South Valley University Faculty Of Science Zoology Department

PACTICAL GENETICS

For 3rd Entomology and Chemistry Level Students

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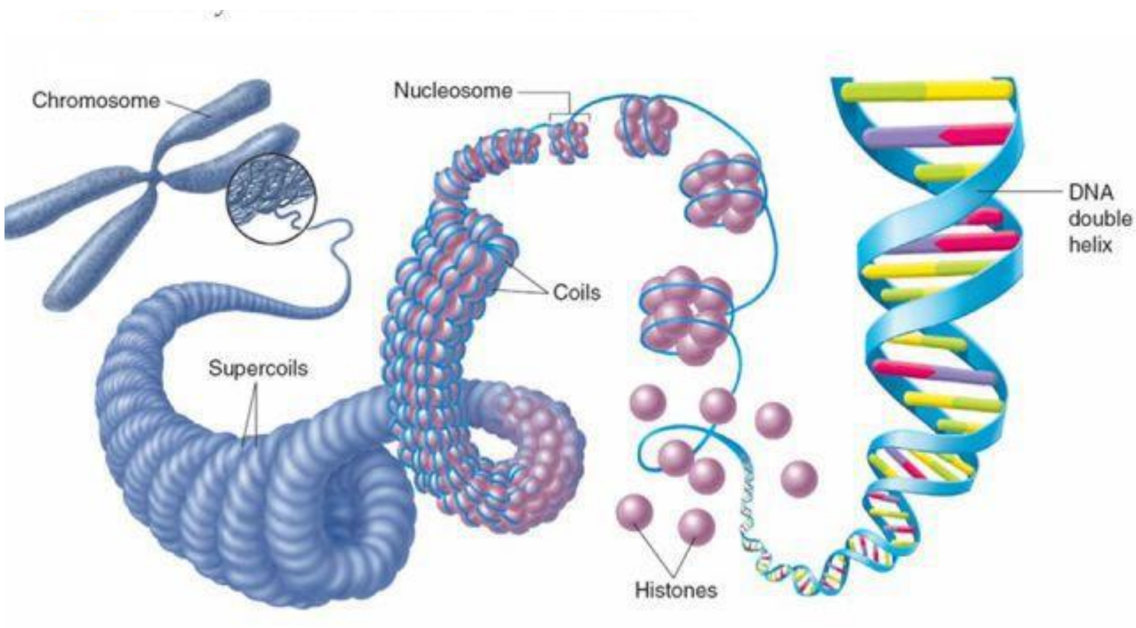

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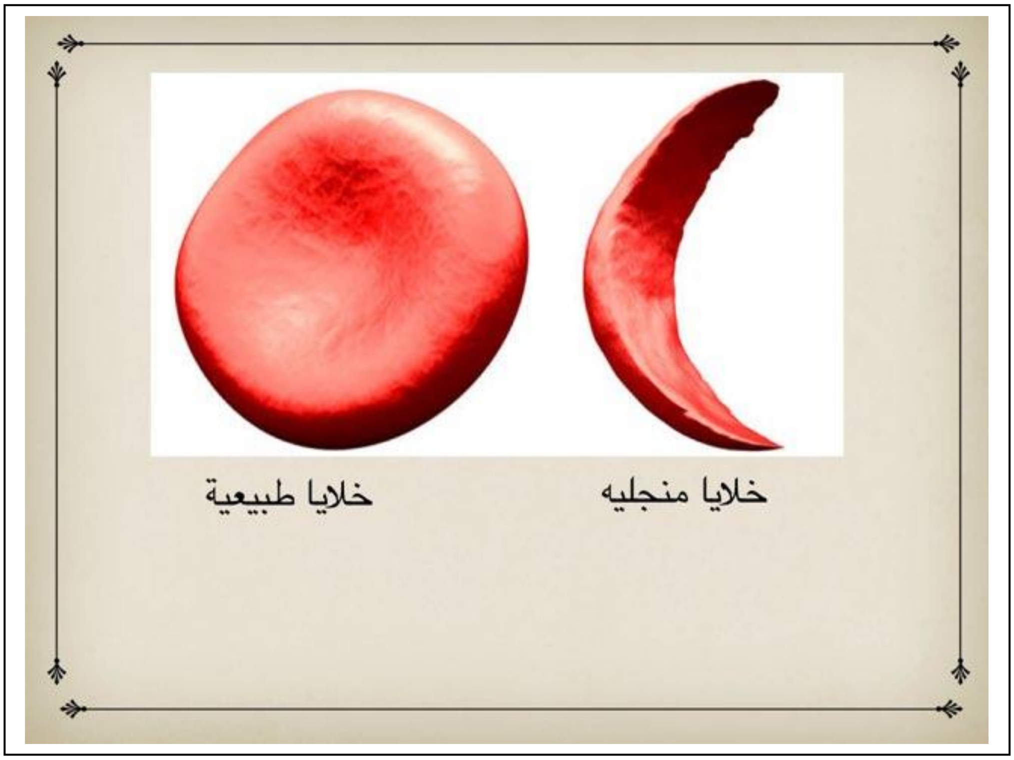
رؤية كلية العلوم

