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Lecture – 5

Gene Interaction

by

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➤ Genes usually function or express themselves singly or individually.

➤ But, many cases are known where two genes of the same allelic pair or genes of two or more different allelic pairs influence one another. This is called gene interaction

Non-allelic gene Interactions These are interactions between genes located on the same chromosome or on different but non-homologous chromosomes controlling a single phenotype to produce a different expression. Each interaction is typical in itself and ratios obtained are different from those of the Mendelian dihybrid ratios.



The interaction of genes may be of following types

- 1) Two gene pairs affecting same character – 9:3:3:1
- 2) Epistasis, one gene hides effect of other
 - a) Recessive Epistasis - 9:3:4
 - b) Dominant epistasis - 12:3:1
- 3) Complementary genes - 9:7 (2 genes responsible for production of a particular phenotype)
- 4) Duplicate genes – 15:1 (same effect given by either of two genes)
- 5) Polymeric gene action - 9:6:1
- 6) Inhibitory gene action - 13 : 3



Gene Interaction

Additive gene effect

Recessive Epistasis

Dominant Epistasis

Complementary genes

Duplicate genes

Polymeric Gene action

Inhibitory gene action

Inheritance Pattern & Example

Comb shape Chicken

Coat Colour Mouse

Fruit colour squash

Flower Colour Lathyrus

Fruit Shape capsella

Fruit Shape Squash

Maize Aleurone colour

**A-/B-
9/16**

**9
Walnut**

**9
Agouti**

**9
white**

**9
Purple**

9


**9
Disc**

**9
White**

**A-/bb
3/16**

**3
Rose**

**3
Albino**

**3
white**

**3
White**

3


**3
Circular**

**3
Red**

**aa/B-
3/16**

**3
Pea**

**3
Black**

**3
yellow**

**3
White**

3


**3
circular**

**3
white**

**aabb
1/16**

**1
Single**

**1
Albino**

**1
green**

**1
white**

1


**1
Long**

**1
White**

RATIO

**9:3:3:1
W:R:P:S**

**9:3:4
Ag:Bl:Al**

**12:3:1
W:Y:G**

**9:7
P:W**

**15:1
Tri: Top**

**9:6:1
D:C:L**

**13:3
W:R**



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ADDITIVE GENE EFFECT

Two gene pairs affecting the same character :

comb shape in chicken

(9:3:3:1-for single character)

Gene R- rose comb -Rp

Gene P –Pea Comb-rP

The dominant alleles of each of the two genes produce separate forms of phenotype when they are alone (heterozygous)

Both R and P when brought together form a new phenotype walnut

Allele R dominant over r

Allele P dominant over p

rr and pp produce single comb




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Parents RRpp x rrPP
(Rose) (Pea)
P. gametes Rp rP

GENETIC EXPRESSION

F1 RrPp walnut

F1 gametes



	RP	Rp	rP	rp
RP	RP RP 1	Rp RP 2	rP RP 3	rp RP 4
Rp	RP Rp 5	Rp Rp 6	rP Rp 7	rp Rp 8
rP	RP rP 9	Rp rP 10	rP rP 11	rp rP 12
rp	RP rp 13	Rp rp 14	rP rp 15	rp rp 16

F2
Generation

9:3:3:1

RP-Walnut 1,2,3,4,5,7,9,10,13= 9

Rp-Rose 6,8,14=3

rP- pea 11,12,15=3

rp- Single 16=1

so the ratio is 9:3:3:1 just like normal dihybrid ratio for two traits but it is for single trait i.e. comb shape having 4 different forms

A Cross Involving a Two-Gene Interaction : 9:3:3:1 ratio for single trait



Rose comb

RRpp



Pea comb

rrPP



Walnut comb

RrPp

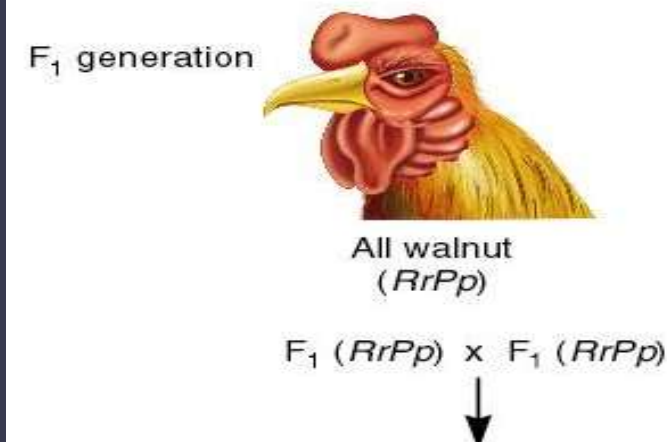
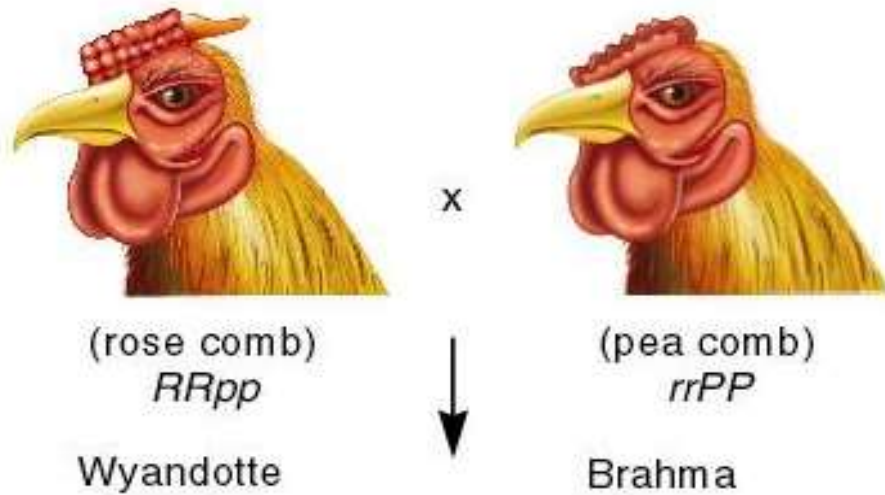


Single comb

rrpp

Four different comb morphologies

Inheritance of comb morphology in chicken described by William Bateson and Reginald Punnett in 1906 : First example of gene interaction



F2 Generation

	RP	Rp	rP	rp
RP	$RRPP$ Walnut	$RRPp$ Walnut	$RrPP$ Walnut	$RrPp$ Walnut
Rp	$RRPp$ Walnut	$RRpp$ Rose	$RrPp$ Walnut	$Rrpp$ Rose
rP	$RrPP$ Walnut	$RrPp$ Walnut	$rrPP$ Pea	$rrPp$ Pea
rp	$RrPp$ Walnut	$Rrpp$ Rose	$rrPp$ Pea	$rrpp$ Single

F_2 generation consisted of chickens with four types of combs
 9 walnut : 3 rose : 3 pea : 1 single

