CHAPTER – 7

EVOLUTION

Introduction

Evolution:

Evolutionary Biology is the study of history of life forms on earth. To understand the changes in flora and fauna that have occurred over millions of years on earth, we must have an understanding of the context of origin of life, i.e., evolution of earth, of stars and indeed of the universe itself.

- The origin of life and evolution of life forms or biodiversity on planet earth in the context of evolution of earth and against the background of evolution of universe itself.

Formation of Universe and Big Bang theory

- When we look at stars on a clear night sky we are, in away, looking back in time. What we see today is an object whose emitted light started its journey millions of year back and from trillions of kilometres away and reaching our eyes now.
- However, when we see objects in our immediate surroundings we see them instantly and hence in the present time. Therefore, when we see stars we apparently are peeping into the past.
- The universe is vast. Relatively speaking the earth itself is almost only a speck. The universe is very old – almost 20 billion years old. Huge clusters of galaxies comprise the universe.
- Galaxies contain stars and clouds of gas and dust. Considering the size of universe, earth is indeed a speck.

The Big Bang theory attempts to explain to us the origin of universe. It talks of a singular huge explosion unimaginable in physical terms. The universe expanded and hence, the temperature came down.

- Hydrogen and Helium formed sometime later. The gases condensed under gravitation and formed the galaxies of the present day universe. In the solar system of the Milky Way galaxy, earth was supposed to have been formed about 4.5 billion years back.
- There was no atmosphere on early earth. Water vapour, methane, carbon dioxide and ammonia released from molten mass covered the surface.
- The UV rays from the sun broke up water into Hydrogen and Oxygen and the lighter H_2escaped. Oxygen combined with ammonia and methane to form water,CO_2 and others. The ozone layer was formed. As it cooled, the water vapor fell as rain, to fill all the depressions and form oceans. Life appeared 500million years after the formation of earth, i.e., almost four billion years back.

- A common permissible conclusion is that earth is very old, not thousand of years as was thought earlier but billions of years old.

Views of Greek thinkers and Idea of 'Panspermia'

- Some scientists believe that life came from outside. Early Greek thinkers thought units of life called spores were transferred to different planets including earth. 'Panspermia' is still a favourite idea for some astronomers.

Theory of spontaneous generation

- For a long time it was also believed that life came out of decaying and rotting matter like straw, mud etc. This was the theory of spontaneous generation.
- Louis Pasteur by careful experimentation demonstrated that life comes only from pre-existing life. He showed that in pre-sterilised flasks, life did not come from killed yeast while in another flask open to air, new living organisms arose from 'killed yeast'. Spontaneous generation theory was dismissed once and for all.

Theory of Oparin of Russia and Haldane

- Oparin of Russia and Haldane of England proposed that the first formof life could have come from pre-existing non-living organic molecules(e.g. RNA, protein, etc.) and that formation of life was preceded by chemicalevolution, i.e., formation of diverse organic molecules from inorganicconstituents.
- The conditions on earth were – high temperature, volcanicstorms, reducing atmosphere containing CH4, NH3, etc.

Chemical evolutionandS.L. Miller's Experiment

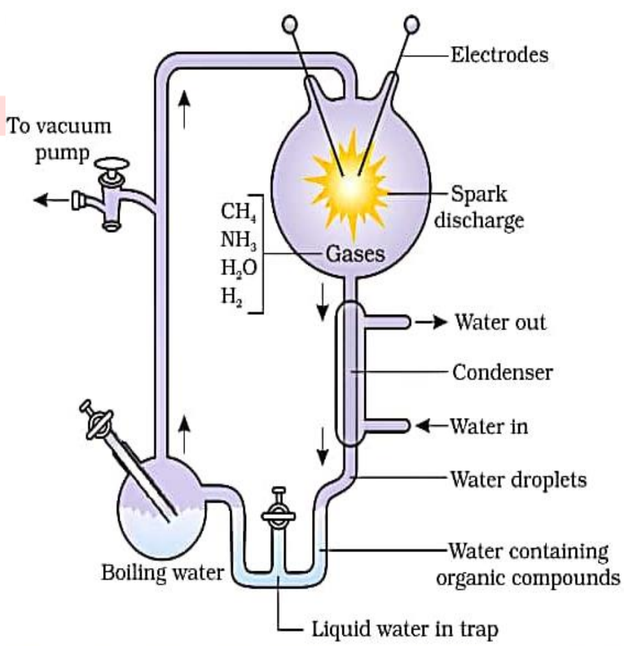


Figure 7.1 Diagrammatic representation of Miller's experiment

- An American scientist created similar conditions in a laboratory scale. He created electric discharge in a closed flask containingCH_4, H_2, NH_3 and water vapour at 8000C.
- He observed formation of aminoacids.
- In similar experiments others observed, formation of **sugars, nitrogen bases, pigment and fats**.
- Analysis of meteorite content also revealed similar compounds indicating that similar processes are occurring elsewhere in space. With this limited evidence, the first part of the conjectured story, i.e., chemical evolution was more or less accepted.

