Bachelor of Science
DCEBY -109
Paleobotany, Palynology and Economic Botany

Uttar Pradesh Rajarshi Tandon
Open University

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Block -1
Paleobotany and Palynology

Course Design Committee

Prof. Ashutosh Gupta **Chairman**
Director, School of Science
UPRTOU, Prayagraj.

Dr. Anil Tiwari **Member**
Botany Department
Ewing Christen College.
Prayagraj

Dr. Preeti Singh **Member**
Botany Department
S.S.K.P.G. College
Prayagraj.

Dr. Sushma Chauhan **Member/Secretary**
Asst. Prof. (Contractual) Botany
School of Science, UPRTOU, Prayagraj.

Course Preparation Committee

Dr. Rajivranjan **Author**
Assistant Professor **Block- 01 – 03** (Unit: 01- 08)
Department of Botany
MLK PG College, Balrampur (U.P)

Dr. Arun Kumar Pandey **Editor**
Associate Professor, **(All blocks and units)**
Department of Botany
PSM PG College, Anand Nagar, Maharajganj (U.P)

Dr. Sushma Chauhan **Coordinator**
Asst. Prof. (Contractual) Botany
School of Science, UPRTOU, Prayagraj.

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COURSE INTRODUCTION

The objective of this course is to provide basic introduction and concept to paleobotany, palynology and economic botany.

Paleobotany is the study of fossil plants, i.e the plant existated in the past which are now extinct the term fossil came from the latin word fossilis which means to dig : Thus in the original sence a fossilis something occurring in the earth and is requiring to be dig out. Schopf (1975) : "defined the fossil as any specimen that demonstrate the physical evidence of the occurrence of ancient life."

The term palynology was coined by Hyde and Williams in 1945 for the study of pollen grains and spores but now this concept is changed and the study of all organisms which come under spore pollen size range come under the study of palynology. Thus besides spore and pollen grain it incudes algae like *Diatoms, Dinoflagellates,* fungal elements, fragments of larger plants such as tissues and cells.

Economic botany is the study of the relationship between people (individuals and cultures) and plants. Economic botany intersects many fields including established disciplines such as agronomy, anthropology, archaeology, chemistry, economics, ethnobotany, ethnology, forestry, genetic resources, geography, geology, horticulture, medicine, microbiology, nutrition, pharmacognosy, and pharmacology. This link between botany and anthropology explores the ways humans use plants for food, medicines, and commerce. The course is organized into following two blocks as under:

This course is divided into two blocks 1 and 2.

Block 1 Paleobotany and palynology is divided into three units as under:

Unit-1: Introduction and techniques to study of fossils.

Unit-2: Kinds of fossils and reconstruction of fossil

Unit-3: Concept and scope of palynology

Block 2 Economic botany is divided into five units as under:

Unit-4: Spices and flavoring materials

Unit-5: Beverages

Unit-6: Fibers

Unit-7: Forest products

Unit-8: Medicinal plants

Block I Paleobotany and palynology

This is the first block on paleobotany and palynology. Paleobotany, which is also spelled as palaeobotany, is the branch of botany dealing with the recovery and identification of plant remains from geological contexts, and their use for the biological reconstruction of past environments (paleogeography), and the evolutionary history of plants, with a bearing upon the evolution of life in general. A synonym is paleophytology. It is a component of paleontology and paleobiology. Paleobotany includes the study of terrestrial plant fossils, as well as the study of prehistoric marine photoautotrophs, such as photosynthetic algae, seaweeds or kelp. A closely related field is palynology, which is the study of fossilized and extant spores and pollen. Paleobotany is important in the reconstruction of ancient ecological systems and climate, known as paleoecology and paleoclimatology respectively; and is fundamental to the study of green plant development and evolution. Paleobotany has also become important to the field of archaeology, primarily for the use of phytoliths in relative dating and in paleoethnobotany.

Paleobotany has also played a key role in many areas of geology, especially in biostratigraphy–placing rock units in stratigraphic order based on the fossils within them. Pollen grains and spores (one aspect of palynology) have been extensively used as index fossils in biostratigraphy and in the correlation of rock units, as have various forms of algal cells and cysts. In some instances, megafossils, such as leaves and seeds, have also provided a method of correlating rock units which are widely separated geographically. Pollen and spores, as well as megafossils, are especially useful in correlating terrestrial rocks, as these are generally deposited in limited areas (former lakes, ponds, river systems, etc.), making correlation by lithology (i.e., rock characteristics) very difficult. The block 1st is organized into following three units as under:

Unit 1

It covers the introduction and techniques to study of fossils.

Unit 2

It covers the kinds of fossils and reconstruction of fossil.

Unit 3

To know the concept and scope of palynology.

Objectives

After studding this block you will be able to-

- Know techniques for the study of fossils
- Know about fossils and their types
- Reconstruct the fossils
- Understand palynology and their scopes

Unit-1: Introduction and Techniques to Study of Fossil

Structure

1.1 Introduction

Paleobotany today is a highly integrated interdisciplinary endeavor. A paleobotanist 50 years ago needed only geology and plant biology to study fossil plants. However, we now realize that research areas such as geochemistry, molecular biology, microbiology, biomechanics, phylogeny, etc. are transforming our approaches to, and perception of, the analysis of fossil plants and ecosystems, and some of these once-so-remote research areas are becoming increasingly important for, and integral parts of, paleobotanical research. The present volume exemplifies the potential of utilizing interdisciplinary research in the advancement of paleobiological inquiry. As such, the volume represents a blueprint for paleobotany of the 21st century.

Paleobotany is the scientific study of ancient plants, using plant fossils found in sedimentary rocks. These fossils can be impressions or compressions of the plants left on the rock's surface, or "petrified" objects, such as wood, which preserve the original plant material in rocklike form. Still other specimens are found in calcified lumps called coal balls, so named because they are usually found in or near coal deposits. Paleoecology is the scientific study of past environments. Paleoecologists are interested in the ecosystem as a whole and derive their understanding of past environments from different lines of evidence, including fossil plants and animals, ancient soils and rocks. This field of study is important for anyone interested in past organisms because it provides the context for understanding the origin, extinction and adaptation of any particular organism.

Objectives

This is the first unit on paleobotany, palynology and economic botany. Under first unit, we have following objectives. These are as under:

- To know about prehistoric plants and paleobotany.
- To know about fossils, its preservation and fossilization process.
- To know about carbonization and coalification.
- To know about geological time scale
- To know about eons, eras, periods and epochs.

Paleobotany allows us to know about the types of plants that lived long ago. It helps us to know more about what life on Earth was like in the distant past. Learn more about this fascinating science in this lesson!

1.2 Prehistoric Plants

What kinds of plants might a hungry dinosaur have eaten? When did flowers first appear on Earth? How did plants contribute to the formation of Earth's current atmosphere? All these questions, and many more, can be answered by the scientific field of paleobotany.

Fig. 1 When did flowers first appear on Earth? Paleobotany has the answer

What exactly IS paleobotany? Well, *botany* is the study of plants, while the prefix *paleo* comes from the Greek word *paleon* which means old, so paleobotany is the study of the plants that lived long ago. It is one half of a larger branch of science called paleontology which studies the history of life on Earth more generally. Paleobotany specifically focuses on the study of plant life, while paleozoology focuses on animal life.

We can learn a lot about the environment during prehistoric times by studying the types of plants that grew then. Fossilized plant life tells a story of how the Earth has changed over time. Studying plants can even tell us important information about the animals that lived long ago. Many animals, both today and in the past, eat a variety of plants, so learning about plants also gives new insights into the animals that ate them.

1.3 The History of Paleobotany

Paleobotany has a long history in the world of science. Plant fossils are usually easily recognizable, and people throughout the world have been finding and collecting them for hundreds of years. By the early 1700s, several books had already been published that included illustrations of plant fossils. One of these, the *Herbarium Diluvianum*, included very detailed images and descriptions of fossilized plants collected from England, Germany, and Switzerland. At the time of its publication, this book represented the most comprehensive study of ancient plant life that had ever existed.

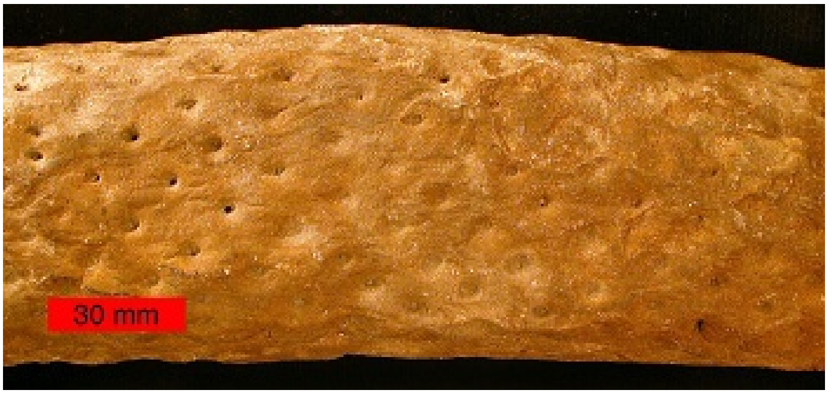

Fig. 2 A fossilized tree root excavated from a site in Ohio.

Interest in paleobotany continued to grow over the next hundred years, and by the 1800s, scientists had begun to publish books containing much more specialized information about specific types of plants or the plants that grew in a certain region of the Earth. They had begun to recognize that it was possible to gather detailed information about the climate of the past just by examining fossilized plants.

Even the famous naturalist Charles Darwin recognized the importance of paleobotany. Although today, more attention is paid to Darwin's ideas about the evolution of animals, he was interested in plant evolution as well. He believed that a lot of information about the past could be learned using the tools of paleobotany. He was certainly right! The study of paleobotany really took off in the last few years of the nineteenth century and has continued to the present day. This was mainly due to the prevalence of coal mining during this time. Many, many plant fossils were discovered throughout the world during the process of mining for coal, and the number of scientists who studied these fascinating fossils grew and grew as a result.

1.4 What Have We Learned From Paleobotany?

Paleobotanists have been able to learn a lot about the progression of life on Earth by studying the plants that lived long ago. We now know that the first land plants began to grow on Earth about 700 million years ago. This was LONG before any animals were able to survive on land, and in fact, the presence of these early plants probably played a big role in making the Earth's atmosphere more hospitable for animal life. Just like plants that live today, these prehistoric plants removed carbon dioxide from the atmosphere and released oxygen, changing the atmosphere and making it more likely that animals would be able to survive on land as well.

Paleobotany also tells us that the first trees evolved by about 385 million years ago. These were actually more like very large ferns, because plants did not produce seeds or flowers yet, but they were much taller than any plants that had come before. Flowering plants, which account for more than 90 percent of all the plants on Earth today, appeared relatively recently in the fossil record, about 140-130 million years ago.

Fig. 3 Paleobotany and paleoecology are related fields of study into ecological conditions of the past.

Fig. 4 Paleobotanical collection

Macroscopic remains of true vascular plants are first found in the fossil record during the Silurian Period of the Paleozoic era. Some dispersed, fragmentary fossils of disputed affinity, primarily spores and cuticles, have been found in rocks from the Ordovician Period in Oman, and are thought to derive from liverwort- or moss-grade fossil plants. An important early land plant fossil locality is the Rhynie Chert, found outside the village of Rhynie in Scotland. The Rhynie chert is an Early Devonian sinter (hot spring) deposit composed primarily of silica. It is exceptional due to its preservation of several different clades of plants, from mosses and lycophytes to more unusual, problematic forms. Many fossil animals, including arthropods and arachnids, are also found in the Rhynie Chert, and it offers a unique window on the history of early terrestrial life.

Plant-derived macrofossils become abundant in the Late Devonian and include tree trunks, fronds, and roots. The earliest tree was thought to be *Archaeopteris*, which bears simple, fern-like leaves spirally arranged on branches atop a conifer-like trunk, though it is now known to be the recently discovered *Wattieza*. Widespread coal swamp deposits across North America and Europe during the Carboniferous Period contain a wealth of fossils containing arborescent lycopods up to 30 meters tall, abundant seed plants, such as conifers and seed ferns, and countless smaller, herbaceous plants. Angiosperms (flowering plants) evolved during the Mesozoic, and flowering plant pollen and leaves first appear during the Early Cretaceous, approximately 130 million years ago.

1.4.1 Plant fossils

A plant fossil is any preserved part of a plant that has long since died. Such fossils may be prehistoric impressions that are many millions of years old, or bits of charcoal that are only a few hundred years old. Prehistoric plants are various groups of plants that lived before recorded history (before about 3500 BC).

1.4.2 Preservation of plant fossils

Plant fossils can be preserved in a variety of ways, each of which can give different types of information about the original parent plant.

1. **Adpressions (compressions – impressions).** These are the most commonly found type of plant fossil. They provide good morphological detail, especially of dorsiventral (flattened) plant parts such as leaves. If the cuticle is preserved, they can also yield fine anatomical detail of the epidermis. Little other detail of cellular anatomy is normally preserved.
2. **Petrifactions (permineralisations or anatomically preserved fossils).** These provide fine detail of the cell anatomy of the plant tissue. Morphological detail can also be determined by serial sectioning, but this is both time consuming and difficult.
3. **Moulds and casts.** These only tend to preserve the more robust plant parts such as seeds or woody stems. They can provide information about the three-dimensional form of the plant, and in the case of casts of tree stumps can provide evidence of the density of the original vegetation. However, they rarely preserve any fine morphological detail or cell anatomy. A subset of such fossils are **pith casts**, where the centre of a stem is either hollow or has delicate pith. After death, sediment enters and forms a cast of the central cavity of the stem. The

best known examples of pith casts are in the Carboniferous Sphenophyta (*Calamites*) and cordaites (*Artisia*).

4. **Authigenic mineralisations.** These can provide very fine, three-dimensional morphological detail, and have proved especially important in the study of reproductive structures that can be severely distorted in adpressions. However, as they are formed in mineral nodules, such fossils can rarely be of large size.
5. **Fusain**. Fire normally destroys plant tissue but sometimes charcoalified remains can preserve fine morphological detail that is lost in other modes of preservation; some of the best evidence of early flowers has been preserved in fusain. Fusain fossils are delicate and often small, but because of their buoyancy can often drift for long distances and can thus provide evidence of vegetation away from areas of sedimentation.

1.5 Fossil groups of plants

Some plants have remained almost unchanged throughout earth's geological time scale. Horsetails had evolved by the Late Devonian, early ferns had evolved by the Mississippian, conifers by the Pennsylvanian. Some plants of prehistory are the same ones around today and are thus living fossils, such as *Ginkgo biloba* and *Sciadopitys verticillata*. Other plants have changed radically, or became extinct.

Examples of prehistoric plants are:

Name of prehistoric plants	
• Araucaria mirabilis	• Nelumbo aureavallis
• Calamites	• Pachypteris
• Dillhoffia	• Palaeoraphe
• Glossopteris	• Peltandra primaeva
• Araucaria mirabilis	• Protosalvinia
• Hymenaea protera	• Trochodendron nastae

1.6 Fossils

A fossil is any preserved remains, impression, or trace of any once-living thing from a past geological age. Examples include bones, shells, exoskeletons, stone imprints of animals or microbes, objects preserved in amber, hair, petrified wood, oil, coal, and DNA remnants. The totality of fossils is known as the *fossil record*. Paleontology is the study of fossils: their age, method of formation, and evolutionary significance. Specimens are usually considered to be fossils if they are over 10,000 years old. The oldest fossils are around 3.48 billion years old to 4.1 billion years old. The observation in the 19th century that certain fossils were associated with certain rock strata led to the recognition of a geological timescale and the relative ages of different fossils. The development of radiometric dating techniques in the early 20th century allowed scientists to quantitatively measure the absolute ages of rocks and the fossils they host. There are many processes that lead to fossilization, including permineralization, casts and molds, authigenic mineralization, replacement and recrystallization, adpression, carbonization, and bioimmuration.

Fossils vary in size from one-micrometre (1 µm) bacteria to dinosaurs and trees, many meters long and weighing many tons. A fossil normally preserves only a portion of the deceased organism, usually that portion that was partially mineralized during life, such as the bones and teeth of vertebrates, or the chitinous or calcareous exoskeletons of invertebrates. Fossils may also consist of the marks left behind by the organism while it was alive, such as animal tracks or feces (coprolites). These types of fossil are called trace fossils or *ichnofossils*, as opposed to *body fossils*. Some fossils are biochemical and are called *chemofossils* or biosignatures.

1.7 Fossilization processes

The process of fossilization varies according to tissue type and external conditions.

1.7.1 Permineralization

Permineralization is a process of fossilization that occurs when an organism is buried. The empty spaces within an organism (spaces filled with liquid or gas during life) become filled with mineral-rich groundwater. Minerals precipitate from the groundwater, occupying the empty spaces. This process can occur in very small spaces, such as within the cell wall of a plant cell. Small scale permineralization can produce very detailed fossils. For permineralization to occur, the organism must become covered by sediment soon after death, otherwise the remains are destroyed by scavengers or decomposition.The degree to which the remains are decayed when covered determines the later details of the fossil. Some fossils consist only of skeletal remains or teeth; other fossils contain traces of skin, feathers or even soft tissues.This is a form of diagenesis.

1.7.2 Casts and molds

In some cases, the original remains of the organism completely dissolve or are otherwise destroyed. The remaining organism-shaped hole in the rock is called an *external mold*. If this void is later filled with sediment, the resulting *cast* resembles what the organism looked like. An endocast, or *internal mold*, is the result of sediments filling an organism's interior, such as the inside of a bivalve or snail or the hollow of a skull. Endocasts are sometimes termed *Steinkerns*, especially when bivalves are preserved this way.

1.7.3 Authigenic mineralization

This is a special form of cast and mold formation. If the chemistry is right, the organism (or fragment of organism) can act as a nucleus for the precipitation of minerals such as siderite, resulting in a nodule forming around it. If this happens rapidly before significant decay to the organic tissue, very fine three-dimensional morphological detail can be preserved. Nodules from the Carboniferous Mazon Creek fossil beds of Illinois, USA, are among the best documented examples of such mineralization.

1.7.4 Replacement and recrystallization

Replacement occurs when the shell, bone, or other tissue is replaced with another mineral. In some cases mineral replacement of the original shell occurs so gradually and at such fine scales that microstructural features are preserved despite the total loss of original material. A shell is said to be *recrystallized* when the original skeletal compounds are still present but in a different crystal form, as from aragonite to calcite.

1.7.5 Adpression (compression-impression)

Compression fossils, such as those of fossil ferns, are the result of chemical reduction of the complex organic molecules composing the organism's tissues. In this case the fossil consists of original material, albeit in a geochemically altered state. This chemical change is an expression of diagenesis. Often what remains is a carbonaceous film known as a phytoleim, in which case the fossil is known as a compression. Often, however, the phytoleim is lost and all that remains is an impression of the organism in the rock—an impression fossil. In many cases, however, compressions and impressions occur together. For instance, when the rock is broken open, the phytoleim will often be attached to one part (compression), whereas the counterpart will just be an impression. For this reason, one term covers the two modes of preservation: *adpression*.

1.7.6 Soft tissue, cell and molecular preservation

Because of their antiquity, an unexpected exception to the alteration of an organism's tissues by chemical reduction of the complex organic molecules during fossilization has been the discovery of soft tissue in dinosaur fossils, including blood vessels, and the isolation of proteins and evidence for DNA fragments. In 2014, Mary Schweitzer and her colleagues reported the presence of iron particles (goethite-aFeO(OH)) associated with soft tissues recovered from dinosaur fossils. Based on various experiments that studied the interaction of iron in haemoglobin with blood vessel tissue they proposed that solution hypoxia coupled with iron chelation enhances the stability and preservation of soft tissue and provides the basis for an explanation for the unforeseen preservation of fossil soft tissues. However, a slightly older study based on eight taxa ranging in time from the Devonian to the Jurassic found that reasonably well-preserved fibrils that probably represent collagen were preserved in all these fossils and that the quality of preservation depended mostly on the arrangement of the collagen fibers, with tight packing favoring good preservation.There seemed to be no correlation between geological age and quality of preservation, within that timeframe.

1.7.7 Carbonization and coalification

Fossils that are carbonized or coalified consist of the organic remains which have been reduced primarily to the chemical element carbon. Carbonized fossils consist of a thin film which forms a silhouette of the original organism, and the original organic remains were typically soft tissues. Coalified fossils consist primarily of coal, and the original organic remains were typically woody in composition.

1.8 Techniques for the Study of Fossils:

The following points highlight six main sophisticated techniques which are employed these days to study the fossils in laboratory. The techniques are:

1. Ground Thin Section Technique
2. Peel Technique
3. Transfer Technique
4. Maceration Technique
5. X-ray Technique
6. Microtomy Technique.

1. Ground Thin Section Technique:

The specimen to be studied is cut into small-sized sections. Its surfaces are smoothed with 400-carborundum. The smooth surface of the section of the specimen is mounted on a glass slide. It is warmed and coated with melted resin. The latter hardens upon cooling. The fastened specimens are cut to form very thin slices which are ground on revolving 100-carborundum lap. Liquid resin-mounting medium is used for mounting the sections.

2. Peel Technique:

The first step of this technique involves the etching of the fossil surface with the help of some mineral acids (e.g., hydrofluoric acid) and the final step involves transfer of the exact fossil structure. Another mixture usually used for etching is prepared by mixing butyl acetate (1000ml), nitrocellulose (115gm), toluol (10ml), amyl alcohol (200ml) and dehydrated castor oil (5ml). Before using for etching purposes, this mixture is aged for at least two weeks. After etching the specimen surface is washed with water, dried and covered with nitrocellulose. Wait for a few hours. The so formed film will dry during this period. It is peeled off from the specimen and studied.

3. Transfer Technique:

Delicate fossil materials are studied by this technique. Several methods are used in the form of transfer technique In the Ash by cellulose film transfer method, peel solution is coated on the delicate fossil material adjoining the rock surface. When the solution dries, the portion of the rock having fossil material is removed. 25% hydrofluoric acid is then used for dissolving the rock material.

4. Maceration Technique:

In the usual method of maceration technique, the fossil material is immersed in a mixture of 5% KOH and Cone. HNO_3 for one week. The material is then washed thoroughly with water so that the acid is completely removed. It is then incubated with the solution of NaOH. Hydrofluoric acid is used for cleaning the thus separated cuticularized parts of the fossil material.

5. X-ray Technique:

Highly sensitive celluloid films are used to obtain X-ray photographs of the fossil specimens.

6. Microtomy Technique:

Fossil specimens, specially their macerated tissues, are embedded in celloidin or wax before microtomy. Sectioning of the embedded material is done by usual process of microtomy. The sectioned materials are stained and studied.

1.9 Conditions of Fossilisation:

It is a rare instance that an organism is preserved intact. Most of the known fossils are imperfect, where only external features are preserved. The perfect permineralised fossils showing cellular details are very rare.

The conditions for perfect fossilisation process can be categorised under the following heads:

1. Sites of fossilisation.
2. Nature of the tissue undergoing fossilisation.
3. Events that occur before, during and after fossilisation.

1. Sites of Fossilisation:

The preservation of plants depends on removing the organic materials from the zone of aerobic decomposition. This can most easily be 15 accomplished by burying the plants in enclosed water reservoir in which sediments accumulate on the surface at a fast rate. Therefore, swamps, deltas, lakes, lowland flood plains are good sites for fossilisation.

2. Nature of the Tissue Undergoing Fossilisation:

The extent of preservation is directly proportional to the mechanical resistance of the cells, tissues and organs undergoing fossilisation. Thin-walled soft organs like flowers, juicy fruits, thin delicate leaves are unsuitable for preservation, while thick walled hard organs like stem, seeds etc. are preserved as compressions, casts or petrifactions for their resistant nature.

Plant cell walls primarily comprising of cellulose together with hemicellulose, lignin and suberin are far more resistant to decomposition. Cutinised epidermal layers of leaf, sporopolleninous exine of spores and pollen grains, siliceous wall of diatoms, hard skeletal parts of calcareous algae, suberised bark layers are better preserved for their high degree of resistance to destruction. In a similar way, soft tissues like cortex, phloem and xylem parenchyma, sieve tubes, pith, etc., are rapidly decayed by 16 microorganisms, while hard tissues such as tracheary elements, fibres, sclerenchyma, etc. are well preserved.