Bateson and Punnett reasoned that comb morphology is
 determined by

two different genes

2nd

Example

Lentil Seed colour

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Two genes,
one phenotype

Where both A and B are present add colour so new phenotype brown is produced

phenotype classes

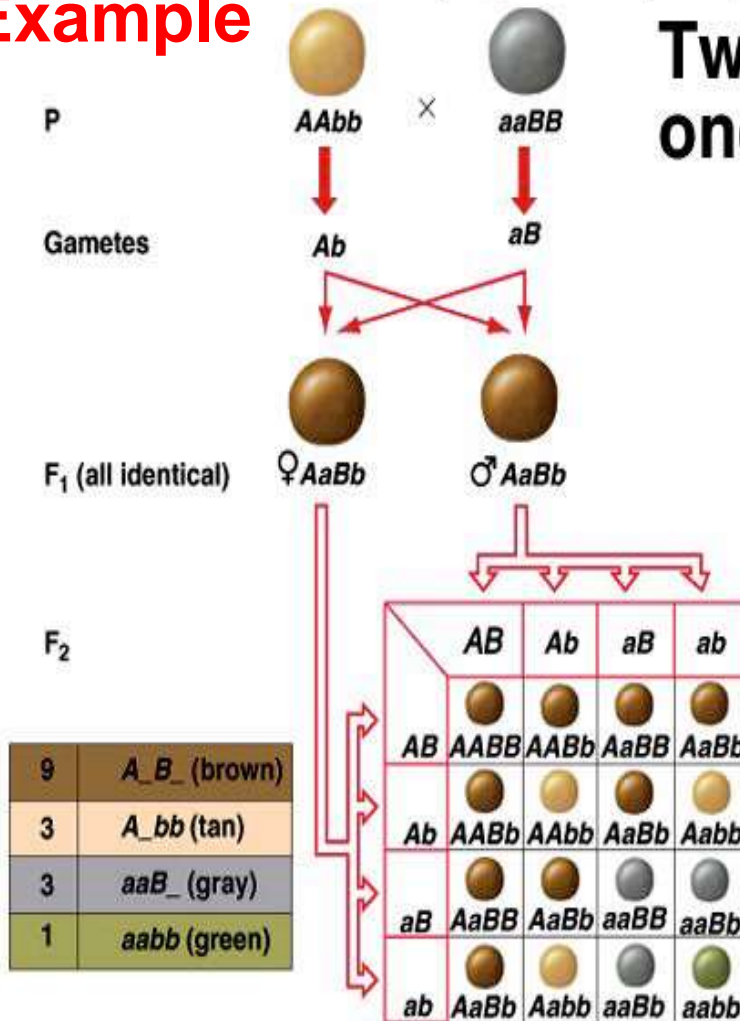
• Dominance Relationships:

- Tan is dominant to green
- Gray is dominant to green
- Brown is dominant to gray, green and tan.
- Tan and Gray are incompletely dominant, giving rise to brown.

• Genotypic classes:

- Brown: A_B_
- Tan: A_bb
- Gray: aaB_
- Green: aabb

9:3:3:1



There are 4 phenotypes in F₂, so are governed by more than one gene
 If it was governed by one gene and its two alleles F₂ would have shown only 3 phenotypes in 1:2:1 ratio



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EPISTASIS

- One gene hides the effect of other gene. It is different from Mendel's Dominance which is meant for **intragenic alleles** (alleles of a gene) but here dominance works at **intergenic level** (alleles of different genes). A gene which masks (hides) the action of another gene (non allelic) is termed as **epistatic gene**. The gene whose effects are masked is called **hypostatic gene**
- For example if two gene A and C with their alleles a and c take part in a cross then epistasis can be of following types
 - 1) **Recessive Epistasis** - Recessive allele (c) of one gene may hide the effect of dominant allele (A) of other gene
 - 2) **Dominant Epistasis** Dominant allele (A) of one gene may hide the effect of dominant allele (C) of other gene.



a) Recessive epistasis:

Here the recessive allele masks the effect of dominant allele of other gene.

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In mice the wild body colour is known as **agouti** (greyish) and is controlled by a gene **A** which is hypostatic to recessive allele **c**.

The dominant allele **C** in the presence of 'a' gives coloured mice.

In the presence of dominant allele **C**, **A** gives rise to agouti.

So, **CCaa** will be **coloured** and **ccAA** will be **albino**.

When coloured mice (**CCaa**) are crossed with albino (**ccAA**), agouti mice (**CcAa**) appear in F_1 .

cc masks the effect of **AA** and is therefore epistatic. Consequently, **cc AA** is **albino**.

The ratio **9 : 3 : 3 : 1** is modified to **9 : 3 : 4**.

The combination **ccaa** is also albino due to the absence of both the dominant alleles.

Recessive Epistasis

Example : Coat colour of Mouse

Coat colour is controlled by Gene A ,
Allele A is hypostatic to recessive allele
(c)

The dominant allele C in absence of A
gives coloured mice

When both C and A are present colour is
Agouti (wild type most common) due to
banded hair : Near skin Grey yellow

Black

Two other colours are Albino and solid
black



AACC (agouti) x aacc (albino)



AaCc (all agouti)

AaCc x AaCc

Genotyp		Phenotype	
e			
A-C-	Agouti	9/16	
A-cc	Albino	3/16	
aaC	Black	3/16	
aacc	Albino	1/16	

The c locus is epistatic to the A locus.
9 (Agouti) : 3 (Black) : 4 (Albino)

F₂ ratio

Parents

CCaa

X

ccAA

Black

Albino

Ca

cA

Genetic Expression

p. gametes

F1

CcAa

-----Agouti

F1 Gametes →

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	CA	Ca	cA	ca
CA	CA CA 1 Agouti	Ca CA 2 Agouti	cA CA 3 Agouti	ca CA 4 agouti
Ca	CA Ca 5 Agouti	Ca Ca 6 Coloured	cA Ca 7 Agouti	ca Ca 8 coloured
cA	CA cA 9 Agouti	Ca cA 10 Agouti	cA cA 11 Albino	ca cA 12 albino
ca	CA Ca 13 Agouti	Ca Ca 14 Coloured	cA Ca 15 albino	Ca Ca 16 Albino

← F2 Generation

CA –Agouti- 1,2,3,4,5,7,9,10,13=9

Ca- Black- 6,8,14=3

cA- Albino- 11,12,15=3 (c masks the effect of A)

