

Lecture 1

FOSSILS AND FOSSILISATION

INTRODUCTION

Earth is a unique planet of the solar system and the existence of life on it differentiates it from other planets. You might be hearing the news on radio and television or reading in the newspapers or on the internet that scientists are working to find the evidence of life on other planets, especially on the planet Mars. Did you ever think how old our mother Earth is? When and where the first form of life appeared? How big were the dinosaurs? In fact, many of us are always curious to know who were our ancestors—monkeys, chimpanzees or others. It is likely to be true to say that the present day life forms such as plants, animals and micro-organisms may not be sufficient to answer these questions. Now, the fundamental question is how we can find the answers to all the questions related to ancient life.

Introduction to Paleontology

Let us think about what happens to an organism after its death; whether it is completely destroyed or it leaves some evidence of its existence. Usually, organisms that have hard parts leave some evidence in the form of shells, skeletons, bones and teeth after their death. Once these hard parts get preserved in the sedimentary rocks they are known as fossils. The age of Earth is about 4.6 billion years and the study of fossils shows that life began on Earth around 3.8 ago. During the course of time, life has faced different phases of evolution, diversification and extinction. Therefore, the history of life can be traced through the study of fossils. In this unit, you will learn about different types of fossils, processes and conditions of fossilization and significance of fossils. In addition, we will also discuss the taxonomy hierarchy and biological nomenclature.

Expected Learning Outcomes

After reading this unit, you will be able to:

- 1- define paleontology and describe its various branches;
- 2- discuss fossils and their types;
- 3- explain the requirements and processes of fossilization;
- 4- elaborate biological taxonomic hierarchy;
- 5- describe code of biological nomenclature; and
- 5- write about the importance of fossils.

PALAEONTOLOGY

In simple words, **Palaeontology** is a branch of geology that deals with the study of ancient life or life of past geologic time. Paleontology is based on the fossil remains of ancient organisms; hence, it may also be defined as the study of fossils. The information, we get from fossils helps us in understanding the history of life as well as the history of the Earth.

Paleontology it is divided into a number of branches as listed below:

- **Invertebrate Paleontology:** It deals with the study of fossils of invertebrate animals such as corals, brachiopods, mollusks, trilobites and echinoderms.

- **Vertebrate Paleontology:** It deals with the study of fossils of vertebrate animals such as fishes, amphibians, reptiles, birds and mammals.
- **Micropaleontology:** It deals with the study of microscopic fossils, which are not visible to the naked eyes, such as foraminifers, radiolarians and ostracods.
- **Paleobotany:** It deals with the study of plant fossils, for example -*Glossopteris*, *Gangamopteris*, *Thinnfeldia*, *Sigillaria*, *Nilssonina*, *Williamsonia* and *Ptilophyllum*.
- **Palynology:** It deals with the study of fossils of pollen grains and spores Dinoflagellate and acritarch.
- **Paleobiology:** It has recently emerged as a new science for the study of fossils. It involves the study of the biological aspects of the fossils. The main focus of paleobiology is to study the evolution, adaptation, function, ecology and behavior of the fossil species rather than studying their geological uses. Paleobiology provides important data, which helps to reconstruct the way of life in which ancient species lived before fossilization.

FOSSILS

In order to study the pre-historic or past life, fossils serve as the only valuable source of information as there is no other consistent source available to study the past life. The word fossil, which comes from the Latin word **fossilium**, was used originally in the sixteenth century to refer to any specimen dug up from the ground, for example mineral, rock and metal as well as organic remains of once-living organisms. It was only during the eighteenth century that the word fossil was strictly used for any evidence of past life preserved in the Earth's crust.

What are Fossils?

The word “fossil” is used to refer to the remains or traces of ancient life which have been preserved by natural processes in the sedimentary rocks. Fossils represent the only direct evidences of ancient life. They may be found as preserved skeletons, bones and shells of the organisms or as preserved impressions of the behavioral activities such as tracks, trails, footprints of the organisms. Use of the term fossil is usually restricted to the remains of organisms that died before thousands or millions of years. It is widely accepted that any organic remains found in the rocks older than **10,000 years** can be termed as fossil. The organic remains younger than 10,000 years and that are still under the process of fossilization are known as **subfossils**.

