2. Heredity and Evolution

VARIATION

- It refers to the differences in the characters or traits among the indivisuals of a species.

Accumulation of Variation

- In asexual reproduction single parent is involved to produce new offsprings. These offsprings have very minor differences between them due to small inaccuracies in copying DNA.
- Sexual reproduction involves two parents, generates greater diversity. Offsprings receives characters from both the parents; different offspring receive different characteristics from their parents.
- Variation increases the chance of survival of species in changing environmental conditions.

  Ex: The accumulation of heat resistant variation in some bacteria will ensure its survival even when the temperature in its environment rises too much due to a heat wave or some other reasons.

  On the other hand, the bacteria which did not have this variation to withstand heat would not survive under these circumstances and die.

Importance of Variations

- They enable the organisms to adapt themselves in changing environment.
- Variations form the basis of heredity.
- They form raw materials for evolution and development of new species.

MENDEL'S EXPERIMENT ON INHERITANCE OF TRAITS

Gregor Johnn Mendel (1822 – 1884) is called as father of genetics. Mendel performed experiments on garden pea ***Pisum sativum*** to study the mechanism of inheritance of characters

S.No.	Character	Contrasting traits	
		Dominant	Recessive
1.	Plant size of height	Tall*	Dwarf*
2.	Position of flower on the stem	Axial	Terminal
3.	Colour of unripe pod	Green	Yellow
4.	Shape of pod	Inflated	Constricted
5.	Shape (form) of seed	Round (smooth)	Wrinkled
6.	Colour of the seed	Yellow	Green
7.	Colour of flower	Violet	White

IMPORTANT DEFINATION

- **Heredity:** It is the process by which characters or traits are passed from the parents to the offspring.
- **Variation:** It means differences between the individual of species.
- **Genetics:** It is the study of heredity and variations. The term 'genetics' was coined by 'William Bateson' in 1906.
- **Chromosomes** are long thread like structures present in the nucleus of a cell which contain hereditary information of the cell.
- **Deoxyribonucleic Acid (DNA)** is a chemical in the chromosomes which carries the hereditary characters or traits in a coded form from one generation to the next in all the organisms.

- **Gene:** It is unit of hereditary which transfer traits from parents to their offspring.
- **Inheritance:** It is the transmission of genetically controlled traits from one generation to next
- **Alleles**: Two alternate forms of genes lying on homologous chromosomes are termed as alleles e.g. trait height has two alleles Tall and Dwarf.
- **Genotype:** It is the genetic constitution of an organism. E.g. like for tall and dwarf TT, Tt and tt.
- **Phenotype:** It is the characteristic which is visible in an organism. E.g. Tall and dwarf.
- **Hybrid:** It is a cross between two genetically dissimilar organisms of the same species.
- **Dominant:** The trait which can express in homozygous as well as heterozygous condition.
- **Recessive:** The trait which can express only in homozygous condition.
- **Homozygous:** If both genes of a character are identical, then organism is said to be homozygous or pure. E.g. Tall (TT)
- **Heterozygous:** If both genes of a character are not identical, than the organism is said to be heterozygous. E.g. Tt , Rr
- **Back cross** is a cross made between a hybrid and one of its parents.
- **Test cross** is a cross between an organism of an unknown genotypes and a homozygous recessive organism.

ADVANTAGES OF SELECTING PEA PLANTS

- They reproduce sexually. They have two distinct, male and female, sex cells called gametes. Their traits are easy to isolate.
- Many generations of pea plants can be produced in a comparatively short time span and their study is much simpler than that of animals.
- The garden pea plants could easily be raised, maintained and handled. Each pea plant produced many seeds in one generation.

MENDEL'S EXPERIMENTAL TECHNIQUE

Mendel conducted breeding experiments in three steps:

1. Selection of pure parent plants (i.e., plants producing similar traits in every generation).
2. Production of first generation of plants by cross breeding (hybridization).
3. Raising of second and subsequent generations by self-fertilization of hybrids.

