Gene interaction –Exception of Mendel’s Laws

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Gene interaction

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Introduction

- **Definition- The phenomenon of two or more genes affecting the expression of each other in various ways in the development of a single character of an organism is known as gene interaction**
- **Most of the characters of living organisms are controlled/ influenced/ governed by a collaboration of several different genes.**
- **Mendel and other workers assumed that characters are governed by single genes but later it was discovered that many characters are governed by two or more genes.**

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- **Such genes affect the development of concerned characters in various ways; this lead to the modification of the typical dihybrid ratio (9:3:3:1) or trihybrid (27:9:9:9:3:3:3:1).**
- **In gene interaction, expression in gene interaction, expression of one gene depends on expression (presence or absence) of another gene.**

Types of Gene Interactions

- **Gene interactions can be classified as**

a) Allelic/ non epistatic gene interaction - This type of interaction gives the classical ratio of 3:1 or 9:3:3:1

b) Non-allelic/ epistatic gene interaction- In this type of gene interaction genes located on same or different chromosome interact with each other for their expression

Discovery of non allelic gene interaction has been made after Mendel and can be best understood by studying phenotypic trait of gene

Epistatic and Hypostatic gene

- **Epistatic gene:**

  When a gene or locus which suppress or mask the phenotypic expression of another gene at another locus such gene is know as epistatic gene. Epistatic is Greek term and meaning is “standing up”.

- **Hypostatic gene:**

  The gene or locus which was suppressed by a epistatic gene was called hypostatic gene.

- **A single character can be governed by two or more genes. They are called *non - allelic* or *intergenic* genetic interactions.**

- **The independent genes (non-homologous) located on the same or on different chromosomes interact with one another for the expression of a single phenotypic trait of an organism.**

Epistasis

- Epistasis involves ***inter-genic suppression*** or, the masking effect which one gene locus has upon the expression of another.
- Thus, epistasis refers to variation resulting from the *interaction of alleles at different loci.*

Types of Epistasis:

A. Dominant Epistasis

- **Dominant epistasis occurs when a dominant allele at one locus (the epistatic locus) produces a particular phenotype, regardless of the genotype at the second locus.**
- **The second gene can express its phenotype only when the epistatic locus is homozygous recessive.**

Dominant epistasis example 1:

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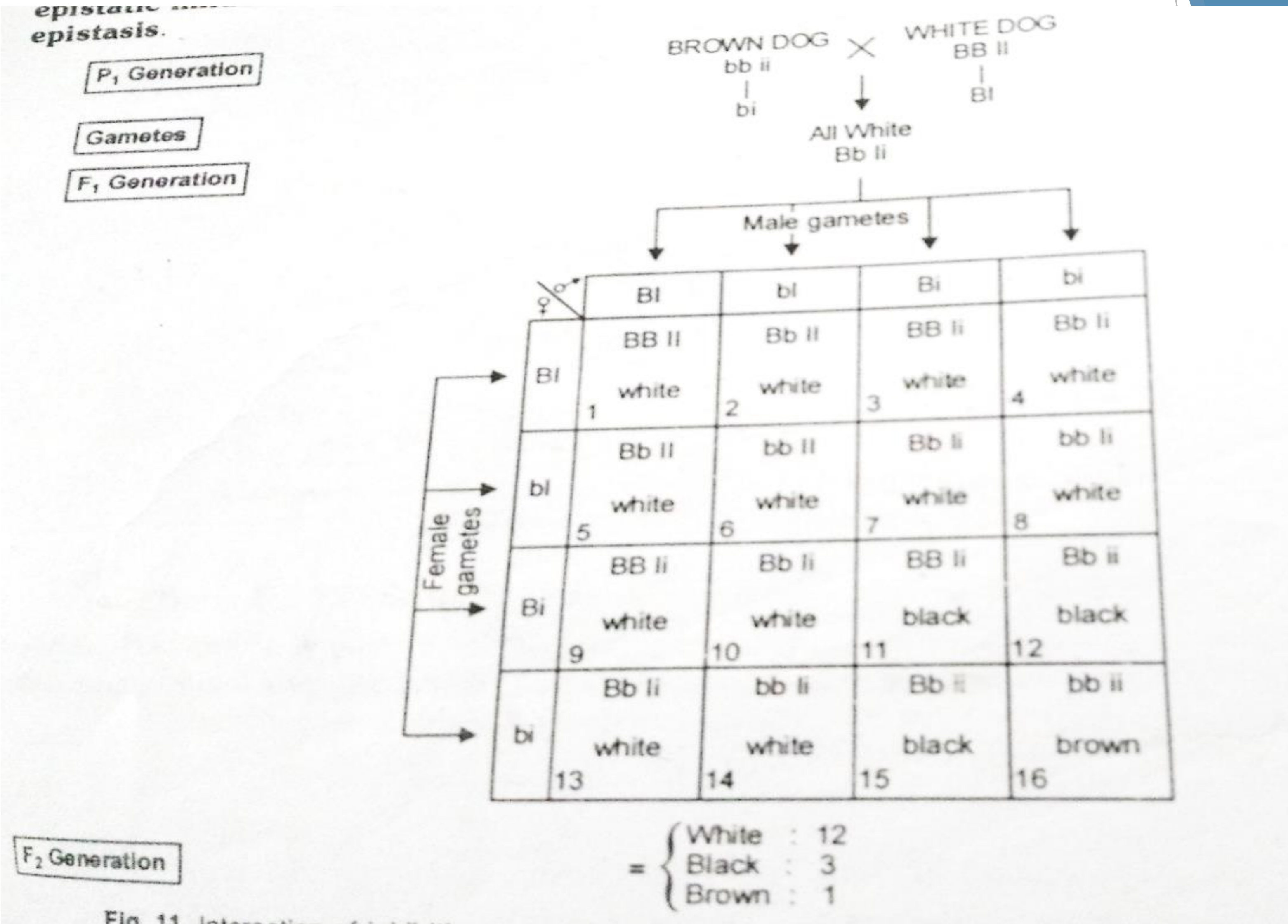