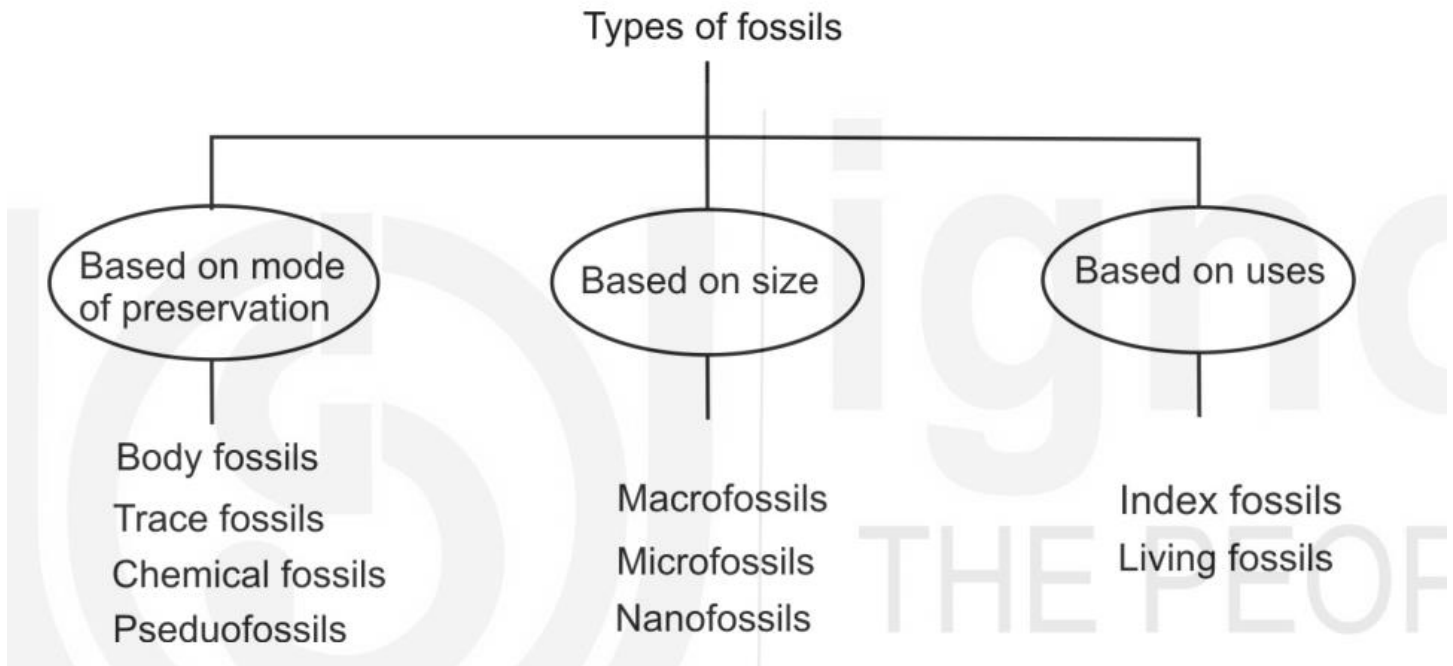
Fossils vary in size from microscopic bacteria of one micrometer in diameter to gigantic dinosaurs or fossil tree trunks measuring several meters long.

Do you know?

Rocks are of three types: igneous, sedimentary and metamorphic. Of these rocks only sedimentary rocks, are formed by a slow process of deposition of sediments (sand, mud, clay) layer by layer carried by rivers and streams into oceans and other water bodies, have the potential to preserve fossils to any reasonable extent. Whereas igneous and metamorphic rocks hardly have the scope to preserve fossils. This is because igneous rocks are derived from the molten material from below the crust of the Earth and are obviously not suitable for the preservation of organisms at such high temperature. Metamorphic rocks, which are formed by the intensive folding and re-crystallization of pre-existing rocks and the process of creating new material, tend to destroy the organic remains.