- In cross breeding experiments, most important precaution required is to avoid self-fertilization between two varieties or traits of plants.
- Mendel removed the anthers (male parts) of the flowers well before the maturity of the female part, i.e., gynoecium of the flowers. This process is called **emasculation.**
- Such flowers were covered to avoid entry of any foreign pollen grain from outside by wind or animals. For making a desired cross, mature pollen grains from the anther of the flower of the desired plant were transferred on the stigma (female part) of the emasculated mature flower.
- The seeds formed by such crosses were collected. These seeds belonged to the **first filial generation** or **F1 generation.** To draw effective conclusions, Mendel used the seeds of F 1 generation to raise the F2 generation by self pollination and also the F2 seeds for raising F3 generation by self-pollination.

MENDEL'S MONOHYBRID CROSS

- A breeding experiment dealing with a single character is called a monohybrid cross. Mendel first selected 'pure line' plants (i.e., the plants that produced similar traits generation after generation).
- Cross between two individuals of a species which is made to study the inheritance of a single pair of genes is called a monohybrid cross. Mendel selected round and wrinkled seed of pea plants for crossing.
- He, then, cross pollinated such plants having the contrasting traits, considering one trait at a time. For instance, in one such cross breeding experiment, he cross bred garden pea plant having round seeds with plant having wrinkled seeds.
- In this monohybrid cross, the pollen grains from the flower of the desired plant raised from round seeds were transferred over the previously emasculated flower of a plant raised from wrinkled seeds or vice-versa.
- After the transfer of pollen grain, the cross pollinated flower was properly covered and seeds produced were allowed to mature. All the seeds of **F1 generation** were carefully observed.
- Mendel observed that all the seeds of F1 generation were of round type and there were no intermediate characteristics. He raised plants from F1seeds and allowed the flowers to self-pollinate to produce the seeds of F2 generation.
- The flowers were kept covered from the beginning to avoid unwanted pollen to reach these flowers. In F2 generation, Mendel observed the appearance of both round and wrinkled seeds in approximately 3:1 proportion.

