[TOPIC 1] The Origin of Life and Evidences of Evolution

SBG STUDY

The study of history of lifeforms on earth is called **evolutionary biology**.

Evolution is a process that results in heritable changes in population spread over many generations leading to diversity of organisms on earth. In simple words, evolution is the study of life process with the time.

1.1 Origin of Life

It is considered a unique event in the history of our universe.

The Universe

(*i*) It is very old-almost **20 billion** years ago. It contains huge galaxies.

(*ii*) **Galaxies** contain stars and clouds of gas and dust.

(*iii*) The origin of universe is explained by **Big Bang theory.**

(*iv*) The **Big Bang theory** states that a huge explosion occurred, the universe expanded, temperature came down and hydrogen and helium were formed later. The galaxies were then formed due to condensation of gases under gravitation.

The Earth

It was supposed to have been formed about 4.5 billion years back in the solar system of the milkyway galaxy.

(*i*) Water vapour, methane, carbon dioxide and ammonia released from molten masses covered the surface.

(*ii*) UV rays from the sun broke up water molecule into hydrogen and oxygen and lighter hydrogen escaped.

(*iii*) Oxygen combined with ammonia and methane to form water, carbon dioxide and others.

(*iv*) Ozone layer formed, as it cooled, the water vapour fell as rain to fill depression and form oceans.

(*v*) Life appeared 500 million (about 4 billion years back) years after the formation of earth.

Theories of Origin of Life

Various theories of origin of life were given by different thinkers and scientists.

(*i*) Theory of **special creation** states that God created life by his divine act of creation. It was given by father **Suarez**.

(*ii*) Theory of **panspermia/cosmozoic** given by early Greek thinkers states that the spores or panspermia came from outer space and developed into living forms. It was given by **Arshenius**.

(*iii*) Theory of **spontaneous generation** states that life originated from decaying and rotting matter like straw, mud, etc. This theory is also known as **theory of abiogenesis or autobiogenesis**.

(a) **Louis Pasteur** rejected the theory of spontaneous generation and demonstrated that life came from pre-existing life.

(b) In his experiment, he kept killed yeast cells in presterilised flask and another flask open into air. The life did not evolved in the former but new living organisms evolved in the second flask.

(*iv*) Theory of **chemical evolution** or **Oparin-Haldane theory** states that life originated from pre-existing non-living organic molecules and that formation of life was preceded by chemical evolution.

The conditions on the earth that favoured chemical evolution were very high temperature, volcanic storms and reducing atmosphere that contained CH_4, NH_3, water vapour, etc.

Experimental Evidence of Chemical Evolution

Miller's experiment provided experimental evidence for chemical evolution.

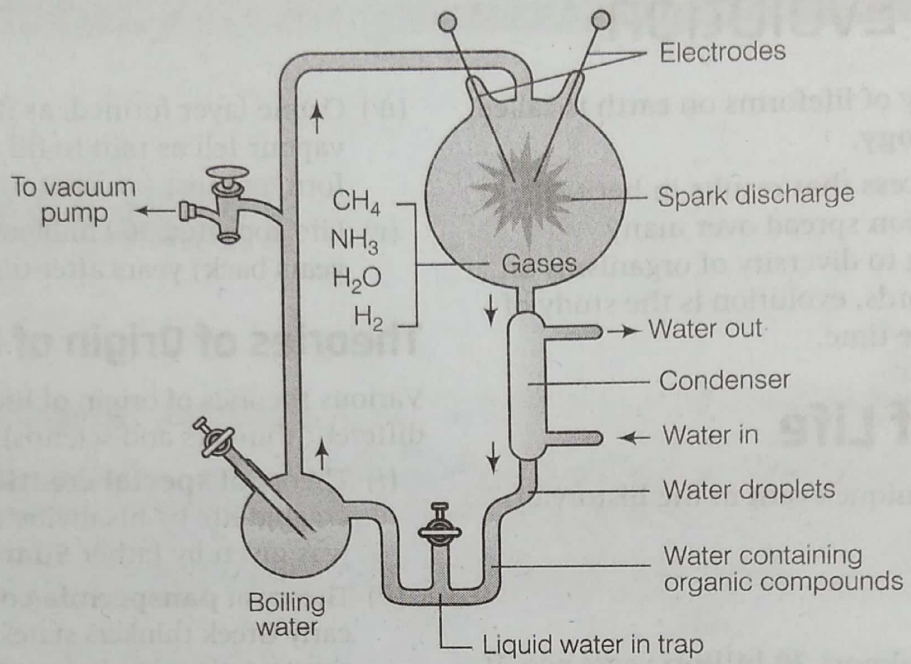


Figure 7.1 Diagrammatic representation of Miller-Urey experiment

(*i*) The experiment was carried out by **SL Miller** and **HC Urey** in 1953.

