplicate and additive epistasis (9:6:1)
4. Duplicate dominant epistasis (15:1)
5. Duplicate recessive epistasis (9:7)
6. Dominant and recessive epistasis (13:3).

1. Dominant Epistasis (12 : 3 : 1)

The dominant allele at one locus mask the expression of both dominant and recessive alleles at another locus resulting in 12 : 3 :1 ratio

Simple Epistasis or Dominant suppressor

Example: Fruit colour in Summer Squash

Fruit colour in Summer Squash

- Three types of fruit colour- White, Yellow and Green
- White colour- Dominant gene W
- Yellow colour- Dominant gene Y
- White is dominant over Yellow and Green
- Green is produced under recessive condition wwyy
- A cross between plants with White and Yellow produced White fruits in F1
- Intermating of F1 plants produced White, Yellow and green coloured fruits in F2 in 12;3:1 ratio

Fruit color in summer squash

Cucubita pepo

- W is dominant to w and epistatic to alleles Y and y
- Hence, W will mask the expression of Y and y alleles
- In F2, plants with genotypes

W-Y- (9/16)
W-yy (3/16) } White fruits

wwY- (3/16) - Yellow fruits

wwyy (1/16) - Green fruits

P	White **WWYY**	X	Green **wwyy**
F1		White **WwYy**	
F2	9 **W – Y –**	=	12 white
	3 **W – yy**		
	3 **wwY -**	=	3 yellow
	1 **wwyy**	=	1 green

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White Fruit x Yellow Fruit

WWyy ↓ wwYY

F1 White fruit (WwYy)

Selfing of F1 fruits - **12 white : 3 Yellow : 1 Green** F_2 progenies

F_2	WY	Wy	wY	wy
WY	WWYY White	WWYy White	WwYY White	WwYy White
Wy	WWYy White	WWyy White	WwYy White	Wwyy White
wY	WwYY White	WwYy White	wwYY Yellow	wwYy Yellow
wy	WwYy White	Wwyy White	wwYy Yellow	wwyy Green

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2. Recessive Epistasis (9 : 3 : 4)

The recessive allele at one locus mask the expression of both dominant and recessive alleles at another locus resulting in 9 : 3 :4 ratio

Also called Supplementary Epistasis.

Example: Grain colour in Maize

- Three colors in maize - Purple, Red and White
- Purple color - in the presence of 2 dominant genes (R and P)
- Red color - in the presence of 1 dominant gene (R)
- White color – homozygous recessive condition (rrpp)

Recessive epistasis **(9 : 3 : 4)**

- Three colors in maize - Purple, Red and White
- Purple color - in the presence of 2 dominant genes (R and P)
- Red color - in the presence of 1 dominant gene (R)
- White color – homozygous recessive condition (rrpp)

Purple grains x White grains

PPRR pprr

F1 Purple grains RrPp

Selfing F1 – Produces F2 progenies

F2	PR	Pr	pR	pr
PR	PPRR Purple	PPRr Purple	PpRR Purple	PpRr Purple
Pr	PPRr Purple	PPrr white	PpRr Purple	Pprr white
pR	PpRR Purple	PpRr Purple	ppRR Red	ppRr Red
pr	PpRr Purple	Pprr white	ppRr Red	pprr white

9 Purple: 3Red : 4 White

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- The allele r is recessive to R but epistatic to alleles P and p.
- In $F_{2,}$ plants with genotypes

  R-P- (9/16) – Purple color grains

  R-pp (3/16) – Red color grains

  rrP- (3/16)) – White color grains

  rrpp (1/16) – White color grains

The dihybrid 9:3:3:1 ratio is modified to 9:3:4 ratio

The epistatic allele is r – produce white color under homozygous recessive condition

3. Duplicate dominant epistasis (15 : 1)

The dominant alleles at either of the two loci mask the expression of recessive alleles at the two loci, resulting in 15 : 1 ratio