Types of Fossils

Many types of fossils are found in the layers of rocks. Among them, some are more common such as body fossils, trace fossils, whereas some others are less common. Based on the mode of preservation, size and uses, fossils are commonly classified into many types;



A- Body Fossils: These are preserved hard parts of the actual organisms. Body fossils may be the whole body of any organism, for example skeleton of dinosaurs, shell of bivalves or body parts of an ancient animal like bones and teeth of fishes, dinosaurs or mammals. These are direct evidence of ancient life and provide information about the shape, size and functions of a once-living organism.

B- Trace Fossils: These are not actual remains of an organism, but are the preserved evidences or impressions of the activities of organisms of the past. Trace fossils may include tracks, trails, burrows, footprints and borings. Trace fossils are also known as **Ichnofossils** and their study is called **Ichnology**.

C- Chemical Fossils: The ancient DNA preserved in rocks is a common example of chemical fossils.

D-Pseudofossils: These are not fossils though they look like fossils.

Dendrite—an ore of manganese, is a classic example of pseudofossil, which is often mistaken for leaves or ferns because of its tree-like structure

Fossils and Fossilization

* **Macrofossils:** These are large fossils more than 0.3 mm in size and can be seen with naked eyes. Bones, teeth and shells of animals as well as wood and leaves of plants are the common examples of macrofossils.

* **Microfossils:** These are very small fossils less than 1 mm in size and require a microscope for their study. Ostracods (animal fossils), pollens and spores (plant fossils) are common examples of microfossils.

* **Nanofossils:** These are very small fossils having a size range between 5 to 60 micrometers (μm) and require an electron microscope for study. Nanoplankton is a typical example of nanofossils.

* **Index Fossils:** These are characterized by short geological range (age), wide geographic distribution, rapid evolutionary rate and distinct morphological features. For example, trilobites having a geological range from Cambrian to Permian are index fossils for the Paleozoic rocks. Index fossils are used for the correlation and dating of rocks.

* **Living Fossils:** Living fossils include those species which have lived for long spans of geologic time and are still living today with their body showing little or no morphologic changes during the course of evolution. Living fossils are very important to paleontologists as they provide the biological data, which is absent in the fossils.

SAQ 1

- In which rocks would you find fossils and why?
- What is palaeontology? List various branches of palaeontology.
- Fossils are remains of _____.
- Pseudofossils are _____ (true fossils/false fossils).

FOSSILISATION Fossilization is the process of transfer of material from biosphere (organic material) to lithosphere (fossil), in which the organic material is being replaced by inorganic mineral matter. The chances of an organism becoming a fossil are very less. It has been observed that for every organism that dies its chances of fossilization are less than one in a million. You would be surprised to know that most remains do not fossilize after death. Let us examine why this is so.

You may be aware that organisms are composed of the following parts:

- soft fleshy parts—made up of unstable organic compounds of carbon, oxygen and hydrogen.
- hard parts, for example shells, skeletons, bones and teeth—made up of stable hard compounds such as calcium carbonate and calcium phosphate.
- both soft and hard parts.

The story of fossilization begins with the death of an organism. After the death of an organism, its body gets exposed to natural agencies like biological (bacterial activity), physical (transportation by river or wind) and chemical (reaction with water or gases). When an organism dies, its soft parts begin to decay under bacterial action. When this process is completed no trace of the soft parts of the organism are left behind. Under this process, the soft-bodied organisms

get completely destroyed, but organisms with hard parts leave their hard parts undestroyed. The hard parts remaining after the completion of decay are then subjected to transportation by wind, water or even by predators, which result in the breakage and fragmentation of the hard parts before reaching into the sedimentation site. At the sedimentation site, these broken and fragmented hard parts get buried under sediments and then they are physically and chemically altered due to the pressure generated by the overlying sediments and water present within the sediments. Once, they pass through all these processes, they are finally converted into fossils. It may be noted that this entire process takes thousands of years and every stage results in significant loss of information about the organism. During the process of fossilization, many organisms get destroyed either at the decay, transportation or alteration stage. Therefore, fossilization or preservation of fossils is considered a chancy business.