(*ii*) They took a closed flask containing CH_4, H_2, NH_3 in the ratio of 2:2:1 and water vapour at 800°C and created electric discharge. These conditions were similar to those in primitive atmosphere.

(*iii*) After a week, formation of amino acids were observed. Complex molecules like sugars, nitrogen bases, pigments and fats were seen in the flask by other scientist.

(*iv*) Analysis of the meteorite also revealed the presence of similar compounds.

(*v*) Chemical evolution of life was more or less accepted.

1.2 Origin of First Cell

(*i*) First non-cellular lifeforms originated three million years ago. These molecules were like RNA, protein and polysaccharides.

(*ii*) Cellular lifeform first evolved about 2000 million years ago. These were single-celled formed in aquatic environment.

(*iii*) This form of **abiogenesis**, i.e. the first form of life arose slowly through evolutionary forces from non-living molecules. It is accepted by many scientists.

In summary, it can be said that

The atomic stage → Molecular stage → Early organic compound → Simple organic compound → Complex organic compound → Protocell → Prokaryotic cell → Eukaryotic cell

Evidences of Evolution

Evidences that suggest the evolution has occurred on earth are derived from

(*i*) Palaeontology

(*ii*) Comparative anatomy and morphology

(*iii*) Biochemical/Physiology

(*iv*) Biogeography

(*v*) Embryology

Palaeontology

(*i*) It is the study of fossils. The fossils are the remains of past organisms preserved in sedimentary rocks.

(*ii*) Rocks form sediments and a cross-section of earth's crust indicates the arrangement of sediments one over the other during the long history of earth.

(*iii*) Different aged rock sediments contain fossils of different lifeforms, who died during the formation of particular sediment. Fossils which were present in a specific area explain presence of that organism in that area only.

(*iv*) Some organisms appear similar to modern organisms. They represent extinct organisms like dinosaurs.

(*v*) A study of fossils in different sedimentary layers indicates the geological period in which they existed. Fossils which are obtained from old rocks are of simple type, while which were obtained from new rocks are of complex type.

(*vi*) The study showed that lifeforms varied over time and certain lifeforms are restricted to certain geological time scale. Hence, new forms of life have evolved at different times in the history of earth.

Comparative Anatomy and Morphological Evidences

These studies highlight the similarities and differences among the organisms of today and those that existed years ago. The evidences come from comparative study of external and internal structure.

Homology

(*i*) In an organisms, the homology indicates common ancestry.

(*ii*) The organs with same structural design and origin but different functions are called **homologous organs.** Examples are:

Forelimbs of some animals like whales, bats and cheetah have similar anatomical structure, such as humerus, radius, ulna, carpals, metacarpals and phalanges.

(*iii*) Other examples of homology are vertebrate hearts or brains. In plants also, thorns and tendrils of *Bougainvillea* and *Cucurbita* represent homology.

(*iv*) Homology is based on divergent evolution. The same structure developed along different directions due to adaptations to different needs. The condition is called **divergent evolution**.

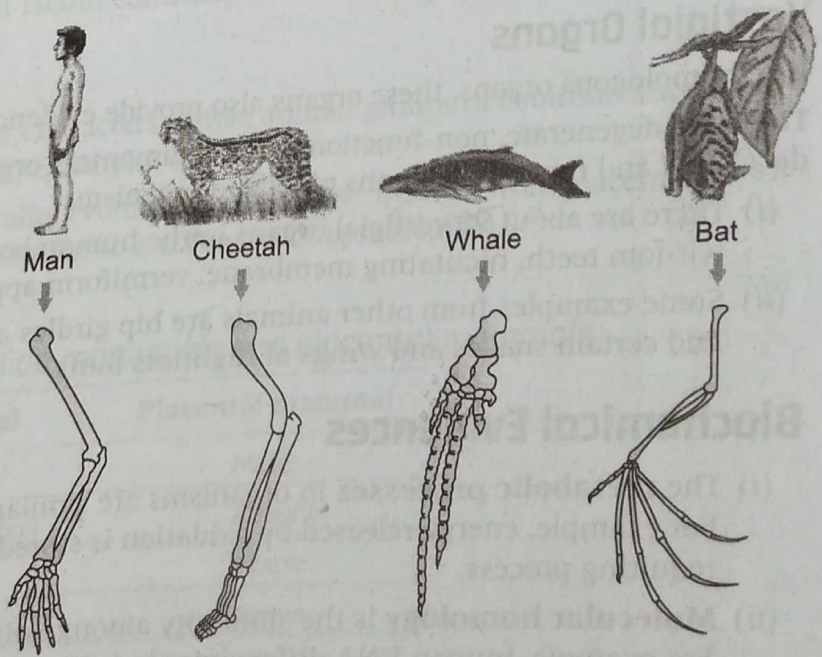


Figure 7.2 Homologous organs in animals (forelimb)

Analogy

(*i*) It refers to a situation exactly opposite to homology.