epistasis.

P1 Generation: BROWN DOG bb ii × WHITE DOG BB II

Gametes: bi | BI

F1 Generation: All White Bb Ii

Male gametes

♀ \ ♂	BI	bI	Bi	bi
BI	BB II white 1	Bb II white 2	BB Ii white 3	Bb Ii white 4
bI	Bb II white 5	bb II white 6	Bb Ii white 7	bb Ii white 8
Bi	BB Ii white 9	Bb Ii white 10	BB ii black 11	Bb ii black 12
bi	Bb Ii white 13	bb Ii white 14	Bb ii black 15	bb ii brown 16

Female gametes

F2 Generation = White : 12, Black : 3, Brown : 1

Fig. 11. Interaction of inhibitive genes in dog ...

Dominant epistasis example 2

Example 2 **Fruit Colour in Cucurbita or Summer Squash (12 : 3 : 1 Ratio) :**

Fruits of *Cucurbita pepo* are white, yellow and green. White is dominant over both yellow and green and is produced by dominant inhibiting gene **W.** In crosses between yellow and green, yellow is expressed. Thus gene yellow (**Y**) acts as dominant to green but recessive to white.

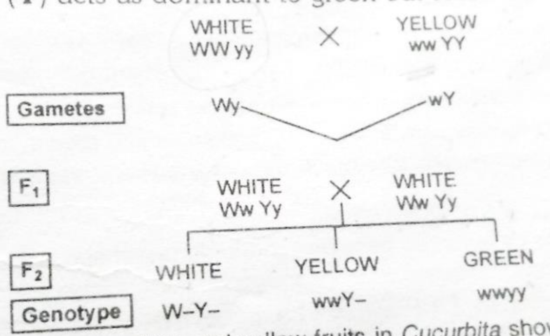


Fig. 13. Results of a cross between white and yellow fruits in *Cucurbita* showing 12 : 3 : 1 ratio in F_2.

The yellow colour develops due to dominant hypostatic gene '**Y**' while the green colour is produced by recessive hypostatic gene **y** only when epistatic gene **w** is recessive. The presence of dominant inhibiting gene **W** produces white colour in two conditions :

(1) when both **W** and **Y** genes are dominant

(2) when **W** gene is dominant and **y** gene is recessive.