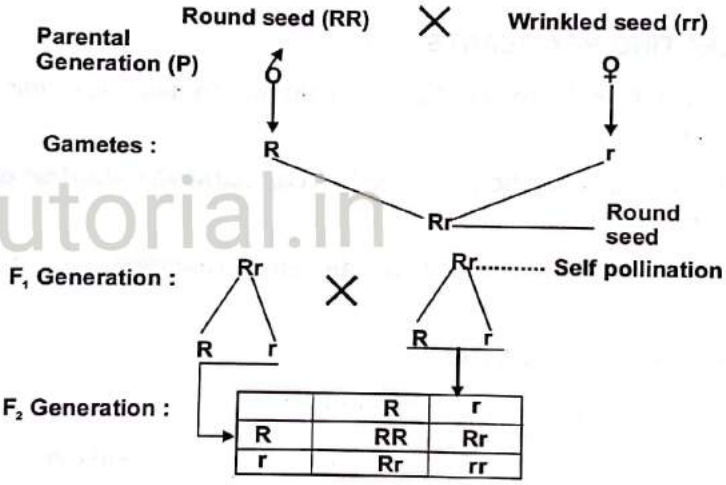


Fig : Monohybrid Cross

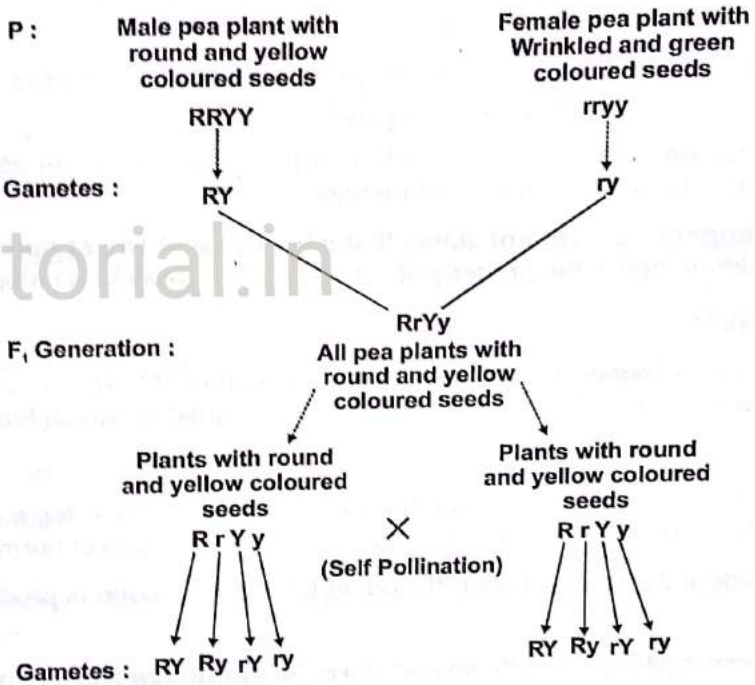
Phenotype	3	:	1		
	Round Seeds		Wrinkled Seeds		
Genotype	1	:	2	:	1
	Homozygous round seeds		Heterozygous round seeds		Wrinkled Seeds

On the basis of monohybrid cross Mendel gave the Principle of segregation.

DIHYBRID CROSS

- Mendel also studied the inheritance of two characters simultaneously.
- A breeding experiment dealing with two characters at the same time is called a dihybrid cross or Cross between two individuals of a species which is made to study the inheritance of two pairs of genes is called a dihybrid cross.

- In one such cross, Mendel considered shape as well as colour of the seeds simultaneously. He selected pure line plants and then cross pollinated flowers raised from seeds of round shape and yellow colour with those from wrinkled seeds and green colour.
- Mendel observed that in F1generation all seeds had the features of only one parental type, i.e., round shape and yellow colour. He raised plants from F1generation seeds and allowed the flowers to self pollinate to produce the seeds of F2generation. These flowers were kept covered from the beginning.
- In F2 generation. Mendel observed the appearance of four types of combinations. These included two parental types (round shaped and yellow coloured seeds, and wrinkled shaped and green coloured seeds) and two new combinations (round shaped and green coloured seeds, and wrinkled and yellow coloured seeds) in approximately same proportion.



	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, yellow	rrYy Wrinkled, yellow	Rryy Wrinkled, green

F_2 Generation :	Plants with Round and Yellow coloured seeds	Plants with Round and Green coloured seeds	Plants with wrinkled and Yellow coloured seeds	Plants with wrinkled and Green coloured seeds
	9	: 3	: 3	: 1

Fig : Mendel's Dihybrid Cross

- On the basis of dihybrid cross Mendel gave the Principle of Independent Assortment.

MENDEL'S CONCLUSION

- Based on the findings of monohybrid and dihybrid crosses, Mendel concluded that -

  (i) In a **monohybrid cross,** only one of two contrasting characters (traits) appeared in F1 generation. However, in F2 generation, both the parental traits appeared in certain proportion.

  (ii) In a dihybrid cross, when two contrasting pairs of traits were considered simultaneously, only one parental combination appeared in F1generation. However, in F2 generation, raised by self-pollination, four combinations of traits appeared. These included two parental type traits and two new combinations in approximately same proportion.

Mendelism (Laws of Mendel)

(i) **Principle of paired factors** states that each trait of the individual is determined by two factors, which are known as genes. The alternative form of gene is called allele.

(ii) **Principle of dominance** states that out of two alleles, only one expresses itself in an organism is called dominant while which does not expresses is called recessive

(iii) **Principle of segregation** states that a pair of contrasting factors or genes remains together and separate or segregate at the time of gamete formation.

