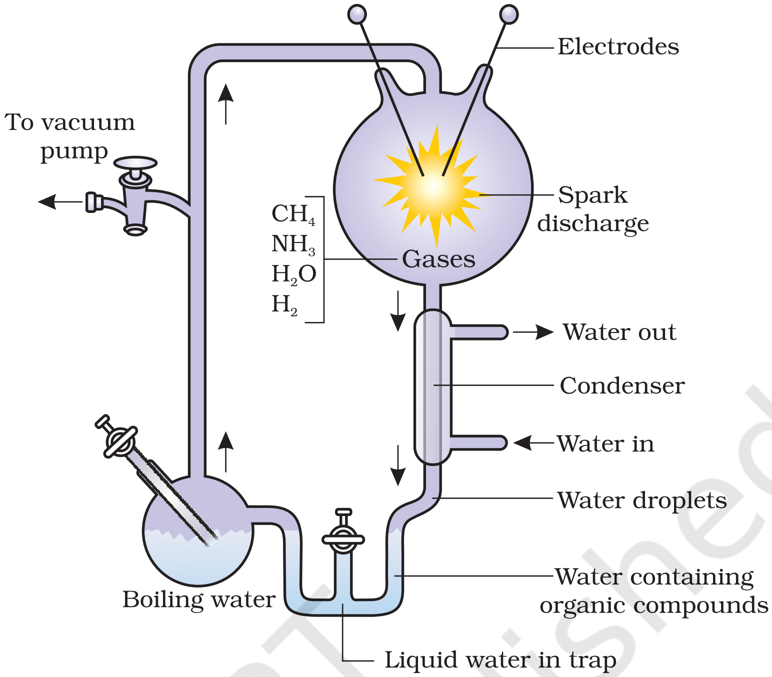

Figure 7.1 Diagrammatic representation of Miller's experiment

Polysaccharides, etc.). These capsules reproduced their molecules perhaps. 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 is accepted by majority. However, once formed, how the first cellular forms of life could have evolved into the complex biodiversity of today is the fascinating story that will be discussed below.

7.2 Evolution of Life Forms – A Theory

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 any more. 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. Let us also remember that 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 recognisable. 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 geological history of earth closely correlates with the biological history of earth. A common permissible conclusion is that earth is very old, not thousand of years as was thought earlier but billions of years old.

7.3 What are the Evidences for Evolution?

Evidence that evolution of life forms has indeed taken place on earth has come from many quarters. 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 (Figure 7.2). They represent extinct organisms (e.g., Dinosaurs). 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. *Do you remember how the ages of the fossils are calculated? Do you recollect the method of radioactive-dating and the principles behind the procedure?*

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. For example, 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. However, this proposal was disapproved on careful study performed by Karl Ernst von Baer. He noted that embryos never pass through the adult stages of other animals.

Comparative anatomy and morphology shows similarities and differences among organisms of today and those that existed years ago.

