HEREDITY AND EVOLUTION

- Reproductive processes give rise to new individuals to continue the existence of a species on the earth. The new individuals have same basic body pattern and characters as parents and other members of the same species.
- But no two individuals of a population are not exactly same. Along with similarities amongst them, they have some dissimilarity too, we call it variation. In fact, no two living things are exactly alike; even identical twins differ in certain ways.
- Variations are produced even during asexual reproduction, due to small inaccuracies in DNA copying. So the new individuals show only very minor differences between them.
- The number of successful variation is maximized by the process of sexual reproduction, which leads to distinct and visible variation.
- It occurs because of substantial differences in genetic makeup (DNA) among individuals, due to fusion of two gametes during reproduction.

ACCUMULATION OF VARIATION DURING REPRODUCTION

- Parent/parents provide two things to the new generation individuals:
  - Common basic body design and
  - Subtle differences or variation.
- If this new generation will undergo reproduction process, the second generation will have differences that they inherited from their parent, as well as few newly created differences.
- Generation by generation these variations accumulate and passed to next generation in different combination during reproduction.
- That is why; the individuals of a population are different from each other. Some of the differences will be unique; others will be inherited from the respective parents.
- So the accumulation of variation during reproduction leads to creation of diversity over succeeding generation.
- Such trait or character which arises due to variation long ago will be more prevalent in population then any newly arisen trait.
- Variations lead to increased chances of survival of a species in changing or unfavourable environment. But all variants in a species do not have equal chances of surviving in the changing environment.
- Those variations which are advantageous in the changing environment can survive and rest other variants would die, e.g. Bacteria which can develop a variation to withstand heat will survive better in a heat wave.

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- **Variation:** Any difference amongst individual organisms of any species and the offspring of the same parents caused either by genetic differences or by the effect of environmental factors, is called variation.
- Variations can be induced by two ways:-
  - By environmental changes
  - By genetic changes.
- **Importance of variation:**
  - They help the individuals to adapt themselves according to the changing environment.
  - Variations give each organism a distinct individuality.
  - They form raw materials for evolution and development of new species.
  - Variations forms basis of heredity.

HEREDITY

- **Heredity:** It is transmission of genetic characters from parents to the offsprings, i.e., from one generation to the next.
- Heredity leads to resemblance amongst individual belonging to same species or transmission of basic set of characters from one generation to the next.
- Hereditary informations are present in the nucleus of fertilised egg or zygote. It is contributed by both parents in case of sexual reproduction, as sperm and ovum fuse to form zygote.
- Thus the similarities between the parents and offsprings are due to "heredity" and the dissimilarities are due to "variation".

INHERITED TRAITS

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

RULES FOR THE INHERITANCE OF TRAITS – MENDEL'S CONTRIBUTION

- Gregor Johann Mendel was an Austrian Geneticist and regarded as "Father of Genetics", because he was the first to explain the mechanism of transmission of characters from one generation to the other. And formulated some "Laws of Inheritance" more than a century ago.
- He conducted his experiment on garden pea (*Pisum sativum*) and interpreted that the inheritance of characters or traits are controlled by factors (later known as genes).
- According to him, factors (genes) are the carrier of hereditary information from one generation to the next.

- **Mendel performed his experiments on garden pea because of the following advantages:**
  - Flowers of pea are bisexual. So the flowers are capable of both self fertilization and Cross fertilization.
  - Peas have sharply defined characters, like tall and dwarf, violet flower and white flower, round seed and wrinkled seed, etc,
  - It has short life cycle, which complete and give result annually.

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- It is easy to maintain and grow.
- Produces large number of seeds.

- Mendel took seven characters with two alternatives for his research, e.g., flower colour, flower position, height, pod shape, pod colour, seed shape, etc.

- **Mendel performed his experiments in three stages:**
- **Firstly,** He made sure that his plant were true breeding line or pure form or homozygous for a trait or character, such as tallness or dwarfness.
- **Secondly,** he cross-pollinated alternate forms of trait (Tall X Dwarf). These cross bred plants are known as hybrids and the hybrid offspring formed are known as F1 or first generation. As the cross involves two forms of a single characters (Height – Tall & Dwarf), it is known as monohybrid cross.
- **Lastly,** Mendel allowed each hybrid to self pollinate up to five generation to understand the inherited characters and ensure the result.