(iv) **Principle of independent assortment** states that inheritance of two or more genes at a time, their distribution in the gamete and in the progeny of subsequent generation is independent of each other

EXPRESSION OF TRAITS

- DNA present in the cell is hereditary material. Gene is a section of DNA carrying the information for a structural or functional protein. Thus it is a sequence of nucleotides, which forms a molecule of DNA.
- Genes are located on the chromosomes.
- Structural and functional proteins determine the expression of a character, e.g. tallness of pea plant depends on the synthesis of enzyme which in turn regulates secretion of hormone gibberellins.
- If the gene is functional the enzyme is produced, in turn the hormone is produced which makes the plants tall.
- If the gene for tallness is altered the protein enzyme is not synthesized, in turn no hormone is produced which affects the growth and plant remains short.
- Every individual has two sets of genes. During fertilization, gametes are formed by the process of meiosis which contains one set of gene. The off spring gets one set of genes from both the parents
- Equal distribution of genes occurs because these genes are located on chromosomes, which occur in homologous pairs.

How Blood Groups are inherited

A person has four blood groups: A, B, AB and O controlled by four genes and the alleles are denoted by I^A, I^B and I^O, which are said to be multiple alleles. Among those I^A and I^B are dominant over gene I^O. I^A and I^B show no dominance over each other and hence called **co-dominant.**

SEX DETERMINATION

- It is the process of determination of sex.
- Factors that determine sex of an individual can be (a) environment and (b) genetic factors.
- **Environment factors:** In some lizards, if fertilized eggs are kept at high temperature maleness is induced and at low temperature femaleness is induced. Snails can change their sex, indicates that sex is not determined genetically.
- **Genetic factors:** In human beings, 23 pairs of chromosomes are present.

— 22 pairs are called autosomes.

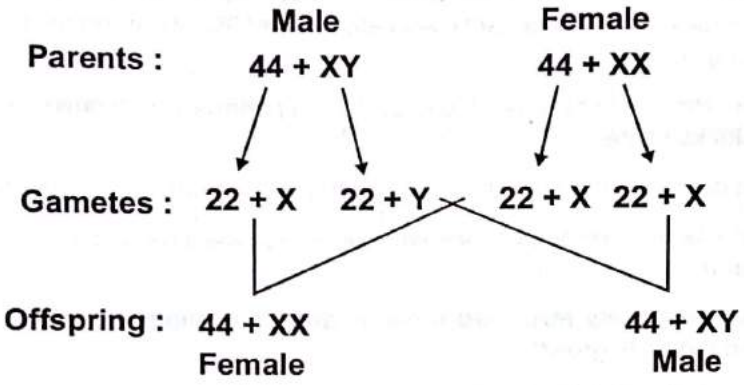
— 23rd pair is called sex chromosome.

— In male 23rd pair is XY.

— In female 23rd pair is XX.

— At the time of fertilization there is a 50% chance of a boy and a 50% chance of a girl being born.

— It is the sperm which determines the sex of child.



THEORIES OF ORIGIN OF LIFE (BIOPOISIS)

- Various theories were put forward about the origin of life. These are

(i) **Theory of special cretion.** According to this theory, the Almighty God Created life.

(ii) **Theory of spontaneous generation.** According to this theory, life originated from non-living materials by the process of abiogenesis using mud, decomposing matter, sun, air, water etc.

(iii) **Cosmozoic theory.** It states that, life came to earth from some heavenly bodies in the form of spores and seeds.

(iv) **Biogenesis.** This theory states that life originated from pre-existing life.

(v) **Modern theory of origin of life**

MODERN THEORY OF ORIGIN OF LIFE

- Earth was formed about 4500 million years ago.
- It is thought that the sun and its planets were formed from a cloud of cosmic dust and gas which condensed rapidly into a compact mass.
- As a result of this, lot of heat and pressure was formed.
- This led to the initiation of various thermonuclear reactions.
- Main condensed mass was converted into the sun.
- Planets were formed by lesser-condensed centre. Earth was one of them.
- During condensation, heavier metals settled into the centre thus forming core of the earth and lighter ones like nitrogen, hydrogen, oxygen, water vapours were more concentrated on teh surface.
- It is believed that water vapours released from the hot inner surface of the earth formed clouds, which brought rains, accompanied with lightning.
- These lightning sparks initiated certain chemical reactions thus, forming simple chemicals such as water, methane, ammonia etc.