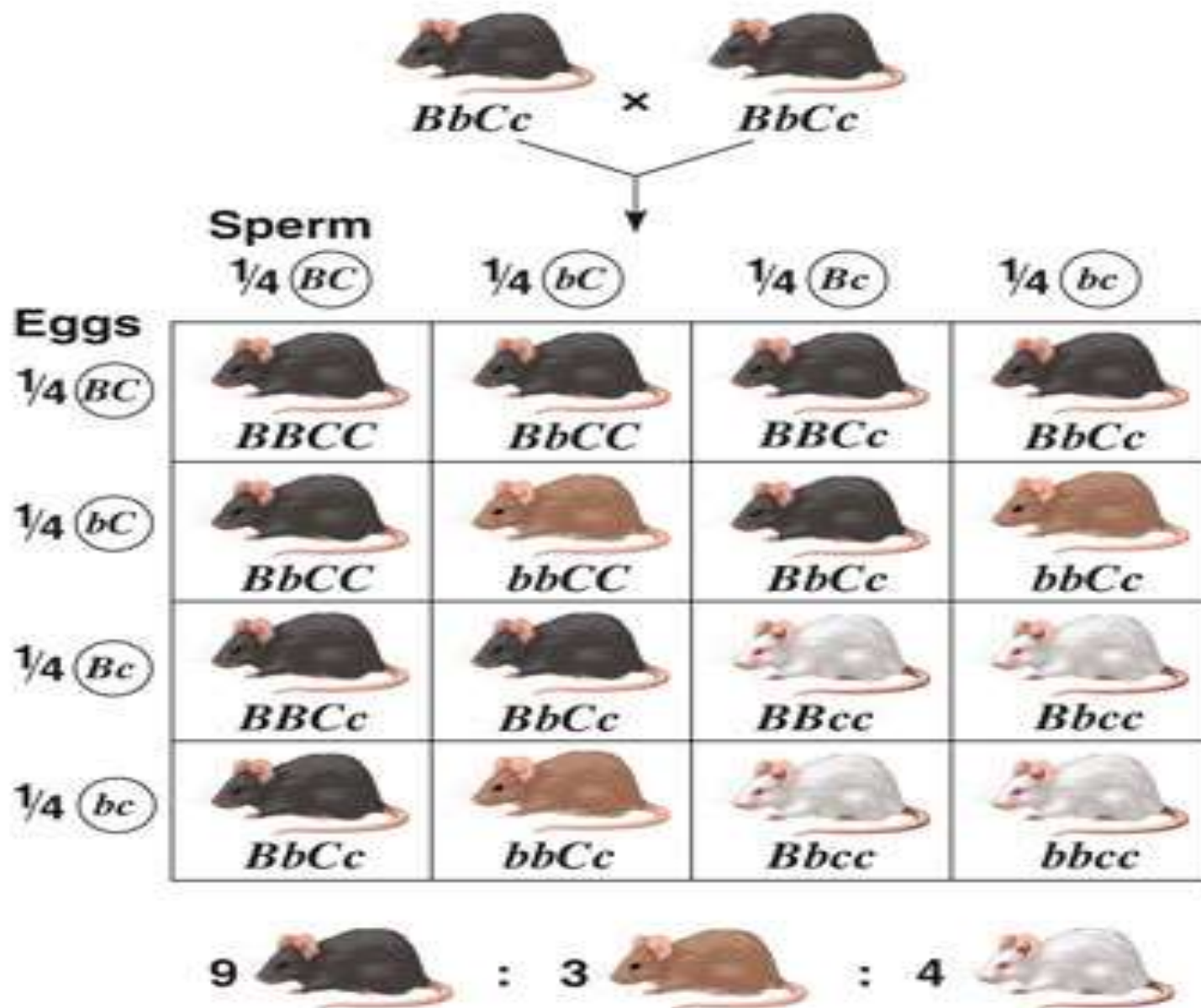
ca- albino -16=1

So the ratio is 9:3:4 (Agouti:Black:Albino)

Cross between Black and Albino : Genetic Expression



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Gamete

F₁

Gametes

F₂

Generation

CCaa
Coloured

Ca

ccAA
Albino

cA

CcAa

Agouti

Selfing of F₁

CCAA Agouti	CCAa Agouti	CcAA Agouti	CcAa Agouti
CCAa Agouti	CCaa Coloured	CcAa Agouti	Ccaa Coloured
CcAA Agouti	CcAa Agouti	ccAA Albino	ccAa Albino
CcAa Agouti	Ccaa Coloured	ccAa Albino	ccaa Albino

F₂ Phenotypic ratio : 9 (agouti) : 3 (Coloured) : 4 (Albino)



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(b) Dominant epistasis:

In **summer squash** or **Cucurbita pepo**, there are three types of fruit colour - yellow, green and white. White colour is dominant over other colours, while yellow is dominant over green. Gene for white colour (W) masks the effects of yellow colour gene (Y). So yellow colour is formed only when the dominant epistatic gene is represented by its recessive allele (w). When the hypostatic gene is also recessive (y), the colour of the fruit is green.

White Fruit - WY , Wy

Yellow Fruit - wY

Green Fruit – wwyy

A cross between a pure breeding white summer squash, (WWYY) with a pure breeding green summer squash, (wwyy) yields white fruits in the F_1 generation. Upon selfing of F_1 the F_2 generation comes to have

12 white fruit : 3 yellow fruit : 1 green fruit.



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Parents WWYY

White

P gametes WY

F1 Generation

F1 Gametes

X wwyy

Green

wy

Hybrid WwYy

-----White

Genetic Expression

F2 generation

Female	WY	Wy	wY	wy
Male				
WY	WY 1 white	Wy 2 white	wY 3 white	wy 4 white
Wy	WY 5 white	Wy 6 white	wY 7 white	wy 8 white
wY	WY 9 white	Wy 10 white	wY 11 Yellow	wy 12 Yellow
wy	WY 13 white	Wy 14 white	wY 15 Yellow	wy 16 green

