WHAT ARE THE EVIDENCES FOR EVOLUTION?

Numerous compelling pieces of evidence found in nature substantiate the occurrence of evolution on Earth, revealing the emergence of diverse life forms over time.

Below are some of the key evidences:

(I) Fossils (Paleontological Evidences)

As species evolved, many became extinct, leaving behind traces of their existence in the form of fossils. Fossils are the preserved remains of organisms' hard parts, such as bones, teeth, shells, and wood, embedded in rocks. Over time, new layers of rock formed, with older fossils typically found in deeper layers and younger ones in upper layers due to the principle of superposition.

(i) **Number and Nature of Fossils in Early Rocks:** The rocks from earlier eras contain fewer fossils, primarily of simple marine invertebrates, reflecting the gradual emergence of life forms in the ancient seas.

(ii) **Distribution of Fossils in the Successive Strata:** The distribution of fossils reveals a trend where early fossils in lower layers are simpler, while those in upper layers are more complex. For instance, the Proterozoic era rocks contain fewer fossils, while the Paleozoic era boasts abundant fossils of invertebrates, fishes, and amphibians. Similarly, the Mesozoic era features fossils of large reptiles like dinosaurs, and the Cenozoic era holds numerous mammalian fossils.

(iii) **Disparity between Past and Present Forms of Life:** Comparing ancient organisms with modern counterparts illustrates significant differences, such as early humans living in primitive conditions without societal structures, unlike modern civilized humans. This disparity underscores the evolutionary changes that life forms have undergone over time.

(iv) **Missing Links (Transitional Forms):** Certain fossil organisms exhibit characteristics bridging two distinct groups, termed missing links. For example, Archaeopteryx lithographica, discovered in 1861, displays features of both reptiles and birds, serving as a transitional form between these groups.

These paleontological evidences collectively support the notion of evolution, illustrating the progressive changes in life forms since their emergence on Earth.

The features of Archaeopteryx reflecting reptilian traits include:

(a) Its body structure closely resembles that of a lizard.
(b) It possesses a lengthy tail.
(c) The bones lack pneumaticity, or air-filled spaces.
(d) Its jaws are equipped with teeth resembling those of reptiles.
(e) It has a relatively weak sternum.
(f) It has free caudal vertebrae, similar to those seen in lizards.
(g) Its hands exhibit a typical reptilian configuration, with each finger ending in a claw.

The avian characteristics of Archaeopteryx include:

(a) It is covered in feathers across its body.
(b) The two jaws have been transformed into a beak.
(c) Its forelimbs have been adapted to form wings.
(d) The hind-limbs are structured according to the typical avian pattern.
(e) It demonstrates a close fusion of skull bones, resembling the fusion observed in birds.

How are the ages of fossils determined?

Explanation: The age of fossils is determined by first establishing the age of the rocks in which the fossils are embedded. Rocks contain certain radioactive elements that undergo decay, transforming into more stable forms. This decay occurs at a consistent rate for each radioactive element, regardless of environmental factors.

Scientists have calculated the duration required for half of the quantity of a radioactive element to transition into its stable form, known as its half-life. Following each half-life period, the element decreases to one-half of its original amount, continuing in subsequent intervals.

Example

The half-life of carbon-14 is 5730 years, indicating that within this duration, half of the C-14 transforms into its stable form, N-14.

By analyzing the relative proportions of radioactive and non-radioactive elements in a rock sample, scientists can estimate its age. This technique is referred to as radioactive dating.

Various methods are employed to determine the age of fossils:

(1) Uranium-Lead method
(2) Radiocarbon method
(3) Potassium-argon method
(4) Electron Spin Resonance (ESR) method - regarded as the contemporary and most precise technique.

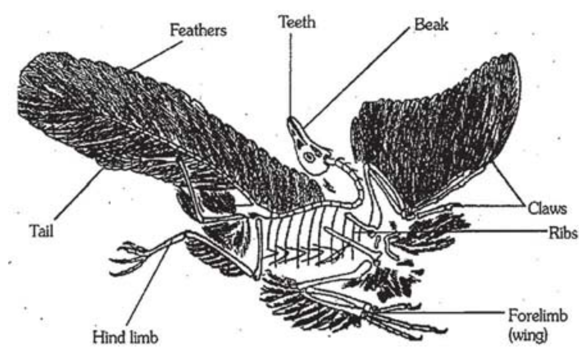
Archaeopteryx

- It serves as a crucial transitional form between reptiles and birds.
- Missing links are intermediary species that are absent in contemporary times.
- Andreas Wagner, hailing from Bavaria, Germany, unearthed its fossil.
- The discovery occurred within rocks dating back to the Jurassic period.

Reptilian characteristics

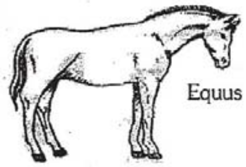
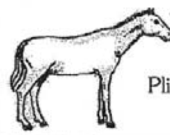
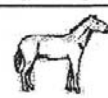
- It boasts a lengthy, lizard-like tail with independent caudal vertebrae.
- Its bones lack pneumaticity, unlike avian bones.
- It features a relatively feeble sternum.
- Teeth are evident in its jaw structure.

