Heredity and Evolution

Differences Between Acquired And Inherited Traits

Acquired traits

An acquired trait is experienced by an individual during his life time. It involves changes in non-reproductive tissues (or somatic cells), which cannot be passed on to the germ cells or progeny. For example, calluses on feet, scars, good cooking skills, knowing to ride a bike etc.

Inherited traits

Inherited trait is a distinguishing quality or characteristic, which one acquires from the ancestors. These involve changes in the DNA. Hence, they are transmitted to the progeny. For example, height, eye colour, blood type, hair colour etc.

Consider the following example to understand inherited traits.

Early understandings of inheritance and evolution

During his voyage, Charles Darwin observed many forms of life. He put forth his theory that evolution occurred as a result of natural selection. Also, variations occur in a population and beneficial variations are selected by nature.

However, he could not explain the reason for the occurrence of variations in the environment. This is because laws of inheritance, inherited and acquired traits, etc. were not known during that time.

Though Mendel performed various experiments and put forth the laws of inheritance, the two scientists never met. As a result, a complete understanding on mechanism of variations could not be established.

Some interesting facts:

- Do you know that Goliath beetle of Africa is the heaviest insect in the world? It weights around 99.22 g.
- Some beetles are even smaller than protozoa.

Mendel and His Experiments

The individuals of a family (parents and offspring) have more similarity in comparison to others. This is because certain characteristics are passed from the parents to the offsprings without any variation..

Heredity is defined as the transmission of characteristics from one generation to another. These characteristics may be physical, mental, or physiological.

Commonly observed heritable features are curly hair, a particular type of ear lobe, hair on ears etc.

Transmission of traits from the parents to progeny - Mendel's Work

Gregor Johann Mendel (1822 – 1884) was the first to carryout the study on the transmission of characteristics from the parents to the offsprings. He proposed that heredity is controlled by factors, which are now believed to be segments of chromosomes or genes.

Mendel performed experiments on a garden pea (*Pisum sativum*) with different visible contrasting characters. He selected seven contrasting pairs of characters or traits in a garden pea. These include round/wrinkled seeds, tall/short plants, green/yellow pod colour, purple/white flower colour, axial/terminal flower, green/yellow seed colour, and inflated/pinched ripe pods.

Mendel's experiment

Mendel performed experiments in three stages:

Mendel's experiment
- Selection of true breeding parents
- Obtaining F_1 plants
- Self pollination of F_1 plants to generate F_2 and F_3 plants

Selection of parents: Mendel selected true breeding pea plants with contrasting characteristics for his experiment. True breeding plant is the one that produces an offspring with the same characteristics on self-pollination. For example, a tall plant is said to be true breeding when all its progeny formed after self-pollination are tall.

Production of F_1 plants: F_1 generation is the first filial generation. It is formed after crossing the desirable parents. For example, Mendel crossed a pure tall pea plant with a pure dwarf pea plant. All F_1 plants were found to be tall.

Results of self-pollination of F_1 plants: Mendel found that on self-pollination of F_1 plants, the progenies obtained in F_2 generations were not all tall plants. Instead, one-fourth of F_2 plants were found to be short.

Mendel's explanation for the reappearance of the short trait:

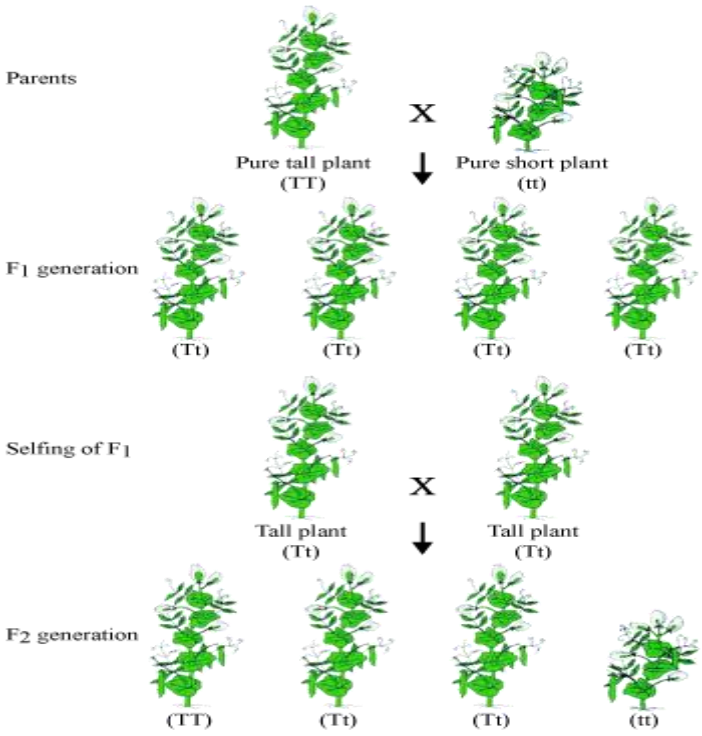
From this experiment, Mendel concluded that F_1 tall plants were not true breeding. They were carrying both short and tall height traits. They appeared tall, because tall trait was dominant over short trait.

