Genetics :- Heredity And Variation

⇒ Is the branch of biological science which deals with the transmission of characteristics from one generation to the next and also the action of hereditary units called Genes as they bring about the changes characteristics which they control.

⇒ Modern Genetics is concerned with the study of genes, the unit of heredity that control the characteristics of organisms. The term genetics was coined and used for the first time by W. Bateson (1905). Heredity or Inheritance is the characteristics transmitted from generation to generation and is therefore fixed for a particular individual

Heredity :- i) It plays an important role in the formation of new species. Heredity involves the transfer of chromosomes from parents to offsprings or one individual to another. This indicates Chromosomal basis of heredity.

ii) The physical basis of heredity are genes while chemical basis of heredity is DNA.

iii) Any inherited trait such as eye colour is referred to as phenotype. All phenotypes results from the presence of a specific gene or combination of genes the genotype. In hybrid one phenotype may be dominant over another when two genotypes produces the same phenotype due to different environments one is called the phenocopy of the other since they differs in genotypes.

Pre-Mendelian views on heredity :- A number of views points were put-forward before mendel to explain the transmission of characters from parents to off springs. They are often called theories of blending inheritance ; moist vapour theory, fluid theory, epigenesis, theory of pangenesis etc.), as they believed that characters of parents blended or got mixed during their transmission to the offsprings. This theory accounted for the fact that offsprings tended to resemble their parents without all members of a population eventually averaging themselves out.

Evidence against theories of blending inheritance :- 1) The trait of sex does not blend itself in universal organisms. Such an organism can either be male or female. This is true. The

2) Childerns of dark and fair coloured parents should be of intermediate colour if blending inheritance is true. The childern are often of different colours, some fair-coloured, some dark-coloured and other of intermediate colours. This phenomenon is called

3) many individuals show ancestral characters not found in immediate parents. This phenomenon is called atavism. for ex :- (i) short tail may be found in some babies (ii) Some persons are able to move pinna or external ear

Kolreuter (1760) a german botanist obtained fertile interspecific hybrids in tobacco. The hybrids did not resemble either of parents. Hybrids were self-pollinated. Some offsprings resembled the hybrids while remaining resembled one of the other grand parents in different characters. This proved that the traits have particular nature and remain discrete.

John Goss (1822) crossed yellow and green seeded pea varieties. The hybrids were all yellow seeded. They were self fallinated, three types of offsprings were produced :- (i) yellow seeded (ii) green seeded (iii) with both yellow & green seeds.

Naudin (1864) concluded that on repeated crossing of hybrids the parental types appear in the offsprings showing that hybrid contains traits of both the parents though they may not be visible externally.

⇒ The work of the above plant breeders gave the following basic features of inheritance :-

1) Every character of traits has two alternate forms in which it is expressed (height → tall / dwarf).

2) Traits are represented in the individuals by distinct particles which do not blend or change.

3) Traits may remain unexpressed for one/more generations and reappear later unchanged.

4) Traits may remain together in one generation and separate in a later generation.

5) One alternative of a trait may express more often than the other.

Terms Related to heredity: → 1) **Character**:- is a well defined morphological or physiological feature of an organism.

2) **Traits** is the distinguishing feature of a character. 3) **Gene**:- is the inherited factor that determine the biological character of an organism.

4) **Allelomorph / Allele**:- a pair of contrasting characters term allele. was given by W. Bateson for alternative form of same gene e.g. T and t, Y and y, R and r are pair of allele.

5) **Dominant allele**:- is one of the factor of an alleles pair which can express itself whether present in homozygous or heterozygous state e.g. T (tallness in pea) R (Round seed in pea).

6) **Recessive allele**:- is the factor of an allele pair which is unable to express its effect in the presence of its contrasting factor in a heterozygote e.g. t in Tt. r in Rr.
The effect of recessive factor is expressed only when it is present in the pure or homozygous state. e.g. tt. in dwarf pea plant.

7) **Wild allele**:- is the one which was originally present in the population and is dominant and widespread.

8) **Homozygous / pure**:- organism have two similar genes / alleles for a particular characters in a homologous pair of chromosomes e.g. TT or tt.

9) **Heterozygous / hybrid**:- organisms containing two different alleles or individual containing both dominant and recessive genes of an allelic pair e.g. Tt is Kpa heterozygous / hybrid.

