D. Analyse and interpret the following.

1. Write the mode of reproduction of an onion, corn, ginger and potato.
2. Make a list of ripened seeds and fruits that are eaten in our society.
3. Germinate a few gram seeds and examine the different requirements of water, temperature and oxygen by putting them in various conditions.

Activities

1. Identify different stages of budding in prepared slides of yeast and draw diagrams.
2. Examine the specimens of onion, corn, ginger and potato and write the mode of their reproduction. Describe how these are cultivated to get new plants.
3. Identify different parts of a flower.
4. Identify and draw the component of the seeds of pea or gram.
5. Perform an experiment to investigate the necessary conditions for seed germination.
6. Draw different stages of binary fission in amoeba after observing through slides or charts.

Science, Technology and Society

1. Grow plants at home using asexual reproduction methods.
2. Describe commercially important applications of asexual reproduction in plants.
3. Justify cloning as a form of asexual reproduction.
4. State the advantages and disadvantages of having large families.
5. Debate the social implications of AIDS and other sexually transmitted diseases.

Unit 15 INHERITANCE

Students Learning Outcomes

The students will be able to:

- Define genetics.
- Explain how genes control inheritance of characters.
- Describe the composition of chromatin material.
- Define a gene (a localized region of DNA that codes for a protein).
- State clearly the difference between a gene and an allele.
- Explain that a gene is a unit of inheritance and that it can be copied and passed on to the next generation.
- Describe the central dogma stating the role of a gene in protein synthesis.
- Describe complete dominance using the terms dominant, recessive, phenotype, genotype, homozygous, heterozygous, P1, F1, F2 generations and proving it diagrammatically through a monohybrid genetic cross.
- Demonstrate that the 3:1 monohybrid F-2 phenotypic ratio is an evidence of segregation of alleles.
- State Mendel's law of Segregation.
- Demonstrate that 9:3:3:1 dihybrid F-2 phenotypic ratio is an evidence of independent assortment.
- State Mendel's law of Independent Assortment.
- Selecting the example of ABO blood group system, explain co-dominance.
- Explain incomplete dominance in Japanese 4 O' Clock plant.
- Describe the sources of variation.
- Relate meiosis with variation.
- Describe variation and explain the difference between continuous and discontinuous variation by giving examples like, height, weight, IQ, gender and blood groups in the population.
- Define organic evolution and explain how variation can lead to evolution.
- Describe how variation leads to competition in a population and differential survival by best fitting the environment.
- Assess selection as a possible means of Evolution.
- Develop an understanding of artificial selection as a means of improvement of yield in economically important plants, like wheat, rice etc.

Introduction

You might have seen that the children of the same parents resemble each other in many characters. At the same time these children have some of their unique characteristics (variations) which they do not share with their brothers and sisters. These similarities and differences have led people to wonder how traits (characters) are transferred from one generation to the next. How do the young ones inherit these characteristics from their parents and yet what determines that the young ones are not identical to their parents? The science of genetics enables the study of various phenomena involved in deciding the pattern of inheritance.

15.1 Introduction to Genetics

Physical and mental characteristics are passed on from one generation to the other. This is observable often in eye colour, complexion of the skin, height, hair colour, etc. in human beings. Although, offsprings and parents in a particular generation may look different, there is a basic similarity that runs from generation to generation. Each generation transfers characters to the next generation. The process by which characters are transferred from parents to offsprings, is called **inheritance** or **heredity**. The branch of biology, which deals with the study of inheritance, variations and factors controlling them, is called **genetics**.

Every cell in the body contains instructions for making characters. These instructions are present in the molecules of **DNA** in the form of chemical codes called **genes**. The cells use instructions present in their DNA to produce particular proteins. The proteins made by a cell make its characters.

15.2 Chromosomes and Genes

Chromosomes are thread-like structures present in cells. They were discovered by **Waldeyer** in 1876. In prokaryotic cells, chromosomes are not enclosed in a nuclear membrane. In eukaryotic cells, chromosomes are found within the nucleus.

> **Tidbit**
> Chromosome is the name given to these structures as they readily absorb dyes and become coloured (Chromo = colour and soma = body).

When a cell is not dividing, its chromatin is in the form of fine threads scattered in the nucleus. During cell division, the chromatin coils and makes compact structures of chromosomes. A chromosome consists of two identical halves. Each half of the chromosome is called a **chromatid**. The two chromatids of a chromosome are attached at a point called the **centromere**. The centromere holds the two chromatids together until they separate during cell division.

15.2.1 Chromatin Material

Chromosomes are composed of chromatin material. In prokaryotes, the chromatin material is made of DNA only. In eukaryotes, the chromatin material is composed of DNA and **histone** proteins. Long molecule of DNA is wrapped around the bundle of histones. The structure made of histones and the DNA wrapped around them, is called a **nucleosome**. Nucleosomes are arranged in the form of beads on a string. This string of beads coils and forms the structure of chromosomes.

