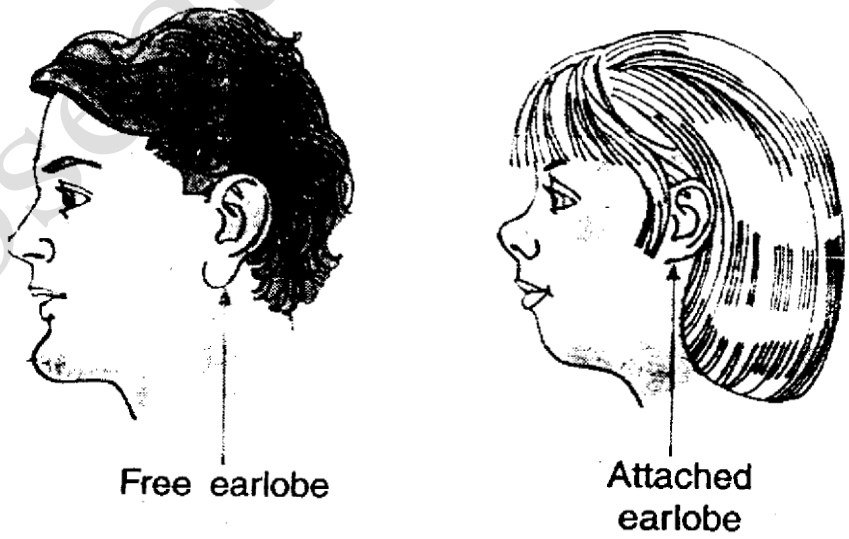
HEREDITY & EVOLUTION

- A recognizable feature of an organism like height, complexion, colour of eye, etc are called Characters or traits.
- The transmission of characters (or traits) from the parents to their offsprings is called heredity.
- The heredity information is present in the sex cells (or gametes) of the parents which fuse to form fertilized egg or zygote. Zygote then develop into an organism of a particular type.
- Thus, gametes constitute the link between one generation and the next, and pass on the parental (father's) and maternal (mother's) characters or traits to the offspring.
- It deals with the phenomenon of **'like begets like'** that is members of each species breed true to their type. Thus, cats are produced by cats and humans are produced by humans.
- Although the offsprings inherit the characters (or traits) of the parents and resemble them very closely, but the resemblance is not complete in all respects. No two individuals are exactly alike and the members of any species differ from one another in some traits or the other.
- These differences in the characters (or traits) among the individuals of a species is called variation.
- Another example of variation in human beings involves our ears. The lowest part of our ear is called earlobe.
- In most of the people, the earlobe is 'hanging' and it is called **free earlobe**. In some people, the earlobe is closely attached to the side of head and it is called **Attached earlobe**.
- So, the free earlobes and attached earlobes are the two variations found in human population.



- Some amount of variations is produced even during asexual reproduction but it is very small. The number of variations produced during sexual reproduction is very large.
- For example, the sugarcane plant reproduces by the process of asexual reproduction, so if we observe a field of sugarcane, we will find very little variations in various sugarcane plants.
- But in animals which reproduce by the process of sexual reproduction, a large number of variations are produced. It is due to these variations that no two human beings look alike.

ACCUMULATION OF VARIATIONS

- The reproduction of organisms produces variations. The variations produced in organisms during successive generations get accumulated in the organism.
- The significance of a variation shows up only if it continues to be inherited by the offspring for several generations.
- For example, a bacterium produces two bacteria by asexual reproduction. Now, suppose that one of the offspring bacterium has a variation due to which it can tolerate a little higher temperature than the other one.
- This variation of little more heat resistance will go on accumulating in the offsprings of successive generations of the bacterium. And this will ultimately give rise to a new variety of bacteria.

IMPORTANCE OF VARIATIONS

- They help the individuals to adapt themselves according to the changing environment.
- Variations give each organism a distinct individually.
- They form raw materials for evolution and development of new species.
- Variations form the basis of heredity.

INHERITED TRAITS

- It is the transmission of particular characteristics from parents to their offsprings, generation to generation.

RULES OF INHERITANCE OF TRAITS: MENDEL'S CONTRIBUTION

- Mendel was an Austrian geneticist and regarded as "Father of Genetics", because he was the first to demonstrate the mechanism of transmission of characters from one generation to the other.
- Mendel worked with seven pairs of varieties of pea plants. The seven pairs of varieties differed in such characters as flower colour, flower position, height, pod shape, pod colour, seed shape, seed colour, etc.
- Mendel selected Garden Pea (pisum sativum) for his experiments because

→ Pea plant showed a number of easily detectable contrasting characters.