التميز في تعليم العلوم الأساسية والبحث العلمي للمساهمة فى التنمية المستدامة

رسالة كلية العلوم

تقدم كلية العلوم جامعة جنوب الوادى تعليم مميز في مجالات العلوم الأساسية وإنتاج بحوث علمية تطبيقية تدعم اقتصاد الوطن من خلال إعداد خريجين متميزين طبقا للمعايير الأكاديمية القومية، وتطوير مهارات وقدرات الموارد البشرية، وتوفير خدمات مجتمعية وبيئية تلبي طموحات مجتمع جنوب الوادي، وبناء الشراكات المجتمعية الفاعلة.

PATTERNS OF INHERITANCE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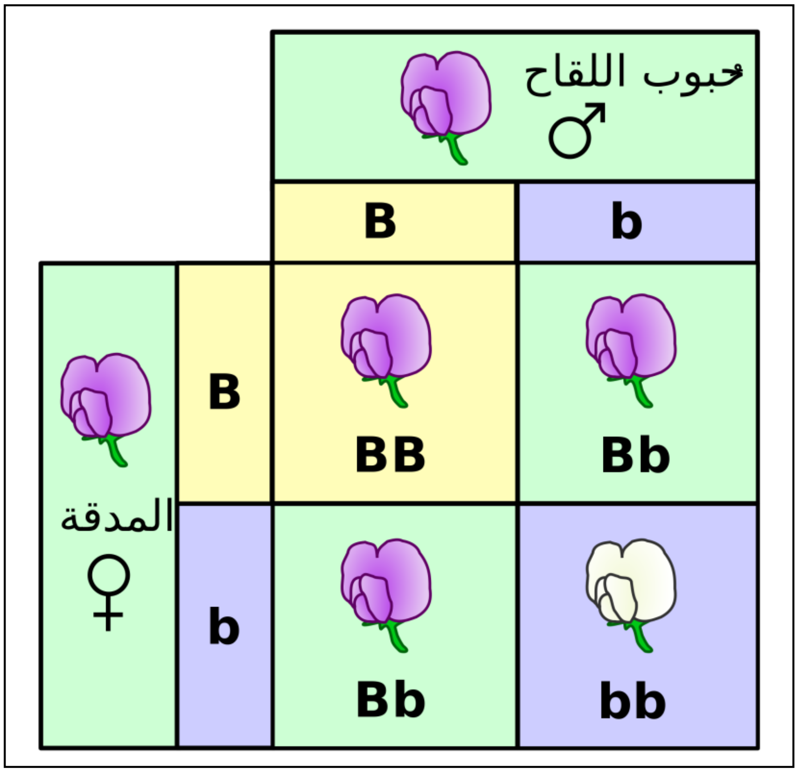
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PATTERNS OF INHERITANCE

Chapter Outline

Introduction

Genetics is the study of heredity. **Johann Gregor Mendel** set the framework for genetics long before chromosomes or genes had been identified, at a time when meiosis was not well understood. **Mendel** selected a simple biological system and conducted methodical, quantitative analyses using large sample sizes. Because of **Mendel's** work, the fundamental principles of heredity were revealed. We now know that genes, carried on chromosomes, are the basic functional units of heredity with the ability to be replicated, expressed, or mutated. Today, the postulates put forth by **Mendel** form the basis of **classical, or Mendelian genetics**. Not all genes are transmitted from parents to offspring according to **Mendelian genetics**, but **Mendel**'s experiments serve as an excellent starting point for thinking about inheritance.