- **Result of Mendel experiments.**
- Mendel found that F1 generation exhibited only one of the trait and never the other (all were tall, never dwarf). Expressed trait (tallness) was termed as **dominant** and the hidden one (dwarfness) as **recessive.**
- Self-pollination of F1 generation resulted in the expression of dominant trait and the recessive traits in the ratio of **3 : 1** in F2, known as **Mendelian Monohybrid Ratio**.
- After self-fertilization of F2 plants, and studying F3 generation **phenotypic ration of 1 : 2 : 1** (pure dominant : hybrid : pure recessive) came out.

- **Dihybrid Cross:** A cross in which two contrasting traits are considered at the same time is called a dihybrid cross.
- Mendel took pea plants with two different characteristics such as a plant with round and green seeds and another plant with wrinkled and yellow seeds.
- F1 generation are all plant with round and yellow seeds Round seed shape and yellow seed colour are thus dominant traits.
- Self-pollination of F1 generation results F2 generation, where some plants have round green seeds and some have wrinkled yellow seeds (same as parents).
- But some progeny shows new combination, i.e., plants with round yellow seeds and wrinkled green seeds. This shows that two separate traits are independently inherited.
- Self-pollination of F1 generation resulted in the ratio of **9 : 3 : 3 : 1** in F2, known as **Mendelian Dihybrid Ratio.**

HOW DO THESE TRAITS GET EXPRESSED

- Cellular DNA is the information source for making proteins in the cell. A section of DNA that provides information for one protein is called the gene for that protein.
- If the proteins work efficiently, the traits get expressed in better ways.

- For example, plants have hormones that can trigger growth. Plant heights depend on the amount of particular plant hormone. The amount of the plant hormone made will depend on the efficiency of the process of making an enzyme involved. If this enzyme works efficiently a lot of hormones will be made and the plant will be tall. If the gene for

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that enzyme has an alternation that makes the enzyme less efficient, the amount of enzyme will be less, and plant will be short. Thus genes control characteristics or traits.

- **Gene:** It may be defined as the unit of inheritance, present on the chromosomes. Which is carried from the parent to offsprings through a gamete and control the expression of a character in the young one.

- Chemically, a gene is a segment of DNA. It is equivalent to the factor of Mendel. In 1909, Johannsen coined the term gene.

- **DNA:** It is carrier of the genetic information from generation to generation. It transmits hereditary characters in a coded language from parents to the offsprings. A segment of DNA is called gene.

- **Chromosomes:** They are long tread like structure present in the nucleus of a cell. Genes are located on the chromosomes. Chromosomes are composed of DNA, RNA and histone and non-histone proteins.

- **Mechanism of Inheritance.**
- During sexual reproduction, both parents must be contributing equally to the DNA of progeny.
- If both patents can determine the trait in the progeny, both parents must be contributing a copy of the same gene. Thus each pea plant must have two sets of all genes, one inherited from each parent, so each germ cell or gamete must have only one gene set.
- Each gene is present, not as a single long thread of DNA, but as separate independent pieces called a chromosome and each cell will have two copies of each chromosome, one each from male and female parents.
- Every germ cell will take one chromosome from each pair and they may be either maternal or paternal origin.
- When two germ cells combine, they will restore the normal number of chromosomes in the progeny, ensuring the stability of the DNA of the species.
- Therefore such mechanism of inheritance explains the result of Mendel experiments and is used by all sexually and asexually reproducing organisms.

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SEX DETERMINATION

- The mechanism by which the sex of an individual is determined as it begins life is called **sex determination**.

- Different species have different strategies for sex determination. Where environmental factors and genetic factors plays the major role in determining the sexes.

- **Role of environmental factors in sex determination.**
- Sex determination is regulated by environmental factors in many species. In some reptiles, the temperatures at which the fertilised egg are kept determine the sex on the individual.

e.g. In some turtle, high incubation temperature results in development of female progeny. In some lizard, high incubation temperature results in development of male progeny.