WY-White- 1,2,3,4,5,7,9,10,13=9

Wy-White- 6,8,14=3

wY-yellow- 11,12,15=3

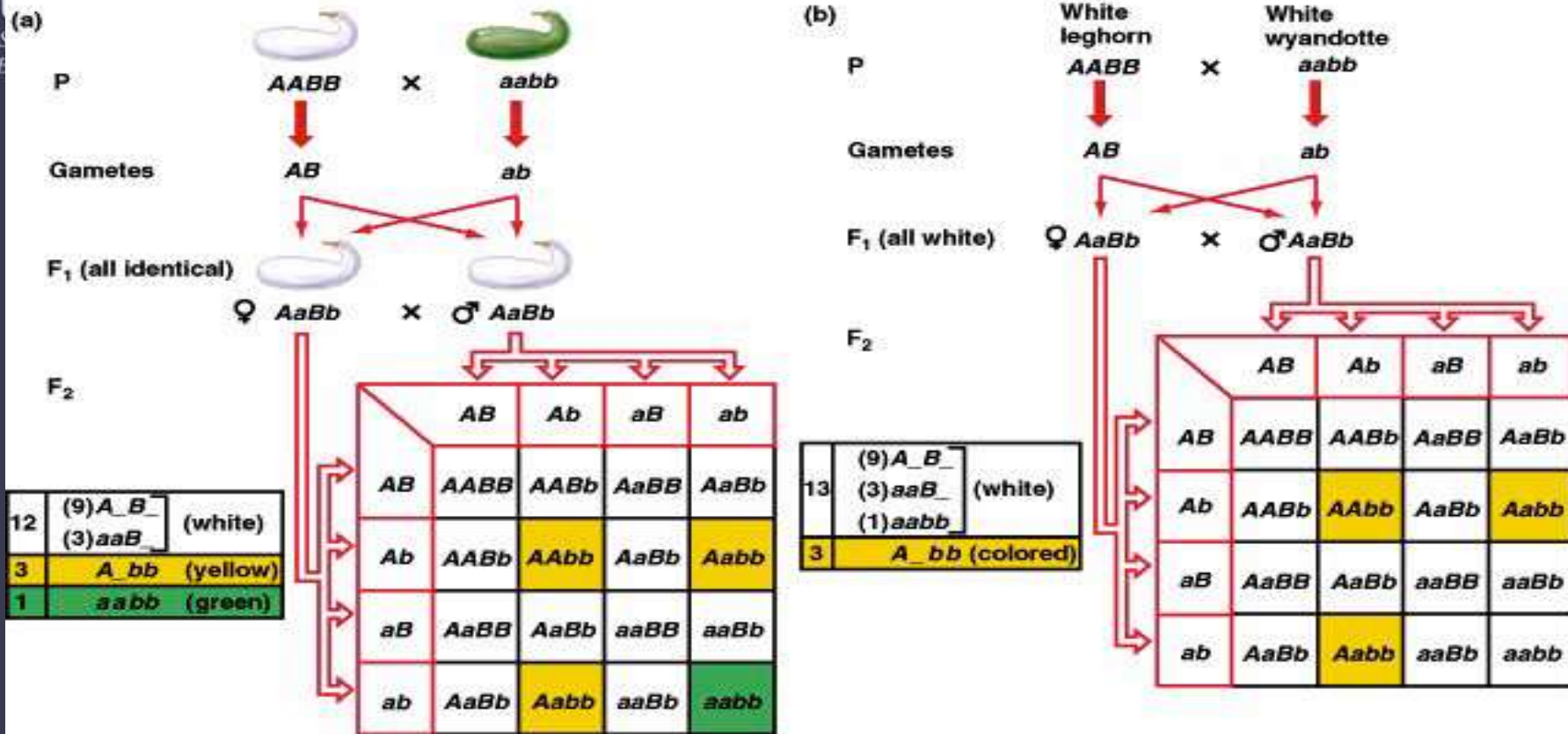
wy-Green-16=1

12 white : 3Yellow :1 green

FRUIT COLOUR SQUASH : 12 : 3 : 1

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Dominant epistasis



F1- $AaBb \times AaBb$

9 $A_B_ - white$ 3 $Aa-bb - Yellow$ 3 $aa-B - White$ 1 $aabb - Green$

A causes Yellow but in presence of B can not express, produce white



COMPLEMENTARY GENES

Two genes are responsible for a particular phenotype. Production of one phenotype requires dominant alleles of both the genes controlling the character.

The complementary genes are two genes present on separate gene loci that interact together to produce dominant phenotypic character, neither of them if present alone, can express itself. It means that these genes are complementary to each other.

Example is flower colour of *Lathyrus odoratus* (Keshari/pea grass). The colour of flower is either purple or white. Purple colour is produced only when dominant A is complemented by Dominant Allele B



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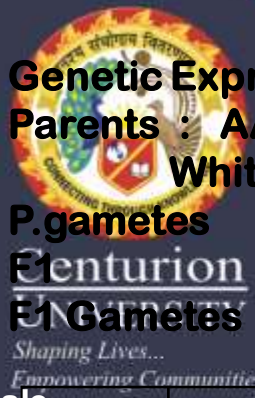
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Bateson and Punnet have demonstrated that in sweet pea (*Lathyrus odoratus*) purple colour of flowers develop as a result of interaction of two dominant genes C and P. In the absence of dominant gene C or P or both, the flowers are white. It is believed that gene C produces an enzyme that catalyzes the formation of necessary raw material for the synthesis of pigment anthocyanin and gene P produces an enzyme which transforms the raw material into the pigment. It means the pigment anthocyanin is the product of two biochemical reactions, the end product of one reaction forms the substrate for the other.



Therefore, if a plant has ccPP, ccPp, CCpp or Ccpp genotypes, it bears only white flowers. Purple flowers are formed in plants having genotype CCPP or CCPp or CcPP or CcPp. From checker board, it is clear that 9 : 7 ratio between purple and white is a modification of 9 : 3 : 3 : 1 ratio.



Genetic Expression

Parents : AAbb

White

P.gametes Ab

F₁ Gametes

Female →

X

aaBB

White

aB

AaBb

Purple

COMPLEMENTAY GENES KESHARI

Male

↓	AB	Ab	aB	ab
AB	AB 1	Ab 2	aB 3	ab 4
Ab	AB 5	Ab 6	aB 7	Ab 8
aB	AB 9	Ab 10	aB 11	ab 12
ab	AB 13	Ab 14	aB 15	ab 16

AB- Purple-1,2,3,4,5,7,9,10,13= 9

Where both (A) and (B) are present flowers are coloured
(when A is complemented by B then only flower is coloured)

Where either (A) or (B) is present colour is white

Ab- White- 6,8,14 = 3

aB- White – 11,12,15 = 3

ab- White -16 = 1

Total white- 3+3+1=7

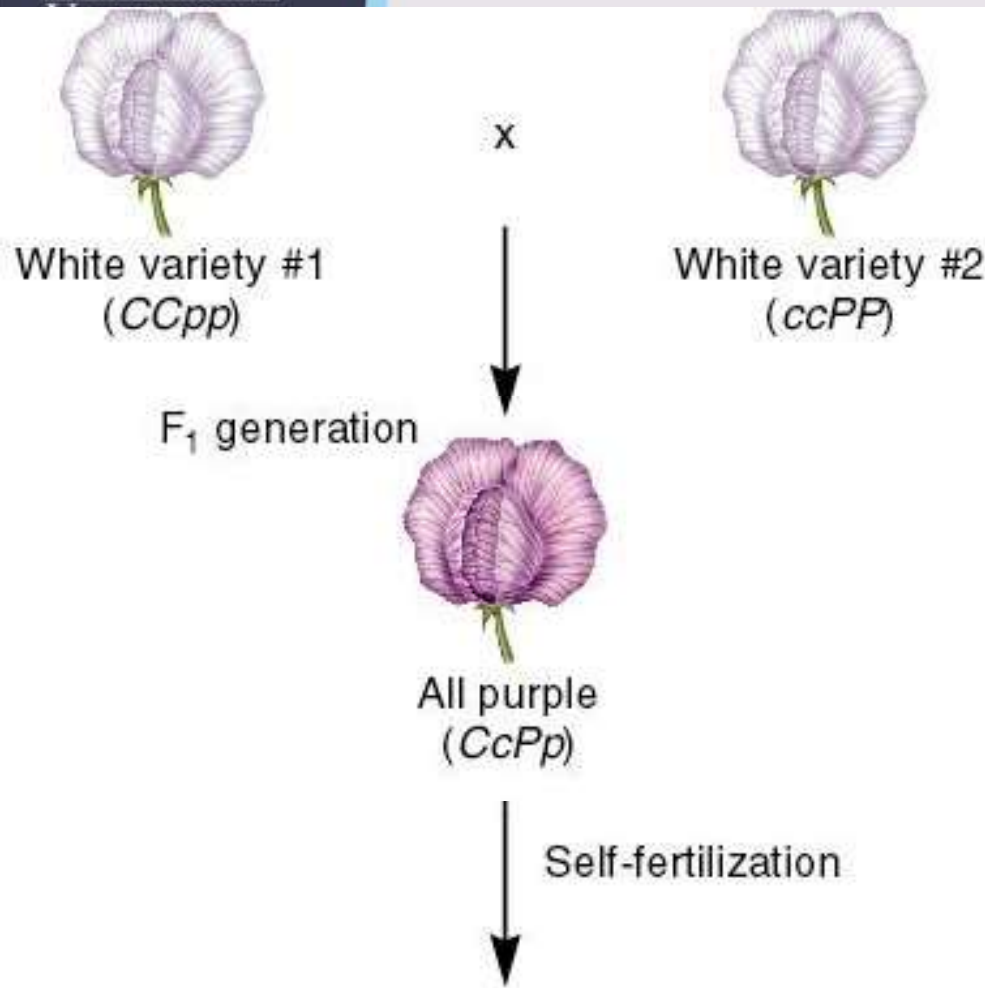
So the ratio becomes 9:7
(Purple : White)

F₂ Generation



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A Cross Producing a 9:7 ratio