10) **Monohybrid cross**:- when only one allelic pair is considered in cross breeding.

11) **Dihybrid cross**:- when two allelic pair are used in cross breeding.

12) **Polyhybrid cross**:- Involvement of > than 2 allelic pair in cross breeding.

13) **First filial Generation**:- 2nd stage of mendel's experiment is called first filial generation.

14) **Second filial generation**:- ~~Second~~ Third stage of mendel's experiment it called second filial generation.

15) **Complete penetrance**:- is 100% ability of an allelic combination to produce expected phenotype.
100% phenotypic expression ex:- Polydactyly, diabetes mellitus.

16) **Incomplete penetrance**:- is failure of an allelic combination to provide 100% phenotypic expression.

17) **Genotype**:- is the sum total of heredity or genetic make up.
⇒ Genotype remains the same throughout the life of an individual.
⇒ Genotype cannot be studied directly, it can be known through the study of ancestors mating and offsprings.
⇒ In a given environments at time, individual with similar genotypes will produce similar phenotypes.
⇒ Individuals with different genotypes may have similar phenotypes e.g. tallness for TT and Tt.

18) **Phenotype**:- is the external feature of organism.
⇒ Phenotype may change with the time and environment e.g. infant, adolescent, young, old
⇒ Phenotype can be known through direct observation.
⇒ Individuals with similar phenotypes may not belongs to same genotype.
⇒ Individuals with different phenotypes usually have different genotypes.

Mendelism!→ Gregor Johann Mendel (1822-84) appropriately K/a Father of Genetics, proposed the theory of inheritance. He performed his experiments on garden pea (from 1856 to 1865) and published his findings on Pisum Sativum in paper "Experiments on Plant hybridization" was published in the fourth volume of "Annual proceedings of Natural history Society of Brunn" in 1866.

⇒ However, Mendel's work remained un-noticed and unappreciated for some 34 years. This is because of:-

1) Limited circulation of "Proceedings of Natural history Society of Brunn".
2) Mendel's conclusions about heredity were ahead of his time.
3) He couldn't convince himself about his conclusion being universal since mendel's failed to reproduce the results on Hawk-weed (Hieracium) undertaken on the suggestion of Nageli.
4) Lack of aggressiveness in his personality.
5) The scientific world was being rocked at that time by Darwin theory of evolution.

It was in 1900 that three workers independently rediscovered the principles of heredity already worked out by Mendel. They were Hugo de Vries of Holland, Carl Correns of Germany and Erich von Tschermak of Austria.

Reasons behind the success of Mendel!→

⇒ Mendel's breeding material consisted of pure lines or pure breeding varieties.
⇒ Mendel's chose only those characters which showed consistent results. He started with 32 varieties, reduce the number to 22 but worked only on seven.
⇒ There is little chance of pollen contamination even the mendel took care to protect the flowers from foreign pollen.
⇒ mendel took only those traits for his studies which did not show linkage, interaction or incomplete dominance.

Mendel's Experiment!→ Mendel conducted cross breeding experiments on garden pea (Pisum sativum). He studied the inheritance of seven different pairs of contrasting characters in this plant but considered only one pair at a time. He crossed two pea plants with alternate characters by artificial pollination ⇒ The resulting hybrids which resembled one of the two parents were then crossed with each other, both traits reappeared in the offsprings in a definite ratio of 3:1. His experiments can be depicted under the following sub headings!→

Selection of material!→ Mendel selected garden pea as his experimental material because it had the following advantages:

1) The pea plants showed a number of well defined contrasting characters.
2) It has perfect bisexual flowers containing both male and female parts. The flowers are predominantly self fertilizing.
3) Because of self-fertilization, plants are homozygous. It is therefore, easy to get pure lines for several generations.
4) It was an annual plant. It short life cycle made it possible to study several generation within a short period.
5) It is easy to cultivate.
6) It is easy to cross because pollen from one plant can be introduced to the stigma of another plant.

Hybridization!→ Because garden pea is self-fertilizing, the anthers need to be removed before maturity. The process of removal of anther is called emasculation.

⇒ At the time of cross pollination the pollen should be mature and stigma should be receptive.
⇒ The stigma is protected against any pollen (from reaching it) by covering it with a bag (bagging).
⇒ For this cross I used pollen from a white flowered individual to fertilize a flowers on a pea plant that produce purple flowers.
⇒ The pollen at the dehiscent stage is brought from the plant, to be used as male parent and is dusted on the stigma of emasculated flower.