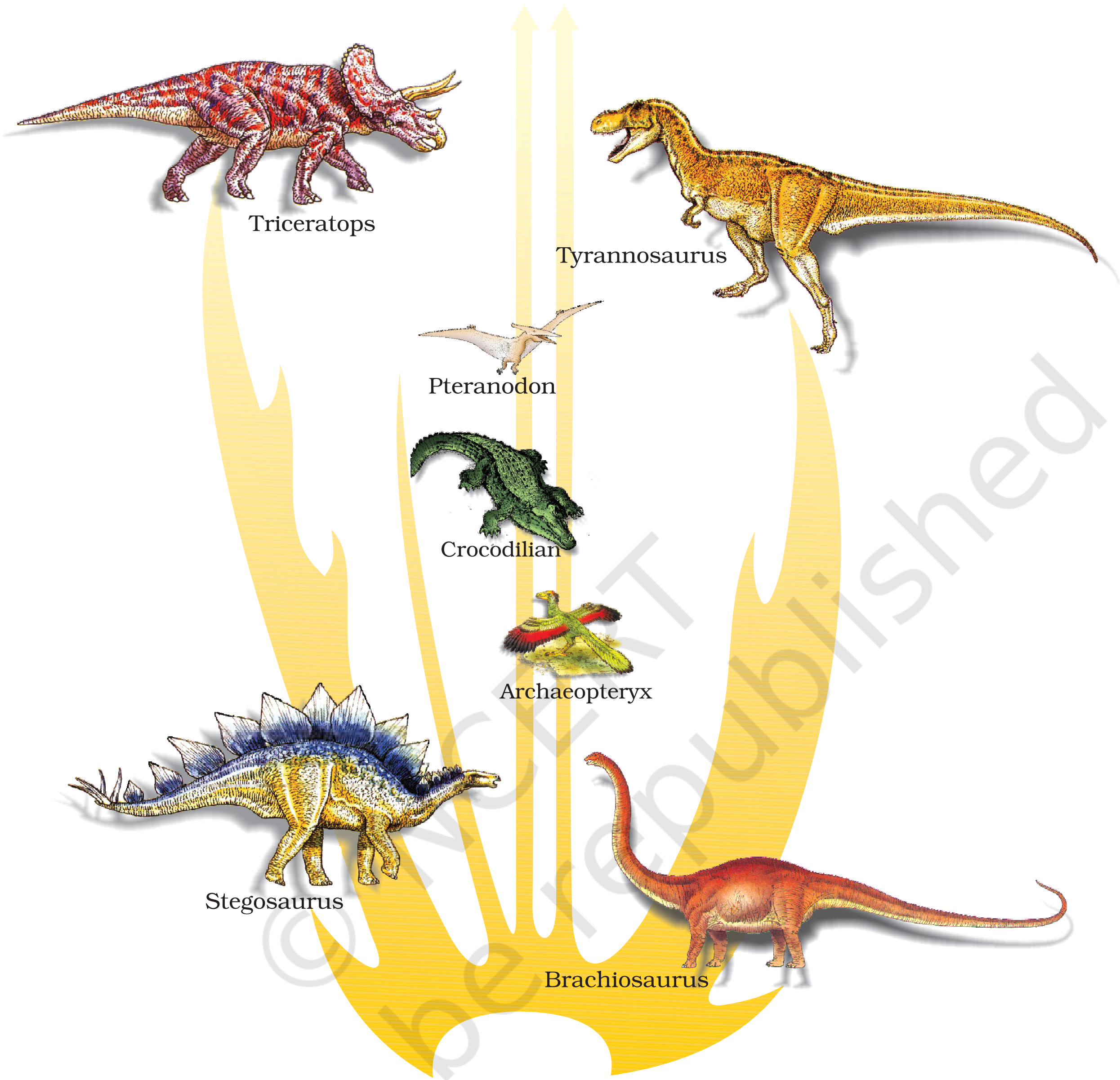

Figure 7.2 A family tree of dinosaurs and their living modern day counterpart organisms like crocodiles and birds

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 (Figure 7.3b). 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. This is **divergent evolution** and these structures are **homologous**. Homology indicates common ancestry. Other examples are vertebrate hearts or brains. In plants also, the thorn and tendrils of *Bougainvillea* and *Cucurbita* represent homology (Figure 7.3a). Homology is based on divergent evolution whereas 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.

In the same line of argument, 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.

Man has bred selected plants and animals for agriculture, horticulture, sport or security. Man has domesticated many wild animals and crops. This intensive breeding programme has created breeds that differ from other breeds (e.g., dogs) but still are of the same group. It is argued that if within hundreds of years, man could create new breeds, could not nature have done the same over millions of years?