Dominant trait: It is a trait or characteristic, which is able to express itself over another contrasting trait. For example, tall plants are dominant over short plants.

Recessive trait: It is a trait which is unable to express its effect in the presence of the dominant trait.

Mendel represented the dominant trait as upper case **T** (i.e. T for tallness), and the recessive trait as lower case **t** (i.e. t for shortness). These traits are actually the genes present in the chromosomes of a cell.

Thus, Mendel's experiment can be represented as follows:



Revival of the trait that was unexpressed in F_1 (dwarf) was observed in some F_2 progeny. Both traits, tall and dwarf, were expressed in F_2 generation in ratio 3:1.

Mendel proposed that something is being passed unchanged from generation to generation. He called these things as 'factors' (presently called genes). Factors contain and carry hereditary information.

Traits may not show up in an individual but are passed on to the next generation.

Inheritance of traits over two generations

The appearance of F_1 plants was similar to their parents i.e. they were tall, but were actually different from their parents. Mendel introduced the terms **genotype** and **phenotype**.

Genotype is the genetic constitution of an organism, which includes all genes that are inherited from both the parents. For example TT, Tt, and tt are genotypes of organisms with reference to their height.

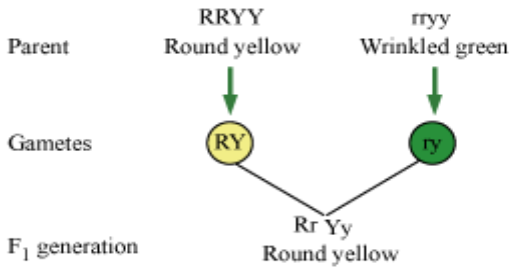
Phenotype is the observable trait or characteristic of an organism, which is the result of genotype. For example, tallness and shortness are phenotypes resulting from different genotypes.

The above experiment of Mendel involved only one pair of contrasting characters (tall/short plant height), so it is called a **monohybrid cross.**

If two pairs of contrasting characters are involved, then the cross is termed as **dihybrid cross**

Inheritance of Two Genes (Dihybrid Cross)

- In dihybrid cross, we consider two characters. (e.g., seed colour and seed shape)
- Yellow colour and round shape is dominant over green colour and wrinkled shape.



	RY	rY	Ry	ry
RY	RRYY Round yellow	RrYY Round yellow	RRYy Round yellow	RrYy Round yellow
rY	RrYY Round yellow	rrYY Wrinkled yellow	RrYy Round yellow	rrYy Wrinkled yellow
Ry	RRYy Round yellow	RrYy Round yellow	RRyy Round green	Rryy Round green
ry	RrYy Round yellow	rrYy Wrinkled yellow	Rryy Round green	rryy Wrinkled green

Phenotypic ratio – 9:3:3:1

Round yellow – 9

Round green – 3

Wrinkled yellow – 3

Wrinkled green –1

Mendel's Laws of Inheritance

Principles of Mendel:

- Each characteristic in an organism is represented by two factors (it means that each cell has two chromosomes, carrying the gene for the same character).
- When two contrasting factors are present in an organism then one of them can mask the presence of the other. Therefore, one is called the **dominant factor**, while the other is called the **recessive factor**.
- When two contrasting factors are present in an individual, they do not blend and produce an intermediate type. However, they remain separate and get expressed in the F_2 progeny. The plant with Tt genotype is tall and not of intermediate height.
- When more than two factors are involved, these are independently inherited.