Evolution of life forms: three connotations

- Conventional religious literature tells us about the theory of special creation.
- This theory has three connotations.
- One, that all living organisms(species or types) that we see today were created as such.
- Two, that the diversity was always the same since creation and will be the same in future also.
- Three, that earth is about 4000 years old.
- All these ideas were strongly challenged during the nineteenth century. Based on observations made during a sea voyage in a sail ship called H.M.S. Beagle round the world, Charles Darwin concluded that existing living forms share similarities to varying degrees not only among themselves but also with life forms that existed millions of years ago.
- Many such life forms do not exist anymore. There had been extinctions of different life forms in the years gone by just as new forms of life arose at different periods of history of earth.
- There has been gradual evolution of life forms. Any population has built in variation in characteristics. Those characteristics which enable some to survive better in natural conditions (climate, food, physical factors ,etc.) would outbreed others that are less-endowed to survive under such natural conditions.
- Another word used is fitness of the individual or population. The fitness, according to Darwin, refers ultimately and only to reproductive fitness.
- Hence, those who are better fit in an environment , leave more progeny than others. These, therefore, will survive more and hence are selected by nature.
- He called it natural selection and implied it as a mechanism of evolution.

Work of Alfred Wallace

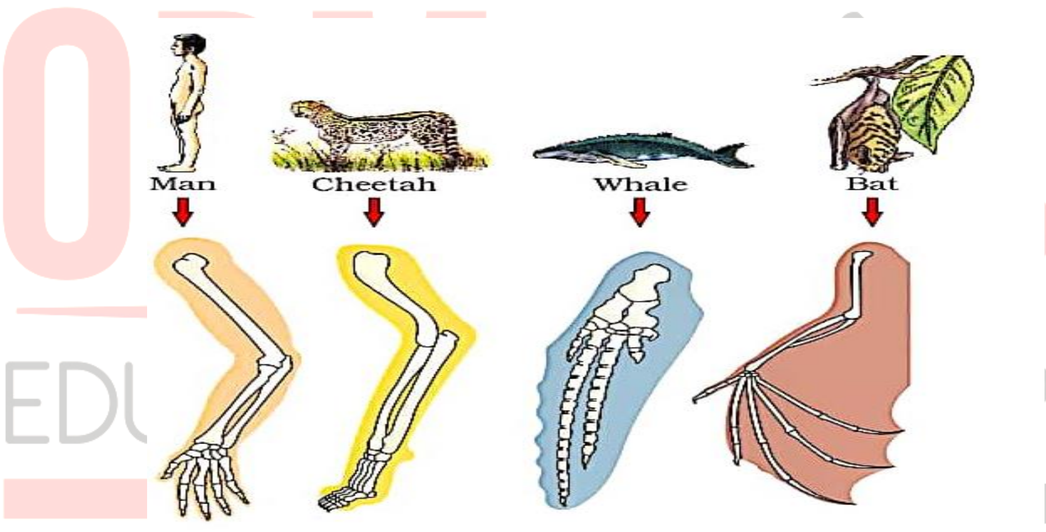
- Alfred Wallace, a naturalist who worked in Malay Archipelago had also come to similar conclusions around the same time. In due course of time, apparently new types of organisms are recognizable.

Evidence of evolution:

Paleontology

- Fossils are remains of hard parts of life-forms found in rocks. 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.
- Different-aged rock sediments contain fossils of different life-forms who probably died during the formation of the particular sediment. Some of them appear similar to modern organisms. They represent extinct organisms (e.g., Dinosaurs).(Figure 7.2).
- A study of fossils in different sedimentary layers indicates the geological period in which they existed. The study showed that life-forms varied over time and certain life forms are restricted to certain geological time spans. Hence, new forms of life have arisen at different times in the history of earth. All this is called paleontological evidence.

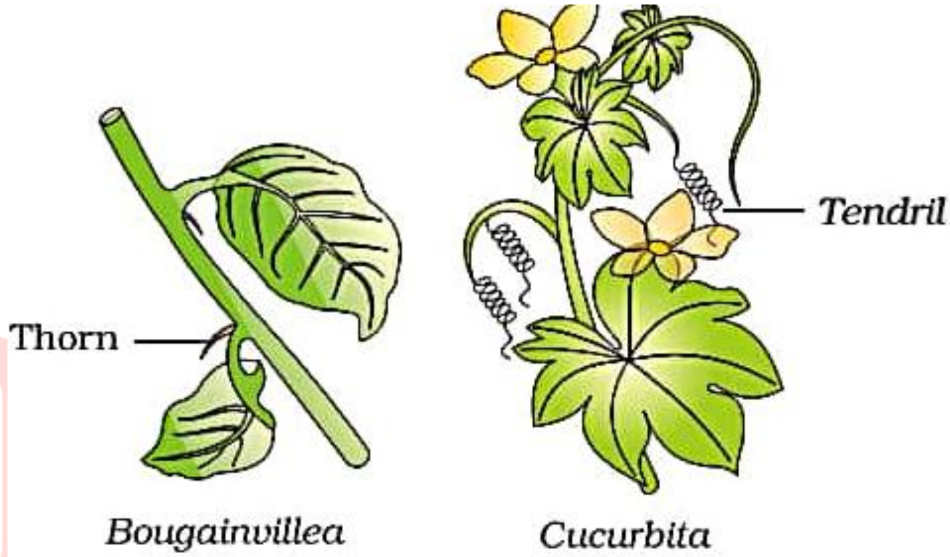
Homologous structure and divergent evolution



(b)

- Comparative anatomy and morphology shows similarities and differences among organisms of today and those that existed years ago. Such similarities can be interpreted to understand whether common ancestors were shared or not.
- For example whales, bats, Cheetah and human (all mammals) share similarities in the pattern of bones of forelimbs.
- Though these forelimbs perform different functions in these animals, they have similar anatomical structure – all of them have humerus, radius, ulna, carpals, metacarpals and phalanges in their forelimbs.
- Hence, in these animals, the same structure developed along different directions due to adaptations to different needs.
- Other examples are vertebrate hearts or brains.