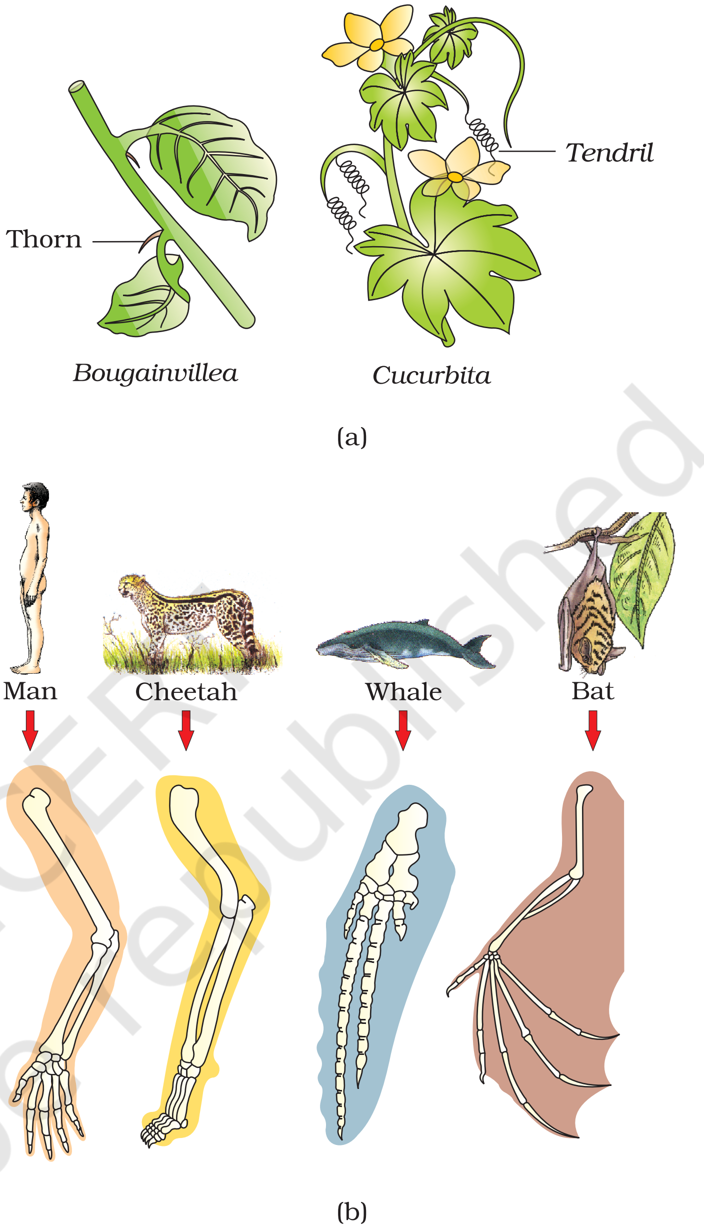

Figure 7.3 Example of homologous organs in (a) Plants and (b) Animals

Another 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. 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, i.e., the proportion was reversed.

(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

The explanation put forth for this observation was that 'predators will spot a moth against a contrasting background'. 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. 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. *Do you know that 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 (Figure 7.4). This understanding is supported by the fact that in areas where industrialisation 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. Remember that no variant is completely wiped out.

Similarly, excess use of herbicides, pesticides, etc., has only resulted in selection of resistant varieties in a much lesser time scale. This is also true for microbes against which we employ antibiotics or drugs against eukaryotic organisms/cell. Hence, resistant organisms/cells are appearing in a time scale 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.

7.4 What is Adaptive Radiation?

During his journey Darwin went to Galapagos Islands. There he 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

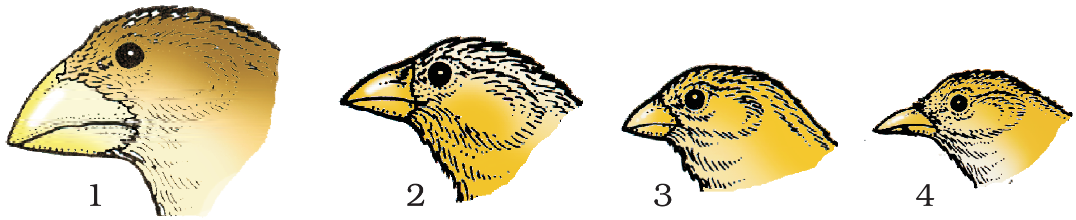

Figure 7.5 Variety of beaks of finches that Darwin found in Galapagos Island

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 (Figure 7.5). 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**. Darwin's finches represent one of the best examples of this phenomenon. Another example is Australian marsupials. A number of marsupials, each different from the other (Figure 7.6) evolved from an ancestral stock, but all within the Australian island continent. When more than one adaptive radiation appeared to have occurred in an isolated geographical area (representing