Mendel's Laws of Inheritance

Based on his experiments, Mendel proposed three laws or principles of inheritance-

- Law of Dominance
- Law of Segregation
- Law of Independent Assortment

Law of dominance and law of segregation are based on monohybrid cross while law of independent assortment is based on dihybrid cross.

Law of Dominance

- According to this law, characters are controlled by discrete units called factors, which occur in pairs with one member of the pair dominating over the other in a dissimilar pair.

- This law explains expression of only one of the parental character in F_1 generation and expression of both in F_2 generation.

Law of Segregation

- This law states that the two alleles of a pair segregate or separate during gamete formation in such a way that a gamete receives only one of the two factors.

- In homozygous parents, all gametes produced are similar; while in heterozygous parents, two kinds of gametes are produced in equal proportions.

Law of independent Assortment

- When two pairs of traits are combined in a hybrid, one pair of character segregates independent of the other pair of character.

- In a dihybrid cross between two plants having round yellow (RRYY) and wrinkled green seeds (rryy), four types of gametes (RY, Ry, rY, ry) are produced. Each of these segregate independent of each other, each having a frequency of 25% of the total gametes produced.

Sex Determination

Have you ever thought how a baby boy or a baby girl is born? What directs the zygote to form a baby boy or a baby girl? What determines the sex of a child? Let us explore.

The answer to these questions lie in thread-like structures called **chromosomes**. These chromosomes are present in the nucleus of all cells. Thus, they are also present in the zygote. They carry the instruction for determining the sex of the baby.

But how many chromosomes do humans have and do all of them determine the sex of a child?

All human beings have 23 pairs of chromosomes out of which two chromosomes are sex chromosomes. These sex chromosomes are responsible for determining the sex of a child. Let us study how sex is determined in human beings.

Hence, the sex of a child is dependent on the father as the sperm containing **X** or **Y** chromosomes decides whether the child will be a male or female.

Environmental factors (**Non-genetic sex determination**):

In some animals such as turtles, lizards, crocodiles, and a few snakes, the sex of the progeny depends upon the incubation temperature of the eggs.

For example, in certain turtles, the eggs hatch to produce male and female organisms, when incubated at low and high temperatures respectively.

Other type of sex determination: Some snails can change their sex. Snails start development as males and later change their sex to females.

Absence of sex determination system: Earthworms are hermaphrodites. They do not have separate sexes as males and females.

Some interesting facts:

- Do you know that in birds, males have same sex chromosomes (ZZ) and females have different sex chromosomes (ZW)? This system of sex determination is reversed compared to the system found in humans.
- In fruit fly (*Drosophila*), sex chromosomes are not present. Sex is determined by the ratio of the number of X chromosomes to autosomes.

Factors Leading To Evolution

To understand variations, let us look at an example of horses by going back to prehistoric times. Earlier, ancestors of horses were small in size (about the size of a pony). They had to constantly face the threat of predators. However, a small group of these horses were swift runners, which helped them escape their predators. Since they were able to escape predation, they survived and passed on their genes to the next generation. Hence, these variant fast-runners were selected, which evolved to give rise to the present day tall, long-legged, modern horses.

Let us understand how variations accumulate to produce an organism more evolved than his ancestors?

Consider the following example:

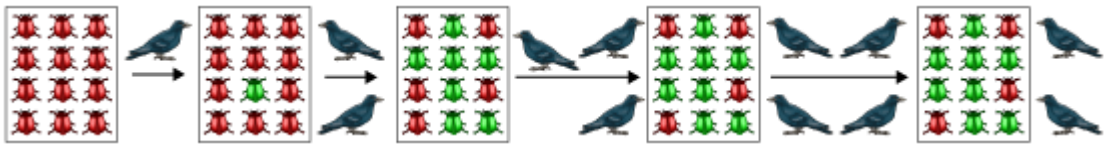
- A small population of beetles live in a bushy area with green leaves. Crows eat these beetles. As a result, variation occurs in these beetles due to sexual reproduction.