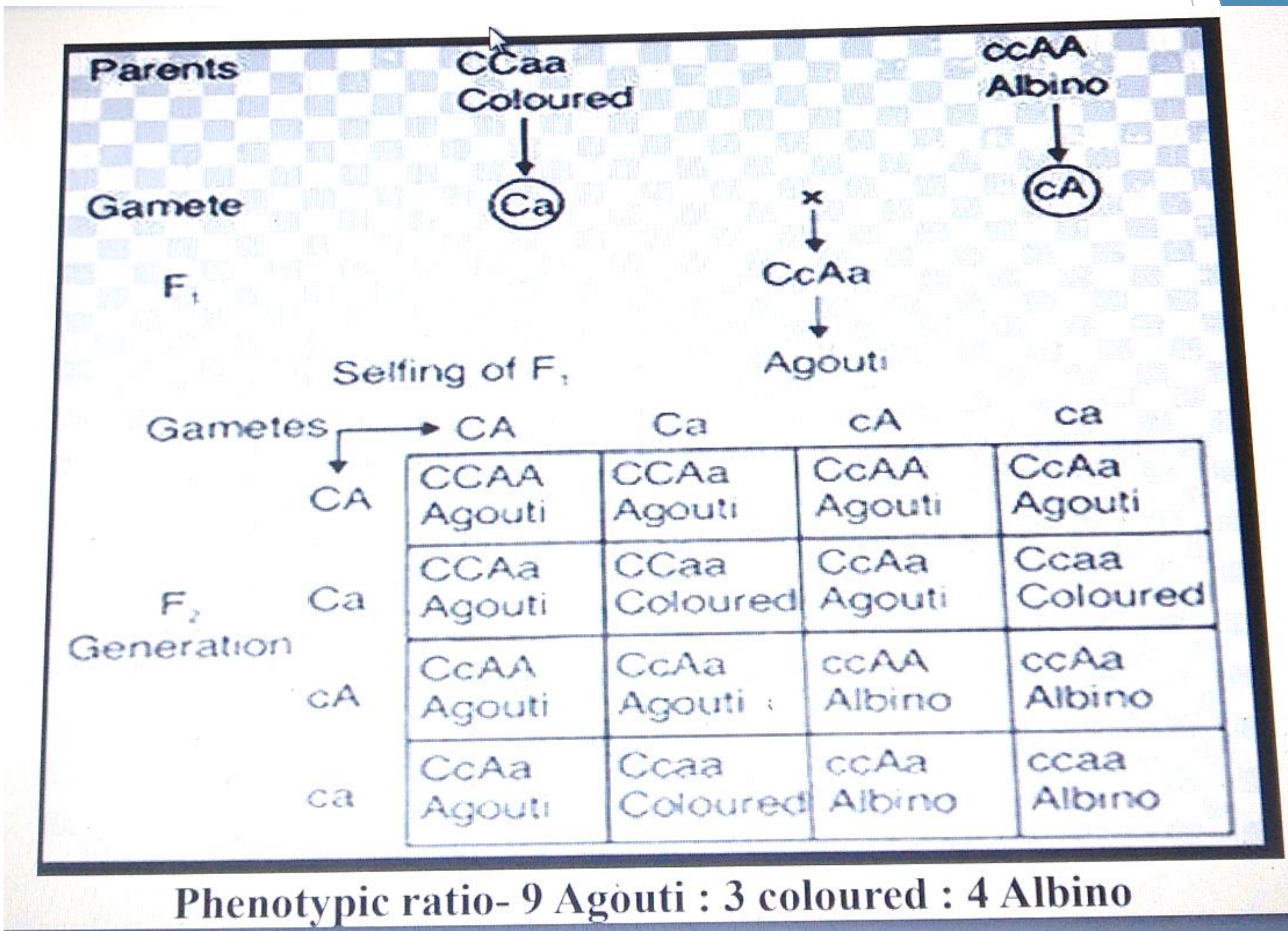
B. Recessive epistasis or, Supplementary gene interaction

- **Recessive epistasis occurs when the recessive alleles of one gene locus (aa - the epistasis locus) suppress the phenotypic expression of the alleles of another gene (BB, Bb or bb alleles). This type of epistasis is called recessive epistasis**

Supplementary gene action (9:3:4)

- In supplementary gene interaction, the dominant allele of one of two gene governing a character produces phenotypic effect
- However dominant allele of the other gene does not produce a phenotypic effect on its own.
- But when it is present with dominant allele of the first gene it modifies the phenotypic effect produced by that gene.
- For example development of agouty (gray) coat color in mice.

