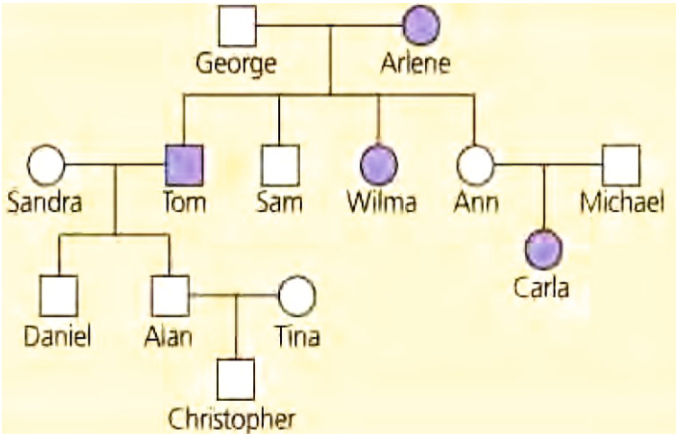
2. The pedigree below traces the inheritance of alkaptonuria, a biochemical disorder. Affected individuals, indicated here by the colored circles and squares, are unable to metabolize a substance called alkapton. which colors the urine and stains body tissues. Does alkaptonuria appear to be caused by a dominant allele or by a recessive allele? Fill in the genotypes of the individuals whose genotypes can be deduced. What genotypes are possible for each of the other individuals?



3. What is denoted by each Of the following symbols in a human pedigree chart?

□ ……………………………………………………..

● ……………………………………………………..

□–○ ……………………………………………………..

(v) A pedigree chart of a human family where some members show a genetic disorder is given below

(a) State whether the following statement regarding the above inheritance is correct or incorrect
"The above character is inherited in an autosomal dominant manner."
(b) Using A for dominant allele and a for the recessive allele, State the possible genotype of each the individuals labelled as 1 - 5 in the above pedigree chart.
1: ………….. 2: …………. 3: ……………. 4: ……………… 5: ……………..

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UNIT 06 Genetics

Monhybrid Inheritance

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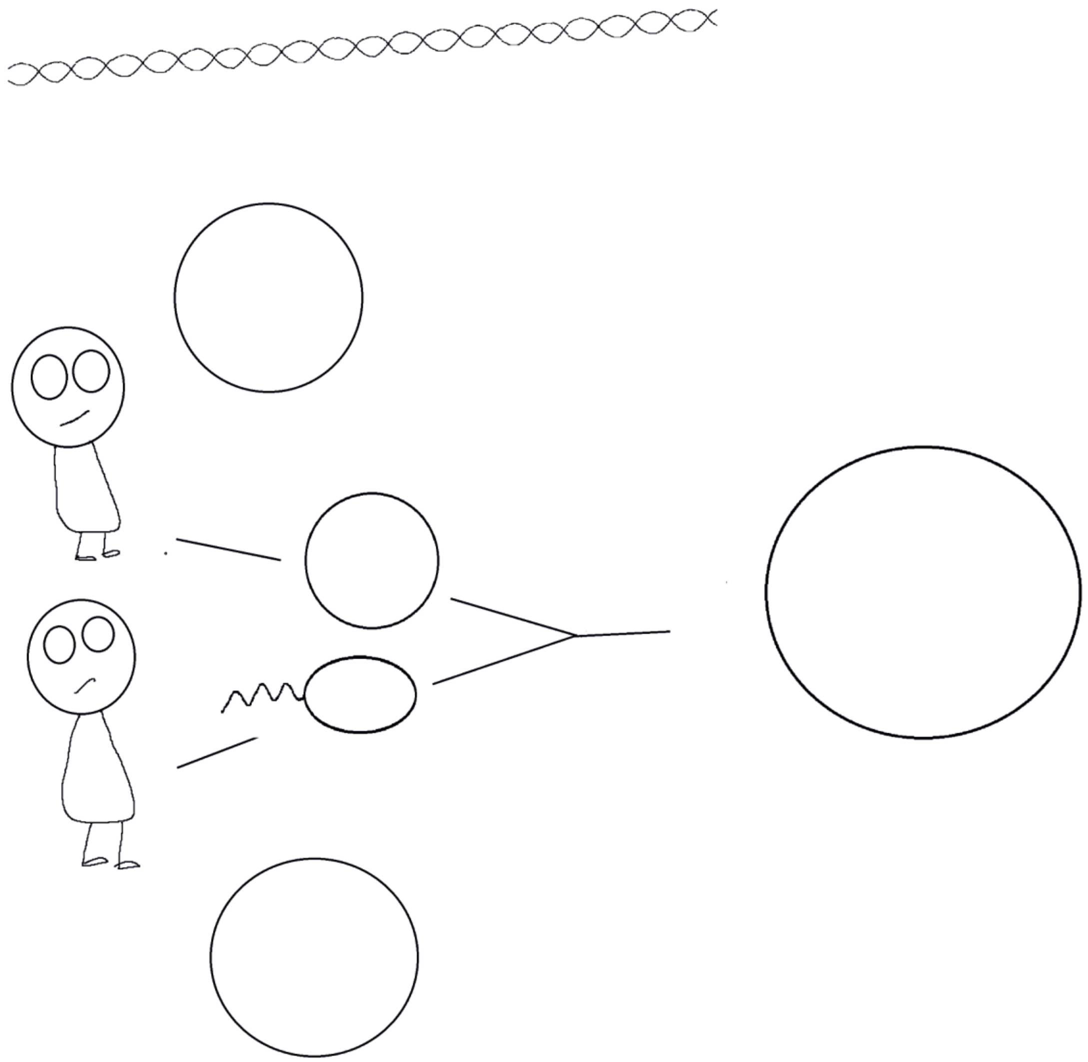


The chance that a child born to the family will have both the widow’s peak and attached earlobes can be calculated using probability rules. Assuming that the alleles corresponding to the two characters are on different chromosomes, the two pairs of alleles assort independently in this dihybrid cross (WwFf x WwFf).

Thus according to multiplication rule,

Chance of having both widow's peak (WWff/Wwff)

and attached ear lobe : Chance of widow's peak x chance of attached earlobe

: 3/4 x 1/4

: 3/16

Questions

1. Night blindness is a condition in which affected people have difficulty seeing in dim light. The allele for night blindness **N,** is dominant to the allele for normal vision, n. (These alleles are not on the sex chromosomes).

   The diagram shows part of a family tree showing the inheritance of night blindness.

   (a) Individual 12 is a boy. What is his phenotype?

   ………………………………………………………………………………

   (b) What is the genotype of individual 1? Explain the evidence for your answer.

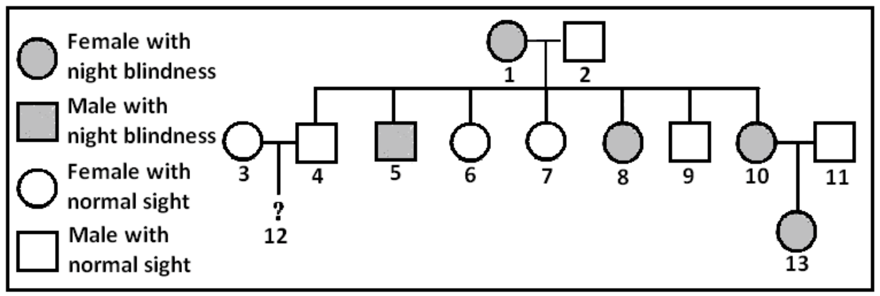
   Genotype:

   ………………………………………………………………………………………………

   Evidence:

   ………………………………………………………………………………………………

   (c) What is the probability that the next child born to individuals 10 and 11 will be a girl with night blindness? Show your working.