Do you know how fossils are formed?

When an organism dies, it falls to the ground and may get buried in the layers of sediments. After thousands or millions of years, its remains get transferred into rocks and become part of the sedimentary layers. Such parts are known as fossils. Finally, after thousands or millions of years, when such sedimentary rocks are exposed on the surface of the Earth by folding, faulting or erosion then fossils can be seen.

Conditions for Fossilization

Like today's organisms which are living in different environments such as in seas, rivers, lakes or on plains or mountains, it is assumed that pre-historic organisms might have lived in similar kinds of environments. It may be noted that all environments are not equally suitable for preservation or fossilization. Hence, the nature or composition of the organisms and type of environment where they are living play an important role in fossilization. The favorable conditions for fossilization are mentioned below:

- **The organisms should have hard parts:** The hard parts of organisms such as shells, bones, teeth and wood take more time to break down and can be preserved as fossils. On the other hand, the soft-bodied organisms, for example, insects, worms and jellyfish decay very quickly after death and are rarely preserved.

- **Rapid burial of organisms after death under a thick cover of sediments:**

If the organisms are quickly buried under the sediment, it cuts the supply of oxygen and prevents destruction of the organisms by scavengers and decay.

- **Environment:** The environment plays an important role in the organism's ability to fossilise. It has been observed that marine organisms are more likely to be fossilized than those living on land because marine organisms have greater chance of being covered rapidly by sediments, which increases the chance of fossilization. Land-based organisms have less chance of being covered by sediments and more risk from scavengers and hence, they have less chances to fossilize.

Processes of Fossilization

Fossilization may occur in many ways. Sometimes, the entire organism including its soft parts is preserved. In rare cases, only hard parts of the organism are fossilized. In few cases, only imprints and traces of organisms are preserved. Hence, different organism types show different processes of fossilization. Fossils occur in many different forms such as unaltered soft parts, unaltered hard parts and altered hard parts. Depending upon the nature of fossils, the processes of fossilization may be classified into the following types:

- i) **Unaltered soft parts** or exceptional preservation
- ii) **Unaltered hard parts** preservation
- iii) **Altered hard parts** preservation, which is further divided into
 - (a) Permineralisation or petrification
 - (b) Replacement
 - (c) Carbonisation
 - (d) Molds and casts
 - (e) Tracks and trails

i) **Unaltered Soft Parts or Exceptional Preservation**

In very rare and ideal situations, the whole of the organism including its soft and hard parts may be found to have been preserved. In this type of preservation, the most fragile and delicate soft parts remain unaltered and provide finer details of the soft parts. This type of preservation takes place in several ways such as fossils preserved in amber, tar or ice.

Amber is the fossilized resin of ancient conifer trees. Usually, the sweetness of resin attracts the insects and they come in contact with resin. Due to the stickiness of resin the insects get trapped in it. Later, lumps of resin fall on the ground and get buried in the sediment and finally, turn to solid amber.

Some organisms may fall into crevasses in glaciated areas or become trapped in permanently **frozen** soil and thus get preserved perfectly. Low temperature and anaerobic (without oxygen) conditions in frozen areas allow the best preservation of the soft body parts of any organism. The woolly Mammoth preserved in the Pleistocene sequence of Siberia is a classical example of preservation in frozen ice.

Sudden burial of the ecosystems by **volcanic ash** and sand storms also leads to excellent preservation of fossils. The well-preserved Cretaceous biota of China and Mongolia are well known examples of biota quickly buried by volcanic ash and sand storms.

ii) **Unaltered Hard Parts Preservation**

Many invertebrates possess hard parts made up of stable compounds such as calcium carbonate, calcium phosphate and silica. It has been found that many shells and skeletons of invertebrates were preserved in the sedimentary rocks with no alteration in their hard parts. However, it does not mean that the organisms are unchanged. In fact, the less stable organic material (soft parts) is removed from their bodies during the process of fossilization. Fossil record has numerous examples of fossil shells which are millions of years old yet cannot be easily differentiated from the modern shells.