(*ii*) Organs which are anatomically different but functionally similar are called **analogous organs.** For example, wings of butterfly and birds. In both, wings perform same function but they have different origin and structure.

(*iii*) Analogous organs are a result of **convergent evolution**. It is the evolution in which different structures evolve for same function and hence, have similarity. It can be said that above organisms had different structures but they came in the same environment and evolved to perform same function.

(*iv*) Other examples of analogy are eyes of *Octopus* and mammals; flippers of penguins and dolphins. In plants, sweet potato (root modification) and potato (stem modification).

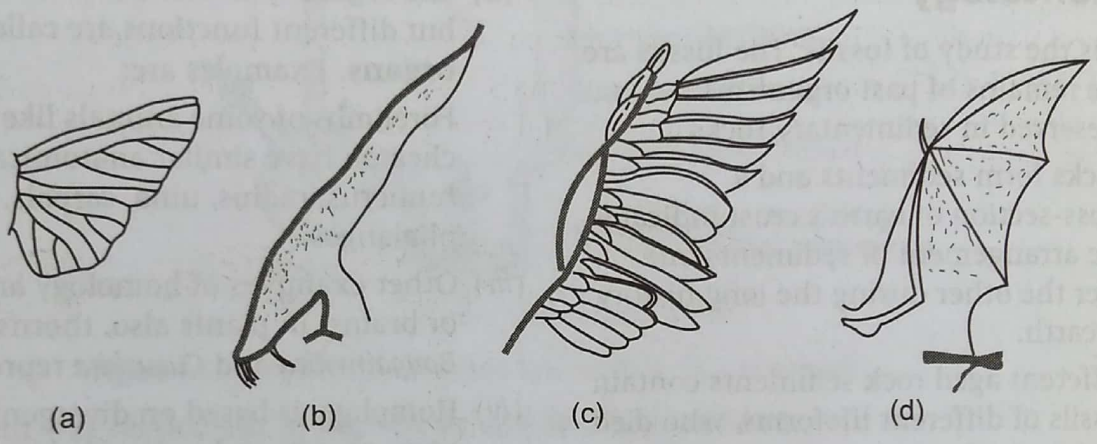


Figure 7.3 Analogous organs (a) Wing of insect (b) Wing of *Pterodactyl* (c) Wing of bird (d) Wing of bat

Vestigial Organs

Like homologous organs, these organs also provide evidences for organic evolution.

These are degenerate, non-functional and rudimentary organs to the possessor, while correspond to fully developed and functional organs of related organisms.

(*i*) There are about 90 vestigial organs in the human body. Some of them are tail bone (coccyx), wisdom teeth, nictitating membrane, vermiform appendix, etc.

(*ii*) Some examples from other animals are hip girdles and bones of the hindlimbs in some whales and certain snakes and wings of flightless birds.

Biochemical Evidences

(*i*) The **metabolic processes** in organisms are similar with some new materials and end products. For example, energy released by oxidation is stored in ATP, which then powers the energy requiring process.

(*ii*) **Molecular homology** is the similarity among animals at the molecular level. For example, human DNA differs in only 1.8% of its base pairs from chimpanzee's DNA and there is no difference between the two in the amino acid sequence for the protein cytochrome-*c*.

(*iii*) In the same way, enzymes perform same function in different organisms. So, it indicates common ancestory among organisms.

Biogeographical Evidences

The species restricted to a region develop unique features. Also, species present in far separated regions show similarity of ancestory.

This can be explained with the help of following processes:

Adaptive Radiation

It is an evolutionary process in which an ancestral stock gives rise to new species adapted to new habitats and new ways of life. In other words, when evolution of organisms starts from a point and then spreads in other habitats then it is known as **adaptive radiation**. Examples are:

(*i*) **Darwin's finches** These were small black birds, which Darwin observed in **Galapagos Island**.

(a) He observed many varieties of finches in the same Island.

(b) All varieties of finches had evolved from original seed-eating finches.

(c) There was alternation in beaks enabling some to become insectivorous and some vegetarian. All these varieties evolved from original species due to different type of food available at different Island.