- In some animals like snails, individual can change the sex, indicating that sex is not always genetically determined, as found in human being.

- **Role of genetic factors in sex determination (Sex determination in Human beings)**
- In human beings, the sex of the individual is genetically determined by chromosomes.

- There are 23 pairs of chromosomes in human beings, which can be divided in to two categories:

1. **Autosomes:** They are 22 pairs and always being perfect pairs in shape, size and genetic information they carry. They control body characters or somatic characters.
2. **Sex Chromosomes:** They are single pair, responsible for determination of sex in Human beings and Drosophila. Sex chromosomes are odd and are not always being a perfect pair.
   Women have a perfect pair of sex chromosomes, both called X. But men have a mismatched pair in which one is normal sized X and the other is a short one called Y. So the women are XX, while men are XY.

- A female individual contains two similar X chromosomes *i.e.* XX (homo-morphic condition). Female, therefore produce same types of gametes. So female is called **homo-gametic.**
- A male individual contains one X and one Y chromosome *i.e.* XY (hetero-morphic condition). Male, therefore produces two different kinds of gametes. So male is called **hetero-gametic.**

- The sex of the child is determined at the time of fertilization when male and female gametes (sperm and ovum) fuse to form zygote.
- If a sperm carrying X chromosome fertilises an ovum having X chromosome, then the child born will be a girl (XX).
- If a sperm carrying Y chromosome fertilises an ovum having X chromosome, then the child born will be a boy (XY).
- All children will inherit an X chromosome from their mother regardless of whether they are boys or girls.
- Thus, the sex of the children will be determined by what they inherit from their father *i.e.* sperm determines the sex of the child.

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EVOLUTION

- **Evolution:** The term evolution means unrolling or unfolding. It is defined as process of gradual and orderly change from one form to another.
- The gradual development in the characters of plant and animals over the course of time in order to fit in better with their environment is known as **biological evolution** or **organic evolution.**
- The present complex forms of life originated from the earlier simpler form of life by gradual modification in the course of generations or organic evolution over a period of time.
- e.g. fish gradually changed to amphibians then reptiles which finally evolved into birds and mammals.
- **Cause of evolution or Raw material for evolution: Variation.**
- There is an inbuilt tendency to variation during reproduction process; In asexual reproduction it occurs because of errors in DNA copying, in sexual reproduction it occurs because of fertilization of male and female gametes.

VARIATIONS IN A POPULATION

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

- **Situation-I**
  1. Initially there were only red beetles in green bushes.
  2. As a result of colour variation, green beetles came up in population, which can pass the colour on its progeny and all its progeny beetles are green.
  3. Green beetles were not easily visible in green bushes, so crows could not eat them.
  4. As a result, number of green beetles increased by reproduction as compare to red ones.

     Green beetles **got the survival advantage or they were naturally selected** as they were not visible in green bushes. This natural selection is exerted by crows resulting in adaptation in the beetles to fit better in their environment.

- **Situation-II**
  1. As a result of variation in green beetles, few blue beetles came up in population, which can pass the colour on its progeny and all its progeny beetles are blue.
  2. Suddenly elephant came and stamped on the bushes and most of the beetles died. By chance, beetles which survived were blue.
  3. Thus the blue beetle slowly increased in number by reproduction in population and now beetles in the population are mostly blue.

     Blue beetles **did not get any survival advantage and their survival was just a matter of chance.** This later changed the common characteristic of resultant population (from green dominating population to blue dominating population). If elephant could not create havoc, the number of green beetles would have been considerably large.

     Accidents can change the frequency of some genes even if they do not get any survival advantage. This is called genetic drift. This lead to diversity without any adaptation.

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- In both situations, a rare variation came to be common characteristics in the population. The frequency of an inherited trait changed over generations since genes control traits, the frequency of certain genes in a population changed over generations. This is the essence of the idea of evolution.

- **Situation-III**
  - As the number of beetles increases but bushes starts suffering from plant disease.
  - Now the beetles become poorly nourished and their average size and weight decreases.
  - Later plant disease gets eliminated and plants become healthy.
  - Average weight and size of beetles increased again to normal.
    No genetic change has occurred. Hence, this change is not inherited over generations.