Case I: Due to the occurrence of variation, the colour of one progeny beetle changes from red to green.

What is the advantage of this variation to green beetles?

The green beetle can hide itself in leaves to escape from being eaten by crows. Thus, the variation provides a survival advantage to the beetle.

Hence, the red beetles are rendered more vulnerable. Their chances of survival to reproduce are lesser in comparison to green beetles. This leads to an increase in the population of green beetles.



Variation in population by natural selection

This type of variation, which increases the survival value of an organism, is **naturally selected**.

Natural selection: It may be defined as a process that results in the increased survival and reproductive success of individuals, who are well adjusted to the environment.

Therefore (as seen above), the population of green beetles increases because the red ones are eaten by the crows. Thus, because of natural selection, the beetle population evolved from red to green colour to fit better in their environment.

Case II: Due to variation, the colour of one progeny beetle changes from red to blue.

- This blue coloured beetle is also able to reproduce and form a small population among the red beetles.
- These blue beetles are equally vulnerable to crows. They are as easily visible as the red beetles.
- Let us assume that one day an elephant tramples the bushes where the red beetles live. Most of the beetles are killed, but those that were able to survive are mostly blue beetles. Now, the beetle population is mostly blue.

In this case, the colour blue offered no survival advantage to the beetles. However, the major population of beetles now consists of only blue beetles (or genes governing this colour). This is because of the accidental survival of blue beetles. However, had the beetle population been large, the elephant could not have destroyed the entire population of the red beetles. Thus, this accidental change in the frequency of genes in small population is referred to as **genetic drift.**

Therefore, it can be concluded that variations can lead to evolution.

Heredity, as we know, maintains a common basic body design (a new born child has all the basic features of a human being). However, variation brings about changes in the basic body design (to ensure that all human beings are not identical).

With subsequent generations, these variations keep on accumulating. Thus, they produce organisms that are more evolved than his ancestors. The above two cases involve changes due to variation, which leads to the evolution of a newly formed species (group of related organisms with common characteristics which are capable of interbreeding). Hence, variations can lead to evolution.

Some interesting facts:

- Do you know that beetles form the largest order of insects? There are more than 300,000 species of beetles in the world.
- The many breeds of dogs exist because of variations.

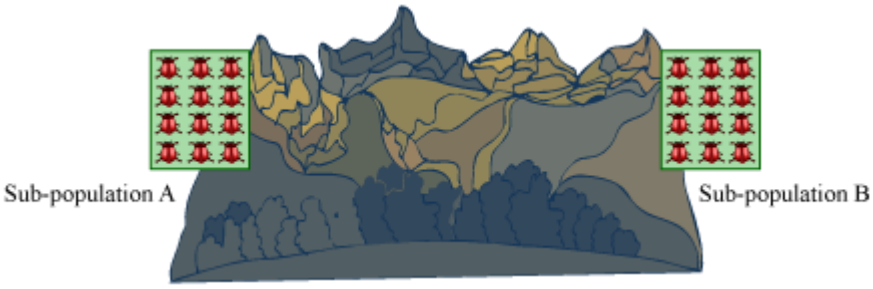
Speciation

Speciation may be defined as an evolutionary process, which involves the formation of one or more species from an existing species.

Do you know how a new species of an organism is formed?

Let us consider the example of beetles.

Let us consider that a population of beetles has split into two separate populations, which cannot reproduce with each other.



Formation of a new species

These two separate populations of beetles are spread on a wide mountain range since their food is widely distributed. Hence, the population of beetles in that area is very large.

Beetles are small insects, which cannot travel to far off places. They gather food from nearby places. As a result, sub-populations of beetles are spread over that area.

Now, let us study how these sub-populations can lead to the formation of an entirely new species.

Geographical isolation:

Since this population of beetles is spread over a large area, reproduction cannot occur between individuals of sub-populations. Reproduction will only occur within a sub-population, which will lead to the production of a new species. Now, if a river starts flowing between the two populations, then the two sub-populations would be further isolated and the chances of gene flow or reproduction further decreases.