Avian Characters



- Feathers on body
- Jaws modified into beak
- Forelimbs modified into wings (reduced)
- Hind limbs built in avian plan

Evolution (Pedigree) of Horse

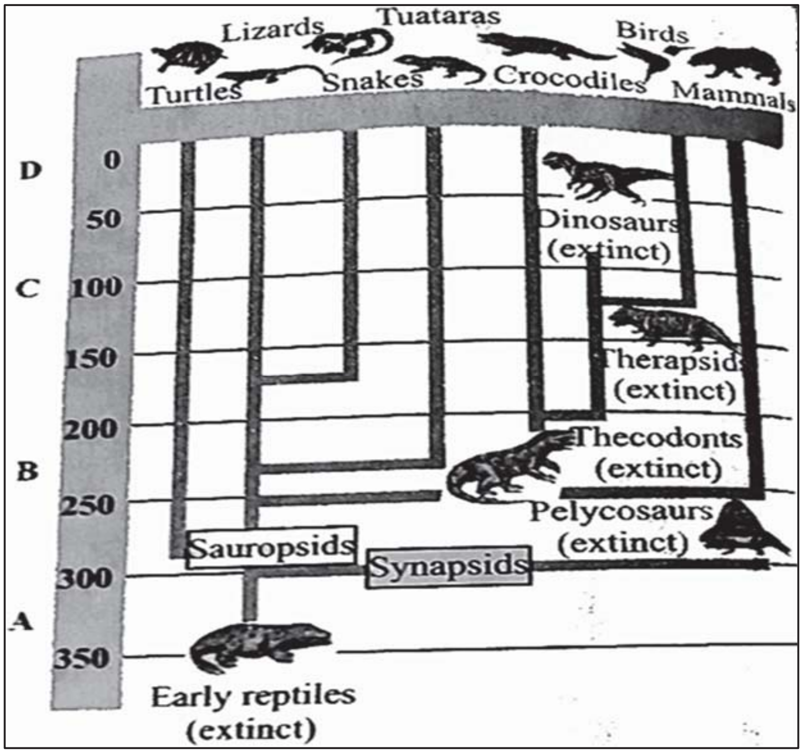
Epochs	Height (in cms)	Appearance	Horse	Bones of limbs	No. of toes
Pleistocene	160	Modern Horse	 Equus		1 - toed (2 Splint bones)
Pliocene	120	Pony like	 Pliohippus		1 - toed (2 Splint bones)
Miocene	100	Donkey like	 Merychippus		3 - toed (No Splint bones)
Oligocene	60	Sheep like	 Mesohippus		3- toed (1 Splint bones)
Eocene	40	Fox like	 Eohippus		4- toed (1 Splint bones)

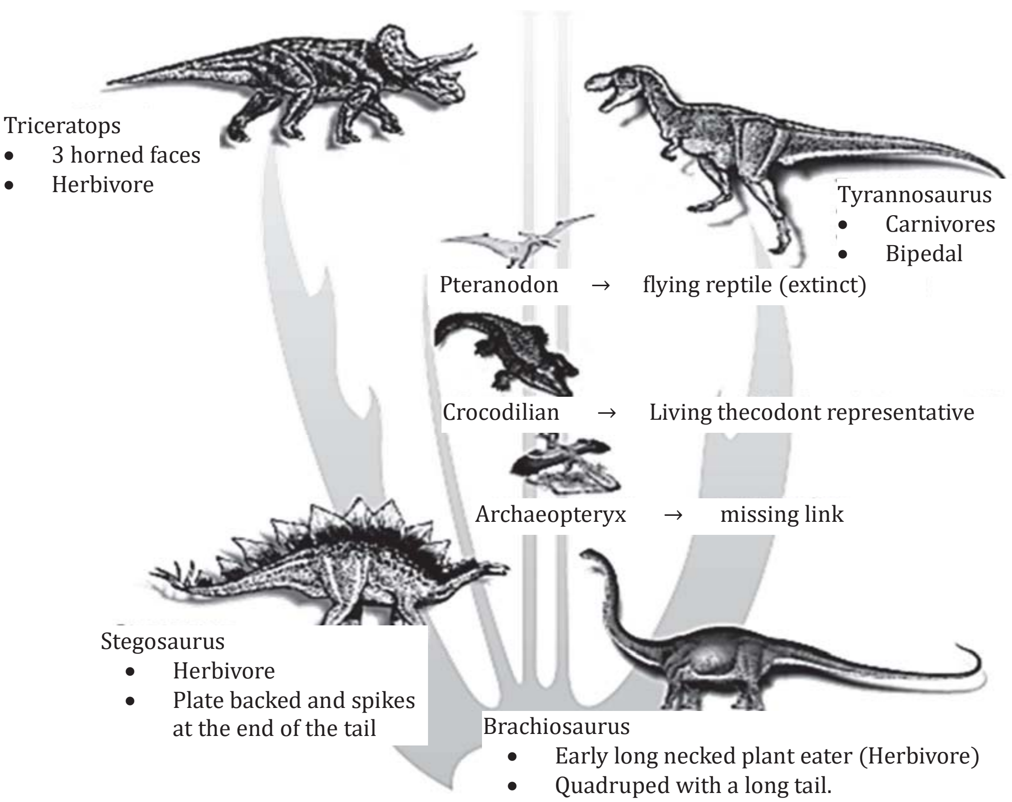
- C. Marsh documented the evolutionary progression of the horse.
- Numerous evolutionary transformations have been noted in the horse:
  (i) Increase in body height, elongation of the neck and legs.
  (ii) Decrease in the count of toes or fingers along with the adoption of a running behavior.
  (iii) Emergence of a high crown on teeth and the creation of cement.
  (iv) Growth in the size of the brain.