Example: Dominant allele- C produces Coloured phenotype while dominant allele A produces no phenotype (albino) but when dominant allele A present with C it produces agouti (grey) phenotype



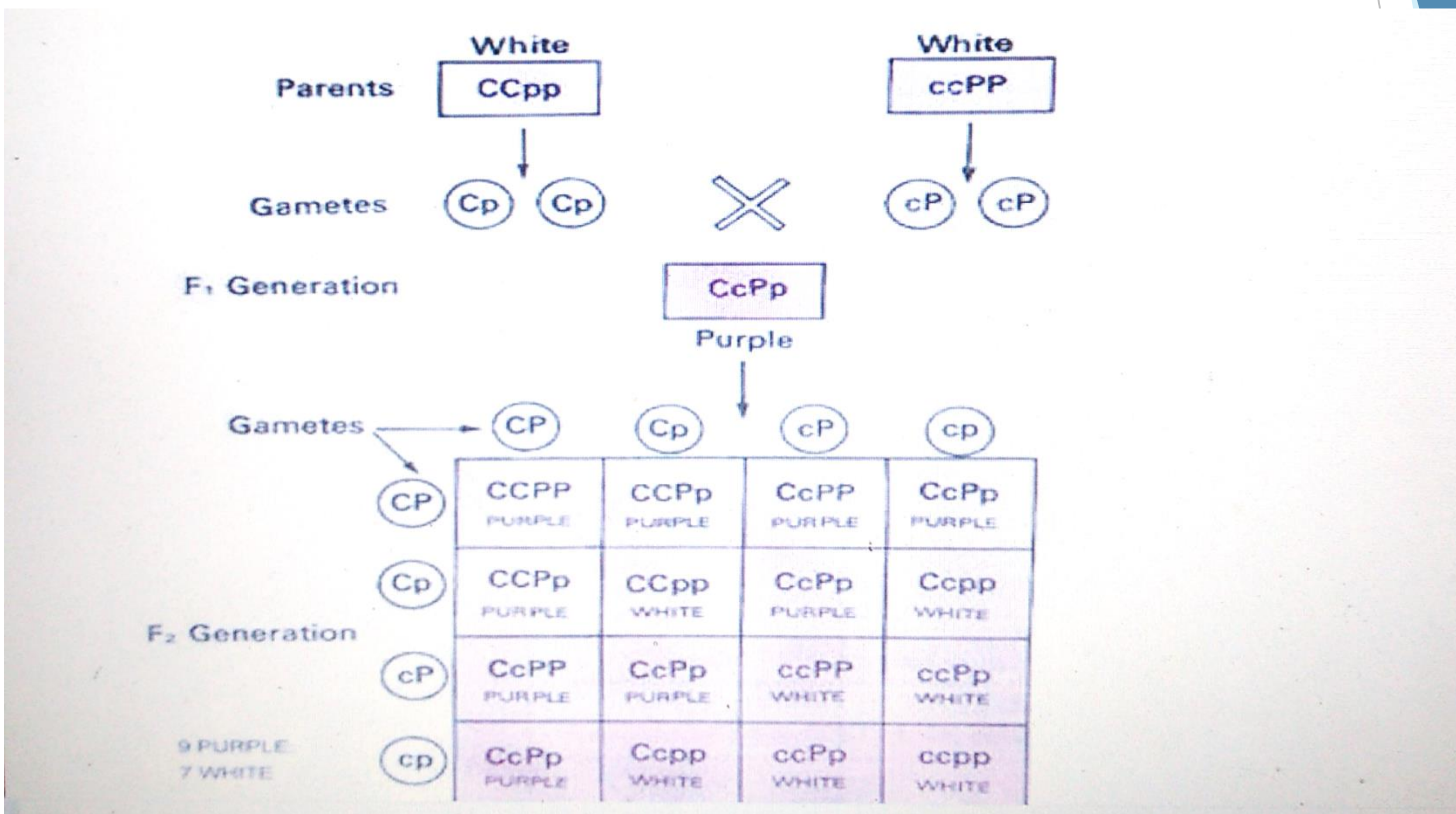
Gametes	CA	Ca	cA	ca
CA	CCAA Agouti	CCAa Agouti	CcAA Agouti	CcAa Agouti
Ca	CCAa Agouti	CCaa Coloured	CcAa Agouti	Ccaa Coloured
cA	CcAA Agouti	CcAa Agouti	ccAA Albino	ccAa Albino
ca	CcAa Agouti	Ccaa Coloured	ccAa Albino	ccaa Albino