	CP	Cp	cP	cp
CP	$CCPP$ Purple	$CCPp$ Purple	$CcPP$ Purple	$CcPp$ Purple
Cp	$CCPp$ Purple	$CCpp$ White	$CcPp$ Purple	$Ccpp$ White
cP	$CcPP$ Purple	$CcPp$ Purple	$ccPP$ White	$ccPp$ White
cp	$CcPp$ Purple	$Ccpp$ White	$ccPp$ White	$ccpp$ White

$9 C_P_ : 3 C_pp : 3 ccP_ : 1 ccpp$

purple

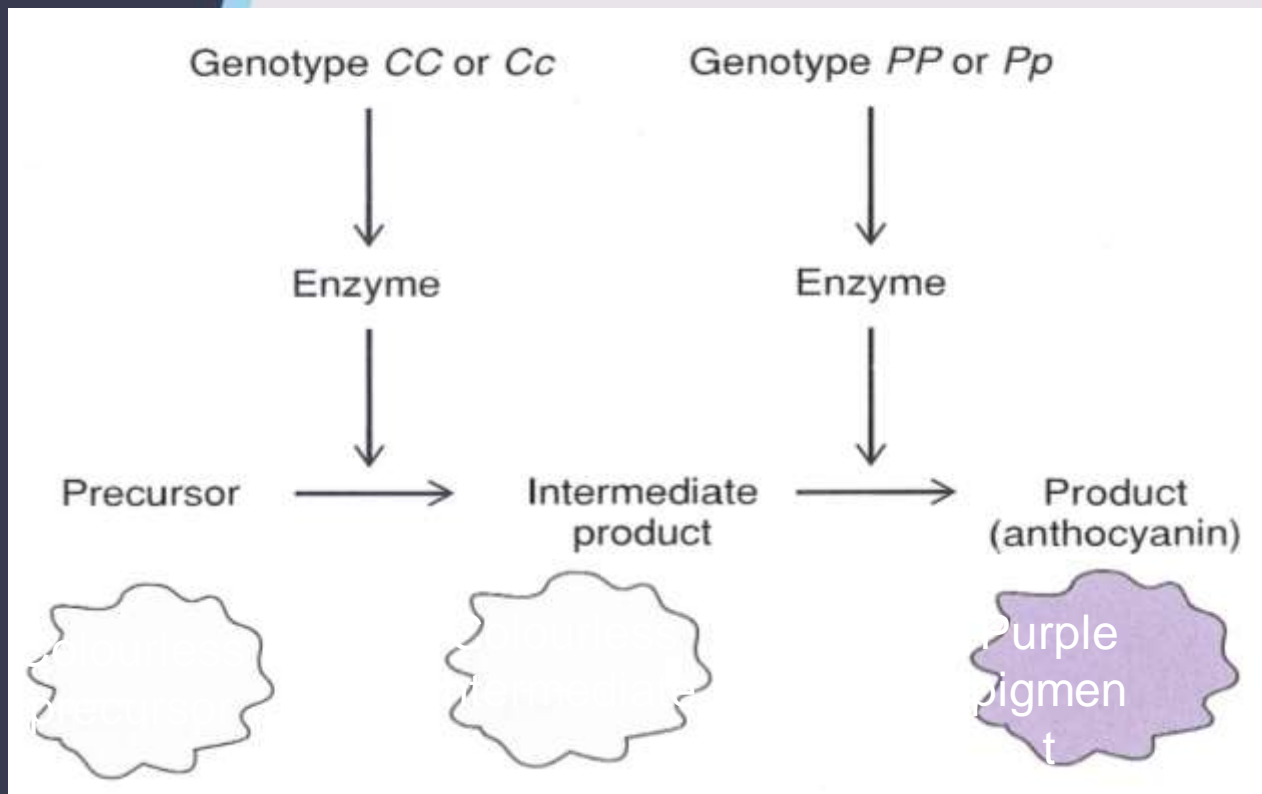
white



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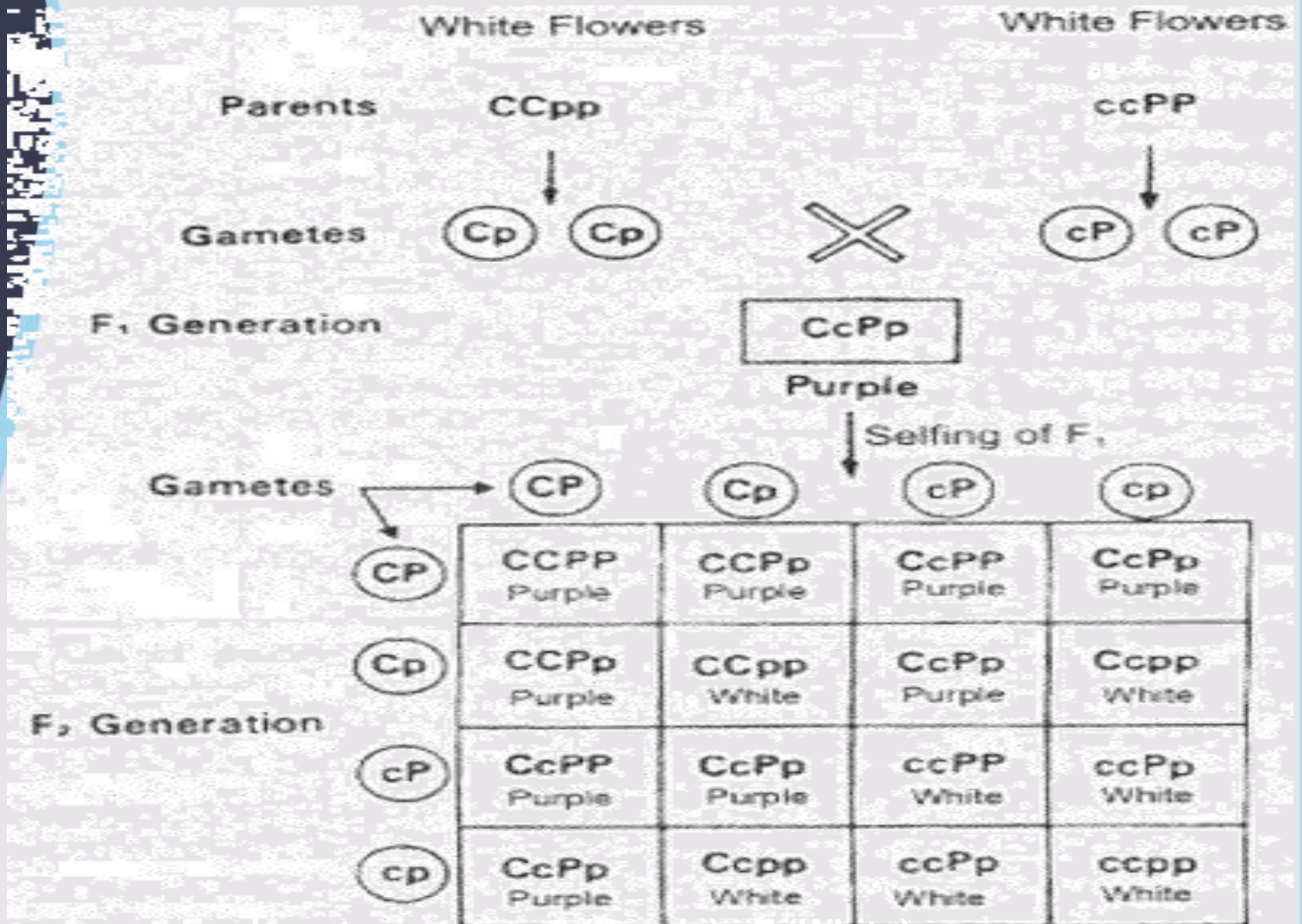
Complementary gene action - interactions arise because the two genes encode proteins that participate in sequence in a biochemical pathway