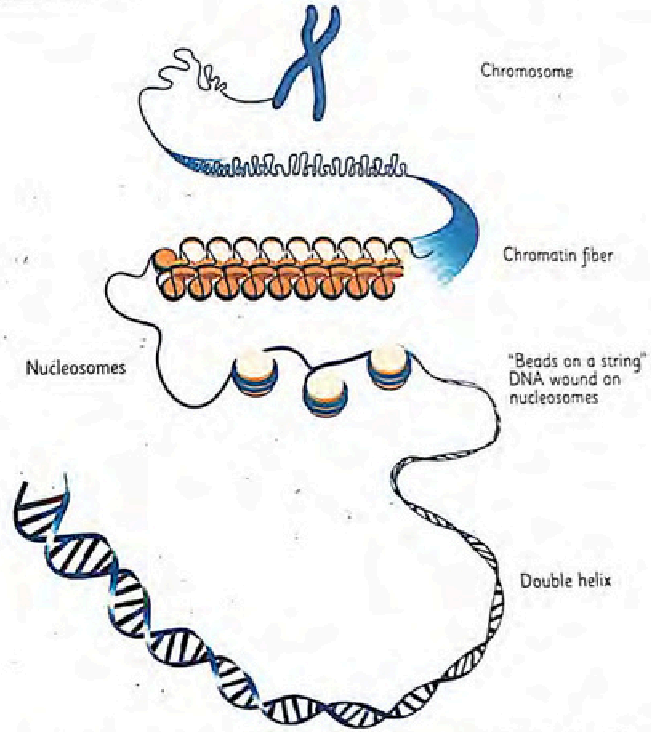


Fig.15.1 Location and Packing of Hereditary Material (DNA) in the cell

15.2.2 Gene and Allele

A gene is the fundamental physical and functional unit of heredity. A gene determines a trait or character, such as the genes for eye colour, earlobe shape, and hair texture. Genes are segments of DNA, consisting of a specific sequence and number of the nucleotides, that has a code for protein synthesis.

Genes are located on chromosomes. Like chromosomes, genes are also in pairs. Before dividing, a cell duplicates its chromosomes. Its genes are also copied. Thus, each daughter cell has an equal distribution of genes. The transfer of genes to the next generation takes place through gametes. The location of the gene on chromosome is called its **locus.** Each chromosome in a pair may carry alternative forms of the same gene. These alternate (different) forms of a gene are called its **alleles**. For example, the gene controlling height in a pea plant exist in two forms. One allele results in the tallness while the other causes, dwarfness.

The combination of the alleles of a gene pair is called **genotype**. When a gene pair has the same genes, the genotype is called **homozygous**. The genotype, in which the gene pair has different alleles, is called **heterozygous**. In the following figures, the homologous chromosomes has three gene pairs i.e. genes for eye colour, hair shape and ear shape.

- Both allelic pair of the eye colour are similar. It means that the genotype for eye colour is homozygous. Both allelic pair for hair shape are also similar. This means that the genotype for hair shape is homozygous.
- The alleles for the ear shape have instructions for different characteristics. One allele has instructions for making a free earlobe while the other allele has instructions for making an attached earlobe. This means that the genotype for ear shape is heterozygous.

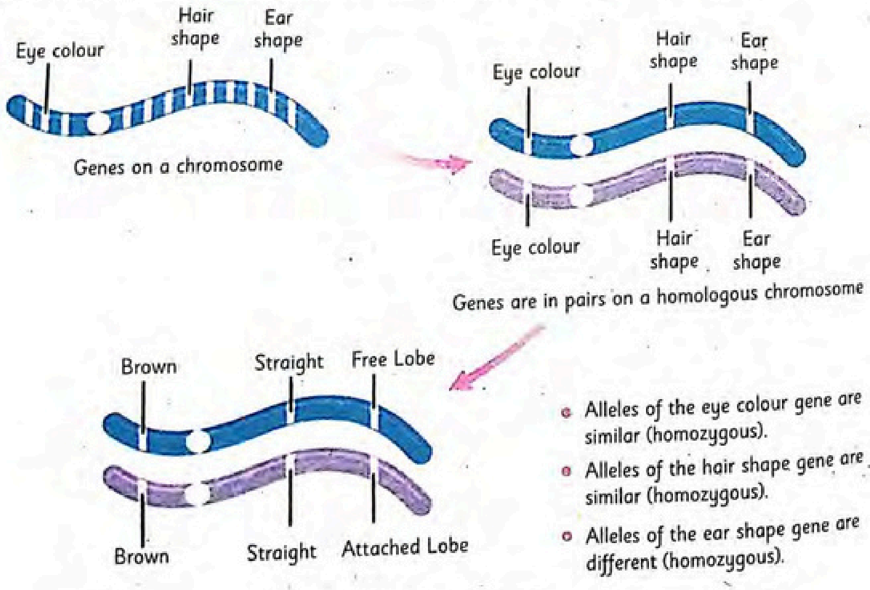


Fig.15.2 Genes and Alleles

15.2.3 Dominant and Recessive Alleles

In the heterozygous genotype one allele may mask the working of the other allele. Such an allele is called the **dominant allele**. The allele which is masked (not expressed) is called a **recessive allele**. The observable outcome of a genotype, in the form of a characteristic, is called **phenotype**. Letters are used to represent alleles. Capital letters refer to dominant alleles, and lowercase letters refer to recessive alleles.

15.2.4 Role of a Gene in Protein Synthesis

How does the gene code for a protein work?

Protein synthesis takes place in two major steps:

Transcription: In the first step of protein synthesis, the two strands of DNA unzip and separate from each other. One strand of DNA acts as a template for making a single strand of Ribonucleic acid (RNA) called the messenger RNA (mRNA). This process is called transcription. In this way, the instructions present in the strand of DNA is copied on the mRNA.

Translation: The mRNA leaves the cell nucleus and travels to the **ribosome**. The ribosome attaches with mRNA. Another type of RNA called the transfer RNA (tRNA) carries specific amino acids to the ribosome. The amino acids are linked together in a specific sequence, eventually forming a protein.