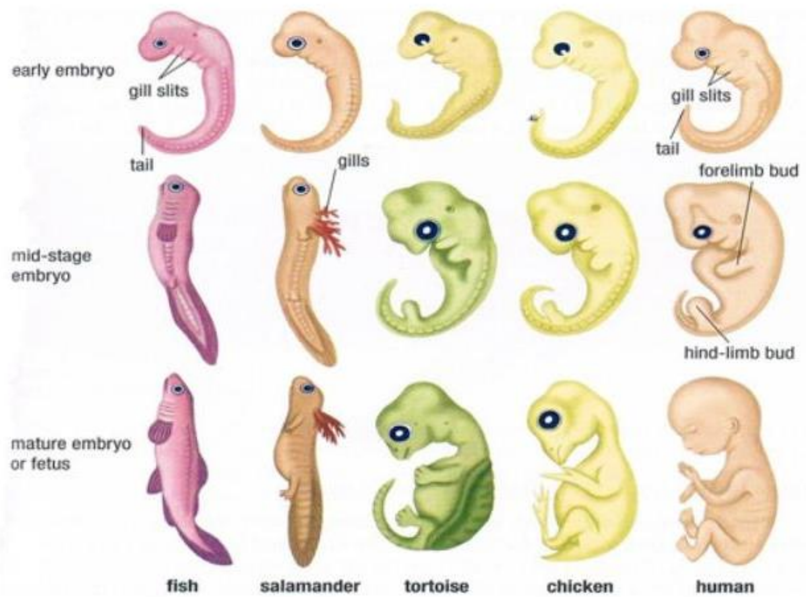
- This is **divergent evolution** and these structures are homologous. **Homology indicates common ancestry**.
- Similarities in proteins and genes performing a given function among diverse organisms give clues to common ancestry. These biochemical similarities point to the same shared ancestry as structural similarities among diverse organisms.
- In plants also, the thorn and tendrils of Bougainvillea and Cucurbita represent homology.



- Homology is based on divergent evolution where as analogy refers to a situation exactly opposite.
- Wings of butterfly and of birds look alike. They are not anatomically similar structures though they perform similar functions. Hence, **analogous structures are a result of convergent evolution** - different structures evolving for the same function and hence having similarity.
- Other examples of analogy are the eye of the octopus and of mammals or the flippers of Penguins and Dolphins .One can say that it is the similar habitat that has resulted in selection of similar adaptive features in different groups of organisms but toward the same function: Sweet potato (root modification) and potato (stem modification) is another example for analogy.

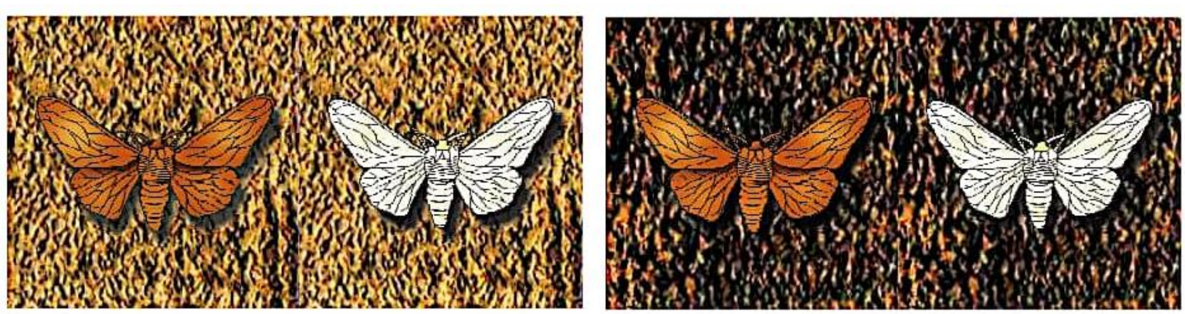
Evidence of evolution:

Embryology



- Embryological support for evolution was also proposed by Ernst Heckel based upon the observation of certain features during embryonic stage common to all vertebrates that are absent in adult.
- The embryos of all vertebrates including human develop a row of vestigial gill slit just behind the head but it is a functional organ only in fish and not found in any other adult vertebrates.
- Karl Ernst von Baer noted that embryos never pass through the adult stages of other animals.

Natural selection



(a) (b)

Figure 7.4 Figure showing white - winged moth and dark - winged moth (melanised) on a tree trunk (a) In unpolluted area (b) In polluted area

- **Industrial Melansim of peppered moth (*Biston betularia)***
- An interesting observation supporting evolution by natural selection comes from England. In a collection of moths made in 1850s,i.e., before industrialisation set in, it was observed that there were more white-winged moths on trees than dark-winged or melanised moths.
- The explanation put forth for this observation was that 'predators will spot a moth against a contrasting background'.
- Before industrialisation 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 doesn't 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 industrialisation did not occur e.g., in rural areas, the count of melanin moths was low.
- However, in the collection carried out from the same area, but after industrialisation, i.e., in 1920, there were more dark-winged moths in the same area.
- During post industrialisation 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.
- This showed that in a mixed population, those that can better-adapt, survive and increase in population size. Remember that no variant is completely wiped out.