A concise overview of evolution

- Roughly 2000 million years ago (mya), the initial cellular life forms emerged on Earth.
- Around 500 mya, invertebrates evolved and began to thrive.
- Jawless fishes likely originated approximately 350 mya.
- Sea weeds and a limited number of plants likely existed around 320 mya.
- The earliest organisms to colonize land were plants, which had already established a significant presence on land by the time animals began to migrate onto land.
- Fish with robust and sturdy fins developed the ability to navigate on land and return to water around 350 million years ago. In 1938, a Coelacanth, a fish thought to be extinct, was unexpectedly caught in South Africa.
- These Coelacanths, or lobefins, eventually evolved into the first amphibians capable of living both on land and in water. Although no specimens of these creatures remain, they served as ancestors to modern-day frogs and salamanders.
- The amphibians later transitioned into reptiles, characterized by their ability to lay thick-shelled eggs that are impervious to drying out in the sun, unlike those of amphibians. Today, their descendants include turtles, tortoises, and crocodiles.
- Synapsids, early reptiles with mammal-like traits, eventually gave rise to mammals.

- Sauropsids, resembling lizards, were early reptiles that diversified into various dinosaurs, modern reptiles, and birds.





A family tree of dinosaurs and their living modern day counterpart organisms like crocodiles and birds

- Over the following 200 million years or so, reptiles of varying shapes and sizes became the dominant life forms on Earth.
- Although giant ferns, known as pteridophytes, were prevalent during this period, they gradually fell, contributing to the formation of coal deposits over time.
- Some terrestrial reptiles transitioned back to aquatic environments, evolving into fish-like reptiles around 200 million years ago, such as the Ichthyosaurs.
- Naturally, the terrestrial reptiles included the dinosaurs. Among them, the largest was the Tyrannosaurus rex, standing approximately 20 feet tall and boasting formidable, dagger-like teeth.
- Approximately 65 million years ago, the dinosaurs mysteriously vanished from the Earth. The exact cause remains uncertain, with theories suggesting either climatic changes or collisions with meteorites. The truth remains elusive.
- Small-sized reptiles from that era still exist in the present day.
- The earliest mammals resembled shrews, leaving behind fossils of small size.
- Mammals were viviparous, giving birth to live young and sheltering them within the mother's body. They exhibited greater intelligence in sensing and evading threats, at the very least.
- As the era of reptilian dominance waned, mammals emerged as the predominant life forms on Earth.

(II) Comparative Analysis of Organism Anatomy and Morphology (Morphological and Anatomical Evidence)

Morphology pertains to the outward appearance of an organism, while anatomy delves into its internal structure and functional arrangement.

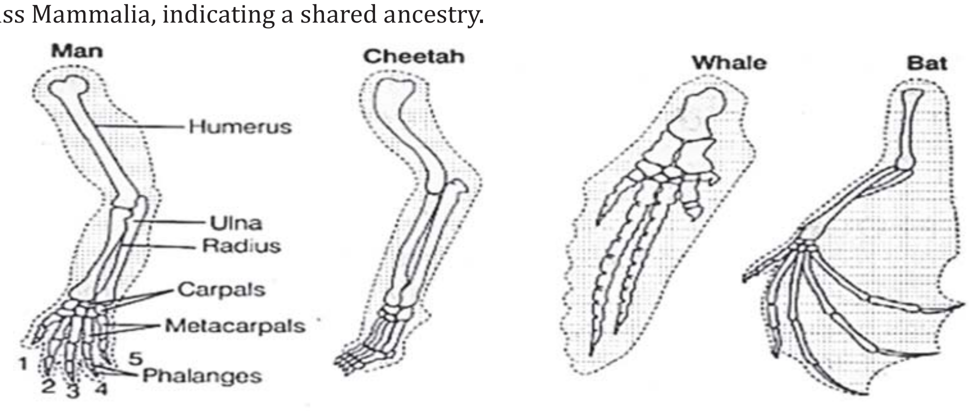
The Earth harbors a rich tapestry of life, comprising a multitude of species across various kingdoms, classes, and phyla. The classification of these organisms' hinges upon discerning their shared characteristics. Consequently, studying these traits is pivotal for taxonomy and evolutionary analysis. Through a meticulous examination of morphology and anatomy, we can discern both the resemblances and distinctions between extant and extinct organisms. Central to this endeavor is the recognition of homologous and analogous structures.