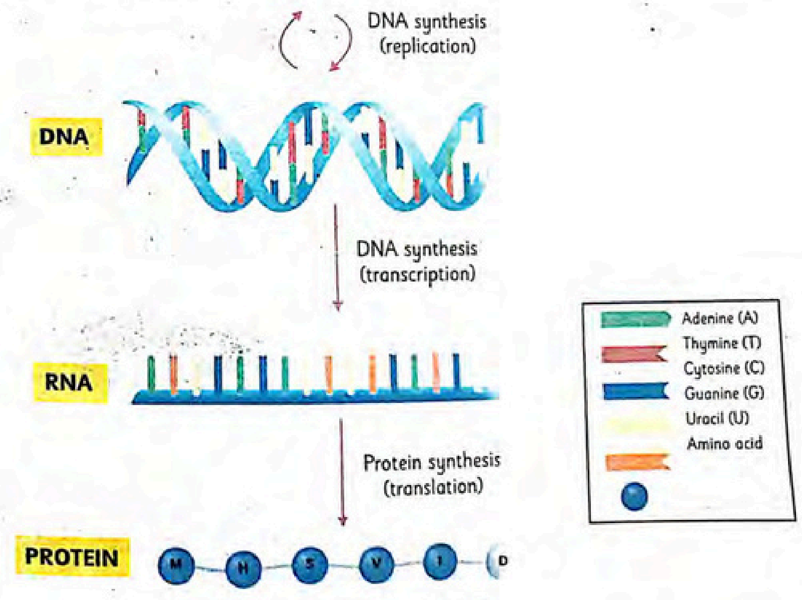


Fig.15.3 The Central Dogma

15.3 Mendel's Work on Inheritance

Gregor Mendel, an Austrian monk, who lived and worked in a small monastery, discovered the fundamental mechanism of inheritance. In the years 1856-1864, Mendel performed his famous experiments on the garden pea plant.

Mendel was certainly not the first to conduct genetic experiments, but he was fortunate to have selected a relatively simple genetic system for his studies. He examined the inheritance relatively well-defined traits and obtained clear-cut results that led to the discovery of several principles of inheritance.

These principles are now the cornerstone of modern genetics, and Gregor Mendel is generally regarded as the "Father of Genetics".

Fig.15.4 Gregor Mendel

15.3.1 Mendel's Laws of Inheritance

Mendel's most famous experiments were performed on the garden pea plant. It was a good choice, because they are easy to grow and are fairly resistant to pests. Peas also have a reasonably short generation time. They complete their life cycle (from seed to next-generation seed) in three months. Thus, results from breeding experiments could be obtained rapidly. Most importantly, the pea plants were pure breeding strains. For example, Mendel had a pure breeding strain of violet-flowered pea that produced violet-flowered offspring exclusively when allowed to self-pollinate.

Every pea plant contains both male and female reproductive parts and normally reproduces through self-pollination. Pea plants have seven easily distinguishable characteristics, such as round versus wrinkled seeds and purple versus white flowers. It helped Mendel to easily observe and calculate the results of his crosses among plants.

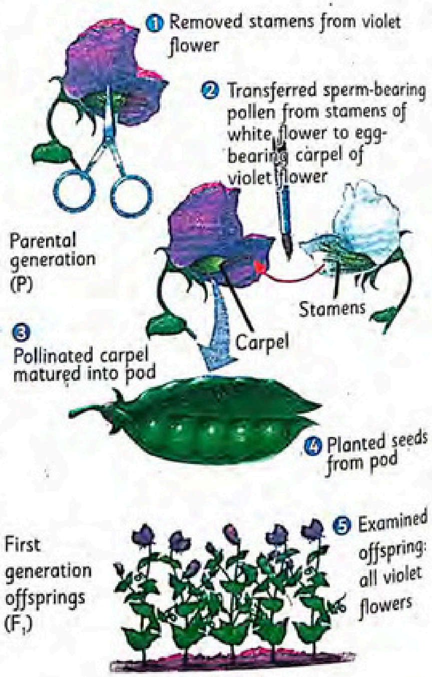


Fig.15.5 Garden pea

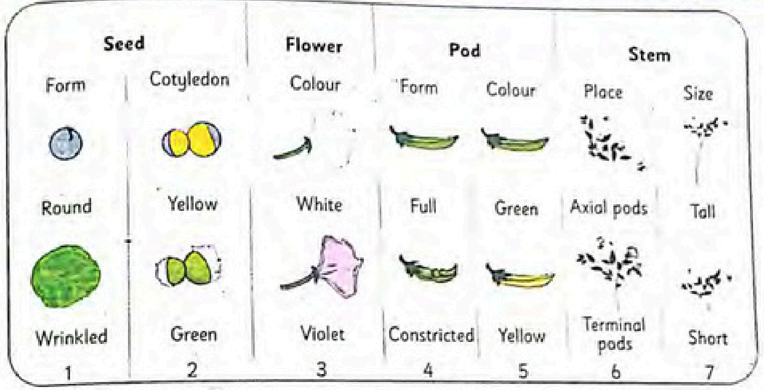


Fig.15.6 Seven characters in the Garden pea studied by Mendel

Focusing on only one trait at a time, Mendel cross-pollinated plants with each of the seven contrasting traits and examined their offsprings. He called the original true-breeding parents the P (for parental) generation and called their first set of offsprings the F_1 (for "first filial," from the Latin word **filius**, meaning son). The F_1 offspring that result from two parents with different characteristics are also called **hybrids.**

Mendel crossed a true-breeding tall plant with a true-breeding short plant. All of the offspring in the F_1 generation were tall. The same thing happened with the other pairs of traits he studied. All offspring of F_1 generation always showed just one of the two traits. Mendel called the trait as the **dominant trait** because it dominated the phenotype, or physical appearance, in the F_1 generation. He called the other trait as **recessive,** because it was masked by the dominant trait in the F_1 generation.