→ Pea plant is annual plant and gives results in a year's time.

→ Large number of seeds are produced per plant.

→ The plant is grown easily and does not require after-care except at the time of pollination.

IMPORTANT TERMS USED

Chromosome: It is a thread like structure in the nucleus of cell formed of DNA which carries the genes.

Genes: A gene is a unit of DNA on a chromosome. It is actually units of heredity which transfer characteristics (or traits) from parents to their offsprings during reproduction. Mendel used the term '**Factors**' for genes. Genes work in pairs. In diagrams, genes are represented by letters. For example, the gene for tallness is represented by letter T where as the gene for dwarfness is represented by letter t. The letters T and t actually represent two forms of the same gene controlling length of stem of plant.

Dominant gene: The gene which decides the appearance of an organism even in the presence of an alternative gene is known as dominant gene.

Recessive gene: The gene which can decide the appearance of an organism only in the presence of another identical gene is called Recessive gene.

Genotype: It is the description of genes present in an organism. Example, genotype of tall plant is TT or Tt and genotype of small plant is tt.

Phenotype: The characteristics (or trait) which is visible in an organism is called its phenotype. Example, being 'tall' or 'dwarf' are phenotypes of a plant.

Inheritance: is the transmission of genetically controlled characteristics (or traits) from one generation to the next.

F_1 generation - When two parents cross (or breed) to produce progeny (or offspring) then their progeny is called First filial generation of F_1 generation.

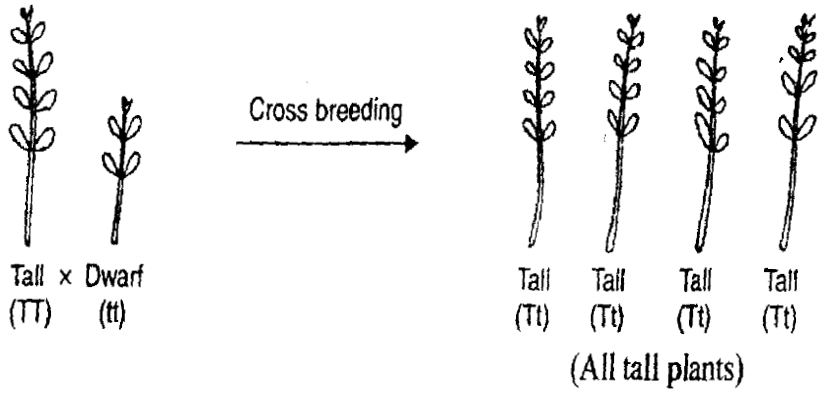
F_2 generation - When the first generation progeny cross among themselves to produce second progeny, then this progeny is called Second generation or F_2 generation.

MONOHYBRID CROSS

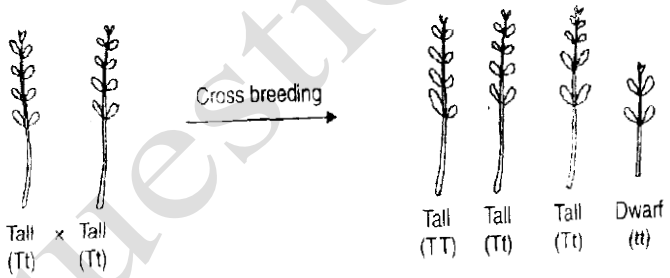
A cross in which only one trait like size of plant (tall or dwarf) or shape of seed / round or wrinkled etc. is considered as **monohybrid cross**.

EXPERIMENT

- Mendel took pea plants with different characteristics as tall plant and a short plant, produced their progeny and calculated the number of tall or short progeny.
- The first generation or F_1 **progeny** formed all tall plants. There were no halfway characteristics in first generation. There was no "medium-height" plants.



- Mendel then allowed the F_1 progeny plant for self-pollination.
- The second generations or F_2 **progeny** of the F_1 tall plants are not all tall, some are short. This indicates that both the tallness and shortness traits were inherited in the F_1 plants, but only the tallness trait was expressed.
- Thus, two copies of the trait are inherited in each sexually reproducing organism. These two may be identical, or may be different, depending on the percentage.



