



CHAPTER

16

HEREDITY AND EVOLUTION

Living organisms produce new individuals that are similar to themselves by the process of reproduction. Generally very low degree of differences are observed in the offsprings produced through asexual reproduction. On the other hand, in case of sexually reproducing organisms, their offsprings develop traits different from those of their parents. In plants like sugarcane and bamboo, which are generally reproduce asexually, we find very little variation amongst individual plants so long as they are grown under similar conditions. But in a number of animals including human beings, which reproduce sexually, quite distinct variations are visible among different individuals (except in identical twins).

DNA (deoxyribonucleic acid), the genetic material provides instructions for making structural and functional proteins that give members of the same species similar recognisable external and internal features which are called **characters** or **traits**. A segment of DNA molecule that provides information for one trait is called the **gene** for the traits.

The genetic material sometimes changed or mutated due to certain internal or external factors. Such changes can cause the genetic material to give different instructions and lead to different kinds of traits being formed. Consequently, small differences or variations in structural and functional characters between members of the same species are observed.

All these variations in a species do not have equal chances of surviving in the environment in which they find themselves. Depending on the nature of variations, different individuals would have different kinds of advantages. Selection of variants by environmental factors forms the basis of evolutionary processes.

16.1. HEREDITY

Long before the discovery of genetic materials, biologists tried to discover rules which would explain why observable characteristics of offsprings are similar to those of their parents and even their grand parents.

A normal child bears all the basic features of a human being. However, it shows variation from their parents. Thus every person possesses certain characters which distinguish himself from others. Can you imagine how much variations exist in human population ?



(a)



(b)

Fig.16.1. (a) Free and (b) attached earlobes. The lowest part of the ear, called the earlobe, is closely attached to the side of the head in some of us and not in others. Free and attached earlobes are two variants found in human populations.

Activity 16.1.

- ☞ Let us observe the ears of all the students in the class. Prepare a list of students having either free or attached earlobes and calculate the percentage of students having each type of earlobe (Fig.16.1).
- ☞ Find out the earlobe types of the parents of each student in the class. Compare the earlobe type of each student with that of their parents.
- ☞ Based on this evidence, suggest a possible rule for the inheritance of earlobe types.

16.1.1. Mendel's Contributions

Of the several theories that have been formulated to explain how traits are inherited, Mendel's theory has provided the foundation upon which all later works in genetics have been built.

Gregor Johann Mendel (1822-1884)

*Gregor Johann Mendel was an Austrian monk, educated in science & mathematics at the University of Vienna. From 1858 to 1865, Mendel worked in the garden of his monastery in the town of Brünn (now Brno), breeding garden pea (**Pisum sativum**) and explaining the characters of the offsprings. This helped him to arrive at the famous laws of inheritance.*



Mendel selected the common garden pea for his experimental work. In garden pea, he found a number of contrasting visible characters, namely, round and wrinkled seeds, tall and dwarf plants, yellow and green seeds and so on.

In garden pea flower, the petals entirely enclose the reproductive structure i.e. male/stamens (which produce pollen) and pistil/female (which produce the egg). Although insects may occasionally penetrate in the flowers, self-fertilization is the rule. In his experiments, Mendel opened the buds and removed the stamens before they are ripened. Then, by dusting the pistil with pollen grains from another plant, he performed cross pollination between them.

In one series of experiments, he selected only one pair of contrasting characters viz. tallness and dwarfness. He crossed a dwarf male plant with a tall female plant and vice versa. The results he obtained in these experiments were the same in all the cases.

Rediscovery of Mendelian principles

Mendel read out his findings before the Brünn Natural History Society in 1865 and was published in the Annual proceedings of the Brünn Natural History Society in 1866. But his findings were not accepted by other scientists of those days. He died in the year 1884. Hugo de-Vries (Holland), Carl Correns (Germany) & E. Von Tschermak (Austria) rediscovered Mendel's discovery in 1900. Mendel did not formulate any Laws of heredity. Carl Correns summarized Mendel's findings into two laws i.e. Law of segregation and Law of independent assortment.