Attached ear lobe

Attached ear lobe, as explained earlier, is a recessively inherited character. In the pedigree chart given below, the inheritance of the trait is analyzed in the same family that was used to study the widow's peak. The dominant allele, which is causing the free ear lobe is denoted with 'F‘ while recessive allele is denoted with ‘f.

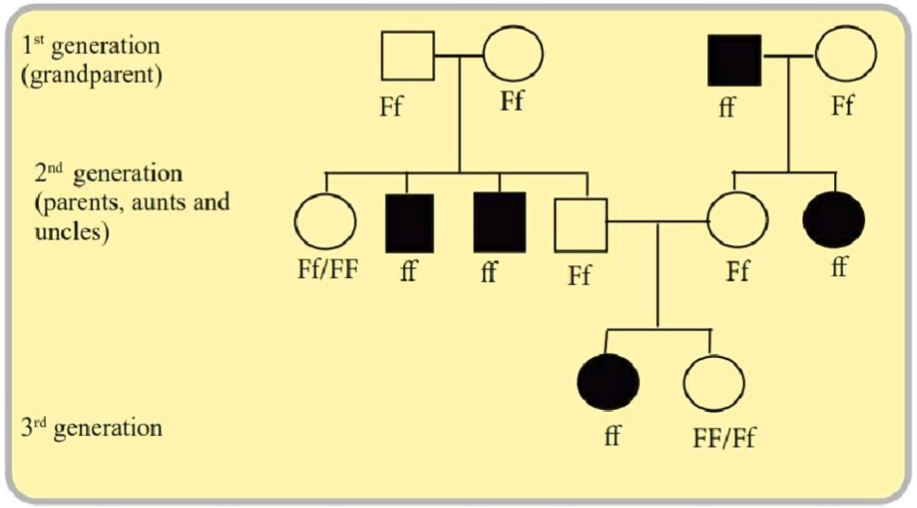
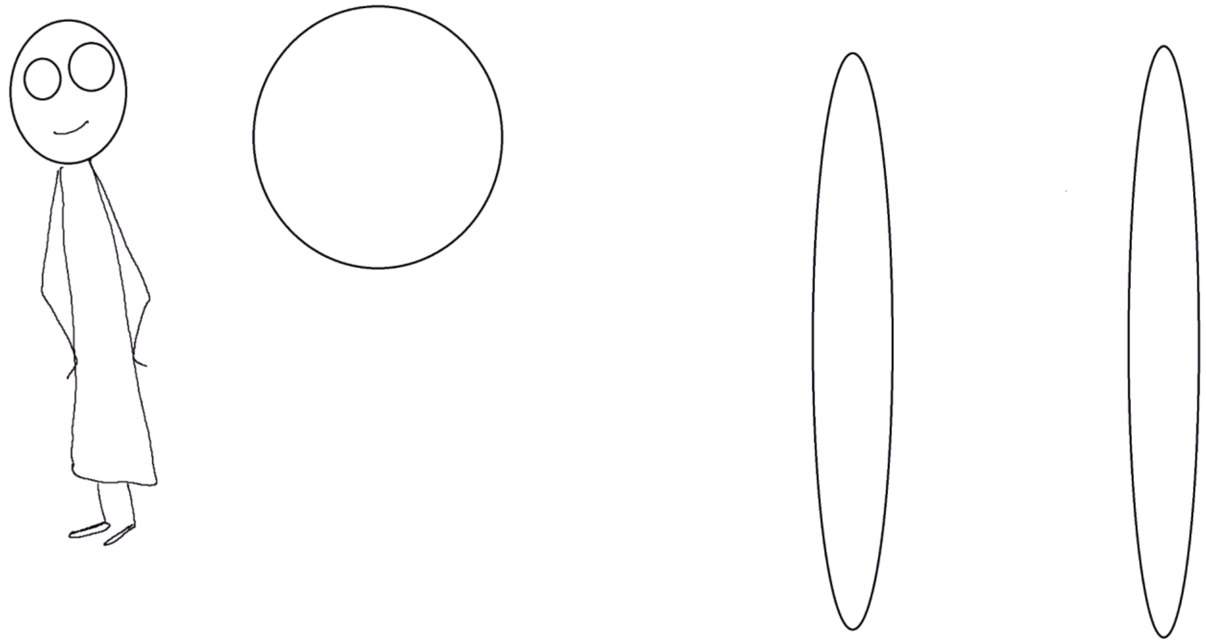


Figure 6.8: The pedigree chart showing the inheritance pattern of attached lobe

In the first generation, both parents lacking the attachment of ear lobes, resulted mixed progenies with attached and free ear lobes. This tells us that those two parents were heterozygous (Ft), and among the progeny, two males with attached ear lobes carry homozygous recessive alleles (fl) and a male and female with free ear lobe may carry heterozygous (Ff) or homozygous dominant alleles (FF). Another cross happened at the first generation between a male with attached ear lobe and a female with free ear lobe. This resulted one daughter with attached earlobe. Therefore, she must possess ff and the other must be Ff. A male from one family and a female from another family, at the second generation expressing free ear lobe phenotype, had resulted progeny having two females, one with attached ear lobes and the other with free ear lobes for the third generation. Therefore, the second generation male and female crossed with free year lobes must be Ff. Third generation female with attached ear lobes must carry fl genotype and the other may carry either FF or Ff.

The probability that another child from the same family will have attached earlobes could be calculated using a monohybrid cross (Ff x Ff). Since homozygous recessive (ff) genotype is causing the condition, the probability is 1/4 for each child.



Scientific basis of Mendel's experiments

Mendelian Heredity (Mendelism)

Principles in heredity were first formulated by an Austrian Augustinian monk named Gregor Mendel, who is now considered the father of modem genetics. Mendel discovered the basic principles of heredity by breeding garden peas in carefully planned experiments

His experiments were conducted decades before the concept of chromosomes. The later discovery of chromosomes as the carriers of genetic units supported Mendel's two basic laws of genetics which are now known as Mendelism.

Vocabulary in genetics

There are numerous heritable variations among individuals of a population such as brown, green, or blue eyes or black, brown, or blond hair in human population. A heritable feature that varies among individuals of a population, such as hair colour or eye colour is called a **character** in genetics. These heritable variants of a character in an organism, such as brown or blond hair or blue, brown or black eye colour in human are called as **traits**. These traits are transmitted from parents to offspring, Observable traits of an organism is known as phenotype.

Mendel has described about 'heritable factors' in explaining his experimental results. These heritable factors are identified to be **genes** in modern genetics. **Gene** is the basic unit by which genetic information is passed from parent to offspring. It is a nucleotide sequence of DNA residing usually at a specific **locus** on a particular chromosome and contributes to the development of one or more traits by coding for specific proteins or peptides. Locus (Loci in plural) is a fixed position on a chromosome.

There are alternative versions of genes which are called **alleles**. Alleles reside on the same locus of different chromosomes. Alleles vary in their sequence of nucleotides. This change can affect the function of the protein encoded by the gene and thus the phenotype of the organism Each diploid organism has at least two copies of each gene, residing on the chromosomes received by the two parents. These copies could be identical or could differ from one another. The condition of having two identical alleles for a given gene is known as **homozygous** state. Alternatively, having two different alleles for a given gene is referred to as **heterozygous** state.