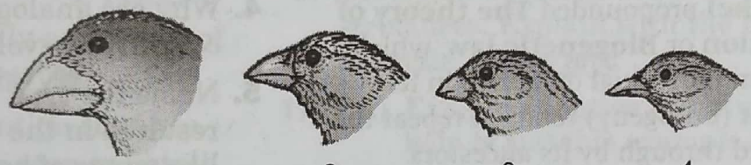


Figure 7.4 Varieties of beaks of finches that Darwin found in Galapagos Island

(*ii*) **Marsupials of Australia** A number of marsupials, different from each other evolved from an ancestral stock, all within the Australian Island continent.

Parallel Evolution

It refers to independent development of similar characters in two animal groups of common ancestry living in similar habitats of different continents. Examples are:

Marsupial mammals in Australia show parallel evolution as they have evolved from placental mammals. All these closely resemble and look similar to a corresponding marsupial.

Few examples are mentioned in the table.

Parallel evolution of Australian marsupials and placental mammals

Australian marsupial	Placental mammal
Marsupial mole	Mole
Numbat (banded anteater)	Anteater
Marsupial mouse	Mouse
Spotted *Cuscus*	Lemur
Flying phalanger (sugar glider)	Flying squirrel
Tasmanian tiger cat	Bobcat
Tasmanian wolf	Wolf

Convergent Evolution

It is the development of similar adaptive functional structures in unrelated groups of organisms. Examples are:

(*i*) Wings of insect, bird and bat.

(*ii*) Spiny anteater and scaly anteater belong to different orders of class–Mammalia. They have acquired similar adaptations for food, e.g. leg ants, termites and insects.

Embryological Evidences

The study of comparative embryology shows common patterns of development.

(*i*) The principles of embryonic development were given by **Von Baer**.

(*ii*) **Ernst Haeckel** propounded **The theory of recapitulation** or **Biogenetic law**, which states that an individual organism in its development (ontogeny) tends to repeat the stages passed through by its ancestors (phylogeny), i.e. ontogeny recapitulates phylogeny.

(*iii*) This means that the life history of an animal reflects its evolutionary history.

For example, during the life history, frog's tadpole larva resembles fishes, the ancestors of amphibia.

The presence of gill clefts in all vertebrate embryos including human provides a strong evidence in support of organic evolution.

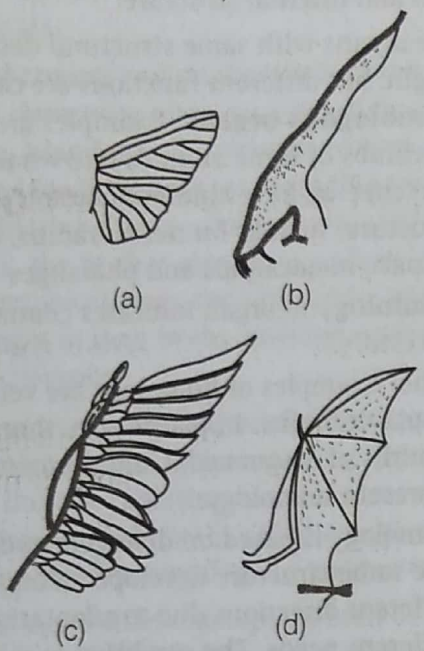
Anthropogenic Evidences

Excess use of herbicides, pesticides, etc., has resulted in selection of resistant varieties in a lesser time scale. This is also true for microbes against which antibiotics or drugs have been used. All these evidences tell us that 'Evolution is a stochastic process based on chance events in nature and chance mutation in the organisms'.

Artificial Selection

Human has created many varieties of plants and many breeds of animals for his use. So, if human can create new species why not nature.

(d) Other examples of analogy are eyes of *Octopus* and mammals; flippers of penguins and dolphins. In plants, sweet potato (root modification) and potato (stem modification).



Analogous organs (a) Wing of insect (b) Wing of *Pterodactyl* (c) Wing of bird (d) Wing of bat

(3)

41. (i) The fossils are the remains of past organisms preserved in sedimentary rocks. **Palaeontology** is the study of fossils.

(a) Rocks form sediments and a cross-section of earth's crust indicates the arrangement of sediments one over the other during the long history of earth.

(b) Different aged rock sediments contain fossils of different lifeforms, who died during the formation of the particular sediment. Fossils which were present in a specific area explain presence of that organism in that area only.

(c) Some organisms appear similar to modern organisms. They represent extinct organisms like dinosaurs.

(d) A study of fossils in different sedimentary layers indicates the geological period in which they existed. Fossils which are obtained from old rocks are of simple type, while which were obtained from new rocks are of complex type.

(e) The study showed that lifeforms varied over time and certain lifeforms are restricted to certain geological time scale. Hence, new forms of life have evolved at different times in the history of earth.