Selfing:→ flowers of F_1 generation were selfed to obtain F_2 plants In order to avoid Contamination from foreign pollens, the flower were covered with paper bags from the beginning.

⇒ Mendel Collected the seeds and raised a new ⇒ The seeds and plants raised from them constitute the second filial or generation of plants. F_2 generation. Further self pollination produced F_3 or third filial generation

Observation:→ F_1 plants were found to have only one type of trait. F_2 generations had 2 types of plants, a large number of the traits found in F_1 generation and smaller number of the other trait not appeared in F_1 generation. In all cases the ratio was 3:1.

⇒1) Mendel's results can be explained using a specific example. When tall plants were crossed with dwarf plants all plants in the F_1 generation were tall. The plants used in the initial Cross are referred to as P_1 and P_2 or parents.

⇒2) When the F_1 plants were self-fertilized both tall and dwarf plants were obtained in a ratio close to 3:1. Similar patterns were obtained for other six pairs of characters also.

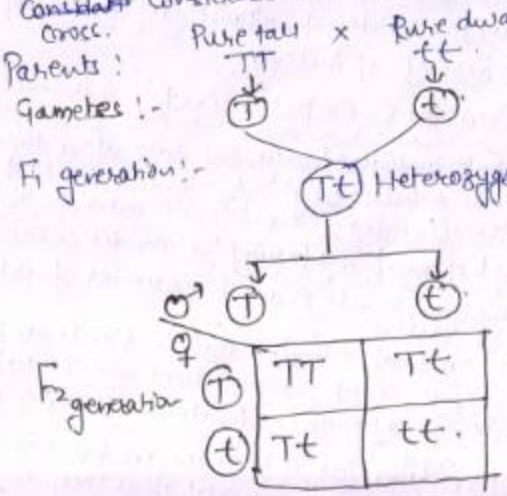
3) For any characters the F_1 individuals derived from crosses between two different varieties having alternative characters showed only one of the traits and never the others. This feature was expressed as dominance of one trait over the other. The trait which appeared in the F_1 generation was called dominant and the other which did not appear in the F_1 population was called recessive.

Summary of Mendel's Experiments → Monohybrid Crosses

Character or trait studied	Parents forms crossed (F_1 cross)	F_1 products	F_2 products Dominant form : Recessive form	Chromosome location.
1. Colour of seed	Yellow Green	All yellow	Yellow : Green 3.01 : 1	1
2. Shape of seed	Round wrinkled	All Round	Round : wrinkled 2.96 : 1	7
3. Flower Colour	Purple white	All purple	Purple : white. 3.15 : 1.	1
4. Colour of pod	Green yellow	All green	Green : yellow 2.82 : 1.	5
5. Shape of pod	Inflated Constricted.	All inflated	Inflated : Constricted. 2.95 : 1.	4
6. Position of flowers	Axial Terminal	All axial	Axial : Terminal 3.14 : 1.	4
Height of plant	Tall Dwarf	All tall	Tall : Dwarf 2.84 : 1	4

Monohybrid Cross:-

The cross in which only alternate forms of a single character are taken into Consideration is called monohybrid Cross.



Phenotype Ratio :- 3 : 1.

Genotype Ratio :- 1 : 2 : 1.

Dihybrid Cross:→

Parents:- Yellow Round pea plant (YYRR) × Green wrinkled pea plant (yyrr)

Gametes:- YR × yr

F1 generation:- YyRr (Yellow Round)

Gametes of F1	YR	Yr	yR	yr
YR	YYRR	YYRr	YyRR	YyRr
Yr	YYRr	YYrr	YyRr	Yyrr
yR	YyRR	YyRr	yyRR	yyRr
yr	YyRr	Yyrr	yyRr	yyrr

Phenotypic Ratio:- Yellow round : Green Round : Yellow wrinkled : Green wrinkled.

9 : 3 : 3 : 1

Back Cross:→

A cross of F1 hybrid with either of the two parents is k/a back cross. When F1 offsprings are crossed with the dominant parents, all the F2 offsprings develop dominant character.

⇒ On the other hand when F1 hybrid is crossed with recessive parent, individuals with both the phenotypes appear in equal proportions. While both the crosses are k/a back cross, the second one is specific as test cross.

(F1) Tt × TT (Parental).