Pedigree analysis

Diagramatic representation of the inheritence of a particular trait within a given family tree, is called pedigree chart. It is constructed by collecting data for many generations Within a given family, so that the pattern of inheritence can be understood.

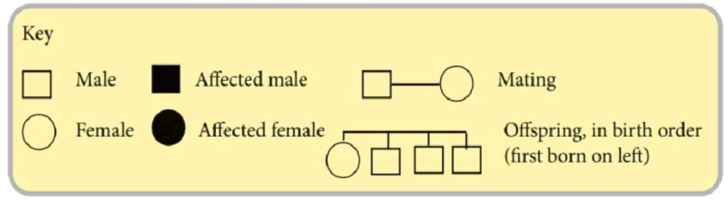


Figure 6.6: Standard Pedigree Symbols

Common Mendelian characteristics in humans analysed with pedigree charts

Widow's peak:

The inheritence of the trait, widow's peak, over three genertations in a particular family is represented in the pedigree chart given below. As shown in figure 6.7, only one grand parent had widow's peak, out of the two pairs. Since widow's peak is a dominant character, grand parents without widow's peak should be homozygous recessive (WW) for the trait. In the next generation some individuals showed the widow's peak, while the others did not. The two grand parents, who express the widow's peak should be heterozygous (WW) for the condition . Likewise, the two parents of the third generation, who are showing widow's peak should be heterozygous for it, as one of both their parents (l" generation) are homozygous recessive (ww). the third generation with widow's peak can carry either WW or WW geneotype, as both their parents are having the trait.

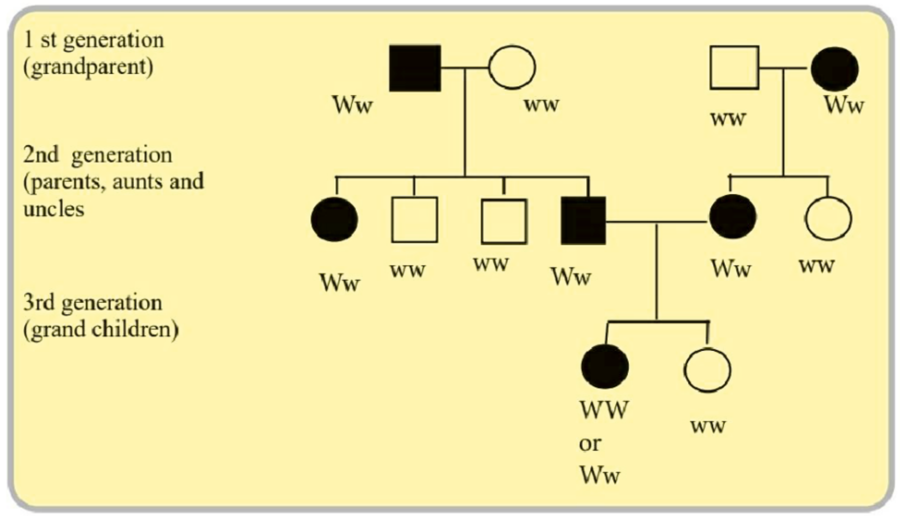
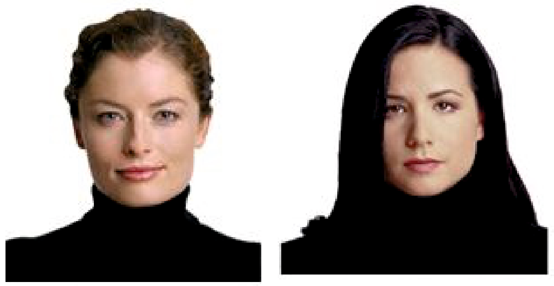
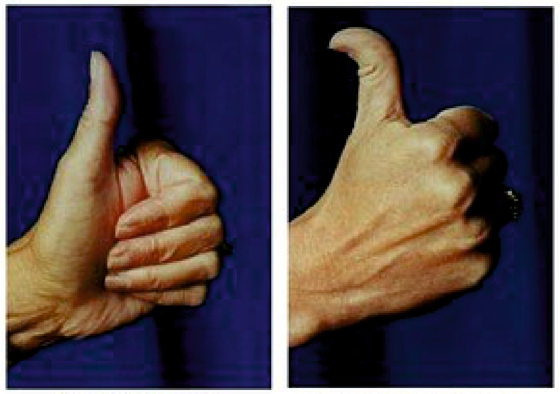


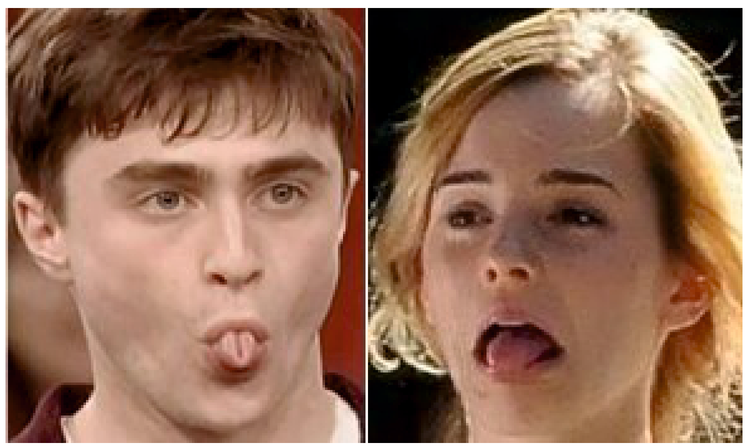
Figure 6.7: Inheritance of Widow's peak



Widow's peak　No Widow's peak



Regular thumb　Hitchhiker's thumb



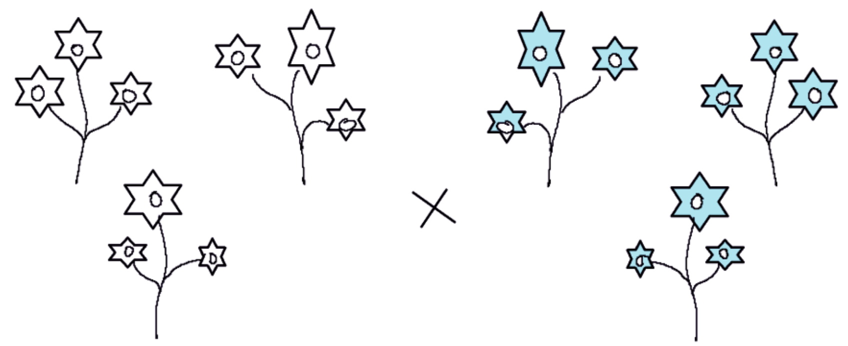
Phenotype is brought about by the interaction between genotype of the individual with its environment The genetic make up, or set of alleles, of an organism is known as its **genotype**. An individual's genotype could be either homozygous or heterozygous With respect to a given gene.