- They later on reacted to form several new and complex compounds.
- Among these were amino acids, which linked together to form the building blocks of life, proteins.
- J.B.S. Haldane, who was a British scientist and later became a citizen of India in 1929 suggested that life developed from inorganic molecules present on earth soon after its formation.
- **Stanley L. Miller** and **Harold C. Urey** in 1953 gave the experimental evidence of the modern theory.
- They demonstrated that on passing electrical discharge or U.V. radiations or both, various complex compounds like methane, ammonia, water reacted to form even more complex compounds such as proteins, nucleic acids, urea, lactic acid etc. About 15% of carbon from methane got converted to organic compounds.
- Later on, other researchers were able to synthsize purines and pyrimidines which are considered as building blocks of life.
- Finally all the compounds formed came together to form large colloidal aggregates.
- These colloidal bodies formed cell like structure which were named s coacervates by the Russian biologist Oparin.
- **Coacervates** selectively absorbed proteins and other materials which increased its internal comlexity and led to its growth.
- They could divide by budding like bacteria.
- The first living cell **protocell** originated in the ocean.

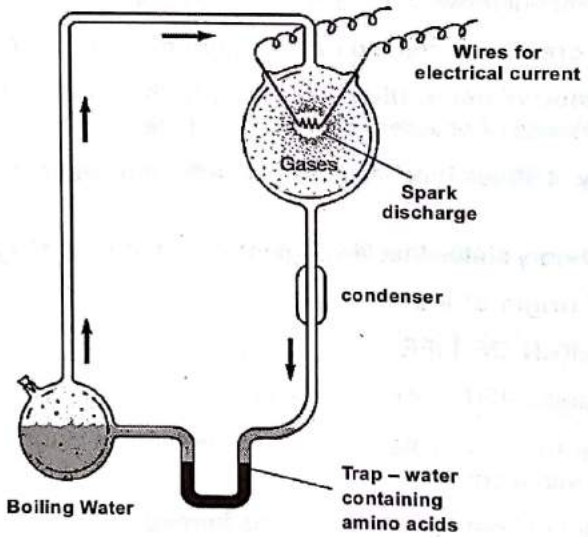


Fig. Urey-Miller Experiment

EVOLUTION

- Term evolution has been derived from the Latin word 'evolvere' which means to 'unroll' or 'unfold'. Evolution is defined as a gradual change in the forms of life from simple to complex that has given rise to the existing diversity of life.
- **Charles Darwin** gave the concept of evolution as descent with modification
- He observed the diversity of life and his observations on the birds of Galapagos Islands stimulated him to think about evolutionary process.
- He has observed that variation exist in nature and one which helps organism to adapt the environment passed to the next generation.

- He published his book; **"The origin of species"** and theory proposed by him is known as **"The Theory of Natural selection"** He explained the best adapted organisms are selected by the nature to pass their characteristics to the next generation.
- The struggle for the survival within the population eliminates the unfit individuals. This is called the survival of the fittest.
- He has no idea that how these variations arose.

Acquired and inherited traits

- Variations arise as a result of (a) sexual reproduction or (b) errors in copying DNA.
- Variations are of two types:– acquired & inherited.
- Trait which is not inherited but develops in response to the environmental conditions is called **acquired traits**. E.g. August Weismann removed the tails of mice by cutting them off for twenty-one generations but progeny born always had a tail. This shows that changes in body cannot pass from generation to generation or change the genes of the germ cells.
- A trait which is controlled by specific genes and is passed from one generation to another is called **inherited traits.** Any change in DNA sequencing of parents will be passed on to the offspring resulting in variation. These variations can either increase or decrease the chances of survival.

  Evolution occurs due to changes in frequency of some inherited traits (genes) in a population over a period of time.
- During natural selection, frequency of a gene having a survival advantage increases which in turn results in evolution of population
- In small populations even accidents can change the frequency of some which do not have any survival value.
- Change in the frequency of some gene caused by chance factor alone is called Genetic drift.
- Genetic drift creates diversity without any adaptations.
- Microevolution constitutes small but significant changes in common characteristics of population of a species.