- **Genetic Drift.**
  - The random changes in gene frequencies occurs by chance and not under the control of natural selection are called **genetic drift.**
  - The effect of genetic drift is very small in large population but large in a small population.

ACQUIRED AND INHERITED TRAITS

- **Inherited traits:** These traits which are controlled by specific genes and passed on from one generation to another. Any alternation in the DNA will be passed on, through germ cells, to the progeny resulting in variation in them.
- **Acquired traits:** These traits are acquired by the organism in their life time. e.g. weight of the beetle is reduced due to starvation there will be no change in the DNA of germ cells, so this trait will not be inherited. This is change in non reproductive tissue and cannot be passed on the DNA of germ cells.

- Therefore the experiences of an individual during its life time cannot be passed on to its progeny and cannot direct evolution.
- If a group of mice are normally bred, all their progeny will have tails. Now if the tails of these mice are cut by surgery in each generation, tailless mice will not be produced. It is so because removal of tails of mice during their life is an acquired character and it will not bring any changes in the DNA (genes) of the germ cells of mice.

- Heredity and genetics are so essential for understanding evolution. Even Darwin, who gave the idea of evolution of species by natural selection in nineteenth century, fails to explain how the variations in the organism arise.

SPECIATION

- **Speciation:** The origin of new species from the existing one is called speciation.

- **Micro-evolution:** The appearance of small but significant variations appears in individuals that simply change the common characteristic of a particular species. (As above discussed in beetles' examples.)
- Micro-evolution does not help in speciation or formation of new species.

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- **Generation of new species:** When a population of a species splits into two population, which cannot reproduce with each other. Then, they can be called two independent species and thus a new species is formed.

- **Example of speciation:**

1. If the bushes the beetles feed on are spread widely over a mountain range, as a result, the beetle population will be very large too.
2. As the beetles feed on the local bushes and do not travel far, so, in this huge population of beetles, there will be sub-populations in neighbourhoods.
3. Even most reproductions will take place within these sub species.
4. Occasionally few beetles can go from one population to another or it can be dropped by crows.
5. In either case, the migrant beetle will reproduce with the local population (new population). This will result in the genes of migrant beetles entering a new population.

   This kind of **gene flow is bound to happen** between populations that are partly, but not completely separated.

6. Now, if between two such sub-populations a large river comes in to existence, which leads to **geographical isolation** and the two populations will be further isolated.
7. Due this geographical isolation the **levels of gene flow between them will decrease** even further.
8. Over generations, **genetic drift will accumulate** different changes in each sub population.
9. **Natural selection will operate differently** in these different geographical locations. For example: If crows are eliminated by eagles in one population then green variation in beetles will not be selected by nature at first. But at another population where the crow number is very high, the green variation will be strongly selected by nature.

   In this way, **both genetic drift and natural selection will make these geographically isolated sub-populations to become more and more different from each other.**

10. Ultimately, **reproductive isolation** will occur between individuals of these two groups. As a result, they will be unable to reproduce even if they happen to meet somehow.
11. Reproductive isolation can occur by a number of way:
    - If the genetic materials (DNA) is changed so much that there is difference in the number of chromosomes. Eventually the germ cells of the two groups cannot fuse with each other.
    - If a new variation emerges in which green females will not mate with red males, but only with green males. (This allows very strong natural selection for greenness.)

12. **When the one group or population become reproductively isolated from pre existing population, a new species is generated.**

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EVOLUTION AND CLASSIFICATION

- **Classification:** The method of arranging organisms into groups on the basis similarities and differences in their characteristics is called classification.
- For Example:-
  1. **Animals**: Protozoa → Porifera → Coelenterata → Helminthes → Annelida → .....
  2. **Plants**: Thallophyta → Bryophyta → Pteridophyta → Gymnosperm → Angiosperm

- **Characteristics:** Characteristic of organisms refers to the details of external and internal appearance or behaviour that distinguish them from one another. e.g. four limbs of humans, photosynthesis in plants, etc.