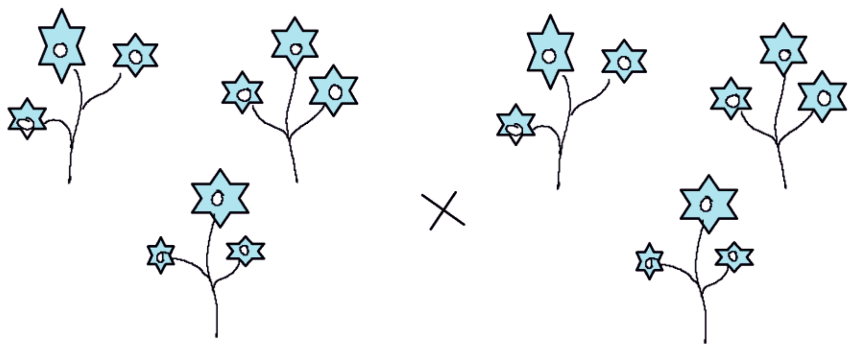
At heterozygous state, the allele which determines the organism's phenotype by masking the expression of the other is referred to as the **dominant allele**. The trait produced by the dominant allele is known as the **dominant trait**. The allele which does not exhibit any noticeable effect on the organism's phenotype at heterozygous state is referred as the recessive allele. The trait hidden on the recessive allele is the **recessive trait**. However, they express their trait when they exist in homozygous state.

Mendel tracked only those characters that occurred in two distinct, contrasting phenotypic forms, such as tall stem length vs, short stem length or purple flower colour vs White flower colour. Such traits are referred to as **contrasting traits.**

Mendel used only the **pure breeding** (sometimes called **true breeding**) varieties for his experiments. Pure breeding plants are obtained by self-pollinating over many generations, producing only the same variety as the parent plant. These uniform lines produced from self-fertilization of pure breeding varieties over many generations are called **pure lines.**
During his experiments, Mendel cross—pollinated pure-breeding garden pea plant varieties which shows contrasting **traits**. For example, purple—flowered plants were cross bred with White- flowered plants, Mating or crossing of two pure—breeding varieties with contrasting **traits** is called **hybridization**. Parental generation is referred to as the **P generation** (parental generation), Plant progeny resulted from these hybridization events are referred to as **F_1 generation** (First Filial generation, the word filial from the Latin Word for "son"). The progeny that results from the self or cross pollination between these F_1 generation plants are known as **F_2 generation** (Second Filial generation).

An organism that is heterozygous with respect to a single gene of interest resulting from a cross between parents having homozygous condition for different alleles of specific gene is referred to as a '**monohybrid**'. Breeding experiment conducted between two organisms With heterozygous condition for a specific character is referred to as '**monohybrid cross**'.
An organism that is **heterozygous** with respect to two genes of interest resulting from a cross





Patterns of inheritance of Mendelian characteristics in humans

Common Mendelian characters

Many human traits follow Mendelian patterns of inheritance. Some common examples are stated below;

Attached or detached earlobe:

The extent to which the earlobe is attached to the head is inherited in the Mendelian pattern. The attached earlobe is a recessive trait. Presence of both copies of the recessive allele (homozygous recessive condition) for ear lobe attachemnt would result in attached ear lobe.

Willow's peak:

The pointed contour of the hairline on the forehead is known as Widow's peak. It is due to a dominant allele, W. Therefore, all individuals who lack a widow's peak must be homozygous recessive (ww).

Dimples on cheek:

Cheek dimples are a genetically transmitted trait found in the muscle of the cheek.

When a person smiles, the shorter muscle on the face pulls up the facial skin. This, in turn, creates a slight depression in the skin, which is called dimple. Dimples often occur on both the cheeks. A single dimple on one cheek is a rare phenomenon. Dimple is a dominant trait and inherited in Mendelian fashion.

Bent thumb (Hitchhiker's thumb) and Straight thumb

Hitchhiker's thumbs is a condition Where thumb bend backwards While stretching due to the hyper extensibility of interphalangeal joints. Having the dominant 'S' allele would produce the dominant phenotype of straight thumb. The absence of the dominant alleles would allow the thumb to bend.

Rolling or non-rolling tongue

The ability to roll the lateral edges of the tongue upwards into a tube is known as tongue rolling. The tongue's intrinsic muscles allow some people to form their tongues into specific shapes. Rolling the tongue into a tube shape is a dominant trait with simple Mendelian inheritance

P generation RrBb X rrbb

Gametes RB Rb rB rb → rb

F_1 RrBb- Red coloured petals with black coloured seeds – 25%

Rrbb- Red coloured petals with brown coloured seeds- 25%

rrBb- white coloured petals with black coloured seeds- 25%

rrbb- white coloured petals with brown coloured seeds- 25%

Figure 6.5: (a) Possible outcomes of a dihybrid test cross

In this example, above four phenotypes are possible with l:l:l:l ratio.

If the unknown phenotype has the RRBb genotype, the resulting dihybrid cross will produce following phenotypes;

P generation RRBb X rrbb

Gametes RB Rb → rb

F_1:

RrBb- Red coloured petals with black coloured seeds-50%

Rrbb- Red coloured petals with brown coloured seeds-50%

The above phenotypes will be resulted with 1:1 ratio.

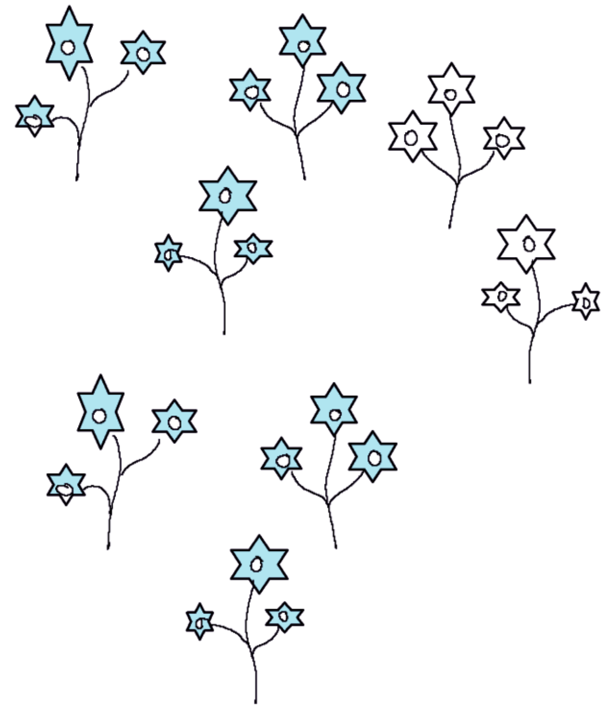
In this manner we can find out the unknown genotype of a dominant phenotype by the testcross.

Figure 6.5: (b) Possible outcomes of a dihybrid test cross

Questions

1. In a test cross, an organism with
   (l) dominant trait is crossed with one of its parents.
   (2) recessive trait is crossed with one of its parents.
   (3) dominant trait is crossed with an organism showing recessive trait.
   (4) recessive trait is crossed with an organism showing dominant trait.
   (5) dominant trait is crossed with an organism of the Fl generation. 2019 AL/Old 31

2. In chickens, R = rose comb, r = single comb. How could determine if a rose combed rooster were heterozygous or homozygous?



The testcross

This is a deliberate breeding process performed in order to determine the unknown genotypes The genotype of an individual showing dominant trait may be due either to double dominant genotype or to heterozygous status. This involves the crossing of an organism having unknown genotype for a selected phenotype along with another organism from same species having homozygous recessive condition for same character

Testcross performed during the monohybrid cross is called as monohybrid testcross. On the other hand, test cross performed during the dihybrid cross is called as dihybrid testcross.