Anthropogenic action on bacteria

- We employ antibiotics or drugs against eukaryotic organisms/cell. Hence, resistant organisms/cells are appearing in a timescale of months or years and not centuries. These are examples of evolution by anthropogenic action.
- This also tells us that evolution is not a directed process in the sense of determinism. It is a stochastic process based on chance events in nature and chance mutation in the organisms

Anthropogenic action on mosquito

- Similarly, excess use of herbicides, pesticides, etc., has only resulted in selection of resistant varieties in a much lesser time scale.

Views of Lamarck

- A French naturalist Lamarck had said that evolution of life forms had occurred but driven by use and disuse of organs.
- He gave the examples of Giraffes who in an attempt to forage leaves on tall trees had to adapt by elongation of their necks.
- The acquired character of elongated neck to succeeding generations, Giraffes, slowly, over the years, came to acquire long necks.

- This conjecture is rejected as acquired characters are not inherited.

Views of Charles Darwin: Natural selection and survival of Fittest

- Natural selection is based on certain observations which are factual. Natural resources are limited, populations are stable in size except for seasonal fluctuation, members of a population vary in characteristics (in fact no two individuals are alike) even though they look superficially similar, most of variations are inherited etc.
- Only some organisms survived and grew at the cost of others that could not flourish. The novelty and brilliant insight of Darwin was this: he asserted that variations, which are heritable and which make resource utilization better for few (adapted to habitat better) will enable only those to reproduce and leave more progeny.
- Hence for a period of time, over many generations, survivors will leave more progeny and there would be a change in population characteristic and hence new forms appear to arise.

Operation of natural selection on different traits :

(a) Stabilising (b) Directional and (c) Disruptive

- Natural selection can lead to stabilization (in which more individuals acquire mean character value), directional change (more individuals acquire value other than the mean character value) or disruption (more individuals acquire peripheral character value at both ends of the distribution curve)

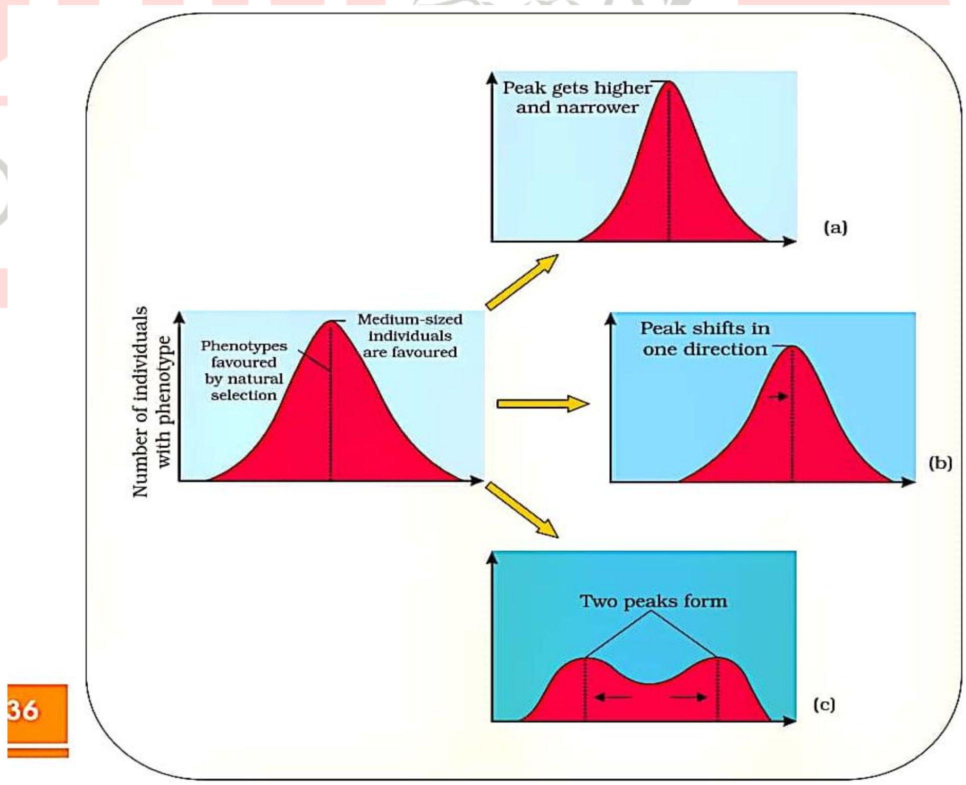


Figure 7.8 Diagrammatic representation of the operation of natural selection on different traits : (a) Stabilising (b) Directional and (c) Disruptive

Adaptive radiation:

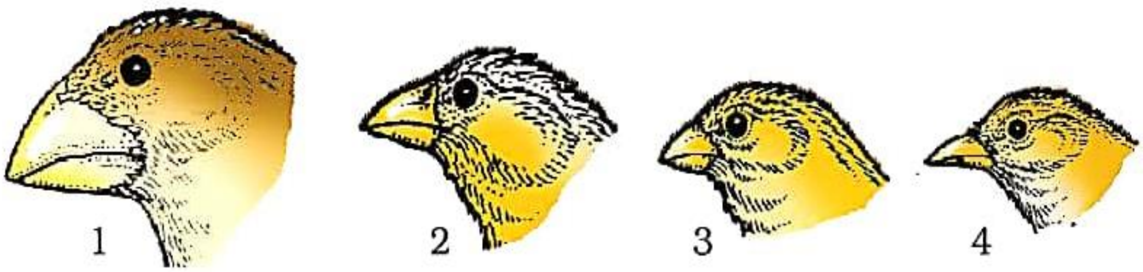


Figure 7.5 Variety of beaks of finches that Darwin found in Galapagos Island

- Darwin in Galapagos Islands observed an amazing diversity of creatures. Of particular interest, small black birds later called Darwin's Finches amazed him.
- He realised that there were many varieties of finches in the same island. All the varieties, he conjectured, evolved on the island itself. From the original seed-eating features, many other forms with altered beaks arose, enabling them to become insectivorous and vegetarian finches.
- This process of evolution of different species in a given geographical area starting from a point and literally radiating to other areas of geography (habitats) is called **adaptive radiation.**

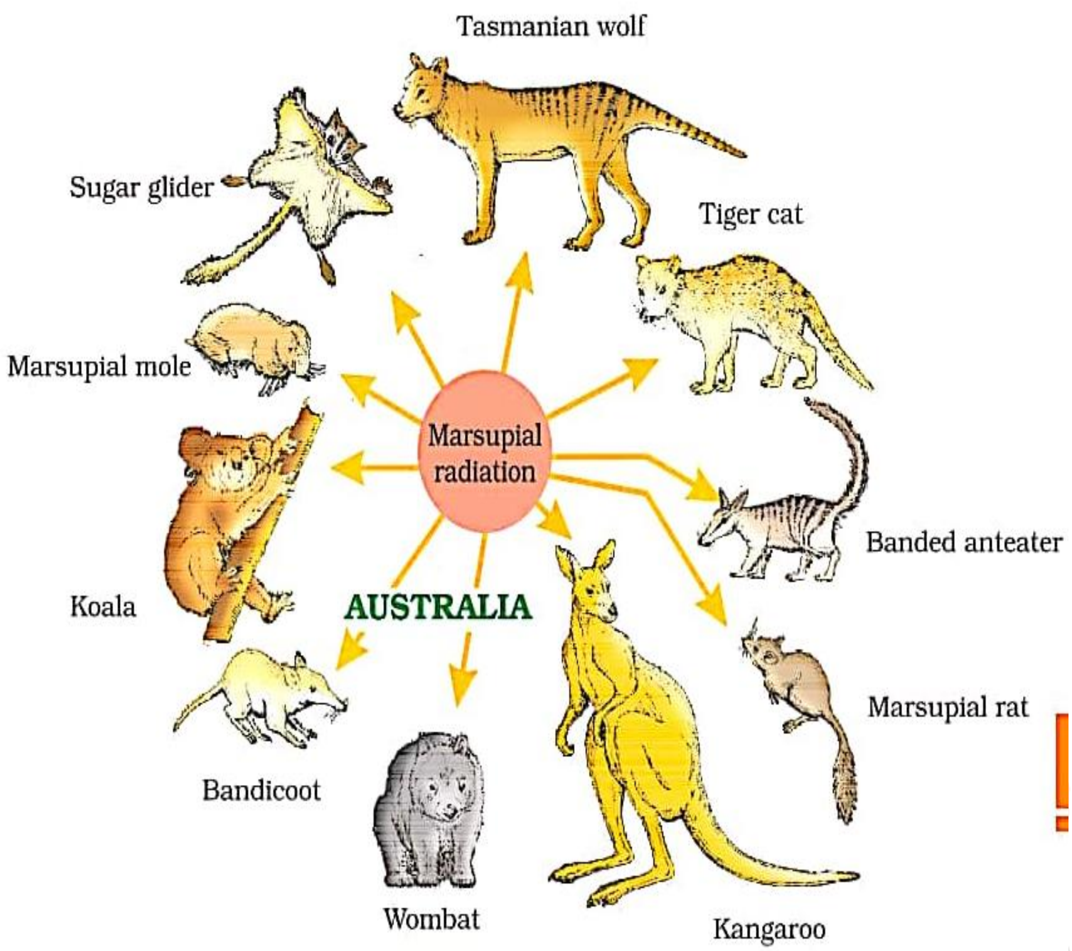


Figure 7.6 Adaptive radiation of marsupials of Australia

- Another example to explain the phenomenon of adaptive radiation are the Australian marsupials. A number of marsupials, each different from the other, evolved from an ancestral stock, but all within the Australian island continent.
- Placental mammals in Australia also exhibit adaptive radiation in evolving into varieties of such placental mammals each of which appears to be 'similar' to a corresponding marsupial (e.g., Placental wolf and Tasmanian wolf-marsupial).

