Evidences and Mechanisms of Organic Evolution

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Abstract

From the very onset of consciousness, humanity has always wondered about its origin. As we attempt to answer some of our deepest questions on our evolution, we find that the natural world though is very unpredictable, has in it plenty of evidences which on close observation leads us to some insights on the mechanism of evolution. This project discusses some important evidences in the evolution of organisms and concludes a few ideas in the mechanism of evolution.

1 Organic Evolution

Evolution as such is a huge concept, that aims to put together, in a chronological manner, all events right from the Origin of the Universe. All events right from the big bang such as the formation of the primordial soup, stars, star clusters and planets, the birth of the solar system the development of Earth etc., come under the idea of evolution. Origin of Life is itself, as Oparin and Haldane proposed and from Miller's experiments, a chemical evolution; from aggregates of biomolecules to higher levels of chemical organization. However we shall restrict ourselves to a biological perspective of evolution, i.e., organic evolution.

The change in the forms of living organisms with time is termed as *organic or biological evolution*. The theory or doctrine of organic evolution was given by **Charles Darwin.** Accordingly, *the present day complex organisms have originated during the course of ages from the earlier simpler forms of life by a process of gradual or abrupt changes occurring in a sequential manner and in accordance with the environmental requirements.* Charles Darwin briefly explained this theory as **descent with modification**. Modification occurs by interaction of genes and environment.

According to evolutionists the unicellular organisms were the first to appear in the world. Some of them gave rise to multicellular organisms. The earlier multicellular organisms were relatively simple, such as the seedless plants and invertebrate animals. The simpler multicellular organisms were later modified into the complex multicellular ones, such as the sea plants and vertebrate animals. The early vertebras were fishes. Some fishes gradually changed into amphibians. Certain amphibians then produced reptiles. Some of the latter finally evolved into birds and mammals. Humans evolved from the now extinct ape-like animals by accumulation of changes from generation to generation.

Organic evolution is one of the key concepts of biology. Theodosius Dobzhansky remarked in 1973 that **nothing in biology makes sense except in the light of evolution.**

2 Evidences of Organic Evolution

Many evidences support the doctrine of organic evolution. These are categorized as:

- Morphological and Anatomical evidences
- Embryological evidences
- Palaeontological evidences
- Biogeographical evidences
- Current evolutionary evidences

2.1 Morphological and Anatomical evidences

Comparative study of the morphology[1] and anatomy[2] of animals and plants show that certain structural features are basically similar. These features include body organization, gradual modification, homologous organs, analogous organs, connecting links, vestigial organs and atavism.

2.1.1 Body organization

The body of all animals and plants is formed of the microscopic units, the *cells*. In most cases, similar cells aggregate to form *tissues*. The tissues gather to form *organs* and organs co-operate to form *organ systems*. **This similarity in body organization indicates a fundamental unity of all animals.**

In sponges, the cells function more or less independently, not organizing themselves into tissues. This gives the sponges a cellular level of organization. In coelenterates, the cells are aggregated into tissues onward the body has organ system level of organization comprising cells, tissues, organs and organ systems.

In bryophytes the plant body is a thallus without root, stem and leaves, or a leafy shoot with stem like central axis bearing a leaf like appendages and root like rhizoids. In pteridophytes, the plant body has true roots, true stems and true leaves with vascular tissues but lacks flowers, fruits and seeds.

Gymnosperms have developed seeds but do not form flowers and fruits. Angiosperms produce flowers, roots and seeds. **This step-wise change from simple to complex body organization provides another definition for evolution.**

[1] study of the form and external/gross structure of organisms and their specific structural features.

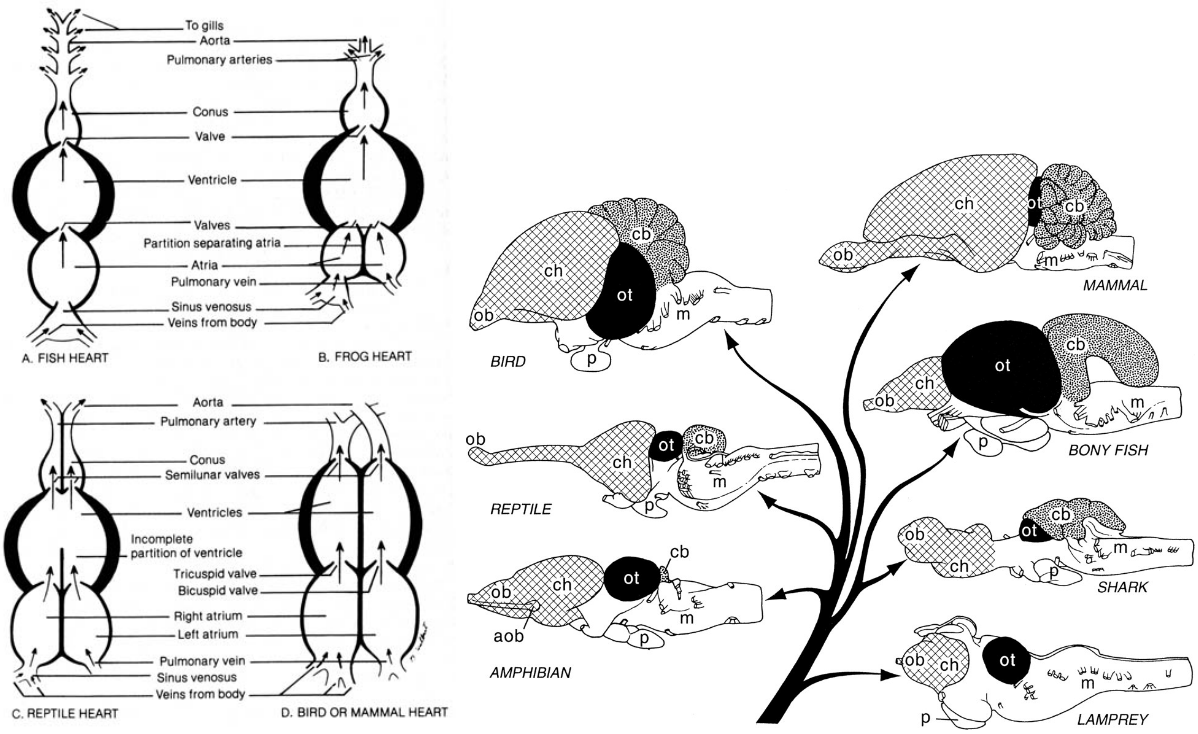
[2] branch of biology and medicine dealing with internal structure of living organisms