16.1.2. Mendel's Laws of Inheritance

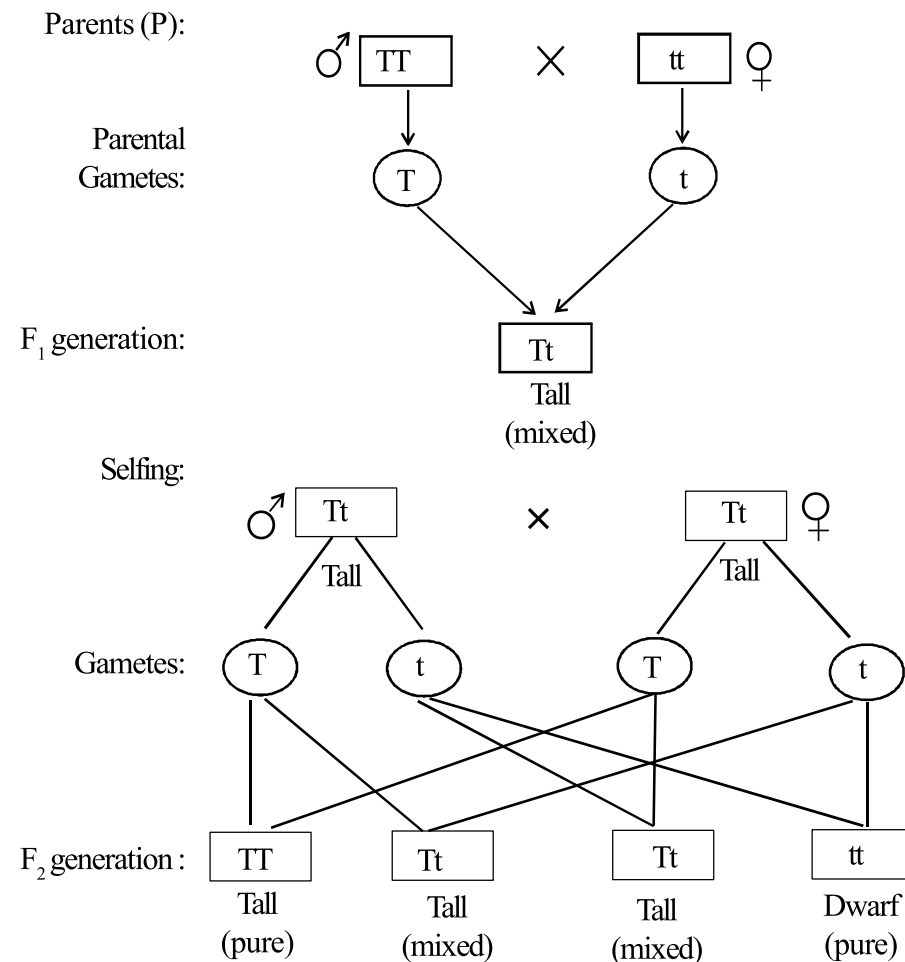
From the results of Mendel's experiments, Carl Correns formulated certain laws to explain the inheritance.

First Law / Law of segregation

Allelic genes in a hybrid do not blend or contaminate each other but segregate & pass into different gametes. This law is derived from a Monohybrid cross.

Monohybrid Cross

In monohybrid cross only one pair of contrasting characters is taken into consideration at a time. Mendel brought about artificial crossing between a tall and a dwarf pea plant. The progeny that resulted from this cross were all tall. This means that only one of the parental traits appear in the progeny. He named this progeny as the first filial generation or F_1 generation.

Monohybrid Cross

The F_1 tall plants were left for reproduction by self pollination. The resulting seeds were collected and sown next year. They gave rise to a mixed generation of tall and dwarf plants, in the ratio of 3:1, i.e. three-fourth tall and one fourth dwarfs. This is known as the second filial generation or F_2 generation. All dwarfs of the F_2 generation bred true, producing dwarf only in third and subsequent generations. Seeds were collected separately from each F_2 tall plants and sown separately. It was seen that one-third of the tall plants bred true, while the other two third again split up in the same ratio of 3:1. The F_2 ratio is therefore 1:2:1. (one pure tall : two mixed tall : one pure dwarf). The ratio of F_2 generation (3:1) considers only its external structural forms is known as **phenotypic ratio**. Whereas the F_2 ratio of 1:2:1 is called as **genotypic ratio**.