Law of Segregation

Mendel discovered that crossing a tall pea with a short pea would produce an F_1 generation of only tall pea plants. But, he wondered, were these offspring tall pea plants really identical to their tall parents, or might they still contain some element of their short parents? To answer this question, Mendel let all seven types of hybrid F_1 generation plant to self-pollinate, producing the F_2 generation.

In each F_2 generation some of the recessive forms of the traits, which had disappeared in the F_1 generation reappeared! Approximately one fourth of the F_2 plants exhibited the recessive characteristic, and three fourths continued to exhibit the dominant form of the trait, like their F_1 parents. This 3:1 ratio of dominant to recessive remained consistent in all of the F_2 offsprings.

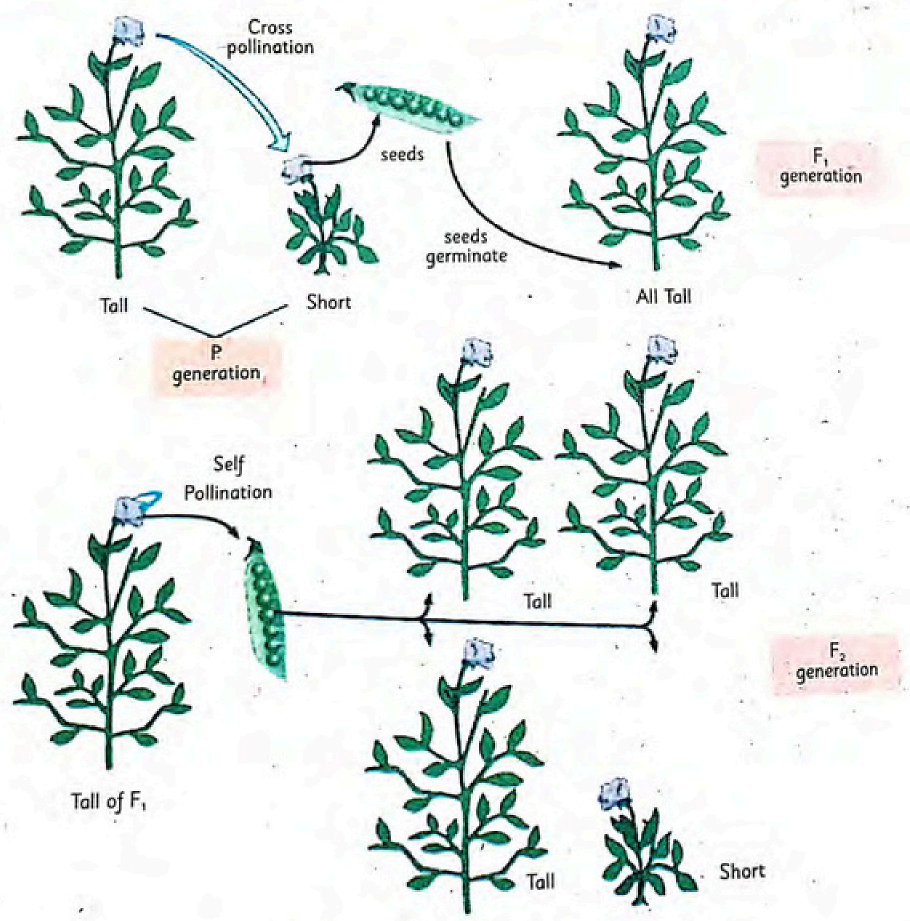


Fig.15.7 Mendel's first experiment (monohybrid cross)

Mendel concluded that within an individual, hereditary information is in the form of paired genes (alleles). During the formation of reproductive cells (gametes), paired genes are separated at random so that each gamete contains only one of the two genes. This led Mendel to propose the law of segregation, which states that; "the paired genes (alleles) are separated during gamete formation and each gamete receives one or the other allele, but not both".

NOT FOR SALE Unit 15 Inheritance

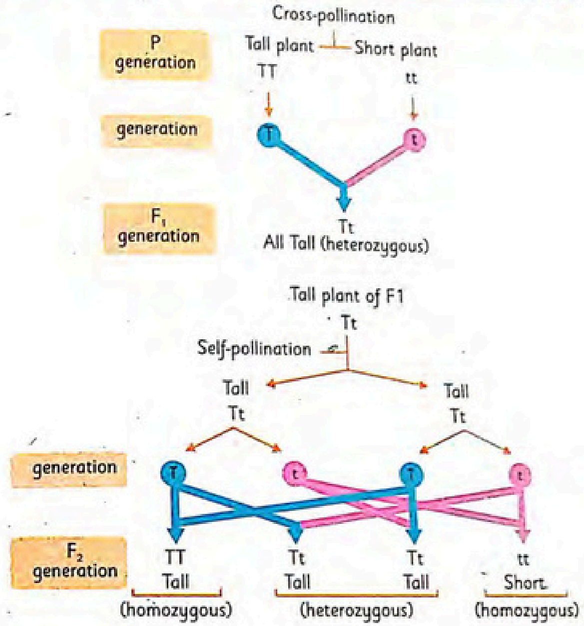


Fig.15.8 Segregation of alleles

In the pea plant, the allele for tallness is dominant. In the F_1 generation, each plant has one allele for tallness (T) and one allele for shortness (t). Each F_1 plant received T allele from one parent and t allele from the other parent. It means, F_1 plants had Tt pair and so were tall. In the F_2 generation, produced by self-pollination of the F_1, 25% of the offspring received both alleles of shortness i.e. tt. So they were short. 50% of F_1 plants received one allele of tallness (T) and one of shortness (t). So they had alleles Tt and were tall. 25% of F_1 plants received both alleles of tallness i.e. TT, so they were also tall.