♂ / ♀	T	T
T	TT	TT
t	Tt	Tt

TT 50% pure tall : 50% Tt hybrid tall.

Test Cross:→

F1 Tt × tt (Recessive parent)

Tt : tt

Tall : Dwarf

1 : 1.

Summary of Mendel's Experiments And Results.

Number of traits/ hybrid (n)	Experiment	Type of Gametes (2^n)	Number of Zygotes/ offsprings (gametes)^2	Number of phenotypes (2^n)	Number of Genotypes (3^n)	Phenotypic Ratio	Genotypic Ratio
1.	Monohybrid cross (Aa Aa)	$2^1 = 2$.	$2^2 = 4$.	$2^1 = 2$.	$3^1 = 3$.	3:1.	1:2:1.
2.	Dihybrid cross (AaBb AaBb)	$2^2 = 4$.	$4^2 = 16$.	$2^2 = 4$.	$3^2 = 9$.	$(3:1)^2$ = 9:3:3:1.	$(1:2:1)^2$ = 2:4:2: 1:2:1: 1:2:1
3.	Trihybrid cross (AaBbCc AaBbCc)	$2^3 = 8$.	$8^2 = 64$.	$2^3 = 8$	$3^3 = 27$.	$(3:1)^3$	$(1:2:1)^3$

Dihybrid test Cross:→

$F_1 \rightarrow (YyRr) \times yyrr$ (Homozygous double recessive parent).

♂ / ♀	YR	Yr	yR	yr
yr	YyRr	Yyrr	yyRr	yyrr

Yellow Round | Yellow wrinkled | Green Round | Green wrinkled

Mendel's principles of inheritance:→ Mendelian principles are the rules of inheritance first discovered by mendel. following principles or laws of inheritance based on monohybrid and polyhybrid crosses.

One gene inheritance:→ study of inheritance of a single pair of alleles/factors of a trait at a time (mono-hybrid cross) is called one gene inheritance. on the basis of his observation on monohybrid cross, mendel proposed a set of generalisations (postulates) which resulted into the formation of following 3 laws of inheritance:-

1) Principle of paired characters:→ A character is represented genetically in an individual by 2 unit factors present on the same locus in the two homologous chromosomes. The 2 unit factors for two of first trait (TT), two of second trait (tt) or two of both trait's (Tt).

A) Law of Dominance:→ It states when a pair of alleles or allelomorphs are brought together in F_1 hybrid, then only one of them expresses itself, making the expression of other completely. In Tt F_1 hybrid:- 'T' is expressed — so dominant 'T' is masked -So recessive.

Exceptions to principle of dominance:→

1) Incomplete dominance (or partial or mosaic dominance)

Correns, 1903:- It is the phenomenon where none of the two contrasting alleles or factor is dominant. The expression of the character in a hybrid of F_1 individual is intermediate or a fine mixture of the expression of the two factors (as found in homozygous state).

⇒ In Complete or mosaic inheritance is not an example of Pre mendelian concept of blending inheritance because the parental types reappears in the F_2 generation. It is however considered to be an example of quantitative inheritance where only a single gene pair is involved.

2) Codominance:→ In it both allelic genes of a genetic trait are equally expressive i.e. the dominant character is not able to suppress the recessive characters and thus both the characters appear side by side in F_1 hybrids.

B) Law of Segregation or law of purity of gametes:-

In F_1 the dominant phenotype appears, the recessive phenotype is not lost but reappears in F_2. This suggested that there is no blending of mendelian factor in F_1, but they stay together and only one is expressed. At the time of the formation of gametes, these two factors obviously separate or segregate, otherwise recessive type will not appear in F_2.

⇒ The gametes which are formed are always pure for a particular character. A gamete may carry either the dominant or the recessive factors but not both as we find in F_1 individuals. This is why it is called either as "Principle of segregation" or as "law of purity of gametes"

3:1 Ratio in F_2 generation of a monohybrid cross suggested that segregation of alleles does take place which can be confirmed by test-cross.

Reciprocal Cross:→ A set of two reciprocal crosses means that the same two parents are used in two experiments in such a way that if in one experiment 'A' is used as the female parent and 'B' is used as the male parent than in the other experiment 'A' will be used as the male parent and 'B' as the female parent. Thus the reciprocal crosses involve two crosses concerning the same characteristics but with the reversed sexes.