SPECIATION

- Speciation is the origin of new species from the existing ones.
- Speciation takes place when variation is combined with geographical isolation.
- A species consists of similar individuals which can interbreed among themselves to produce fertile offsprings.
- Interbreeding among individuals of different populations maintain a free flow of genes in these populations.
- Geographical isolation of a population caused by various types of barriers such as rivers, mountain and seas. It leads to the reproductive isolation due to which there is no flow of genes between separated groups of population. This is also considered as genetic drift.

ORIGIN OF LIFE

- In 1929, J.B.S Haldane speculated that life must have originated from simple inorganic molecules such as methane, ammonia, hydrogen sulphide etc., which were present on the Earth when it was formed.
- A mass of water at high temperature and an atmosphere containing gases methane, ammonia and hydrogen sulphide surrounded the Earth.
- Electric discharges and torrential rains occurred for millions of year.
- These conditions on the earth have converted simple inorganic molecules into complex organic molecules.

- These complex molecules have joined to form first primitive living organism.

  Stanley L. Miller and Harold C. Urey provided experimental evidence in favour of this idea in 1953.
- They created the conditions of ancient Earth in an experimental setup.
- Earth consists of gases like methane, ammonia and hydrogen sulphide and water vapours. When gases were subjected to electric discharges in a reducing atmosphere for a few days; it could give rise to amino acids that form protein molecules.
- Formation of carbon containing (organic) molecules in the laboratory confirms the possibility of origin of life from lifeless matter on primordial Earth.

EVOLUTION AND CLASSIFICATION

- Classification is to place diverse forms of life into groups and sub-groups on the basis of similarities and differences among them.
- It provided us an idea of diversity of life interrelations among living beings and the order of evolution of life.
- Classification refers to a particular form or function of organisms which are used to describe, identify and classify them.
- All organisms share some basic characteristics the cell. Cell is the basic unit of structure and function of living beings; therefore, it is taken as the primary characteristic for classifying organisms.
- Most, but not all organisms share the next level of classification. For example presence or absence of a well-defined nucleus in the cell.
- First division of organisms is made on the basis of the organization of the cell, whether it is prokaryotic or eukaryotic.
- Other characteristics of the organisms depend upon the characteristics of cells which form tissues, organs, organ system and the organism.
- Hierarchy is the framework of classification in which these groups are arranged in the order of increasing or decreasing levels of similarities.
- Organisms that originated first and have not changed much during the course evolution are called **primitive or lower organisms. E.g. bacteria.**
- Organisms that originated later and have changed much during the course of evolution are called **advanced organisms e.g. primates**.

TRACING EVOLUTIONARY RELATIONSHIPS

- Different organisms have similar characteristics because they are either inherited from a common ancestor or they perform a common function.
- **Homologous organs** are organs have same basic structure modified to perform different function in different organisms. E.g. Limbs of amphibians, reptiles, birds and mammals have same basic structure but they are modified to perform different functions.
- Homologous characteristics also help us to identify an evolutionary relationship between apparently different species. Mammals are related to amphibians, reptiles and birds at some stage of evolution because of similarity in basic structure of their limbs.
- **Analogous organs** are organs which look similar because they perform same function, but they do not have same origin and basic structure.

  E.g. Wings of butterfly, wings of a bat and wings of birds look similar because they perform same function of flying but they do not have same origin and basic structure.
- **Vestigeal organs** are organs which occurred in reduced form and are useless to the possessor, but are homologus to fully developed, functional organs in the ancestors. E.g. Vermiform Appendix of the large intestine and nictating membranes in the eye of human beings.