In this experiment (Fig. 16.3), both **TT** and **Tt** are tall plants while only **tt** is a dwarf plant. In other words, a single copy of 'T' is enough to make the plant tall while both copies have to be 't' for the plant to be dwarf. Traits which are transmitted unchanged in the F_1 generation, Mendel called it as **dominant**. Those which are hidden in F_1 but reappeared in F_2 , he called it as **recessive**. Here tallness is dominant and dwarfness is recessive.

Second Law / Law of independent assortment

The segregation in one pair of allele is independent of the segregation in any other pair of allele. This law is derived from a dihybrid cross.

Dihybrid Cross

In dihybrid cross two pairs of contrasting characters are taken into consideration at a time. What do the progeny of a round and yellow seed with wrinkled, and green seed look like? They are all round and yellow seeds in F_1 progeny. Round and yellow seeds are thus dominant traits. But what happens when these F_1 progeny are used to generate F_2 progeny by self pollination? From the knowledge of the previous monohybrid experiment, the expected F_2 progeny are round, yellow seeds and some wrinkled and green seeds. However, there would also be some F_2 progeny that showed new mixtures. All possible combinations took place in the following proportion i.e. 9 round, yellow; 3 round, green; 3 wrinkled, yellow and 1 wrinkled, green. Thus the phenotypic ratio of F_2 generation in dihybrid cross is 9:3:3:1. What will be the genotypic ratio of F_2 generation in dihybrid cross?

Dihybrid cross can be explained by the checkerboard method as shown below.

Parents (P) : ♂ $\boxed{RR YY}$ × ♀ $\boxed{rr yy}$
 (round , yellow) (wrinkled, green)

Parental gametes : $\textcircled{RY}$ $\textcircled{ry}$

F₁ generation $\boxed{Rr Yy}$
 (round, yellow)

F₁ gametes : $\textcircled{RY}$ $\textcircled{Ry}$ $\textcircled{rY}$ $\textcircled{ry}$

F₂ generation :

Male gametes of F₁ generation

Female gametes of F ₁ generation	♂ ♀	RY	Ry	rY	ry
	RY	RRYY Round, yellow)	RR Yr Round, yellow	Rr YY Round, yellow	Rr Yy Round, yellow
	Ry	RR Yy Round, yellow	RR yy Round, green	RrYy Round, yellow	Rr yy Round, green
	rY	RrYY Round, yellow	Rr Yy Round, yellow	rr YY Wrinkled, yellow	rrYy Wrinkled, yellow
	ry	RrYy Round, yellow	Rr yy Round, green	rr Yy Wrinkled, yellow	rr yy Wrinkled, green

The genotypic ratio of F₂ generation in dihybrid cross is 1:2:2:4:1:2:1:2:1.
 i.e. 1(RRYY) : 2 (RRYy) : 2(RrYY) : 4 (RrYy) : 1(RRyy) : 2(Rr yy) : 1(rr YY)
 : 2(rr Yy) : 1(rr yy)

Thus the Round/Wrinkled traits and Yellow / Green seed traits are independently inherited.

Whether the genotypes of F₁ generation are homozygous or heterozygous can be determined by back cross or test cross.

Glossary of some genetical terms

Phenotype : Characters that we can see through naked eye, e.g. Tall & dwarf plants.

Genotype : Genetic constitution of an individual e.g. TT for tallness, and tt for dwarfness.

Allele/Allelomorph : Alternative form of the same factor/gene.

Homozygote : True breeds e.g., Tall is genotypically represented by TT.

Heterozygote: Hybrid ; Tall is represented by Tt.

Dominant : The character which appears in F_1 generation is called Dominant character.

Recessive : The other parental character which is not appear in the F_1 generation is called recessive character.

Back cross : It is a cross between F_1 offspring and one of its parents.

Test cross : A cross made between an F_1 offspring and its recessive parent.

Activity 16.2.

- ☞ Take two middle size cotton carry bags.
- ☞ Add 100 yellow pea seeds in one carry bag, representing mother's 50 sets of 'XX' chromosomes.
- ☞ Add 50 yellow and 50 green pea seed in the other bag, representing 50 sets of 'XY' chromosomes of a father.
- ☞ Take out one seed each, from each bag representing the two sex chromosomes.
- ☞ Repeat at least ten times to get ten pairs.
- ☞ Calculate the number of similar and dissimilar pairs of pea seeds.