EXPLANATION OF RESULTS OF MONOHYBRID INHERITANCE

(i) Mendel said that each trait is determined by a pair of 'factors'. This means that the tall pea plant has two factors TT for the trait for tallness and dwarf pea plant has two factors tt for the trait of dwarfness.

(ii) The factors of inheritance of tallness "TT" separate into two gametes "T" and "T", and the factors of inheritance of dwarfness "tt" into two other gametes "t" and "t".

(iii) The gametes of tall pea plant then cross with the gametes of dwarf pea plant by the process of fertilization to form zygotes which then produce various progeny in the F_1 generation or first filial generation.

(iv) In the F_1 generation, all the progeny plants have factors Tt in which "T" is the factor for tallness which is a dominant trait. Since all the plants in the F_1 generation have the factors, "Tt", so all of them are tall.

(v) The small letter 't' represents **recessive trait** of dwarfness, which does not show up in first generation in the presence of **dominant trait** "T".

(vi) When tall pea plants formed in first generation (Tt) are cross-fertilized with each other, then they will produce second generation (F_2) pea plants.

- In F_2 generation, the pea plants produced have genotype TT, Tt, Tt and tt. The plants having genotype TT, Tt and Tt all contain the factor T for dominant trait "tallness", so all the three palnts (TT, tt and Tt) are tall.
- The plant having genotype "tt" has both factors 't' for the recessive trait dwarfness, so it is a dwarf plant.
- So, in F_2 generation we get three tall plants and one dwarf plant, so the phenotypic ratio in monohybrid cross will be:

Tall Plants: Dwarf Plants = 3: 1

- In F_2 generation, we get one plant having genotype TT, two plants having genotype Tt and one plant having genotype tt. So, genotypic ratio in monohybrid cross will be:

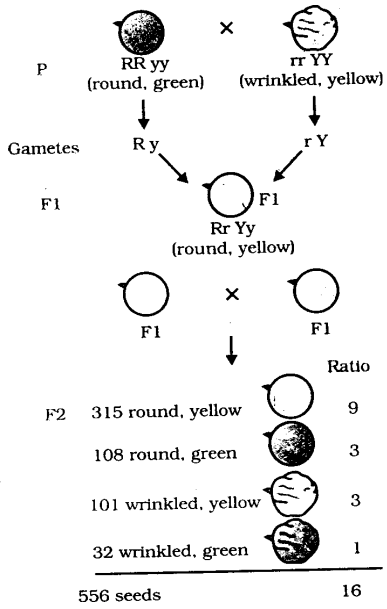
Tt: Tt: tt ➔ 1: 2: 1

DIHYBRID CROSS

A cross in which two contrasting traits are considered at the same time is called a Dihybrid cross.

EXPERIMENT CONSIDERING TWO TRAITS

- Mendel took pea plants with two different characteristics such as plant with ***round-yellow seeds*** and a plant with ***wrinkled green seeds***.
- F_1 progeny have all yellow round seeds. Yellow coloured and round seeds are thus dominant traits.
- In F_2 progeny, some are round yellow seeds and some were wrinkled green seeds.
- But some F_2 progeny shows new mixtures. Some plants were having wrinkled yellow seeds, while other were having round green seeds.
- Therefore, yellow / green colour trait and round seed / wrinkled seed trait are independently inherited.
- The phenotypic ratio of different types of seeds can be written as:



9: 3: 3: 1 = Round yellow seed: Round green seed: Wrinkled yellow seed: wrinkled green seeds

- Thus, the ratio of each phenotype of the seeds in the F_2 generation is 9: 3: 3: 1. This is known as DIHYBRID RATIO.
- On the basis of this observation, Mendel concluded that though the two pairs of original characteristics (seed shape and colour) combine in the F_1 generation but they separate and behave independently in subsequently generations.

HOW ARE CHARACTERISTICS TRANSMITTED TO PROGENY

- The characteristics or traits of parents are transmitted to their progeny (offsprings) through gene present on their chromosomes during the process of sexual reproduction.
- There is a pair of genes for each characteristics of an organism (one is dominant gene and the other is recessive gene). Each parent possesses a pair of genes for each characteristics on a pair of chromosomes.
- Each parent passes only one of the two genes of the pair for each characteristic to its progeny through gametes. Thus, the male gamete and female gamete carry one gene for characteristic from the gene pairs of parents.
- But when a male gamete fuses with a female gamete during fertilisation, they make a new cell called zygote with a full set of genes.
- This zygote grows and develops to form a new organism having characteristics from both the parents which it has inherited through genes.
- The progeny inherits two genes for each trait from its parents but the trait shown by the progeny depends on which inherited gene is dominant of the two.