- **Characteristics form the basis for the classification.**
  1. All organisms are made up cells but cells design may differ in among different organism. Sometime **cells are without nucleus** e.g. bacteria. And a major group called **have cells with nucleus.**
  2. Organism with nucleated cells may be made of one cells and grouped as **unicellular organism**, and **multi-cellular organisms** have so many cells.
  3. Among multi-cellular organisms, whether they can undertake photosynthesis or not will provide the next level of classification. And we divide it between **plants** and **animals**.
  4. Again in animals, we can think on other characteristic for further classification *i.e.* whether the skeleton is inside the body or around the body.

- By identifying hierarchies of characteristics between species, evolutionary relationships of the species can be worked out.
- If the characteristics in different species are similar, they are said to be inherited from a common ancestor. In evolutionary term it means that the two species are closely related.

- **If any two species having more characteristics in common, they will be more closely related. And, the more closely they are related, the more recently they will have had a common ancestor.**

- For example: A brother and sister are closely related as they have common ancestor (parents). Sister and her first cousin are also related but lesser than brother and sister, because they too have common ancestors but in the form of grandparents.

- In the same way, classification of species is, in fact, a reflection of their evolutionary relationship.
- We can, thus, form small groups of species with recent common ancestors, then super groups of these groups with more distant common ancestors, and so on.
- Theoretically, we can go on moving backwards until we reach a common ancestor at the very beginning of the evolutionary time.
- If this is the case, then at some point in the history of the earth, non living material must have given rise to life.

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TRACING EVOLUTIONARY RELATIONSHIP

- Enormous numbers of organism that exist on earth have large number of common characteristics which provides evidences in favour of biological or organic evolution and help in tracing evolutionary relationship.
- The similarities in characteristics of different organisms show that they are inherited from a common ancestor

- **Homologous Organs:** The organs which perform different functions in different species but have similar basic structure and origin are called homologous organs.
- Exp: (i) The forelimb of a frog, a lizard, a bird and a man. Here, the basic structure of the limbs is similar though it has been modified to perform different functions in various vertebrates.
- Exp: (ii) The tendril of Passiflora and thorn of Bougainvillea. Both are modified branches but perform different functions.
- **Such homologous characteristics help to identify an evolutionary relationship between apparently different species.**

- **Analogous organs:** Those organs which have different origin and structure, but similar appearance and perform similar functions are called analogous organs.
- Example: (i) The wings or birds and bats. They 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.
- Example: (ii) The wings of butterfly and bird.
- The designs of two wings, their structure and components are very different. They look similar because they have common function of flying but their origins are not common. So **analogous organs do not help in identifying any evolutionary relationship**.

FOSSILS

- **Fossils:** Fossils are the preserved remains or impressions of the dead animals and plants that lived in the remote past.
- When the 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.
- Example, a dead insect which is gets caught in hot mud, it will not decompose quickly and mud will eventually hardens and retain the impression of body parts of insects and thus preserved as fossil.
- **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.

- **Careful studies of fossils tell us about the process of evolution, such as:**
  1. The plants and animals that existed in the past were different from present day forms.
  2. Over a period of time there was a gradual progress from simpler to more complex forms.
  3. Some plants and animals were more abundant in one period but later on they disappeared.

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4. Fossil records of various animals when arranged according to their geological time, show link between one group of animals to another group.
5. Mammals among animals and angiosperms among plants are most evolve forms of today.

- **Determination of the age of fossil.**
- There are three way of determining age of fossils:
- **Relative method**: 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 deeper layers.
- **By radioactive elements**: The age of fossil is determined with the help of certain radioactive elements such as uranium present in rock. Uranium disintegrates into lead with passage of time at constant and known rate. By calculating amount of lead in a rock, one can approximately judge the age of rock and age of fossil present.
- **Carbon dating:** CO_2 of air contains a small proportion of radioactive carbon (C^{14}). CO_2 is used during photosynthesis and there is equal proportion of C^{14} among carbon atoms of all organisms.
- The radioactivity of C^{14} is lost at a precise rate. Half life C^{14} of is about 5600 years. If the fossil shows radioactivity on fourth of that found in the living organisms, the organisms died about 11,200 years ago (two half lives of C^{14}).