Genetic drift and natural selection:

Genetic drift and natural selection can give rise to different changes in sub-populations. For example, a particular sub-population of beetles evolves to blue or green colour due to natural selection or genetic drift. This will result in changes in subsequent generations. Thus, the two populations of beetles become completely different from each other.

These sub-populations will eventually be incapable of reproducing with each other. For example, the green female beetles of an area will prefer to reproduce with the green males only because green beetles have the survival advantage. Therefore, this results in the formation of a new species of green beetles, which are reproductively isolated.

Let us now consider another example of speciation:

Darwin observed natural selection among unique finches on the Galapagos Islands. These finches are popularly known as Darwin's finches.

Can all animals be separated into different species? It may not always be possible because certain animals form a ring species. Suppose a group of birds have sub-species A, B, C, D, E, and F. Then, subspecies-A can mate with B; subspecies-B can mate with A and C; subspecies-C can mate with B and D; subspecies-D can mate with C and E, and so on. As a result, they form a ring.

This speciation occurs due to geographical isolation. This type of speciation is observed in greenish warblers (*Phylloscopus trichiloides*) in the Himalayas and Larus gulls in the arctic.

Relationship between Evolution and Classification

In a family, do siblings show more resemblance with each other or with their cousins?

We observe that we look more like our own brothers and sisters than our cousins i.e. siblings resemble more than cousins.

Why is it so?

Let us consider an example. Ram and Anuj are siblings, while Rajat is their cousin. Now, Ram and Anuj are more closely related, as they share a recent common ancestor i.e. their parents. However, Ram and Rajat are also related, but less closely than Ram and Anuj. Ram and Rajat share a common ancestor i.e. their grandparents.

With subsequent generations, variations make organisms more different than their ancestors.

Therefore, we can classify organisms according to their resemblance, which is similar to creating an evolutionary tree.

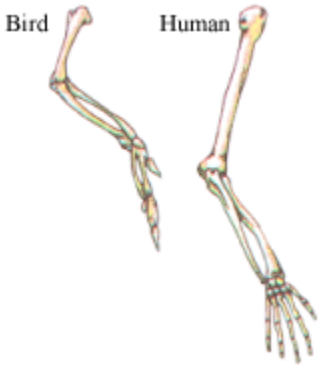
Classification refers to identification, naming, and grouping of organisms into a formal system based on similarities in internal and external structure, or evolutionary history. It determines the methods for organizing the diversity of life on Earth.

Evidences of Evolution

Let us understand how evolutionary relationships can be traced using various evidences.

There is a diversity of living organisms on Earth, yet different types of organisms have some features in common.

Consider the following example:



Forelimbs of humans and wings of birds look different externally. However, their skeletal structure is similar. Thus, their origin is similar (as wings in birds are modifications of forearms), but functions are different. While wings help a bird in flight, the forearm helps human beings in various activities. These structures are called **homologous structures** or **organs**.

Homologous organs:

The homologous organs are similar in form (or are embryologically similar), but perform different functions in different organisms. The bone structure observed in wings of birds, flippers of dolphins and arms of human beings is similar, but perform different functions. They belong to the same group of animals, the vertebrates, and therefore, exhibit **homology**.

Now, consider the wings of a bird and an insect. They are similar in function, but this similarity does not mean that these animals are more closely related. When carefully observed, the wings of a bird and an insect are not similar. Such organs, which have similar functions in different organisms (but are not closely related), are known as **analogous organs**.

Analogous organs:

The organs that perform similar functions in different organisms of different origins are **analogous**. For example, wings of birds and wings of insects; fins of fishes and flippers of whales; wings of birds and wings of bats (bird wings are made of feathers, while bat wings are folds of skin) all exhibit analogy. Both are used for flight, but they are structurally different. Also, they are found in organisms which are not related.

Do you know that genetic fingerprinting or DNA testing (using samples of DNA) can distinguish individuals of the same species? This technique is used in forensic science laboratories to analyze samples of blood, hair, and saliva.

Fossils as an evidence of evolution

What are fossils?

A group of students went for trekking. After a tiresome day, when they dug the ground to pitch their tents, one of them discovered skeletal remains of a dead animal inside the ground. They examined it closely to find out which animal the skeletal belonged to. However, surprisingly, the features of the skeletal remains resembled more than one animal. Later, when they took it to a lab for examination, they discovered that the remains were of an ancestral reptile, as old as 1000 years!