2.1.2 Gradual modification

Certain vertebrate organs such as heart show gradual modification, which is the actual mechanism of organic evolution. The heart is two chambered, (one auricle and one ventricle) in the fishes, three-chambered (two auricles and one ventricle) in the amphibians, incompletely four-chambered (two auricles and partly divided ventricle) in most of the reptiles, and completely four-chambered (two auricles and two ventricles) in crocodiles, birds and mammals.

In the brain, the change concerns enlargement of cerebrum[3] and cerebellum.[4]

Figure 1: Evolution of vertebrate heart and brain



2.1.3 Homologous Organs

The organs of different species of common descent which look different and perform different functions, but have the similar basic structure, similar topographic relationship, and similar embryonic origin are called homologous organs. The term homologous organs was coined by Richard Owen (1804-1892). Homology is based on *divergent evolution.* The following are a few prominent examples for homologous organs:

Vertebrate Forelimbs: The forelimbs of vertebrates, such as man, cheetah, whale and bat, afford a good example of the homologous organs. The forelimbs of these animals have

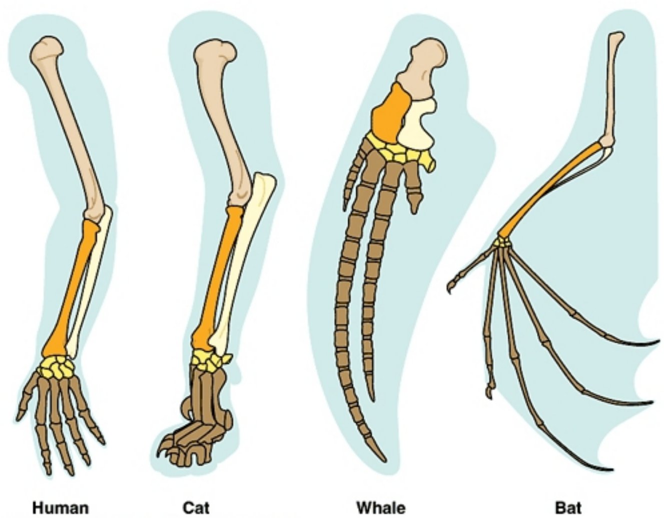
[3] the part of the brain which serves as a centre of higher mental activities

[4] the part of a brain that serves as a centre of coordination

different shapes and serve different purposes. They are used for grasping in man, for running in cheetah, for swimming in whale and for flying in bat. They are, however, built on the same plan.

In each case, the forelimb consists of upper arm having a single bone, *humerus*; the forearm containing two bones, *radius* and *ulna*; and the hand having *carpals* in the wrist, *metacarpals* in the palm, and *phalanges* in the digits. **All vertebrates have basic similarity in the structure of their forelimbs because they inherited it from an ancestor which had five-digited, or pentadactyle limbs.** The pentadactyle limb of the ancestral vertebrate became modified according to the special needs of the subsequent generations during the course of evolution. The modification has been minor, e.g., reduction in the number of digits, fusion of certain bones and external form.

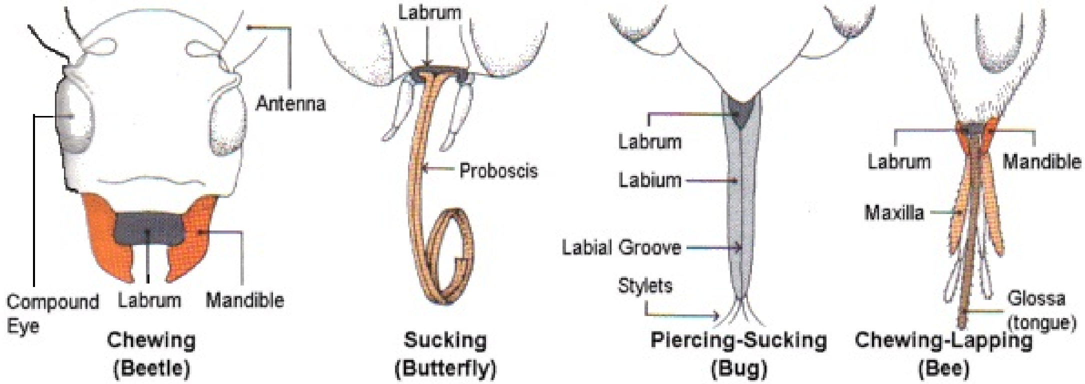
Figure 2: Forelimbs of mammals showing homology. Although forelimbs look different and serve different functions they all have similar bones arranged in similar segments.