(1) Homologous Structures

These are anatomical features found in disparate organisms that share a similar underlying structure or blueprint but serve different functions. This resemblance in structure is attributed to their common ancestry.

To elucidate further, consider the following examples:

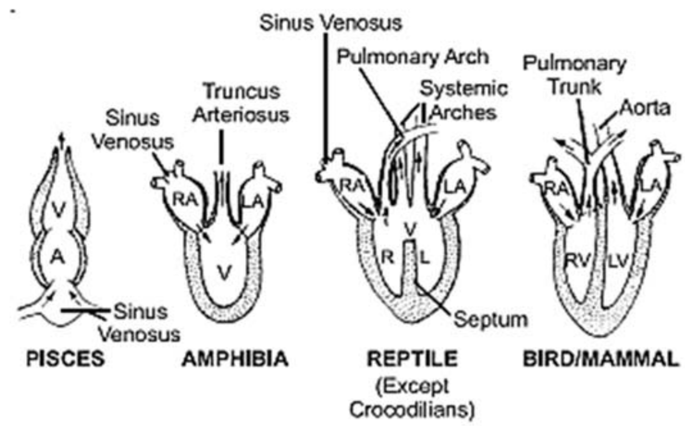
(i) The skeletal arrangement of forelimbs in whales, bats, cheetahs, and humans' bears striking similarities. Despite the diverse ecological niches these species inhabit, they all belong to the class Mammalia, indicating a shared ancestry.



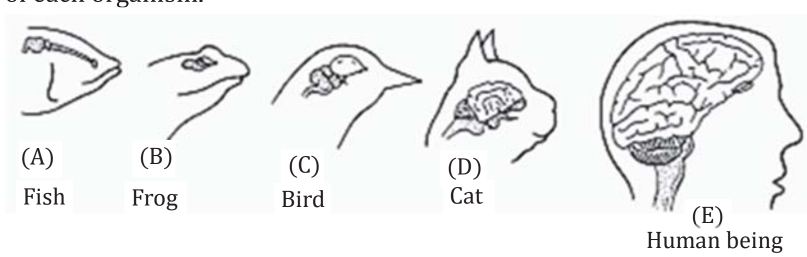
Upon closer examination of their forelimbs, it becomes evident that these organisms exhibit comparable, albeit not identical, anatomical structures. Specifically, each of them possesses a humerus, radius, ulna, carpals, metacarpals, and phalanges in their forelimbs. However, divergent functionalities emerge when we consider the roles these forelimbs fulfill across the animal kingdom.

Observing these animals, we notice that a common structure, namely the forelimbs, has evolved along distinct trajectories to accommodate varied requirements. This phenomenon, known as divergent evolution, elucidates how a shared ancestral structure diverges toward disparate functionalities in response to each organism's unique demands. Therefore, homologous structures emerge as manifestations of divergent evolution.

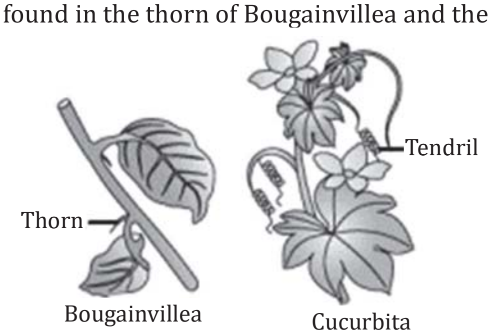
(ii) Comparison of Vertebrate Hearts and Brains: The hearts of diverse vertebrates, spanning from fishes to mammals, exhibit a fundamental similarity in their structure. However, they manifest varying degrees of specialization influenced by factors such as habitat, energy needs, and evolutionary progression.



Similarly, the brains of vertebrates exhibit a foundational resemblance in structure, yet they undergo a progressive increase in complexity from fishes to mammals, adapting to the evolving requirements of each organism.



(iii) Homologous structures are not limited to animals; they can also be identified in plants. An illustrative example is found in the thorn of Bougainvillea and the tendril of Cucurbita.



In the case of these plants, both thorns and tendrils emerge from axillary positions and originate as modifications of axillary buds. However, they serve distinct purposes: thorns function primarily in safeguarding the plant, whereas tendrils facilitate the plant's climbing behavior.