Thus, palaeontology evidence helps in detailed study of progress of evolution from old to new forms. **(2½)**

(ii) Refer to Answer No. 35. **(2½)**

[TOPIC 2] Biological Evolution, Its Mechanism and Evolution of Man

The important theories related to biological evolution are:

(*i*) Lamarckism or Lamarck's theory of evolution.

(*ii*) Darwinian theory of evolution.

(*iii*) Mutation theory of evolution.

2.1 Lamarck's Theory of Evolution

The Lamarck's theory states that lifeforms occurred due to the use and disuse of organs.

Example, Giraffes in beginning did not have long necks. Gradually, their necks became longer to access leaves from taller trees. This acquired character passed on to further generations and finally giraffes acquired long necks. This is called **'inheritance of acquired characters'**.

(*i*) Lamarck explained this theory in his book *Philosphie Zoologique*.

(*ii*) **August Weismann** offered the greatest opposition to the inheritance of acquired characters and put forward his theory of **'continuity of germplasm'** in 1892. He said, those variations which arise in germplasm, inherit in the next generation.

2.2 Darwin's Theory of Evolution

It is explained by Charles Robert Darwin in his book, *'On the Origin of Species by means of Natural Selection'*. It is based on his observations during a sea voyage around the world in ship **HMS Beagle**. The two key concepts of Darwinism are **branching descent** (adaptive radiation) and **natural selection.**

According to this theory:

(*i*) There has been gradual evolution of life forms with new forms arising at different periods of history.

(*ii*) Population of all organisms have variations in characteristics, which make them adapt better to environment. Means individuals of a population are never same.

(*iii*) Some of these characteristics enable individuals to survive better in natural conditions and reproduce. This is called **survival of the fittest.**

(*iv*) The organisms which adapt well in the environment will be selected by nature and will survive more in nature. This is called **natural selection.** It means that individual has more chances to reproduce.

(*v*) Adaptability is inherited and fitness is the end result of ability to adapt and get selected by nature.

(*vi*) Natural selection is based on following facts:

(a) Limited natural resources. So, there is struggle for existence, which can be of intraspecific, interspecific or environmental struggle.

(b) Varying characteristics in the members of a population.

(c) Variations are generally inherited.

(d) Population size is stable except seasonal fluctuation.

(*vii*) **Alfred Russel Wallace** also got the same results about natural selection and informed Darwin about his results by writing paper.

(*viii*) Darwin's natural selection and survival of the fittest theory was based on sexual selection only.

(*ix*) At last, he said natural selection leads to formation of a new species.

Examples of Natural Selection

Industrial Melanism

There are two varieties of moth, white-winged and dark-winged.

(*i*) Before industrial revolution in England, white-winged moths were more in number than dark-winged moths. Because there was less pollution, which leads to light trunk of trees due to lichen. So, on light background white-winged moth were not visible, while dark-wing moth could be eaten by predators very easily.

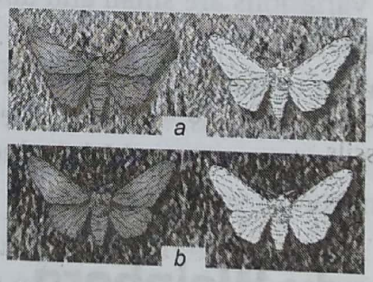


Figure 7.5 showing white-winged moth and dark-winged moth (melanised) on a tree trunk (a) In unpolluted area (b) In polluted area

(*ii*) After industrialisation, dark-winged moths became more than white-winged moths.

(*iii*) This is because during industrialisation, tree trunks covered by white lichens became dark due to air pollution (dust and soot particles). So, now white-winged moth could be detected easily.

(*iv*) Due to this, white-winged moths could be easily eaten up by the predators as they fail to camouflage.

(*v*) So, nature selected only those moths which were better suited. But none of them were eradicated completely.

Chemical resistance

(*i*) The excess use of herbicides and pesticides leads to resistant varieties of microbes in very less time.

(*ii*) Due to this, pathogenic bacteria appeared in very short period.

2.3 Mutation Theory of Evolution

The mutation theory was put forth by **Hugo de Vries** based on his work on evening primrose.

(*i*) It states that evolution occurs by sudden large differences in the population, i.e. mutation and not by minor changes as Darwin stated.

(*ii*) The mutation caused speciation and de Vries called it **saltation** or **single step large mutation.**

(*iii*) Mutations are random and directionless, while variations are small and directional as per Darwin.

(*iv*) According to Darwin, evolution is slow and continuous process, while de Vries said it is a single-step process, which is due to discontinuous variations.