The pair of yellow seeds will represent the number of female children and the pairs of yellow and green seeds will represent the number of male children. Write the numbers of male and female children.

Let us answer these.

1. What is a gene ?
2. Why did Mendel select garden pea for his experiments ?
3. What is the genotypic ratio of F_2 generation in a monohybrid cross ?
4. What are back cross and test cross ?
5. How many perfect pairs of chromosomes are found in the father of a girl ?

16.2. The origin of life

Darwin's theory of evolution tells us how life evolved from simple to more complex forms and Mendel's experiments give us the mechanism for the inheritance of traits from one generation to the next. But neither tells us anything about how life began on earth in the first place.

Chemical evolution is one means of explaining the origin of life on Earth through the formation of complex organic compounds like the DNA molecule, capable of reproducing themselves. Alexander Ivanovich Oparin (1894), a biochemist, first produced an account for the chemical origin of life.

J.B.S. Haldane, a British scientist, suggested in 1929 that life might have developed from the simple inorganic molecules which were present on earth soon after it was formed. How did these organic molecules arise ?

An answer was suggested by the experiment conducted by Stanley L. Miller and Harold C. Urey in 1953. They performed a simple experiment by assembling a mixture of ammonia, methane and hydrogen sulphide all believed to be present in the atmosphere of the primitive earth, over water. This was maintained at a temperature just below 100°C and electric sparks were passed through the mixture of gases to simulate lightening. At the end of the week, the mixture was analysed and was found to have acquired a mixture of amino acids, which are building blocks of protein molecules.

In the primitive condition of our planet these amino acids were converted to DNA and the nucleic acid is capable of replicating itself. Once a living organism has been formed from non-living organic compound, more living things would arise. All living organisms may have had a common ancestry in the soup of organic materials. The sea should have been the home of first life.

Let us answer these.

1. Who had first proposed the chemical origin of life ?
2. Name three gases that were present on the primitive atmosphere of the earth.

16.3. Evolution

Evolution is a process of gradual change from one form of life to another through a series of intermediate forms. In the course of this process, new forms were formed and get established along side or in the place of the original types. The evolution in living organisms is known as organic evolution.

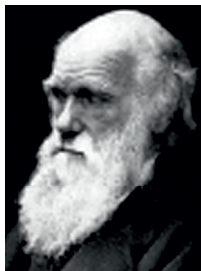
As already stated, the first living organisms emerged over 3000 million years ago and today the earth is inhabited by more than two million different species. How these new species had evolved or how the present day plants and animals came into being ?

The process of changing the genetic material (DNA) has occurred gradually and continuously since life started on earth. The inheritable variations had been the means of life survival when external conditions changed on earth, these variations become traits evident in different species alive on earth today.

There are three different theories to explain the course of organic evolution.

1. **Lamarckian Theory of Inheritance of Acquired Characters propounded by Jean Baptist Lamarck in 1809.**
2. **Theory of Natural Selection propounded by Charles Darwin and Alfred Russel Wallace in 1858.**
3. **Mutation theory propounded by Hugo de-Vries in 1901.**

If we breed a group of mice, all these progeny will have tails. Now, if the tails of these mice are surgically removed in each generation, will these tailless mice produce a tailless progeny? Obviously not, because changes in the non-reproductive tissues can not be passed on to the DNA of the germ cells. So, the removal of the tails can not change the genes of the germ cells of the mice.

**Charles Robert Darwin (1809-1882)**

Charles Darwin was born on February 12, 1809 at Shrewsbury. He was educated at Shrewsbury and later sent to Cambridge. During his three years' stay there he used to mix with the Cambridge naturalists. At the age of 22, he was entertained as a naturalist on board the Admiralty vessel, H.M.S. Beagle which sailed from the shores of England on a long five year voyage of survey (December, 27, 1831 to October 2, 1836,) in the South Atlantic and Pacific Oceans. The studies that he conducted during this five year voyage were to change forever the way we look at the variety of life on earth. But he did not know the mechanism whereby variation arose in the species. Darwin's work was published with R. Wallace's paper in the "Proceeding of the Linnean Society" in 1859, later on Darwin published his famous book "Origin of species". Darwin expired on 19 th April 1882 at the age of 73 years.