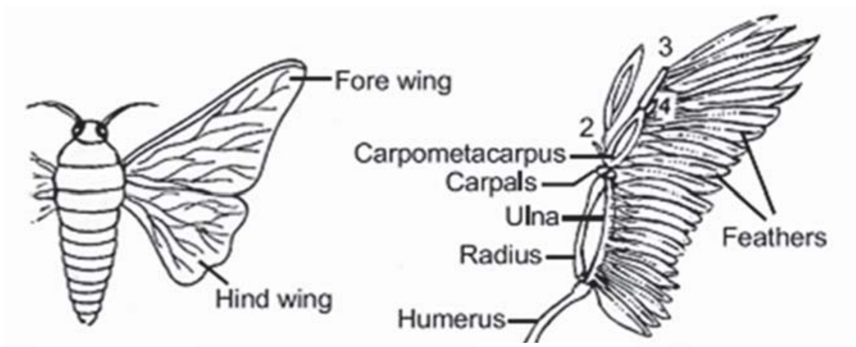
(iv) Example of Biochemical or Molecular Homology: Having explored structural resemblances across various organisms, let's delve deeper into molecular intricacies. Consider, for instance, the proteins present in the blood of humans and apes, which exhibit striking similarities, indicating a shared ancestral lineage. Moreover, we can discern analogous genes in disparate or unrelated organisms, further reinforcing the notion of a common origin.

(2) Analogous Structures

Analogous structures refer to organs in different organisms that perform similar functions despite lacking anatomical similarity. Morphologically, they may or may not resemble each other externally. The concept of analogy pertains to the property of bearing such analogous structures. Unlike homology, which suggests a shared ancestry, analogy does not imply common descent.

Examples of analogous structures abound, such as:

(i) The wings of butterflies and birds. While both serve the common function of flight, butterflies belong to the invertebrate category, whereas birds are vertebrates. Internally, the designs and components of their wings differ significantly. However, externally, they may appear similar due to their shared function of flying.



Insect wings
A

Bird wings
B

Now, let's explore how analogous structures are intertwined with the process of evolution.

In this context, consider the example where anatomically distinct structures evolve towards a common function due to adaptations to similar needs or environments. This phenomenon is known as convergent evolution, where disparate structures originating from different lineages converge towards a shared purpose.

(ii) An illustrative instance of this concept can be observed in the comparison between the eye of an octopus and that of mammals. Despite differences in their internal structures, particularly in the position of the retina, both eyes serve the common function of vision.

(iii) Similarly, the flippers of penguins and dolphins provide another example. Penguins, as birds, and dolphins, as mammals, possess flippers adapted for swimming. Despite differing internal structures and evolutionary origins, these flippers serve the shared function of aquatic locomotion.

(iv) Further exemplifying analogous structures, consider the comparison between sweet potatoes and potatoes. While sweet potatoes are modified underground roots and potatoes are modified underground stems, their primary function of storing food remains consistent. Despite their distinct origins, they serve a similar purpose, demonstrating convergent evolution.

(v) Additionally, the concept extends to botanical examples, such as tendrils used for support and climbing. While leaf tendrils are present in Pisum, stem tendrils are observed in Passiflora.

Despite originating from different plant parts, both adaptations serve the shared function of aiding in climbing and support.

(3) Vestigial Organs

Vestigial organs are believed to be remnants of structures that were once complete and functional in the ancestors of organisms. The study of vestigial organs provides an evolutionary perspective on these rudimentary vestiges, suggesting that adaptations to new environments rendered these structures obsolete. Such vestiges are termed vestigial organs.

Examples of vestigial organs include the rudimentary remnants of the reptilian jaw apparatus, as well as the vestigial hind limbs observed in pythons and Greenland whales. In humans, numerous vestigial structures hint at evolutionary relationships with other mammals, particularly primates.

For instance, muscles of the external ear and scalp are often rudimentary and non-functional in humans, yet they remain functional in many other mammals. Reduced tailbones, the nictitating membrane of the eye, the appendix of the caecum, rudimentary body hair, and wisdom teeth are additional examples of vestigial organs.

The human appendix, for instance, is speculated to be a remnant of the large caecum, an organ used for cellulose digestion in herbivorous mammals. Similarly, non-functional vestiges of the pelvic girdle in pythons and porpoises suggest that these creatures evolved from four-footed ancestors.

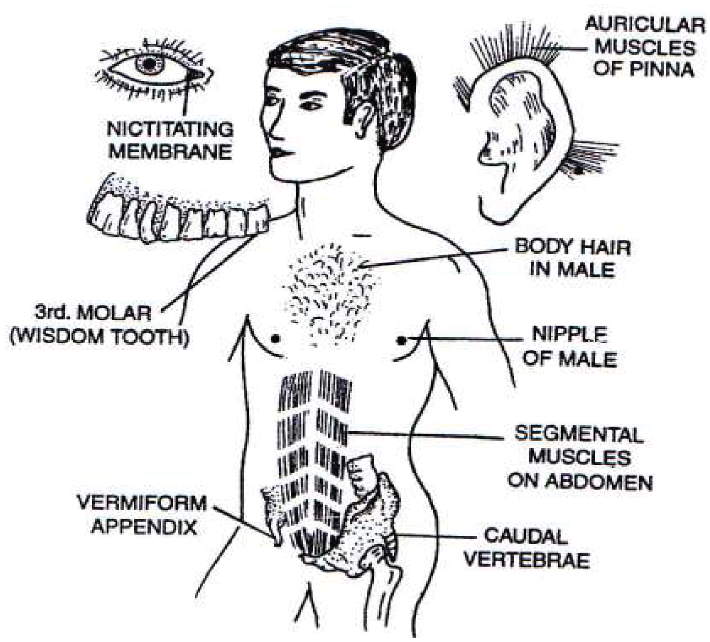


Fig.: Some vestigial organs in human Body

(4) Connecting Links

Connecting links are organisms that exhibit characteristics belonging to two distinct groups. They serve as crucial intermediaries in understanding evolutionary relationships. Here are some significant examples of connecting links.