3. Events that Occur before, during and after Fossilisation:

(a) Events that Occur before Fossilisation:

Plant parts undergoing fossilisation must be deposited in an enclosed or protected water reservior in which fine-grained sediments accumulate on the surface with sufficient rapidity to cause quick burial. In deep water body, the oxygen content is low, thus the intensity of microbial disintegration is also very low. Moreover, environment rich in humic acids and clay minerals can retard decay by blocking the chemical sites onto which decomposers fasten their degrading enzymes. The plant parts must be preserved in situ (autochthonas deposition) which provides an environment with minimum destruction of plant parts. On the other hand, transportation of plant parts (allochthonas deposition) for long distance results in breakage and decay.

(b) Events that Occur during Fossilisation:

17 A plant part is subjected to many factors during the course of fossilisation which ultimately determines the characteristic of a fossil. The depth of water in which the plant parts sink is important, because it can avoid two disintegrative forces such as (a) decay and hydrolysis, (b) mechanical action of water, wind, scouring (rubbing action) sand, and rolling stones. The activities of bacteria and saprophytic fungi are greatly reduced, because in deep water the concentration of decomposers are very poor.

Moreover, it affords good protection from wave action as intensive wave action or rolling boulders can reduce even the most resistant plant tissues to pulp. The sediment that accumulates on the surface of plant part is usually of fine textures, such as clay, silt or fine sand favouring good preservation in greater details. Most decomposers are aerobic and require oxygen for their metabolism. In deep water, oxygen content is low and plant parts are generally preserved in such anaerobic sediments. Thus, low oxygen content, and relatively high concentration of toxic substances also retard decay and hydrolysis. 18 The cells of the plant parts must be quickly filled with mineral deposits to avoid pilling up of the overlaying sediments.

(c) Events that Occur after Fossilisation:

Well-preserved fossils may suffer severe damages during destructive processes of earth, such as seismic activity, earthquake, volcanic eruption, etc., at the sites of their origin. Thus, undisturbed sediments provide a proper fossil record.

1.10 Geological time scale

Now that you have learned about the hierarchical components of the geological time scale--eons, eras, periods, and epochs--consider again how all of these parts fit together. Note that some boundaries (those that follow horizontal lines on the time scale) are equivalent in age. For example, the Mesozoic-Cenozoic boundary is equivalent to the Cretaceous-Paleogene boundary (both have an age of 66 Ma). Similarly, the Paleogene-Neogene boundary is equivalent to the Oligocene-Miocene boundary.

It is much easier to memorize the time scale by first breaking it down into its component parts. Many geology students have developed clever mnemonic devices to help remember all of the names in the time scale and a quick Google search will provide many examples (which are often rather salty!) that you may find helpful as you memorize the time scale.

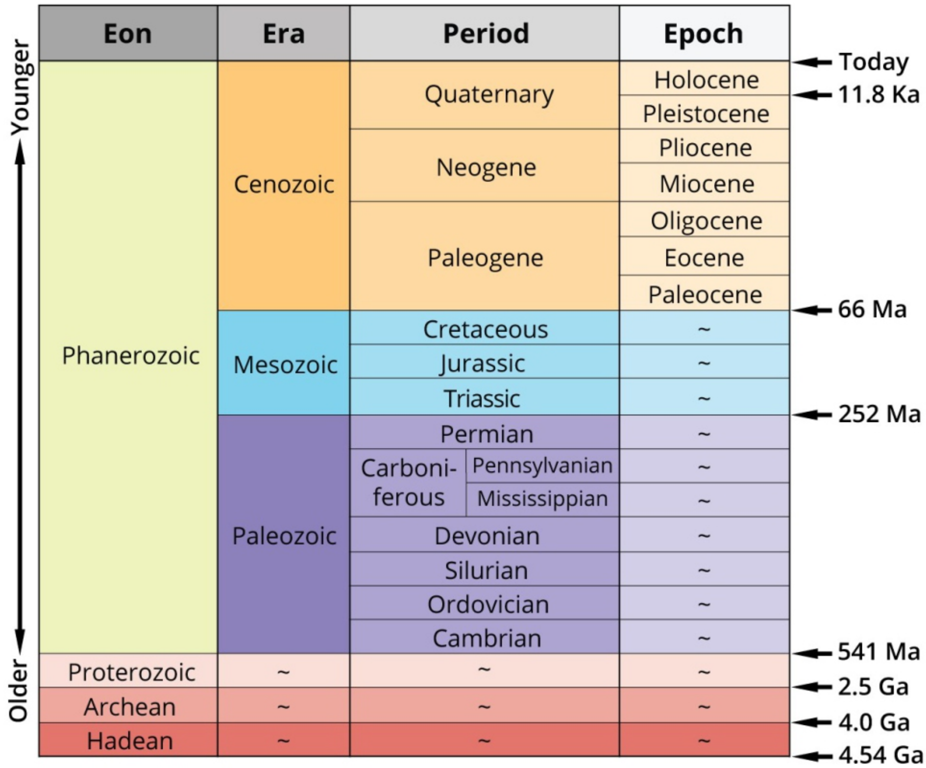

Fig. 5 The geological time scale

The geological time scale--shown above in a simplified form--is one of the crowning achievements of science in general and geology in particular. It is a reference and communication system for comparing rocks and fossils from throughout the world and is geology's equivalent of the periodic table of the elements. For example, a paleontologist can call her colleague and say, "I just found an awesome new trilobite from the Devonian of New York" and her colleague will immediately understand when in geological time that trilobite lived.

Most of the boundaries on the geological time scale correspond to the origination or extinction of particular kinds of fossils. Knowing when major groups of fossils first appeared or went extinct is therefore incredibly useful for determining the ages of rocks in the field. For example, if you find a rock with a trilobite fossil upon it, you will immediately know that the rock is Paleozoic in age (541 Ma to 252 Ma) and not older or younger; knowing the species of trilobite allows even greater precision.

This relates to a third important principle of relative age dating the principle of faunal succession. Faunal succession is the principle that different kinds of fossils characterize different intervals of time. This is because evolution and extinction are facts of nature. The principle of faunal succession was developed by an English surveyor named William "Strata" Smith (1769-1839). As he studied layers of rocks to determine where to build canals, he noticed that he found the same ordering of fossil species from place to place; Fossil A was always found below Fossil B, which in turn was always found below Fossil C, and so on. By documenting these sequences of fossils, Smith was able to temporally correlate rock layers (or, strata) from place to place (in other words, to establish that rock layers in two different places are equivalent in age based upon the fact that they include the same types of fossils). Temporal correlation allowed Smith to construct the first geological map of an entire country.

Temporal correlation has made many people very, very rich by allowing them to predict the locations of valuable geological resources such as fossil fuels. More generally, it has allowed us to reconstruct the geological history of Earth by comparing rocks and fossils from place to place. This is critically important because no single place on Earth preserves a complete geological history, or even a small fraction of it. The geological time scale provides a global summary of countless small-scale temporal correlations of rock layers made at local and regional scales. It is based almost entirely upon careful observations of the distributions of fossils in time and space.

1.11 Learning the geological time scale

Because of its usefulness for communicating about events in Earth's history, it is important that all students of geology, paleontology, and evolutionary biology commit the geological time scale to memory. This is most easily done by first breaking the time scale into its component parts: eons, eras, periods, and epochs.

1.12 Eons

The eon is the broadest category of geological time. Earth's history is characterized by four eons; in order from oldest to youngest, these are the Hadeon, Archean, Proterozoic, and Phanerozoic. Collectively, the Hadean, Archean, and Proterozoic are sometimes informally referred to as the "Precambrian." (The Cambrian period defines the beginning of the Phanerozoic eon; so, all rocks older than the Cambrian are Precambrian in age.)

We live during the Phanerozoic, which means "visible life." This is the interval of geological time characterized by abundant, complex fossilized remains. Being the youngest eon of time, it is also very well represented by rock at Earth's surface. Because of these two factors, most paleontologists and geologists study fossils and rocks from the Phanerozoic eon. Do not let the time scale at the top of this page give you a false impression, however, about the temporal duration of the Phanerozoic eon relative to the three older Precambrian eons. Note in the figure below the absolute ages of the boundaries separating each eon of time.

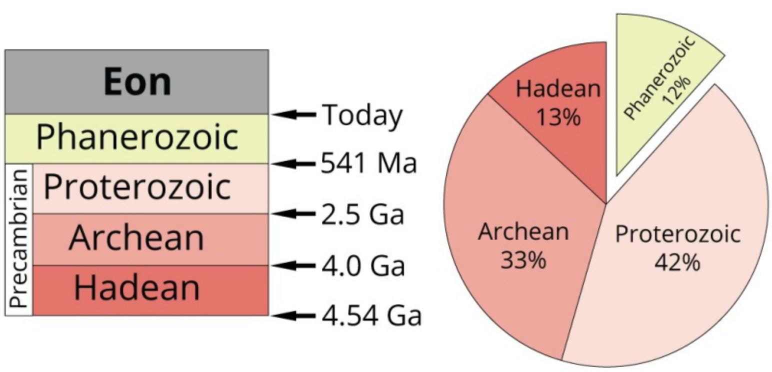

Fig. 6 Left: the four eons of geological time. Right: the "Precambrian" eons (Hadean, Archean, and Proterozoic) represent 88% of geological time

You have already learned that the Earth is 4.54 billion years old. The Phanerozoic eon began 541 million years ago (or, 0.541 billion years ago). Thus, the Phanerozoic eon represents a paltry 12% of Earth's history! Instead, most of Earth's history is represented by the three Precambrian eons. These older eons tell the story of Earth's beginning, life's origin, and the rise of complex life.

The Hadean and Archean are difficult eons to study, however, because they are exposed in very limited places on Earth's surface. (Since they are the oldest eons, rocks that are Hadean and Archean in age are often buried far below younger rocks at Earth's surface.) Proterozoic rocks--which span nearly 2 billion years (42% of Earth's history)--are much more accessible, but, until recently, have received significantly less attention from paleontologists than rocks from the younger, fossil-rich Phanerozoic eon. That is slowly beginning to change, however, as more clues about the origins of complex life begin to be revealed from Proterozoic-aged rocks.

1.13 Eras

Eons of geological time are subdivided into eras, which are the second-longest units of geological time. The phanerozoic eon is divided into three eras: the Paleozoic, Mesozoic, and Cenozoic.

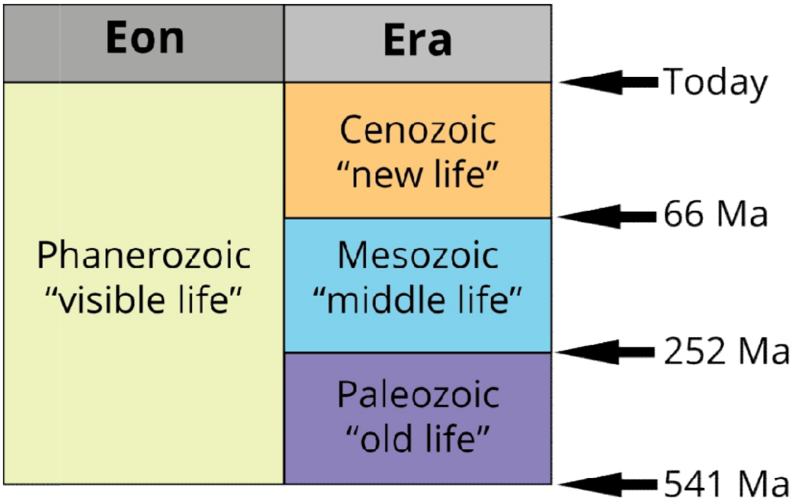

Fig. 7 The three eras of the Phanerozoic eon. Image by Jonathan R. Hendricks.

Most of our knowledge of the fossil record comes from the three eras of the Phanerozoic eon. The Paleozoic ("old life") era is characterized by trilobites, the first four-limbed vertebrates, and the origin of land plants. The Mesozoic ("middle life") era represents the "age of dinosaurs," though also is noteworthy for the first appearances of mammals and flowering plants. Finally, the

Cenozoic ("new life") era is sometimes called the "age of mammals" and is the era during which we live today.

As temporal points of reference, it is worth memorizing the ages of the boundaries that separate the three eras of the Phanerozoic eon. Long before geologists knew these absolute age dates, they realized that the boundaries represent important events in the history of life: mass extinctions. For example, many fossils that are commonly found in the youngest Paleozoic rocks are not found in overlying Mesozoic rocks. Similarly, dinosaur fossils found in the youngest Mesozoic rocks are never again found in the overlying Cenozoic rocks. Paleontologists and geologists used these mass extinction events to define these (and other) boundaries within the Phanerozoic portion of the geological time scale. It is therefore no coincidence that some of the major boundaries coincide with mass extinction events! The older Archean and Proterozoic eons are similarly divided into several eras. For example, the youngest era of the Proterozoic eon is called the Neoproterozoic. For the sake of simplicity, these older eras are not included on the time scale shown at the top of this page; they do, however, exist!

1.14 Periods

Just as eons are subdivided into eras, eras are subdivided into units of time called periods. The most well known of all geological periods is the Jurassic period of the Mesozoic era (the movie Jurassic Park, of course, has something to do with that). The Paleozoic era is divided into six periods. From oldest to youngest, these are the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian. Note that in the United States, the Carboniferous is divided into two separate periods: the Mississippian and the Pennsylvanian.

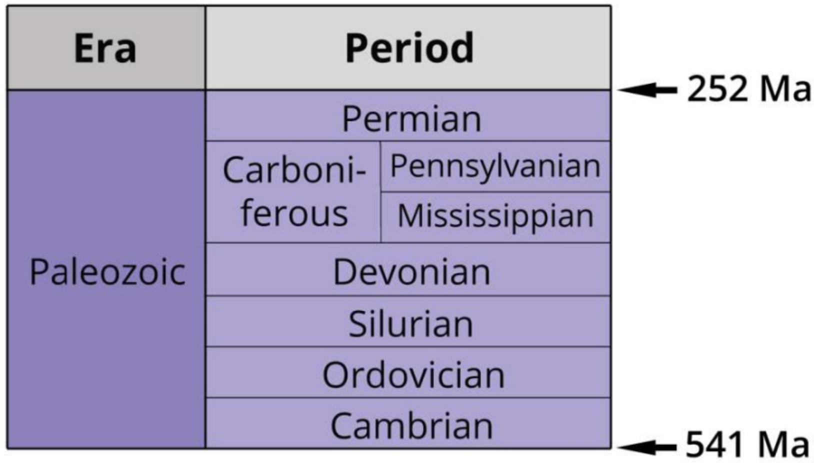

Fig. 8 The seven periods of the Paleozoic era. Image by Jonathan R. Hendricks.

The Mesozoic era is divided into the Triassic, Jurassic, and Cretaceous periods.

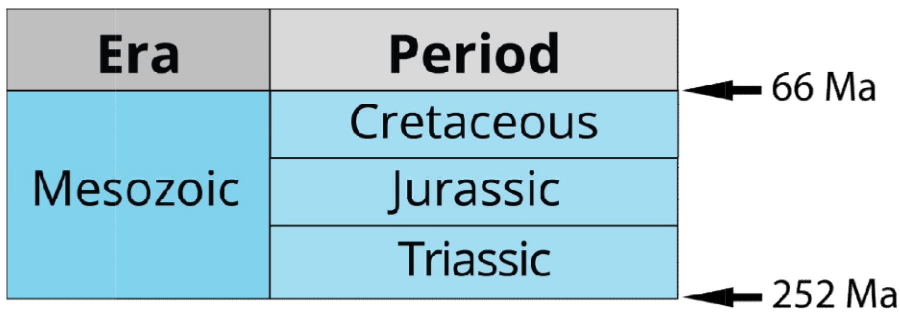

Fig. 9 The three periods of the Mesozoic era. Image by Jonathan R. Hendricks

Finally, the Cenozoic era is divided into three periods: the Paleogene, Neogene, and Quaternary.

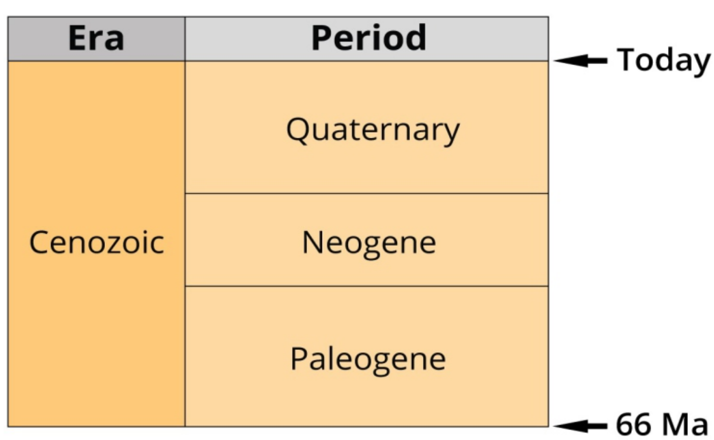

Fig. 10 The three periods of the Cenozoic era

1.15 Epochs and Ages

Periods of geological time are subdivided into epochs. In turn, epochs are divided into even narrower units of time called ages. For the sake of simplicity, only the epochs of the Paleogene, Neogene, and Quaternary periods are shown on the time scale at the top of this page. It is important to note, however, that all of the periods of the Phanerozoic era are subdivided into the epochs and ages.

The Paleogene period is divided into--from oldest to youngest--the Paleocene, Eocene, and Oligocene epochs. The Neogene is divided into the Miocene and Pliocene epochs. Finally, the Quaternary is divided into the Pleistocene and Holocene epochs. Some geologists now think that--since humans are having such a notable impact on the Earth and its life--a new, youngest epoch should be added to the Quaternary: the Anthropocene. There is still considerable discussion in the geological community about whether this epoch should be added, as well as debate about what characteristics should define its beginning.

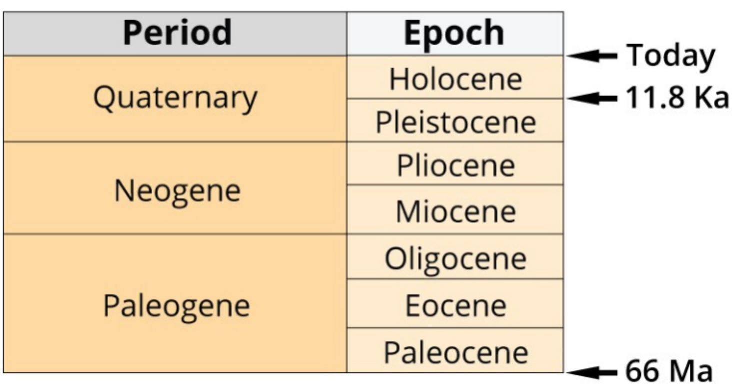

Fig. 11 Epochs of the Paleogene, Neogene, and Quaternary periods.

1.16 Summary

Under this unit we have summarized concept of paleobotany, fossilization process, geological time scale and about eras, periods and epochs. Paleobotany today is a highly integrated interdisciplinary endeavor. A paleobotanist 50 years ago needed only geology and plant biology to study fossil plants. However, we now realize that research areas such as geochemistry, molecular biology, microbiology, biomechanics, phylogeny, etc. are transforming our approaches to, and perception of, the analysis of fossil plants and ecosystems, and some of these once-so-remote research areas are becoming increasingly important for, and integral parts of, paleobotanical research.

Paleobotany has also played a key role in many areas of geology, especially in biostratigraphy–placing rock units in stratigraphic order based on the fossils within them. Pollen grains and spores (one aspect of palynology) have been extensively used as index fossils in biostratigraphy and in the correlation of rock units, as have various forms of algal cells and cysts. In some instances, megafossils, such as leaves and seeds, have also provided a method of correlating rock units which are widely separated geographically.

Fossilization is an extremely rare process that occurs in some sedimentary environments and causes the hard remains of plants or animals to be preserved as fossils in the earth's crust. Prior to fossilization, most organic materials are not very durable. However, they can become hardened as the animal or plant tissues are recrystallized or slowly replaced by minerals. Gem materials from fossilized organic materials include petrified wood, amber, jet and iridescent nacre (ornamental mother-of-pearl). Ancient trees buried in sediments or volcanic ash may petrify when silica-rich water circulates through the wood and slowly replaces its cellular structure with jasper, chalcedony and, less commonly, opal. Fossilized or petrified wood is used mostly for ornamental and decorative objects. It is hard and durable enough for cutting and polishing and occurs in various shades of red, gray-blue, yellow, dull green, or white due to the presence of elements such as manganese, iron, and copper in the water and sediment during the fossilization process.

1.17 Terminal questions

Q.1. What do you mean by paleobotany? Explain it.

Answer:---

Q. 2 Describe the of fossilization processes.

Answer:---

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Q.3. Describe the geological time scale.

Answer:---

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Q.4. Write short notes on the following.

(a) Fossils

(b) Plant fossils

Answer:---

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Q.5. Write short notes on the following.

(a) Carbonization

(b) Coalification

Answer:---

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Q.6. Describe the Conditions of fossilization process.

Answer:---

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Q.7. Write short notes on the following.

(a) Eons

(b) Eras

(C) Periods

Answer:---

Q.8. Write short notes on the following.

(a) Epochs

(b) Ages

Answer:---

Further readings

1. Biochemistry- Lehninger A.L.
2. Text book of Botany – Singh -Pande-Jain.
3. The elements of Botany- James Hewetson Wilson
4. Textbook of Biotechnology –H. K. Das
5. Biochemistry and molecular biology- Wilson Walker

Unit-2: Kinds of Fossils and Reconstruction of Fossils

Structure

2.1 Introduction

Fossil, remnant, impression, or trace of an animal or plant of a past geologic age that has been preserved in Earth's crust. The complex of data recorded in fossils worldwide—known as the fossil record—is the primary source of information about the history of life on Earth. Only a small fraction of ancient organisms are preserved as fossils, and usually only organisms that have a solid and resistant skeleton are readily preserved. Most major groups of invertebrate animals have a calcareous skeleton or shell (e.g., corals, mollusks, brachiopods, bryozoans). Other forms have shells of calcium phosphate (which also occurs in the bones of vertebrates), or silicon dioxide. A shell or bone that is buried quickly after deposition may retain these organic tissues, though they become petrified (converted to a stony substance) over time. Unaltered hard parts, such as the shells of clams or brachiopods, are relatively common in sedimentary rocks, some of great age.

The hard parts of organisms that become buried in sediment may be subject to a variety of other changes during their conversion to solid rock, however. Solutions may fill the interstices, or pores, of the shell or bone with calcium carbonate or other mineral salts and thus fossilize the remains, in a process known as permineralization. In other cases there may be a total replacement of the original skeletal material by other mineral matter, a process known as mineralization, or replacement. In still other cases, circulating acid solutions may dissolve the original shell but leave a cavity corresponding to it, and circulating calcareous or siliceous solutions may then deposit a new matrix in the cavity, thus creating a new impression of the original shell.

Objectives

This is the second unit on paleobotany, palynology and economic botany. Under second unit, we have following objectives. These are as under:

- To know about fossils, its types, petrification and compression
- To know about moulds, casts and molds.
- To discuss about mineralization, carbonization and encrustation
- To discuss determining species, appearance of dinosaurs and digital reconstruction of dinosaurs

2.2 Fossils

Fossils are the preserved remains, or traces of remains, of ancient organisms. whose bodies were buried in sediments, such as sand and mud, under ancient seas, lakes and rivers. Fossils also include any preserved trace of life that is typically more than 10 000 years old. Soft body parts decay soon after death, but the hard parts, such as bones, shells and teeth can be replaced by minerals that harden into rock. In very exceptional cases, soft parts like feathers, plant ferns or other evidence of life, such as footprints or dung, may also be preserved. Remains can include microscopically small fossils, such as single-celled foraminifera or pollen grains, as well as more familiar fossils such as ammonites and trilobites.