HOW DO GENES CONTROL THE CONTROL THE CHARACTERISTICS?

A gene is the section of DNA on a chromosome which codes for the formation of protein controlling a specific characteristic(or trait) of the organism.

For example, a plant progeny has gene for the characteristic called 'tallness'. Now, the gene for tallness will give instructions to the plant cells to make a lot of plant growth hormones. And due to the formation of excess of plant growth hormones the plant will grow too much and hence become tall.

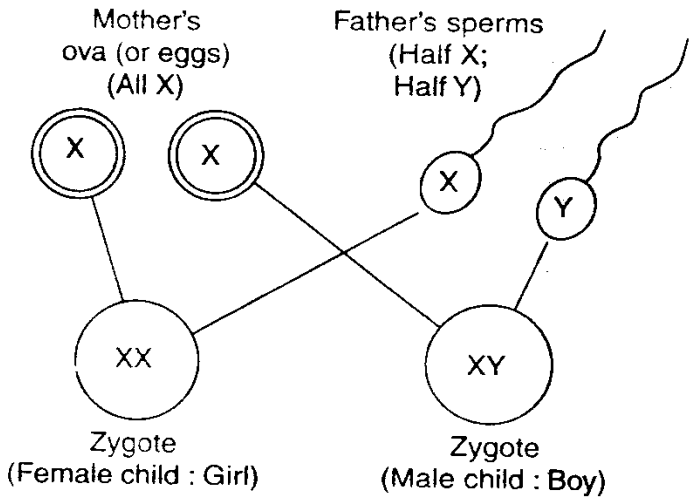
On the other hand, if the plant has the gene set for dwarfness, then less plant growth hormones will be produced due to which the plant will grow less, remain short and hence becomes a dwarf plant.

SEX DETERMINATION

- A person can have a male sex or a female sex. The process by which the sex of person is determined is called sex determination.
- The chromosomes which determine the sex of a person are called sex chromosomes. There are two types of sex chromosomes, one is called **X chromosome** and the other is called **Y chromosome**.
- A male has one X chromosome and one Y chromosome **(XY)**. This means that half the male gametes

will have X chromosomes and the other half will have Y chromosomes.

- A female has two X chromosomes (but no Y chromosome). This means that all the female gametes will have only X chromosomes **(XX)**.



THE SEX OF A CHILD DEPENDS ON WHAT HAPPENS IN FERTILIZATION.

(a) If a sperm carrying X chromosome fertilises an ovum (or egg) which carries X chromosomes, then the child born will be a girl (or female). This is because the child will have **XX** combination of sex chromosomes.

(b) If a sperm carrying Y chromosome fertilises an ovum (or egg) which carries X chromosomes, then the child born will be a boy (or male). This is because the child will have **XY** combination of sex chromosomes.

- In some of the animals, sex determination is also controlled by the environmental factors. For example, in some reptiles, the temperature at which the fertilized egg is kept, plays a role in determining the sex of the offspring.
- It has been found that in a turtle, high incubation temperature leads to the development of female offsprings.
- In the case of a lizard, high incubation temperature results in male offsprings.

EVOLUTION

- The word 'evolution' has been derived from the Latin word 'evolvere' which means to "unroll" or "unfold".
- Evolution is the sequence of gradual changes which take place in the primitive organisms over millions of years in which new species are produced.
- It is through the constant process of evolution taking place in the organisms since the origin of life that such an enormous variety of plants and animals have come to exist on this earth at present.

HOW EVOLUTION OCCURS?

There is an inhibit tendency to variation during reproduction because of errors in DNA copying and as a result of sexual reproduction. Let us study this with an illustration.

A group of 12 red beetles live in some bushes with green leaves. Their population will grow by sexual reproduction and can therefore generate variations.