Examples:

(a) **Neopilina**

Neopilina serves as a connecting link between Annelida and Mollusca. Resembling mollusks, it features a shell, mantle, and a large muscular foot. However, it also retains annelid characteristics, including segmentally arranged gills, nephridia, muscles, and a larval stage reminiscent of trochophores.

(b) **Peripatus**

Peripatus, an arthropod, serves as a connecting link between Annelida and Arthropoda. It embodies both arthropod and annelid characteristics. Arthropod features include a haemocoel, tracheae as respiratory organs, and a tubular heart with ostia. On the other hand, it exhibits annelid traits such as a worm-like body structure, eye arrangement, unjointed legs, presence of segmental nephridia, soft cuticle, and continuous muscle layers in the body wall.

(III) Embryological Evidence

Biogenetic Law

Embryological evidence supporting evolution was initially proposed by Ernst Haeckel, who observed certain features common to all vertebrate embryos that are absent in adults.

For instance, embryos of all vertebrates, including humans, develop a row of vestigial gill slits just behind the head. However, this feature is functional only in fish and not present in any other adult vertebrate. However, Karl Ernst Von Baer later refuted this proposal, noting that embryos never pass through the adult stages of other animals.

Nevertheless, a notable similarity exists in the sequence of embryonic development among different vertebrates. Gill clefts and the notochord appear during embryonic development in all vertebrates, from fish to mammals. The notochord is subsequently replaced by the vertebral column in all adult vertebrates, while gills are replaced by lungs in adult amphibians and mammals. Such consistent patterns in embryonic development underscore the concept of evolution from common ancestors. Occasionally, embryonic features such as the tail and gill slits persist into adulthood.

Ernst Haeckel proposed the idea that ontogeny, or the development of the embryo, recapitulates phylogeny, or the ancestral sequence. This notion is encapsulated in his Biogenetic Law: "Ontogeny recapitulates phylogeny."

Furthermore, developmental evidence for evolution can also be gleaned from plants. It is widely believed that mosses and ferns are more evolved than algae. The protonema of mosses bears resemblance to certain green algae, hinting at their evolutionary relationship. Both bryophytes and pteridophytes possess ciliated sperms and require water for fertilization. Although gymnosperms do not need water for fertilization, primitive gymnosperms like cycads and ginkgo possess ciliated sperms similar to pteridophytes. This suggests that gymnosperms have descended from ancestors resembling pteridophytes. The persistence of ancestral traits in embryos is termed palatogenesis.

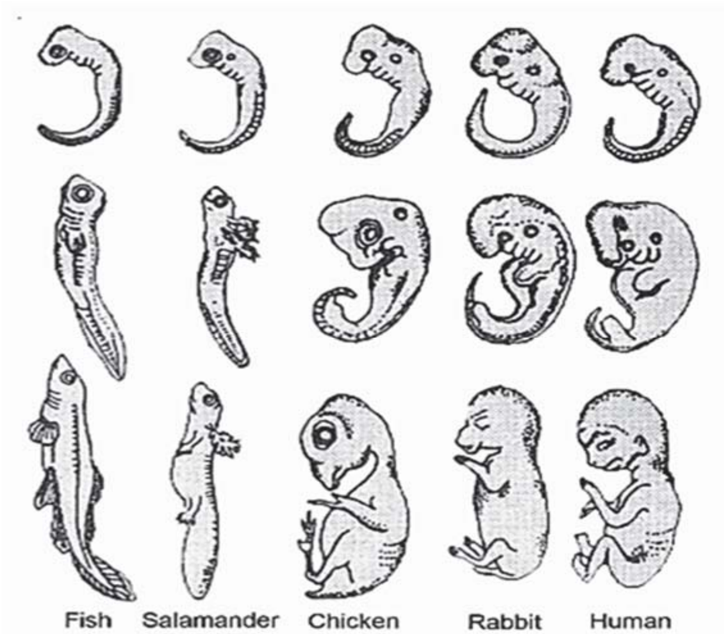


Fig. : Similarity in the embryo of different vertebrates

(IV) Biogeographical Evidence

Biogeography is the study of the distribution patterns of animals and plants across different regions of the Earth.

Restricted Distribution: Regions isolated from the mainland often harbor unique fauna and flora.