Enzyme C and enzyme P cooperate to make a product, therefore they complement one another





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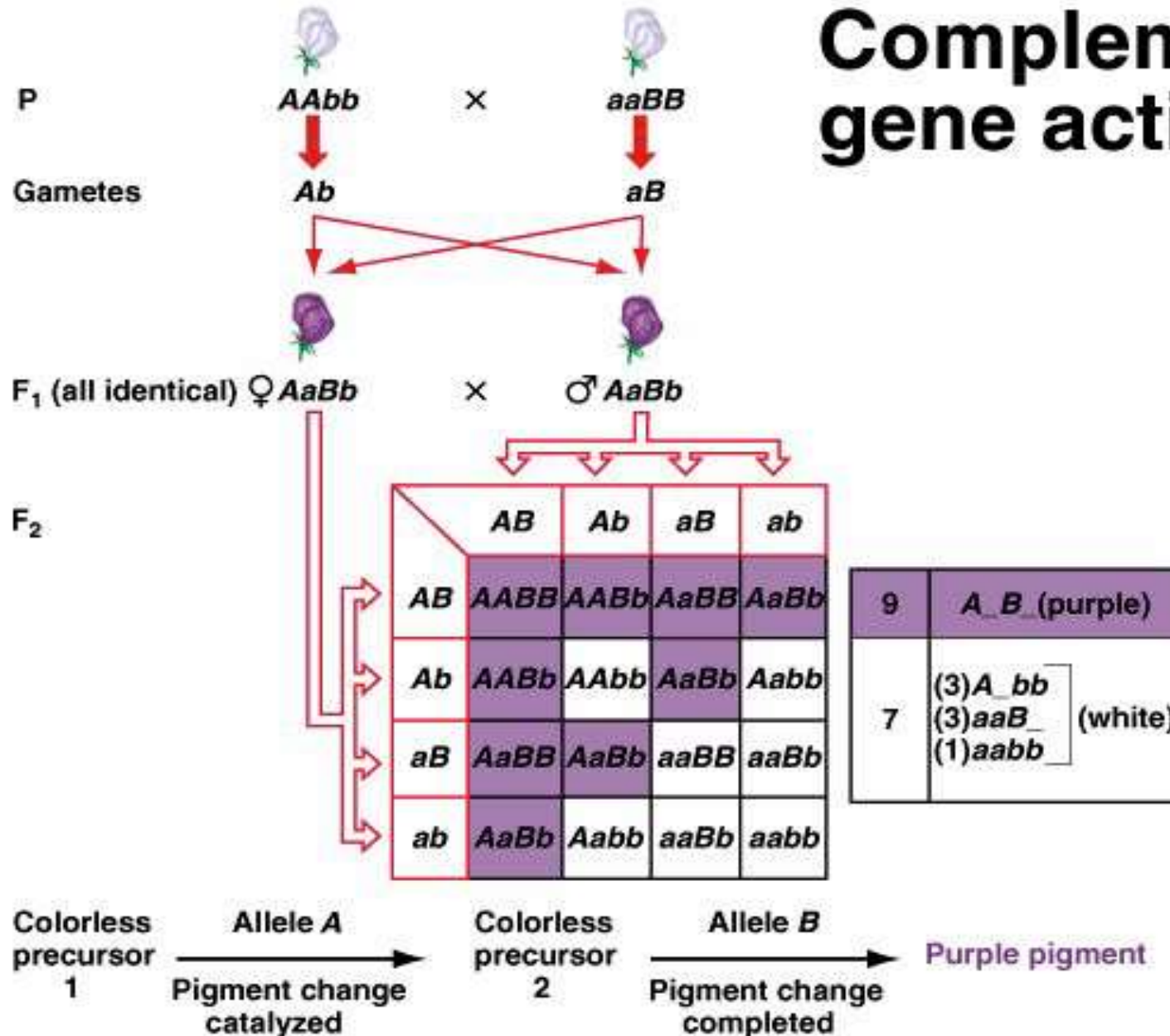


F₂ phenotypic ratio - 9 (Purple) : 7 (White)

Results of an experiment showing inheritance of flower colour in *Lathyrus odoratus* controlled by complementary genes



Complementary gene action





Duplicate genes

If the dominant alleles of two gene loci produce the same phenotype, whether inherit together or separately, the 9 : 3 : 3 : 1 ratio is modified into a 15 : 1 ratio.

The capsules of shepherd's purse (*Capsella*) occur in two different shapes, i.e., triangular and top-shaped. When a plant with triangular capsule is crossed with one having top-shaped capsule, in F_1 only triangular character appears. The F_1 offspring by self crossing produced the F_2 generation with the triangular and top-shaped capsules in the ratio of 15 : 1.

Only those with the genotype $aabb$ would produce plants with top - shaped capsules.



DUPLICATE GENES

Same effect is given by either of two genes (A) or (B)

Example is **Capsella bursa -pastoris (Shepherd's Purse)** Fruit shape of two types

a) **Triangular** (Heart shape) capsule

b) **Top shaped** (Narrow) capsule

Genetic Expression

Parents **AABB** X **aabb**
Triangular X **Top shaped**
P gametes **AB** **ab**
F1 (Hybrid) **AaBb** ----- **triangular**

F1 gametes	AB	Ab	aB	ab
AB	AB 1	Ab 2	aB 3	ab 4
Ab	AB 5	Ab 6	aB 7	Ab 8
aB	AB 9	Ab 10	aB 11	ab 12
ab	AB 13	Ab 14	aB 15	ab 16

AB- 1,2,3,4,5, 7,9,10,13=9
(Triangular)

Ab-6,8,14=3(Triangular)