- **Also called Duplicate gene action**

Example: Awn character in Rice

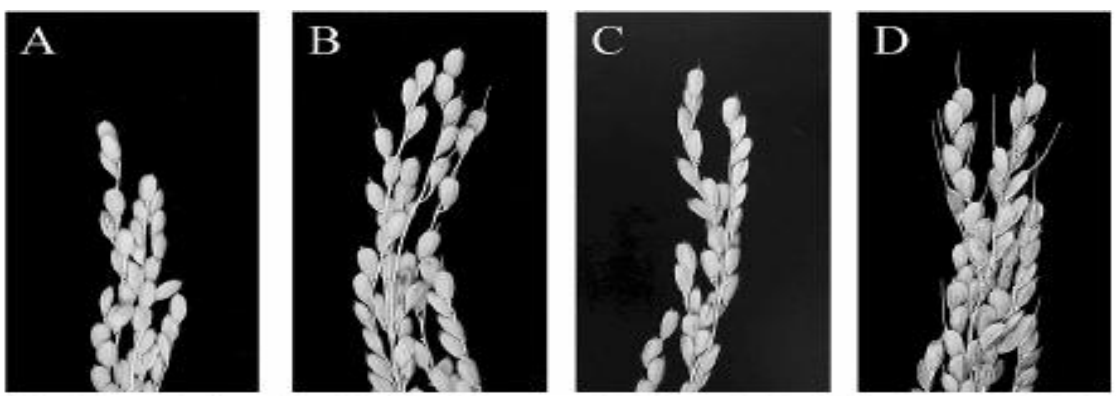
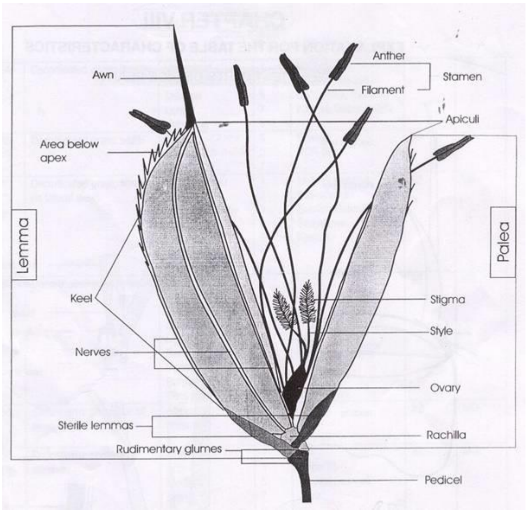


Fig. 2. Characterization of *An9*, *An10* and *An6-mer*. A: Taichung 65. B: *An9* homozygote. C: *An10* homozygote. D: *An6-mer* homozygote.



Development of Awn in Rice is controlled by 2 dominant duplicate genes (A and B)

Presence of any one of these 2 dominant genes will produce awn (A or B)

The awnless condition develops when both these genes are in homozygous recessive state (aabb)

A cross was made between

Awned plants x **Awnless plants**

AABB aabb

F_1 **Awned plants AaBb**

Selfing of F_1

15 Awned plants and **1 Awnless plant** in F_2

The allele A is epistatic to B / b alleles and all plants having allele A will develop awn

Another dominant allele B is epistatic to alleles A and a, also develop awn

In F2, plants with genotypes

A-B- (9/16), A-bb (3/16) and aaB- (3/16) – develop AWN

aabb (1/16) double recessive condition – develop AWNLESS

F2	AB	Ab	aB	ab
AB	AABB Awned	AABb Awned	AaBB Awned	AaBb Awned
Ab	AABb Awned	AAbb Awned	AaBb Awned	Aabb Awned
aB	AaBB Awned	AaBb Awned	aaBB Awned	aaBb Awned
ab	AaBb Awned	Aabb Awned	aaBb Awned	aabb awnless

15 Awned : 1 Awnless

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4. Duplicate recessive epistasis (9:7)

When recessive alleles at either of the two loci mask the expression of dominant alleles at the two loci it is called Duplicate recessive epistasis

- **Also called Complementary Epistasis**

Example: Flower color in Sweet pea

Flower color in Sweet pea

- Purple colour is controlled by 2 dominant duplicate genes (A and B)
  When these genes are in separate individuals AAbb or aaBB or aabb – they produce white colour

  A cross was made between

  Purple Flower plants x **White flower plants**

  AABB aabb

  F1 **Purple flower (AaBb)**

  Selfing of F1

  9 Purple flower and **7 white flower** in F2

- **The allele "a" is epistatic to B / b alleles and mask the expression**
- **Another allele "b" is epistatic to alleles A and a**
- **In F2, plants with genotypes**

  A-B- (9/16)– develop PURPLE flowers

  A-bb (3/16), aaB- (3/16) and aabb (1/16) – develop WHITE flowers
- **Two phenotypes of Purple and white in 9 :7 ratio are produced**

F2	AB	Ab	aB	ab
AB	AABB Purple	AABb Purple	AaBB Purple	AaBb Purple
Ab	AABb Purple	AAbb White	AaBb Purple	Aabb White
aB	AaBB Purple	AaBb Purple	aaBB White	aaBb White
ab	AaBb Purple	Aabb White	aaBb White	aabb White

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5. Dominant and Recessive epistasis (13 : 3)

The dominant and recessive alleles at one locus mask the expression of both dominant and recessive alleles at second locus resulting in 13 : 3 ratio.