iii) **Altered Hard Parts Preservation**

The story of alteration of the hard parts starts after the burial of the organisms. Most shells and skeletons of animals contain pores, for example, bone marrow in vertebrates. Once an organism gets buried under the thick cover of sediment, the water containing dissolved minerals present within the sediments fills the pores and replaces or alters the hard parts. The pressure generated by sediments facilitates the process of alteration, which may take place in the following ways:

(a) **Permineralization or Petrification:** It is a slow process and involves the removal of organic material by mineralized solution. Most of the shells, bones and wood are porous. In addition, the decay of soft parts increases the porosity of these organic materials. When these porous materials are buried under sediments, the overburden increases the temperature and pressure. As a consequence, the chemical reaction occurs between groundwater and soluble minerals present in the sediments. This reaction leads to the formation of mineralized solution, which fills the pores of organic material thus paving the way for the solution to precipitate in pores. In this way, the organic material is partially or completely replaced by the inorganic matter consisting of silica, calcite or pyrite. Petrification is a very slow process in which replacement occurs molecule by molecule. As a result, very fine details about the organisms get preserved. The petrified wood of trees and bones of dinosaurs or tusks of elephants are common examples of permineralization.

(b) **Replacement:** It is also a slow process of fossilization. In this process, the underground water slowly fills the pores of organic material and completely dissolves the hard parts of the organisms trapped in sediments. At the same time the groundwater carries minerals in solution that replace the organic material with such minerals as silica, calcite, hematite and pyrite.

(c) **Carbonization:** In this process, the soft-bodied animals as well as the stems and leaves of plants buried under the sediments are decomposed or pressed and thus losing hydrogen, nitrogen, oxygen and other volatile constituents. As a result, a thin carbon film is left behind. Such films are enriched in carbon and appear as black shiny fossils. Carbon films create impressions in the rock outlining the shape of the organisms. Plant leaves are commonly preserved in this process. You may find most of the carbonized fossils in the coal mines.

(d) **Molds and Casts:** This process involves the natural duplication of the original organisms. When a shell gets buried in sediment, subsequently, the sediment becomes hard. At the same time the water running through the sediment may dissolve the shell completely, leaving behind an impression or a void of the shell. Such an impression is known as **mold**. If the void is filled with grains of sand or clay, it hardens and produces a replica of the original shell shape, which is known as **cast**.

Tracks and Trails: While moving on the soft ground such as mud and sand, the organisms may leave behind impressions of their movements. For example, the foot prints, burrows and borings are preserved when the soft ground materials harden in rock. These types of fossil impressions are also described as trace fossils.

TAXONOMIC HIERARCHY

The science of classification of life both extinct and extant forms into meaningful categories or groups, is called **taxonomy**. Based on a certain set of features comprising physical, morphological or molecular characters, the organisms can be grouped or classified. For example, all animals having hair are grouped together in a broad group or category known as mammals. Similarly, animals having feathers are grouped into birds. It may be noted that taxonomy as a science is as old as the human language, but modern work in this science began in the mid seventeenth century by main contributions of Carl Linnaeus who is known as the father of modern taxonomy. He was the first scientist who proposed an orderly system for classification of various organisms present on the Earth. He proposed that species is the fundamental unit of the biological taxonomy.

At present there are seven main categories of the biological taxonomic hierarchy. In descending order (i.e., higher to lower category), these are

Kingdom, Phylum, Class, Order, Family, Genus, and Species.

IMPORTANCE OF FOSSILS

Geology is the science dealing with study of the planet Earth and this study can never be completed without taking fossils into consideration. As you know fossils are naturally occurring clues to the past life and therefore, are important to interpret the history of Earth as well as evolution of life on it. As a result, fossils are often considered as written texts preserved in the rocks in the form of remains of ancient life that provide valuable clues to the following:

Evolution of Life

Based on the changes in life, the history of Earth has been divided into five main time divisions, which form the geological time scale. These divisions from oldest to youngest are:

- **Cenozoic:** It is marked by the presence of recent or modern life.
- **Mesozoic:** It is marked by the presence of medieval or middle life.
- **Palaeozoic:** It is marked by the presence of ancient or old life.
- **Proterozoic:** It is marked by the presence of earlier life.
- **Archeozoic:** It is marked by the absence of life or presence of most primitive life.