Phenotypic ratio- 9 Agouti : 3 coloured : 4 Albino

Complementary gene interaction

- If both gene loci have homozygous alleles and both of them produce identical phenotypes the F2 ratio become 9:7 instead 9:3:3:1
- In such case, the genotype aaBB, aaBb, Aabb, aabb produce one phenotype.
- Both dominant alleles when present together each other are called complementary genes and produce a different

Example: In sweet pea Presence of genes CC, cc, PP and pp in homozygous condition produces no color (white) because expression of colour gene doesn't occur in homozygous condition while expression of colour gene occurs when these two genes present in heterozygous condition



Inhibitory gene action

- **When dominant allele of one gene locus (B) in homozygous (BB) and heterozygous (Bb) condition produce the same phenotype the F2 ratio becomes 13:3 instead of 9:3:3:1**
- **While homozygous recessive (bb) condition produces different phenotype.**
- **Homozygous recessive (bb) condition inhibits phenotypic expression of other genes so know as inhibitory gene action.**
- **A gene for colour, B gene is inhibitory**

Gene B when present in homozygous recessive condition that is bb, it inhibit the action of other gene and other gene produces no phenotype

13/16 = White

3/16 = coloured

White leg horn × White plymouth Rock

AABB ↓ aabb

AaBb × AaBb

White White

AB = 9 white

Ab = 3 coloured

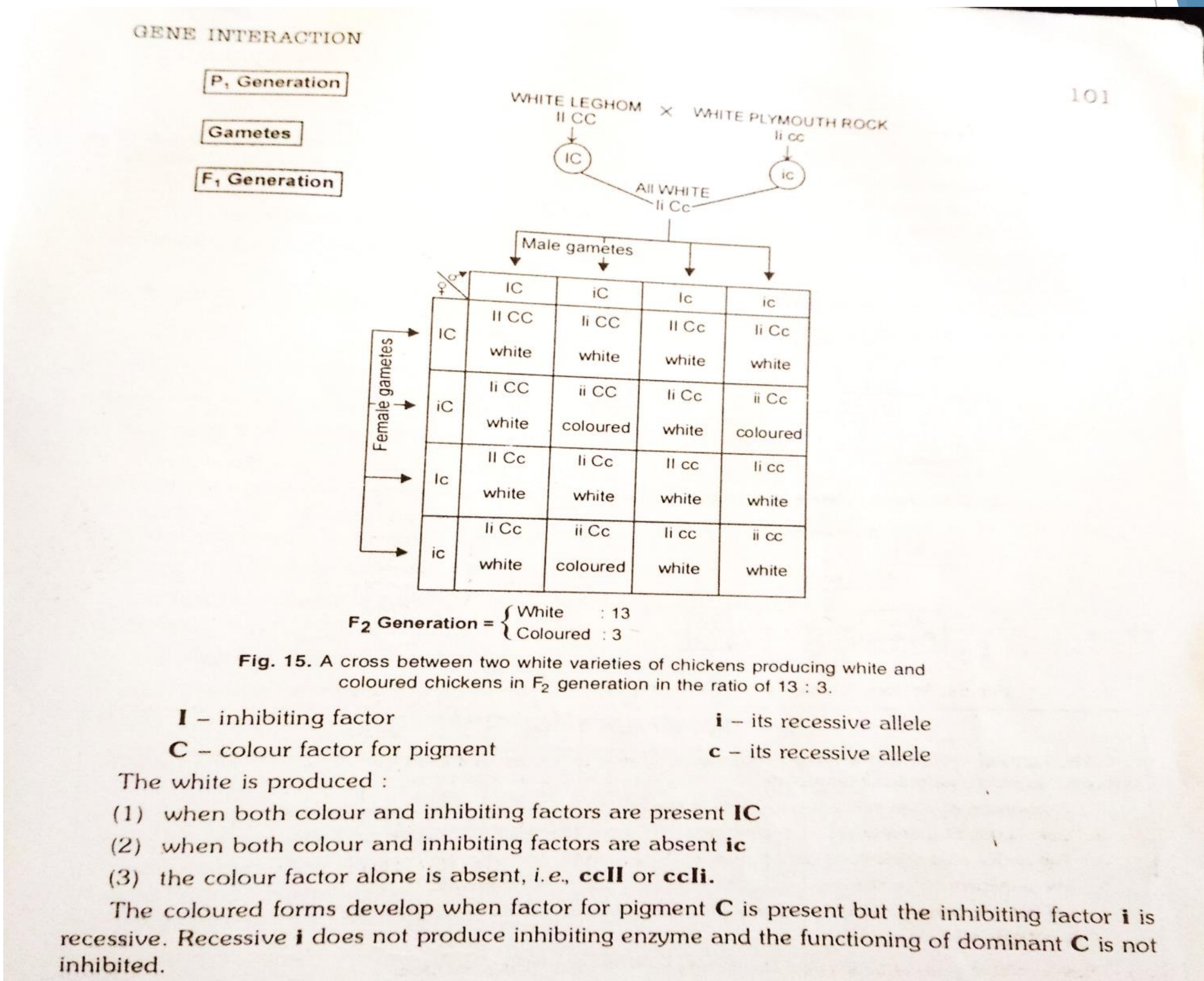
aB = 3 white

ab = 1 white

13 : 3

	AB	Ab	aB	ab
AB	AABB White	AABb White	AaBB White	AaBb White
Ab	AABb White	AAbb* Coloured	AaBb White	Aabb* Coloured
aB	AaBB White	AaBb White	aaBB White	aaBb White
ab	AaBb White	Aabb* Coloured	aaBb White	aabb White

Example of Inhibitory Gene Action



P_1 Generation: WHITE LEGHOM II CC × WHITE PLYMOUTH ROCK Ii cc

Gametes: IC, ic

F_1 Generation: All WHITE Ii Cc

Male gametes / Female gametes

♀ \ ♂	IC	iC	Ic	ic