On examining the internal structure of the forelimbs of vertebrates, a similar surprising uniformity is found in the arrangement of principal muscles, nerves and blood vessels. The uniformity is so close that in comparative anatomy the same name is given to the corresponding part in all vertebrates, Moreover, the forelimbs of all vertebrates develop in the embryo from the same parts and in a similar manner.

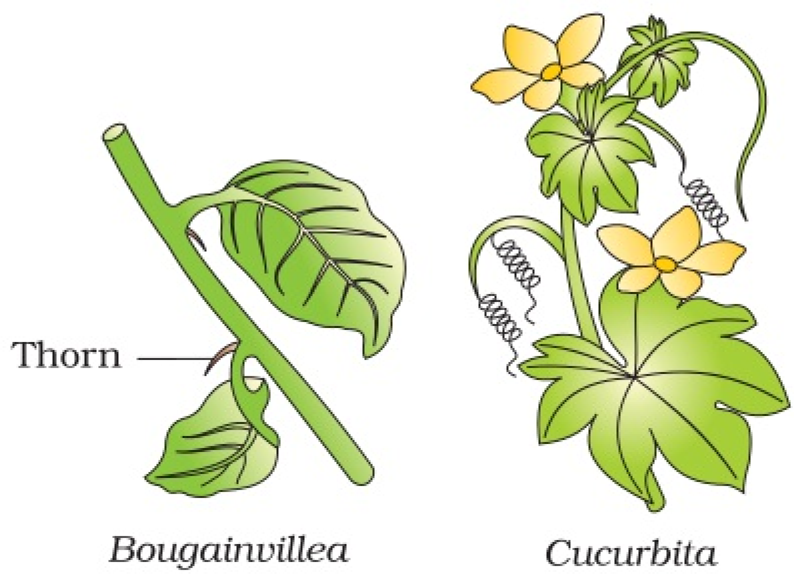
Insect mouth parts: In all the insects, the mouth parts include a labrum, a pair of mandibles and two pairs of maxillae, and these help in feeding. But they are differently modified in different insects. This modification is associated with the feeding habit of the insect in cockroach, the mouth parts are adapted for chewing solid food, in mosquito for sucking liquid food, in housefly for sponging fluids, and in the butterfly for siphoning nectar. The similarity in the fundamental structure of the apparently different mouth parts indicates the common ancestry of all insects.

Figure 3: Mouthparts of different insects show homology



Thorns and Tendrils of Some Plants: A thorn of glory-of-the-garden (Bougainvillea[5]) and a tendril of passion flower (Passiflora[6]) or tendril of cucurbita[7] are homologous organs in plants. They look different and help the plant in climbing in different manner but both arise in the axillary position and are modified branches.

Figure 4: Homologous organs: Thorns of *Bougainvillea* and tendrils of *Cucurbita*



[5] *Bougainvillea glabra*, a plant with flowers that are generally pink or green and are papery
[6] plants belonging to the family of angiosprems, *Passifloraceae*
[7] plants belonging to the family of angiosprems, *Cucurbitaceae*, which includes melons, gourds etc.,

2.1.4 Analogous Organs

The organs which have the same function and are superficially alike but are quite different in fundamental structure and embryonic origin are called the analogous organs. Analogy is based on *convergent evolution.* The following are examples of analogous organs:

Insect and Bird Wings: The wing of an insect and the wing of a bird are analogous organs. Both these organs are used for flying in the air, but they are very different in structure. An insect wing is an extension of the integument, whereas a bird wing is formed of limb bones covered with flesh, skin and feathers. The superficial similarity of these organs is due to adaptation to flying rather than to inheritance from a common ancestor. Each has evolved from separate ancestral population as a means of more efficient mode of locomotion. Similarity developed in distantly related groups as an adaptation for the same function is called analogy, or convergent evolution.

Figure 5: Analogy in insect and bird wings

Fins and Flippers: The pectoral fins of fishes and the flippers of dolphins are flattened organs used for swimming. However, the two have different structure. The flippers are the modified pentadactyle forelimbs whereas the fins are not pentadactyle. Hence, the two are analogous organs developed for aquatic life. Similarly, flippers of penguins and dolphins are analogous organs.

Cephalopod and Vertebrate eyes: Eyes of cephalopods (Octopus, Sepetia, etc.,) and vertebrates (fishes, amphibians, reptiles, birds and mammals) have many morphological features in common besides the same. However, there are striking differences between the two groups. The retina of the vertebrate eye originates as an outgrowth of the embryonic brain. Whereas the entire eye of a cephalopod develops as a modification of the skin. Thus, the eyes of cephalopods are analogous to the eyes of vertebrates.

Tuberous root and potato: Sweet potato and potato are modifications for food storage. However, sweet potato is an underground tuberous root whereas potato is an underground tuberous stem. Therefore the two are analogous organs.

2.1.5 Connecting Links

The living organisms which possess characters of two different groups of organs are known as connecting links. Euglena, lung fishes and egg-laying mammals are familiar instances of connecting links.

Euglena: Euglena, a protist is often regarded a connecting link between plants and animals. Its plant characters are chloroplasts and photo-autotrophic nutrition. Its animal features include contractile vacuole, mouth and binary fission.

Lungfish The lungfish is a connecting link between fishes and amphibians. Like other fishes they have paired fins, dermal scales and gills. they resemble amphibians in having internal nares, a single or double lung for breathing air and three-chambered heart. The lungfish thus suggest a mechanism in which amphibians could evolve from fish.