Also called as Inhibitory gene action

Example: Anthocyanin pigmentation in rice

- Green color of plants is governed by gene “I”
- Purple color is governed by the dominant gene “P”
- The gene “I” is dominant over gene “P”
- A cross was made between

Green	X	Purple
IIpp	↓	iiPP
F_1	Green IiPp	

Intermating of F_1 -13 green and 3 purple plants (13:3) in F_2

The allele “I” is epistatic to alleles P and p

In F_2, plants with genotypes

I-P- (9/16), I-pp (3/16), and iipp (1/16) – were **GREEN**

“I” will mask the effect of P or p

iiP- (3/16) – were **PURPLE** (“I” is absent)

Dominant and Recessive epistasis

F2	IP	Ip	iP	ip
IP	IIPP Green	IIPp Green	IiPP Green	IiPp Green
Ip	IIPp Green	IIpp Green	IiPp Green	Iipp Green
iP	IiPP Green	IiPp Green	iiPP Purple	iiPp Purple
ip	IiPp Green	Iipp Green	iiPp Purple	iipp Green

13 green : 3 purple plants

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6. Duplicate genes with cumulative effect (9 : 6 : 1)

Two dominant alleles have similar effect when they are separate but produced enhanced effect when they are together, resulting in 9 : 6 : 1

Also called **polymeric gene action**

Example: Fruit shape in Summer Squash

Fruit shape in Summer Squash

- Three types of fruit shape
  - ❖ Disc - 2 dominant genes A and B
  - ❖ Spherical – either gene A or gene B
  - ❖ Elongated – double recessive aabb

A cross between

Disc	X	Elongated
AABB		aabb

F_1 Disc shaped AaBb

Intermating of F_1

Disc : Spherical : Elongated fruits in F_2

In F_2, Plants with genotypes

A-B- (9/16)	– Disc shaped fruits
A-bb (3/16) and aaB- (3/16)	– Spherical fruits
aabb (1/16)	– Elongated fruits

F2	AB	Ab	aB	ab
AB	**AABB** **Disc**	**AABb** **Disc**	**AaBB** **Disc**	**AaBb** **Disc**
Ab	**AABb** **Disc**	**AAbb** **Spherical**	**AaBb** **Disc**	**Aabb** **Spherical**
aB	**AaBB** **Disc**	**AaBb** **Disc**	**aaBB** **Spherical**	**aaBb** **Spherical**
ab	**AaBb** **Disc**	**Aabb** **Spherical**	**aaBb** **Spherical**	**aabb** **Elongated**

9 Disc : 6 Spherical : 1 Elongated

Summary

Genotypes	A - B-	A -b b	a a B -	aabb
Independent assorment/ Non-epistasis	9	3	3	1
Dominant epistasis	12		3	1
Recessive epistasis	9	3	4	
Dominant and Recessive interaction	13		3	
Duplicate dominant interaction	15			1
Duplicate recessive interaction	9	7		
Duplicate genes with cumulative effect	9	6		1

S No	Dominance	Epistasis
1.	Interaction of two alleles of the same gene, thus involving single locus	Interaction of two or more genes, thus involving two or more loci
2.	Always refers to Heterozygotes therefore, it is not fixable	Refers to homozygotes and heterozygotes therefore, it is fixable in homozygotes
3.	Dominance is of three types viz., complete, incomplete and overdominance	Epistasis is of several types viz., dominance, duplicate and recessive
4.	Partial dominance alters the normal segregation ratio of 3:1 into 1:2:1	It modifies the normal dihybrid ratio in F2
5.	It is known as intragenic or intralocus gene interaction	It is known as intergenic or interallelic or interlocus gene interaction
6.	Recessive genes can express only in homozygous condition	Recessive genes can also exhibit masking effect