Case - I

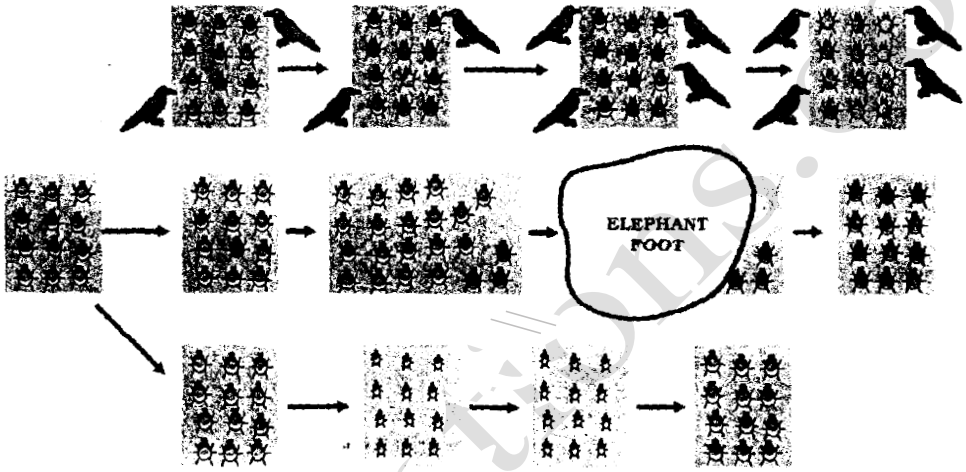
- A colour variation arises in one beetle that is green instead of red. This beetle passes the colour on its progeny and all its progeny beetles are green.
- Crows can't see green coloured beetles on the green leaves of bushes and therefore cannot eat them.
- As a result, there are more green beetles than red ones in the population.
- This type of variation gives a survival advantage. It was naturally selected. The more crows there are, the more red beetles would be eaten, and the more the proportion of green beetles in the population would be.
- Thus natural selection is directing evolution in the beetle population. It results in the adaptations in the beetle population to fit to their environment better.

Case - II

- Due to colour variation during reproduction, a blue colour beetle appears instead of red. This beetle can pass the colour on to its progeny so that all its progeny beetles are blue.
- Crows can see both red and blue beetles and therefore can eat them.
- Initially, there are less number of blue beetles and more of red beetles.
- Then an elephant stumps on the bushes kills most of the beetles. By chance, few beetles that survived were mostly blue.
- Thus, the blue beetle population slowly expands and beetles in the population are mostly blue.
- There is no survival advantage, instead there is a matter of accidental survival of beetles of one colour.
- The elephant would not have caused such major horror in the beetle population, if the beetle population had been very large.
- Accidents in small populations can change the frequency of some genes in a population, even if they give no survival advantage.
- This is notion of **genetic drift** which provides diversity without any adaptations.
- In both situations, a rare variation came to a common characteristics in a population.

Case - III

- As the beetle population begins to expand, the bushes start suffering from a plant disease and the amount of leaf material for the beetles is reduced.
- Thus the beetles are poorly nourished and the average weight of adult beetles has decreased.
- No genetic change has occurred.
- After a few years, the plant disease is eliminated and enough food is available for the beetles. Due to this, beetles come back to its normal size and weight.
- This change is not inherited over generation.



GENETIC DRIFT

- The random changes in gene frequencies occurring by chance and not under the control of natural selection are called genetic drift.
- It is an evolutionary force operating in small population.
- Gene frequency in small populations changes by chance.

ACQUIRED TRAIT

A trait (or characteristic) of an organism which is not inherited but develops in response to the environment is called an **acquired trait**. For example, if the weight of the beetle is reduced due to starvation, that will not change the DNA of the gene cells. Therefore, low weight is not a trait that can be inherited by the progeny of a starving beetle.

Consider another example, if we breed a group of mice, all their progeny will have tails, as expected. Now, if the tails of these mice are removed by surgery in each generation, these tailless mice will not have tailless progeny, because removal of the tail cannot change the genes of the germ cells of mice.

INHERITED TRAIT

Inherited traits are those traits that can be transmitted to future generations in which changes have occurred in the genes (or DNA) present in the reproductive cells (or gametes) of parent organisms.

For example, the change of red colour to green colour in beetle has been brought about by a change in the genes (or DNA) of the reproductive cells. The green colour of this beetle is an inherited trait which can be passed onto the next generation.

DARWIN'S THEORY OF EVOLUTION

Charles Robert Darwin gave the theory of evolution in his famous book **"The Origin of Species"**. This theory is also called **Theory of Natural Selection** because it suggests that the best adapted organisms are selected by nature to pass on their characteristics (or traits) to next generation.

