Paper: PRINCIPLES OF ECOLOGY & EVOLUTION

Topic: EVIDENCES FROM PALAEONTOLOGY OR PALAEOBIOLOGY

Palaeontology is the study of fossil remains of plants and animals that lived in the past.

FOSSILS **(Latin; *Jossilum* = something dug out)** are actual remains, traces or impressions left by the organisms that lived in the past and got preserved in the sedimentary rocks. These include bones, teeth, shells and other hard parts of animals or impressions of plants pressed into shale or insects trapped in tree resin.

Study of plant fossils is called palaeobotany and of animal fossils palaeozoology. Leonardo de Vinci (1452-1519) of Italy is called the 'Fathe r of Palaeontology' and Cuvier (1800) the 'Founder of Modern Palaeontology'.

Fossil records provide the most direct evidence of evolution, whereas all other evidences are indirect.

Formation of Fossils

Fossils are formed in different ways based on the environmental conditions. The fossils may include original remains of the hard parts (bones, teeth, shell, etc.) in the sedimentary rocks, petrifaction of hard and soft parts, carbonised films, molds (impressions of organisms in rocks), casts (molds filled with foreign material) and as actual remains in peat, amber, asphalt and ice. The land animals may also get fossilised in amber (hardened resin), asphalt (hardened tar), volcanic ash, peat bogs and sand deposits or in ice.

The animals or plants are only preserved and fossilized when they are suddenly buried in the silt of water, lava, ice or sand. As soon as the animal, plant or any other organism dies, its body decomposes sooner or later.

Decomposition is caused by several agents. Scavengers of all sorts from vultures to bacteria and fungi take care of the soft parts very rapidly. Harder tissues such as shell, bones and wood are more resistant. Nevertheless, enzymes secreted by certain fungi and bacteria, acids occurring naturally in the soil, and the combined action of environmental agents such as water, wind, and temperature destroys even the hardest organic remains with time.

However, under very special circumstances some parts may be preserved, with varying amounts of modifications, to form fossils. Thus, shells which are inorganic in nature are usually preserved completely unaltered; **bones and wood, on the other hand**, are often **mineralized** or **petrified** (*i.e.*, turned to stone). The organic matter in wood or bone gradually disintegrates, leaving the structure somewhat porous. Water seeps into the interior of the bone and minerals dissolved in the water are slowly deposited there. Thus, the porosities gradually become filled with deposits of such materials as lime or silica. The portions of the original structure composed of inorganic materials may remain substantially as they were in life, or they also may be dissolved away and replaced by minerals. The replacing material may preserve the details of the original structure with great fidelity, or on the other hand, it may preserve only the general form of the original.

Yet fossils may contain some of the original material found in the living organism; for example, amino acids have been found in fossils of millions of years old.

Nature of Fossils

A fossil is a record of an organism that lived in the past, whose remains have come into comparative equilibrium with the sediments in which it was buried.

Fossils fall into the following two broad classes:

1. Unaltered fossils: Some specimens are preserved relatively unchanged from their original condition; teeth, bones and shells occasionally are found virtually intact buried in sediments. Even more dramatically, remains of organisms have been frozen in Arctic ice fields. Under exceptionally favourable conditions, the entire animal body gets preserved in ice, petroleum spring, asphalt , resin, amber and oil-soaked ground .

EXAMPLE:

1. Mammoths (an extinct form related to elephant) have been found in their hairy entirety throughout Siberia and have served as an extensive source of fossil ivory. Their flesh was so well preserved that it was eaten by dogs. Creatures (*e.g.*, largest mammals such as elephants, mastodons and paramylodons) have been trapped in asphalt or tar-pits at Rancho La Bera in Los Angeles (California).
2. Likewise, in Poland two skeletons of the woolly rhinoceros, with some of the flesh and skin preserved, have been found buried in oil-soaked ground. The remains of great Iris deer are found in peat bogs of Ireland
3. 3. In the same way, the human bodies, their clothings and food, who lived in the plateau of Arizona (USA) and New Mexico, have been preserved in the dry air and remained as such for hundreds of years.