Let us explore more about fossils.

Fossils are the remains of organisms that once existed on Earth. They represent the ancestors of plants and animals, which are alive even today.

Various kind of fossils

Fossils provide evidences of evolution by revealing the characteristics of the past organisms, and the changes that have occurred in these organisms to give rise to a present organism.

Appearance of fossils

Fossils have the same shape as that of the original animal, but their colour and texture may vary widely. The colour of a fossil depends upon the type of minerals that form it.

For example, the fossil of a bone will not have some constituents of the bone in it. It has the same shape as the bone, but it is chemically more like a rock.

Age of fossils

Let us assume that around 100 million years ago, some invertebrates died and got buried in soil in that area. With the accumulation of sediment on top, it turned into a sedimentary rock.

A million years later, some dinosaurs died at the same place with their bodies getting buried on top of the sedimentary rock. As a result, the mud, containing the dinosaurs, also turned into rock.

Another million years later, some horse-like creatures died in the same area and got fossilized into rocks, above the dinosaur fossils. Some time later, due to soil erosion or floods in that area, the rocks containing horse-like fossils got exposed.

Now, if that area is excavated deeper, dinosaur and invertebrate fossils can also be found. Thus, by digging that area, scientists can easily conclude that horse-like animals evolved much later than dinosaurs and invertebrates.

Therefore, the above example suggests that the fossils found closer to the surface of the Earth are more recent than those present in the deeper layers.

The science dealing with the study of fossils is called Palaeontology.

Formation of Fossils

Most organisms decay after their death, but in certain conditions, the hard parts of the organisms are preserved.

When some organisms die, they get buried under the sediments of sand and other minerals. The sediment keeps on depositing over time and their soft parts decay, but hard parts survive and absorb minerals. Many years later, minerals replace their hard parts and convert them into fossils.

The sediments which cover the fossils get converted into sedimentary rocks.

Due to the movement of the earth, the rocks may be pushed upwards and the fossils get exposed as the rocks crack.

Importance of Fossils

(i) They inform us about the types of living things that existed in the past.

(ii) They inform us about the extent to which living things have changed over time.

(iii) The most recent fossil is found in a rock nearest to earth's surface. Therefore, they inform us about the time when a particular life form existed.

Evolutionary line

Let us understand how the study of modifications or evolution of characteristics helps us relate animals and thus, create an evolutionary line.

We can organize animals in an evolutionary line on the basis of the following factors:

Increasing complexity of organs:

Evolution of the eye

1. The eye was present in the earliest organisms in the form of a simple patch of photosensitive cells called an eyespot. This was found in lower organisms such as *Euglena.*

2. This eyespot gradually became modified into a cup-like structure and developed the ability to discriminate between light and darkness. These were called pit eyes. They were found in some living invertebrates such as *Planaria*.

3. Insects have compound eyes, which are made of a thousand units. Hence, the image formed on the retina is a collection of several small images.

4. Human eyes are highly evolved. They are often compared to cameras. It is highly complex in structure and function.

Decreasing complexity of organs:

Vestigial organs

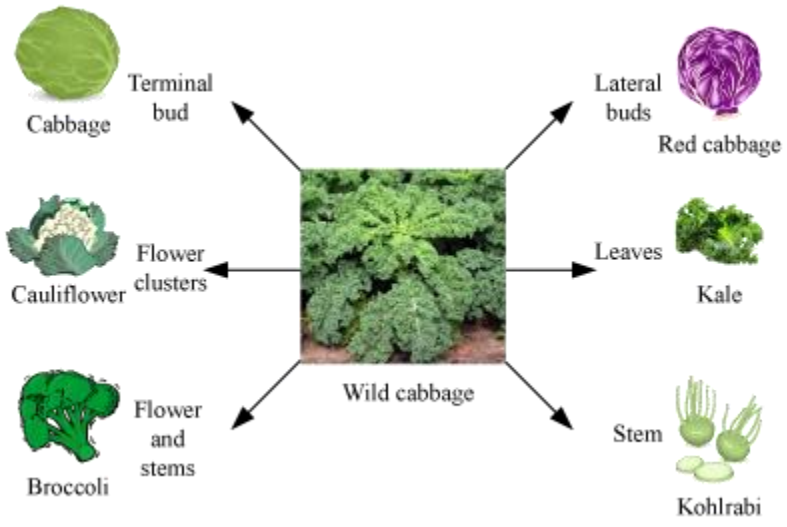
There are some organs in the human body, which are present in the reduced form and do not perform any function. For example, the nictitating membrane of the eye, third pair of molars, vermiform appendix, body hair, nipples in males etc. **Such organs, which are present in a reduced form and do not play any role in the normal body functions, are known as vestigial organs**. These organs are remnants of the organs, which were once complete and functional in the ancestors, but disappeared gradually either because of a change in the mode of life or because they became non-functional.