One of the most accepted theories of organic evolution is the theory of Natural Selection proposed by Charles Darwin along the following lines.

16.3.1. Over production of offspring and a consequent struggle for existence

The multiplication of individual of a species occurs in a geometrical proportion. But a large majority of the individuals do not survive and consequently the numbers of individuals in a species remain more or less the same. The survivors in any population remain survive because of being better adapted to reach the limited resources, food etc. of the environment. These limited resources are the cause of struggle for existence.

16.3.2. Variations and their inheritance

The survivors in the struggle for existence have certain favourable variations. As a result of struggle for existence only those individuals showing variation in the right direction survive, and these variations are transmitted to the offspring. Others with unfavourable variations perish, resulting to the survival of the fittest.

16.3.3. Natural Selection

Nature or the environment selects those individuals best fitted for survival. The survival of fittest is a result of selection and proliferation of only those organisms which are most suitably adapted to the environment and most successful in mating.

16.3.4. Formation of new species (Speciation)

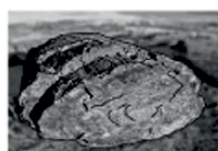
Speciation is the evolution of a new species from the pre-existing one. A species consists of a population of organisms which are able to breed amongst themselves in the natural conditions. Whenever segments of a population are isolated geographically over a period of a number of generations the two isolated segments of the population might gather enough genetic differences to result in a lack of genetic exchange even if the original barrier is removed. In this way new species are being generated.

How will you observe the occurrence of evolution in nature ?

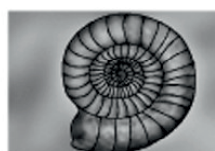
16.3.5. Fossils

When organisms die, their bodies will decompose and be lost. But, fossils are the material remains or traces of organisms preserved inside the earth's crust. Fossilization or formation of fossils involves the conversion of an organism or its parts into a hard structure or rock. While a body or some parts of it get caught in hot mud, they will not decompose quickly and the mud will eventually harden and retain the impression of the body or body parts. How do we know how old the fossils are ? It is reasonable to suppose that the fossils we find closer to the surface are more recent than the fossils we find in deeper layers. Fig.16.3., shows various forms of fossils.

From the study of these fossils one can understand about the life forms of the past. It enables us to trace the origin and trend of evolution of several groups of plants and animals.



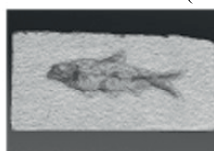
Fossil- tree trunk



Fossil- invertebrate
(Ammonite)



Fossil- invertebrate
(Trilobite)



Fossil- fish (Knightia)



Fossil- dinosaur skull
(Rajasaurus)

Fig.16.3. Various kind of fossils. Note the different appearances and degrees of detail and preservation.

The dinosaur skull fossil shown was found only a few years ago in the Narmada valley.

16.3.6. Homologous and Analogous Organs.

Homologous organs are those structures of organisms, which have the same embryonic origin, though they may or may not perform the same function. A front flipper of whale, a wing of bird, a forelimb of sheep, a human hand (Fig.16.4) perform different functions but they have a common origin. In plants a thorn (in *Bougainvillea*) and a tendril (in *Cucurbita*) are morphologically & functionally different, but they are homologous organs.

On the other hand wings of dragon fly, wings of eagle and wings of bat (Fig.16.5.) appear similar and perform same function but are different in their basic structure and developmental origin. So they are called analogous organs. Thorns (in *Duranta*), spines (in *Opuntia*) and prick les (in Rose) are sharpened and pointed structures. Due to their difference in origin they are analogous structures.