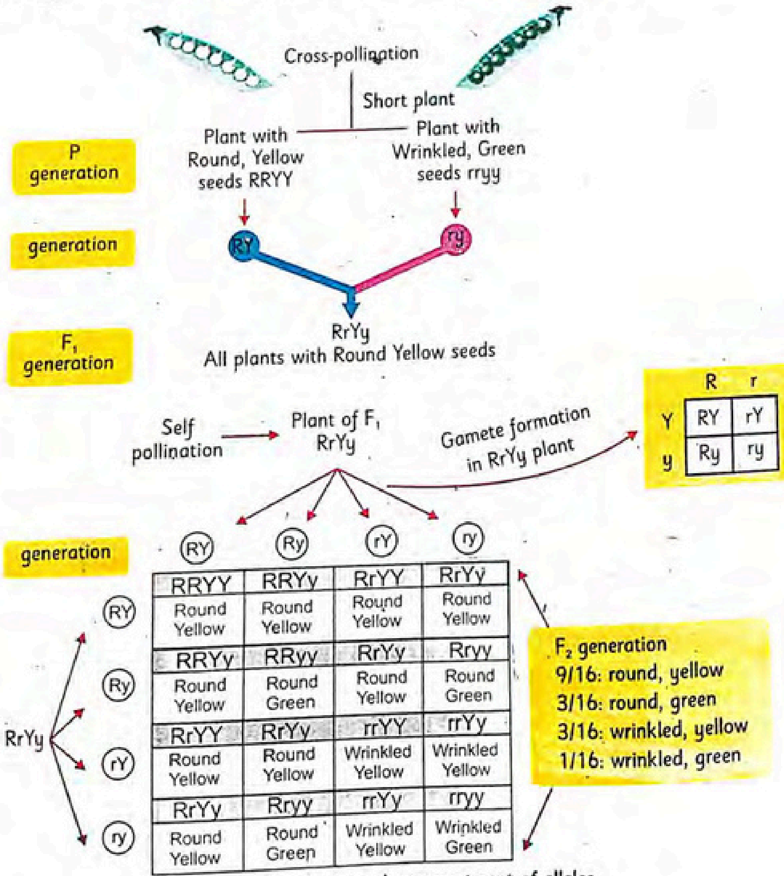
Law of Independent Assortment

In his next experiments, Mendel did **dihybrid crosses**. In a dihybrid cross, the inheritance of two characteristics is studied at a time. In such experiments, he noticed that the height of the plant and the shape of the seeds and the colour of the pods had no impact on one another. In other words, being tall did not automatically mean the plants had to have green pods, nor did green pods have to be filled only with wrinkled seeds. Different traits seemed to be inherited independently. Mendel crossed true-breeding plants having round yellow seeds (genotype of RRYY) with plants having wrinkled, green seeds (rryy).

The seeds of the F_1 offsprings showed only the dominant characteristics in seeds, which are seeds of a round and yellow phenotype. When F_1 hybrids were self-fertilized, however, four different types of seeds were found among the F_2 generation. The ratio of these types was, 9/16 round and yellow, 3/16 round and green, 3/16 wrinkled and yellow, and 1/16 wrinkled and green. The F_2 generation appeared in the ratio of 9:3:3:1

The F_1 plants (RrYy), produced four types of gametes i.e. RY, Ry, rY, and ry. When these plants were allowed to self-pollinate, there were 16 combinations of alleles in F_2 generation. It means that alleles R and r segregated independently of the alleles Y and y.

Mendel's discovery is referred to as the **law of independent assortment**. It states that "alleles separate independently of one another during the formation of gametes."



	R	r
Y	RY	rY
y	Ry	ry

	(RY)	(Ry)	(rY)	(ry)
(RY)	RRYY Round Yellow	RRYy Round Yellow	RrYY Round Yellow	RrYy Round Yellow
(Ry)	RRYy Round Yellow	RRyy Round Green	RrYy Round Yellow	Rryy Round Green
(rY)	RrYY Round Yellow	RrYy Round Yellow	rrYY Wrinkled Yellow	rrYy Wrinkled Yellow
(ry)	RrYy Round Yellow	Rryy Round Green	rrYy Wrinkled Yellow	rryy Wrinkled Green

Fig.15.9 Independent assortment of alleles

15.3.2 Dominance Relations

One of Mendel's greatest contributions to the study of heredity was the concept of dominance. Mendel observed that a heterozygous offsprings (e.g. Tt) can show the same phenotype (tall) as the homozygous offsprings (TT). So he concluded that some alleles dominated over the others. However, the relationship of alleles is not as simple as the dominant and recessive patterns described by Mendel. Dominance relations are of three types.

1. Complete dominance 2. Incomplete dominance 3. Co-dominance

1. Complete Dominance: In complete dominance, one allele is completely dominant over the other allele e. g. allele for tallness "T" is completely dominant over the allele for dwarfness "t". So, in the heterozygous condition "Tt", T hides the effect of t and the plant appears tall.