2. **Petrified Fossils (Altered Fossils):** Petrified fossils are formed by the replacement of organic parts of dead and decaying organisms' molecule by molecule by minerals. The process is called petrification.

Petrified fossils are formed in the sedimentary rocks, on the bottom of lakes, rivers or sea when animals or plants or their parts get buried in the sediment. The process of petrification successfully preserves the hard parts. Under very favourable conditions, even the finest details of soft tissues, like muscles or other organs are also preserved by the replacement of their organic material with minerals.

Types of Fossils

Fossils are formed in a variety of ways, depending upon the organic material involved and environmental conditions.

1.Entire organism preserved: In a continuous dry or cold regions, all organic remains, even the softer body parts, may remain unchanged for a long time under exceptionally favourable conditions. Organisms may be preserved intact in a medium that protects them from decay by bacterial action. Among the most perfect fossils known are the insects preserved in amber, a fossil resin from pines, especially *Picea succinifera.* Millions of years ago insects such as bugs, aphids, caddice-fly, may-fly, etc., became entangled and entombed in soft, sticky resin exuding from pine trees. The resin hardened and eventually changed to amber, preserving the minutest details of structure of the contained insects. A few extinct animals are known from frozen specimens in which flesh and bones have been preserved in remarkable fresh condition for thousands of years. For example, woolly mammoth has occurred principally in Arctic Tundra (Siberia). Likewise, intact fossils of *Elaphas* and *Mastodon* have been obtained from oil-rich swampy soils from Los Angeles (California).

A ground sloth was found well preserved in an extinct volcanic crater in New Mexico in 1928. The skeleton of this Pleistocene mammal is complete.

2. Original hard parts/Skeletons preserved: In case of invertebrate animals and angiospermic plants the harder parts such as shells, chitinous exoskeleton or spicules of animals and woody tissue of plants get preserved and fossilised. The skeletons of vertebrates make perfect fossils because they could be well preserved in their original shapes and structure.

3. Altered hard parts of organism preserved: Sometimes the original hard parts of an organism get completely altered due to various factors like carbonization, petrification and mineralization

4. **Traces of organisms preserved:** Occasionally neither an entire organism nor a part of it is fossilized, instead the organism left certain impressions or marks in certain hard media. They too bear great palaeontological significance and are of the following types:

(i) Moulds and casts. A mould is an impression of some hard parts, i.e., shell of an organism buried in the sediment or mud, which, in course of time, hardened to become a rock. Later on, the organism decays, the organic material is removed by percolating acidified water and a cavity (pit or depression) is formed that shows the external configurations and surface marking of the original material. **It is called external mould.**

Sometimes, however, the internal cavity of part (e.g., shell) is filled with mud or sediment or mineral deposits before the shell is dissolved by the action of percolating water. In such cases these moulds **are called internal moulds.** These represent internal structure of the shell and the exact shape of the animal. The moulds are available largely for molluscan shells, Foraminifera and Radiolaria.

If the mould showing external form, later on, is filled with mineral matter, natural cast of the original object is produced which reflects only its external form. Natural moulds and casts form a very large proportion of the fossils that are found in sandstones and limestones. For the preparation of artificial casts, latex (rubber) solution, melted wax or plaster of Paris is filled in the external mould.

Natural moulds of several men and dogs, whose artificial casts have been produced by plaster of Paris,
have been found in the ancient ash-covered town of Pompeii where they were mass buried by the

eruption of the Mt. Vesuvius in 79 A.D.

(ii) Tracks and trails. Tracks (footprints) are formed over dryland or sea bottom or in muddy environments, where wet sand and mud receive impressions of the feet of passing animal and they are covered by the sediment before they are disturbed or eroded. Such fossils of footprints are very common for Dinosaur reptiles from Triassic rocks of Connecticut Valley. The tracks of Missippian amphibians form another example of track. With the help of these tracks palaeontologists gather information regarding the size and shape of foot, length of limb and posture and gait of the animal concerned Contents

Trails are the irregular markings of moving animals on the sedimentary rocks, such as those formed due to the crawling of a worm or snail, the dragging tentacles of a jelly-fish, the impressions of the fins of fish, and markings of the movements of crustaceans or urchins.