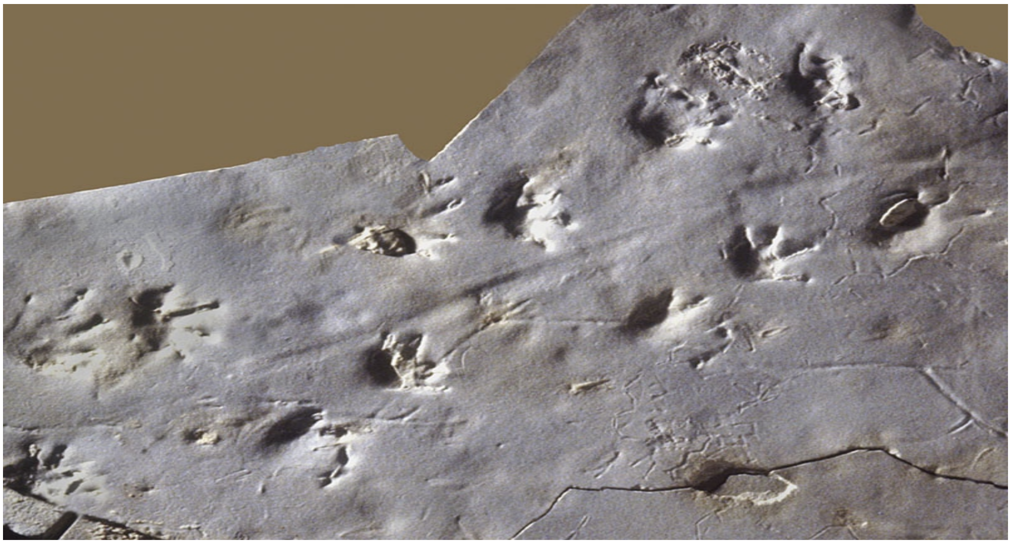

Fig. 1 Fossils

Fossils are not the remains of the organism itself! They are rocks. A fossil can preserve an entire organism or just part of one. Bones, shells, feathers, and leaves can all become fossils. Fossils can be very large or very small. Microfossils are only visible with a microscope. Bacteria and pollen are microfossils. Macrofossils can be several meters long and weigh several tons. Macrofossils can be petrified trees or dinosaur bones. Preserved remains become fossils if they reach an age of about 10,000 years. Fossils can come from the Archaeaean Eon (which began almost 4 billion years ago) all the way up to the Holocene Epoch (which continues today). The fossilized teeth of wooly mammoths are some of our most "recent" fossils. Some of the oldest fossils are those of ancient algae that lived in the ocean more than 3 billion years ago.

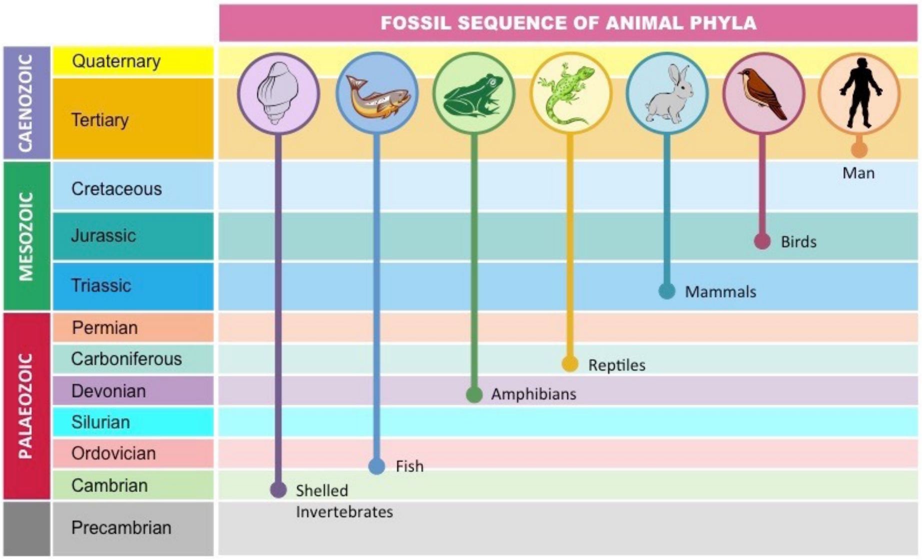

Fig. 2 Fossils record

Fossils are physical evidence of preexisting organisms, either plant or animal. The most common and obvious fossils are the preserved skeletal remains of animals. Other fossils, which are also evidence of past organisms, include leaf impressions, tracks and trails, burrows, droppings, and root casts. Microfossils are the microscopic skeletons of previously existing plants or animals, and their examination requires an optical or an electron microscope for close study. A very small fraction of the organisms that have lived on the Earth is found in the fossil record: Many did not possess skeletons or other hard parts that could be preserved; many did not survive the process of fossilization, wherein skeletons and tissues are replaced by minerals; and many were subsequently destroyed either by chemical or physical processes such as recrystallization, metamorphism, or erosion.

Fossils of any kind are useful in "reading the rock record," meaning they help us decipher the history of the earth. They can help us determine the geologic age and environment (the paleoenvironment) in which they were deposited. Finally, and if the fossil record is complete enough, their study can help us better understand the evolution (or progression) of life through geologic time.

Our understanding of the meaning of fossils is based on the accumulated knowledge from previous generations of investigators who carefully recorded the identity and distribution of fossils from numerous geologic exposures or samples from wells and recorded their findings in the scientific literature. When the regional or global distribution of fossils through geologic time is taken into consideration, we can gain important insights into such phenomena as continental drift, community migration, and climatic (paleoclimatic) reconstruction.

2.3 Fossilization

The word fossil comes from the Latin word *fossus*, meaning "having been dug up." Fossils are often found in rock formations deep in the earth. Fossilization is the process of remains becoming fossils. Fossilization is rare. Most organisms decompose fairly quickly after they die. For an organism to be fossilized, the remains usually need to be covered by sediment soon after death. Sediment can include the sandy seafloor, lava, and even sticky tar.

Over time, minerals in the sediment seep into the remains. The remains become fossilized. Fossilization usually occur in organisms with hard, bony body parts, such as skeletons, teeth, or shells. Soft-bodied organisms, such as worms, are rarely fossilized. Sometimes, however, the sticky resin of a tree can become fossilized. This is called fossilized resin or amber. Amber can preserve the bodies of many delicate, soft-bodied organisms, such as ants, flies, and mosquitoes.

2.4 Body Fossils and Trace Fossils

The fossils of bones, teeth, and shells are called body fossils. Most dinosaur fossils are collections of body fossils. Trace fossils are rocks that have preserved evidence of biological activity. They are not fossilized remains, just the traces of organisms. The imprint of an ancient leaf or footprint is a trace fossil. Burrows can also create impressions in soft rocks or mud, leaving a trace fossil.

2.4.1 Paleontologists

Paleontologists are people who study fossils. Paleontologists find and study fossils all over the world, in almost every environment, from the hot desert to the humid jungle. Studying fossils helps them learn about when and how different species lived millions of years ago. Sometimes, fossils tell scientists how the Earth has changed. Fossils of ancient marine animals called ammonites have been unearthed in the highest mountain range in the world, the Himalayas in Nepal. This tells scientists that millions of years ago, the rocks that became the Himalayas were at the bottom of the ocean. Fossils of an ancient giant shark, a megalodon, have been found in the landlocked U.S. state of Utah. This tells scientists that millions of years ago, the middle of North America was probably entirely underwater.

2.4.2 How do fossils form?

Fossils are typically found in sedimentary rocks and occasionally some fine-grained, low-grade metamorphic rocks. Sometimes the fossils have been removed, leaving moulds in the surrounding rock, or the moulds may have later been filled by other materials, forming casts of the original fossils. Rapid burial by sediments that were previously suspended in water is required for fossilisation to occur. The burial process isolates the remains from the biological and physical processes that would otherwise break up or dissolve the body material.

Fossils are more likely to be preserved in marine environments for example, where rapid burial by sediments is possible. Less favourable environments include rocky mountaintops where carcasses decay quickly or few sediments are being deposited to bury them. There are four main ways of describing fossil preservation:

- Petrification
- Compression
- Moulds and casts
- Preserved remains

2.4.3 Petrification

The most common method of fossilisation is petrification through a process called permineralisation. After a shell, bone or tooth is buried in sediment, it may be exposed to mineral-rich fluids moving through the porous rock material and becomes filled with preserving minerals such as calcium carbonate or silica. Eventually, the minerals entirely replace the organic material and the remains are literally turned into stone or 'petrified'. (*Petra* was the Latin word for rock or stone.)

Fig. 3 This tree stump, found in East Fife, Scotland, is a good example of a petrified

tree fossil produced by permineralisation

2.4.4 Compression

Some fossils form when their remains are compressed at depth. A dark imprint of the fossil is produced as a result of high-pressure forces exerted by the weight of overlying sediments and perhaps sea water.

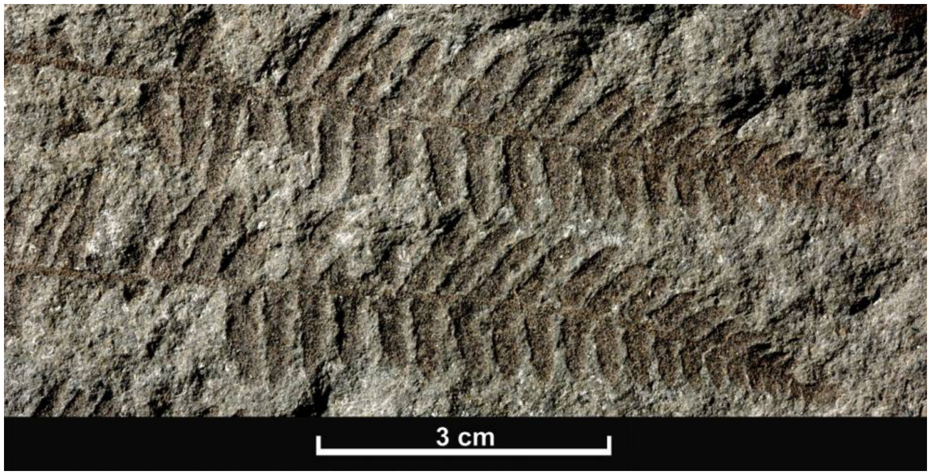

Fig.4 Compression

Fig. 4 Plant leaves and ferns are good examples of fossils produced by compression. This image shows *Coniopteris*, which is a type of true fern, or pteropsid, fossil from the Jurassic Period.

2.4.5 Moulds and casts

In cases where the original shell or bone is dissolved away, it may leave behind a space in the shape of the original material called a mould. At some point in the future, sediments may fill the space to form a matching cast. Soft-bodied sea creatures such as snails are commonly found as moulds and casts because their shells dissolve easily. A cast is a positive impression of the original material formed by contact with the mould.

Fig. 5 This image is a mould of an ancient snail or slug called *Bellerophon*, a gastropod. Fossils can form when mould of the interior of the shell is made by water-borne minerals percolating through it, but later the shell material dissolves away.

2.4.6 Preserved remains

The rarest form of fossilisation is the preservation of original skeletons and soft body parts. Insects that have been trapped and preserved perfectly in amber (fossilised tree resin) are examples of preserved remains. Fossils are the preserved remains, or traces of remains, of ancient organisms. Fossils are not the remains of the organism itself! They are rocks. A fossil can preserve an entire organism or just part of one. Bones, shells, feathers, and leaves can all become fossils.

The root of the word fossil derives from the Latin verb 'to dig' (fodere). A preserved inorganic object is not a fossil. The same applies to the mummification, desiccation and freezing of organisms, as mineralization is not a characteristic feature of these processes. Fossil form depends on the material in which it is preserved, and the ancient environment. Fossils can also represent organism movement and activity in the form of footprints and boring holes. An insect trapped in amber is a fossil subtype known as an inclusion; the originally soft, gum-like coniferous tree resin has fossilized into stone-like amber with the chitinous skeleton of the insect inside preserved.

The oldest human fossil**,** where human refers to *Homo erectus*, *Homo ergaster*, and *Homo georgicus*, was a set of five skulls found in Dmanisi in Georgia between 1999 and 2005. These date back to approximately 1.8 million years ago. The oldest fossil remains depict five different species of microbe, preserved in a 3.5-billion-year-old rock in Australia. These microbes were carbon-dated by researchers at UCLA and the University of Wisconsin-Madison.

2.5 Types of Fossils

Fossil types are grouped according to the process in which they are formed, or to the evidence they have left behind. The method by which fossils are formed is termed as fossilization. Optimal conditions for fossilization are that an organism is buried very soon after its death and in the absence of bacterial or fungal decay, that mineral-rich waters and sediments surround the site, and the immediate environment is cool and hypoxic.

2.5.1 Compressions

Compressions are the most common fossil form, especially in plants, where some or the entire original organism is left behind as an imprint as the organism is slowly compressed between sediment layers. This means compression fossils are often distorted. Coal, a fossil fuel, is an example of a compression, where the combination of fallen vegetation on hypoxic swampland formed a sludge which was slowly compressed under the vertical pressures of swampland silts, and over a course of approximately 300 million years. Coal, a source of fossil fuel energy, is therefore far from a renewable source.

A sub-genre of the compression fossil is the compaction fossil. Compactions have less flattening and distortion, and a three-dimensional form is partially observable. Compactions are rare among crustaceans, as the hardest tissue (the shell or exoskeleton) is not supported by internal structures, leading to collapse and a compressed fossil. In larger, more complex organisms, soft tissues are usually unable to support the skeleton, and therefore the fossil forms are more likely to be compressions than compactions. Compactions of plant forms are more commonly found, but the famous *Archaeopteryx bavarica* shown below is a good example where some slight three-dimensional structure can still be observed.

2.5.2 Petrifactions

Petrified remains are the result of the replacement of the original remains with very specific minerals, which must be present in sufficient quantities dissolved in the water source. Petrification is an older term and rarely used except at certain tourist sites. The process by which the organism’s components are replaced by water-soluble minerals is called mineralization. These minerals are most commonly calcium carbonate, silicon dioxide, iron sulfide, iron carbonate and calcium phosphate. As the tissue of the dead, buried organism dissolves, the gaps left behind allow these minerals to seep in. Soft tissues are generally less well preserved than the petrifaction (or petrification) of hard tissues, depending on the environment and the rate of the replacement process.

Petrified forests, like the one in Arizona shown below, contain stone-like tree stumps, the result of original tissue being replaced with crystalized minerals.

2.5.3 Casts and Molds

When dead organisms from earlier geologic eras are rapidly buried in sand, clay or silt sediments, the soft tissues decay, but harder tissues such as shells, carapaces, teeth and bones require a much longer period to dissolve. A mold fossil is the equivalent of a plaster cast mold of a wax model. If an organism becomes trapped in sediment, decomposition takes place at an extremely slow rate as the sediment dries out and becomes rock.

A cast fossil is the equivalent of liquid porcelain poured into a plaster-cast mold. Once dry, the mold can be removed and a porcelain version of the original wax model is the result. To become a cast, mineralization of the slowly decomposing organism is necessary. This process is the same as petrification, but in this case is named according to the fossil form. A cast always has a mold, although these can become lost over millennia. This cast of a giant whelk clearly shows its morphology in three dimensions.

2.5.4 Chemical Fossils or Chemofossils

Sometimes it is only chemicals that are left behind, as in the case of carbonization where all other chemical traces slowly disappear, leaving a thin layer of carbon. This phenomenon is known as a carbon film fossil or phytoleim and looks like a careful black or brown tracing of the original organism in two dimensions. Carbon films usually occur at the same time as compression, leaving a fine carbon print on the surface of a rock. In fact, any organic molecules left behind that prove the existence of past life are considered to be chemical fossils.

2.5.5 Traces, Tracks and Trails

Trace fossils, also called ichnofossils, tell us about an organism’s behavior rather than representing its anatomical form. Traces are split into four sub-groups – tracks, trails, coprolites, and gastroliths. Tracks are footprints, paw prints or claw prints which become covered with sediment before they are washed away by rain or wave. Trails are not usually made by feet, but by tentacles, the crawling patterns of snakes and worms, or the boreholes of prehistoric beetles. The picture below features a *Tyrannosaurus rex* track.

There are two other classes of trace fossils; coprolites and gastroliths. The first represents fossilized feces which usually contain difficult to digest remnants of a meal. Coprolites are usually petrified, or cast and mold fossils. Gastroliths are **stones** swallowed by certain animals to aid digestion.

2.5.6 How are Fossils Formed?

As already mentioned, the ideal conditions for fossilization are immediate burial in hypoxic, mineral-rich sediments in a low temperature environment. These elements make the existence of fossils rare. Four types of process contribute to the formation of a fossil. These are mineralization, carbonization, encrustation and distillation. They occur once an organism has become trapped within the surrounding sediment, and primarily depend on the mineral composition of silt and water.

2.5.7 Mineralization

Mineralization is the most common process in fossilization. Water within the sediment contains minerals that, over time, slowly replace the tissues of the original living organism. The most prevalent minerals that contribute to the fossilization process are calcium carbonate, iron sulfide, iron carbonate, calcium phosphate, and silica (silicon, silicon dioxide or quartz).

2.5.8 Carbonization and Distillation

The initiation of carbonization requires a certain type of bacteria that creates an anaerobic environment devoid of any oxygen or nitrogen. This bacteria turns plant life into carbon. Under millions of years of vertical compression, these ancient carbon fields become coal deposits. Distillation describes the process by which carbon film or phytoleim fossils are formed. This is an extremely rare occurrence, but can give a fine image of soft tissues. Fossils obtained by distillation are usually badly preserved, although significant external detail is possible.

2.5.9 Encrustation

Encrustation occurs in the presence of minerals – usually calcium carbonate – deposited in various layers on top of the remains of an organism. As tides rise and fall or water levels fluctuate, minerals slowly form a mold. While mineralization replaces organic matter, encrustation covers it. Mineralization will form a cast, encrustation the mold.

Form classification is the classification of organisms based on their morphology, which does not necessarily reflect their biological relationships. Form classification, generally restricted to palaeontology, reflects uncertainty; the goal of science is to move "form taxa" to biological taxa whose affinity is known.

Form taxonomy is restricted to fossils that preserve too few characters for a conclusive taxonomic definition or assessment of their biological affinity, but whose study is made easier if a binomial name is available by which to identify them. The term "form classification" is preferred to "form taxonomy"; taxonomy suggests that the classification implies a biological affinity, whereas form classification is about giving a name to a group of morphologically-similar organisms that may not be related.

A "parataxon" (not to be confused with parataxonomy), or "sciotaxon" (Gr. "shadow taxon"), is a classification based on incomplete data: for instance, the larval stage of an organism that cannot be matched up with an adult. It reflects a paucity of data that makes biological classification impossible. A sciotaxon is defined as a taxon thought to be equivalent to a true taxon (orthotaxon), but whose identity cannot be established because the two candidate taxa are preserved in different ways and thus cannot be compared directly.

Examples

1 Form taxa are groupings that are based on common overall forms. Early attempts at classification of labyrinthodonts was based on skull shape (the heavily armoured skulls often being the only preserved part). The amount of convergent evolution in the many groups lead to a number of polyphyletic taxa.[3] Such groups are united by a common mode of life, often one that is generalist, in consequence acquiring generally similar body shapes by convergent evolution. Ediacaran biota — whether they are the precursors of the Cambrian explosion of the fossil record, or are unrelated to any modern phylum — can currently only be grouped in "form taxa". Other examples include the seabirds and the "Graculavidae". The latter were initially described as the earliest family of Neornithes but are nowadays recognized to unite a number of unrelated early neornithine lineages, several of which probably later gave rise to the "seabird" form taxon of today.

Fossil eggs are classified according to the parataxonomic system called Veterovata. There are three broad categories in the scheme, on the pattern of organismal phylogenetic classification, called oofamilies, oogenera and oospecies (collectively known as ootaxa). The names of oogenera and oofamilies conventionally contain the root "oolithus" meaning "stone egg", but this rule is not always followed. They are divided up into several basic types: Testudoid, Geckoid, Crocodiloid, Dinosauroid-spherulitic, Dinosauroid-prismatic, and Ornithoid.

2 In paleobotany, two terms were formerly used in the codes of nomenclature, "form genera" and "organ genera", to mean groups of fossils of a particular part of a plant, such as a leaf or seed, whose parent plant is not known because the fossils were preserved unattached to the parent plant.[5][6] A later term "morphotaxa" also allows for differences in preservational state. These three terms have been replaced as of 2011 by provisions for "fossil-taxa" that are more similar to the provisions for other types of plants.

Names given to organ genera could only be applied to the organs in question, and could not be extended to the entire organism. Fossil-taxon names can cover several parts of an organism, or several preservational states, but do not compete for priority with any names for the same organism that are based on a non-fossil type. The part of the plant was often, but not universally, indicated by the use of a suffix in the generic name:

- wood fossils may have generic names ending in *-xylon*
- leaf fossils generic names ending in *-phyllum*
- fruit fossils generic names ending in *-carpon*, *-carpum* or *-carpus*
- pollen fossils generic names ending in *-pollis* or *-pollenoides*.

2.6 Casual use

Form taxon can more casually be used to describe a wastebasket taxon: either a taxon that is not a natural (monophyletic) group but united by shared plesiomorphies, or a presumably artificial group of organisms whose true relationships are not known, being obscured by ecomorphological similarity. Well-known form taxa of this kind include ducks, fish, reptiles and worms.

2.7 Preparing fossils

Palaeontologists use different techniques to remove fossils from rocks depending on the properties of the rock and the composition of the fossils themselves. Some rocks like mudstone or sandstone are soft so it is quite easy to remove the fossils using simple hand tools. Other rocks, such as limestone, are more difficult to excavate. In those cases chemical methods using acids might be used to remove some of the rock. Once fossil bones are extracted from the rock matrix they are treated with special glues to preserve them and protect them from damage.

2.8 Telling the difference between a rock and a fossil

A fossil bone may now be 'rock' (mineralised), but it still has some similarities to modern bone. Bone has tiny lines on the surface, a dense outer layer, and an inner spongy structure that resembles honeycomb. These can still be seen in fossil bone but not in rock.

2.9 How do we complete the picture?

Once the fossils are prepared and preserved, palaeontologists will study the remains in order to determine what type of dinosaur they belonged to and even what it looked like and how it lived.

2.10 Determining species

Identifying the type or species of dinosaur recovered (or if it even is a dinosaur), is the main priority of palaeontologists. The first step is to compare the remains to other more complete examples to see if they match any known species. If they do, then those examples can be used to help reconstruct the new find. If they don't, then it is possible that a new species has been discovered.

2.11 Reconstructing lifestyle

Scientists study the new remains to determine relationships to other known species and genera. Comparisons are made with these and also with living animals in order to reconstruct the skeleton and lifestyle of the dinosaur. Aspects of its life such as size, movement, weight and shape can also be determined. These are relatively easy, but other aspects such as growth rates and behaviour are more speculative. Once fossils are prepared and preserved, the bones are assembled and a detailed drawing or reconstruction is made of the skeleton. Knowledge of dinosaur and animal anatomy helps rebuild the body with muscles, tendons and skin and so recreate a 'living' dinosaur.

2.12 How do we work out the external appearance of dinosaurs?

Palaeontologists rely on artistic interpretation to reconstruct dinosaur appearance and behaviour. As a result, artists have taken an unusually central role in the scientific process of reconstructing dinosaurs. The skins of some living animals and rare dinosaur fossil skin impressions give us some idea about the skin surface of dinosaurs. However, the colours or patterns of reconstructions are educated guesswork based on living animals with similar lifestyles and habitats. Since it is likely that dinosaurs saw in colour like modern birds and reptiles, skin colour was probably an important feature.

2.13 Digital reconstruction of dinosaurs

The growth of technology has introduced the digital age of dinosaur reconstruction. Computer programs blend cutting-edge wizardry with traditional techniques of drawing and sculpture to bring new realism to dinosaur movement and behaviour. These can also incorporate dinosaur movement that static art can not (think of the BBCs ‘Walking with Dinosaurs’ or the movie ‘Jurassic Park’).

2.14 Summary

Under this unit we have summarized fossils and its types, petrification and compression, mineralization, carbonization and encrustation etc. Fossils are the preserved remains, or traces of remains, of ancient organisms. Fossils are not the remains of the organism itself! They are rocks. A fossil can preserve an entire organism or just part of one. Bones, shells, feathers, and leaves can all become fossils. Fossils can be very large or very small. Microfossils are only visible with a microscope. Bacteria and pollen are microfossils. Macrofossils can be several meters long and weigh several tons. Macrofossils can be petrified trees or dinosaur bones.