Mendel's Experiments

By the end of this section, you will be able to:

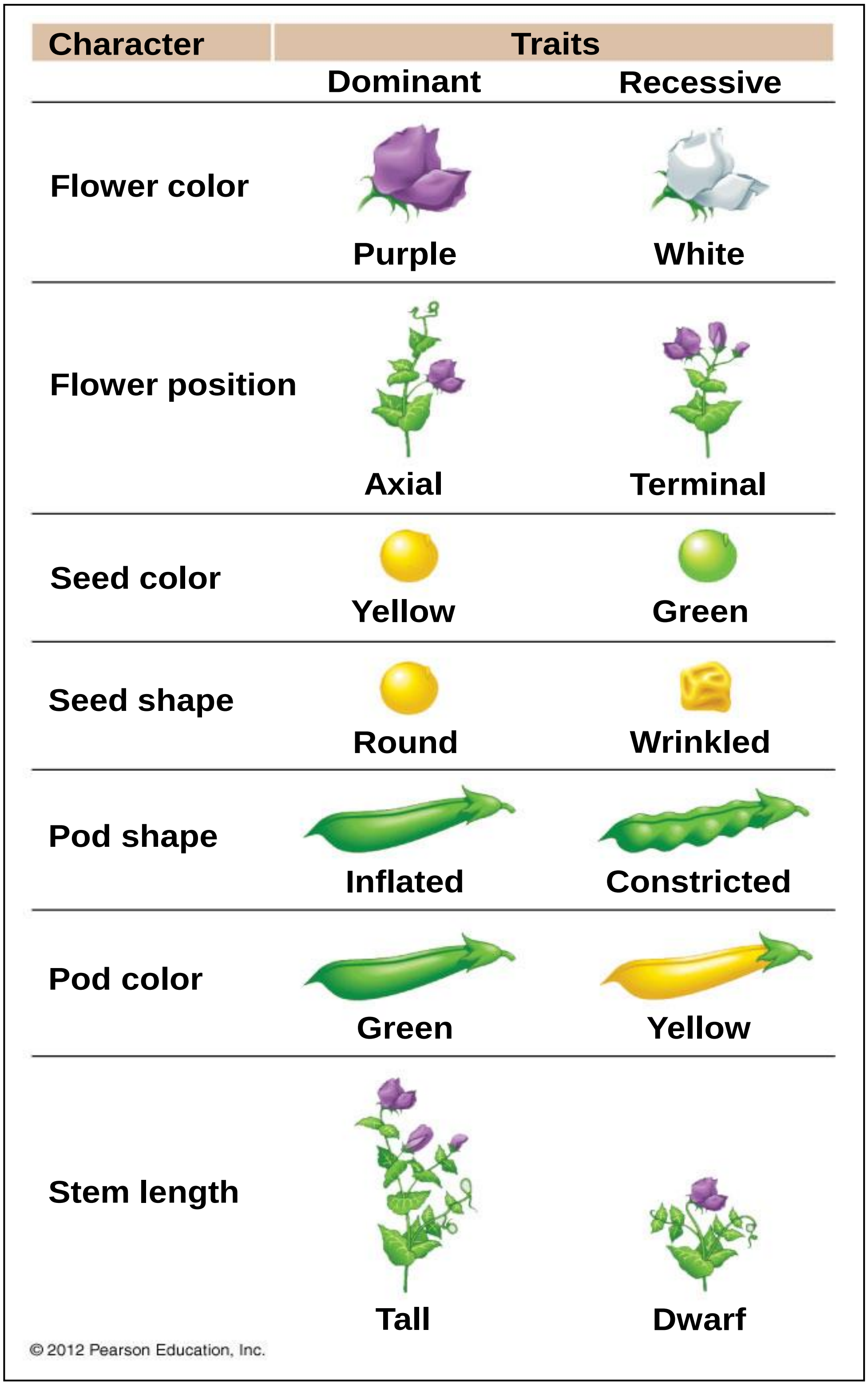
- Explain the scientific reasons for the success of Mendel's experimental work
- Describe the expected outcomes of monohybrid crosses involving dominant and recessive alleles