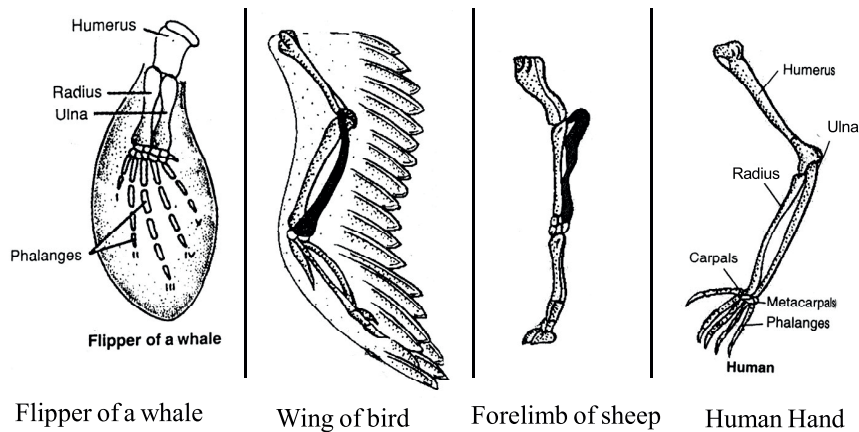


Fig.16.4. Homologous structures

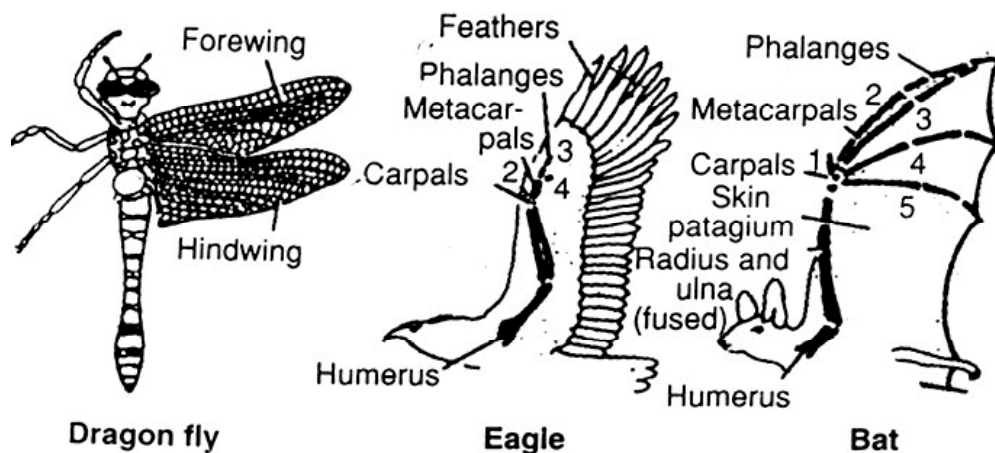


Fig.16.5. Analogous organs in animal

Homologous structures which is specialised to perform a variety of different functions represent evolution of new forms in several directions from the common ancestral type. Whereas analogous structures does not bear close phylogenetic link but shows adaptation to perform the same function during the course of evolutionary history.

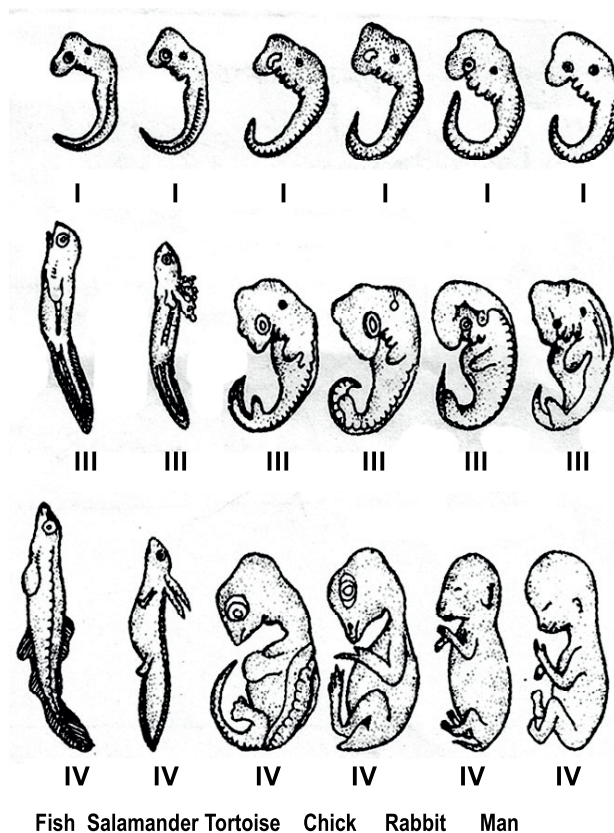


Fig.16.6. Depicting the remarkable similarity in the early embryos of some vertebrates

16.3.7. Resemblance among vertebrate Embryos

There is a close relationship among the early embryonic stages of vertebrates. Fig.16.6. shows the embryonic development of some vertebrates.