Egg-laying mammals: The egg-laying mammals such as spiny ant-eater and duck-billed platypus, link the mammals with the reptiles. They are decidedly mammals as they have mammalian features, such as hair, mammary glands, diaphragm, single aortic arch etc., But they resemble the reptiles in having a large coracoid in the pectoral girdle , in laying large eggs with yolk and shell having cloaca. They are thus midway between reptiles and mammals and are sometimes described as unfinished mammals. They show the stage through which the reptiles have evolved into mammals.

Figure 6: (a)Lungfish and (b)Duck-billed Platypus

2.1.6 Vestigial Organs

The organs which occur in reduced form and are useless to the possessor, but are homologous to the fully developed functional organs of related animals are called vestigial organs. These organs were fully developed, functional and necessary in ancestral forms, but are gradually disappearing in living forms due to change in mode of their life. It would be wasteful to continue providing nutrients, blood and space to organs that no longer have a role. Some examples of vestigial organs in human beings are given below.

Tail Bone/Coccyx: It is a small triangular bone at the end of the sacrum. It consists of four rudimentary vertebrae fused together. It is a vestige of the tail of an ancestral form.

Canine and Wisdom teeth: Carnivores have large projecting canines to tear the body of the prey. Human canines are small due to different modes of taking food. Wisdom teeth are the third and last molars. They, besides being very small, appear very late or do not appear at all. This suggests that they are becoming useless for the purpose of grinding and may eventually disappear.

Nictitating membrane In frog, pigeon and cat, the third eyelid (nictitating membrane)is well developed and is moved across the eye at intervals for cleaning the cornea. In man, cornea is cleaned by the upper eyelid. Consequently, the third eyelid has become reduced and nonfunctional in the course of time. It is merely a small, pinkish, triangular flap in the inner angle of eye.

Caecum and Vermiform Appendix Vermiform appendix is a blind tube at the end of the caecum in certain mammals including man. In herbivores, the caecum and vermiform appendix are large structures and serve for the digestion of cellulose content of food by bacterial action. In man, the habit of taking soft and cooked food has reduced the need of bacterial digestion. The caecum and appendix have consequently become very small and and serve no useful role. Instead the vermiform appendix becomes diseased in man due to infection. This disease is called appendicitis and requires surgical removal of the appendix. The caecum and appendix are present in man because they were present in the ancestral forms.

2.1.7 Atavism

Atavism[8]*, also called reversion or throwback, is a reappearance of a certain ancestral , not parental, structure which has either completely disappeared or greatly reduced.* There are many examples for atavistic structures in man, such as the occurrence of a short tails in some babies, presence of additional mammae in two rows, power of moving pinna in some cases, large canines, very long and dense hair, etc.

The presence of these structures only in a few individuals of a species can be explained on the assumption that that there is a tendency among animals to develop structures of their remote ancestors.

Atavism is also observed in plants. In citrus leaf the lamina is separated from wing petiole by means of a joint or constriction. Occasionally the winged part of the petiole gets enlarged to produce two lateral leaflets. The citrus leaf was once trifoliate compound leaf but during the course of evolution the two leaflets have degenerated.