Mendel's seminal work was accomplished using the garden pea, ***Pisum sativum***, to study inheritance. This species naturally self-fertilizes, meaning that pollen encounters ova within the same flower. The flower petals remain sealed tightly until pollination is completed to prevent the pollination of other plants. The result is highly inbred, or "**true-breeding**," pea plants. These are plants that always produce offspring that look like the parent. By experimenting with true-breeding pea plants, **Mendel** avoided the appearance of unexpected traits in offspring that might occur if the plants were not true breeding. The garden pea also grows to maturity within one season, meaning that several generations could be evaluated over a relatively short time. Finally, large quantities of garden peas could be cultivated simultaneously, allowing **Mendel** to conclude that his results did not come about simply by chance.

Mendel performed **hybridizations**, which involve mating two true-breeding individuals that have different traits. In the pea, which is naturally self-pollinating, this is done by manually transferring pollen from the anther of a mature pea plant of one variety to the stigma of a separate mature pea plant of the second variety.

Plants used in first-generation crosses were called P, or parental generation, plants (**Figure 1.2**). **Mendel** collected the seeds produced by the P plants that resulted from each cross and grew them the following season. These offspring were called the F1, or the first filial (filial = daughter or son), generation. Once **Mendel** examined the characteristics of the F1 generation of plants, he allowed them to self-fertilize naturally. He then collected and grew the seeds from the F1 plants to produce the F2, or second filial, generation. **Mendel's** experiments extended beyond the F2 generation to the F3 generation, F4 generation, and so on, but it was the ratio of characteristics in the P, F1, and F2 generations that were the most intriguing and became the basis of **Mendel's** postulates.

Dominant and recessive traits of Pea plants that were studied by Mendel



Genetic Practice

Chapter (1):1st Law (the principle of segregation)

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1. In peas, seeds may be round (R) or wrinkled (r). What proportion of the offspring in the following crosses would be expected to be wrinkled?
   a. true-breeding round x true-breeding wrinkled.
   b. two heterozygous round individuals.
   c. Rr x rr
2. A brown-eyed man marries a blue-eyed woman, and they have eight brown-eyed children. What are the genotypes of all the individuals in the family?
3. In cats, long hair is recessive to short hair. A true-breeding (homozygous) short-haired male is mated to a long-haired female. What will their kittens look like?
4. Two cats are mated. One of the parent cats is long-haired (recessive allele). The litter which results contains two short-haired and three long-haired kittens. What does the second parent look like, and what is its genotype?
5. Mr. and Mrs. Jones have six children. Three of them have attached earlobes (recessive) like their father, and the other three have free earlobes like their mother. What are the genotypes of Mr. and Mrs. Jones and of their numerous offspring?
6. About 80% of the human population can taste the chemical phenol-thiocarbamide (PTC), while the other 20% can't. This

characteristic is governed by a single gene with two alleles, a tasting allele and a non-tasting allele. What does this statistic tell us about which allele (tasting or non-tasting) is dominant?

2nd Law (the principle of independent assortment):

1. For the purpose of this problem assume that in humans the gene for brown eyes is dominant to that for blue eyes.
   a. A brown-eyed man marries a blue-eyed woman, and they have eight brown-eyed children. What are the genotypes of all the individuals in the family?
   b. What is the probability that the first child produced in parents who are both heterozygous for brown eyes will be blue-eyed?
   c. If the first child is a brown-eyed girl (same parents as in b), what is the probability that the second child will be a blue-eyed boy?