Monohybrid testcross

Let's consider an example for monohybrid testcross. In this example we Want to know the genotype of the given tall pea plants. In order to do that, we will cross the tall pea plant with the dwarf pea plant. Since dwarf is a recessive trait the genotype of it will be tt.

There may be two possible genotypes for tall pea plants;

1. TT
2. Tt

Assume that unknown pea plant is having genotype of TT

Cross between TT and tt will result the following

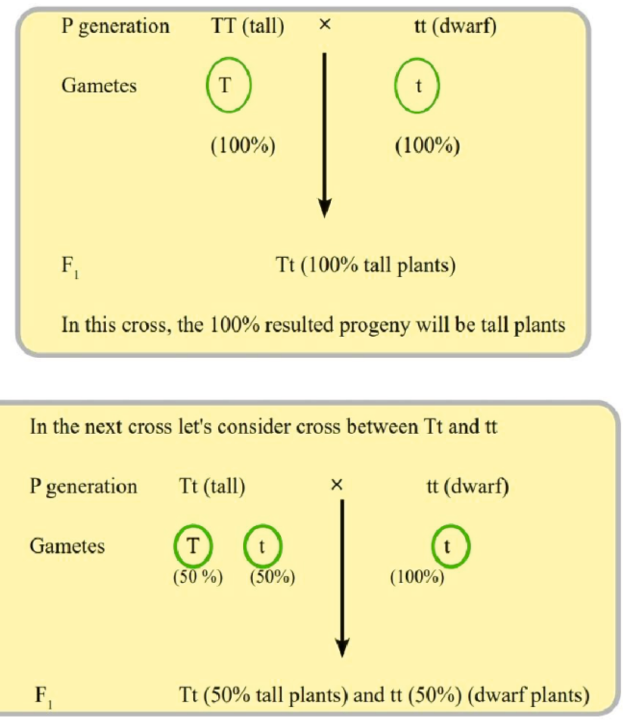


Figure 6.4:Two possible outcomes of a monohybrid test cross

Questions

1. Tall pea plant character dominant to short. Use the rule of multiplication to find out the probability of having a short plant if both parents are carriers for short.

2. Use the rule of multiplication and addition to find out the probability of having a heterozygous tall plant if both parents are carriers for short.

3. In a dihybrid cross for seed color and seed shape, Probabilities genotype of seed color BB = 1/4, Bb = 1/2 and bb = 1/2. Probabilities of genotype of seed shape, RR = 1/4, Rr = 1/2, rr = 1/4. Find probability of getting BbRr in BbRr x BbRr cross.

4. If AaBb crossed with AaBb what is the probability of getting following genotypes in the population.
(a) AABB (b) AaBb (c) AABb (d) aaBb (e) Aabb

5. In a cross of BbRr x BbRr find probability of bbRr and bbrr genotypes.

6. In a cross between AaBb x AaBb. What is the probability of dominant phenotype and double recessive phenotypes in the offsprings.

7. In a cross of AaBb x AaBb find probability of A_B_, A_bb, aaB_, aabb Phenotypes.

8. In a cross between AaBbcc x AaBbCc. What is the probability of AaBBCc among resulting offsprings.

9. Probability calculated for 3 factor cross AaBbCc x AaBbCc. ABC are dominant alleles. What is the probability that off springs will posses at least one recessive phenotype.

10. In a cross of YyBbRr x yyBbrr find probability of YBR phenotype.

11. In a cross of YyBbRr x yyBbrr, find probability of Y_BBRr and Y_BbR_, genotypes.

12. In a cross of AaBbCc x AaBBCC find probability that the offspring will be AABbCc or AABBCC.

13. For the same cross described in the section above (*AaBbCCdd* x *AabbCcDd*), what are the odds of getting offspring with the recessive phenotype for all four traits?

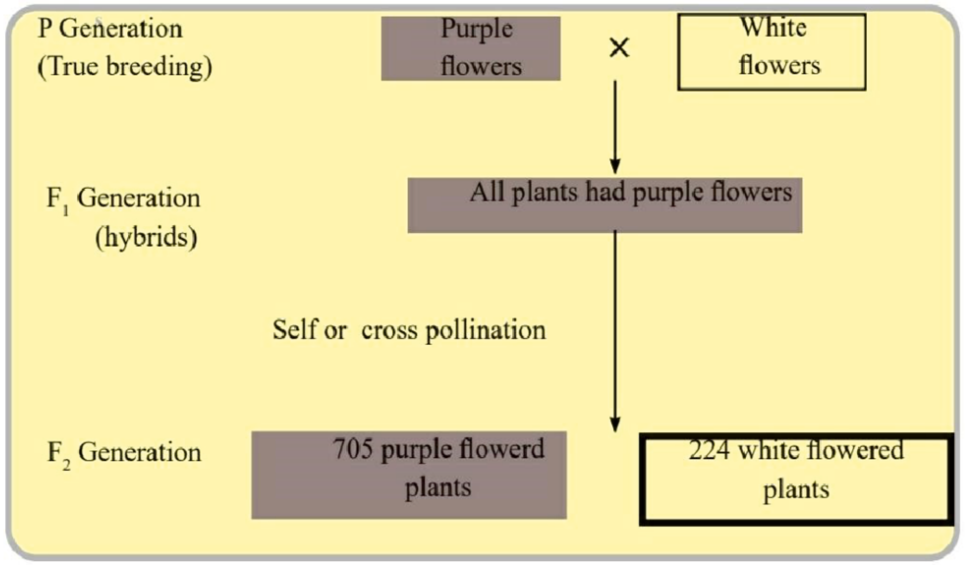
14. In a cross of AaBbCc x AaBBCC find probability of AaBbCC genotype.
A trihybrid cross for flower color, seed color and seed shape.
Y: Dominant allele for yellow colour petals y: Recessive allele for white coloured petals
B: Dominant allele for black coloured seeds b: Recessive allele for brown coloured seeds
R: Dominant allele for round seeds r: Recessive allele for wrinkled alleles
YyBbRr x yyBbrr
(i) What is the probability of forming YyBbRr genotype.
(ii) How may are going to have (yyBbrr) genotype
(iii) Assume that the above crossing has resulted 640 plants in the F1 generation. How many are having Yellow coloured petals with black round seeds
(iv) Determine the number of plants exhibits dominant phenotype for at least for two characters.

between parents having homozygous conditions for different alleles of two specific genes is referred to as a '**dihybrid**'. Breeding experiment conducted between two organisms with heterozygous conditions for two specific characters is referred to as a '**dihybrid cross**'.

Breeding an organism having unknown genotype for a specific dominant trait with an organism having homozygous recessive condition for the same specific trait is called a test cross. This is usually done to reveal the unknown genotypes for specific dominant traits in an organism.

Monohybrid Cross

Mendel derived his first law of inheritance by following only a single character in one breeding experiment, such as flower colour. He started by crossing pure breeding parents with contrasting **traits**. All the F_1 progeny produced from pure breeding parents are **monohybrids**, meaning that they are heterozygous for the particular character being followed in the cross. F_1 hybrid pea plants were then self- or cross-pollinated and F_2 generation was produced to explore the traits resulting from a monohybrid cross (Figure 6.1).