2. Incomplete Dominance: In many cases an allele does not completely mask the action of the second allele. Rather, they interact in such a way that the heterozygous individual shows a blending/mixing of both phenotypes.

In the Japanese 4 O'clock plant, the inheritance of flower colour is an example of incomplete dominance. Two alleles control the characteristic of flower colour i.e. red (R) and white (r). When the red-flowering plant (RR) self-pollinates, it produces only red-flowering offspring. Similarly, when a white-flowering plant (rr) self-pollinates, it produces only white-flowering offspring. However, when a red flower is crossed with a white flower, all of the F_1 offspring have pink flowers. We know that all these F_1 offsprings are heterozygous (Rr). Here, alleles R and r show incomplete domindnce. That is why, the phenotype is intermediate.

When two pink flowers (Rr) are crossed, the genotype ratio of F_2 plants is 1 RR : 2 Rr : 1 rr. It results in 1 red : 2 pink : 1 white flowered plants.

For Your Information

Scientific investigation is a pursuit to find the answer to a question using scientific method. In turn, scientific method is a systematic process that involves using measurable observations to formulate, test or modify a hypothesis. In genetics, the information is in the form of large mathematical data. Therefore, knowledge of mathematics is required for data analysis to interpret the data obtained from certain experiments.

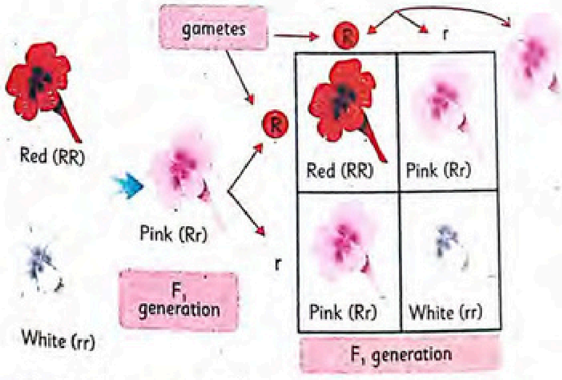


Fig.15.10 Incomplete dominance in Japanese 4 O' Clock plant

3. Co-dominance: It is not an intermediate expression of alleles like incomplete dominance. In co-dominance, different alleles of a gene are completely expressed in a heterozygous condition.

Tidbit

In incomplete dominance, the phenotype of a heterozygous offspring is intermediate between the phenotypes of both parents. On the other hand, in co-dominance, the phenotype of heterozygous offspring represents the phenotypes of both parents.

The trait of ABO blood group system shows the example of co-dominance between two alleles. There are three alleles for this trait i.e. I^A, I^B and i.

The allele I^A makes antigen A on RBCs while allele I^B makes antigen B. Allele i does not produce any antigen on RBCs.

Both the I^A and the I^B alleles are dominant to the i allele. Thus individuals with I^AI^A and I^Ai genotypes have A blood group. Similarly, the individuals with I^BI^B and I^Bi genotypes have type B blood group. Individuals with ii genotype have O blood group. In individuals with I^AI^B genotypes, I^A and I^B alleles are expressed in the phenotype, so the person has AB blood group. It means that alleles I^A and I^B show co-dominance

Genotype	Relationship between alleles	Antigen produced	Phenotype
I^AI^A or I^Ai	Allele I^A is dominant over i	A	Blood Group A
I^BI^B or I^Bi	Allele I^B is dominant over i	B	Blood Group B
ii	Allele i is recessive	No Antigen	Blood Group O
I^AI^B	Allele I^A and I^B are co-dominant	A and B	Blood Group AB

Fig.5.11 ABO blood group - an example of Co-dominance

15.4 Variation and Evolution

Individuals show great differences of form, size, colour, habit and physiology among themselves. These differences are termed as **variations**. Variation can be defined as differences in traits between individuals of the same species. Variations are necessary for natural selection. Natural selection favours individuals with traits that are best adapted to their environment and enable them to change when the environment changes.

15.4.1 Sources of Variations

Variations are produced due to genetic differences among individuals. Sometime environmental conditions also cause variations. The following are the main sources of variations.

a. Genetic recombination of chromosomes

We know that gametes are produced by meiosis. During meiosis, the homologous chromosomes separate and move independently to different nuclei. In this way, new combinations of chromosomes are produced in the daughter cells (gametes).

b. Crossing over

During prophase of meiosis, crossing-over occurs. In this process, the chromatids of homologous chromosomes exchanges genes. It results in chromosomes with different combinations of genes in different gametes.

Science, Technology and Society

The beauty of nature is because of the diversity among living organisms. The basis of biodiversity lies in the genetic variations that occur among organisms. Recombination of chromosomes and crossing over of genes during meiosis are responsible for these variations.