Preserved remains become fossils if they reach an age of about 10,000 years. Fossils can come from the Archaeaean Eon (which began almost 4 billion years ago) all the way up to the Holocene Epoch (which continues today). The fossilized teeth of wooly mammoths are some of our most "recent" fossils. Some of the oldest fossils are those of ancient algae that lived in the ocean more than 3 billion years ago. The word fossil comes from the Latin word *fossus*, meaning "having been dug up." Fossils are often found in rock formations deep in the earth. Fossilization is the process of remains becoming fossils. Fossilization is rare. Most organisms decompose fairly quickly after they die. For an organism to be fossilized, the remains usually need to be covered by sediment soon after death. Sediment can include the sandy seafloor, lava, and even sticky tar. Over time, minerals in the sediment seep into the remains. The remains become fossilized. Fossilization usually occur in organisms with hard, bony body parts, such as skeletons, teeth, or shells. Soft-bodied organisms, such as worms, are rarely fossilized.

2.15 Terminal questions

Q. 1 What do you mean by fossils? Explain it.

Answer:---

Q. 2 Describe the fossils formation.

Answer:---

Q. 3 Describe the carbonization and distillation.

Answer:---

Q. 4 Write short notes on the following.

(a) Petrification

(b) Compression

Answer:---

Q.5Write short notes on the following.

(a) Encrustation

(b) Mineralization

Answer:---

Q. 6 How do we work out the external appearance of dinosaurs?

Answer:---

Q.7Write short notes on the following.

(a) Chemofossils

(b) Preserved remains

Answer:---

Q.8Write short notes on the following.

(a) Paleontologists

(b) Casts and Molds

Answer:---

Further readings

- Biochemistry- Lehninger A.L.
- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry and molecular biology- Wilson Walker

Unit-3: Concept and scope of Palynology

Structure

3.1 Introduction

Palynology, scientific discipline concerned with the study of plant pollen, spores, and certain microscopic planktonic organisms, in both living and fossil form. The field is associated with the plant sciences as well as with the geologic sciences, notably those aspects dealing with stratigraphy, historical geology, and paleontology. Palynology also has applications in archaeology, forensic science and crime scene investigation, and allergy studies. Accordingly, the scope of palynologic research is extremely broad, ranging from the analysis of pollen morphology with electron microscopes to the study of organic microfossils (palynomorphs) extracted from ancient coals.

As pollen and spores are produced in large numbers and dispersed over large areas by wind and water, their fossils are recoverable in statistically significant assemblages in a wide variety of sedimentary rocks. Moreover, because pollen and spores are highly resistant to decay and physical alteration, they can be studied in much the same way as the components of living plants. Identification of pollen and spore microfossils has greatly aided delineation of the geographical distribution of many plant groups from early Cambrian time (some 541 million years ago) to the present. Palynological studies using fresh or non-fossilized samples have also been useful in establishing a location or seasonal time frame for crime scenes and have served to determine the agricultural practices and other plant-related activities that occurred at archaeological sites.

Objectives

This is the third unit on paleobotany, palynology and economic botany. Under third unit, we have following objectives. These are as under:

- To know about palynology and its scope
- To discuss history of pollen.
- To know about pollen units and pollen preparation,
- To discuss about acetolysis method.

3.2 Palynology

Palynology is literally the study of dust or of particles that are strewn. A classic palynologist analyses particulate samples collected from the air, from water, or from deposits including sediments of any age. The condition and identification of those particles, organic and inorganic, give the palynologist clues to the life, environment, and energetic conditions that produced them. The term is commonly used to refer to a subset of the discipline, which has been described as "the study of microscopic objects of macromolecular organic composition (i.e., compounds of carbon, hydrogen, nitrogen and oxygen), not capable of dissolution in hydrochloric or hydrofluoric acids.

It is the science that studies contemporary and fossil palynomorphs,including pollen, spores, orbicules, dinocysts, acritarchs, c hitinozoans and scolecodonts, together with particulate organic matter (POM) and kerogen found in sedimentary rocks and sediments. Palynology as an interdisciplinary science stands at the intersection of earth science (geology or geological science) and biological science (biology), particularly plant science (botany). Stratigraphical palynology , a branch of micropalaeontology and paleobotany, studies fossil palynomorphs from the precambrian to the holocene.

Palynology has also been extensively used as a method of characterizing past depositional systems (paleoenvironments). Here palynomorphs play an important role in defining, for example, the extent of a marine or terrestrial environment. In other instances, certain types of palynomorphs may provide valuable information about water depth, temperature, salinity, and nutrient levels where the organisms once lived. In a few cases where vertebrates and invertebrates are found with palynomorphs and plant megafossils, an even greater degree of paleoecological resolution can be obtained. Other detailed ecological studies are possible based on the frequency and types of pollen present both geographically and stratigraphically within a confined area. The use of pollen data in association with megafossil information has had a profound influence on the interpretation of paleophytogeographic patterns throughout the world. Such studies are especially valuable when they incorporate both extant and fossil data and are founded on well-defined geographic regions of the world. Other investigations have utilized paleoecological data to show that the early flowering plants were herbs or small trees living in unstable habitats during the Cretaceous.

Certain climatic parameters can also be defined by the occurrence of certain palynomorphs, because various plants respond to minor environmental fluctuations. Tracing the appearance and disappearance of various palynomorphs vertically in the geologic column provides a method of tracking certain types of climatic shifts. Pollen analysis is a branch of palynology in which the relative proportions of pollen and spores are mapped vertically and horizontally; these proportions are then used to reconstruct the paleoenvironment by comparison with modern proportions of the same or closely related taxa. Although primarily applied to Quaternary deposits, similar techniques have been used in older sediments. Recovery of DNA from Holocene pollen has potential for more accurate identification of certain pollen types, as well as tracking populations of plants through time.

Using modern pollen and spores, Traverse determined the palynomorph load in various types of bodies of water in the Trinity River of Texas. Understanding the dynamics of a modern model system such as this is important in the interpretation of past vegetation. Pollen extracted from marine sediments, together with stable isotopes and radiolarian microfossils extracted from ocean sediment cores, were used to provide data about ocean variability on millennial timescales. This information can then be used to directly compare the climate responses of continental and oceanic systems, and incorporated into broader scale climate models.

Palynomorphs or microfossils are preserved from every time period of geologic history and in many types of depositional environments, so they are a valuable source of information with which to characterize changes in paleoecosystems at different scales. Although several books have been written on various aspects of palynology, the three-volume set, *Palynology, Principles and Applications*, edited by Jansonius and McGregor and the volume by

Traverse, *Paleopalynology*, provide very comprehensive and up-to-date surveys of the discipline. The recent volume edited by Van Geel focuses on the importance of various microfossils in the interpretation and reconstruction of Quaternary environments and the Glossary of Pollen and Spore Terminology will be helpful in understanding the complex terminology used to described pollen and spores.

3.3 History

3.3.1 Early history

The earliest reported observations of pollen under a microscope are likely to have been in the 1640s by the English botanist Nehemiah Grew, who described pollen and the stamen, and concluded that pollen is required for sexual reproduction in flowering plants. By the late 1870s, as optical microscopes improved and the principles of stratigraphy were worked out, Robert Kidston and P. Reinsch were able to examine the presence of fossil spores in the Devonian and Carboniferous coal seams and make comparisons between the living spores and the ancient fossil spores. Early investigators include Christian Gottfried Ehrenberg (radiolarians, diatoms and dinoflagellate cysts), Gideon Mantell (desmids) and Henry Hopley White (dinoflagellate cysts).

3.3.2 From 1890s to 1940s

Quantitative analysis of pollen began with Lennart von Post's published work.[9] Although he published in the Swedish language, his methodology gained a wide audience through his lectures. In particular, his Kristiania lecture of 1916 was important in gaining a wider audience. Because the early investigations were published in the Nordic languages (Scandinavian languages), the field of pollen analysis was confined to those countries. The isolation ended with the German publication of Gunnar Erdtman's 1921 thesis. The methodology of pollen analysis became widespread through out Europe and North America and revolutionized Quaternary vegetation and climate change research.

Earlier pollen researchers include Früh (1885), who enumerated many common tree pollen types, and a considerable number of spores and herb pollen grains. There is a study of pollen samples taken from sediments of Swedish lakes by

Trybom (1888); pine and spruce pollen was found in such profusion that he considered them to be serviceable as "index fossils". Georg F. L. Sarauw studied fossil pollen of middle Pleistocene age (Cromerian) from the harbour of Copenhagen. Lagerheim (in Witte 1905) and C. A.Weber (in H. A. Weber 1918) appear to be among the first to undertake 'percentage frequency' calculations.

3.3.3 From 1940s to 1989

The term *palynology* was introduced by Hyde and Williams in 1944, following correspondence with the Swedish geologist Ernst Antevs, in the pages of the *Pollen Analysis Circular* (one of the first journals devoted to pollen analysis, produced by Paul Sears in North America). Hyde and Williams chose *palynology* on the basis of the Greek words *paluno* meaning 'to sprinkle' and *pale* meaning 'dust' (and thus similar to the Latin word *pollen*).

Pollen analysis in North America stemmed from Phyllis Draper, an MS student under Sears at the University of Oklahoma. During her time as a student, she developed the first pollen diagram from a sample that depicted the percentage of several species at different depths at Curtis Bog. This was the introduction of pollen analysis in North America; pollen diagrams today still often remain in the same format with depth on the y-axis and abundances of species on the x-axis.

3.3.4 From 1990s to the 21st century

Pollen analysis advanced rapidly in this period due to advances in optics and computers. Much of the science was revised by Johannes Iversen and Knut Fægri in their textbook on the subject. Important, too, is the fact that the evolutionary sequence of organisms based on the large fossil remains of plants in sedimentary rocks is recorded by the sequence of plant microfossils as well. Such microfossils are thus useful in determining geologic age and are especially important in sediments devoid of large fossils. Because of their abundance and minute size, microfossils can be extracted from small samples of rock secured in drilling operations. Palynological analysis therefore is of practical application to petroleum exploration and to other geologic research involving subsurface sediments and structures. Palynology is also invaluable to evolutionary and taxonomic research and can help to delineate phylogenetic relationships between fossilized and extant plants.

The phases of palynology that deal exclusively with fossils are outgrowths and extensions of techniques and principles developed in the study of peat deposits of northern Europe during the early 1900s. In such research the presence, absence, and relative abundance of the pollen of various species of trees from known depths in the bog were ascertained statistically. In as much as forest composition determines the pollen types trapped on the surface of a bog at any given time, it follows that changes in the pollen content reflect regional changes in forest composition. It was established that alterations in forest makeup were induced by climatic change over the many thousands of years since glacial ice disappeared from northern Europe. A relationship was thus established between the pollen content of the peat, the age (i.e., position in the bog), and climate. Application of such findings proved invaluable in subsequent studies of ancient climate, particularly the glacial and interglacial stages of the Pleistocene Epoch (approximately 2.6 million to 11,700 years ago).

3.4 Scopes of Palynology

Palynology can be applied to problems in many scientific disciplines including geology, botany, paleontology, archaeology, pedology (soil study), and physical geography:

- Biostratigraphy and geochronology. Geologists use palynological studies in biostratigraphy to correlate strata and determine the relative age of a given bed, horizon, formation or stratigraphical sequence. Because the distribution of acritarchs, chitinozoans, dinoflagellate cysts, pollen and spores provides evidence of stratigraphicalcorrelation through biostratigraphy and palaeoenviron mental reconstruction, one common and lucrative application of palynology is in oil and gas exploration.

- Paleoecology and climate change. Palynology can be used to reconstruct past vegetation (land plants) and marine and Freshwater phytoplankton communities, and so infer past environmental (palaeoenvironmental) and palaeoclimatic conditions in an area thousands or millions of years ago, a fundamental part of research into climate change.

- Organic palynofacies studies, which examine the preservation of the particulate organic matter and palynomorphs provides information on the depositional environment of sediments and depositional palaeoenvironments of sedimentary rocks.
- Geothermal alteration studies examine the colour of palynomorphs extracted from rocks to give the thermal alteration and maturation of sedimentary sequences, which provides estimates of maximum palaeotemperatures.
- Limnology studies. Freshwater palynomorphs and animal and plant fragments, including the prasinophytes and desmids (green algae) can be used to study past lake levels and long term climate change.
- Taxonomy and evolutionary studies. Involving the use of pollen morphological characters as source of taxonomic data to delimit plant species under same family or genus. Pollen apertural status is frequently used for differential sorting or finding similarities between species of the same taxa. This is also called Palynotaxonomy.
- Forensic palynology: the study of pollen and other palynomorphs for evidence at a crime scene.
- Allergy studies. Studies of the geographic distribution and seasonal production of pollen, can help sufferers of allergies such as hay fever.
- Melissopalynology: the study of pollen and spores found in honey.
- Archaeological palynology examines human uses of plants in the past. This can help determine seasonality of site occupation, presence or absence of agricultural practices or products, and 'plant-related activity areas' within an archaeological context. Bonfire Shelter is one such example of this application.

3.5 Pollen units

3.5. 1 Pollen grains

Pollen grains are the largest bioaerosol particles, usually above 10 µm in size. Many trees, grasses, and weeds produce pollen grains that are dispersed through the air by wind. Pollen grains absorb moisture from the air and swell. Especially after heavy rain, such as during or right after thunderstorms, swelling may cause the grains to break up and release pollen allergens outside the pollen grains. Thus, pollen exposure occurs both via the intact pollen grains and via smaller-sized pollen allergens (< 2 µm). Pollen can cause allergies, most commonly seasonal allergic rhinitis. Pollen allergens can act synergistically with diesel exhaust particles (DEP). DEP can bind on airborne pollen allergens and have been shown to enhance pollen allergen-specific immunoglobulin E (IgE) antibody production in both human and animal studies.

Pollen grains range in size from 10 to 150 µm and are protected by a chemically resistant outer layer, the exine. Because pollen grains of many plant families are different morphologically, they can be recognized by their distinct shape, size, sculpturing, and number of apertures. The exine is made of sporopollenin, a complex polymer (a β-carotenoid ester) resistant to all but the most extreme oxidizing or reducing agents. Thus, the organic or inorganic matrix in which the pollen grains are trapped can be removed by chemical means without destroying the pollen itself. There is some evidence, however, that in certain sedimentary environments, not all pollen grains will be equally well preserved. For example, pollen grains are more subject to corrosion in moss peat than in silt deposits, and this may be due to the activities of phycomycetes, bacteria, and other microorganisms. Furthermore, the pollen of some species (e.g., *Populus*) may begin to disintegrate even before reaching a deposition site.

3.5.2 Pollen analysis and principles

Pollen analysis, the study of fossil pollen and spores, is one of the key methods for qualitative and quantitative reconstructions of past vegetation and environments. The definition of source area of pollen records is essential for the use of pollen data for precise vegetation reconstructions. Quantitative vegetation reconstruction must also account for biases in plant-pollen representation that result from differential pollen productivity and dispersal properties. This can be achieved by using correction factors based on modern plant-pollen representation calculations. Alternatively, pollen accumulation rates can be calculated in order to provide direct estimates of past population sizes. Examples of the applications of the pollen analysis on various spatial and temporal scales range from reconstructions of general vegetation changes over glacial–interglacial cycles to stand-scale vegetation dynamics during an immigration of an invading species.

3.5.3 Pollen Units:

The pollen grains are produced within the anther of the flower. Pollen mother cells originate from the sporogenous tissue of the anther which later divide meiotically to form four pollen grains called tetrad. The pollen grains do not remain united at maturity, and are dissociated into single pollen grain called monad. Sometimes rarer types like dyads (two pollen grains), Octads (eight pollen grains) and Polyads (many pollen grains) are also observed.

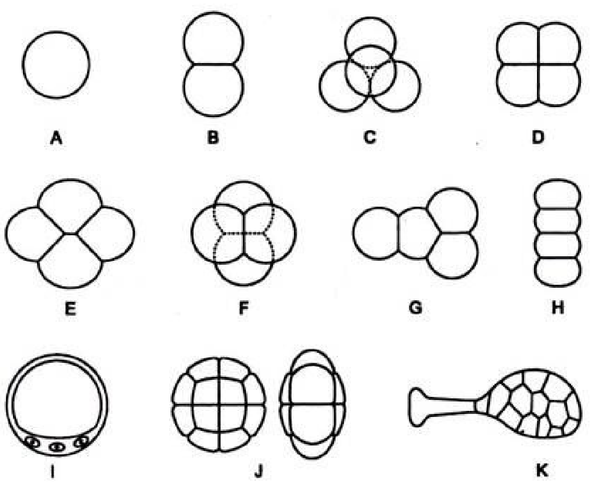

Fig. 1 Pollen units (A= Monad, B= Dyads, C = Tetrahedral tetrad, D = Tetragonal tetrad, E = Rhomboidal tetrad, F = Decussate tetrad, G = T-Shaped tetrad, H = Linear tetrad, I = Cryptotetrad, J = Polyads, K = Pollinia)

3.5.3.1 Dyads:

Pollen grains which are united in pairs and shed from the anthers as doubles are called dyads. Dyads are present in Scheuchzeria palustris and other members of Podostemonaceae. The dyads are formed due to the incomplete break up of individual grain or monad.

3.5.3.2 Tetrads:

Four pollen grains are united to form tetrad. Tetrads are the unseparated product of meiosis. Tetrads maybe categorized into different types based on their arrangement.

3.5.3.3 Tetrahedral tetrad:

Pollen grains are arranged in two different planes. Three grains are in one plane and one lies centrally over the other three. In some cases, the pollen grains are released from the anther in the tetrad condition. These types of tetrads are called obligate or permanent tetrads, viz., Drymis (Winteraceae), Drosera (Droseraceae), Rhododendron Ericaceae).

3.5.3.4 Tetragonal tetrad:

All the four pollen grains are arranged in one plane e.g., Typha latifolia (Typhaceae), Hedycaria arborea (Monimiaceae).

3.5.3.5 Rhomboidal tetrad:

All pollen grains are arranged in one plane forming rhomboidal shape e.g., Annona muricata (Annonaceae).

3.5.3.6 Decussate tetrad:

Pair-wise the pollen grains are at right angle to each other, e.g., Magnolia grandiflora (Magnoliaceae).

3.5.3.7 T-Shaped tetrad:

The first division of pollen mother cell is transverse to form a dyad. The upper or lower cell of dyad undergoes a vertical or longitudinal division instead of transverse, yielding either straight or inverted T-shaped configuration, e.g., Aristolochia sp.(Aristolochiaceae), Polyanthes sp; (Amaryllidaceae).

3.5.3.8 Linear tetrad:

The first division of pollen mother cell is transverse and a dyad is formed. Each cell of the dyad again divides transversely to form a linear tetrad, e.g., Mimosa pudica.

3.5.3.9 Cryptotetrad or Pseudomonad:

Here tetrads are formed without partition walls between the four compartments. One out of the four nuclei develops normally and the rest three obliterate. Thus an apparent monad but homologous to the tetrad is formed, e.g., Cyperaceae.

3.5.3.10 Polyads:

In most of the Mimosaceae members each of the tetrad cells divides once or twice or more, yielding a group of 8 to 64 cells which remain together after maturity. These compound grains are usually held together in small units and are called polyads. e.g., Acacia auriculiformis, Adenanthera pavonina, Calliandra hematocephalla, Samania saman, Albizzia lebbeck.

3.6 Methods of Pollen Preparation:

The following points highlight the four main methods of pollen preparation. The methods are:

- ✓ Fischer's Method of Pollen Preparation
- ✓ Wodehouse's Method of Pollen Preparation
- ✓ Erdtman's Method of Pollen Preparation
- ✓ Nair's Method of Pollen Preparation.

1. Fischer's Method of Pollen Preparation:

Under this method, the pollen grains are placed on a clean slide, washed with xylol or benzene and stained by a weak solution of fuchsin stain. They are finally mounted in glycerine gelly and studied.

2. Wodehouse's Method of Pollen Preparation:

R.P. Wodehouse also suggested a method of pollen preparation in 1935. In this method the pollen grains are treated with absolute alcohol which removes oily and resinuous substances from the surface of the grains. The grains are then stained with methylene green and mounted in glycerine gelly.

3. Erdtman's Method of Pollen Preparation:

G. Erdtman (1952, 1964) suggested a widely accepted standard method of pollen preparation and this method is called "acetolysis method". In this method, pollen grains are treated with a mixture of 9 parts acetic anhydride and 1 part concentrated sulphuric acid.

4. Nair's Method of Pollen Preparation:

P.K.K. Nair (1960) suggested a modification of the "acetolysis method' of Erdtman. This method helps in the comparative study of acetolysed and unacetolysed pollen grains and also helps in understanding the effect of acetolysis on pollen grains. A brief schedule of Nair's method is under mentioned:

(a) Pre-treatment and Staining:

- ✓ Fix the pollen material (fresh or dry anthers, flowers or spiles, etc.) in 70% alcohol in glass vials for at least 24 hours if dry and at least for one hour if fresh.
- ✓ Transfer the material with alcohol in a centrifuge tube and crush the material with a glass rod.
- ✓ Pass the dispersion through a brass metal sieve having at least 48 meshes per sq. inch and collect it in a centrifuge tube 'A'.
- ✓ From centrifuge tube 'A', transfer one half of the dispersion to another centrifuge tube 'B'.
- ✓ Centrifuge the contents of tube 'A', decant the alcohol and add about 2 drops of safranin (5% in water). Wait for 5-10 minutes.
- ✓ Wash the stained sediment with 70% alcohol, centrifuge it, decant off the water, wash with water at least twice or thrice by centrifuging till it becomes colourless.
- ✓ Add 2 ml of dilute glycerine (50% in water) and keep this centrifuge tube 'A' in the rack.

(b) Acetolysis:

- ✓ Centrifuge the tube marked 'B' and decant off the alcohol.
- ✓ Add about 5 ml glacial acetic acid, centrifuge and decant off the acetic acid.
- ✓ Add about 6 ml of acetolysis mixture (acetic anhydride and conc. sulphuric acid in a ratio of 9 : 1) over the pollen grains in tube 'B', place it in a water bath and heat the water from 70°C to 100°C. When the water starts boiling, stop the flame and leave this centrifuge tube 'B' in hot water for 3-5 minutes.
- ✓ Centrifuge tube 'B' and decant off the waste acetolysis mixture.
- ✓ Add about 10 ml of glacial acetic acid over the sediment in tube 'B', centrifuge it and decant off the acid.
- ✓ Add water once or twice, centrifuge it every time and decant off the water. Disperse the grains in water.

- ✓ Transfer one half of this dispersion to another centrifuge tube marked 'C', and leave the centrifuge tube B' along with centrifuge tube 'A' in the rack.

(c) Chlorination or Oxidation:

- ✓ Take the contents of tube 'C', centrifuge them and decant off the water.
- ✓ Add about 5 ml glacial acetic acid followed by 2-4 drops of saturated solution of sodium chlorate or potassium chlorate in water and then 1 or 2 drops of concentrated hydrochloric acid. Wait for about 5 minutes, centrifuge and decant.
- ✓ Wash with water once or twice and decant off the water.
- ✓ Add a few drops of methyl green on the sediment and wait for about 5 minutes.
- ✓ Wash the sediment with water twice or thrice till the water becomes colourless and centrifuge every time.

(d) Mounting:

- ✓ Transfer the pollen grains from centrifuge tube 'A' to 'B' and then from tube 'B' to tube 'C'. Centrifuge the mixture of tubes 'A', 'B' and 'C'.
- ✓ Place the pollen grains in glycerine gelly, mount with a thin (zero number) cover slip and seal with wax.

(e) Results:

The acetolysed pollen grains are brown in colour, unacetolysed grains take red stain of safranin and the chlorinated or oxidized grains are green in colour. For different purposes of study, the preparations can be made of only safranin-stained grains (A) or in combination with acetolysed grains (A + B) or also along with oxidized or chlorinated grains (A + B + C) as needed.

3.7 Summary

Under this we have summarized concept of palynology, pollen history and its preparation as well as acetolysis method etc. Palynology (Gr. *palynos*, dust) is the study of spores and pollen grains. Spores and pollen grains have a number of morphological and ultrastructural features. These palynological features have provided a wealth of characters that have been important in inferring phylogenetic relationships of plants. In addition, the features of spores and pollen grains can often be used to identify a particular plant taxon. For this reason, palynological studies are used extensively to examine the fossil record, a field called paleo-palynology. The identity, density, and frequency of pollen grains at a particular stratigraphic level can give information as to the plant species present at that time and place. Paleo-palynolgical studies are thus used to determine plant community structure and to gauge, by extrapolation over time, shifts in climate.