Mendel, during his experiment, crossed pure breeding purple flowered plants and White flowered plants. Then he allowed the resulting F_1 hybrids to self and cross-pollinate with other F_1 hybrids. Finally, he observed the F_2 generation plants for the colour of the flowers. During his observation, all F_1 plants produced purple colour flowers. However, in the F_2 generation, both purple and white flowered plants appeared in a ratio of approximately 3: l. Among the heterozygote resulted in the F_1 generation, the "heritable factor" responsible for

Eg. 2: A trihybrid cross for flower colour, seed colour and seed shape.

Y: Dominant allele for yellow colour petals y: Recessive allele for White coloured petals

B: Dominant allele for black coloured seeds b: Recessive allele for brown coloured seeds

R: Dominant allele for round seeds r: Recessive allele for wrinkled alleles

YyBbRr x yyBbrr

(YyBbRr) : Yellow coloured petals y: Recessive alleles for white coloured petals

(yyBbrr) : White coloured petals black wrinkled seeds.

Flower color	
Genotype	Probability
YY	0
Yy	½
yy	½

Seed shape	
Genotype	Probability
BB	¼
Bb	½
bb	¼

Shape of the seeds	
Genotype	Probability
RR	0
Rr	½
rr	½

The above crossing has resulted 640 plants in the Fl generation. Determine the number of plants exhibits dominant phenotype for at least two characters.

1. Possible genotypes with their individual probabilities for above conditions

   YyBBRr : 1/2 (probability Yy) x 1/4 (BB) x 1/2 (Rr) = 1/16

   YybbRr : l/2 x l/2 x1/2 = 1/8

   YyBBrr : l/2 x l/4 x l/2 = 1/16

   YyBbrr : l/2 x l/2 x l/2 = 1/8

   YybbRr : l/2 x l/4 x 1/2 = 1/16

   yyBbRr : l/2 x l/2 x l/2 = 1/8

   yyBBRr : l/2 x l/4 x 1/2 = 1/16

2. Probability of exhibiting at least two dominant characters: 1/16 + 1/8 + 1/16 + 1/8 + 1/16 + 1/8 +1/16:10/16: 5/8

3. Number of plants expected to exhibit at least two dominant characters : 5/8 x 640: 400 plants

ii. The recessive allele from the egg and the dominant allele from the sperm; the probability of the event = 1/4 (according to example in above 3rd sentence)

So, the probability of getting an F_2 heterozygote = 1/4 + 1/4 = 1/16

Prediction of the inheritance patterns in multifactorial crosses

When the pattern of inheritance of two or more characters of an organism is being traced during a genetic cross, it could be called as multifactorial cross. Finding out the outcomes of a multifactorial cross through a Punnett square may be a difficult task. Therefore, applying rules of probability may be useful to predict the outcomes of a multifactorial crossing.

According to the law of segregation, a multifactorial cross can be considered equivalent to multiple independent monohybrid crosses occurring simultaneously

Eg. : Dihybrid cross for seed color and seed shape,

Probabilities for seed color (based on the Punnett square for monohybrid cross)

Seed color	
Genotype	Probability
BB	¼
Bb	½
bb	¼

Seed shape	
Genotype	Probability
RR	¼
Rr	½
rr	¼

B: dominant allele for black colour seed b: recessive allele for brown coloured seeds

R: dominant allele for round shaped seeds r: recessive allele for wrinkled shaped seeds.

The probability of each of the genotypes in the F2 generation can be determined by using the multiplication rule.

Probability of BbRr = 1/2 (probability of Bb) x 1/2 (probability Rr) = 1/4

Probability of bbRr = 1/4 (bb) x 1/2 (Rr) = 1/8

Probability of bbrr = 1/4 (bb) x 1/4 (rr) = 1/16

producing White flowers were suppressed in presence of the "heritable factor" that produces purple flowers. As a result, the heterozygotes were all producing purple colour flowers. Therefore, the ‘heritable factor” for purple flower colour is dominant to the White (dominant trait). Accordingly, the factor for white flower colour is referred as the recessive trait.

Mendel observed that the same pattern of inheritance consistently occured in six other characters; position of the flower, colour of the seed, shape of the seed, shape of the pod, colour of the pod and the length of the stem.

Mendel’s first law of inheritance: The law of segregation

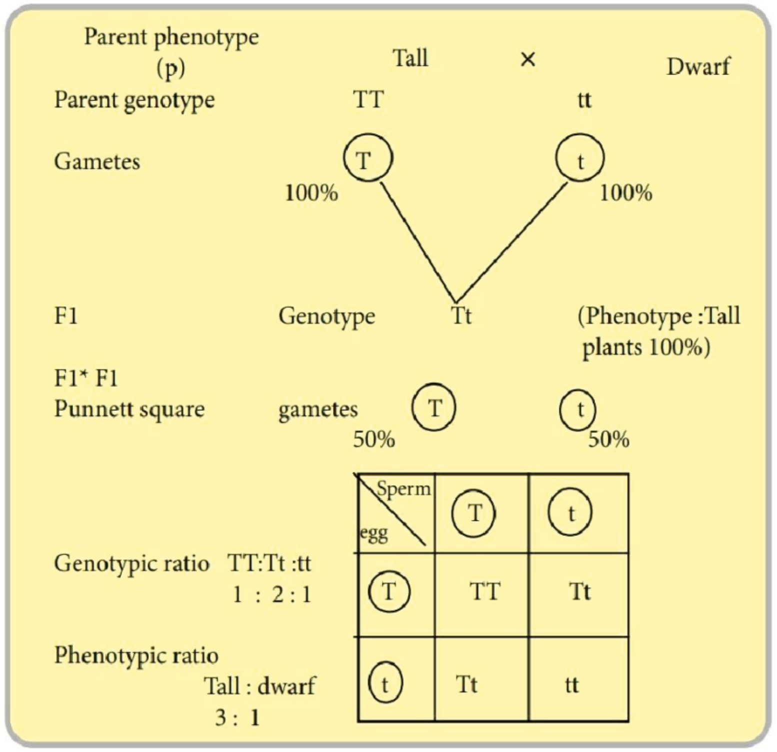
Mendel’s first law was put forward to explain the 3:1 inheritance pattern observed among the F2 offspring in his monohybrid experiments using Pea plants.

As per his hypothesis, each ‘heritable character’ is determined by two "heritable factors” which are known as alleles. During the formation of gametes, the alleles for a ‘heritable character” are separated and get in to each of the gametes formed. This is now known as **Mendel’s law of segregation or Mendel’s first law in inheritance.**

Analyzing genotype and phenotype ratios using Punett square

In Pea plants, Mendel observed two different **traits** based on stem lengths; tall and dwarf. For his experiments, pure breeding tall and dwarf Pea plants Were selected for cross pollination. Thereafter the F_1 generation was self pollinated in order to obtain F_2 generation.

During self pollination of F| hybrids, gametes carrying different alleles fuse randomly. Such random fusion of gametes produces zygotes with four genetic combinations. A Punnett square can be used to illustrate these genetic combinations. A Punnett square is a graphical representation of the possible geneotypes of an offspring arising from a particular cross or breeding event. An example is given figure 6.2.



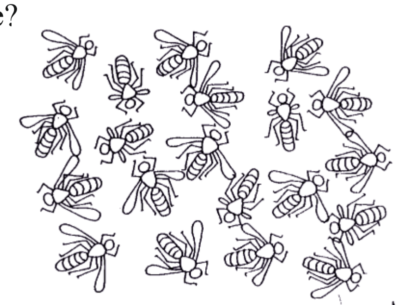
Questions

1. In garden peas, round peas are dominant to wrinkled peas. If you crossed a homozygous dominant and homozygous recessive what would be the genotype and phenotype of the offspring?