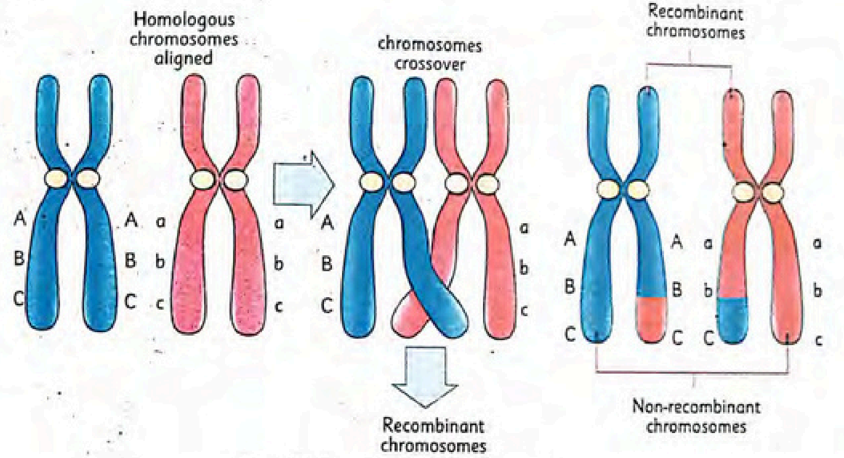


Fig.5.12 Crossing over – a source of variations

c. Random Fertilization

Each gamete has a unique genetic composition, because of the recombination of chromosomes and genes in meiosis. When gametes combine randomly during fertilization, the organisms produced are different from all others of the species.

d. Mutation

Mutation is defined as any change in the nucleotide sequence of DNA. Alleles arise by mutation. The original allele is termed as the wild type, and the new allele as the mutant allele. If there were no mutations, there would be no variation.

e. Environmental conditions

Although the environment has no role in the initial production of variations, once variations are produced, the individuals with variations are best suited to that particular environment and have more chances of survival. Accumulation of such variations, generation after generation, results in the production of new species ultimately.

15.4.2 Continuous and Discontinuous Variations

Variations are generally divided into two types i.e. continuous variations and discontinuous variations:

i. Continuous Variations

These variations deal with a wide range of phenotype ranging from one extreme to the other. It means that a lot of intermediate characters can be observed between the two extremes of a character. The characters that show continuous variations are controlled by many genes. For example, skin colour in humans is controlled by several genes. More dark genes in an individual will result in darker skin colour. The same is the effect of certain other characters like height, weight, IQ (intelligence quotient) etc.

Human height (a continuous variation) Ear shape (a discontinuous variation)

Fig.15.13 Continuous and Discontinuous variations

ii. Discontinuous Variations

These variations show only a few clear-cut phenotypes. A few genes control the characters that show discontinuous variations. Human blood group is an example of discontinuous variation. There are only 4 types of blood groups which are blood group A, B, AB and O. There are no other possibilities and there are no values in between. So this is discontinuous variation. Similarly, the gene controlling ear lobes in humans, is also an example of discontinuous variation.

Activities

1. Record the heights of class fellows to predict which kind of variation it is?
2. Present the data of class fellows' heights in graphical form.

Place these two boxes side by side.

15.4.3 Organic Evolution

Evolution simply means gradual change. Organic evolution is defined as the development of advanced types of organisms from pre-existing types of organisms over time. Various plants and animals, living today, have descended from simpler and imperfect forms, by gradual modification. We call this historical process as organic evolution.

Science, Technology and Society

Humans show wide phenotypic diversity across the globe. This diversity is because of their adaptations to various environmental conditions. Human environments and selective pressures related to these environments vary greatly across geographical regions and across populations. The data available from the genome of different populations shows the exact locations of the genes responsible for these adaptations.

Variations and Natural Selection Lead to Evolution

The English naturalist, **Charles Darwin** (1809–1882) presented the evidence to support that the evolution of new organisms does occur. He developed a theory called **theory of natural selection** to explain evolution. According to this theory, changes in population occur over time through natural selection. In other words, natural selection is the mechanism of evolution.

Natural selection is the process through which individuals with better characters (variations) produce more surviving offsprings than the individuals lacking these variations. As a result, the population gradually includes more individuals with better variations. Natural selection works in the following way.

1. Overproduction: Living organisms tend to produce excessive number of organisms. The resources in the environment are not sufficient for such large populations. Each generation experiences substantial mortality. There are genetic **variations** among individual of a population.

2. Competition: As resources in an environment are limited, organisms compete with one another to get sufficient resources to live. During this competition, the individuals with better variations are able to survive. The individuals with poor adaptability are excluded from the environment. This is called **natural selection.**

3. Reproduction: Better variations assist individuals in their struggle for survival. Such individuals pass on the favourable variations to their offspring.

4. **Speciation:** When this process repeats over many generations, each new generation has a higher proportion of individuals with better variations. So, after many generations and through continuous natural selection; the population changes entirely and new species may evolve.

Example of Natural Selection

An example of natural selection is the evolution of pesticide resistance in insect species. Pesticides are poisons used to kill pests (harmful insects). When a new type of pesticide is used, a relatively small amount may kill 99 % of pests. But later sprayings are less and less effective.

For example, in the early 1950s, a pesticide was introduced to control flour beetles. Only a small concentration of pesticide was enough to control them. The survivors of the first pesticide treatments had variations that enabled them to resist the chemical attack. Their offsprings inherited the variation for pesticide resistance. In each generation, the percentage of pesticide-resistant individuals increased in population. Thus, the population underwent an evolution that resulted in adaptation against the pesticide. Today, the flour beetles are not killed even by very high concentrations of the same pesticide.