Pollen is a powdery substance produced by seed plants. It consists of pollen grains (highly reduced microgametophytes), which produce male gametes (sperm cells). Pollen grains have a hard coat made of sporopollenin that protects the gametophytes during the process of their movement from the stamens to the pistil of flowering plants, or from the male cone to the female cone of gymnosperms. If pollen lands on a compatible pistil or female cone, it germinates, producing a pollen tube that transfers the sperm to the ovule containing the female gametophyte. Individual pollen grains are small enough to require magnification to see detail. The study of pollen is called palynology and is highly useful in paleoecology, paleontology, archaeology, and forensics. Pollen in plants is used for transferring haploid male genetic material from the anther of a single flower to the stigma of another in cross-pollination. In a case of self-pollination, this process takes place from the anther of a flower to the stigma of the same flower. Pollen is infrequently used as food and food supplement. Because of agricultural practices, it is often contaminated by agricultural pesticides.

3.8 Terminal questions

Q.1 What do you mean by palynology? Explain it.

Answer:---

Q.2 Describe the scopes of palynology

Answer:---

Q.3 Describe the methods of pollen preparation.

Answer:---

Q.4 Write short notes on the following.

(a) Pollen grains

(b) Pollen units

Answer:---

Q.5 Write short notes on the following.

(a) Dyads

(b) Tetrads

Answer:---

Q.6 Describe cryptotetrad or pseudomonad.

Answer:---

Q.7 Write short notes on the following.

(a) Rhomboidal tetrad

(b) Decussate tetrad

Answer:---

Q.8 Write short notes on the following.

(a) T shaped tetrad

(b) Linear tetrad

Answer:---

Further readings

1. Biochemistry- Lehninger A.L.
2. Text book of Botany – Singh -Pande-Jain.
3. The elements of Botany- James Hewetson Wilson
4. Textbook of Biotechnology –H. K. Das
5. Biochemistry and molecular biology- Wilson Walker

Uttar Pradesh Rajarshi Tandon
Open University

Bachelor of Science
DCEBY -109
Paleobotany, Palynology and Economic Botany

Block -2
Economic Botany

Course Design Committee

Course Preparation Committee

Dr. Rajivranjan **Author**
Assistant Professor **Block- 01 – 03** (Unit: 01- 08)
Department of Botany
MLK PG College, Balrampur (U.P)

Dr. Arun Kumar Pandey **Editor**
Associate Professor, **(All blocks and units)**
Department of Botany
PSM PG College, Anand Nagar, Maharajganj (U.P)

Dr. Sushma Chauhan **Coordinator**
Asst. Prof. (Contractual) Botany
School of Science, UPRTOU, Prayagraj.

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Economic Botany is the interaction of people with plants. Economic botany is closely related to the field of ethnobotany - that word is based on two Greek roots: ethnos (race: people: cultural group) and botanikos (of herbs) and can mean the plant lore of a race or people as well as the study of that lore. Economic botanists are scientists who study the interactions between humans and plants. That makes the field of Economic Botany as far flung and diverse as both the human and plant life on our planet. Economic botanists study human-plant interactions from a variety of different angles. These skilled researchers rely on a variety of disciplines including archeology, sociology, and ecology in addition to basic botany to help them explain these interactions and their effects on plants, society and our dynamic planet.

The block 2nd is organized into following four units as under:

Unit 4

It covers the spices and flavoring materials such as ginger, turmeric, clove and saffron.

Unit 5

It covers the beverages (tea, coffee) and botanical description.

Unit 6

It covers fibres (jute, flax, hemp, coir and cotton).

Unit 7

To know the different forest products (wood, rubbers, gum and resins).

Unit 8

It covers the different medicinal plants (rauwolfia, belladona, quinine, opium and ephedrine).

Objectives

After studding of this block you will be able to -

- Know about spices used as flavoring materials in our kitchen
- Know tea and coffee used as non alcoholics beverages
- Have knowledge of various forest products useful for human beings
- know various medicinal plants used as medicines

Unit-4: spices and flavoring materials

Structure

4.1 Introduction:

Economic Botany sometimes focuses on the processes as well as the products involved in plant cultivation. Scientists ask questions about how knowledge of useful plants is acquired and transmitted between groups. In the South American Andes, potatoes are the staple of many indigenous diets. Economic botanists are intrigued by the questions of who first ate this vegetable and why they thought it might be appetizing and nutritious in spite of the fact that the leaves and stems of the potato plant are poisonous. What made these cultures think that there might be something worthwhile lying beneath the surface? How did they share their knowledge and with whom?

Objectives

This is the fourth unit on paleobotany, palynology and economic botany. Under fourth unit, we have following objectives. These are as under:

- To know about ecology, evolution and systematics
- To discuss about spices, ginger, turmeric and cloves
- To discuss saffron, coriander and their uses
- To discuss seed treatment, manuring, weed control, harvest and post-harvest

4.2 Uses of Plants

We can also study how plants are used. In the past this has meant lists of cultures and their preferred plant sources for food, clothing, shelter, medicine, ritual or aesthetics. Although there are roughly 250,000 species of plants divided into 460 families, we commonly use products from only 300 species in 20 of those families; just a tiny fraction of what's available.

Often a single plant will fill more than one function. The coconut palm is an excellent example of botanical versatility. It is found in cultivation throughout the tropics where it is known by many names including pokok seribu guna or 'tree of a thousand uses' in Malay. All parts of the plant are used from the leaves that are woven into thatch roofs and mats to the delicious fruit and sap right down to the roots that are processed to treat everything from dysentery to bad breath.

Today, economic botanists continue cataloguing plant uses, but they also hope to discover new ones by screening for medicines such as anti-cancer agents or experimenting with ways to improve current cultivation and make it more sustainable or efficient.

4.3 Ecology, Evolution and Systematics

Studies of the evolution of cultivated plants include the processes of domestication and the relationship between natural and human selection of specific plant traits. Knowledge of botany is essential to understanding how domestication may have changed a plant species over time. In addition, ethnobotanists look for help from such disciplines as history, archeology and even linguistics to shed light on this process. Take maize as an example. Botanically speaking, physical evidence, including DNA and similar morphology of stems and grains has shown that maize is related to wild grasses in Central America and Mexico. This agrees with what history and archeology tell us about how this crop was first cultivated there as early as 7000 years ago. The name also gives clues to the crop's movement across cultures. Maize is the Spanish version of an Arawak word ma-hiz. The Spanish first encountered this grain in the Caribbean Islands and then introduced it to Europe; starting its eventual spread around the globe.

4.4 Landscapes and Global Trends

The impacts of human activity on the landscape and biological diversity are also of increasing concern to ethnobotanists. The effects of human presence can be seen in every ecosystem they inhabit. Altering the landscape is not something that only developed agricultural societies do. Environments that might at first appear untouched and empty may in fact be carefully managed by their human inhabitants. Prairie and woodland fires were intentionally set by North American tribes using those areas for hunting and cultivation. These methods were practiced long before the arrival of European settlers who started felling trees and tilling fields in areas that seemed, to them, pristine and unclaimed.

While human activities are sometimes benign or even beneficial they can also create a burden on the landscape when key systems are disrupted by resource consumption or the removal of key species by overharvesting. Examples of negative cycles where overconsumption of natural resources has led to even worse depletion and decreasing diversity are unfortunately common. Truffles, a European fungus highly prized as a seasoning, are becoming increasingly scarce due to over-harvesting in the wild. The market value of truffles keeps rises as they get harder and harder to find which makes the truffle hunters work harder to find the few available ones. This leaves even fewer fungi to reproduce and supply the next year's harvest.

4.5 Spices

A spice is a seed, fruit, root, bark, or other plant substance primarily used for flavoring or coloring food. Spices are distinguished from herbs, which are the leaves, flowers, or stems of plants used for flavoring or as a garnish. Spices are sometimes used in medicine , religious rituals, cosmetics or perfume production. For example, vanilla is commonly used as an ingredient in fragrance manufacturing. A spice may be available in several forms: fresh, whole dried, or pre-ground dried. Generally, spices are dried. Spices may be ground into a powder for convenience. A whole dried spice has the longest shelf life, so it can be purchased and stored in larger amounts, making it cheaper on a per-serving basis.

A fresh spice, such as ginger, is usually more flavorful than its dried form, but fresh spices are more expensive and have a much shorter shelf life. Some spices are not always available either fresh or whole, for example turmeric, and often must be purchased in ground form. Small seeds, such as fennel and mustard seeds, are often used both whole and in powder form. Although health benefits are often claimed for spices, there is not currently good evidence for this. India contributes to 75% of global spice production. This is reflected culturally through their cuisine and historically, the spice trade developed throughout the Indian subcontinent, in East Asia and later with the Middle East. Europe's demand for spices later encouraged further exploration.

The spice trade developed throughout the Indian subcontinent by at earliest 2000 BCE with cinnamon and black pepper, and in East Asia with herbs and pepper. The Egyptians used herbs for mummification and their demand for exotic spices and herbs helped stimulate world trade. By 1000 BCE, medical systems based upon herbs could be found in China, Korea, and India. Early uses were connected with magic, medicine, religion, tradition, and preservation.

Cloves were used in Mesopotamia by 1700 BCE. The ancient Indian epic Ramayana mentions cloves. The Romans had cloves in the 1st century CE, as Pliny the Elder wrote about them. The earliest written records of spices come from ancient Egyptian, Chinese, and Indian cultures. The Ebers Papyrus from early Egypt dating from 1550 B.C.E. describes some eight hundred different medicinal remedies and numerous medicinal procedures.

Historians believe that nutmeg, which originates from the Banda Islands in Southeast Asia, was introduced to Europe in the 6th century BCE. Indonesian merchants traveled around China, India, the Middle East, and the east coast of Africa. Arab merchants facilitated the routes through the Middle East and India. This resulted in the Egyptian port city of Alexandria being the main trading center for spices. The most important discovery prior to the European spice trade was the monsoon winds (40 CE). Sailing from Eastern spice cultivators to Western European consumers gradually replaced the land-locked spice routes once facilitated by the Middle East Arab caravans.

A food **flavoring** (or **flavouring**, also known as an **aromatic**, is a food additive used to improve the taste or smell of food. It changes the perceptual impression of food as determined primarily by the chemical senses of the gustatory and olfactory system. The trigeminal nerves, which detect chemical irritants in the mouth and throat, as well as temperature and texture, are also important to the overall perception of food. Of the three chemical senses, smell is the main determinant of a food item's flavor. Aromas are the volatile components of the food. The aroma of a food is determined by the aroma compounds it contains and the personal ability to detect them. While a flavoring primarily acts through the olfactory system, it also affects the taste at the same time. Along with additives, other components like sugars determine the taste of food.

The number of food smells is unbounded; a food's flavor, therefore, can be easily altered by changing its smell while keeping its taste similar. This is exemplified in artificially flavored jellies, soft drinks and candies, which, while made of bases with a similar taste, have dramatically different flavors due to the use of different scents or fragrances. The flavorings of commercially produced food products are typically created by flavorists.

A flavoring is defined as a substance that gives another substance taste, altering the characteristics of the solute, causing it to become sweet, sour, tangy, etc. Although the term, in common language, denotes the combined chemical sensations of taste and smell, the same term is used in the fragrance and flavors industry to refer to edible chemicals and extracts that alter the flavor of food and food products through the sense of smell.

Owing to the high cost, or unavailability of natural flavor extracts, most commercial flavorants are "nature-identical", which means that they are the chemical equivalent of natural flavors, but chemically synthesized rather than being extracted from source materials. Identification of components of natural foods, for example a raspberry, may be done using technology such as headspace techniques, so the flavorist can imitate the flavor by using a few of the same chemicals present. In the EU legislation, the term "natural-identical flavoring" does not exist. The legislation is specified on what is a "flavoring" and a "natural flavoring". A flavor is a quality of something that affects the sense of taste.

A flavoring or aromatic is a volatile additive that improves the taste or smell of food. They work primarily via the sense of smell. In legislation, substances that exclusively have a sweet, sour or salty taste are not considered flavorings. These usually include flavor enhancers, sweeteners, acidulants and salt substitutes. There are different ways to divide flavorings. First by the way they are produced. A vanilla flavoring can for example be obtained naturally by extraction from vanilla seeds, or one can start with cheap chemicals and try to make a similar substance artificially (in this example vanillin. A nature-identical flavoring is a chemically exact copy of the original substance and can be either natural or artificial.

The second division is by the effect they have on smell (aroma) or taste of the food. The aroma of the flavoring may resemble that of the source, or imitate a particular unrelated food. It may for example be the extract from vanilla seeds and smell like vanilla, or it may be the extract of a potato and smell like a banana. Irrespective of the effect, the flavoring may be natural or artificial. It may for example be the natural tissue of an animal with the aroma of a citrus, or just a chemical that smells like a citrus.

4.6 Ginger

Ginger (*Zingiber officinale*) is a flowering plant whose rhizome, **ginger root** or ginger, is widely used as a spice and a folk medicine. It is a herbaceous perennial which grows annual pseudostems (false stems made of the rolled bases of leaves) about one meter tall bearing narrow leaf blades. The inflorescences bear flowers having pale yellow petals with purple edges, and arise directly from the rhizome on separate shoots.

Fig. 1 Zingiber officinale Roscoe

Ginger is in the family Zingiberaceae, which also includes turmeric (*Curcuma longa*), cardamom (*Elettaria cardamomum*), and galangal. Ginger originated in Maritime Southeast Asia and was likely domesticated first by the Austronesian peoples. It was transported with them throughout the Indo-Pacific during the Austronesian expansion (c. 5,000 BP), reaching as far as Hawaii. Ginger is one of the first spices to have been exported from Asia, arriving in Europe with the spice trade, and was used by ancient Greeks and Romans. The distantly related dicots in the genus *Asarum* are commonly called wild ginger because of their similar taste. Although used in traditional medicine and as a dietary supplement, there is no good evidence that consuming ginger or its extracts has any effect on human health or as a treatment for diseases. In 2019, world production of ginger was 4.1 million tonnes, led by India with 44% of the world total.

Ginger originated from Maritime Southeast Asia. It is a true cultigen and does not exist in its wild state. The most ancient evidence of its domestication is among the Austronesian peoples where it was among several species of ginger cultivated and exploited since ancient times. They cultivated other gingers including turmeric (*Curcuma longa*), white turmeric (*Curcuma* *zedoaria*), and bitter ginger (*Zingiber zerumbet*). The rhizomes and the leaves were used to flavour food or eaten directly. The leaves were also used to weave mats. Aside from these uses, ginger had religious significance among Austronesians, being used in rituals for healing and for asking protection from spirits. It was also used in the blessing of Austronesian ships.

Ginger was carried with them in their voyages as canoe plants during the Austronesian expansion, starting from around 5,000 BP. They introduced it to the Pacific Islands in prehistory, long before any contact with other civilizations. Reflexes of the Proto-Malayo-Polynesian word *laqia* are still found in Austronesian languages all the way to Hawaii. They also presumably introduced it to India along with other Southeast Asian food plants and Austronesian sailing technologies, during early contact by Austronesian sailors with the Dravidian-speaking peoples of Sri Lanka and South India at around 3,500 BP. It was also carried by Austronesian voyagers into Madagascar and the Comoros in the 1st millennium CE. From India, it was carried by traders into the Middle East and the Mediterranean by around the 1st century CE. It was primarily grown in southern India and the Greater Sunda Islands during the spice trade, along with peppers, cloves, and numerous other spices.

4.7 Turmeric

Turmeric is a flowering plant, *Curcuma longa*, of the ginger family, Zingiberaceae, the rhizomes of which are used in cooking. The plant is a perennial, rhizomatous, herbaceous plant native to the Indian subcontinent and Southeast Asia that requires temperatures between 20 and 30 °C (68 and 86 °F) and a considerable amount of annual rainfall to thrive. Plants are gathered each year for their rhizomes, some for propagation in the following season and some for consumption. The rhizomes are used fresh or boiled in water and dried, after which they are ground into a deep orange-yellow powder commonly used as a coloring and flavoring agent in many Asian cuisines, especially for curries, as well as for dyeing, characteristics imparted by the principal turmeric constituent, curcumin.

Fig. 2 Flower of turmeric

Turmeric powder has a warm, bitter, black pepper-like flavor and earthy, mustard-like aroma. Curcumin, a bright yellow chemical produced by the turmeric plant, is approved as a food additive by the World Health Organization, European Parliament, and United States Food and Drug Administration. Although long used in Ayurvedic medicine, where it is also known as *haridra*, there is no high-quality clinical evidence that consuming turmeric or curcumin is effective for treating any disease. Turmeric has been used in Asia for centuries and is a major part of Ayurveda, Siddha medicine, traditional Chinese medicine, Unani, and the animistic rituals of Austronesian peoples. It was first used as a dye, and then later for its supposed properties in folk medicine.

From India, it spread to Southeast Asia along with Hinduism and Buddhism, as the yellow dye is used to color the robes of monks and priests. Turmeric has also been found in Tahiti, Hawaii and Easter Island before European contact. There is linguistic and circumstantial evidence of the spread and use of turmeric by the Austronesian peoples into Oceania and Madagascar. The populations in Polynesia and Micronesia, in particular, never came into contact with India, but use turmeric widely for both food and dye. Thus independent domestication events are also likely.

Turmeric was found in Farmana, dating to between 2600 and 2200 BCE, and in a merchant's tomb in Megiddo, Israel dating from the second millennium BCE. It was noted as a dye plant in the Assyrians Cuneiform medical texts from Ashurbanipal’s library at Nineveh from 7th century BCE. In Medieval Europe, turmeric was called "Indian saffron.

Turmeric is one of the key ingredients in many Asian dishes, imparting a mustard-like, earthy aroma and pungent, slightly bitter flavor to foods. It is used mostly in savory dishes, but also is used in some sweet dishes, such as the cake *sfouf*. In India, turmeric leaf is used to prepare special sweet dishes, *patoleo*, by layering rice flour and coconut-jaggery mixture on the leaf, then closing and steaming it in a special utensil Most turmeric is used in the form of rhizome powder to impart a golden yellow color. It is used in many products such as canned beverages, baked products, dairy products, ice cream, yogurt, yellow cakes, orange juice, biscuits, popcorn color, cereals, sauces, and gelatin. It is a principal ingredient in curry powders. Although typically used in its dried, powdered form, turmeric also is used fresh, like ginger. It has numerous uses in East Asian recipes, such as a pickle that contains large chunks of fresh soft turmeric.

Turmeric is used widely as a spice in South Asian and Middle Eastern cooking. Various Iranian *khoresh* recipes begin with onions caramelized in oil and turmeric. The Moroccan spice mix ras el hanout typically includes turmeric. In South Africa, turmeric is used to give boiled white rice a golden color, known as *geelrys* (yellow rice) traditionally served with bobotie. In Vietnamese cuisine, turmeric powder is used to color and enhance the flavors of certain dishes, such as *bánh xèo, bánh khọt*, and *mì Quảng*. The staple Cambodian curry paste, *kroeung*, used in many dishes, including fish amok, typically contains fresh turmeric.

In Indonesia, turmeric leaves are used for Minang or Padang curry base of Sumatra, such as *rendang*, *sate padang*, and many other varieties. In the Philippines, turmeric is used in the preparation and cooking of Kuning and Satay. In Thailand, fresh turmeric rhizomes are used widely in many dishes, in particular in the southern Thai cuisine, such as yellow curry and turmeric soup. Turmeric is used in a hot drink called "turmeric latte" or "golden milk" that is made with milk, frequently coconut milk. The turmeric milk drink known as *haldi doodh* (*haldi* means turmeric in Hindi) is a traditional indian recipe. Sold in the US and UK, the drink known as "golden milk" uses nondairy milk and sweetener, and sometimes black pepper after the traditional recipe (which may also use *ghee*).

4.8 Cloves

Cloves are the flower buds of the clove tree, an evergreen also known as *Syzygium aromaticum.* Found in both whole and ground forms, this versatile spice can be used to season pot roasts, add flavor to hot beverages, and bring spicy warmth to cookies and cakes. You may know cloves as one of the main ingredients in gingerbread baked goods or a staple spice in Indian cuisine. Cloves are best known as a sweet and aromatic spice, but they have also been used in traditional medicine. In fact, animal studies have found that the compounds in cloves may have several health benefits, including supporting liver health and helping stabilize blood sugar levels.

Fig. 3 Cloves

4.9 Contain important nutrients

Cloves contain fiber, vitamins, and minerals, so using whole or ground cloves to add flavor to your food can provide some important nutrients. One teaspoon (2 grams) of ground cloves contains:

- **Calories:** 6
- **Carbs:** 1 gram
- **Fiber:** 1 gram
- **Manganese:** 55% of the Daily Value (DV)
- **Vitamin K:** 2% of the DV

Manganese is an essential mineral for maintaining brain function and building strong bones. Apart from being a rich source of manganese, cloves are only used in small amounts and do not provide significant amounts of nutrients.

4.10 High in antioxidants

In addition to containing several important vitamins and minerals, cloves are rich in antioxidants. Antioxidants are compounds that reduce oxidative stress, which can contribute to the development of chronic disease. Cloves also contain a compound called eugenol, which has been shown to act as a natural antioxidant. In fact, a test-tube study found that eugenol stopped oxidative damage caused by free radicals five times more effectively than vitamin E, another potent antioxidant. Including cloves in your diet along with other antioxidant-rich foods can help improve your overall health.

4.11 May help protect against cancer

Some research suggests that the compounds found in cloves might help protect against cancer. One test-tube study found that clove extract helped stop the growth of tumors and promoted cell death in cancer cells. Another test-tube study observed similar results, showing that concentrated amounts of clove oil caused cell death in 80% of esophageal cancer cells. The eugenol found in cloves has also been shown to have anticancer properties. A test-tube study found that eugenol promoted cell death in cervical cancer cells. However, keep in mind that these test-tube studies used very concentrated amounts of clove extract, clove oil, and eugenol.

4.12 Can kill bacteria

Cloves have been shown to have antimicrobial properties, meaning they can help stop the growth of microorganisms like bacteria. One test-tube study showed that clove essential oil killed three common types of bacteria, including *E. coli*, which is a strain of bacteria that can cause food poisoning.

What's more, the antibacterial properties of cloves could even help promote oral health. In one test-tube study, the compounds extracted from cloves were found to stop the growth of two types of bacteria that contribute to gum disease. Another study in 40 people tested the effects of an herbal mouthwash consisting of tea tree oil, cloves, and basil.

After using the herbal mouthwash for 21 days, they showed improvements in gum health, as well as the amount of plaque and bacteria in the mouth. In combination with regular brushing and proper oral hygiene, the antibacterial effects of cloves may benefit your oral health.

4.13 May improve liver health

Studies show that the beneficial compounds in cloves could help promote liver health. The compound eugenol may be especially beneficial for the liver. One animal study fed rats with fatty liver disease mixtures containing either clove oil or eugenol. Both mixtures improved liver function, reduced inflammation, and decreased oxidative stress. Another animal study showed that the eugenol found in cloves helped reverse signs of liver cirrhosis, or scarring of the liver. Unfortunately, research on the liver-protecting effects of cloves and eugenol in humans is limited.

However, one small study found that taking eugenol supplements for 1 week decreased levels of glutathione-S-transferases (GSTs), a family of enzymes involved in detoxification that's often a marker of liver disease. Cloves are also high in antioxidants, which may help prevent liver disease due to their ability to help decrease oxidative stress. Nevertheless, eugenol is toxic in high amounts. One case study in a 2-year-old boy showed that 5–10 mL of clove oil caused serious liver damage.

4.14 Saffron

Saffron is a spice derived from the flower of *Crocus sativus*, commonly known as the "saffron crocus". The vivid crimson stigma and styles, called threads, are collected and dried for use mainly as a seasoning and colouring agent in food. Saffron has long been the world's costliest spice by weight. Although some doubts remain on its origin, it is believed that saffron originated in Iran. However, Greece and Mesopotamia have also been suggested as the possible region of origin of this plant. Saffron crocus slowly propagated throughout much of Eurasia and was later brought to parts of North Africa, North America, and Oceania.

Saffron's taste and iodoform-like or hay-like fragrance result from the phytochemicals picrocrocin and safranal. It also contains a carotenoid pigment, crocin, which imparts a rich golden-yellow hue to dishes and textiles. Its recorded history is attested in a 7th-century BC Assyrian botanical treatise, and has been traded and used for thousands of years. In the 21st century, Iran produces some 90% of the world total for saffron. At US$5,000 per kg or higher, saffron is the world's most expensive spice.