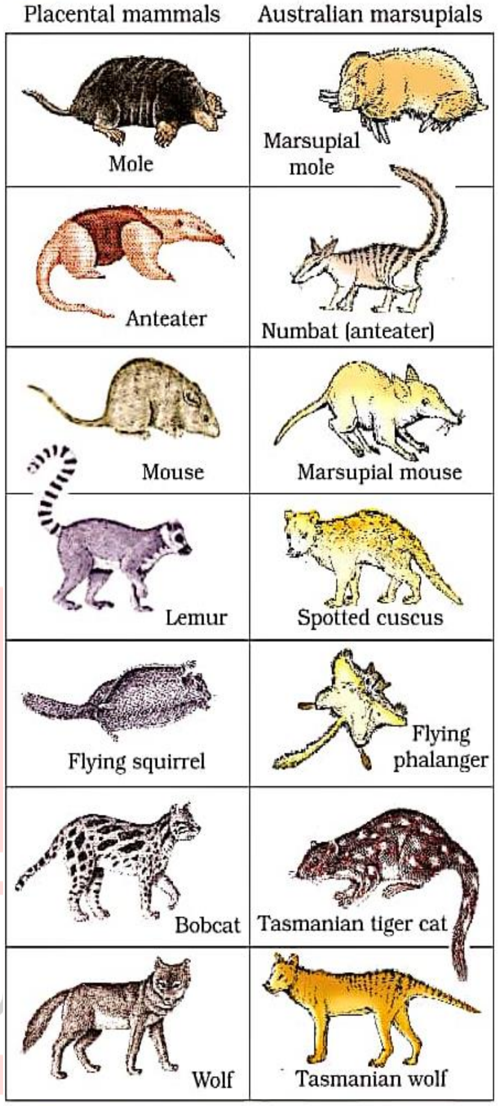


Figure 7.7 Picture showing convergent evolution of Australian Marsupials and placental mammals

Adaptive radiationand Convergent evolution

- When more than one adaptive radiation appeared to have occurred in an isolated geographical area (representing different habitats), is called as convergent evolution.

Key concepts of Darwinian Theory of Evolution

- The essence of Darwinian theory about evolution is natural selection. Environmental conditions change with time. The organism which is able to utilizes the resources in a better manner than others is favored to reproduce and exist.
- The organisms those who survive and reproduce are called to be fit. Natural selects for fitness. Fitness is based on characteristics which are inherited.

- Hence, there must be a genetic basis for getting selected and to evolve. Another way of saying the same thing is that some organisms are better adapted to survive in an otherwise hostile environment.
- Adaptive ability is inherited. It has a genetic basis.
- Fitness is the end result of the ability to adapt and get selected by nature.
- **Branching descent** and **natural selection** are the two key concepts of Darwinian Theory of Evolution.

The novelty and insight of Darwin

- The novelty and brilliant insight of Darwin:
- He asserted that variations, which are heritable and which make resource utilisation better for few (adapted to habitat better) will enable only those to reproduce and leave more progeny.
- Over many generations, survivors will leave more progeny and there would be a change in population characteristic andhence new forms appear to arise.

Comparative study about Australian Marsupials and placental mammals

Australian Marsupials

- Australia is the home to the world's largest and most diverse selection of marsupials: mammals with a pouch in which they rear their young. The marsupial carnivores — order Dasyuromorphia — are represented by two surviving families: the Dasyuridae with 51 members, and the Myrmecobiidae with the numbat as its sole surviving member.
- The Tasmanian tiger, was the largest Dasyuromorphia and the last living specimen of the family Thylacinidae; however, the last known specimen died in captivity in 1936.
- The world's largest surviving carnivorous marsupial is the Tasmanian devil; it is the size of a small dog and hunts although it is opportunistic. It became extinct on the mainland some 600 years ago and is now found only in Tasmania.
- There are four species of native cat, all of which are threatened species. The remainder of the Dasyuridae are referred to as "marsupial mice".
- There are two species of marsupial mole — order Notoryctemorphia — that inhabit the deserts of Western Australia.

Placental mammals

- The indisputable remains of Australian placental mammals started from the Miocene, when Australia moved closer to Indonesia.
- After 15 mya bats appeared reliably in the fossil record, and after 5 to 10 mya rodents did.
- Australia has indigenous placental mammals from two orders: the bats, order Chiroptera, represented by six families, and the mice and rats, order Rodentia, family Muridae.
- Bats and rodents are relatively recent arrivals to Australia. Bats probably arrived from Asia, and they are present in the fossil record only from as recently as 15 mya.

- Although 7% of the world's bats species live in Australia, there are only two endemic genera of bats. Rodents first arrived in Australia 5 to 10 mya and underwent a wide radiation to produce the species collectively known as the "old endemics".
- The old endemics are represented by 14 extant genera. About a million years ago, the rat entered Australia from New Guinea and evolved into seven species of *Rattus*, collectively called the "new endemics".

Views of Darwin and dE Vries on mutation

- Mendel talked about inheritable 'factors' influencing phenotype, Darwin either ignored these observations or kept silence.
- In the first decade of twentieth century, Hugo de Vries based on his work on evening primrose brought forth the idea of mutations – large difference arising suddenly in a population.
- De Vries believed that it is mutation which causes evolution and not the minor variations (heritable) that Darwin talked about. Mutations are random and directionless while Darwinian variations are small and directional.
- Evolution for Darwin was gradual while de Vries believed mutation caused speciation and hence called it **saltation** (single step large mutation). Studies in population genetics, later, brought outsome clarity.