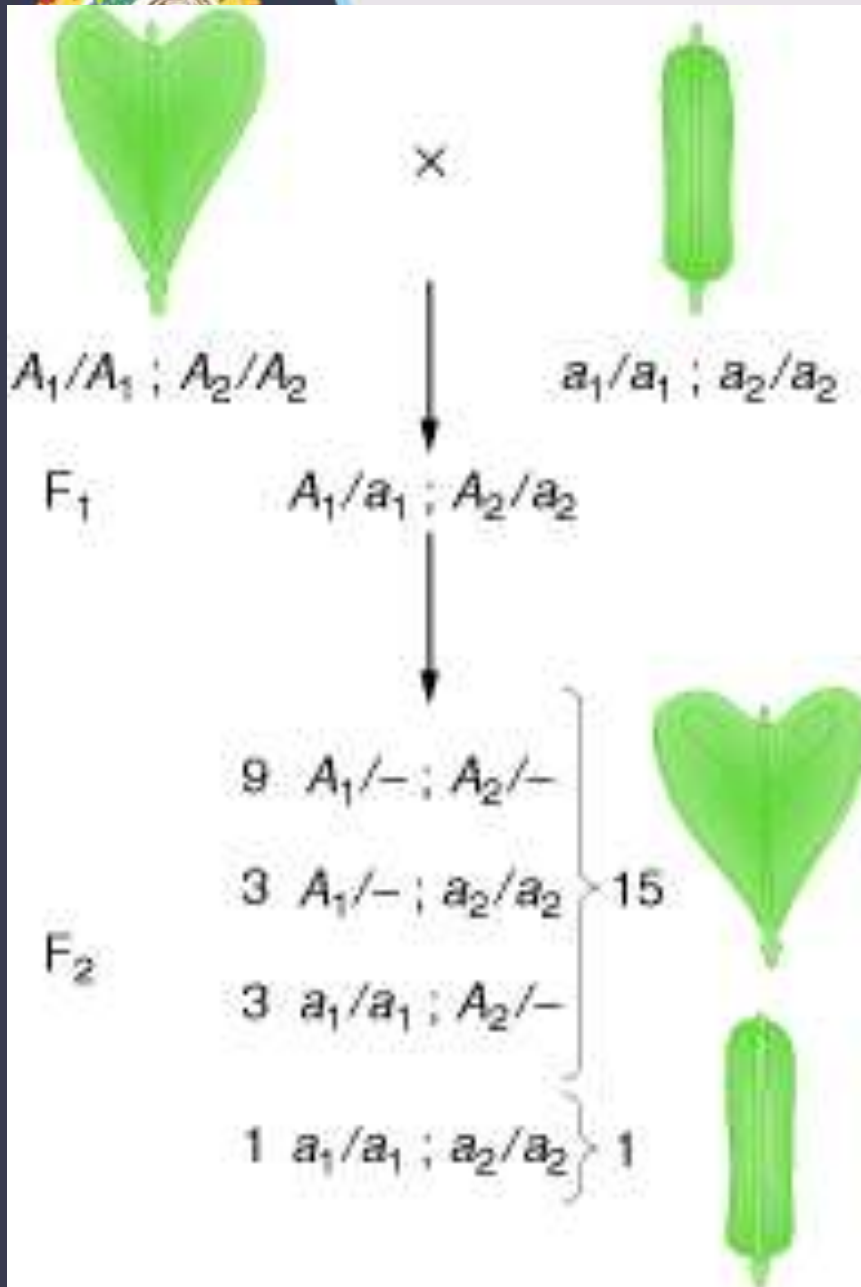
aB-11,12,15 =3 (Tringular)

ab-16 =1 (top shaped) So the ratio is 15:1

This is example of gene interaction,two genes involved in same pathway.It is based on the idea that some genes may be present more than once in the genome

F2 generation

15 (Triangular): 1 (Top)



$A_ \text{ or } B_ = \text{heart shape}$



$aa \text{ and } bb = \text{narrow shape}$



Fruit shape in Shepherd's purse

Duplicate Dominant Epistasis



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In a cross between two lines differing in fruit shape (Heart shape vs narrow) F₁ generation shows all heart shaped like intragenic dominance but F₂ generation shows a ratio of 15:1 and not 3:1 as that of monohybrid cross. It means that trait fruit shape is controlled by two genes (A and B) and their Alleles a and b. 15 :1 ratio is therefore modification of dihybrid ratio 9:3:3:1 in which 9,3 and 3 are grouped. The triangular shape results by the presence of at least one dominant allele of either gene. The two gene appear to be identical in function and is in contrast with complementary genes or 9:7 ratio where both dominant alleles are required for a phenotype and they complement each other.

Duplicate genes provide alternative genetic determination of a specific phenotype



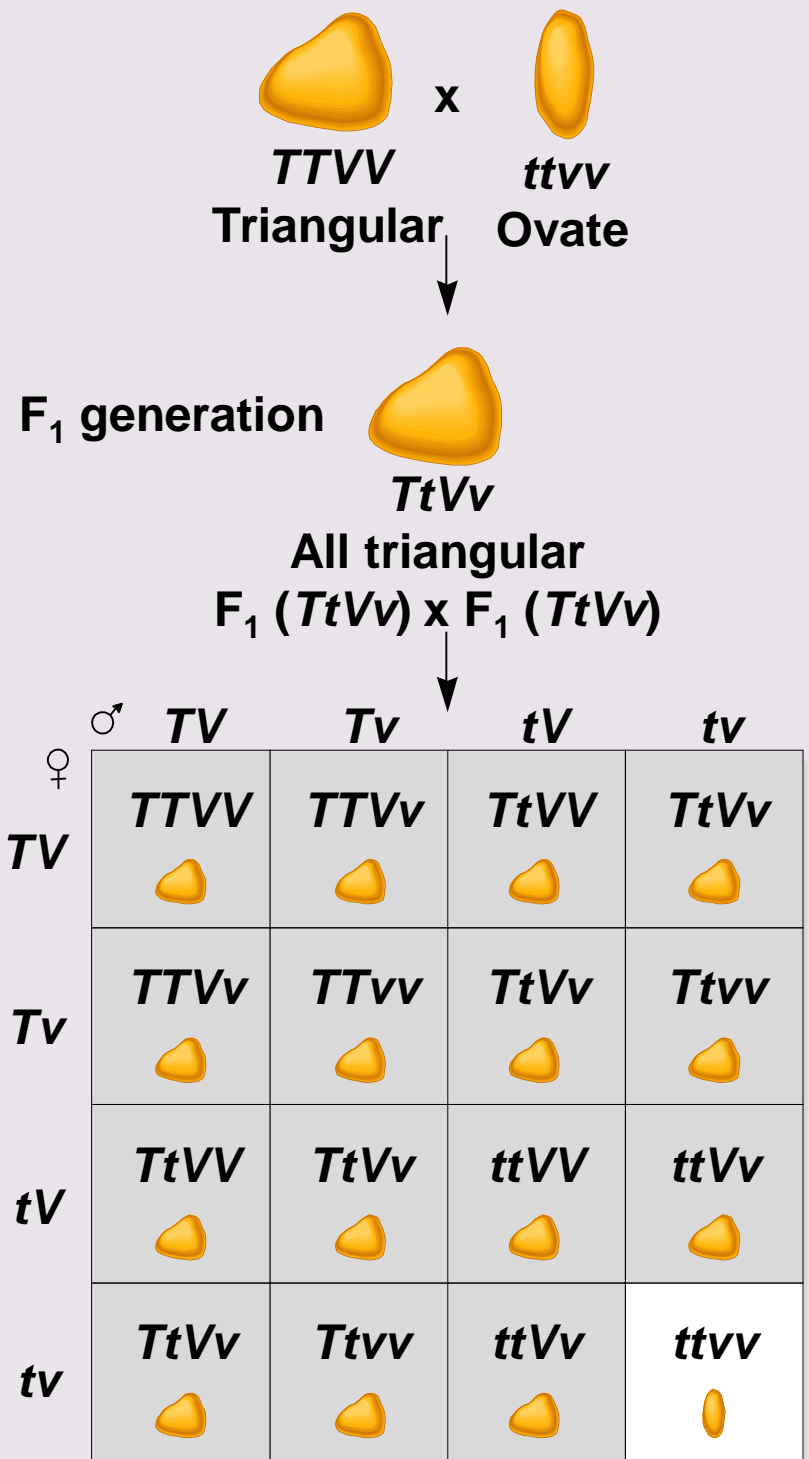
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Duplicate Gene Action Epistasis

15:1 ratio results

Shepherd's Purse (*Capsella*)