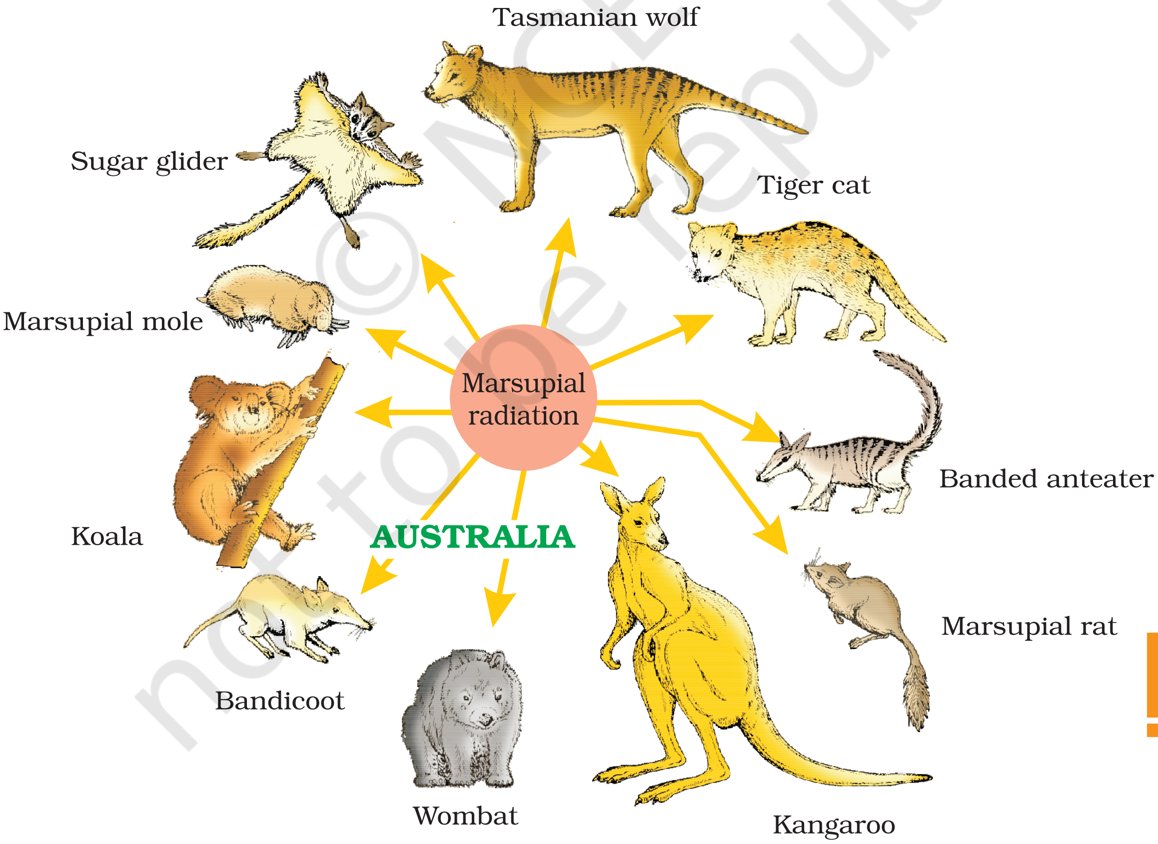

Figure 7.6 Adaptive radiation of marsupials of Australia

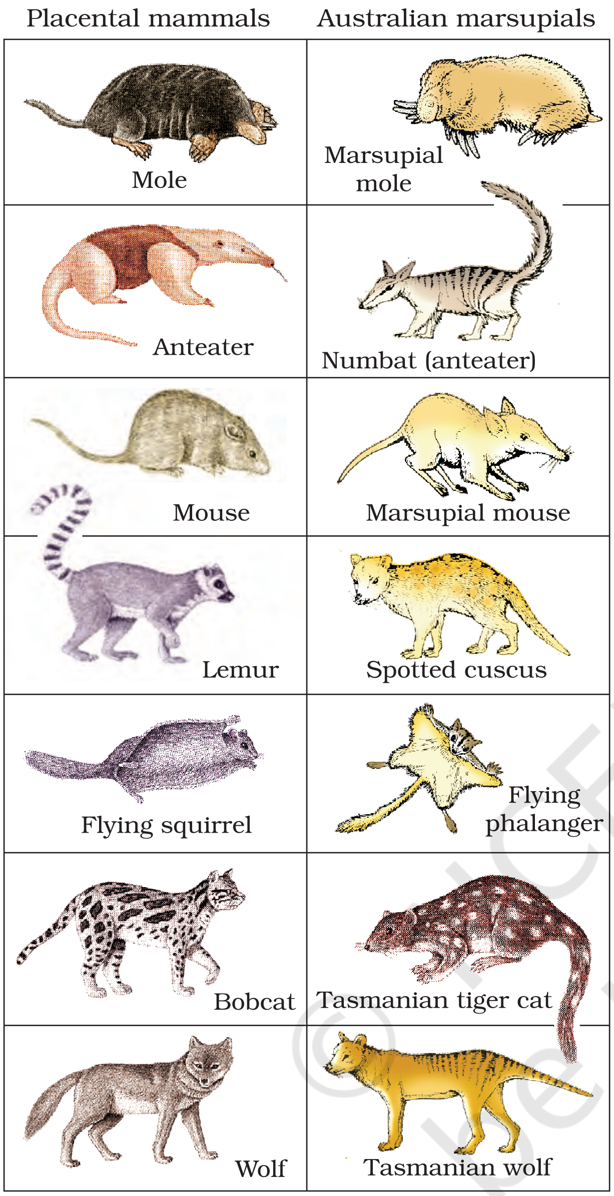

Figure 7.7 Picture showing convergent evolution of Australian Marsupials and placental mammals

different habitats), one can call this convergent evolution. 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).

7.5 Biological Evolution

Evolution by natural selection, in a true sense would have started when cellular forms of life with differences in metabolic capability originated on earth.

The essence of Darwinian theory about evolution is natural selection. The rate of appearance of new forms is linked to the life cycle or the life span. Microbes that divide fast have the ability to multiply and become millions of individuals within hours. A colony of bacteria (say A) growing on a given medium has built-in variation in terms of ability to utilise a feed component. A change in the medium composition would bring out only that part of the population (say B) that can survive under the new conditions. In due course of time this variant population outgrows the others and appears as new species. This would happen within days. For the same thing to happen in a fish or fowl would take million of years as life spans of these animals are in years. Here we say that fitness of B is better than that of A under the new conditions. Nature selects for fitness. One must remember that the so-called 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 (Figures 7.7 and 7.8).

Even before Darwin, a French naturalist Lamarck had said that evolution of life forms had occurred but driven by use and disuse of