Population genetics: Hardy-Weinberg principle

- In a given population one can find out the frequency of occurrence of alleles of a gene or a locus. This frequency is supposed to remain fixed and even remain the same through generations.
- Hardy-Weinberg principle states that the allele frequencies in a population are stable and is constant from generation to generation. The gene pool (total genes and their alleles in a population) remains a constant. This is called genetic equilibrium.
- Sum total of all the allelic frequencies is 1. Individual frequencies, for example, can be named **p, q**, etc. In a diploid, p and q represent the frequency of allele **A** and allele **a**.
- The frequency of **AA** individuals in a population is simply p2. This is simply stated in another ways, i.e., the probability that an allele **A** with **a** frequency of **p** appear on both the chromosomes of a diploid individual is simply the product of the probabilities, i.e., **p2**.
- Similarly of **aa** is **q2**, of **Aa 2pq**. Hence, **p2+2pq+q2=1**. This is a binomial expansion of $\mathbf{(p+q)^2}$.
- When frequency measured, differs from expected values, the difference (direction) indicates the extent of evolutionary change.
- Disturbance in genetic equilibrium, or Hardy- Weinberg equilibrium, i.e., change of frequency of alleles in a population would then be interpreted as resulting in evolution.

Factors affecting Hardy-Weinberg equilibrium

- Five factors are known to affect Hardy-Weinberg equilibrium.
  These are:

- i) gene migration or gene flow,
- ii) genetic drift,
- iii) mutation,
- iv) genetic recombination and
- v) natural selection.
- When migration of a section of population to another place and population occurs, gene frequencies change in the original as well as in the new population. New genes/alleles are added to the new population and these are lost from the old population.
- There would be a gene flow if this gene migration, happens multiple times. If the same change occurs by chance, it is called genetic drift.
- Sometimes the change in allele frequency is so different in the new sample of population that they become a different species.
- The original drifted population becomes founders and the effect is called **founder effect**.
- Microbial experiments show that pre-existing advantageous mutations when selected will result in observation of new phenotypes. Over few generations, this would result in Speciation.
- A critical analysis makes us believe that variation due to mutation or variation due to recombination during gametogenesis , or due to gene flow or genetic drift results in changed frequency of genes and alleles in future generation.

Brief account of chemical evolution

- We have no idea about how the first self-replicating metabolic capsule of life arose. The first non-cellular forms of life could have originated 3 billion years back. They would have been giant molecules (RNA, Protein, Polysaccharides, etc.). These capsules reproduced their molecules perhaps.

Evolution of unicellular organisms

- The geological history of earth closely correlates with the biological history of earth. All the existing life forms share similarities and share common ancestors.
- However, these ancestors were present at different periods in the history of earth (epochs, periods and eras).
- The first cellular form of life did not possibly originate till about 2000 million years ago. These were probably single-cells.
- All life forms were in water environment only. This version of a **biogenesis**, i.e., the first form of life arose slowly through evolutionary forces from non-living molecules are accepted by majority.

The development of membranous envelop from non-cellular aggregates

- About 2000 million years ago (mya) the first cellular forms of life appeared on earth. The mechanism of how non-cellular aggregates of giant macromolecules could evolve into cells with membranous envelop is not known.

Evolution of unicellular O_2 releasing organisms

- Some of the early cells had the ability to release O_2.
- The reaction could have been similar to the light reaction in photosynthesis where water is split with the help of solar energy captured and channelized by appropriate light harvesting pigments.
- Slowly single-celled organisms became multi-cellular life forms.
- Sea weeds and few plants existed probably around 320 mya. We are told that the first organisms that invaded land were plants. They were widespread on land when animals invaded land.

Brief account of Coelacanth and lobefins, evolutionary history of vertebrates

- By the time of 500 mya, invertebrates were formed and active. Jawless fish probably evolved around 350 mya. In 1938, a fish caught in South Africa happened to be a Coelacanth which was thought to be extinct.
- These animals called lobefins evolved into the Evolution of multicellular organisms from unicellular organisms first amphibians that lived on both land and water.
- There are no specimens of these left with us. These were ancestors of modern day frogs and salamanders.
- The amphibians evolved into reptiles. They lay thick shelled eggs which do not dry up in sun unlike those of amphibians. We only see their modern day descendants, the turtles, tortoisesand crocodiles.

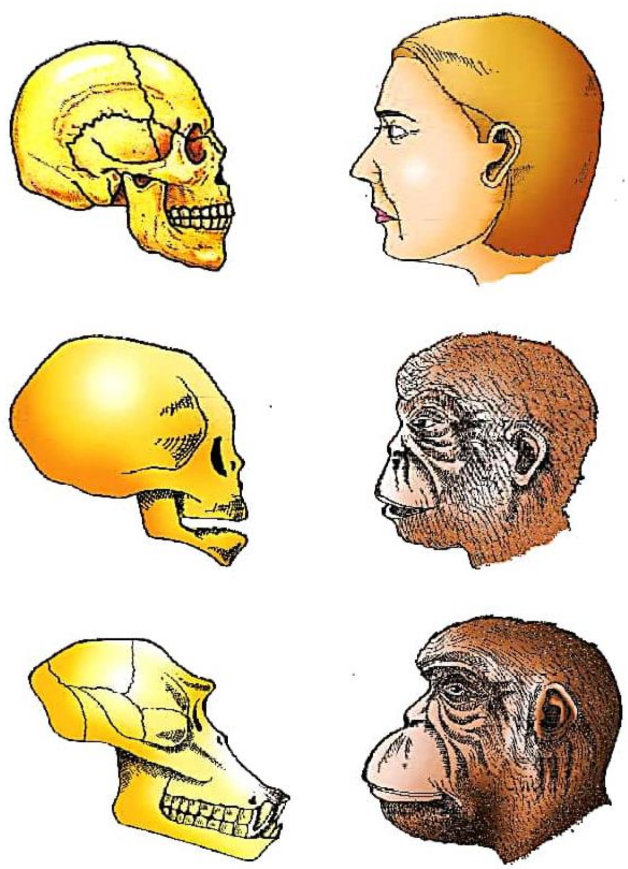
Evolutionary history of dinosaurs

- Some of the land reptiles went back into water to evolve into fish like reptiles probably 200mya (e.g. Ichthyosaurs).
- The land reptiles were, of course, the dinosaurs. The biggest of them, i.e., *Tyrannosaurus rex* was about 20 feet in height and had huge fearsome dagger like teeth.
- About 65 mya, the dinosaurs suddenly disappeared from the earth. We do not know the true reason.
- May be climatic changes killed them, or most of them evolved into birds. Small sized reptiles of that era still exist today.