2.4 Hardy-Weinberg Principle

This principle states that allele frequencies in a population are stable and is constant from generation to generation. If population is large and there is random mating among members of the population, i.e. gene pool is constant. This is called **genetic equilibrium** or **Hardy-Weinberg equilibrium**.

(*i*) It can be expressed by following equation:

$$p^2 + 2pq + q^2 = 1$$

where, p and q are frequencies of different alleles.

(*ii*) Any fluctuation in genetic equilibrium leads to evolution.

Factors Affecting Hardy-Weinberg Equilibrium

Gene Migration or Gene Flow

Due to migration, new genes or alleles are added to the new population and these are lost from the old population, in turn, changing the frequencies. There would be a gene flow if this gene migration happens multiple times. So, gene flow change the frequency of allele.

Genetic Drift

The changes occurring in frequencies by chance is called **genetic drift.** Sometimes due to changes in allele frequency in new population, some different species are formed. This is called **founder effect** and the original drifted population is called **founder.**

Mutations

These occur randomly and at very slow rates. They lead to new phenotypes and due to considerable genetic variation, speciation occurs.

Genetic Recombination

During gametogenesis, crossing over in meiosis leads to new combination of genes.

Natural Selection

It occurs due to the inheritance of variations, which leads to survival of the fittest.

So, if above five factors are absent in a population it means there is no evolution going on in that population. It has following effects:

(*i*) **Stabilisation** Larger number of individuals acquire mean character value.

(*ii*) **Directional change** Large number of individuals acquire value other than mean character value. Means natural selection is taking place in one direction.

(*iii*) **Disruption** More individuals acquire peripheral character value at both ends of the distribution curve. Here natural selection is taking place in two different populations.

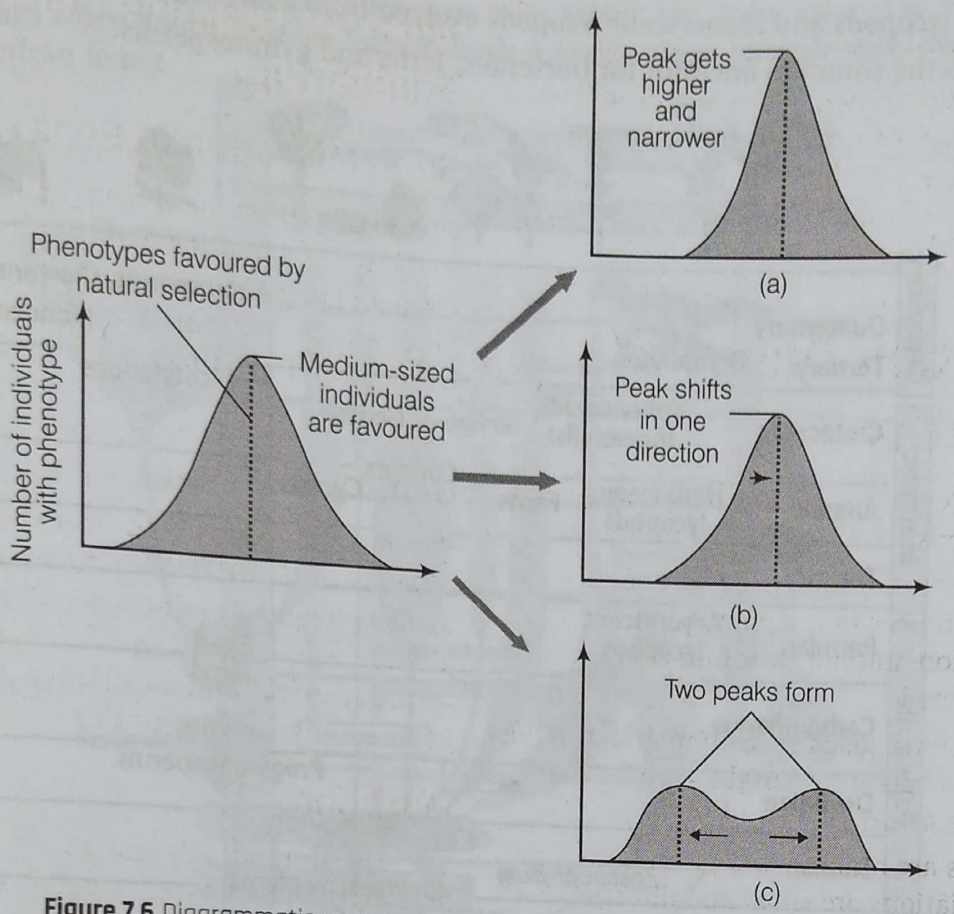


Figure 7.6 Diagrammatic representation of natural selection on different traits (a) Stabilising (b) Directional and (C) Disruptive

2.5 A Brief Account of Evolution

(*i*) About 2000 million years ago (mya), the first cellular form of life appeared on earth.