2. What is the probability of having AaBb peas from the cross aaBb x AaBb?

3. In peas cross of flower color and flower position between 2 unknown parents, it was found that 1st generation plants were 2/8 (purple - axial), 2/8 (purple - terminal), 2/8 (white - axial), and 2/8 (white - terminal). What are the genotypes and phenotypes of parents?

4. A left-handed man with black eyes married a right-handed woman with blue eyes, and they got 2 children with the following phenotypes:
   a. Right-handed, black-eyed.
   b. Right-handed, blue-eyed.

   What are the genotypes of all members if you know that black and right-handed are the dominant alleles?

5. Consider 3 yellow-round peas labeled A, B, and C. Each was grown into a plant and crossed with green-wrinkled peas. Exactly 100 peas were collected from each cross and they showed that:

   A: 51 yellow-round, 49 green-round

   B: 100 yellow-round

   C: 24 yellow-round, 26 yellow-wrinkled, 25 green-round, 25 green-wrinkled.

   What are the genotypes of A, B, and C?

6. In genetic experiments of a particular plant. Determine the genotype of each cross in the following knowing that the traits being studied are seeds color and stem length:

	y-t	y-d	g-t	g-d
yellow-tall x yellow-tall	90	30	31	11
yellow-dwarf x yellow-dwarf	0	40	0	14
yellow-dwarf x green-tall	20	19	23	21

7. A type of poultry produces a crest due to a dominant allele (C), while smooth head has the recessive allele (c).

Chapter (2): Non-Mendelian Genetics - Practice

1. In plants known as "four o'clocks", the allele for the dominant red-flower color is **incompletely dominant** over the allele for white-flowers. A gardener allows several heterozygous pink-flowered four o'clocks to self pollinate and collects 200 seeds.

2-Draw a Punnett square for the cross. Identify the flower color phenotypes and theoretical percentage.

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2. Skin color in humans is determined by a polygenic inheritance system, possibly involving as many as 9 genes. For simplicity let's consider the influence of 2 genes: A and B, where the dominant allele darkens skin color. Suppose a woman who is AABb mates with a man who is Aabb.

List all of the possible genotypes of the gametes that could be produced by each the parents. Identify the percent ratios.

Genotype: ___________ Ratio: _____
Genotype: ___________ Ratio: _____
Genotype: ___________ Ratio: _____
Genotype: ___________ Ratio: _____

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3. In rabbits, white coat color (CW) and black coat color (CB) are codominant, and both of these alleles are dominant over albino (c); heterozygotes (CWCB) are spotted.

Draw a Punnett Square that shows the genotypes and phenotypes of the offspring from a heterozygous black-coated rabbit and a homozygous white-coated rabbit?

4. Mrs. Eryth is carrier of the sex-linked hemophilia allele (XAXa) and Mr. Eryth is normal (XAY)

Draw a Punnet square that shows the theoretical genotypes and phenotypes among their children.

B. They actually have 4 male and 4 female children; how many of each sex would be expected to be hemophiliacs, carriers, and normal?

hemophiliac #carrier # normal

%: ______ ______ ______

#: ______ ______ ______

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5. If several pea plants with the genotype TTYy are crossed with pea plants with the genotype Ttyy, what percentage of the offspring will be expected to have the TTYy allele combination?

6. Basic body color for horses is influenced by several genes, one of which has several different alleles. Two of these alleles—the chestnut (dark brown) allele and a diluting (pale cream) allele (often incorrectly called ‘albino’)—display incomplete dominance. A horse heterozygous for these two alleles is a palomino (golden body color with flaxen mane and tail). Is it possible to produce a herd of

pure-breeding palomino horses? Why or why not? Work the Punnett's square for mating a palomino to a palomino and predict the phenotypic ratio among their offspring.

7. In humans, the alleles for blood type are designated IA (A-type blood), IB (B-type blood) and i (O-type blood). What are the expected frequencies of phenotypes in the following matings? Draw a Punnett square showing the results for a).

%A %B

%O %AB

a) heter A x heter B : ____ ____

____ ____

b) IAIB x IAi : ____ ____

____ ____

c) IAIA x IBIB : ____ ____

____

d) AB x O : ____

____ ____

8. Blood type analysis is used frequently as evidence in paternity suits. Consider the following hypothetical cases presented in the table. The blood type of the mother and child are given; indicate which blood type(s) MUST be the father's for each situation.