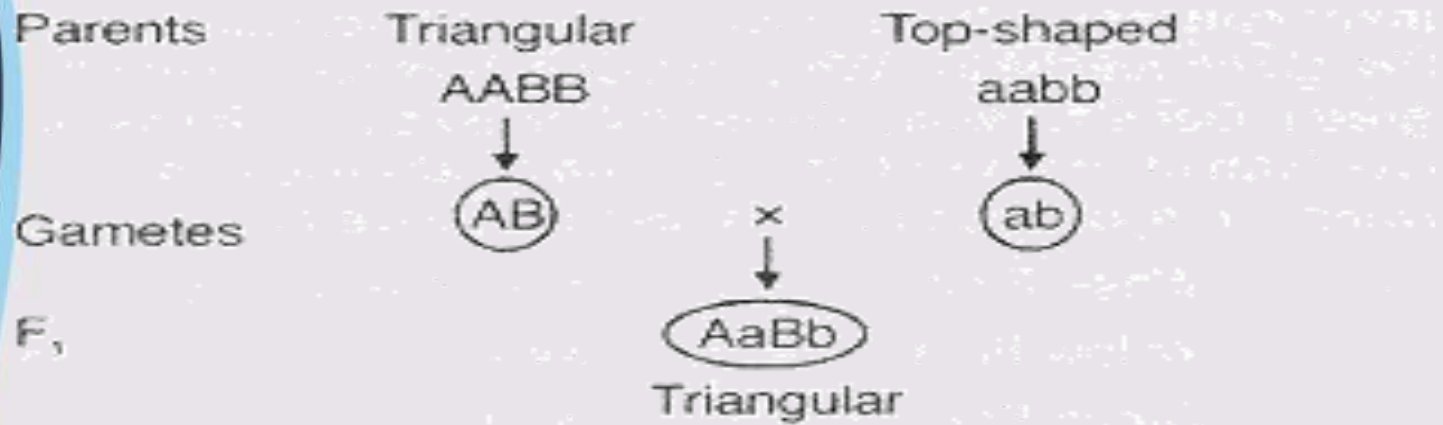
Fruit Shape Triangular / Top (Ovate)
shape





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Selfing of F_1

Gametes

	AB	Ab	aB	ab
AB	$AA BB$ Triangular	$AA Bb$ Triangular	$AA Bb$ Triangular	$Aa Bb$ Triangular
Ab	$AA Bb$ Triangular	$AA bb$ Triangular	$AA bb$ Triangular	$Aa bb$ Triangular
aB	$Aa BB$ Triangular	$Aa Bb$ Triangular	$Aa Bb$ Triangular	$aa Bb$ Triangular
ab	$Aa Bb$ Triangular	$Aa bb$ Triangular	$Aa bb$ Triangular	$aa bb$ Top shaped

F_2 Generation

F_2 phenotypic ratio : 15 (triangular) : 1 (Top shaped)



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2nd Example : Petal colour in snapdragon Redundancy : Duplicate Genes

P AABB

aabb

AB

ab

AaBb

F1 AaBb X

AaBb

F2 15/16 Red : 1/16 white

Whenever a dominant gene is present, the trait is expressed.

One allele is sufficient to produce the pigment.



Polymeric gene action 9:6:1

Two completely dominant genes controlling a character produce same phenotype, when their dominant alleles are alone, But when dominant alleles are together, the phenotypic effect is enhanced and become cumulative or additive effect

Example -1 Awn length on Barley fruit

$AABB \times aabb$

A/B - Median Awn

$A \ \& \ B$ – long Awn

ab - Awnless

Example-2 Fruit shape Squash (Disc/Circular/Long) 9:6:1

$AaBb \times AaBb$

9 $A \ B$ – Disc

3 $A-bb$ – Circular

3 $aa-B$ – Circular

1 $aabb$ – Long



Example awn length on Barley fruit AB- Median Awn

A & B – long Awn

ab- Awnless

Genetic Expression

Parents AABB(Long awn)

X

aabb(Awnless)

P gametes

AB

ab

F1

AaBb

Long awn



F1 gametes	AB	Ab	aB	ab
AB	AB 1	Ab 2	aB 3	ab 4
Ab	AB 5	Ab 6	aB 7	Ab 8
aB	AB 9	Ab 10	aB 11	ab 12
ab	AB 13	Ab 14	aB 15	ab 16

AB – Long Awn -1,2,3,4,5,7,9,10,13=9

Ab- Medium Awn -6,8,14=3

aB- medium Awn-11,12,15=3

ab-Awnless-16=1

F2 Generation : Phenotypic ratio

9(Long) : 6(Medium) :1(awnless)



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INHIBITORY GENE ACTION

Inhibitory gene action Example Maize Aleurone colour 13:3

One dominant gene produces concerned phenotype and its recessive allele produces contrasting phenotype. The second gene (dominant) has no effect on concerned phenotype but stops expression of dominant allele of first gene, so when both dominant alleles are present, phenotype as that of recessive homozygote is produced

. Genetic Expression

Parents RRII(White aleurone) X rrii (White aleurone)

P gametes RI ri

F1 hybrid -----RrIi -----White

F1 gametes



Genetic Expression

Parents RRII(White aleurone) X rrii (White aleurone)

P gametes RI ri

E₁ hybrid -----RrIi -----White

F₁ gametes

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	RI	Ri	rl	ri
RI	RI RI	Ri RI	rl RI	ri RI
Ri	RI Ri	Ri Ri Red	rl Ri	ri Ri Red
rl	RI rl	Ri rl	rl rl	ri rl
ri	RI ri	Ri ri Red	rl ri	ri ri

RI-White-1,2,3,4,5,7,9,10,13=9

Ri- **Red**- 6,8,14=3

rl- white -11,12,15=3

ri-white-16=1

**So phenotypic Ratio
becomes**

13 (White) : 3 (Red)

Inhibitory gene action Example Maize Aleurone colour 13:3



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Second Example 13:3

Inhibitory gene (one gene inhibits expression of the other) 13: 3

Example –Feather colour in Fowl (White/Coloured)

Epistasis

$AaBb \times AaBb$

9 A B –white

3 A-bb –white

3 aa-B- coloured

1 aabb –white

B is responsible for colour but in presence of A cannot express



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Masking gene action (12:3:1)

Dominant alleles of two genes affecting a character produce distinct phenotypes when they are alone, but when dominant alleles of both genes are present together, expression of dominant allele of one gene masks the expression of other and when both genes are present in recessive state, a different phenotype is produced

Example Barley seed colour –Black/Yellow/White

Parents	BByy (Black)	X	bbYY (Yellow)
P gametes	By		bY
F1 (Hybrid)	BbYy		Black
F1 gametes			



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Parents BByy (Black) X bbYY (Yellow)
P gametes By bY
F1 (Hybrid) BbYy Black
F1 gametes

	BY	By	bY	by
BY	BY BY	By BY	bY BY	by BY
By	By BY	By By	bY By	by By
bY	bY BY	bY By	bY bY	by bY
by	by BY	by By	by bY	by by

BY – Black -

1,2,3,4,5,7,9,10,13=9

By –Black- 6,8,14=3

bY- Yellow-11,12,15=3

by-white-16=1

F2 Generation ---- 12 (Black) : 3 (Yellow) : 1 (White)

When both B and Y are present both express but Black colour is so intensive that yellow colour produced by Y is not detected

B gives Black colour,Y gives Yellow colour and b and y donot produce colour



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Empowering Communities...*

THANK YOU