Limitations of Law of Segregation:- The law applies only to diploid organisms that form haploid gamete to reproduce sexually.

⇒ The law only applies to traits controlled exclusively by a single gene pair in which one of the two alleles is dominant over the other.

⇒ The law does not apply to:-
(i) Alleles that are incompletely dominant or codominant.
(ii) Genes that are pleiotropic, complementary or epistatic.
Traits caused by many gene pairs.

Inheritance of two genes:-
To verify his results of monohybrid crosses, Mendel also crossed pea plants differing in two characters (dihybrid cross) This helped him to understand inheritance of two genes (i.e. two pair of alleles) at a time.

⇒ It was found that inheritance of one pair of allele (one trait) does not interfere in the inheritance of other pair of allele (second trait). Based upon it Mendel proposed a second set of generalisations (postulates) which is now called law of independent assortment.

c) Law of Independent assortment:- It states that when two pairs of independent alleles are brought together in F_1 hybrid, they show independent dominant effects. In the formation of gametes law of segregation occurs and the factors assort independently at random.

Limitations of law of Independent assortment:-
⇒ The two factors of each trait assort at random and independent of the factors of other traits at the time of meiosis (gametogenesis) and get randomly as well as independently rearranged in the offsprings.

⇒ The law of independent assortment is applicable to only those factors or genes which are present on different chromosomes.
:- one gene pair on one pair of homologous chromosomes and the other gene pair on another pair of homologous chromosomes.
Though Mendel did not know about chromosomes, all the traits he studied were on different pair of homologous chromosomes.

⇒ That is why he concluded that gene pairs segregate independently of one another. Mendel's gene pair did not show linkage.

Post Mendelism:- Mendel explained inheritance in terms of discrete hereditary factors (now called genes). All patterns of inheritance could not be explained on the basis of Mendel's principle alone.

⇒ Bateson then proposed a hypothesis according to which more than one gene (two, three or more) may interact to produce the same character, or many genes may exert influence on the development of every hereditary character with one, two or several genes having a predominant effect. Though genes are inherited as units many interact in different patterns to produce the traits. This is called gene interaction.

Gene interaction / modification of F_2 ratio:-
Modification of the normal phenotypic expression of genes due to interaction of their alleles and nonallelic genes. Correspondingly gene interaction is of two types:-

Intragenic and Intergenic

Intragenic interaction:- In it two alleles of a gene when are present on the same gene locus on the two homologous chromosomes react with each other in such a way as to produce an expression different from the normal dominant-recessive phenotype, e.g. Incomplete dominance, codominance, multiple alleles.

Incomplete dominance:- (1:2:1 ratio)
⇒ It is the phenomenon of neither of the two alleles being dominant so that the expression by the hybrid is intermediate between the expression of the two alleles in homozygous state. F_2 phenotypic ratio is 1:2:1 similar to genotypic ratio.

⇒ In Mirabilis jalapa (four o'clock) and Antirrhinum majus (snapdragon / dog flowers) there are 2 types of flowers Colour in pure state red and white.

⇒ When the 2 types of plants are crossed the hybrids or plants of f_1 generation have pink flowers. If the latter are selfed the plants of F_2 generation are of three types)- red, pink and white flowered in the ratio of 1:2:1.

⇒ The pink colour apparently appears either due to mixing of red and white colour (Incomplete dominance) or expression of a single gene for pigmented flowers which produces only pink colour (Quantitative inheritance)

Codominance :→ (1:2:1) Ratio :→ may be defined as phenomenon of two alleles (different forms or mendelian factor present on the same gene locus on homologous chromosomes) lacking dominant - recessive relationship and both expressing themselves in the organism.

⇒ Human red blood corpuscles posses two types of native antigens – M and N (Landsteiner and Levine 1927). These alleles are codominants. An individual can be MM, MN or NN, having one (MM or NN) or both the types (MN) antigens.

⇒ If a cattle with black coat is crossed with a cattle with white coat, the F1 hybrids possess neither black nor white coat colour but have roan colour, where black and white patches appear separately. The effect is produced due to juxtaposition of small patches of red and white colour. Hence the alleles which are able to express themselves independently when present together are called codominant alleles.

Multiple alleles :→ They are multiple forms (more than two alternatives) of mendelian factor or gene which occur on the same gene locus distributed in different organisms in the gene pool with a organism carrying only two alleles and gametes only allele.