Answer

following questions. Provide a punnett square to support your answers where indicated. Express probabilities as percentages. For instance, a probability of one chance in ten would be 10%.

Mother	Child	Father's blood type(s) (A, B, AB or O)
A	O	
B	AB	
O	O	
B	B	
A	B	

9-In some chickens, the gene for feather color is controlled by codominance. The allele for black is B and the allele for white is W. The heterozygous phenotype is known as erminette.

a. What is the genotype for black chickens?
b. What is the genotype for white chickens?
c. What is the genotype for erminette chickens?

10-If two erminette chickens were crossed, what is the probability that:

d. They would have a black chick? %
e. They would have a white chick? %
f.

Parents: X

11-A black chicken and a white chicken are crossed. What is the probability that they will have erminette chicks? %

Parents: X

12-In snapdragons, flower color is controlled by incomplete dominance. The two alleles are red (R) and white (W). The heterozygous genotype is expressed as pink.

g. What is the phenotype of a plant with the genotype RR?
h. What is the phenotype of a plant with the genotype WW?
i. What is the phenotype of a plant with the genotype RW?

13-A pink-flowered plant is crossed with a white-flowered plant. What is the probability of producing a pink-flowered plant? %

Parents: X

14-What cross will produce the most pink-flowered plants? Show a punnett square to support your answer.

Parents: X

15-Another type of non-mendelian trait: Multiple alleles. Human hair color is controlled by one gene with four alleles (with some incomplete dominance):

hR = red HBd = blonde HBr = brown hbk = black

The possible genotypes and phenotypes:

dhR = strawberry blonde HBdHBd or HBdhbk = blonde

What do you think your parent's

phenotypes and genotypes for hair

color are? What are your phenotype

and genotype for hair color?

If someone with auburn hair has children with someone with red hair (but whose mother had black hair), what are the genotype and phenotype probabilities for their children?

Chapter (3): Epistasis (Gene Interaction)

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The following points highlight the top six types of epistasis gene interaction. The types are: 1. Recessive Epistasis 2. Dominant Epistasis 3. Dominant [Inhibitory] Epistasis 4. Duplicate Recessive Epistasis 5. Duplicate Dominant Epistasis 6. Polymeric Gene Interaction.

Epistasis Gene Interaction: Type # 1.

Recessive Epistasis [9:3:4 Ratio]:

When recessive alleles at one locus mask the expression of both (dominant and recessive) alleles at another locus, it is known as recessive epistasis. This type of gene interaction is also known as supplementary epistasis. A good example of such gene interaction is found for grain colour in maize.

There are three colours of grain in maize, viz., purple, red and white. The purple colour develops in the presence of two dominant genes (R and P), red colour in the presence of a dominant gene R, and white in homozygous recessive condition (rrpp).

A cross between purple (RRPP) and white (rrpp) grain colour strains of maize produced plants with purple colour in F1. Inter-mating of these F1 plants produced progeny with purple, red and white grains in F2 in the ratio of 9 : 3 : 4 (Fig. 8.2).

Parents Purple Grains PPRR × White Grains pprr

F1 PpRr Purple Grains

F2

	PR	Pr	pR	pr
PR	PPRR [P]	PPRr [P]	PpRr [P]	PpRr [P]
Pr	PPRr [P]	PPrr [W]	PpRr [P]	Pprr [W]
pR	PpRR [P]	PpRr [P]	ppRR [R]	ppRr [R]
pr	PpRr [P]	Pprr [W]	ppRr [R]	pprr [W]

P = Purple, R = Red, and W = White grains

Fig. 8.2. Recessive epistasis for grain colour in maize. The normal dihybrid segregation ratio of 9 : 3 : 3 : 1 is modified to 9 : 3 : 4 in F_2.

Here allele r is recessive to R, but epistatic to alleles P and p. In F2, all plants with R-P-(9/16) will have purple grains and those with R-pp genotypes (3/16) have red grain colour. The epistatic allele r in homozygous condition will produce plants with white grains from rrP-(3/16) and rrpp (1/16) genotypes.