For instance, Australia boasts:

(a) Egg-laying mammals.

(b) Pouched mammals exclusively found in Australia. This limited distribution can be elucidated as follows: Australia became separated from the Asian mainland during the Mesozoic era, prior to the evolution of placental mammals. Placental mammals, being better adapted, outcompeted egg-laying and most pouched mammals elsewhere in the world. The egg-laying and pouched mammals of Australia survived because placental mammals couldn't reach the continent due to the lack of a land route.

(c) The deserts of America are home to cacti, while those of Africa host euphorbias.

(d) The double coconut is confined to the Seychelles islands.

Birds in the Galapagos Islands exhibit variations in bills and feeding habits. The bills of several species resemble those of different, distinct families of birds found on the mainland. It is believed that all these birds evolved from a single common ancestor.

Artificial Selection

A Manifestation of Evolutionary Evidence

Artificial selection, as its name implies, entails the deliberate breeding of plants or animals to cultivate desired traits. This process is conducted artificially through various breeding techniques, hence earning the designation of "artificial selection." Below are examples illustrating artificial selection:

(i.) The development of various breeds of dogs, cows, and sheep.

(ii.) The cultivation of diverse vegetables such as broccoli, kale, cauliflower, etc., derived from wild mustard through selective breeding methods.

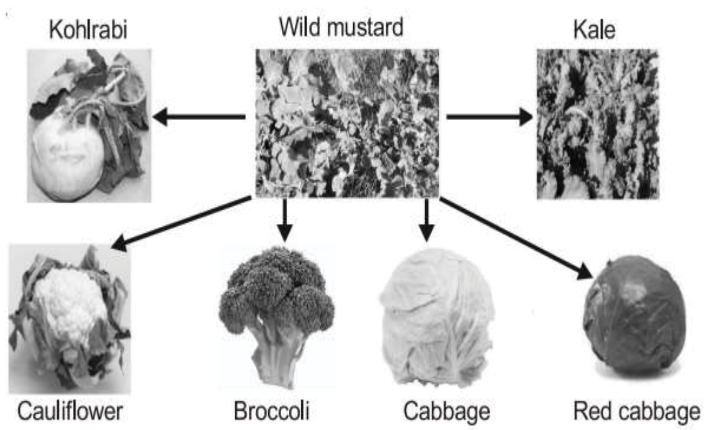


Fig.: Evolution of wild mustard

Throughout history, humans have played a pivotal role in the domestication and selective breeding of wild animals and plants to enhance desired traits. This practice spans various domains, including agriculture, horticulture, sports, and security.

In agriculture, humans selectively bred cows, buffaloes, and other livestock to augment milk yield and quality. Similarly, in horticulture, various crops were bred to improve yield, nutritional content, and resistance to diseases.

In the realm of sports, humans have selectively bred superior breeds of fowl, bulls, and horses for activities such as cock-fighting, bull racing, and horse racing, respectively.

Furthermore, for security purposes, humans have bred robust and powerful breeds of horses, camels, dogs, and other animals.

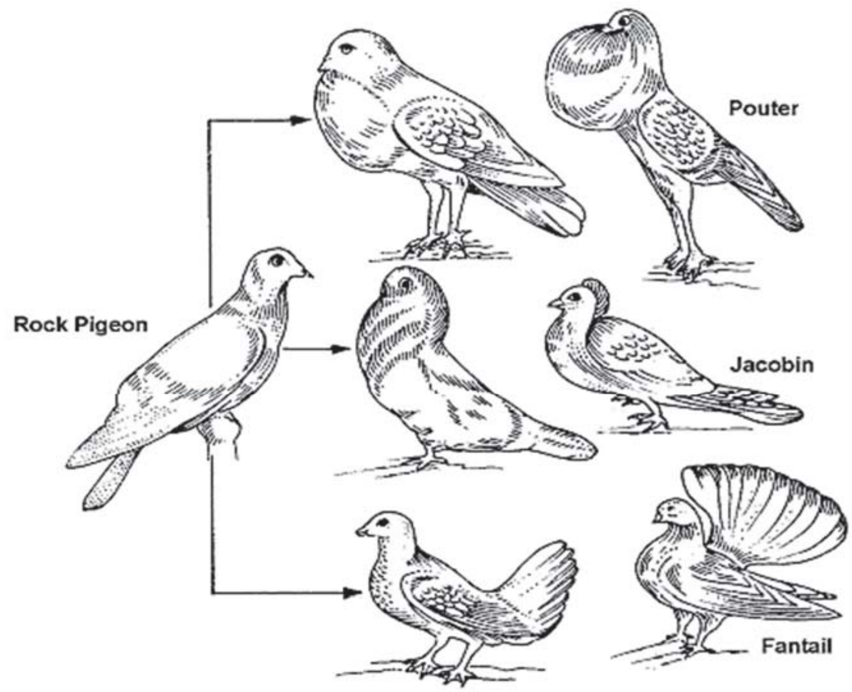


Fig. : Variation among breeds of domestic pigeons.
Ancestry of different breeds can be traced to wild rock pigeon. (Artificial Selection)

Critics of evolution often pose the question: If humans can create new breeds within a span of mere hundreds of years, could not nature have accomplished similar feats over millions of years? This argument highlights the potential parallels between human-driven selective breeding and natural evolutionary processes.