⇒ A well known and simplest example of multiple allelism is the inheritance of ABO blood group system in human being (discovered by Karl Landsteiner).

⇒ ABO blood group system in human being is an example of both codominant and multiple alleles. Human beings has six genotypes and four blood groups – A, B, AB and O. The blood groups are determined by two types of antigens present in the surface coating of red blood cells – A and B. The antigens occurs oligosaccharide rich head region of a glycophorin. Blood group A person have antigen A, group B have antigen B, AB have both antigens while blood group O persons do not carry any antigen in the coating of their erythrocytes.

⇒ In human population 3 different alleles for ABO blood group systems are found I^A, I^B and I^O or i. I^A and I^B are mutant alleles and are dominant over I^O or i which is wild allele.

⇒ I^A and I^B are responsible for A and B antigens (glycoproteins) while I^O or i does not produce any of these A or B antigens.

⇒ A person is having only two of these three alleles and blood type can be determined by their antigen types. Six genotypes combinations are possible with these three alleles.

Blood type (Phenotype)	Genotype	Antigen	Antibodies
A	I^AI^A / I^Ai^O	A	b
B	I^BI^B / I^Bi^O	B	a
AB	I^AI^B	Both A and B	Neither a nor b
O	i^Oi^O	Neither A nor B	Both a and b

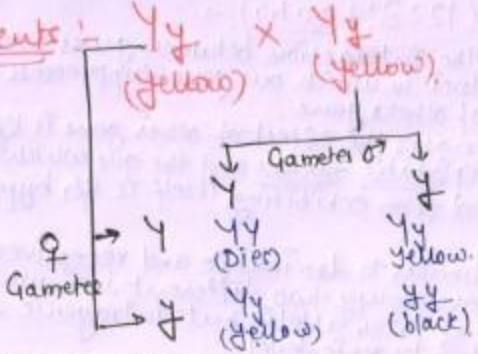
⇒ **Self-sterility in tobacco Nicotina** is controlled by four genes designated as S_1, S_2, S_3 and S_4.

Lethal Gene (2:1 Ratio) :→ They are gene which control some vital function of the organism and cause death of the organism either in homozygous recessive / homozygous dominant condition.

⇒ The individual dies in embryonic state in absolute lethality (yellow fur in mice), before reproductive maturity in sublethality (e.g. sickle-cell anaemia) and after sexual maturity in delayed lethality, with the death of homozygous lethal the monohybrid ratio comes to 2:1.

⇒ L. Cuenot worked on the inheritance of mouse body colour he showed that yellow body colour was dominant over normal brown colour and controlled by a single gene (Y) yellow mice could never be obtained in homozygous condition when yellow mice were crossed among themselves, segregation of yellow and brown body colour was obtained in 2:1 ratio.

⇒ Brown individuals were pure, thus homozygous, hence dominant allele for yellow body colour is lethal in homozygous condition.



yellow 2 : 1 black

Intergenic Interaction:- In intergenic or nonallelic interaction, two or more independent genes present on same or different chromosomes interact to produce a different expression e.g. epistasis, duplicate gene, Complementary genes, supplementary genes, inhibitory genes etc.

Complementary genes (9:7 ratio):-

⇒ Complementary genes may be defined as two or more dominant genes present on separate gene loci (nonallelic pair) which interact to produce a particular phenotypic trait, but neither of them produces the phenotypic trait in the absence of other.

⇒ There is complementation between two genes implying that both genes are necessary for the production of a particular phenotype.

Characteristics:- (i) Complementary genes are non-allelic genes.

(ii) They are present on separate gene loci.

(iii) Together in dominant form they produce a specific phenotypic characters.

(iv) Absence of either of the two is not able to produce specific phenotypic character as these genes work in collaboration.

⇒ Complementary genes were first studied by Bateson and Punnett (1906) in case of flowers colour of sweet pea (Lathyrus odoratus), here the flower colour is purple if dominant alleles of two genes C and P are present together.

⇒ The colour is white if the double dominant condition is absent. Bateson and Punnett crossed two white flower strains (CCpp, ccPP) of sweet pea and obtained purple flowered plants (CcPp) in the F1 generation.

⇒ Clearly both the parents have contributed a gene or factor for the synthesis of this purple colour. The purple flowered plants of F1 generation were then allowed to self-breed.