EVOLUTION BY STAGES

- New organs are produced in organisms because of the arising of new need or desire, which is influenced by environmental conditions.
- The complicated organ cannot be generated by a single DNA change. Such complex organs are created bit by bit over generations.

- **Origin of Eye:**
- The complicated organ like eye cannot be generated by a single DNA change. This complex structure of eye must have evolved over generations, from simplest to complex form.
- During development of eyes, first of all very simple, a rudimentary eye also came in existence which could have given fitness advantage to the organism. e.g. Eye spots in a flat worm named Planaria.
- Starting from this basic design, more and more complex eyes were evolved in various organisms in a step wise manner.
- Eyes of insects, octopus and vertebrate are structurally different. This tells about their separate evolutionary origin.

- **Origin of Feathers:**
- Origin of feather can start out just for the purpose of providing insulation during cold. Later this feature might have proved to be useful for the purpose of flight.
- Feathers were present in some Dinosaurs but these were not used for flying. Later birds have the adaptation of flying, using feather.
- This shows close relationship of birds to reptiles and proves that character appearing as a variation can become useful later to perform different function.

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- **Artificial Selection in Cabbage**
- **Very dissimilar looking structures evolve from a common ancestral design.** This history of evolutionary relationship can be estimated by analysis of organ structure in fossils. We can see this evolutionary relationship in some present day example, such as wild cabbage plant.

- Humans have, over more than two thousand years, cultivated wild vegetables as a food plant, and generated different vegetables from it by **artificial selection.**
- Some farmers wanted short distances between leaves and bred **Cabbage.**
- Few selected for arrest flower development and bred **Broccoli.**
- Others farmers selected for swollen parts and **Kohlrabi** came up.
- Few farmers preferred big leaves and thus led to breeding of **Kale.**
- It is concluded that all these evolved from common ancestor i.e wild cabbage.

- **Evolutionary relationship can also be traced by the idea that says "changes in DNA during reproduction are the basic events in evolution."**
- So, comparing the DNA of different species give us a direct estimate of how much 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 idea of evolution. Evolution is just a production of diversity of life forms and shaping of this diversity by the environmental selection.
- The only progress in evolution appears to be more and more complex body designs of organisms have emerges over the ages.

- When a new species is formed, it is not necessary that old species will disappear from earth. It will all depends on environmental condition of that time. Also it is not as if the newly formed species are in anyway better than the older one.
- It is simply that genetic drift and natural selection processes have combined to form a population having different body design which cannot interbreed with the other population.
- It is a common belief that chimpanzees are the ancestors of human beings. It is not true that human beings have evolved from chimpanzee. Actually both chimpanzee and human beings had a common ancestor long time ago. The two offsprings of that ancestor evolved in their own separate ways to form modern day chimpanzee and human beings.

- Again, it is not as if the body design of older organisms were insufficient. This is because many of older and simple forms of organisms still survive on earth.
- For example, one of the simplest and primitive life form called bacteria still inhabit some of the most inhospitable or unfavourable habitats, such as hot springs, deep see thermal vents and the ice in Antarctica.

- Human beings are not the pinnacle of evolution, but simply yet another species in the teeming spectrum of evolving life.

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HUMAN EVOLUTION

- The same tools for tracing evolutionary relationship, like, excavating, time dating and study of fossils as well as determining DNA sequences have been used for studying human evolution.
- There is a great diversity of human forms and features across the planet. Due to this diversified forms and features skin colour is the most commonest way to identifying these social races.
- Regardless of all this diversification all humans over the globe are a single species. Because any two social race of humans can interbreed successfully.
- Regardless of where we have lived for the past few thousand years, we all come from Africa. So the earliest member of human species (*Homo sapiens*) can be traced back to Africa.
- A couple of hundred thousand year ago, some of our ancestors left Africa while others stayed on.
- The residents spread across Africa, the migrants slowly spread from Africa to west Asia then to central Asia, Eurasia, South Asia, Islands of Indonesia and the Philippines to Australia, crossed the Bering land bridge and then to America.
- These different migrating groups of ancestors lived their lives in the then prevailing environmental and developed genetic variations to become different coloured with specific features in different geographical regions in modern time.

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