Thus the normal segregation ratio of 9 : 3 : 3 : 1 is modified to 9 : 3 : 4 in F2 generation. Such type of gene interaction is also found for coat colour in mice, bulb colour in onion and for certain characters in many other organisms.

Epistasis Gene Interaction: Type # 2.

Dominant Epistasis [12 : 3 : 1 Ratio]:

When a dominant allele at one locus can mask the expression of both alleles (dominant and recessive) at another locus, it is known as dominant epistasis. In other words, the expression of one dominant or recessive allele is masked by another dominant gene. This is also referred to as simple epistasis.

An example of dominant epistasis is found for fruit colour in summer squash. There are three types of fruit colours in this cucumber, viz., white, yellow and green. White colour is controlled by dominant gene W and yellow colour by dominant gene G. White is dominant over both yellow and green.

The green fruits are produced in recessive condition (wwgg). A cross between plants having white and yellow fruits produced F1 with white fruits. Inter-mating of F1 plants produced plants with white, yellow and green coloured fruits in F2 in 12 : 3 : 1 ratio (Fig. 8.3). This can be explained as follows.

Parents: White Fruit WWgg × Yellow Fruit wwGG

F_1: WwGg White Fruit

F_2:

	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]

W = White Fruit, Y = Yellow fruit, G = Green Fruit

Fig. 8.3. Dominant epistasis for fruit colour in Summer squash. The normal dihybrid modified to 12 : 3 : 1 in F_2 generation.

Here W is dominant to w and epistatic to alleles G and g. Hence it will mask the expression of G/g alleles. Hence in F2, plants with W-G-(9/16) and W-gg (3/16) genotypes will produce white fruits; plants with wwG-(3/16) will produce yellow fruits and those with wwgg (1/16) genotype will produce green fruits.
Thus the normal dihybrid ratio 9 : 3 : 3 : 1 is modified to 12:3: 1 ratio in F2 generation. Similar type of gene

interaction has been reported for skin colour in mice and seed coat colour in barley.

Epistasis Gene Interaction: Type # 3.

Dominant [Inhibitory] Epistasis [13 : 3 Ratio]:

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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 purple (iiPP) colour plants, the F1 was green. Inter-mating of F1 plants produced green and purple plants in 13 : 3 ratio in F2 (Fig. 8.4). This can be explained as follows.

Parents: Green Plant IIpp × Purple Plant iiPP

F_1: IiPp Green Plant

F_2:

	IP	Ip	iP	ip
IP	IIPP [G]	IIPp [G]	IiPP [G]	IiPp [G]
Ip	IIPp [G]	IIpp [G]	IiPp [G]	Iipp [G]
iP	IiPP [G]	IiPp [G]	iiPP [P]	iiPp [P]
ip	IiPp [G]	Iipp [G]	iiPp [P]	iipp [G]

G = Green Plant, P = Purple Plant

Fig. 8.4. Inhibitory epistasis for anthocyanin pigmentation in rice. The normal dihybrid ratio is modified to 13 : 3 ratio in F_2 generation.

Here the allele I isepistatic to alleles P and p. Hence in F2, plants with I-P-(9/16), I-pp (3/16) and iipp (1/16) genotypes will be green because I will mask the effect of P or p. Plants with iiP-(3/16) will be purple, because I is absent.

In this way the normal dihybrid segregation ratio 9 : 3 : 3 : 1 is modified to 13 : 3 ratio. Similar gene interaction is found for grain colour in maize, plumage colour in poultry and certain characters in other crop species.

Epistasis Gene Interaction: Type # 4.
Duplicate Recessive Epistasis [9 : 7 Ratio]:
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 if 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) or recessive (aabb) they produce white flower.

A cross between purple flower (AABB) and white flower (aabb) strains produced purple colour in F1. Inter-mating of F1 plants produced purple and white flower plants in 9 : 7 ratio in F2 generation (Fig. 8.5). This can be explained as follows.
Here recessive allele a isepistatic 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.