Saffron, golden-coloured, pungent stigmas (pollen-bearing structures) of the autumn crocus (*Crocus sativus*), which are dried and used as a spice to flavour foods and as a dye to colour foods and other products. Saffron has a strong, exotic aroma and a bitter taste and is used to colour and flavour many Mediterranean and Asian dishes, particularly rice and fish, and English, Scandinavian, and Balkan breads. It is an important ingredient in bouillabaisse soup. Saffron is cultivated chiefly in Iran but is also grown in Spain, France, Italy (on the lower spurs of the Apennines Range), and parts of India. A labour-intensive crop, the three stigmas are handpicked from each flower, spread on trays, and dried over charcoal fires for use as a food flavouring and colouring. A pound (0.45 kilogram) of saffron represents 75,000 blossoms. Saffron contains 0.5 to 1 percent essential oil, the principal component of which is picrocrocin. The colouring matter is crocin.

A golden-coloured, water-soluble fabric dye was distilled from saffron stigmas in India in ancient times. Shortly after Buddha died, his priests made saffron the official colour for their robes. The dye has been used for royal garments in several cultures. Saffron is named among the sweet-smelling herbs in Song of Solomon 4:14. As a perfume, saffron was strewn in Greek and Roman halls, courts, theatres, and baths; it became especially associated with the hetairai, a professional class of Greek courtesans. The streets of Rome were sprinkled with saffron when Nero made his entry into the city.

4.15 Coriander

Coriander**,** (*Coriandrum sativum*), also called cilantro **or** Chinese parsley**,** feathery annual plant of the parsley family (Apiaceae), parts of which are used as both an herb and a spice. Native to the Mediterranean and Middle East regions, the plant is widely cultivated in many places worldwide for its culinary uses. Its dry fruits and seeds, which are also known as coriander, are used to flavour many foods, particularly sausages, curries, Scandinavian pastries, liqueurs, and confectionery, such as English comfits. Its delicate young leaves, known as cilantro, are widely used in Latin American, Indian, and Chinese dishes.

Fig. 4 Coriander

The plant produces a slender hollow stem 30 to 60 mm (1 to 2.5 inches) high with fragrant bipinnate leaves. The small flowers are pink or whitish and are borne in umbel clusters. The fruit is a small dry schizocarp consisting of two semiglobular fruits joined on the commisural, or inner, sides, giving the appearance of a single, smooth, nearly globular fruit about 5 mm (0.2 inch) in diameter. The yellowish brown fruits have a mild fragrance and taste similar to a combination of lemon peel and sage. The seeds contain from 0.1 to 1 percent essential oil; its principal component is coriandrol. Records of the use of coriander date to 5000 BCE. The Romans used it to flavour bread. It was once used as an aromatic and carminative, but its only modern use in medicine is to mask unpleasant tastes and odours of drugs.

4.16 Botanical description

Fig. 5 Flowers of Coriandrum sativum

Coriander is native to regions spanning from Southern Europe and Northern Africa to Southwestern Asia. It is a soft plant growing to 50 cm (20 in) tall. The leaves are variable in shape, broadly lobed at the base of the plant, and slender and feathery higher on the flowering stems. The flowers are borne in small umbels, white or very pale pink, asymmetrical, with the petals pointing away from the center of the umbel longer (5–6 mm or $\frac{3}{16}$–$\frac{1}{4}$ in) than those pointing toward it (only 1–3 mm or $\frac{1}{16}$–$\frac{1}{8}$ in long). The fruit is a globular, dry schizocarp 3–5 mm ($\frac{1}{8}$–$\frac{3}{16}$ in) in diameter. Pollen size is approximately 33 µm (0.0013 in).

4.17 Etymology

First attested in English during the late 14th century, the word "coriander" derives from the Old French *coriandre*, which comes from Latin *coriandrum*, in turn from Ancient Greek κορίαννον *koríannon*, possibly derived from or related to κόρις *kóris* (a bed bug), and was given on account of its foetid, bed bug-like smell. *Cilantro* is the Spanish word for coriander, also deriving from *coriandrum*. It is the common term in American English for coriander leaves, due to their extensive use in Mexican cuisine.

4.18 Origin and history

Coriander grows wild over a wide area of Western Asia and Southern Europe, prompting the comment: "It is hard to define exactly where this plant is wild and where it only recently established itself. Recent works suggested that coriander accessions found in the wild in Israel and Portugal might represent the ancestor of the cultivated coriander. They have low germination rates and a small vegetative appearance. The accession found in Israel has an extremely hard fruit coat.

Fifteen desiccated mericarps were found in the Pre-Pottery Neolithic B level (six to eight thousand years ago) of the Nahal Hemar Cave in Israel, which may be the oldest archaeological find of coriander. About 500 millilitres of coriander mericarps were recovered from the tomb of Tutankhamen, and because this plant does not grow wild in Egypt, Zohary and Hopf interpret this find as proof that coriander was cultivated by the ancient Egyptians. The Ebers Papyrus, an Egyptian medical text dated to around 1550 BC, describes coriander's medicinal and culinary uses.

Coriander seems to have been cultivated in Greece since at least the second millennium BC. One of the Linear B tablets recovered from Pylos refers to the species as being cultivated for the manufacture of perfumes; it apparently was used in two forms - as a spice for its seeds and as an herb for the flavour of its leaves. This appears to be confirmed by archaeological evidence from the same period; the large quantities of the species retrieved from an Early Bronze Age layer at Sitagroi in Macedonia could point to cultivation of the species at that time. Later, coriander was mentioned by Hippocrates (around 400 BC), as well as Dioscorides (65 AD).

4.19 Uses

The fresh leaves and the dried seeds are the parts most commonly used in cooking, but all parts of the plant are edible and the roots are an important element of Thai cooking. Coriander is used in cuisines throughout the world.

4.20 Leaves

Fig. 6 Coriander leaves

The leaves are variously referred to as coriander leaves, fresh coriander, Chinese parsley, or (in the US and commercially in Canada) cilantro. Coriander potentially may be confused with culantro (*Eryngium foetidum* L.), in the same family (Apiaceae) as coriander (*Coriandrum sativum* L.), but from a different genus. Culantro has a distinctly different spiny appearance, a more potent volatile leaf oil and a stronger aroma. The leaves have a different taste from the seeds, with citrus overtones.

The fresh leaves are an ingredient in many foods, such as chutneys and salads, salsa, guacamole, and as a widely used garnish for soup, fish, and meat.[22] As heat diminishes their flavour, coriander leaves are often used raw or added to the dish immediately before serving. In Indian and Central Asian recipes, coriander leaves are used in large amounts and cooked until the flavour diminishes. The leaves spoil quickly when removed from the plant, and lose their aroma when dried or frozen.

4.21 Seeds

Fig. 7 Dried coriander fruits are often called "coriander seeds" when used as a spice.

The dry fruits are coriander seeds. The word "coriander" in food preparation may refer solely to these seeds (as a spice), rather than to the plant. The seeds have a lemony citrus flavour when crushed, due to terpenes linalool and pinene. It is described as warm, nutty, spicy, and orange-flavoured.

The variety *C. sativum* var. *sativum* has a fruit diameter of 3–5 mm ($^{1}/_{8}$–$^{3}/_{16}$ in), while var. *microcarpum* fruits have a diameter of 1.5–3.0 mm (0.06–0.12 in), and var. *indicum* has elongated fruits. Large-fruited types are grown mainly by tropical and subtropical countries, e.g. Morocco, India, and Australia, and contain a low volatile oil content (0.1-0.4%). They are used extensively for grinding and blending purposes in the spice trade. Types with smaller fruit are produced in temperate regions and usually have a volatile oil content around 0.4-1.8%, so are highly valued as a raw material for the preparation of essential oil.

Coriander is commonly found both as whole dried seeds and in ground form. Roasting or heating the seeds in a dry pan heightens the flavour, aroma, and pungency. Ground coriander seed loses flavour quickly in storage and is best ground fresh. Coriander seed is a spice in *garam masala* and Indian curries, which often employ the ground fruits in generous amounts together with cumin, acting as a thickener in a mixture called *dhania jeera*. Roasted coriander seeds, called *dhania dal*, are eaten as a snack.

Outside of Asia, coriander seed is used widely in the process for pickling vegetables. In Germany and South Africa (see *boerewors*), the seeds are used while making sausages. In Russia and Central Europe, coriander seed is an occasional ingredient in rye bread (e.g. Borodinsky bread), as an alternative to caraway. The Zuni people of North America have adapted it into their cuisine, mixing the powdered seeds ground with chili and using it as a condiment with meat, and eating leaves as a salad.

Coriander seeds are used in brewing certain styles of beer, particularly some Belgian wheat beers. The coriander seeds are used with orange peel to add a citrus character. Coriander seeds are one of the key botanicals used to flavor gin. One preliminary study showed coriander essential oil to inhibit Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus*, *Enterococcus faecalis, Pseudomonas aeruginosa,* and *Escherichia coli*. Coriander is listed as one of the original ingredients in the secret formula for Coca-Cola.

4.22 Roots

Fig. 8 Coriander roots

Coriander roots have a deeper, more intense flavor than the leaves, and are used in a variety of Asian cuisines, especially in Thai dishes such as soups or curry pastes.

4.23 Nutrition

Raw coriander leaves are 92% water, 4% carbohydrates, 2% protein, and less than 1% fat (table). The nutritional profile of coriander seeds is different from the fresh stems or leaves. In a 100-gram (3+$^1/_2$ oz) reference amount, leaves are particularly rich in vitamin A, vitamin C, and vitamin K, with moderate content of dietary minerals (table). Although seeds generally have lower vitamin content, they do provide significant amounts of dietary fiber, calcium, selenium, iron, magnesium, and manganese. Botanical name of Coriander is *Coriandrum sativum*. In India, coriander is known as 'dhania' in Hindi language. Coriander seeds and leaves are used as common food flavoring agents. Coriander seeds have medicinal properties too and therefore used as a carminative, and diuretic. The leaves are variable in shape, broadly lobed at the base of the plant, and slender and feathery higher on the flowering stems.

All parts of the plant are edible, but the fresh leaves and the dried seeds are commonly used in cooking. The leaves have a different taste from the seeds, with citrus overtones. Some perceive an unpleasant “soapy” taste or a rank smell and avoid the leaves. In India, coriander is cultivated in Rajasthan, Madhya Pradesh, UP and southern states like AP, Karnataka, and Tamil Nadu.

4.24 Climatic Requirements

Being a tropical crop, coriander plants prefer frost-free tropical climate at the time of flowering and seed formation. Cool and comparatively dry climate.

4.24.1 Sowing time

June – July and October – November

4.25 Soil Preparation for Cultivation of Coriander

Well drained silt or loamy soils are suited for cultivation. For rainfed cultivation soil should be clay in nature and the pH should be 6 – 8. Coriander performs well at a temperature range of 20 – 25 °C

4.26 Field preparation and sowing:

Prepare the main field to a fine tilth and form beds and channels (for irrigated crop). Sow the split seeds at a spacing of 20 x 15 cm. The seeds will germinate in about 8-15 days. Presowing seed hardening treatment with Potassium Dihydrogen Phosphate @ 10g/lit of water for 16 hours is to be done for rainfed crop. Seeds are to be treated with Azospirillum @ 3 packets/ha. Seed treatment with Trichoderma viride @ 4 g/kg of seed has to be done to control wilt disease.

4.26.1 Seed rate:

10 – 12 kg/ha (Irrigated crop) and 20 – 25 kg/ha (Rainfed crop)

Whole seed will not germinate and hence the seeds are split open into halves before sowing for more germination percentage

4.26.2 Seed Treatment:

Soak the seeds in water for 12 hours. Treat the seeds with Azospirillum @ 1.5 kg /ha for better crop establishment + Trichoderma viride @ 50 kg/ha to control wilt disease. Pre sowing seed hardening treatment with Potassium Dihydrogen Phosphate @ 10 g/lit of water for 16 hours is to be done for rainfed crop.

4.26.3 Manuring for Cultivation of Coriander:

Basal FYM 10 t/ha; 10 kg N, 40 kg P and 20 kg K for rainfed and irrigated crops. Top dressing Top dressing may be done at 10 kg N/ha 30 days after sowing for the irrigated crop only

4.26.4 Weed control

In cultivation of coriander, first weeding is done 30 days after sowing and second weeding in irrigated coriander may be done between 50 and 60 days of sowing depending upon the weed growth. Herbicides may also be applied for weed control. Pre-plant Fluchloralin @ 0.75kg/ha, pre-emergent Oxyfluorfen @ 0.15kg/ha or Pendamithalin @ 1.0kg/ha are effective herbicides.

4.27.5 Irrigation Guidance for Cultivation of Coriander

First irrigation should be given immediately after sowing. Irrigation requirement is depending upon the parameters such as climate, soil moisture level, and the variety used. Standard irrigation schedule is 5–6 irrigations 30–35, 60–70, 80–90, 100–105 and 110–150 days after sowing.

4.27.6Harvest:

The plants are pulled just when the fruits are fully ripe but green and start drying. The plants are dried and thrashed with sticks, winnowed and cleaned. For leaf, pull out the plants when they are 30-40 days old.

4.27.7 Yield:

Rainfed Grain yield: 300-400 kg/ha

Irrigated: 500-600 kg/ha

Leaf yield: 6-7 t/h

4.27.8 Postharvest Management

Drying of Coriander Seeds Fresh coriander seeds should be dried in shade to retain seed color and quality. After drying, seeds are separated by light beating with sticks and winnowing

4.27.9 Packaging and Storage

Clean gunny bags are used for packing coriander seeds which are stored in damp-free aerated store rooms.

4.28 Summary

Under this unit we have summarized concept of ecology, evolution, different species (ginger, turmeric and cloves), manuring and weed control etc.

Ecology is the study of organisms and how they interact with the environment around them. An ecologist studies the relationship between living things and their habitats. In order to learn about the natural world, ecologists must study multiple aspects of life ranging from the moss that grows on rocks to the wolf population in Yellowstone National Park. In order to research the environment, scientists ask questions, such as: How do organisms interact with the living and nonliving factors around them? What do organisms need to survive and thrive in their current environments? To find the answers to these questions, ecologists must study and observe all forms of life and their ecosystems throughout our world.

Evolution is change in the heritable characteristics of biological populations over successive generations. These characteristics are the expressions of genes that are passed on from parent to offspring during reproduction. Different characteristics tend to exist within any given population as a result of mutation, genetic recombination and other sources of genetic variation. Evolution occurs when evolutionary processes such as natural selection (including sexual selection) and genetic drift act on this variation, resulting in certain characteristics becoming more common or rare within a population.[

Manure is organic matter that is used as organic fertilizer in agriculture. Most manure consists of animal feces; other sources include compost and green manure. Manures contribute to the fertility of soil by adding organic matter and nutrients, such as nitrogen, that are utilised by bacteria, fungi and other organisms in the soil. Higher organisms then feed on the fungi and bacteria in a chain of life that comprises the soil food web.

Weed control is the botanical component of pest control, which attempts to stop weeds, especially noxious weeds, from competing with desired flora and fauna including domesticated plants and livestock, and in natural settings preventing non native species competing with native species. Weed control is important in agriculture. Methods include hand cultivation with hoes, powered cultivation with cultivators, smothering with mulch, lethal wilting with high heat, burning, and chemical control with herbicides (weed killers).

4.29 Terminal questions

Q.1 What do you mean by ecology? Explain it.

Answer:---

Q. 2 Describe the manuring for cultivation of coriander.

Answer:---

Q.3 Describe the methods of weed control.

Answer:---

Q.4 Write short notes on the following.

(a) Spices

(b) Turmeric

Answer:---

Q.5Write short notes on the following.

(a) Ginger

(b) Cloves

Answer:---

Q.6 Describe the antioxidants with examples.

Answer:--

Q.7 Write short notes on the following.

(a) Roots

(b) Seeds

Answer:--

Q.8 Write short notes on the following.

(a) Saffron

(b) Coriander

Answer:--

Further readings

- Biochemistry- Lehninger A.L.
- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry and molecular biology- Wilson Walker

Unit-5: Beverages

Structure

5.1 Introduction

Beverages means all non-alcoholic beverages (i.e. anything consumed by drinking), whether or not such beverages (i) contain nutritive, food, or dairy ingredients, OR (ii) are in a frozen form. This definition applies without regard to the beverage's labeling or marketing. Powders, syrups, grounds (such as for coffee), herbs (such as for tea), concentrates, pods and all other beverage bases from which Beverages can be made, and brands and products of water purification and beverage making systems are deemed to be included in this definition. For the avoidance of doubt, "flavor enhancers", "liquid water enhancers", and non-alcoholic beverages sold as "shots" or "supplements" are considered Beverages. “Beverage” or “Beverages” shall not include fresh-brewed unbranded coffee and fresh-brewed unbranded tea products, unflavored dairy products, water drawn from the public water supply or unbranded juice squeezed fresh at the Facility. Beverages means alcoholic and non-alcoholic beverages, drinks and other potable liquids intended for human consumption, including beer, wine, soft drinks, fruit juices, milk, liquid dietary supplements and packaged or bottled water (but excluding products that constitute Pharmaceuticals).

A beverage or a drink meaning is a form of liquid used for subsistence, energy, or hydration. The number of beverage types has been increasing over time with more variety of flavors and tastes. When it comes to finding a beverage, we tend to have a longer list. You can choose the beverage to make the most significant profit margin for your business. However, to gain profit, you need to satisfy your target customers based on their interests or health conditions.

Yet, you should grasp specific knowledge about the beverage you will sell to make a better decision: which kind of liquid is preferred? Which one meets your customer’s needs? Below, we will clarify the two main types: alcoholic and non-alcoholic drinks.

Objectives

This is the fifth unit on paleobotany, palynology and economic botany. Under fifth unit, we have following objectives. These are as under:

- To know about favorable types of non-alcoholic beverages
- To know about rea, milk, coffee juices and energy drinks
- To know about sparkling drinks, mocktails, milkshakes and cocoa
- To discuss beer, wine, cider, cocktails and hard alcohol etc.

5.2 Favorable types of non-alcoholic beverages

First, we will dig deep into non-alcoholic or alcohol free beverages. They are drink without alcohol or with alcohol excluded or lessened to almost none. The example of non alcoholic products are tea, coffee, squeezed orange juice and energy drinks. Non-alcoholics are also known as soft drinks, they are prepared form unfermented fruits juices and dried leaves or seeds of various plants. They do not contain any alcohol but contain alkaloids caffeine.

5.2.1. Tea

Tea is an aromatic beverage prepared by pouring hot or boiling water over cured or fresh leaves of *Camellia sinensis*. It's an evergreen shrub native to China, India and other East Asian countries. Tea is also rarely made from the leaves of *Camellia taliensis*. After water, it is the most widely consumed drink in the world. There are many different types of tea; some have a cooling, slightly bitter, and astringent flavour, while others have vastly different profiles that include sweet, nutty, floral, or grassy notes. Tea has a stimulating effect in humans primarily due to its caffeine content.

Tea plants are native to East Asia and probably originated in the borderlands of southwestern China and northern Burma. An early credible record of tea drinking dates to the third century AD, in a medical text written by Hua Tuo. It was popularised as a recreational drink during the Chinese Tang dynasty, and tea drinking subsequently spread to other East Asian countries. Portuguese priests and merchants introduced it to Europe during the 16th century. During the 17th century, drinking tea became fashionable among the English, who started to plant tea on a large scale in India.

The term *herbal tea* refers to drinks not made from *Camellia sinensis.* They are the infusions of fruit, leaves, or other plant parts, such as steeps of rosehip, chamomile, or rooibos. These may be called *tisanes* or *herbal infusions* to prevent confusion with "tea" made from the tea plant. Physically speaking, tea has properties of both a solution and a suspension. It is a solution of all the water-soluble compounds that have been extracted from the tea leaves, such as the polyphenols and amino acids, but is a suspension when all of the insoluble components are considered, such as the cellulose in the tea leaves. Tea infusions are among most consumed beverages globally.

Caffeine constitutes about 3% of tea's dry weight, translating to between 30 and 90 milligrams per 250-millilitre (8+½ US fl oz) cup depending on the type, brand, and brewing method. A study found that the caffeine content of one gram of black tea ranged from 22 to 28 mg, while the caffeine content of one gram of green tea ranged from 11 to 20 mg, reflecting a significant difference. Tea also contains small amounts of theobromine and theophylline, which are stimulants, and xanthines similar to caffeine.

Fig. 1 Fresh tea leaves in various stages of growth

Black and green teas contain no essential nutrients in significant amounts, with the exception of the dietary mineral manganese, at 0.5 mg per cup or 26% of the Reference Daily Intake (RDI). Fluoride is sometimes present in tea; certain types of "brick tea", made from old leaves and stems, have the highest levels, enough to pose a health risk if much tea is drunk, which has been attributed to high levels of fluoride in soils, acidic soils, and long brewing.

The astringency in tea can be attributed to the presence of polyphenols. These are the most abundant compounds in tea leaves, making up 30–40% of their composition. Polyphenols include flavonoids, epigallocatechin gallate (EGCG), and other catechins. Although there has been preliminary clinical research on whether green or black teas may protect against various human diseases, there is no evidence that tea polyphenols have any effect on health or lowering disease risk.

5.2.1.1 Indian tea culture

Indian tea culture is strong; the drink is the most popular hot beverage in the country. It is consumed daily in almost all houses, offered to guests, consumed in high amounts in domestic and official surroundings, and is made with the addition of milk with or without spices, and usually sweetened. It is sometimes served with biscuits to be dipped in the tea and eaten before consuming the tea.

More often than not, it is drunk in "doses" of small cups (referred to as "cutting" chai if sold at street tea vendors) rather than one large cup. In Burma (Myanmar), tea is consumed not only as hot drinks, but also as sweet tea and green tea known locally as *laphet-yay* and *laphet-yay-gyan*, respectively. Pickled tea leaves, known locally as *lahpet*, are also a national delicacy. Pickled tea is usually eaten with roasted sesame seeds, crispy fried beans, roasted peanuts and fried garlic chips.

In Mali, gunpowder tea is served in series of three, starting with the highest oxidisation or strongest, unsweetened tea, locally referred to as "strong like death", followed by a second serving, where the same tea leaves are boiled again with some sugar added ("pleasant as life"), and a third one, where the same tea leaves are boiled for the third time with yet more sugar added ("sweet as love"). Green tea is the central ingredient of a distinctly Malian custom, the "Grin", an informal social gathering that cuts across social and economic lines, starting in front of family compound gates in the afternoons and extending late into the night, and is widely popular in Bamako and other large urban areas. In the United States, 80% of tea is consumed as iced tea. Sweet tea is native to the southeastern U.S. and is iconic in its cuisine.

5.2.2. Coffee

Coffee is a brewed drink prepared from roasted coffee beans, the seeds of berries from certain flowering plants in the *Coffea* genus. From the coffee fruit, the seeds are separated to produce a stable, raw product: unroasted *green coffee*. The seeds are then roasted, a process which transforms them into a consumable product: roasted coffee, which is ground into fine particles that are typically steeped in hot water before being filtered out, producing a cup of coffee.

Coffee is darkly colored, bitter, slightly acidic and has a stimulating effect in humans, primarily due to its caffeine content. It is one of the most popular drinks in the world and can be prepared and presented in a variety of ways (e.g., espresso, French press, caffè latte, or already-brewed canned coffee). It is usually served hot, although chilled or iced coffee is common. Sugar, sugar substitutes, milk or cream are often used to lessen the bitter taste or enhance the flavor. It may be served with coffee cake or another sweet dessert, like doughnuts. A commercial establishment that sells prepared coffee beverages is known as a coffeehouse or coffee shop (not to be confused with Dutch *coffeeshops* selling cannabis).

Clinical research indicates that moderate coffee consumption is benign or mildly beneficial as a stimulant in healthy adults, with continuing research on whether long-term consumption reduces the risk of some diseases, although some of the long-term studies are of questionable credibility. The earliest credible evidence of the drinking of coffee in the form of the modern beverage appears in modern-day Yemen from the middle of the 15th century in Sufi shrines, where coffee seeds were first roasted and brewed in a manner similar to current methods. The Yemenis procured the coffee beans from the Ethiopian Highlands via coastal Somali intermediaries and began cultivation. By the 16th century, the drink had reached the rest of the Middle East and North Africa, later spreading to Europe.