FOSSILS PROVIDE EVIDENCE OF EVOLUTION

- Fossils provide us direct evidence of the types of organisms (Plants, animals and microbes) that existed at a particular geological time and help us to reconstruct the evolutionary process.
- Fossils are preserved remains or impressions of organisms that lived in the past.
- Some fossils provide us links between existing groups of plants and animals for example feather imprints preserved along with dinosaur's bones indicate that birds have evolved for reptiles. Archaeopteryx is connecting link between the reptiles and birds. It looks like birds but has many other features like reptiles.
- Age of fossils can be found out by estimation of the depth of the layer of rocks in which it is found and by the carbon-dating method

STAGES OF EVOLUTION

- Series of DNA changes (mutation), cause evolution of complex organisms, created bit-by-bit over generations.
- The structure of the eyes in each of these organisms is different, having separate evolutionary origin. The various stages of evolution of structure of eye.
  - (i) Planaria is having rudimentary eyes consisting of a few photosensitive cells which detect light.
  - (ii) Insects have well-developed eyes with mosaic vision.
  - (iii) Octopus (Mollusca) and vertebrates also have well-developed eyes.
- The structure of wings also evolved through a series of stages.
  - (i) Feathers originated in dinosaurs for the first time and provided insulation in cold weather. They have never used it for flying
  - (ii) Birds adapted the feathers to flight later.
  - (iii) Fossils of a small dinosaur have imprints of feathers along bones of forearm and head but they have never used it for flying
  - (iv) This indicates the evolution of feathers in the initial stages were not useful for flying which means that a character that originated for one function evolved later to perform another function.
  - (v) Fossils showing intermediated stages form connecting links between two groups and provide a direct evidence of evolution.
- The process of evolution is visible through living examples of cultivated plants.
- Two thousand years ago man started cultivation of wild cabbage as a food.
- Man selected plants with desired characteristics and multiplied them.
- This process of artificial selection led to evolution of number of different looking new varieties like cabbage, broccoli, cauliflower, kohlrabi, kale, Brussels sprout and red cabbage.

By comparing the DNA of different species evolutionary relationships can be traced very accurately

- More distantly related organisms have greater number of difference in their DNA therefore it gives a direct estimate of how much the DNA has changed during the formation of these species.
- Molecular phylogeny is used to trace the changes in DNA is now extensively used to define evolutionary relationships.

Evolution as the process of Creation of Diversity

Diversity of forms of life has emerged as a result of environment selection over time.

- Evolution has progressed with passage of time from simple to complex body types. But evolution is not the process of replacement of older species by new species.

- Natural selection and genetic drift have led to the formation of populations that are reproductively isolated from the original populations.
- Human beings are not at the top of evolutionary ladder. They represent a species originated quite recently in the diversity of evolving life.
- Human being and chimpanzees have great similarities at even at molecular level. That does not mean humans have evolved from chimpanzees.
- Human beings and chimpanzees have common ancestor a long time ago. The two species evolved in their own separate ways to give rise to the existing forms.

Ernst Haeckel (1834-1919) formulated that 'ontogeny recapitulates phylogeny' (biogenetic law). This means that the developmental stages that an organism goes through repeat the evolutionary history of the group to which the organism belongs.

HUMAN EVOLUTION

- To study human evolutionary relationships various tools were used:
  (i)Excavating (ii) Time-dating (iii) Fossils (iv) Determining DNA sequences
- Although there is great diversity of human forms all over the world yet all humans are a single species.
- It is wrong to say that man has evolved from monkey.
- Man, monkey and ape have evolved from a common stock of anestors called **anthropoid mammals.**
- One of the oldest fossiles of apes is reported from South Africa (proconsul).
- **Ramapithecus** is considered to be earliest man like primates.
- Its fossil has been discovered from Siwalika hills of India, 14–15 million year ago.
- **Several** species belonging to genus Homo can be recognized from fossil record.
- Homo habilis lived in Africa about two million years ago.
- Homo erectus appeared 1.7 million years go and is believed to have migrated to Asia and Europe.
- ***Homo erectus erectus*** (Java man) fossil was reproted from Java.
- Fossils similar to Java men have been discovered in other parts of the world e.g., Peking man ***(Homo erectus pekinensis).***
- Neanderthal man ***(Homo sapiens neanderthalensis)*** appeared in north Aftrica.
- **Cro-magnon man** (homo sapiens fossilis) successors to neanderthal man were peak of stone age.
- Man of today ***(Homo sapiens sapiens)*** spread about 10,000 years ago all over the world.
- Its members migrated westwards, eastwards and southwards forming present day while, mongoloid and negroid races.