Evolutionary history of mammals

- First mammals were like shrews. Their fossils are small sized. Mammals were viviparous and protected their unborn young inside the mother's body.
- Mammals were more intelligent in sensing and avoiding danger in comparison. When reptiles came down mammals took over this earth.
- There were in South America mammals resembling horse, hippopotamus , bear, rabbit, etc. Due to continental drift, when South America joined North America, these animals were overridden by North American fauna.
- Due to continental drift pouched mammals of Australia survived because of lack of competition from any other mammal.
- Some mammals live wholly in water. Whales, dolphins, seals and sea cows are some examples.

Origin and evolution of man



. A comparison of the skulls of adult modern human being, baby chimpanzee and adult chimpanzee. The skull of baby chimpanzee is more like adult human skull than adult chimpanzee skull

- The most successful story is the evolution of man with language skills and self-consciousness. About 15 mya, primates called *Dryopithecus* and *Ramapithecus* were existing. They were hairy and walked like gorillas and chimpanzees.
- *Ramapithecus* was more man-like while *Dryopithecus* was more ape-like. Few fossils of man-like bones have been discovered in Ethiopia and Tanzania.
- These revealed hominid features leading to the belief that about 3-4 mya, man-like primates walked in eastern Africa. They were probably not taller than 4 feet but walked up right.
- Two mya, *Australopithecines* probably lived in East African grasslands. Evidence shows they hunted with stone weapons but essentially ate fruit.
- Some of the bones among the bones discovered were different. This creature was called the first human-like being the hominid and was called *Homo habilis*.
- The brain capacities were between 650-800cc. They probably did not eat meat.
- Fossils discovered in Java in 1891 revealed the next stage, i.e., *Homoerectus* about 1.5 mya. *Homo erectus* had a large brain around 900cc.*Homo erectus* probably ate meat.
- The Neanderthal man with a brain size of 1400cc lived in near east and central Asia between 1,00,000-40,000years back. They used hides to protect their body and buried their dead.
- *Homo sapiens* arose in Africa and moved across continents and developed into distinct races. During ice age between 75,000-10,000 years ago modern *Homo sapiens* arose.
- **Pre-historic cave** art developed about18,000 years ago. One such cave paintings by Pre-historic humans can be seen at **Bhimbetka rock shelter** in Raisen district of Madhya Pradesh.
- Agriculture came around 10,000 years back and human settlements started.

IMPORTANT TERMS

Sl No.	Terms	Explanation
1	Evolution	The process by which different kinds of living organisms are believed to have developed from earlier forms during the history of the earth
2	Evolutionary Biology	Is the subfield of biology that studies the evolutionary process (natural selection, common descent, speciation) that produced the diversity of life on earth

3	Big Bang theory	Is a cosmological model of the observable universe from the earliest known periods through its subsequent large-scale evolution
4	Panspermia	The theory that life on the eath originated from microorganisms or chemical precursors of life present in outer space and able to initiate life on reaching a suitable environment
5	Biogenesis	Is the production of new living organisms or organelles
6	Geological period	Is the subdivisions of geological time enabling cross-referencing of rocks and geological events from place to place
7	Homology	Is the study of similarities between organisms to determine common ancestors based on genes, physiology or development
8	Divergent evolution	Is the accumulation of differences between closely related populations within species, leading to speciation
9	Analogy	A comparision between two organisms, typically for the purpose of explanation or clarification
10	Convergent evolution	Is the independent evolution of similar features in species of different periods or epochs in time.
11	Common ancestry	Is a concept in evolutionary biology applicable when one species is the ancestor of two or more species later in time
12	Anthropogenic action	Human impact on the environment includes changes to biophysical environments and ecosystem
13	Adaptive radiation	Is a process in which organisms diversify rapidly from an ancestral species into a multitude of new forms
14	Branching descent	It is defined as a process by which new species originate from a single descent
15	Saltation	Single step large mutation
16	Hardy-Weinberg principle	States that allele and genotype frequencies in a population will remain constant from generation to generation in the absence of other evolutionary influnces

17	Gene flow	Is the transfer of genetic variation from one population to another.
18	Genetic drift	Is the change in the frequency of an existing gene variant in a population due to random sampling of organisms
19	Founder effect	Is the loss of genetic variation that occurs when a new population is established by a vey small number of individuals from a large population
20	mya	million years ago
21	Coelacanth (Lobefins)	A lage bony marine fish with three lobed tail fin and fleshy pectoral fins
22	*Ichthyosaurs*	Is a fish like dinosaurs found in late Triassic and early Jurassic peiod
23	*Tyrannosaurus rex*	The biggest of the dinosaurs
24	Hominid features	Organisms showing human like features