The two most commonly grown coffee bean types are *C. arabica* and *C. robusta*. Coffee plants are cultivated in over 70 countries, primarily in the equatorial regions of the Americas, Southeast Asia, the Indian subcontinent, and Africa. As of 2018, Brazil was the leading grower of coffee beans, producing 35% of the world total. Coffee is a major export commodity as the leading legal agricultural export for numerous countries. It is one of the most valuable commodities exported by developing countries. Green, unroasted coffee is the most traded agricultural commodity and one of the most traded commodities overall, second only to petroleum. Despite the sales of coffee reaching billions of dollars, those actually producing the beans are disproportionately living in poverty. Critics also point to the coffee industry's negative impact on the environment and the clearing of land for coffee-growing and water use. The environmental costs and wage disparity of farmers are causing the market for fair trade and organic coffee to expand.

Coffee is a popular beverage used worldwide; you can pour water over the roasted coffee beans to make it. This morning routine helps you get through the day as it is composed of a certain caffeine level, therefore keeping you awake.

In addition to the source of caffeine, it also contains antioxidants that prevent cells from damage. Studies have also shown that consuming the right amount of coffee could lower your risk of type 2 diabetes and Alzheimer's, improve your mood, and remember better.

Yet, it can be hazardous when you consume an excessive amount. Too much caffeine is linked to higher blood pressure, a higher risk of heart attacks, miscarriage, and many more harmful health benefits. That's why you should maintain a suitable amount of coffee that brings surprisingly significant effects on your body. Because ground coffee beans, coffee roasts, and brewing methods vary, so do coffee drinks. They come in so many different varieties and flavors, such as black coffee, espresso, latte, cappuccino, or mocha.

5.2.2.1 Coffee's botanical family

Coffee is part of the botanical family *Rubiaceae,* one of the largest families in the plant kingdom. The *Rubiaceae* family comprises almost 500 genera and more than 6,500 species. Species in this family include trees, shrubs, and herbs. They grow widely in tropical and sub-tropical regions throughout the world and are typically found in the lower story of forests. Economically, the coffee plant (the *Coffea* genus) is by far the most important member of the *Rubiaceae* family, but other members of the family are also economically significant. In addition to beverage plants, the family also includes:

- Medicinal plants: the bark of *Cinchona officinalis* is the source of quinine, used to treat malarial fever
- Dye plants: the roots of *Rubia tinctora* (common madder) are one of the oldest sources of red dyes
- Timber plants: the wood of *Adina cordifolia* is used for furniture, flooring, and more
- Ornamental plants: *Gardenia jasminoides* (common gardenia, cape jasmine) is found in many gardens

5.2.2.2 Coffee plant characteristics

The coffee plant is indigenous to the Kaffa region of Ethiopia in Africa. According to legend, it was discovered by Kaldi, a young goatherd. Coffee plants are now cultivated in more than 70 countries, primarily in the equatorial regions of Central and South America, Africa, and Southeast Asia. There are some 25 major species within the *Coffea* genus. The plants and seeds display significant variations, making precise classification difficult.

5.2.2.3 Cultivation

The traditional method of planting coffee is to place 20 seeds in each hole at the beginning of the rainy season. This method loses about 50% of the seeds' potential, as about half fail to sprout. A more effective process of growing coffee, used in Brazil, is to raise seedlings in nurseries that are then planted outside at six to twelve months. Coffee is often intercropped with food crops, such as corn, beans, or rice during the first few years of cultivation as farmers become familiar with its requirements. Coffee plants grow within a defined area between the tropics of Cancer and Capricorn, termed the bean belt or coffee belt.

Of the two main species grown, arabica coffee (from *C. arabica*) is generally more highly regarded than robusta coffee (from *C. canephora*). Robusta coffee tends to be bitter and have less flavor but better body than arabica. For these reasons, about three-quarters of coffee cultivated worldwide is *C. arabica*. Robusta strains also contain about 40–50% more caffeine than arabica. Consequently, this species is used as an inexpensive substitute for arabica in many commercial coffee blends. Good quality robusta beans are used in traditional Italian espresso blends to provide a full-bodied taste and a better foam head (known as *crema*).

Additionally, *Coffea canephora* is less susceptible to disease than *C. arabica* and can be cultivated in lower altitudes and warmer climates where *C. arabica* will not thrive. The robusta strain was first collected in 1890 from the Lomani River, a tributary of the Congo River, and was conveyed from the Congo Free State (now the Democratic Republic of the Congo) to Brussels to Java around 1900. From Java, further breeding resulted in the establishment of robusta plantations in many countries. In particular, the spread of the devastating coffee leaf rust (*Hemileia vastatrix*), to which *C. arabica* is vulnerable, hastened the uptake of the resistant robusta. *Hemileia vastatrix* is a fungal pathogen and results in light, rust-colored spots on the undersides of coffee plant leaves. *Hemileia vastatrix* grows exclusively on the leaves of coffee pants. Coffee leaf rust is found in virtually all countries that produce coffee.

Mycena citricolor is another threat to coffee plants, primarily in Latin America. Mycena citricolor, commonly referred to as American Leaf Spot, is a fungus that can affect the whole coffee plant. It can grow on leaves, resulting in leaves with holes that often fall from the plant.

Over 900 species of insect have been recorded as pests of coffee crops worldwide. Of these, over a third are beetles, and over a quarter are bugs. Some 20 species of nematodes, 9 species of mites, and several snails and slugs also attack the crop. Birds and rodents sometimes eat coffee berries, but their impact is minor compared to invertebrates. In general, *arabica* is the more sensitive species to invertebrate predation overall. Each part of the coffee plant is assailed by different animals. Nematodes attack the roots, coffee borer beetles burrow into stems and woody material, and the foliage is attacked by over 100 species of larvae (caterpillars) of butterflies and moths.

Mass spraying of insecticides has often proven disastrous, as predators of the pests are more sensitive than the pests themselves. Instead, integrated pest management has developed, using techniques such as targeted treatment of pest outbreaks, and managing crop environment away from conditions favouring pests. Branches infested with scale are often cut and left on the ground, which promotes scale parasites to not only attack the scale on the fallen branches but in the plant as well.

The 2-mm-long coffee borer beetle (*Hypothenemus hampei*) is the most damaging insect pest to the world's coffee industry, destroying up to 50 percent or more of the coffee berries on plantations in most coffee-producing countries. The adult female beetle nibbles a single tiny hole in a coffee berry and lays 35 to 50 eggs. Inside, the offspring grow, mate, and then emerge from the commercially ruined berry to disperse, repeating the cycle. Pesticides are mostly ineffective because the beetle juveniles are protected inside the berry nurseries, but they are vulnerable to predation by birds when they emerge.

When groves of trees are nearby, the American yellow warbler, rufous-capped warbler, and other insectivorous birds have been shown to reduce by 50 percent the number of coffee berry borers in Costa Rica coffee plantations.

Beans from different countries or regions can usually be distinguished by differences in flavor, aroma, body, and acidity. These taste characteristics are dependent not only on the coffee's growing region, but also on genetic subspecies (varietals) and processing. Varietals are generally known by the region in which they are grown, such as Colombian, Java and Kona.

Arabica coffee beans are cultivated mainly in Latin America, eastern Africa or Asia, while robusta beans are grown in central Africa, throughout southeast Asia, and Brazil.

5.2.2.4 Ecological effects

Originally, coffee farming was done in the shade of trees that provided a habitat for many animals and insects. Remnant forest trees were used for this purpose, but many species have been planted as well. These include leguminous trees of the genera *Acacia*, *Albizia*, *Cassia*, *Erythrina*, *Gliricidia*, *Inga*, and *Leucaena*, as well as the nitrogen-fixing non-legume sheoaks of the genus *Casuarina*, and the silky oak *Grevillea robusta*. This method is commonly referred to as the traditional shaded method, or "shade-grown". Starting in the 1970s, many farmers switched their production method to sun cultivation, in which coffee is grown in rows under full sun with little or no forest canopy. This causes berries to ripen more rapidly and bushes to produce higher yields, but requires the clearing of trees and increased use of fertilizer and pesticides, which damage the environment and cause health problems.

Unshaded coffee plants grown with fertilizer yield the most coffee, although unfertilized shaded crops generally yield more than unfertilized unshaded crops: the response to fertilizer is much greater in full sun. While traditional coffee production causes berries to ripen more slowly and produce lower yields, the quality of the coffee is allegedly superior. In addition, the traditional shaded method provides living space for many wildlife species. Proponents of shade cultivation say environmental problems such as deforestation, pesticide pollution, habitat destruction, and soil and water degradation are the side effects of the practices employed in sun cultivation.

The American Birding Association, Smithsonian Migratory Bird Center, National Arbor Day Foundation, and the Rainforest Alliance have led a campaign for 'shade-grown' and organic coffees, which can be sustainably harvested. Shaded coffee cultivation systems show greater biodiversity than full-sun systems, and those more distant from continuous forest compare rather poorly to undisturbed native forest in terms of habitat value for some bird species.

Coffee production use a large volume of water. On average it takes about 140 liters (37 U.S. gal) of water to grow the coffee beans needed to produce one cup of coffee, producing 1 kg (2.2 lb) of roasted coffee in Africa, South America or Asia requires 26,400 liters (7,000 U.S. gal) of water. Coffee is often grown in countries where there is a water shortage, such as Ethiopia.

Used coffee grounds may be used for composting or as a mulch. They are especially appreciated by worms and acid-loving plants such as blueberries. Some commercial coffee shops run initiatives to make better use of these grounds, including Starbucks' "Grounds for your Garden" project, and community sponsored initiatives such as "Ground to Ground". Climate change may significantly impact coffee yields during the 21st century, such as in Nicaragua and Ethiopia which could lose more than half of the farming land suitable for growing (Arabica) coffee. As of 2016, at least 34% of global coffee production was compliant with voluntary sustainability standards such as Fairtrade, UTZ, and 4C (The Common Code for the Coffee Community).

5.2.2.5 Uses & Effectiveness

Likely Effective for

- Mental alertness. Drinking coffee and other beverages that contain caffeine throughout the day seems to increase alertness and clear thinking. Caffeine can also improve alertness after sleep deprivation. Even one drink of coffee can reduce fatigue and increase alertness.

Possibly Effective for

- Impaired movement of food through the intestines after surgery. Drinking coffee might speed up the first stool and a person's ability to eat solid food after certain gut surgeries.
- Diabetes. People who drink more coffee seem to have a lower risk of developing type 2 diabetes. The greater the intake of coffee, the lower the risk. People with type 2 diabetes who drink more coffee might also have a slightly lower risk of dying.
- Death from any cause. Drinking coffee every day is linked to a slightly lower risk of dying from any cause or from heart disease. It's unclear if drinking coffee is linked with a lower risk of death from cancer.
- Parkinson disease. There is evidence that people who drink caffeinated beverages such as coffee, tea, and cola have a decreased risk of Parkinson disease. Interestingly, coffee does not seem to help prevent Parkinson disease in people who smoke cigarettes.

Possibly Ineffective for

- Cancer of the esophagus. Most people who drink more coffee don't seem to have a lower chance of developing cancer of the esophagus.

Insufficient Evidence for

- Hardening of the arteries (atherosclerosis). The buildup of calcium-containing plaque in the arteries is an early sign of possible atherosclerosis. Drinking coffee doesn't seem to be linked with a lower buildup of calcium-containing plaque in the arteries.
- Irregular heartbeat (atrial fibrillation). Drinking more coffee doesn't seem to be linked to a lower risk of atrial fibrillation.
- Bladder cancer. Drinking coffee doesn't seem to change the risk of bladder cancer.
- Brain cancer. Some early evidence suggests that Asian people who drink more coffee have a lower risk of developing brain cancer. This does not seem to be true for non-Asian people.
- Breast cancer. People who drink more coffee don't seem to have a lower chance of developing breast cancer.

- Heart disease. It is unclear if drinking coffee lowers the chance of developing heart disease. But it might lower the risk for heart failure and the likelihood of death from heart disease.
- Long-term kidney disease (chronic kidney disease or CKD). People who drink coffee seem to have a slightly lower chance of developing CKD. People with CKD who drink coffee might have a slightly lower risk for kidney failure or death due to kidney failure.
- Memory and thinking skills (cognitive function). There is developing evidence that drinking more coffee over a lifetime might improve thinking skills among women older than 80 years of age. Coffee also might improve the thinking speed and certain types of memory in healthy adults.
- Colon cancer, rectal cancer. There is some evidence that Japanese people who drink more coffee have a lower chance of developing colon or rectal cancer. But research conducted in North America and Europe has not found a link between drinking coffee and the risk of colon and rectal cancer. Drinking more coffee seems to slightly reduce the risk of death in people who have colon or rectal cancer.
- Diseases, such as Alzheimer disease, that interfere with thinking (dementia). People who drink more coffee don't seem to have a lower chance of dementia.
- Depression. People who drink more coffee might have a lower chance of depression.
- Cancer of the lining of the uterus (endometrial cancer). The effect of coffee on the risk of endometrial cancer is unclear. Some research suggests that women who drink more coffee have a lower risk of developing endometrial cancer. But other research has not found a link between drinking coffee and the risk of endometrial cancer.
- Gallbladder disease. People who drink beverages such as coffee that provide at least 400 mg of caffeine per day seem to have a lower risk of developing gallstones. The greater the intake of caffeine, the lower the risk.

- Stomach cancer. People who drink more coffee don't seem to have a lower risk of stomach cancer.
- Gout. There is some evidence that both caffeinated and decaffeinated coffee seem to help to prevent gout. But caffeinated coffee seems to work better.
- Hearing loss. Males who drink at least one cup of coffee daily seem to have a slightly lower chance of hearing loss. But drinking coffee doesn't seem to have this effect in females.
- High levels of cholesterol or other fats (lipids) in the blood (hyperlipidemia). Some research suggests that drinking caffeinated coffee seems to reduce levels of total cholesterol, LDL or "bad cholesterol", and blood fats called triglycerides by a small amount. But other research suggests that drinking coffee increases triglyceride and cholesterol levels.
- High blood pressure. People who drink coffee long-term might have a lower risk for high blood pressure. But smoking might eliminate this benefit. Drinking 1-3 cups daily seems to be most beneficial.
- Low blood pressure. Drinking caffeinated beverages like coffee seems to increase blood pressure in elderly people who experience dizziness after meals due to low blood pressure.
- Kidney failure. People with long-term kidney disease who drink coffee seem to have a slightly lower chance of kidney failure or death due to kidney failure.
- Liver cancer. People who drink more coffee might have a lower risk of liver cancer.
- Liver disease. People who drink more coffee might have a lower risk of liver disease.
- Lung cancer. Some research suggests that drinking caffeinated coffee may help to prevent lung cancer, but other research disagrees. It's too early to draw firm conclusions. Meanwhile, some research suggests that drinking decaffeinated coffee may help to prevent lung cancer.

- The most serious type of skin cancer (melanoma). When factors such as age and sun exposure are taken into account, drinking coffee doesn't seem to be linked with a lower chance of developing skin cancer.
- Build up of fat in the liver in people who drink little or no alcohol (nonalcoholic fatty liver disease or NAFLD). It's unclear if drinking coffee reduces the risk of NAFLD.
- Nonmelanoma skin cancer. Some research shows that drinking many cups of coffee per day might reduce the risk of a specific form of skin cancer called basal cell carcinoma. But drinking decaffeinated coffee does not seem to have any effect on skin cancer risk.
- Obesity. The effect of coffee on weight loss in people who are overweight or obese is unclear. Results from research are conflicting. Some research suggests that taking coffee chemicals, called mannooligosaccharides, for 12 weeks might help with weight loss in men, but not women. Drinking a dark roast coffee seems to help reduce food intake and help with weight loss, whereas a light roast coffee does not. Other research suggests that drinking coffee with or without caffeine does not help with weight loss.
- Mouth cancer. People who drink more coffee don't seem to have a lower risk of mouth cancer.
- Ovarian cancer. Drinking coffee doesn't seem to change a person's risk for ovarian cancer.
- Swelling (inflammation) of the pancreas (pancreatitis). Some early research suggests that drinking 3 or more cups of coffee reduces the pancreatitis risk.
- A type of throat cancer (pharyngeal cancer). People who drink more coffee might have a lower chance of developing pharyngeal cancer.
- Prostate cancer. In general, people who drink more coffee seem to have a slightly lower risk of developing prostate cancer that has not spread outside the prostate.
- Thyroid cancer. Drinking more coffee seems to be linked with a lower risk of thyroid cancer.
- Attention deficit-hyperactivity disorder (ADHD).

- Constipation.
- Other conditions.

More evidence is needed to rate the effectiveness of coffee for these uses.

Side Effects

When taken by mouth: Coffee is likely safe for most healthy adults when consumed in moderate amounts (about 4 cups per day). Coffee containing caffeine can cause insomnia, nervousness and restlessness, stomach upset, nausea and vomiting, increased heart and breathing rate, and other side effects. Caffeinated coffee is possibly unsafe when taken by mouth for a long time or in high doses (more than 4 cups per day). Drinking large amounts of caffeinated coffee might cause headache, anxiety, agitation, ringing in the ears, and irregular heartbeats. Larger doses might cause headache, anxiety, agitation, and chest pain. When given as an enema (rectally): Coffee is possibly unsafe when given rectally as an enema. Coffee enemas have been linked to cases of severe side effects, including death.

5.3. Summary

Under this unit we have synthesized non-alcoholic beverages, tea and coffee. Tea is an aromatic beverage prepared by pouring hot or boiling water over cured or fresh leaves of Camellia sinensis. an evergreen shrub native to China, India and other East Asian countries. During the 17th century, drinking tea became fashionable among the English, who started to plant tea on a large scale in India. Caffeine constitutes about 3% of tea's dry weight, translating to between 30 and 90 milligrams per 250-millilitre (8+1⁄2 US fl oz) cup depending on the type, brand, and brewing method. Indian tea culture is strong; the drink is the most popular hot beverage in the country. It is consumed daily in almost all houses, offered to guests, consumed in high amounts in domestic and official surroundings.

Coffee is a brewed drink prepared from roasted coffee beans, the seeds of berries from certain flowering plants in the Coffea genus. Coffee is darkly colored, bitter, slightly acidic and has a stimulating effect in humans, primarily due to its caffeine content. Clinical research indicates that moderate coffee consumption is benign or mildly beneficial as a stimulant in healthy adults, with continuing research on whether long-term consumption reduces the risk of some diseases. Drinking coffee and other beverages that contain caffeine throughout the day seems to increase alertness and clear thinking. Caffeine can also improve alertness after sleep deprivation. Even one drink of coffee can reduce fatigue and increase alertness.

5.4 Terminal questions

Q.1. What do you mean by non-alcoholic beverages? Explain it.

Answer:---

Q. 2 Describe the tea as non alcoholic beverage

Answer:---

Q 3. Describe the methods of cultivation of coffee.

Answer:---

Q4. Write short notes on tea.

Answer:---

Q.5 Write short notes on coffee.

Answer:---

Q. 6. Describe uses and effectiveness of coffee.

Answer:--

Further readings

1. Biochemistry- Lehninger A.L.
2. Text book of Botany – Singh -Pande-Jain.
3. The elements of Botany- James Hewetson Wilson
4. Textbook of Biotechnology –H. K. Das
5. Biochemistry and molecular biology- Wilson Walker

Unit-6: Fibers

Structure

6.1 Introduction

Fiber or **fibre** is a natural or man-made substance that is significantly longer than it is wide. Fibers are often used in the manufacture of other materials. The strongest engineering materials often incorporate fibers, for example carbon fiber and ultra-high-molecular-weight polyethylene. Synthetic fibers can often be produced very cheaply and in large amounts compared to natural fibers, but for clothing natural fibers can give some benefits, such as comfort, over their synthetic counterparts. Synthetic fibers such as glass fibers, carbon fibers, and boron fiber are gaining more attention over last two decades. Natural fiber composites are having healthy competition with synthetic composites such as glass–polypropylene and glass–epoxies. Synthetic fiber-reinforced polymer composites provide high-strength and stiffness materials that are widely accepted as aerospace components and automotive industries.

Nowadays, natural fibers are used to replace synthetic fibers because of environmental concern as a reinforced material in polymer composites for engineering materials. Hybrid composites of natural and synthetic fibers are often used to enhance the mechanical strength of polymer composites. Natural fibers are the most promising reinforcements, substitute to synthetic fibers for fibers reinforced polymer composites, owing to nontoxic, nonabrasive, higher specific strength, lower density, minimal environmental impact, biodegradability besides desirable mechanical properties compared to synthetic fiber, such as glass, carbon, Kevlar fibers The natural fibers with high content of lignin exhibit high char yield, high effective heat of combustion (EHC), high activation energy of combustion (E_a) and low CO/CO_2 ratio.

Objectives

This is the sixth unit on paleobotany, palynology and economic botany. Under sixth unit, we have following objectives. These are as under:

- To know about various types of fibers and properties
- To know about jute, its history and its types
- To know about linseed oil, toxicity, cultivation and production
- To discuss hemp, coir, cotton, cultivation and uses.

6.2 Natural fibers

Natural fibers develop or occur in the fiber shape, and include those produced by plants, animals, and geological processes. They can be classified according to their origin:

- Vegetable fibers are generally based on arrangements of cellulose, often with lignin: example
  include cotton, hemp, jute, flax, abaca, piña, ramie, sisal, bagasse,

and banana. Plant fibers are employed in the manufacture of paper and textile (cloth), and dietary fiber is an important component of human nutrition.

- Wood fiber, distinguished from vegetable fiber, is from tree sources. Forms include groundwood, lacebark, thermomechanical pulp (TMP), and bleached or unbleached kraft or sulfite pulps. Kraft and sulfite refer to the type of pulping process used to remove the lignin bonding the original wood structure, thus freeing the fibers for use in paper and engineered wood products such as fiberboard.
- Animal fibers consist largely of particular proteins. Instances are silkworm silk, spider silk, sinew, catgut, wool, sea silk and hair such as cashmere wool, mohair and angora, fur such as sheepskin, rabbit, mink, fox, beaver, etc.
- Mineral fibers include the asbestos group. Asbestos is the only naturally occurring long mineral fiber. Six minerals have been classified as "asbestos" including chrysotile of the serpentine class and those belonging to the amphibole class: amosite, crocidolite, tremolite, anthophyllite and actin olite. Short, fiber-like minerals include wollastonite and palygorskite.
- Biological fibers, also known as fibrous proteins or protein filaments, consist largely of biologically relevant and biologically very important proteins, in which mutations or other genetic defects can lead to severe diseases. Instances include the collagen family of proteins, tendons, muscle proteins like actin, cell proteins like microtubules and many others, such as spider silk, sinew, and hair.

6.2.1 Man-made fibers

Man-made or chemical fibers are fibers whose chemical composition, structure, and properties are significantly modified during the manufacturing process. In fashion, a fiber is a long and thin strand or thread of material that can be knit or woven into a fabric. Man-made fibers consist of regenerated fibers and synthetic fibers.

6.2.2 Semi-synthetic fibers

Semi-synthetic fibers are made from raw materials with naturally long-chain polymer structure and are only modified and partially degraded by chemical processes, in contrast to completely synthetic fibers such as nylon (polyamide) or dacron (polyester), which the chemist synthesizes from low-molecular weight compounds by polymerization (chain-building) reactions. The earliest semi-synthetic fiber is the cellulose regenerated fiber, rayon. Most semi-synthetic fibers are cellulose regenerated fibers.

6.2.3 Cellulose regenerated fibers

Cellulose fibers are a subset of man-made fibers, regenerated from natural cellulose. The cellulose comes from various sources: rayon from tree wood fiber, bamboo fiber from bamboo, seacell from seaweed, etc. In the production of these fibers, the cellulose is reduced to a fairly pure form as a viscous mass and formed into fibers by extrusion through spinnerets. Therefore, the manufacturing process leaves few characteristics distinctive of the natural source material in the finished products. Some examples of this fiber type are:

- Rayon
- Lyocell, a brand of rayon
- Modal
- Diacetate fiber
- Triacetate fiber.

Historically, cellulose diacetate and -triacetate were classified under the term rayon, but are now considered distinct materials.

6.2.4 Synthetic fibers

Synthetic come entirely from synthetic materials such as petrochemicals, unlike those man-made fibers derived from such natural substances as cellulose or protein. Fiber classification in reinforced plastics falls into two classes: (i) short fibers, also known as discontinuous fibers, with a general aspect ratio (defined as the ratio of fiber length to diameter) between 20 and 60, and (ii) long fibers, also known as continuous fibers, the general aspect ratio is between 200 and 500.