2. In humans brown eyes are dominant over blue eyes. What type of offspring would you expect if you crossed a heterozygous brown eyed person to a heterozygous brown eyed person?

3. Pod colour of pea plants were determined by two alleles. Y– Yellow, y —Green. Two pea plants heterozygous for the characters of pod color are crossed. Draw a Punnett square to determine the phenotypic ratios of the offspring.

4. The drawing below shows fruit flies produced in a genetics experiment.
   (a) State the way in which the two types of flies are different, and count the numbers of each type.
   (b) Which characteristic is dominant and which is recessive? The numbers of each type represent the ratio resulting from crossing two types of fly. Assume that "A" and "a" represent the alleles involved in the cross. Which of the following crosses would produce this ratio?
   AA x aa; Aa x Aa; AA x AA; or aa x aa?



5. In a certain plant yellow fruit is dominant to white fruit. A heterozygous plant with yellow fruit is crossed with a plant with white fruit. Determine the probable offspring.

6. A Tall plant (T) is dominant to short plant (t). If all offspring of a cross are heterozygous, what were the genotypes of the parents?

7. A round seeded plant (R) is dominant to a wrinkled seeded plant (r). What parental genotypes will produce offspring that are 50% homozygous dominant and 50% heterozygous?

8. In pea plants purple flowers are dominant to white flowers.
(a) What parental genotypes would produce offspring that are all heterozygous for the purple trait?
(b) A white flowered plant is crossed with a plant that is heterozygous for the trait. What percentage of the offspring will have purple flowers?
(c) If out of 100 offspring 74 are purple flowered and 26 are white, what were the probable genotypes and phenotypes of the parents? What are the parental genotypes needed to produce 100% white flowers?

9. In humans, tongue rolling is a dominant trait, those with the recessive condition cannot roll their tongues. Bob can roll his tongue, but his mother could not. He is married to Sally, who cannot roll her tongue. What is the probability that their first born child will not be able to roll his tongue?

10. Which of the following statements regarding the cross Rr x Rr is correct?
(1) The probability of having the allele r in both the egg and sperm at fertilization is 1/2.
(2) This is a dihybrid cross because two alleles are involved.
(3) According to Mendelian inheritance, the probability of having dominant phenotype in F_2 generation by interbreeding of F_1 is 9/16
(4) If 1:2:1 ratio of phenotypes was obtained in F_2 generation by interbreeding of F_1 generation, it may be due to codominance.
(5) R and r are linked. 2020 AL/31

Probability laws and Mendelian inheritance

Mendel's laws of segregation and independent assortment reflect the same rules of probability that applies to tossing coins, rolling dice, and drawing cards from a deck. **Probability** measures how likely an event is to occur out of the number of possible outcomes. It is calculated by dividing the number of events of interest by the number of total possible outcomes.

1. The probability scale ranges from 0 to 1.
   An event that is certain to occur has a probability of 1, While an event that is certain not to occur has a probability of 0.
   During allele segregation in a Fl plant (heterozygous) of a monohybrid cross,
   -probability of each egg carrying the dominant allele = 1/2
   -probability of each egg carrying the recessive allele = 1/2

2. The probabilities of all possible outcomes for an event add up to 1.
   During allele segregation in a heterozygous Fl plant, probability of all events (having dominant and recessive alleles) = 1/2 +1/2= 1

3. When the occurrence of an event does not affect the occurrence of another event (independent events), the probability of simultaneous occurrence of both events can be obtained by multiplying the probability of one event by the probability of the other event. This is known as the **Multiplication Rule** or **Product rule in Probability.**

In Mendel's monohybrid crosses, for a F_2 plant to have wrinkled seeds (rr), both the egg and the sperm that come together must carry the r allele.
The probability that the egg will have an r = 1/2
The probability that the sperm will have an r = 1/2
The probability of both gametes at fertilization carrying r allele = 1/2 x 1/2 = 1/4.

4. The probability that any one of two or more mutually exclusive events will occur is calculated by adding their individual probabilities. This is the addition rule or sum rule of probability
   There are two possible mutually exclusive ways for producing Fz heterozygotes.
   i. The dominant allele come from the egg and the recessive allele from the sperm; the probability of the event = % (according to example in above 3rd sentence)

4. Using the same traits as above, cross a dwarf and homozygous red plant with a yellow and heterozygous tall plant. (You chose the letters you want to use)
   1. What percent of the offspring will be totally heterozygous?
   2. What is the phenotype ratio?
   3. What percent of the offspring will have red fruit and dwarf vines?

5. An aquatic arthropod called a Cyclops has antennae that are either smooth or barbed. The allele for barbs (B) is dominant over smooth (b). In the same organism Non-resistance to pesticides (N) is dominant over resistance to pesticides (n). If a homozygous barbed Cyclop bearing pesticide resistance, was crossed to a double recessive Cyclop, what are the expected phenotypic and genotypic ratios for F_2 generation?

6. In fruit flies alleles for grey body colour G, is dominant to the allele for black body g, and the allele for normal wings N, is dominant to the allele for vestigial wings n. A cross between a grey bodied, normal winged fly and black bodied vestigial winged fly resulted in the following offspring.

   Grey bodied, Normal winged - 25   Grey bodied, Vestigial winged - 26
   Black bodied, Normal winged- 24   Black bodied, Vestigial winged - 27

   (a) Give the genotype of the grey bodied, normal winged offspring.
   (b) What phenotypic ratio would you expect in the offspring produced if the grey bodied normal winged parent has been crossed with a fly of the same genotype?

7. In guinea pigs, black hair colour (B) is dominant and brown hair colour (b) is recessive. Long hair (L) is dominant and short hair (l) is recessive. Answer the following questions:
   (a) Diagram the cross: BbLl x BbLL
   (b) What are the phenotypes of the parent generation?
   (c) What are the genotypes and phenotypes of the F1 generation?

8. Suppose in a strain of soybeans, high oil (H) content in the seeds is dominant to low oil content and four seeds (E) in a pod is dominant to two seeds in a pod. A farmer crosses two soybean plants, both with high oil content and four seeds per pod. The resulting F1 offspring have a phenotypic ratio of 9:3:3:1 (High oil / four seeds : High oil / two seeds : Low oil / four seeds : Low oil / two seeds). What genotype were the parent plants? Suppose the farmer chooses two of the high oil / four seed plants and crosses them. The F2 generation have all high oil / four seed phenotypes. What were the genotypes of the plants chosen by the farmer to cross?

9. If two individuals having genotype AaBb for two particular traits are crossed, how many different genotypes can appear in the progeny according to Mendel's laws?
   (1) 2   (2) 3   (3) 4   (4) 8   (5) 16   2023 AL/30

10. A cross between two individuals having heterozygous genotype for tm raracters usually results in 9: 3: 3: I ratio of phenotypes in their progeny. In some cases the phenotypic ratio in the progeny is 3: 1. This may be due to
   (1) codominance. (2) interaction of genes (3) incomplete dominance. (4) polygenic
   (5) gene linkage.   2019 AL/Old 33

Dihybrid Cross

Mendel identified his second law of inheritance by following two characters at the same time, using **dihybrid crosses**. A cross between two heterozygous organisms with contrasting traits for two specific characters being followed is known as a **dihybrid**. Breeding experiment conducted between two organisms with heterozygous conditions for two specific characters is referred to as a '**dihybrid cross**". The aim of the Mendel's dihybrid cross experiment was to find out whether the alleles for one character assort into gametes dependently or independently of the alleles of the other character.