⇒ Both purple and white flowered plants appear in the F2 generation in the ratio of 9:7. It is the modification of the dihybrid ratio of 9:3:3:1.

⇒ The appearance of purple colour in 9/16 population shows that the colour is determined by two dominant genes (C and P), when either of the two is absent (CcPP or CCPp, CcPp, Ccpp) the pigement does not appear.

⇒ The dominant gene C produces an enzyme which converts the raw material (precursor) into chromogen. The dominant gene P gives rise to an oxidase enzyme that changes chromogen into purple anthocyanin pigement.

⇒ This is confirmed by mixing the extract of the two types of flowers when purple colour is formed. This purple colour formation is two-step reaction and the two genes cooperate to form the ultimate product. Here the end product of first reaction forms the substrate for the other reaction.

Raw material A (Precursor A) → Chromogen (Precursor B) → Anthocyanin

Enzyme C — Gene C.

Enzyme P (oxidase) — Gene P

⇒ Dominance of both the genes ensures the production of both the enzymes needed to produce the pigment anthocyanin. Hereby the flower appears coloured.

Parents: White flower (♂) CCpp × White flower (♀) ccPP

Gametes: Cp, cP

F1 generation :- → CcPp

Purple flower, white flower

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

Supplementary genes (9:3:4 Ratio)

There are two independent genes present on different gene loci, each producing its own trait. These gene interact when present in dominant state to produce a new trait.

Characteristics:- There are a pair of non-allelic genes present on different loci on the chromosomes.

⇒ One non-allelic gene in the dominant state is able to produce its phenotypic character independently.

Remarks:- ⇒ Second non-allelic gene in dominant state can modify the phenotypic effect of first non-allelic gene.

⇒ Second non-allelic gene may/may not produce its own effect independently in collaborative supplementary genes/ Supplementary genes respectively.

⇒ In mice and guinea pigs coat colour is governed by two dominant genes A and C, the agouti coloured guinea pigs have genotype CCAA. The black mice possess factor for black colour (C) but not the gene (A) for agouti colour. If gene for black colour is absent agouti is unable to express itself and mice with a genotype ccAA are albino. Here presence of gene C produced black colour and addition of gene A changes its expression to agouti colour.

Parents:- Agouti CCAA × Albino ccaa

Gametes:- CA, ca

Agouti

F1 generation:- CcAa.

♂ / ♀	CA	cA	Ca	ca
CA	CCAA	CcAA	CCAa	CcAa.
cA	CcAA	ccAA	CcAa.	ccAa.
Ca.	CCAa.	CcAa	CCaa	Ccaa
ca.	CcAa.	ccAa.	Ccaa.	ccaa

Agouti 9 : Black 3 : albino 4.

Epistasis (12:3:1 ratio)

Epistasis is the interaction between genes present at two separate loci in which one gene suppresses or masks the expression of other gene.

⇒ The gene that masks the effect of other gene is K/a inhibiting or epistatic factor and the one which is being prevented from exhibiting itself is K/a hypostatic factor.

⇒ Although it is similar to dominance and recessiveness but the two factors occupy two different loci while dominance work at inter allelic but intragenic level, epistasis works at intergenic level.

⇒ Epistasis reduces the numbers of phenotypes appearing in F_2 generation of dihybrid cross. Thus instead of normal 9:3:3:1 dihybrid ratio, epistasis may result in the ratio of 9:3:4. (recessive epistasis) 12:3:1 / 13:3 (dominant epistasis)

Dominant epistasis:- A dominant epistatic allele suppresses the expression of a non-allelic gene whether the latter is dominant or recessive.

⇒ Fruit colour of summer squash (Cucurbita pepo) is governed by a gene which produces yellow colour in dominant state (Y) and green colour in recessive state (yy). There is a non-pigment forming epistatic gene which in dominant state (W-) produces white colour (W-Y-, W-yy) while in recessive state it allows the yellow (wwY-) and green (wwyy) expression.

Parents:- WWYY (white fruit) × wwyy (green fruit).

Gametes:- WY, wy

Wwyy (white fruit).

	WY	Wy	wY	wy
WY	WWYY.	WWYy.	WwYY.	WwYy.
Wy	WWYy.	WWyy.	WwYy.	Wwyy.
wY	WwYY.	WwYy.	wwYY.	wwYy.
wy	WwYy.	Wwyy.	wwYy	wwyy.