[8]Latin, *atavus* means a remote ancestor

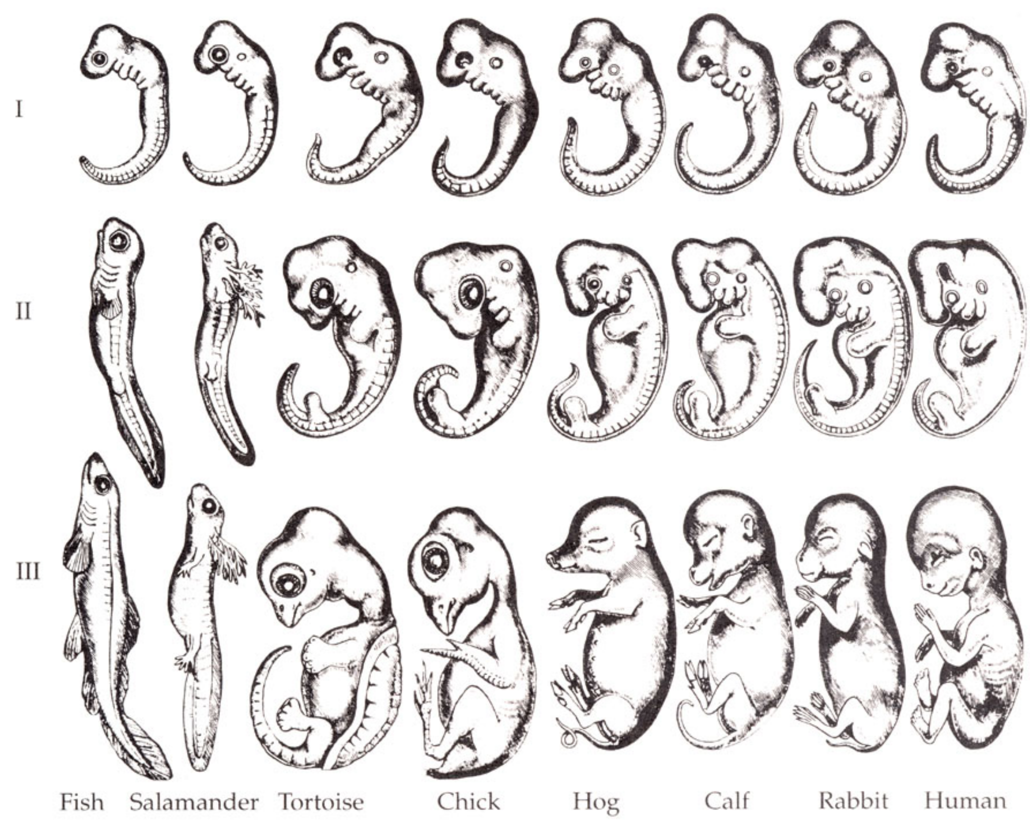
2.2 Embryological evidences

The comparative study of embryology of different animal groups show striking structural similarities between them. The aspects of embryology which lend support to the doctrine of organic evolution are *similar early development, resemblance among vertebrate embryos, recapitulation theory* etc.,

2.2.1 Similar early development

All animals start life as a single cell, the zygote. In all cases the zygote undergoes cleavage,producing a many-celled hollow blastula. The blastula changes into gastrula having in most cases three primary germ layers, namely, ectoderm, mesoderm and endoderm. The entire animal develops from these three layers. Each of the three primary germ layers produces the same set of organs in all the animals. The similar early development and same fate of the three layers in all the animals are of great significance. They establish a close relationship among the animals and suggest that all of them have evolved in a series from a common ancestor.

Figure 7: Ernst Haeckel's controversial embryo drawings



2.2.2 Recapitulation Theory

Von Baer in 1828, put forward **Baer's law**, which was later called the **biogenetic law** by Ernst Haeckel in 1866 on *embryological parallelism.* It states that an animal in its individual development from a egg to adult repeats or recapitulates in a condensed form the stages through which its ancestors have passed in the course of their evolution. This statement can be briefly put as follows - **ontogeny repeats phylogeny**. Ontogeny is the life history of an individual animal and phylogeny is the evolutionary history of the race of the animal. This means that the organism repeats its ancestral history during its development.

2.3 Palaeontological evidences

Palaeontology[9] *is the study of past life based on fossil records.* The fossils are the remains or impressions of the ancient organisms preserved by natural means in some medium. The media in which the fossils occur include sedimentary rocks, amber[10], asphalt[11], volcanic ash, ice, peat bogs[12], sand and mud. Palaeontology furnishes the most direct and most reliable evidence for evolution as it deals with the actual organisms that lived in the past.

Figure 8: Fossil remains of Archaeopteryx lithographica the ancient bird or 'lizard-bird' found Andreas Wagner in 1861 from the Upper Jurassic limestone rocks of Solenhofen in Germany. Although is skeleton looks very lizard-like, the impressions of feathers clearly show that it was a bird.

[9]Greek. *palaios* means old or ancient; *ontos* means being and *logos* means study

[10]A glass like substance formed by hardening of resin of coniferous trees

[11]hardened tar, material left in petroleum spring after evaporation of oil

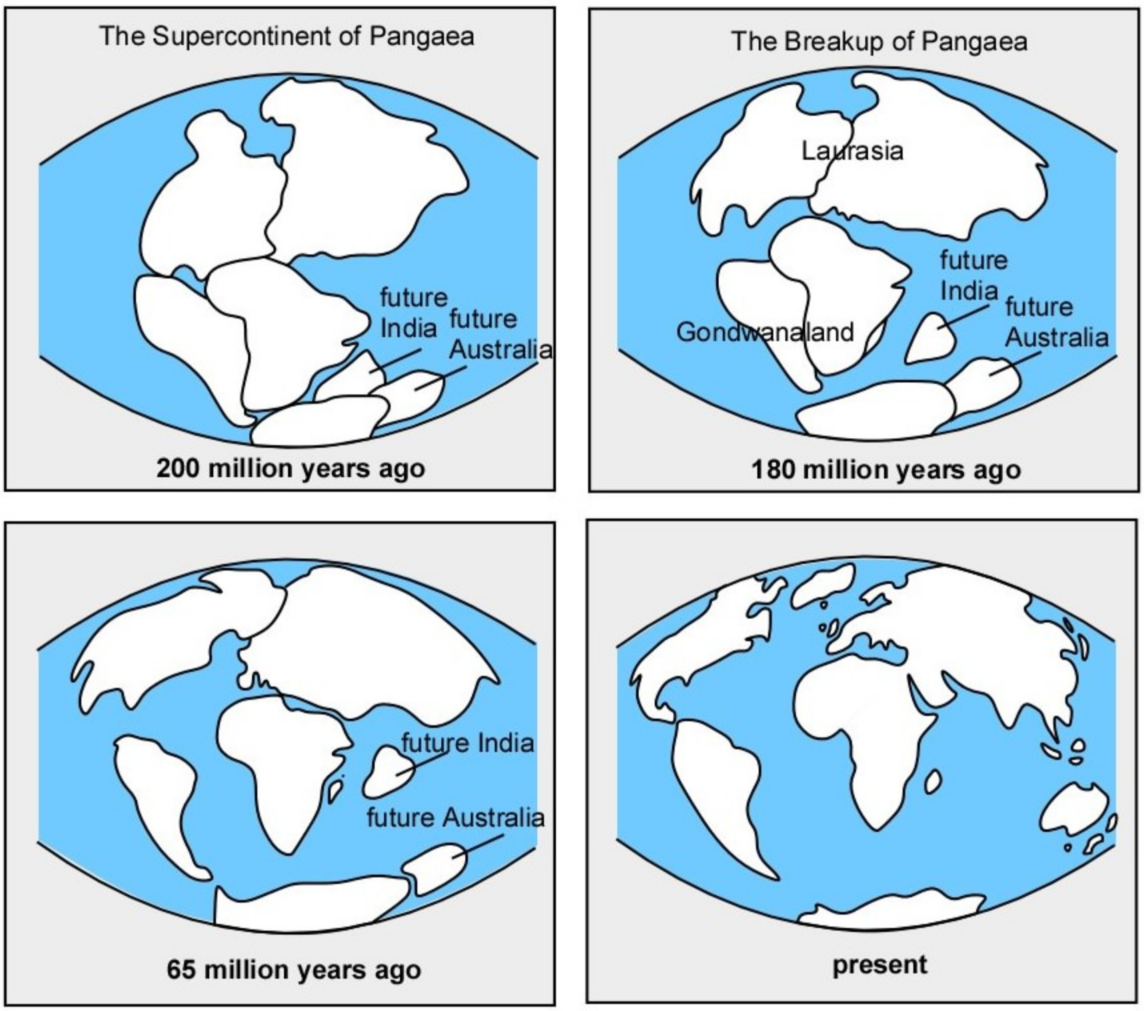
[12]wet, soft ground with decaying vegetable matter