(*ii*) Some of these cells had the ability to release O_2 by splitting water molecule with the help of solar energy.

(*iii*) Slowly, single-celled organisms became multicellular lifeforms.

Evolution of Plants

Plants evolution occurred before animals.

(*i*) Bryophytes were the first plant to colonise lands and were evolved before the vascular plants like pteridophytes and gymnosperms.

(*ii*) Vascular plants first originated in Silurian period.

(*iii*) Existence of sea weeds and few plants were reported around 320 million years ago (mya).

(*iv*) Herbaceous lycopods and arborescent lycopods evolved from *Zosterophyllum* of Palaeozoic era.

(*v*) *Psilophyton* is the common ancestor for horsetails, ferns and gymnosperms.

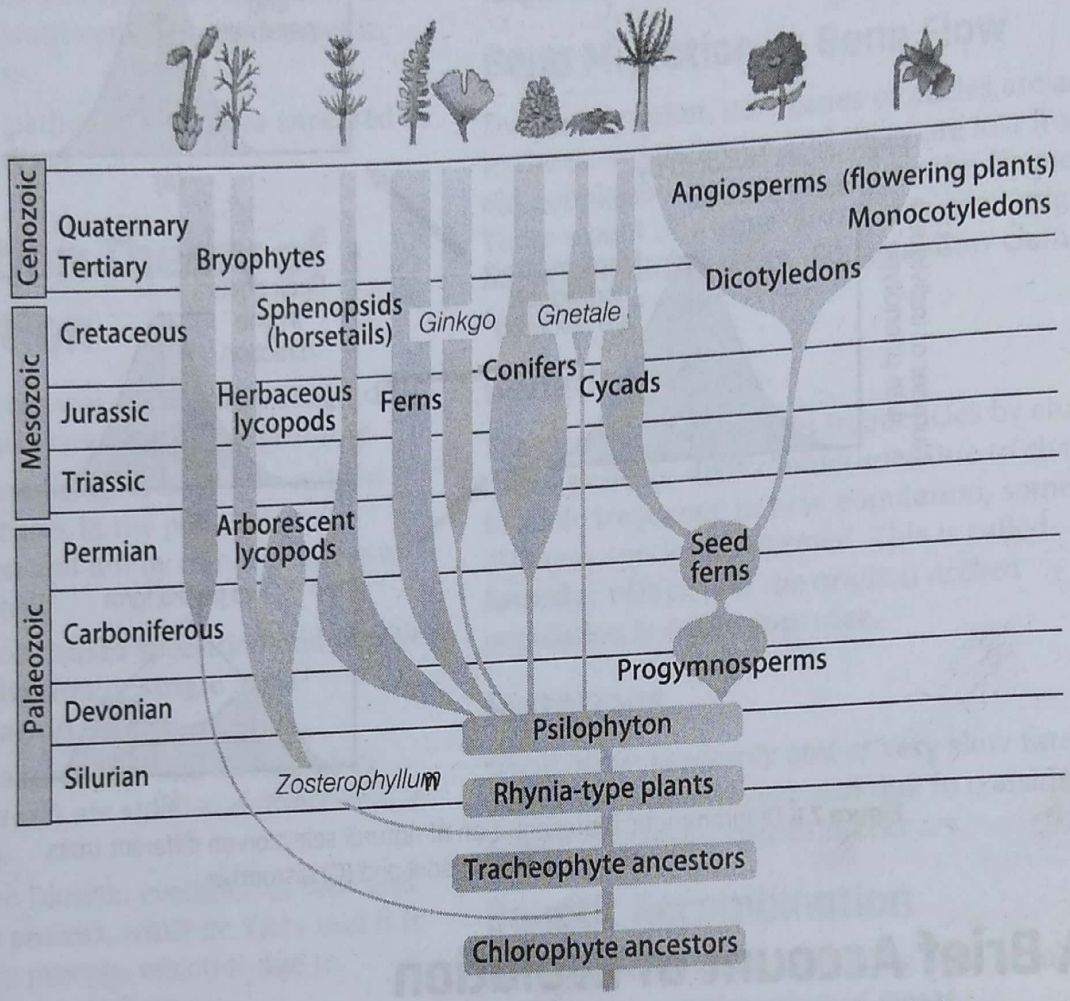


Figure 7.7 Sketch of the evolution of plant forms through geological periods

Evolution of Animals

It occurred around 500 mya.

(*i*) First animals were invertebrates.

(*ii*) Jawless fish and amphibious fish with stout and strong fins originated around 350 mya.