It is difficult to differentiate a human embryo from the other vertebrate embryos of **Rabbit**, **Chick**, **Tortoise**, **Salamander** and **Fish** at their early stage of embryogenesis. There are similarities in having gill clefts, notochord, tail, rudimentary eyes and ears, limb buds, etc. The study of embryonic development among vertebrates can also give a clear idea about the evolution of different vertebrates.

Let us answer these.

1. Define organic evolution.
2. Who proposed the theory of natural selection ?
3. What are fossils ?
4. Mention two examples of analogous organs in plant.

16.4. Human evolution

More than a hundred years ago Charles Darwin suggested in his Descent of Man, a common ancestry for apes and humans based on their similarities in anatomy and behaviour. A great diversity of human form and features makes us a great confusion about the origin of human races. Human races have yellow, black and white or brown skin colour.

But all human individuals belong to a single species. It had been proved by using tools for tracing evolutionary relationship like excavating, time dating, studying fossils as well as determining DNA sequence.

The earliest member of human species, *Homo sapiens* has appeared about 300,000 years ago. Our genetic foot prints can be traced back to our African roots. From Africa they migrate slowly to West Asia, then to Central Asia, Eurasia, South Asia, East Asia, then to Indonasia and the Philippines to Australia.

There is no single line of migration. They went forwards and backwards.

In India, the earliest fossil remains of *Homo sapiens* in the form of skull and other bones was discovered in Bhimbetka near Bhopal. It is about 25 to 60 thousand years old. Like all other species in this planet, human being evolved as an accident of evolution and were trying to live their lives the best they could.

Let us answer these.

1. Trace the migratory root of human species.
2. From where the earliest fossil of human species, was discovered in India ?

POINTS TO REMEMBER

- ⇒ Variations arising as a result of mutation can be inherited.
- ⇒ All variations do not have equal chance of survival.
- ⇒ Variations may lead to increase survival of an individual.
- ⇒ Mendel selected garden pea (*Pisum sativum*) with many contrasting characters for his experiment on inheritance.
- ⇒ Sexually reproducing organisms have two copies of genes for the same trait. If the copies are not identical, the trait that gets expressed is called the dominant trait and the other is called the recessive trait.
- ⇒ Traits in one individual may be inherited separately, giving rise to new combinations of traits in the offspring of sexually reproducing organisms.
- ⇒ In dihybrid cross a trait of one pair can combine with another trait of the second pair.
- ⇒ In human beings, the sex of the child depends on whether the paternal chromosome is X (for girls) or Y (for boys).
- ⇒ Mendel formulated certain principles to explain the inheritance, viz. Principle of segregation and Principle of independent assortment.
- ⇒ Life on earth had originated from inorganic molecules.
- ⇒ Organic evolution is a process of gradual change of living organisms from simple forms to complex forms through a series of intermediate forms.
- ⇒ The theory of organic evolution through natural selection was proposed by Darwin.
- ⇒ Speciation may take place when variation is combined with geographical isolation.
- ⇒ Evolution can be worked out by the study of not just living species, but also fossils.
- ⇒ Evolution from a common ancestor can be achieved from the study of embryonic development.
- ⇒ The earliest human species, *Homo sapiens* had appeared about 300,000 years ago in Africa.

EXERCISES

1. What is the Phenotypic ratio in F_2 generation of a dihybrid cross ?
2. What supportive evidence for evolution is provided by comparative embryology ?
3. What is heredity ? What are the laws of inheritance?
4. Explain the term adaptation and how it is related to evolution.
5. How does the creation of variations in a species promote survival ?
6. How do Mendel's experiments show that traits may be dominant or recessive ?
7. How is the sex of a child determined in human being ?
8. What factors could lead to the formation of a new species ?
9. How does the study of fossils provide an evidence in favour of organic evolution?
10. Explain, the theory of organic evolution proposed by Charles Darwin.
11. Explain three evidences of organic evolution.
12. Give three points of difference between homologous and analogous organs with suitable examples.
13. How does the experiment of Miller and Urey provide some support to the hypothesis of Oparin.
14. How the human beings who look so different from each other in terms of size, colour and looks said to belong in the same species ?
15. Draw neat labelled diagrams of two homologous organs in animals.

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