2.4 Biogeographical evidences

The study of distribution of animals and plants in the world is called biogeography.[13]

It is held that, about 250 million years ago, all present-day continents formed a single large irregular land mass called the **pangaea**.[14] This land mass later split up and the smaller land masses (continents) gradually floated over it to their present positions. As the continents drifted away the seas separated them forming barriers to free intercontinental movements of organisms. Because of different environmental conditions existing on the wide-apart continents, organisms evolved independently.

Figure 9: Pangaea and its break up into continents



[13]Greek. *bios* means life; *geo* means Earth and *grapho* means to write.
[14]Greek. *pangaea* means all of Earth.

3 Evolutionary Processes

Although the entire mechanism and the theory of evolution still remains controversial, the processes of evolution are certainly not controversial. Based on the above mentioned evidences, the following conclusions about the processes of evolution seems to be obvious.

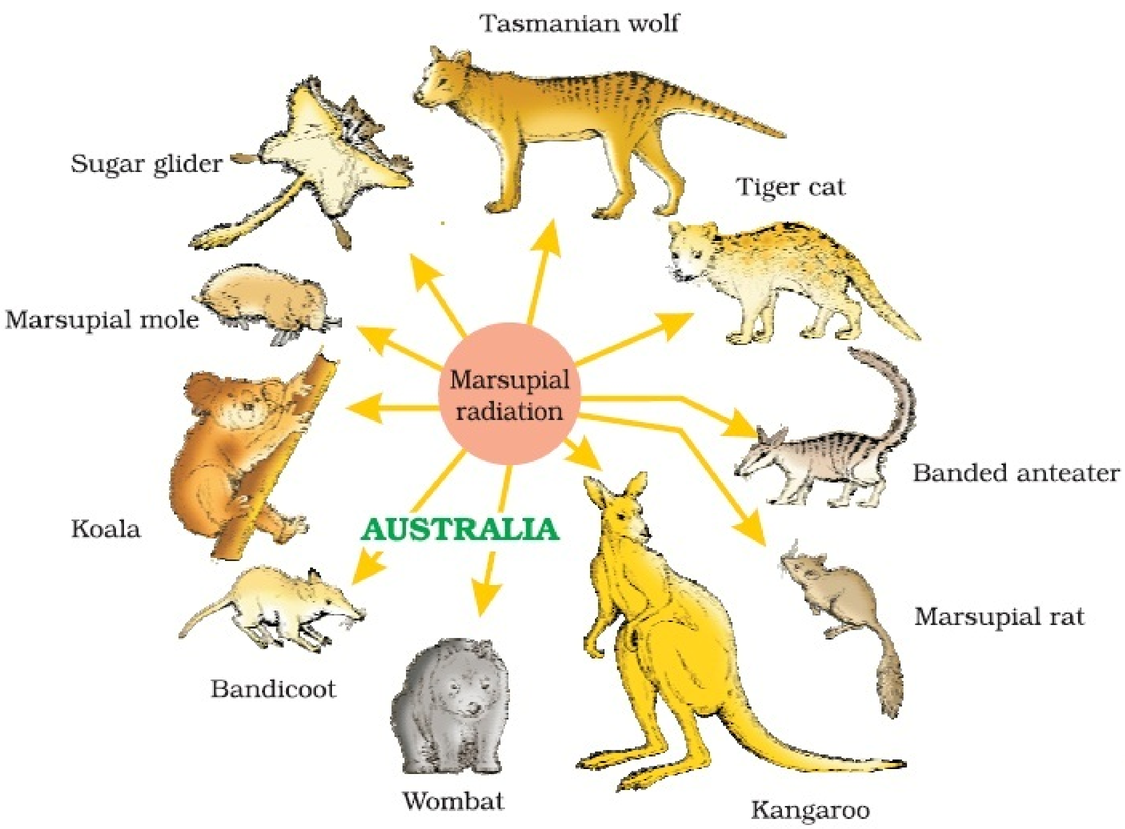
3.1 Divergent Evolution

The evolutionary process which produces new species diverged from a single ancestral form and adapted to new invaded habitats and to modes of life necessary there, is known as adaptive radiation or divergent evolution.