(iii) Burrows and borings. Some animals live in burrows, tubes and holes in the ground, wood or rocks either for taking shelter or in search of food. The presence of such burrows or tubes in the sedimentary rocks of ancient past are called **fossil burrows**. They belong to bivalve and other molluscs, worms and sponges. Fossil burrows provide us information regarding behaviour of their resident animals.

Borings are holes made by animals for the sake of food and shelter. Such fossil holes occur on fossil shells, wood and organic objects.

(iv) Gastroliths and coprolites. Gastroliths are hard stony pieces found from stomachs of ancient reptiles and fishes. **Coprolites** are fossilised faeces of ancient animals. Their study provides valuable information about the food and feeding habits of fossil forms to whom the faeces belong.

Determination of Age of Fossils or Dating of Fossils

Paleontologists use following methods to determine the age of fossils or rocks that contain fossils:

Stratigraphy: Stratigraphy provides sequential arrangement of fossils in the rocks from which relative age of fossils can be determined. It shows that the lower strata of rocks contain the oldest fossils and uppermost strata contain the recently formed fossils.

Radiometric Dating: It relies on half-life decay of radioactive elements to allow scientists to date the rocks and the fossils contained there-in directly. This is also called radioactive clock method or radioactive dating method. The method of radioactive dating was introduced by Boltwood in 1907. It is based on degradation of radioactive nuclei into stable nonradioactive element by loosing electrons. Each radioactive element has its half life which means one gram of a radioactive element changes into half a gram in a specific time. The half life of each radioactive element is fixed.

For example, ^{238}uranium changes to ^{206}lead (^{206}Pb) in 4.5 billion years and radioactive carbon ^{14}C changes to radio-isotope of carbon ^{12} C in 5,579 or 56 x 103 years .

Uranium-Lead Method: In this method, the amount of ^{238}uranium and ^{206}lead in a given rock is estimated accurately and the age of the rock is calculated on the basis of half life. This method can be used only to determine the age of very old rocks and fossils because of very long half life of uranium (4.5 billion years).

Radioactive Carbon Method: Radioactive carbon (^{14}C) method of determining age of fossils was suggested by W.F. Libby (1950). ^{14}C is a radio-isotope of carbon ^{12}C. Its half life is about 5,600 years. When bones are formed, small amount of ^{14}C is incorporated and its amount remains constant throughout the life of an organism.

Upon death the radioactivity is gradually lost. By determining the amount of radioactivity in the bones, it is possible to approximate the time of death or fossilisation. Since the half life of ^{14}C is small, radioactive carbon dating method can give the age of fairly recent fossils (about 11,000 years to recent).

Potassium-Argon Method: This method is recently used to determine the age of the earliest known hominoid fossils from East Africa. The half life of radioactive potassium is 11 .6 x 109 years .

Fossil Parks in India

Fossil park is a large area of fossil bearing rocks dug out and preserved to show fossils in rocks . In India, the fossil parks are:

- Birbal Sahani Institute of Palaeobotany, Lucknow
- About 50 million years old Fossil Forest at Mandla District, Madhya Pradesh
- About 260 million years old Coal-forming Forest in Odisha
- About 100 million years old fossil forest in Raj Mahal Hills in Bihar
- National Fossil Park, Tiruvakkarai in South Arcot District of Tamil Nadu

Significance of Fossils

The study of fossils has great significance. It helps in understanding the prehistoric forms, process of organic evolution and in reconstructing palaeographic (It deals with study of ancient geography during different geological eras and epochs) maps. Fossils are extensively used as indicators for prehistoric climate (salinity, sunlight and depth of water and availability of oxygen, etc.) and as stratigraphic indicators as well. Recently, fossils are used commercially to detect petroleum reserves, coal reserves, gas reserves and reserves of various metal ores. The fossils which indicate the age of the rock in which they are found, are called **index fossils.**