(*iii*) The first amphibians and ancestors of modern day frogs were **lobefins** (*Coelacanth*). It is a living fossil.

(*iv*) Reptiles dominated the earth, around 200 mya.

(*v*) Land reptiles were dinosaurs of which *Tyrannasaurus* (about 20 feet in height) was the biggest. They disappeared around 65 mya.

(*vi*) **In Triassic period**, mammals appeared and the first mammals were like shrews.

(*vii*) **Mammals** were viviparous and protected their unborn young inside the mother's body.

(*viii*) When reptiles came down, mammals took over the earth.

(ix) Before continental drift, horse, hippopotamus, bear, rabbit, etc., were present in South America, but afterward when South America joined North America, these animals were overridden by North American fauna.

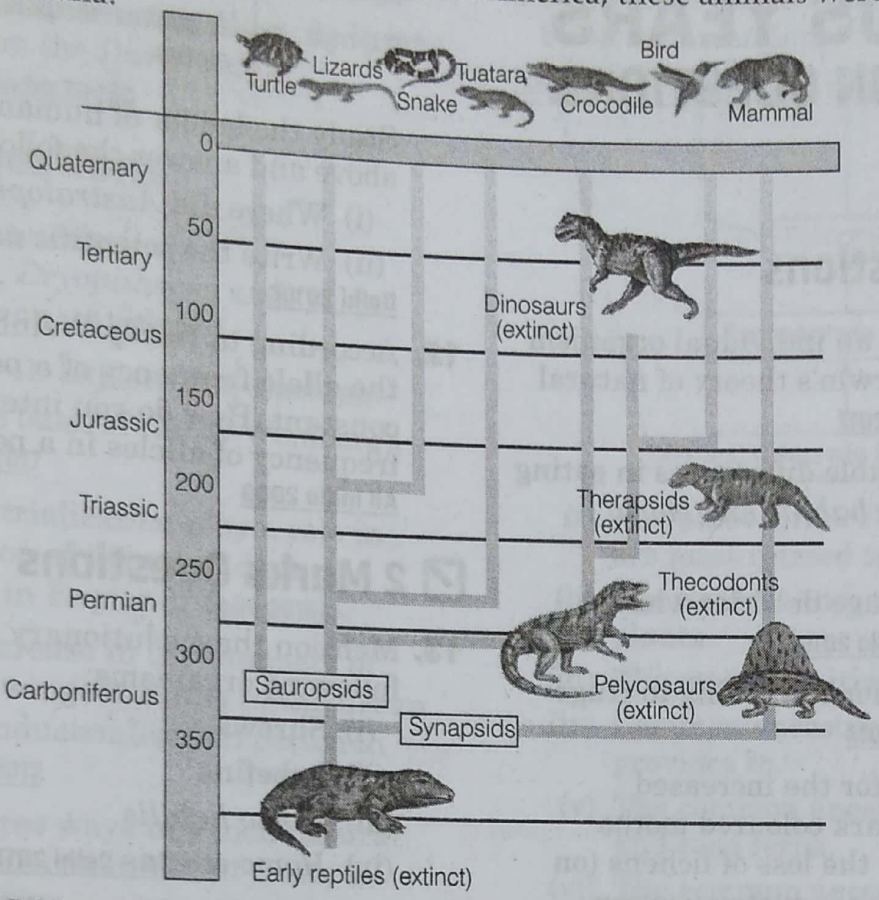


Figure 7.8 Representative evolutionary history of vertebrates through geological periods

Human Evolution

Various stages of human evolution

Human ancestors	Origin period	Characteristics
Dryopithecus	20-25 mya	More ape-like, arms and legs of same length, brain large and ate soft fruits and leaves.
Ramapithecus	14-15 mya	More man-like, walked erect and teeth like modern man.
Australopithecus	3-4 mya	Man-like primates, tall, walked straight, ate fruits, having brain capacity 400-600cc. Fossils found in Tanzania and Ethoipia.
Homo habilis	2 mya	First humans-like being, brain capacity 650-800cc, herbivores and fossils found in East Africa.
Homo erectus (java man)	1.5 mya	Brain capacity 900cc, food was meat. Fossils found in Java.
Homo sapiens neander-thalensis (primitive man)	100000-40000 years ago	Brain size 1400cc, used hides to protect body and body buried after death. Fossils found in East and Central Asia.
Homo sapiens sapiens (modern man)	75000-10000 years ago	Started agriculture, human settlement started, prehistoric cave art developed.

Dryopithecus → *Ramapithecus* → *Australopithecus* → *Homo habilis* → *Homo erectus*

Dryopithecus → Apes

Homo erectus → *Homo neanderthalensis* → Cromagnon man → *Homo sapiens sapiens*