3.1.1 Australian marsupials

Adaptive radiation or divergent evolution is shown Australian marsupial mammals. A number of marsupials, each different from the other evolved from ancestral stock, but all within the Australian island continent. They flourished and evolved along different lines into fossorial, arboreal, semi-aquatic, aquatic and terrestrial forms.

Figure 10: Adaptive radiation in Australian marsupials



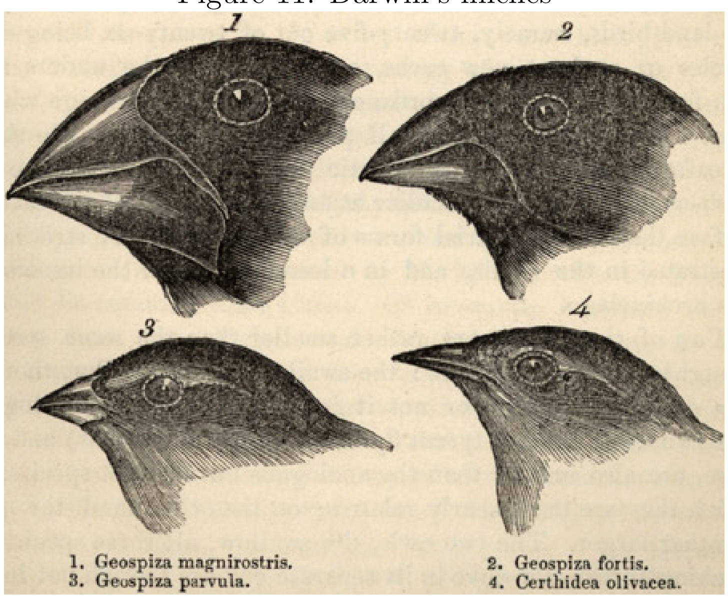
3.1.2 Darwin's finches

Another example of divergent evolution is shown by Darwin's finches in Galapagos island. These finches to avoid competition diverged along different lines from a common ancestral stock. They adapted to new invaded habitats and to modes of life necessary in such habitats by showing variations in bill shape, feather colour etc.

A recent analysis by a team of evolutionary biologists and applied mathematicians indicates that evolution is doing linear algebra when it creates new species, at least for one famous evolutionary feature the beaks of Darwin's finches.

Darwin's works Charles Darwin was intrigued by the variety of finches on his visit to the Galpagos Islands in 1835. He noticed that the birds' beaks seemed fine-tuned to their diet: those with small, pointed beaks tended to feast on insects, for example, while those with stout beaks ate vegetation. The find helped him formulate his theory of evolution by natural selection.

Figure 11: Darwin's finches



A recent mathematical analysis Wondering if there was some sort of mathematical pattern behind the adaptations, a team from Harvard University, analyzed the beak shapes of 13 of Darwin's finches, including six species in the genus *Geospiza* and three in the genus *Camarhynchus*. Using carefully digitized profiles from specimens in Harvard's Museum of Comparative Zoology, the researchers then set out to see to what extent linear transformations the simplest mathematical functions that can act on geometric objects could "collapse" the two-dimensional curves representing the finches' upper beaks onto a common shape.

Mathematically, any two curves are related by some kind of transformation. But linearity imposes severe constraints. In two dimensions, it allows shapes to change only via scaling and shearing. Roughly speaking, a scaling transformation is one that stretches or squeezes two perpendicular axes but keeps them perpendicular, while a shear transformation shoves one axis toward the other, changing the angle between them.

The answer, whatever it turns out to be, likely lies in the details of gene expression. Scientists had already established that two proteins are largely responsible for beak shape in *Geospiza* - *calmodulin* controls length, while *bmp4* affects width and depth. So some kind of correspondence between these beaks is expected.

It may help explain how Darwin's finches and possibly other organisms as well were able to adapt so quickly to their environments. If successful changes in phenotype depend only on two or three parameters instead of thousands it makes it much more feasible that you can get that much change in a relatively short time.

3.2 Convergent Evolution

The development of similar adaptive functional structures in unrelated group of organisms is referred as convergent evolution.

3.2.1 Wings of insects, birds and bats

Insect is an invertebrate, while bird and bat are both vertbrates belonging to class Aves and Mammalia respectively. Wings in these three distantly related animal forms are used for flying in the air but these are very different in basic structure and origin. Each has evolved from separate ancestral population differently but as a means of more efficient mode of locomotion.