Hence in F2, plants with A-B-(9/16) genotypes will have purple flowers, and plants with aaB-(3/16), A-bb-(3/16) and aabb (1/16) genotypes produce white flowers. Thus only two phenotypic classes, viz., purple and white are produced and the normal dihybrid segregation ratio 9 : 3 : 3 : 1 is changed to 9 : 7 ratio in F2 generation.

Parents Purple Flower AABB × White Flower aabb

↓

F_1 AaBb Purple Flower

F_2

	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]

P = Purple Flower, W = White Flower

Fig. 8.5. Duplicate recessive epistasis for flower colour in sweet pea. The normal dihybrid segregation ratio 9 : 3 : 3 : 1 is changed to 9 : 7 in F_2.

Epistasis Gene Interaction: Type # 5.
Duplicate Dominant Epistasis [15 : 1 Ratio]:

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. This is also called duplicate gene action. A good example of duplicate dominant epistasis is awn character in rice. Development of awn in rice 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. Inter-mating of F1 plants produced awned and awnless plants in 15 : 1 ratio in F2 generation (Fig. 8.6). This can be explained as follows.

Parents Awned Rice AABB × Awnless Rice aabb

F_1 AaBb Awned Rice

F_2

	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]

A = Awned Rice, a = Awnless Rice

Fig. 8.6. Duplicate dominant epistasis for awn character in rice. The normal dihybrid segregation ratio 9 : 3 : 3 : 1 is changed to 15 : 1 ratio in F_2 generation.

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/a. Individuals with this allele also will develop awn character. Hence in F2, plants with A-B-(9/16), A-bb-(3/16) and aaB-(3/16) genotypes will develop awn.

The awnless condition will develop only in double recessive (aabb) genotype (1/16). In this way only two classes of plants are developed and the normal dihybrid segregation ratio 9 : 3 : 3 : 1 is modified to 15 : 1 ratio in F2. Similar gene action is found for nodulation in peanut and non-floating character in rice.

Epistasis Gene Interaction: Type # 6.

Polymeric Gene Interaction [9:6:1 Ratio]:

Two dominant alleles have similar effect when they are separate, but produce enhanced effect when they come together. Such gene interaction is known as polymeric gene interaction. The joint effect of two alleles appears to be additive or cumulative, but each of the two genes show complete dominance, hence they cannot be considered as additive genes. In case of additive effect, genes show lack of dominance.

A well-known example of polymeric gene interaction is fruit shape in summer squash. There are three types of fruit shape in this plant, viz., disc, spherical and long. The disc shape is controlled by two dominant genes (A and B), the spherical shape is produced by either dominant allele (A or B) and long shaped fruits develop in double recessive (aabb) plants.

A cross between disc shape (AABB) and long shape (aabb) strains produced disc shape fruits in F1. Inter-mating of F1 plants produced plants with disc, spherical and long shape fruits in 9 : 6 : 1 ratio in F2 (Fig. 8.7). This can be explained as follow.

Parents — Disc Shape Fruit AABB × Long Shape Fruit aabb

F_1 — AaBb Disc Shape Fruit

F_2

	AABB	Ab	aB	ab
AB	AABB [D]	AABb [D]	AaBB [D]	AaBb [D]
Ab	AABb [D]	AAbb [S]	AaBb [D]	Aabb [S]
aB	AaBb [D]	AaBb [D]	aaBB [S]	aaBb [S]
ab	AaBb [D]	Aabb [S]	aaBb [S]	aabb [L]

D = Disc shape fruit, S = Spherical fruit, L = Long fruit

Fig. 8.7. Polymeric gene interaction for fruit shape in summer squash. The normal dihybrid segregation ratio 9 : 3 : 3 : 1 is modified to 9 : 6 : 1 ratio in F_2.

Here plants with A—B—(9/16) genotypes produce disc shape fruits, those with A-bb-(3/16) and aaB-(3/16) genotypes produce spherical fruits, and plants with aabb (1/16) genotype produce long fruits. Thus in F2, normal dihybrid segregation ratio 9:3:3: 1 is modified to 9 : 6 : 1 ratio. Similar gene action is also found in barley for awn length