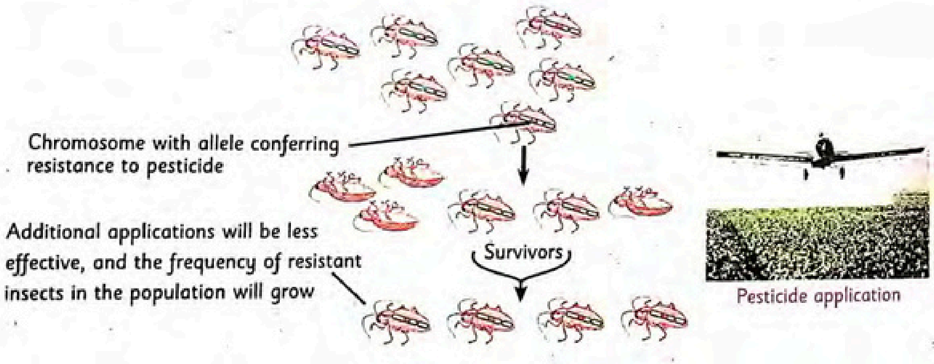


Fig.15.14 Evolution in insects

15.4.4 Artificial Selection and Crop Improvement

Long before Darwin and Wallace, farmers and breeders were using the idea of selection to cause major changes in the features of their plants and animals. They allowed only the plants and animals with desirable characteristics to reproduce, causing the evolution of farm stock. This process is called artificial selection because people (instead of nature) select the organism they want to reproduce. Essentially all present-day crops have been extensively reshaped from their wild ancestors by the repeated application of artificial selection. For example, the major cereals (rice, wheat, maize, sorghum and millet) were all developed from wild grasses by artificial selection between 7,000 and 12,000 years ago.

The varieties of animals which are artificially bred are called **breeds**. Many breeds of sheep, goat, cow, hen etc. have been produced by artificial selection to increase the production of meat, milk, eggs, wool etc.

Tidbit

In artificial selection, humans favour specific traits while in natural selection the environment selects or rejects variations.
Artificial selection produces a great deal of change in a species in a short time.

Fig.15.15 Different breeds of hen

The varieties of plants which are bred are known as **varieties** or **cultivars**. Many plant varieties (cultivars) have been produced for better quantity and quality of food in plants like wheat, rice, potato, and apple etc.

Fig.15.16 Varieties (cultivars) of potato and apple

Artificial selection has also been used to shape the aesthetic features of organisms that surround us in everyday life. Many ornamental plants breeds of dogs, cats, rabbits, or horses are the result of selection for features that particular breeders regarded as desirable.

For Your Information

The theory proposed by Darwin suggests that unicellular organisms evolved into multicellular organisms. One of the recent theories of evolution, the theory of intelligent design, proposes that certain features of the universe and of living organisms are best explained by an intelligent cause and not by an undirected process such as natural selection. According to this theory, there is a creator of the universe. Therefore there should be a Creator of the universe and an Owner of the balance visibly everywhere from our body to the farthest corners of the vast universe. Who is that Creator? That Almighty Creator is one. He is ALLAH. He brought into existence everything and Whose existence is without any beginning or end.

Key Points

- Genetics is the branch of biological science dealing with heredity.
- Heredity is responsible for transformation of characters of parents to offsprings.
- Mendel is the father of genetics. He formulated laws of inheritance by studying the inheritance of characters in the garden pea.
- True-breeding individuals are genetically homozygous, with similar alleles in a gene pair.
- A cross of two heterozygous individuals for a character gives rise to offspring in 3:1, if there is complete dominance of one allele over the other.
- A dihybrid cross of individuals for two gene pairs yields four different classes of phenotypes in 9:3:3:1 ratio.
- Incomplete dominance of two alleles results in the production of intermediate expression of character in the heterozygous individual.
- More than one gene pair affecting single trait results in gradation in the intensity of expression of character.
- New combination of genes arise by crossing over.
- Variation can be defined as differences in traits between individuals of the same species.
- Continuous variations deals with a variety of phenotypes ranging from one extreme to the other.
- Discontinuous variations deals with a few clear-cut phenotypes and no intermediate characters can be found.
- Evolution means gradual change through the passage of time.
- Evolution by means of natural selection is best explained by Darwin's theory of Natural Selection.
- Artificial selection is used to improve commercially useful plants and animals.

Exercise

A. Select the correct answer.

1. Genes are short segments of:
   a. Proteins b. Carbohydrates c. DNA d. Lipids
2. The various forms of a gene responsible for the same trait are called:
   a. Centromere b. Character c. Trait d. Allele
3. Natural selection operates to produce changes in:
   a. Individuals b. Populations c. Races d. Phyla
4. How many different types of gametes will be produced by a plant having a genotype AaBb?
   a. Three b. Four c. Six d. Eight
5. Speciation is the evolutionary process by which _____.
   a. A new gene pool is formed b. Evolutionary path of a species converge
   c. Hybrid species is formed d. Shows differences in physical traits
6. Phenotype is the expression of:
   a. Genetic makeup b. Physical makeup c. Chemical composition Metabolism
7. The round structure formed when DNA coils around the histone protein is:
   a. Centromere b. Chiasma c. Nucleosome d. Chromatin
8. An allele which completely masks the effect of other allele in a heterozygote:
   a. Dominant b. Recessive c. Co-dominant d. Incomplete dominant
9. The central dogma is best represented by
   a. DNA + RNA = Protein b. DNA —> RNA + Protein
   c. DNA —> RNA —> Protein d. Protein —> RNA —> DNA
10. Type of dominance pattern followed by I^A and I^B alleles of the human blood group system:
    a. Complete dominance b. Co-dominance
    c. Incomplete dominance d. None of the above
11. What are the possible genotypes of the parents of homozygous recessive individual?
    a. Homozygous dominant b. Homozygous recessive
    c. Heterozygous d. Both 'b' and 'c'

B. Write short answers to the following questions.

1. If a man with type AB blood group marries a woman with type O blood group. What type of blood group do you expect in the offsprings?
2. How can crossing bring variations?
3. How are DNA and proteins packed to form a chromosome?