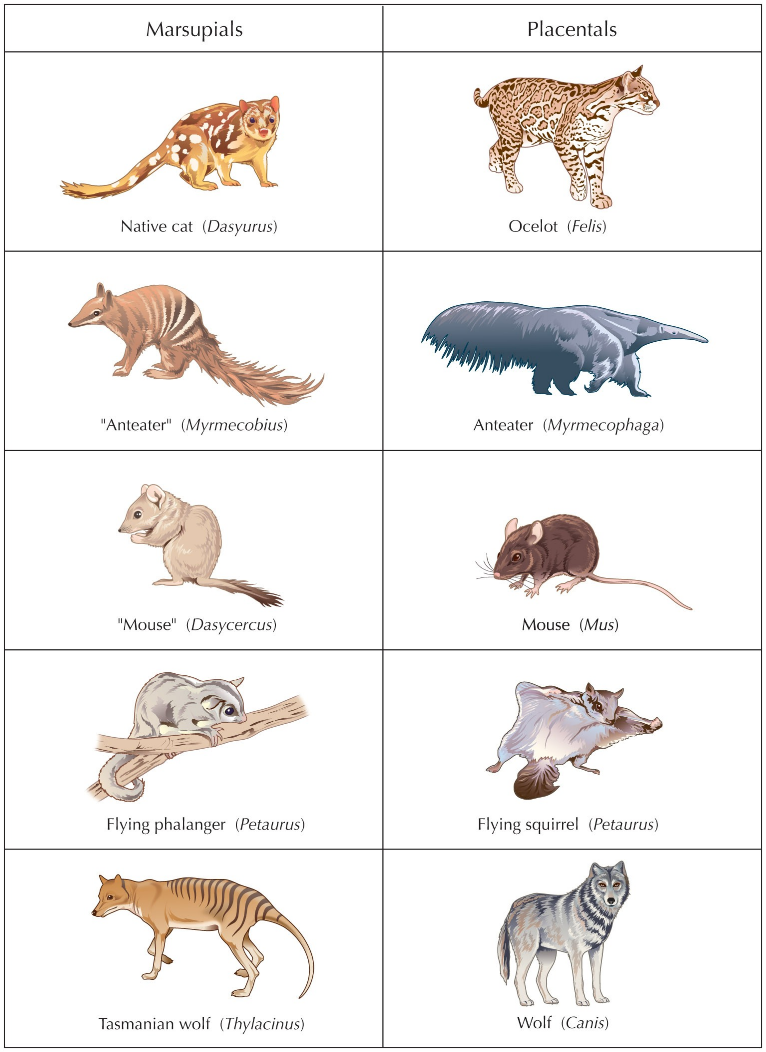
3.2.2 Convergent evolution in placental and marsupial mammals

Convergent evolution is observed in many placental and marsupial mammals. In fact it is parallel evolution that takes place, which is a special case of convergent evolution. Wolf, cat, anteater, flying squirrel, ground hog and house mouse among the placental mammals are paralleled in evolution by marsupial mammals, namely, Tasmanian wolf, native cat, anteater, flying phalanger, wombat and marsupial mouse respectively.

Placental wolf and Tasmanian wolf, for instance, are closely related forms found in similar habitat but in different continents. Placental wolf is found in Asia, while Tasmanian wolf is found in Australia. Thee animals had common ancestry. They reveal independent development of similar structures in two animal groups of common ancestry at their respective habitats.

In evolutionary view modern species occur at sites where they evolved from ancestors which inhabited those regions. It is not that species were individually placed in suitable environment by the creator.

Figure 12: Convergent evolution in placental and marsupial mammals



4 Current Evolution

It is interesting to note that evolution is occurring in nature even now. Rather it is taking place more rapidly than in many of the past ages. Some remarkable instances of evolutionary changes noted within historic times are mentioned as follows.

4.1 Rabbits of Porto Santo

Some rabbits were introduced into Porto Santo, a small island in the Atlantic Ocean in early fifteenth century. The island had no rabbits before this. The rabbits multiplied very rapidly as they were no carnivorous enemies. In 400 years, they became quite different from the ancestral European stock. They were only half as large, developed a different colour pattern and became more nocturnal. More importantly, they failed to breed with the ancestral stock. They were, in fact, a new species of rabbits.

4.2 Viruses and Bacteria

A striking evidence for evolution is the rapid change of certain viruses, bacteria and insects within recent years. These forms evolve within short periods; strains resistant to antibiotics.

4.3 White and Melanised moths of England

Another interesting observation supporting evolution by natural selection comes from England. In a collection of moths made in 1850s, i.e., before industrialization set in, it was observe that there were more white-winged moths on trees than dark-winged or melanised moths. However, in the collection carried out from the same area, but after industrialization, i.e., in 1920, there were more dark-winged moths in the same area, i.e., the proportion was reversed.

The explanation put forth for this observation was that predators will spot a moth against a contrasting background. During post-industrialization period, the tree trunks became dark due to industrial smoke and soots. Under this condition the white-winged moth did not survive due to predators, dark-winged or melanised moth survived. Before industrialization set in, thick growth of almost white-coloured lichen covered the trees in that background the white winged moth survived but the dark-coloured moth were picked out by predators. Lichens can be used as industrial pollution indicators. They will not grow in areas that are polluted. Hence, moths that were able to camouflage themselves, i.e., hide in the background, survived. This understanding is supported by the fact that in areas where industrialization did not occur e.g., in rural areas, the count of melanic moths was low. This showed that in a mixed population, those that can better-adapt, survive and increase in population size. However, no variant is completely wiped out.

Figure 13:

5 Conclusions

Thus, having deeply examined some of the evidences for evolution. we have understood a few processes by which evolution takes place. Nature's decisions and mechanisms are indeed bizarre; some seeming to have a chemical basis as seen under embryological evidences and others, a mathematical basis as seen under Darwin's finches. The idea of evolution is a biologist's deep theoretical interest to retell the story of *living organization* in a chronological manner based on solid evidences and strong arguments rather than on unsubstantiated ideas. This divine childlike curiosity makes evolution a subject worth learning and teaching.

6 Acknowledgments

I would like to thank my biology teachers, Mrs. Jasmin Nisha, Mr. Swaminathan, Mrs. Uma Maheswari and Mrs. Selvathangam for introducing the vast subject of Evolution to me. I am especially grateful to Mrs. Uma Maheswari who proof-read the entire paper. I thank the management of The Hindu Colony Chellammal Vidyalaya Senior Secondary School, the senior principal Dr. S Sekar and the principal Mrs. Ganga Prabhu.