Darwin's theory of evolution can be described as follows:-

(1) Within any population, there is **natural variation**. Some individual have more favourable variations than others.

(2) Even though all species produce a large number of offsprings, **populations** remain fairly constant naturally.

(3) This is due to the **struggle** between members of the same species and different species for food, space and mate.

(4) The **struggle for survival** within populations eliminates the unfit individuals. The fit individuals possessing favourable variations survive and reproduce. This is called natural selection (or survival of the fittest).

(5) The individuals having **favourable variations** pass on these variations to their progeny from generation to generation.

(6) These variations when accumulated over a long period of time, lead to the **origin of a new species**.

ORIGIN OF LIFE ON EARTH

- A British scientist **J. B. Haldane** suggested in 1929 that life must have developed from the simple inorganic molecules (such as methane, ammonia, hydrogen sulphide, etc.) which were present on the earth soon after it was formed.
- He said that the conditions on earth at that time (including frequent lighting) could have converted simple inorganic molecules into complex organic molecules which were necessary for life.
- These complex organic molecules must have joined together to form first primitive living organisms.
- Haldane also suggested from theoretical consideration that life (or living organism) originated in the sea water.
- The theory of origin of life on earth proposed by Haldane was confirmed by experiments conducted by **Stanley L. Miller** and **Harold C. Urey** in 1953.

- They assembled an apparatus to create an early earth atmosphere which was supposed to consist of gases like methane, ammonia and hydrogen sulphide, etc over water (but no oxygen).
- At the end of one week, it was found that about 15% of carbon (from methane) had been converted into simple compounds of carbon including 'amino acids' which make up protein molecules found in living organisms.
- This experiment provides the evidence that the life originated from inanimate matter (or lifeless matter) like inorganic molecules.

SPECIFICATION

The origin of new species from the existing one is called specification.

- **Micro-evolution** - This means that the changes which are small but significant variations appear in individuals that simply changes the common characteristics (traits) of a particular species.

GENERATION OF NEW SPECIES

When a population of a species splits into two populations, it cannot reproduce with each other. Then, they be called two independent species. Then a new species is generated, for example

- A huge population of beetles fed on bushes spread a wide mountain range.
- The beetle population becomes very large.
- Individual beetles feed mostly on a nearly bushes.
- In that huge population of beetles, there will be sub-populations. There male and female beetles meet for reproduction to happen, so most reproduction will be within these sub-populations.
- Occasionally a migrant beetle might go from one site to another or a beetle is picked up by a crow from one site ad dropped in the other site. This migrant beetle will reproduce with local population.
- Over generations genetic drift will accumulate different changes in each sub-population. Also natural selection may also operate differently in different geographic locations.
- Together the processes of genetic drift and natural selection will result in these two isolated sub-populations of beetles becoming more and more different from each other.
- Eventually, members of these two groups will be incapable of reproducing with each other and two generations of beetles are being generated.

EVOLUTION AND CLASSIFICATION

- **Hierarchy** - It is a type of social organisation in which the individuals are ranked according to their dominance relative to other group members. Higher up in the hierarchy, the similarities between members of a group become fewer.
- **Characteristic** - They are the details of appearance or behaviour of a particular form or a particular function. For example, four limbs of human beings is a characteristic and that plants can perform photosynthesis is also a characteristic.

SOME BASIC CHARACTERISTICS OF ORGANISMS

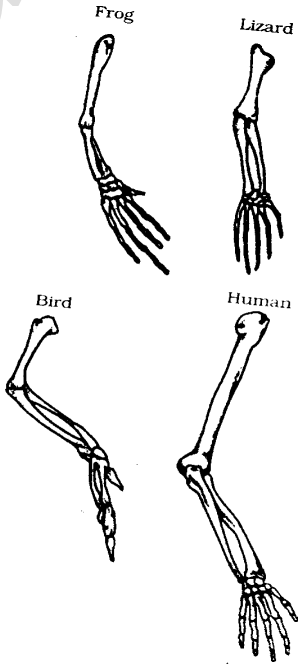
- Cell is the basic unit of life in all organisms.
- A basic characteristic of cell design that differs among different organisms is whether the cell has a nucleus or not.
- Among organism with nucleated cells, some are unicellular and others are multicellular.
- Among multicellular organisms, some can undertake photosynthesis and others cannot.
- Among multicellular organisms, some have skeleton inside the body and other around the body.
- The more characteristic two species will have in common, the more closely they are related.
- The more closely they are related, the more nearer they have common ancestor. For example, a brother and sister are closely related and they have a common ancestor, their parents in the first generation.
- A girl and her first cousin are also related but less than the girl and her brother. The cousins have common ancestors, their grand-parents in the second generation thus classification of species is a reflection of their evolutionary relationship.