Dating of Rocks

Life is continuously changing through time, resulting in the appearance of new life-forms and disappearance of some of the older ones. The sedimentary rocks contain fossils deposited layer by layer. The principle of order of superposition states that in a sedimentary rock succession, the layers at the bottom are deposited first and hence, are the oldest. The beds overlying them are younger. The fossils contained in this succession will keep changing and it may not be possible to have the same forms throughout the succession. As a result, it is possible to

characterize the different layers of the rock succession based on their enclosed fossils. We assign relative geologic age to these fossiliferous layers on the basis of their fossil content. The branch of stratigraphy that deals with relative ages of sedimentary rocks is known as **biostratigraphy**.

There are some ancient organisms, which lived on the Earth for a very short period of time, but they had a wide geographic distribution, rapid evolutionary rate and distinct morphological features. The fossils of such organisms are called **index fossils** and these have served as key fossils to date the rocks. For example, trilobites are used as index for dating rocks of Lower Paleozoic Era and ammonites are used for dating the rocks of Mesozoic Era. Fossils are also used for biostratigraphic correlation, in which rock successions of two geographically separated areas can be correlated on the basis of fossils present in them in order to understand their spatial and temporal distribution.

Palaeogeography, Palaeoclimate, Palaeoenvironment, Discovering Oil and Coal Deposits

SUMMARY

Let us quickly summarise what you have read in this unit.

- Fossils are clues of past life and their study is known as paleontology.
- There are two principle types of fossils: body and trace fossils. The other types of fossils are chemical fossils; on the basis of size, fossils can be classified as macrofossils, microfossils and nanofossils; on their usage they can be index fossils and living fossils; objects that look like fossils, but are of inorganic origin are called pseudofossils.
- Fossilization is the process of transfer of material from biosphere to lithosphere, in which organic material is being replaced by inorganic mineral matter.
- The presence of hard parts and rapid burial after death under a thick cover of sediments are two important conditions for fossilization.
- Preservation of unaltered soft parts, unaltered hard parts and altered hard parts are main processes of fossilization.
- Alteration of hard parts occurs mainly due to permineralization or petrification, replacement, carbonization and formation of molds and casts.
- Taxonomy is the science of classification of life into categories. It has seven main categories such as Kingdom, Phylum, Class, Order, Family, Genus and Species.
- Codes of biological nomenclature are a uniform, globally accepted scientific method for naming the organisms.
- Fossils are very useful in geology. They are used to know pre-historic life and its evolution, to date the rocks, to determine the ancient geography, climate, and environment and also for discovering and correlating oil and coal deposits.

TERMINAL QUESTIONS

1. What are fossils? Describe various types of fossils.
2. Explain how fossils are preserved.
3. What is taxonomy? How are the organisms arranged in taxonomic hierarchy?
4. Give a brief account of the codes of biological nomenclature. Discuss the code of nomenclature in naming the species.
5. Write the importance of fossils in Geology? Discuss in detail.

Self-Assessment Question

- 1 a) We find fossils in the sedimentary rocks. Since these rocks are formed by a slow process of layer by layer deposition of sediments carried by rivers and streams into oceans and other water bodies they are suitable for the preservation of fossils.
b) The science of fossils is known as palaeontology. Invertebrate palaeontology, vertebrate palaeontology, micropalaeontology, palaeobotany and palynology are the main branches of palaeontology.
c) Body and trace fossils are the main types of fossils. The other types of fossils are chemical fossils, macrofossils, microfossils, nanofossils, index fossils and living fossils. Pseudofossils are a false impression of fossils.
d) Past life.
e) False fossils.
- 2 a) italics, underlined.
b) genus, trivial name, name of the species.

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