IC	II CC white	Ii CC white	II Cc white	Ii Cc white
iC	Ii CC white	ii CC coloured	Ii Cc white	ii Cc coloured
Ic	II Cc white	Ii Cc white	II cc white	Ii cc white
ic	Ii Cc white	ii Cc coloured	Ii cc white	ii cc white

F_2 Generation = White : 13, Coloured : 3

Fig. 15. A cross between two white varieties of chickens producing white and coloured chickens in F_2 generation in the ratio of 13 : 3.

I – inhibiting factor   **i** – its recessive allele

C – colour factor for pigment   **c** – its recessive allele

The white is produced :

(1) when both colour and inhibiting factors are present **IC**

(2) when both colour and inhibiting factors are absent **ic**

(3) the colour factor alone is absent, *i.e.*, **ccII** or **ccIi.**

The coloured forms develop when factor for pigment **C** is present but the inhibiting factor **i** is recessive. Recessive **i** does not produce inhibiting enzyme and the functioning of dominant **C** is not inhibited.

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. In this case both the genes show complete dominance.**

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.

Parents AA BB x aa bb

Long awned x awnless

Aa Bb

Long awned

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

Ratio = 9 Long awned: 6 Awned: 1 awnless

Pleiotropism

- The phenomenon of multiple effect (multiple phenotypic expression) of a single gene is called **Pleiotropism.**
- One gene has got its own effect on different parts or different characteristics of one and the same organism.

Examples for pleiotropism in fishes

- L, D, B and G colour genes in common carp have many pleiotropic effects. For example, Blue (bb) and gold (gg) common carp have lowered growth rate as a pleiotropic effect.
- The S allele in *T. aurea* produces *saddle back* in the heterozygous state (S+).
- The a allele in channel catfish produces *albinism* in the homozygous state (aa).