HOMOLOGOUS ORGANISMS

They are those organs which have the same basic structural design and development origin but have different functions and appearance.

These organs follow the same basic plan of organisation during their development but has been modified to perform different functions

Example, **the forelimbs of a frog, lizard, bird, human**

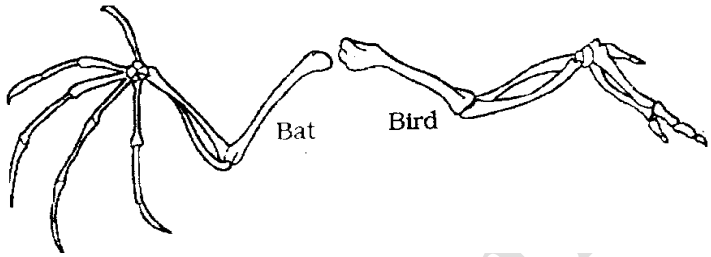


- Here, the basic structure of limbs is similar though it has been modified to perform different function in various vertebrates.
- Such a homologous characteristics helps to **identify an evolutionary relationship** between apparently different species.

ANALOGOUS ORGANS

They are those organs which have different basic structural design and development origin but have similar appearance and perform similar functions.

For example, **the wings of birds and bats**



- The wings of birds and bats look similar but have different design in their structure. Wings of bats are skin folds stretched mainly between elongated fingers but wings of birds are a feathery covering all along the arm.
- The design of the two wings, their structure and components are very different. They look similar because they have a common use for flying but their origins are not common.

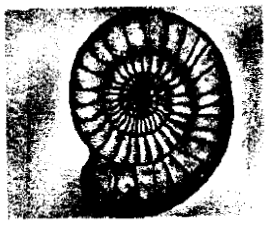
FOSSILS

- Fossils are the preserved traces or remains of living organisms of geological part.
- When organisms die, their bodies will decompose and get lost.
- But some parts of the body may be in the environment that does not let it decompose completely.
- For example, a dead insect which gets caught in hot mud, it will not decompose quickly and the mud will eventually harden and retain the impression of the body parts of the insect and thus preserved as fossils.
- Fossils provide one of the most acceptable evidences in support of evolution because we can study the evolutionary past of individuals in the form of their fossils.

KIND OF FOSSILS

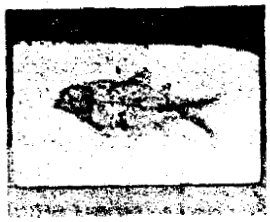
Fossils are of various kinds depending upon their differences in appearance and degrees of detail and preservation. They are, fossil tree trunk, fossil invertebrate **(Ammonite)**, fossil invertebrate **(trilobite)**, fossil-fish **(Knighter)** and fossil dinosaur skull **(Rajasanrus)**.

Fossil tree trunk



Fossil invertebrate (Ammonite)

Fossil invertebrate (Trilobite)



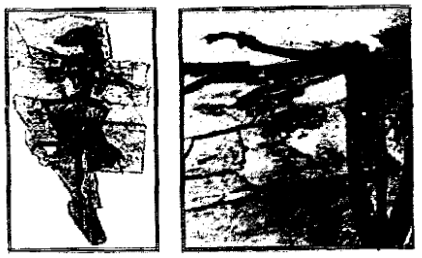
Fossil fish (Knightia)

Fossil dinosaur skull (Rajasaurus)

HOW DO WE KNOW HOW OLD THE FOSSILS ARE?

There are two ways to know the age of fossils:-

- First way is **relative**. If we dig the earth and locate fossils. The fossils we find closer to the surface are more recent than the fossils we find in dipper layer.
- Second way is **DATING FOSSILS** by detecting the ratios of different isotopes of the same element in the fossil material.
- It can be done by working out the ratio of Uranium to lead in a rock or fossil. It is so because radioactive uranium decays spontaneously to lead at a constant and known rate. This property is used to determine the age of rocks or fossils.
- Fossils also provide evidence of instances wherein a change useful for one function to start which can become useful later for quite a different function.
- For example, feathers was developed initially to provide insulation in cold weather but later these have become useful for the function of flight in birds.
- This speculation is based on the evidence from fossil records of small dinosaur. In fact, some dinosaurs had feathers but it could not fly using the feathers.
- Birds seem to have later adapted the feathers to flight since dinosaurs were ancient reptiles and many of them had also characters of birds.
- Therefore, these fossil evidences suggest that birds are very closely related to reptiles and have evolved from them.