Changed functions of organs

Some structures during the course of evolution changed their functions. For example, some past reptiles (which later evolved into bird ancestors) would have had feathers, which were not necessarily used for flying, but instead only provided them with protection. Later, during the course of evolution, these animals developed the ability to fly and evolved into ancestors of birds. The present day birds use feathers for flight. This proves that reptiles and birds are closely related, and that the evolution of wings actually started during the reptilian age.

Let us recall an example of evolution of any organism in the recent years.

Evolution in the cabbage plant:



Early farmers cultivated wild cabbage or *Brassica oleracea*. This wild cabbage developed into many varieties such as cabbage, broccoli, kohlrabi, cauliflower, kale, and brussels. These varieties were artificially selected because of their characteristic traits.

Red Cabbage: It resembles the common cabbage, but its main stem grows to a height of about 60-90 cm. The lateral buds on the stem develop into small heads (sprouts) similar to the heads of cabbage. These buds are consumed as cooked vegetables. It is grown for selecting large bud size.

Cabbage: In a cabbage, the terminal bud is consumed. It can be eaten raw in salads or cooked as vegetable. It is selected for short petioles.

Broccoli: They are selected for large edible inflorescence. The edible parts of a broccoli are clusters of flowers, before the opening of flower buds. It is selected for large flower stalks.

Cauliflower: They are also selected for large edible inflorescence.

Kale: It resembles the wild cabbage, but it is selected for its large leaves and terminal inflorescence of yellow flowers.

Kohlrabi: It has a thick basal portion in the stem, which is edible. It is also called turnip cabbage.

Evolution and progress or advanced life

Evolution cannot always be equated with progress.

Evolution simply creates more complex body designs, but this does not imply that the simple body designs are inefficient. Bacteria, with a simple body design, are still the most widely found organisms on Earth. They can survive in hot springs, deep sea, and even freezing environments.

Therefore, human beings cannot be considered as the highest evolved species or culminating species. In fact, humans are only a branch of evolution!

Interesting Facts

Do you know that *Archaeopteryx* is a type of fossil, discovered in the rocks of the Jurassic period? It had teeth in jaws, claws on fingers, long reptile-like tail, feathers, beak, jaws, and bird-like wings. It is considered as a connecting link between the reptiles and birds.

Human Evolution

Do you think all human beings belong to the same species?

All human beings regardless of their skin, colour, place of origin, and other features belong to a single species. They are known as ***Homo sapiens*.**

Human evolution is studied using radioactive carbon-dating methods with the study of fossils and DNA sequences. It has been discovered that both human beings and chimpanzees have evolved from a common ancestor (i.e. from primates).

Now, you know that primates gave rise to both chimpanzees and humans. But, do you know where evolution first took place?

Human beings (*Homo sapiens*) evolved from primates in Africa between 100,000 and 200,000 years ago.

Human beings are sociable (i.e. society forming) and upright walking species. The earliest member of the human species (*Homo sapiens)* can be traced back to Africa.

Evolution of *Homo sapiens*

From Africa, humans moved to West Asia, Europe, central Asia, and so on. They then moved to Indonesia, Philippines, and Australia. At last, they moved to America.

Do you know that human evolution began around 4 - 5 million years ago? Those ancestors had a brain capacity of about 450 cc. Homo sapiensare modern humans, which appeared around 120,000 years ago.