Mendel crossed a true—breeding plant with yellow-round seeds with a true breeding plant with green-wrinkled seeds (Figure 6.3). The cross produced dihybrid F| plants, all of which have yellow—round seeds. As shown by the monohybrid crosses, the allele for yellow seeds is dominant (Y) over the allele for green seeds (y) which is recessive likewise, the allele for round seed is dominant (R), and the allele for wrinkled seed is recessive (r). The F1 hybrids, are heterozygous for the two characters being followed in the cross (YyRr). The cross between FI dihybrids produced the F_2 generation.

This lead towards two alternative hypothesis for inheritance which predict different phenotypic ratios as shown in Figure 6.3.

1. The two characters could be transmitted from parents to offspring as a package. The dominant Y and R alleles or the recessive y and r alleles are passed together, generation after generation This is called **dependent assortment** of alleles. According to this hypothesis only two types of gametes are possible; Le. YR and yr. Thus the phenotypic ratio of the F2 generation would be similar to that of a monohybrid cross (3:1)

2. The two characters (seed colour and seed shape) could be transmitted from parents to offspring independent of each other i.e. Y allele could be passed either with R or r allele vice versa. This is called **independent assortment** of alleles.
   This hypothesis predicts four different allelic combinations for a biallelic locus and thus four different types of gametes from F1 generation; i.e, YR, Yr, yR and yr. According to this, both male and female gametes have four possibilities for each. Therefore, during the union of male and female gametes, there are 16 (4 x 4) equally probable ways in which the alleles can combine to produce the F_2 generation. As shown in Figure 3, these combinations would give rise to four different phenotypes with a ratio of 9:3:3:l (nine Yellow round to three Green-round to three Yellow-wrinkled to one Green-wrinkled).

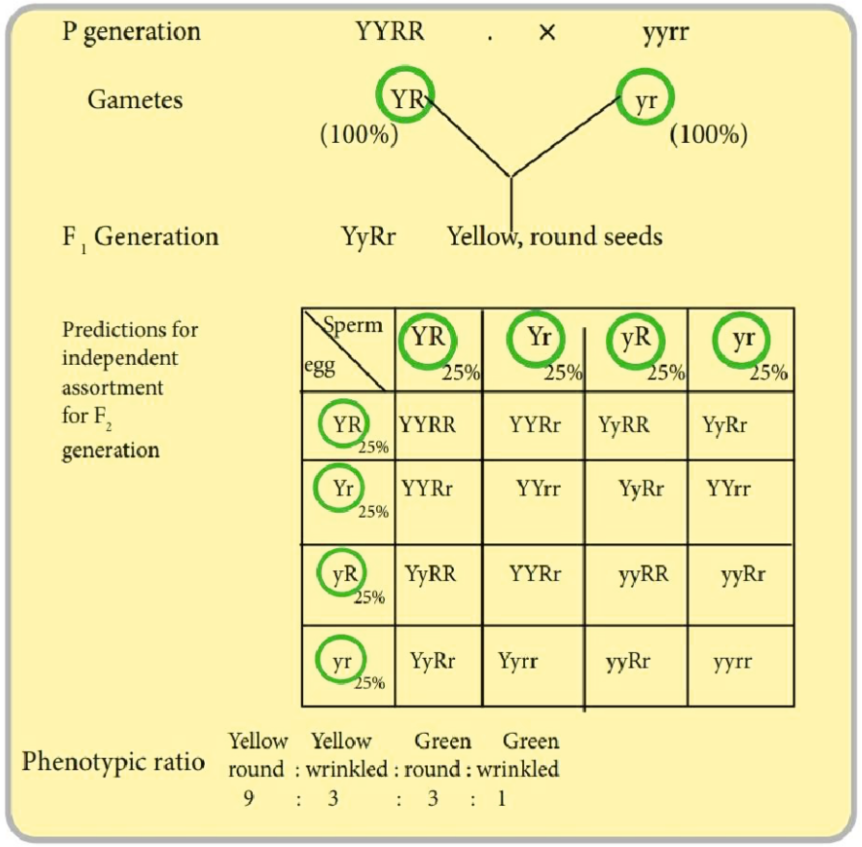


Figure 6.3: Alternative forms of inheritance patterns possible in a dihyhrid cross

Mendel's experiment produced the four distinct phenotypes (Yellow—round, Green—round, Yellow—wrinkled and Green—wrinkled seeds) predicted in the second alternative hypothesis in the ratio of 9:3:3:1. This showed that, the alleles responsible for each trait assorted independently of those of the other.

Mendel's second law of inheritance (The law of independent assortment)

Based on these experiments, Mendel put forward his second law of inheritance - the law of independent assortment. The law states that, alleles separate and pair up independently during the formation of gametes. As a result of that, two or more genes assort independently irrespective of the other.

However, according to current knowledge, this condition applies to two circumstances only;

- To genes located on different chromosomes (genes on non—homologous chromosomes)
- To genes located far apart on the same chromosome

Success of Mendel's experiments

Mendel followed a scientific approach in conducting his experiments. The following features in his experiments helped him to unravel the two fundamental principles of heredity.

- Mendel carried out thousands of genetic crosses of any given kind. This allowed his results to closely resemble the probability predictions. Usually, the larger the sample size, the closer the results to the value predicted based on the probability. He kept accurate records of his results, These records helped him to trace the patterns which otherwise would go unnoticed.
- He usually followed up each cross for at least two offspring generations (F_1 and F_2). This helped him to uncover some of the traits hidden in the Fl generation.
- He did a quantitative analysis of the phenotypes of the resulting offspring

Desirable properties in garden peas for genetic experiments

Garden peas (*Pisum satívum*) carry following desirable properties which makes it a suitable organism to study patterns of inheritance

- Pea plants are available in many varieties with contrasting traits.
- The generation time is short.
- A large number of offspring is produced from each cross.
- Crossing between the plants could be strictly controlled (self/ cross pollination).

Questions

1. Tall *Pea* plants "T", are dominant to dwarf *Pea* plants "t". Round seeds "R", is dominant to wrinkled seeds "r".
   If a homozygous tall *Pea* plant bearing round seeds, was crossed to a double recessive plant, what are the expected phenotypic and genotypic ratios for F_2 generation? Show how you can identify the genotype of *Pea* plants with same phenotype.

2. A homozygous dominant corn plant producing starchy endosperm and coloured seeds was hybridized with a homozygous recessive corn plant producing non starchy endosperm and colourless seeds. All F_1 plants produce starchy endosperm and coloured seeds. When two F_1 plant was crossed following progenies were resulted.
   Starchy/Colored - 1856
   Non-starchy/Coloured - 585
   Starchy/Colorless - 673
   Non-starchy/Colourless - 332 Explain these results fully.

3. Yellow fruit and dwarf vines are recessive traits in tomatoes. Red fruit and tall vines are dominant. Complete a Punnett square and answer the questions for a completely dominant red and tall plant crossed with a heterozygous red and dwarf plant. (You chose the letters you want to use)
   1. What percent of the offspring will be totally heterozygous?
   2. What is the genotype ratio?