Natural Selection
A Testament to Evolution

Charles Darwin and Alfred Russel Wallace introduced the concept of natural selection, which refers to the process by which nature selects certain traits for survival and reproduction. A compelling illustration of natural selection is found in Industrial Melanism.

(1) Industrial Melanism

Prior to the onset of industrialization in England in the 1850s, white-winged moths outnumbered dark-winged or melanistic moths. However, following industrialization, particularly in the 1920s, this trend reversed. During the post-industrialization era, the population of dark-winged moths significantly surpassed that of white-winged moths in the same region of England. What could account for this phenomenon?

This can be explained as follows:

Moths typically rest on tree trunks. Prior to industrialization, air pollution was minimal, resulting in lighter-colored tree trunks devoid of smoke and soot deposition. Additionally, there was a dense growth of nearly white-colored lichen covering the tree trunks. In such conditions, predators (birds) found it challenging to detect or locate white-winged moths against the light-colored backdrop of tree trunks, while dark-winged moths stood out prominently. Consequently, birds preyed upon and consumed more dark-winged moths, leading to a decline in their population.

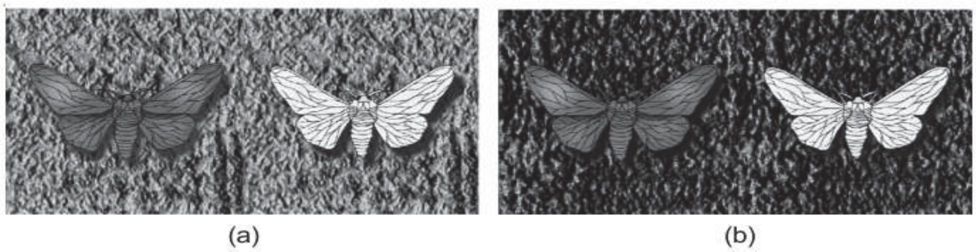


Fig.: Figure showing white-winged moth and dark-winged moth (melanized) on a tree trunk
(a) In unpolluted area (b) In polluted area

However, with the advent of industrialization, pollution levels surged, resulting in a darkening of the tree trunks. This darkening occurred due to the deposition of smoke and soot on the bark, as well as the absence of lichens, which do not thrive in polluted environments. The presence of sulfur dioxide (SO_2) in the smoke played a role in eradicating lichens, thereby exposing the dark brown color of the bark.

Consequently, the once-effective camouflage of the white-winged moths was compromised, leaving them vulnerable to predation by birds. This shift in environmental conditions led to a decline in the population of white-winged moths.

This explanation gains further support from observations in rural areas, where industrialization had not occurred. In these regions, the count of melanic (dark-winged) moths remained low, while the population of white-winged moths predominated.

Therefore, this scenario underscores the principle that within a mixed population comprising various moth variants, those individuals capable of better adaptation are more likely to survive and produce offspring. This process, known as natural selection, serves as a mechanism driving evolution. It's essential to note that while certain variants may decline in numbers, they are not entirely eradicated.

(2) Antibiotic or Drug Resistance

We regularly employ drugs and antibiotics to combat microbial infections. Over time, certain microbes have evolved "resistance" to these medications by undergoing changes or modifications in their structures. Those microbes that successfully developed resistance managed to survive, thereby being favored by natural selection. Thus, the acquisition of "drug resistance" by microbes serves as another instance of natural selection in action. Notably, this form of natural selection occurs within relatively short periods, often spanning mere months or years rather than centuries.

(3) Herbicide resistance (developed in wild varieties)

Similarly, herbicide and pesticide resistance developed in weeds and pests respectively after prolonged use of herbicides and pesticides. This is also an example of natural selection which supports the process of evolution. All above mentioned examples (industrial melanism, drug resistance etc.) are due to the involvement and actions of man and that is why these are described as the examples of evolution by anthropogenic action. All above mentioned evidences also suggest that evolution is a stochastic process which is based on many probabilities. It is based on chance events in the nature and chance mutations in the organisms. And we can see in the example of moths, the survival of moths was dependent on the pollution created by man and if industrialization would not have occurred, any other probability would have been there which would have determined the survival of moths. Hence, many probabilities are there for every phenomenon occurring in the nature and evolution cannot be seen as a directed process in the light of determinism.

Example: Fossilization can occur under the following conditions:

(1) Animals are buried and preserved through natural processes.
(2) Animals are consumed by scavengers.
(3) Animals are preyed upon by predators.
(4) Animals are affected by harsh environmental conditions.

Solution: Fossilization primarily occurs when animals are buried and preserved by natural processes. This is because if animals are consumed or destroyed, they cease to exist in any form on Earth, making fossilization impossible.