This is a small dinosaur from the dromaesaur family.

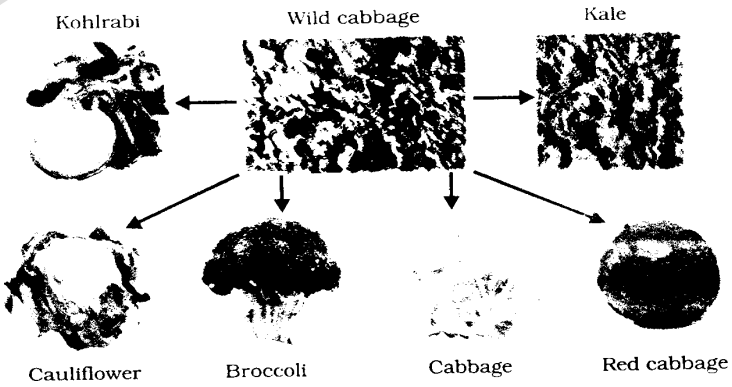
Feather imprints were preserved along this dinosaur's bones. Here we can see feathers on the forearm.

Here s a close-up of the fossil's head feathers.

This dinosaur could not fly, and it's possible that the evolution of feathers had nothing to do with flight.

ARTIFICIAL SELECTION

- It is the process by which man selects traits useful for improving the qualities of domesticated plants and animals.
- Animals or plans with desirable characteristics or traits are inter-breed with the aim to produce new strain of organisms for a specific purpose.
- Human have more than two thousand years have cultivated wild cabbage as a food plant and generated different vegetables from it by selection. This is Artificial Selection.
- Farmers who wanted to select for short distances between leaves, and have bred the cabbage.
- Some have wanted to select for arrested flower development, and have bred **broccoli,** or for sterile flowers and have made the **cauliflower**.
- Some have selected for swollen parts, and come up with **Kohlrabi**. Some have selected for slightly larger leaves and come up with a leafy vegetable called **Kale.**



The traces of evolutionary relationships depends on the idea that changes in DNA during reproduction are

the basic events in evolution. Then, comparing the DNA of different species give a direct estimate of how much of the DNA has changed during the formation of these species. This method is now extensively used to define evolutionary relationships.

EVOLUTION SHOULD NOT BE EQUATED WITH PROGRESS

- There is no real progress in the concept of evolution. Evolution is just the production of diversity of life forms and shaping of this diversity by the environmental selection.]
- The only progress in evolution appears to be that more and more complex body designs of organisms have emerged over the ages.
- When a new species is formed, it is not necessary that the old species will disappear from earth. It will all depend on the environment.
- Also it is not as if the newly formed species are in any way better than the older ones.
- It is common belief that chimpanzees are the ancestors of human beings. It is, however, not true that human beings have evolved from chimpanzees. Actually, both chimpanzees and human beings had a common ancestor long time ago. The two offsprings, of that ancestor evolved in their own separate ways to form the modern day chimpanzees and human beings.
- It is not as if the body designs of older organism were inefficient. This is because many of the older and simpler forms of organisms still survive on earth.
- For example, one of the simplest and primitive life forms called 'bacteria' still inhabit some of the most unfavourable habitats such as hot springs, deep-sea thermal vents and the ice in Antarctica.

HUMAN EVOLUTION

- Human evolution has been studied by various tools of tracing evolutionary relationship like excavating (digging earth), carbon-dating, studying - fossils and determining DNA sequences.
- The human races were even identified on the basis of their skin colour and named as white, black, yellow or brown.
- It is now known that the so-called human races have not evolved differently. In fact, there is no biological basis for dividing human beings into different races. All human beings (whether, white or black) belong to single species called Homo sapiens.
- It has now been establish by research that the earliest members of the human species came from Africa.
- So, irrespective of where we have lived for the past few thousand years, we all come from Africa.
- About hundred thousand years ago, some of our ancestors left Africa, while others stayed back. Those who left Africa, spread across the whole earth.