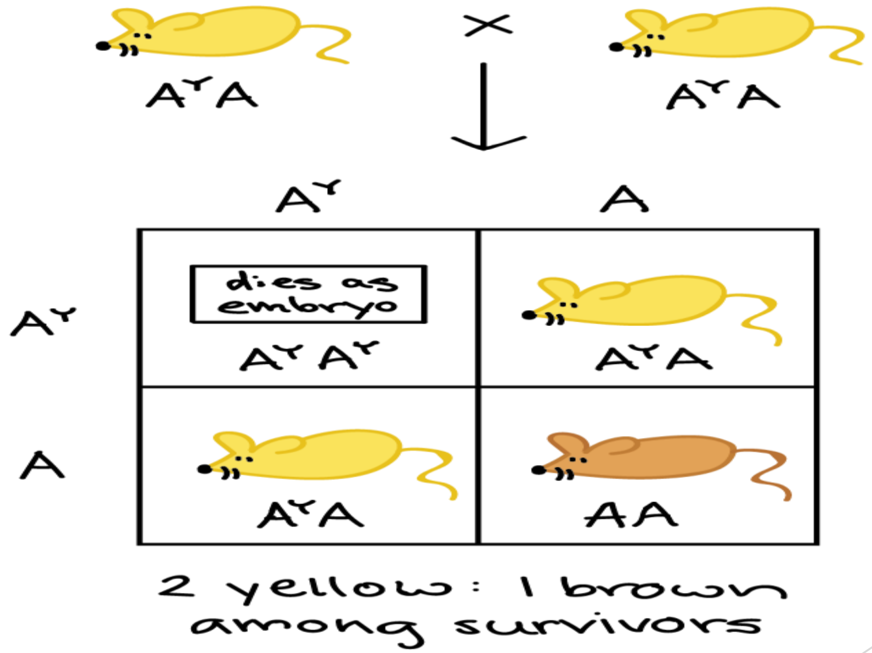
- **One of the examples of pleiotropy in humans is phenylketonuria (PKU). This disorder is caused by a deficiency of the enzyme phenylalanine hydroxylase, which is necessary to convert the essential amino acid phenylalanine to tyrosine. A defect in the single gene that codes for this enzyme therefore results in the multiple phenotypes associated with PKU, including mental retardation, eczema, and pigment defects that make affected individuals lighter skinned.**
- **Sickle cell anemia include pain, damaged organs, strokes, high blood pressure, and loss of vision.**

Lethal genes

- A gene whose phenotypic effect is sufficiently drastic to kill the bearer is called lethal gene.
- Death from different lethal genes may occur at any time from fertilization of the egg to advanced age.
- Lethal genes may be dominant, incompletely dominant or recessive.

Dominant lethal genes

- Dominant lethal gene in common mice. Lethal genes Ay kill the carriers in the homozygous state
- The Aa gene in heterozygous or, recessive condition will survive.



Recessive lethal genes

- Tay Sachs Disease causes death of young children only in homozygous condition which are unable to produce enzyme needed for normal fat metabolism.
- An accumulation of fat in nerve sheaths hampers transmission of nerve impulse leading to poor muscular control and mental deficiency.

Coat Colour in Rabbit:

1. The colour of the skin in rabbits is influenced by a series of multiple alleles.
2. The normal colour of the skin is brown. Besides it there are white races called albino and Himalayan as the mutant races.
3. The Himalayan is similar to albino but has darker nose, ear, feet and tail.
4. The mutant genes albino (a) and Himalayan (a^h) occupy the same locus and are allelic. Both albino and Himalayan are recessive to their normal allele (+).
5. A cross between an albino and Himalayan produces a Himalayan in the F_1 and not intermediate as is usual in the case of other multiple alleles.

	Albino		×		Himalayan			
	a/a		↓		a^h/a^h			
F_1			a^h/a (Himalayan)					
	a^h/a	×		a^h/a	(Selfing)			
F_2	a^h/a^h	:		a^h/a	:	a^h/a	:	a/a
				3	:			1
				Himalayan	:			Albino

(Representing a cross between an albino and Himalayan races of rabbits)

Multiple Alleles

- A type of inheritance unknown to Mendel is called *multiple allelism*.
- An allele represents one of several alternate phases of a gene.
- Some genes occur in more than two allelic forms (in contrast to alternative forms).
- In such cases the various allelic forms are collectively referred to as *multiple alleles*.

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Thank you………………