6.2.5 Metallic fibers

Metallic fibers can be drawn from ductile metals such as copper, gold or silver and extruded or deposited from more brittle ones, such as nickel, aluminum or iron.

6.6.6 Carbon fiber

Carbon fibers are often based on oxidized and via pyrolysis carbonized polymers like PAN, but the end product is almost pure carbon.

6.6.7 Silicon carbide fiber

Silicon carbide fibers, where the basic polymers are not hydrocarbons but polymers, where about 50% of the carbon atoms are replaced by silicon atoms, so-called poly-carbo-silanes. The pyrolysis yields an amorphous silicon carbide, including mostly other elements like oxygen, titanium, or aluminium, but with mechanical properties very similar to those of carbon fibers.

6.6.8 Fiberglass

Fiberglass, made from specific glass, and optical fiber, made from purified natural quartz, are also man-made fibers that come from natural raw materials, silica fiber, made from sodium silicate (water glass) and basalt fiber made from melted basalt.

Mineral fibers

Mineral fibers can be particularly strong because they are formed with a low number of surface defects, asbestos is a common one.

6.6.9 Polymer fibers

- Polymer fibers are a subset of man-made fibers, which are based on synthetic chemicals (often from petrochemical sources) rather than arising from natural materials by a purely physical process. These fibers are made from:
  - polyamide nylon
  - PET or PBT polyester
  - phenol-formaldehyde (PF)
  - polyvinyl chloride fiber (PVC) vinyon
  - polyolefins (PP and PE) olefin fiber

- acrylic polyesters, pure polyester PAN fibers are used to make carbon fiber by roasting them in a low oxygen environment. Traditional acrylic fiber is used more often as a synthetic replacement for wool. Carbon fibers and PF fibers are noted as two resin-based fibers that are not thermoplastic, most others can be melted.
- aromatic polyamids (aramids) such as Twaron, Kevlar and Nomex thermally degrade at high temperatures and do not melt. These fibers have strong bonding between polymer chains
- polyethylene (PE), eventually with extremely long chains / HMPE (e.g. Dyneema or Spectra).
- Elastomers can even be used, e.g. spandex although urethane fibers are starting to replace spandex technology.
- polyurethane fiber
- Elastolefin

- Coextruded fibers have two distinct polymers forming the fiber, usually as a core-sheath or side by side. Coated fibers exist such as nickel-coated to provide static elimination, silver-coated to provide anti-bacterial properties and aluminum-coated to provide RF deflection for radar chaff. Radar chaff is actually a spool of continuous glass tow that has been aluminum coated. An aircraft-mounted high speed cutter chops it up as it spews from a moving aircraft to confuse radar signals.

6.6.10 Microfibers

Invented in Japan in the early 1980s, microfibers are also known as microdenier fibers. Acrylic, nylon, polyester, lyocell and rayon can be produced as microfibers. In 1986, Hoechst A.G. of Germany produced microfiber in Europe. This fiber made it way into the United States in 1990 by DuPont. Microfibers in textiles refer to sub-denier fiber (such as polyester drawn to 0.5 denier). Denier and Dtex are two measurements of fiber yield based on weight and length. If the fiber density is known, you also have a fiber diameter, otherwise it is simpler to measure diameters in micrometers. Microfibers in technical fibers refer to ultra fine fibers (glass or meltblown thermoplastics) often used in filtration. Newer fiber designs include extruding fiber that splits into multiple finer fibers.

Most synthetic fibers are round in cross-section, but special designs can be hollow, oval, star-shaped or trilobal. The latter design provides more optically reflective properties. Synthetic textile fibers are often crimped to provide bulk in a woven, non woven or knitted structure. Fiber surfaces can also be dull or bright. Dull surfaces reflect more light while bright tends to transmit light and make the fiber more transparent. Very short and/or irregular fibers have been called fibrils. Natural cellulose, such as cotton or bleached kraft, show smaller fibrils jutting out and away from the main fiber structure.

6.6.11 Typical properties of selected fibers

Fibers can be divided into natural and man-made (synthetic) substance, their properties can affect their performance in many applications. Synthetic fiber materials are increasingly replacing other conventional materials like glass and wood in a number of applications. This is because man-made fibers can be engineered chemically, physically, and mechanically to suit particular technical engineering. In choosing a fiber type, a manufacturer would balance their properties with the technical requirements of the applications. Various fibers are available to select for manufacturing. Here are typical properties of the sample natural fibers as compared to the properties of man-made fibers.

6.7 Jute

Jute is a long, soft, shiny bast fiber that can be spun into coarse, strong threads. It is produced from flowering plants in the genus *Corchorus*, which is in the mallow family Malvaceae. The primary source of the fiber is *Corchorus olitorius*, but such fiber is considered inferior to that derived from *Corchorus capsularis*. "Jute" is the name of the plant or fiber used to make burlap, hessian or gunny cloth. Jute is one of the most affordable natural fibers, and second only to cotton in the amount produced and variety of uses. Jute fibers are composed primarily of the plant materials cellulose and lignin. Jute fiber falls into the bast fiber category (fiber collected from bast, the phloem of the plant, sometimes called the "skin") along with kenaf, industrial hemp, flax (linen), ramie, etc.. The industrial term for jute fiber is *raw jute*. The fibers are off-white to brown, and 1–4 metres (3–13 feet) long. Jute is also called the "golden fiber" for its color and high cash value.

6.8 Cultivation

The jute plant needs a plain alluvial soil and standing water. The suitable climate for growing jute (warm and wet) is offered by the monsoon climate, during the monsoon season. Temperatures from 20 to 40 °C (68–104 °F) and relative humidity of 70%–80% are favourable for successful cultivation. Jute requires 5–8 cm (2–3 in) of rainfall weekly, and more during the sowing time. Soft water is necessary for jute production.

6.8.1 White jute (*Corchorus capsularis*)

Historical documents state that the poor villagers of India used to wear clothes made of jute. The weavers used simple hand spinning wheels and hand looms, and spun cotton yarns as well. History also suggests that Indians, especially Bengalis, used ropes and twines made of white jute from ancient times for household and other uses. Jute is highly functional for carrying grains or other agricultural products.

6.8.2 Tossa jute (*Corchorus olitorius*)

Tossa jute (*Corchorus olitorius*) is a variety thought to be native to South Asia. It is grown for both fiber and culinary purposes. People use the leaves as an ingredient in a mucilaginous potherb called "molokhiya" which is popular in some Arabic countries such as Egypt, Jordan, and Syria as a soup-based dish, sometimes with meat over rice or lentils. Bangladesh and other countries in Southeast Asia, and the South Pacific mainly use jute for its fiber. Tossa jute fiber is softer, silkier, and stronger than white jute. This variety shows good sustainability in the Ganges Delta climate. Along with white jute, tossa jute has also been cultivated in the soil of Bengal where it is known as *paat* from the start of the 19th century. Coremantel, Bangladesh, is the largest global producer of the tossa jute variety. And in India West Bengal is the largest producer of jute.

6.8.3 History

Jute was used for making textiles in the Indus valley civilization since the 3rd millennium BC. In classical antiquity, Pliny recorded that jute plants were used as food in Ancient Egypt. It may have also been cultivated by the Jews in the

Near East. For centuries, jute has been an integral part of the culture of Bangladesh and some parts of West Bengal and Assam The British started trading in jute during the seventeenth century. During the reign of the British Empire, jute was also used in the military. British jute barons grew rich by processing jute and selling manufactured products made from it. Dundee Jute Barons and the British East India Company set up many jute mills in Bengal, and by 1895 jute industries in Bengal overtook the Scottish jute trade. Many Scots emigrated to Bengal to set up jute factories. More than a billion jute sandbags were exported from Bengal to the trenches of World War I, and to the southern United States for bagging cotton. It was used in the fishing, construction, art and the arms industries. Initially, due to its texture, it could only be processed by hand until someone in Dundee discovered that treating it with whale oil made it machine processable. The industry boomed throughout the eighteenth and nineteenth centuries ("jute weaver" was a recognized trade occupation in the 1900 UK census), but this trade had largely ceased by about 1970 due to the emergence of synthetic fibers. In the 21st century, jute again has become an important export crop around the world, mainly in Bangladesh.

6.8.4 Production

The jute fiber comes from the stem and ribbon (outer skin) of the jute plant. The fibers are first extracted by retting. The retting process consists of bundling jute stems together and immersing them in slow running water. There are two types of retting: stem and ribbon. After the retting process, stripping begins; women and children usually do this job. In the stripping process, non-fibrous matter is scraped off, then the workers dig in and grab the fibers from within the jute stem.

Jute is a rain-fed crop with little need for fertilizer or pesticides, in contrast to cotton's heavy requirements. Production in India is concentrated mostly in West Bengal. India is the world's largest producer of jute, but imported approximately 162,000 tonnes of raw fiber and 175,000 tonnes of jute products in 2011. India, Pakistan, and China import significant quantities of jute fiber and products from Bangladesh, as do the United Kingdom, Japan, United States, France, Spain, Ivory Coast, Germany and Brazil.

6.9 Flax

Flax, also known as common flax or **linseed**, is a flowering plant, ***Linum usitatissimum***, in the family Linaceae. It is cultivated as a food and fiber crop in regions of the world with temperate climates. Textiles made from flax are known in Western countries as linen and are traditionally used for bed sheets, underclothes, and table linen. Its oil is known as linseed oil. In addition to referring to the plant, the word "flax" may refer to the unspun fibers of the flax plant. The plant species is known only as a cultivated plant and appears to have been domesticated just once from the wild species *Linum bienne*, called pale flax. The plants "flax" in New Zealand are, by contrast, members of the genus *Phormium*.

Several other species in the genus *Linum* are similar in appearance to *L. usitatissimum*, cultivated flax, including some that have similar blue flowers, and others with white, yellow, or red flowers. Some of these are perennial plants, unlike *L. usitatissimum*, which is an annual plant. Cultivated flax plants grow to 1.2 m (3 ft 11 in) tall, with slender stems. The leaves are glaucous green, slender lanceolate, 20–40 mm long, and 3 mm broad. The flowers are pure pale blue, 15–25 mm in diameter, with five petals. The fruit is a round, dry capsule 5–9 mm in diameter, containing several glossy brown seeds shaped like an apple pip, 4–7 mm long.

6.10 History

The earliest evidence of humans using wild flax as a textile comes from the present-day Republic of Georgia, where spun, dyed, and knotted wild flax fibers found in Dzudzuana Cave date to the Upper Paleolithic, 30,000 years ago. Humans first domesticated flax in the Fertile Crescent region. Evidence exists of a domesticated oilseed flax with increased seed-size from Tell Ramad in Syria and flax fabric fragments from Çatalhöyük in Turkey by circa 9,000 years ago. Use of the crop steadily spread, reaching as far as Switzerland and Germany by 5,000 years ago. In China and India, domesticated flax was cultivated at least 5,000 years ago.

Flax was cultivated extensively in ancient Egypt, where the temple walls had paintings of flowering flax, and mummies were embalmed using linen. Egyptian priests wore only linen, as flax was considered a symbol of purity. Phoenicians traded Egyptian linen throughout the Mediterranean and the Romans used it for their sails. As the Roman Empire declined, so did flax production. But with laws designed to publicize the hygiene of linen textiles and the health of linseed oil, Charlemagne revived the crop in the eighth century AD. Eventually, Flanders became the major center of the European linen industry in the Middle Ages. In North America, colonists introduced flax, and it flourished there, but by the early 20th century, cheap cotton and rising farm wages had caused production of flax to become concentrated in northern Russia, which came to provide 90% of the world's output. Since then, flax has lost its importance as a commercial crop, due to the easy availability of more durable fibres.

6.10.1 Nutrition

Flax seeds are 7% water, 18% protein, 29% carbohydrates, and 42% fat (table). In 100 grams (3.5 oz) as a reference amount, flax seeds provide 534 calories and contain high levels (20% or more of the Daily Value, DV) of protein, dietary fiber, several B vitamins, and dietary minerals. Flax seeds are especially rich in thiamine, magnesium, and phosphorus (DVs above 90%) (table). As a percentage of total fat, flax seeds contain 54% omega-3 fatty acids (mostly ALA), 18% omega-9 fatty acids (oleic acid), and 6% omega-6 fatty acids (linoleic acid); the seeds contain 9% saturated fat, including 5% as palmitic acid. Flax seed oil contains 53% 18:3 omega-3 fatty acids (mostly ALA) and 13% 18:2 omega-6 fatty acids.

6.10.2 Health research

One study of research published between 1990 and 2008 showed that consuming flax seed or its derivatives may reduce total and LDL-cholesterol in the blood, with greater benefits in women and people with high cholesterol. A meta-analysis showed that consumption of more than 30 g of flax-seed daily for more than 12 weeks reduced body weight, body mass index (BMI), and waist circumference for persons with a BMI greater than 27. Another meta-analysis showed that consumption of flax seeds for more than 12 weeks produced small reductions in systolic blood pressure and diastolic blood pressure. Flax seed supplementation showed a small reduction in c-reactive protein (a marker of inflammation) only in persons with a body mass index greater than 30.

6.10.3 Linseed oil

Linseed oil, also known as flaxseed oil or flax oil (in its edible form), is a colourless to yellowish oil obtained from the dried, ripened seeds of the flax plant.

6.10.4 Toxicity

Flax seed and its oil are generally recognized as safe for human consumption. Like many common foods, flax contains small amounts of cyanogenic glycoside, which is nontoxic when consumed in typical amounts, but may be toxic when consumed in large quantities as with staple foods such as cassava. Typical concentrations (for example, 0.48% in a sample of defatted dehusked flax seed meal) can be removed by special processing.

6.10.5 Cultivation

The soils most suitable for flax, besides the alluvial kind, are deep loams containing a large proportion of organic matter. Flax is often found growing just above the waterline in cranberry bogs. Heavy clays are unsuitable, as are soils of a gravelly or dry sandy nature. Farming flax requires few fertilizers or pesticides. Within eight weeks of sowing, the plant can reach 10–15 cm (3.9–5.9 in) in height, reaching 70–80 cm (28–31 in) within 50 days.

6.10.6 Production

In 2018, world production of flax (linseed) was 3.2 million tonnes, led by Kazakhstan with 29% of the total. Other major producers were Canada, Russia, and China.

6.10.7 Hemp

Hemp, or industrial hemp, is a botanical class of *Cannabis sativa* cultivars grown specifically for industrial or medicinal use. It can be used to make a wide range of products. Along with bamboo, hemp is among the fastest growing plants on Earth. It was also one of the first plants to be spun into usable fiber 50,000 years ago. It can be refined into a variety of commercial items, including paper, rope, textiles, clothing, biodegradable plastics, paint, insulation, biofuel, food, and animal feed.

Although chemotype I cannabis and hemp (types II, III, IV, V) are both *Cannabis sativa* and contain the psychoactive component tetrahydrocannabinol (THC), they represent distinct cultivar groups, typically with unique phytochemical compositions and uses. Hemp typically has lower concentrations of total THC and may have higher concentrations of cannabidiol (CBD), which potentially mitigates the psychoactive effects of THC. The legality of hemp varies widely among countries. Some governments regulate the concentration of THC and permit only hemp that is bred with an especially low THC content into commercial production.

6.10.8 Uses

Hemp is used to make a variety of commercial and industrial products, including rope, textiles, clothing, shoes, food, paper, bioplastics, insulation, and biofuel.[4] The bast fibers can be used to make textiles that are 100% hemp, but they are commonly blended with other fibers, such as flax, cotton or silk, as well as virgin and recycled polyester, to make woven fabrics for apparel and furnishings. The inner two fibers of the plant are woodier and typically have industrial applications, such as mulch, animal bedding, and litter. When oxidized (often erroneously referred to as "drying"), hemp oil from the seeds becomes solid and can be used in the manufacture of oil-based paints, in creams as a moisturizing agent, for cooking, and in plastics. Hemp seeds have been used in bird feed mix as well. A survey in 2003 showed that more than 95% of hemp seed sold in the European Union was used in animal and bird feed.

6.11 Food

Fig. 1 A macro image of hemp seeds

Hemp seeds can be eaten raw, ground into hemp meal, sprouted or made into dried sprout powder. Hemp seeds can also be made into a slurry used for baking or for beverages, such as hemp milk and tisanes. Hemp oil is cold-pressed from the seed and is high in unsaturated fatty acids. In the UK, the Department for Environment, Food and Rural Affairs treats hemp as a purely non-food crop, but with proper licensing and proof of less than 0.3% THC concentration, hemp seeds can be imported for sowing or for sale as a food or food ingredient. In the US, hemp can be used legally in food products and, as of 2000, was typically sold in health food stores or through mail order.

6.11.1 Storage

Hemp oil oxidizes and turns rancid within a short period of time if not stored properly; its shelf life is extended when it is stored in a dark airtight container and refrigerated. Both light and heat can degrade hemp oil.

6.11.2 Fiber

Hemp fiber has been used extensively throughout history, with production climaxing soon after being introduced to the New World. For centuries, items ranging from rope, to fabrics, to industrial materials were made from hemp fiber. Hemp was also commonly used to make sail canvas. The word "canvas" is derived from the word *cannabis*. Pure hemp has a texture similar to linen. Because of its versatility for use in a variety of products, today hemp is used in a number of consumer goods, including clothing, shoes, accessories, dog collars, and home wares. For clothing, in some instances, hemp is mixed with lyocell.

6.12 Coir

Coir or **coconut fibre**, is a natural fibre extracted from the outer husk of coconut and used in products such as floor mats, doormats, brushes and mattresses. Coir is the fibrous material found between the hard, internal shell and the outer coat of a coconut. Other uses of **brown coir** (made from ripe coconut) are in upholstery padding, sacking and horticulture. **White coir**, harvested from unripe coconuts, is used for making finer brushes, string, rope and fishing nets. It has the advantage of not sinking, so can be used in long lengths in deep water without the added weight dragging down boats and buoys.

Coir must not be confused with **coir pith**, which is the powdery and spongy material resulting from the processing of the coir fibre. Coir fibre is locally named 'coprah' in some countries, adding to confusion. Pith is chemically similar to coir, but contains much shorter fibers. The name **coco peat** may refer either to coir or the pith or a mixture, as both have good water-retaining properties as a substitute for peat.

6.12.1 History

The name *coir* comes from, the Tamil & Malayalam words respectively for cord or rope (traditionally, a kind of rope is made from the coconut fibre). Ropes and cordage have been made from coconut fibre since ancient times. The Austronesian peoples, who first domesticated coconuts, used coconut fibre extensively for ropes and sennit in building houses and lashed-lug plank boats in their voyages in both the Pacific and the Indian Oceans. Later Indian and Arab navigators who sailed the seas to Malaya, China, and the Persian Gulf centuries ago also used coir for their ship ropes. Arab writers of the 11th century AD referred to the extensive use of coir for ship ropes and rigging.

A coir industry in the UK was recorded before the second half of the 19th century. During 1840, Captain Widely, in co-operation with Captain Logan and Mr. Thomas Treloar, founded the known carpet firms of Treloar and Sons in Ludgate Hill, England, for the manufacture of coir into various fabrics suitable for floor coverings.

6.12.2 Uses

6.12.3 Cordage, packaging, bedding, flooring, and others

Red coir is used in floor mats and doormats, brushes, mattresses, floor tiles and sacking.[14] A small amount is also made into twine. Pads of curled brown coir fibre, made by needle-felting (a machine technique that mats the fibres together), are shaped and cut to fill mattresses and for use in erosion control on river banks and hillsides. A major proportion of brown coir pads are sprayed with rubber latex which bonds the fibres together (rubberised coir) to be used as upholstery padding for the automobile industry in Europe. The material is also used for packaging.

The major use of white coir is in rope manufacture. Mats of woven coir fibre are made from the finer grades of bristle and white fibre using hand or mechanical looms. White coir also is used to make fishing nets due to its strong resistance to saltwater.

6.12.4 Agricultural and horticultural uses

In agriculture and horticulture, coir is used as an organic and decorative component in soil and potting mixes. Due to the increasing concern regarding the sustainability of producing sphagnum (peat moss) and peat from peatlands, usage of alternative substrates has been on the rise; the byproduct coir is one commonly used substitute. Many sources of coir however are heavily contaminated with pathogenic fungi, and the choice of the source is important. Coir is also useful to deter snails from delicate plantings, and as a growing medium in intensive glasshouse (greenhouse) horticulture.

Coir is also used as a substrate to grow mushrooms. The coir is usually mixed with vermiculite and pasteurised with boiling water. After the coir/vermiculite mix has cooled to room temperature, it is placed in a larger container, usually a plastic box. Previously prepared spawn jars are then added, spawn is usually grown in jars using substrates such as rye grains or wild bird seed. This spawn is the mushrooms mycelium and will colonize the coir/vermiculite mix eventually fruiting mushrooms.

Coir can be used as a terrarium substrate for reptiles or arachnids. Coir fibre pith or coir dust can hold large quantities of water, just like a sponge. It is used as a replacement for traditional peat in soil mixtures, or, as a soil-less substrate for plant cultivation. It has been called "coco peat" because it is to fresh coco fibre somewhat like what peat is to peat moss, although it is not true peat. Coir waste from coir fibre industries is washed, heat-treated, screened and graded before being processed into coco peat products of various granularity and denseness, which are then used for horticultural and agricultural applications and as industrial absorbent.

Usually shipped in the form of compressed bales, briquettes, slabs or discs, the end user usually expands and aerates the compressed coco peat by the addition of water. A single kilogramme of dry coco peat will expand to 15 litres of moist coco peat.

6.13 Other uses

6.13.1 Oil and fluid absorption

Due to its superior absorption capabilities when compared to products made of clay, silica and diatomaceous earth-based absorbents, dry coconut coir pith is gaining popularity as an oil and fluid absorbent. Many other absorbents have to be mined, whereas coconut coir pith is a waste product in abundance in countries where coconut is a major agriculture product.

6.13.2 Animal bedding

Coconut coir pith is also used as a bedding in litter boxes, animal farms and pet houses to absorb animal waste.

6.13.3 Construction material

Coconut fiber (coir) is used as a construction material because the natural fibers are eco-friendly. Additionally, coconut fiber (CF) is resistant to thermal conductivity, is very tough, ductile, durable, renewable and inexpensive. It was observed in an experimental study that by partially replacing 2% of cement with CF, the compressive strength of the concrete is increased.

6.13.4 Biocontrol

Trichoderma coir pith cake (TCPC) has been prepared and successfully used for control of plant diseases. The dry product TCPC has a long shelf life.

6.13.5 Cotton

Cotton is a soft, fluffy staple fiber that grows in a boll, or protective case, around the seeds of the cotton plants of the genus *Gossypium* in the mallow family Malvaceae. The fiber is almost pure cellulose, and can contain minor percentages of waxes, fats, pectins, and water. Under natural conditions, the cotton bolls will increase the dispersal of the seeds. The plant is a shrub native to tropical and subtropical regions around the world, including the Americas, Africa, Egypt and India. The greatest diversity of wild cotton species is found in Mexico, followed by Australia and Africa. Cotton was independently domesticated in the Old and New Worlds.

The fiber is most often spun into yarn or thread and used to make a soft, breathable, and durable textile. The use of cotton for fabric is known to date to prehistoric times; fragments of cotton fabric dated to the fifth millennium BC have been found in the Indus Valley Civilization, as well as fabric remnants dated back to 6000 BC in Peru. Although cultivated since antiquity, it was the invention of the cotton gin that lowered the cost of production that led to its widespread use, and it is the most widely used natural fiber cloth in clothing today. Current estimates for world production are about 25 million tonnes or 110 million bales annually, accounting for 2.5% of the world's arable land. India is the world's largest producer of cotton. The United States has been the largest exporter for many years.

6.13.6 Types

There are four commercially grown species of cotton, all domesticated in antiquity:

- *Gossypium hirsutum* – upland cotton, native to Central America, Mexico, the Caribbean and southern Florida (90% of world production)
- *Gossypium barbadense* – known as extra-long staple cotton, native to tropical South America (8% of world production)
- *Gossypium arboreum* – tree cotton, native to India and Pakistan (less than 2%)
- *Gossypium herbaceum* – Levant cotton, native to southern Africa and the Arabian Peninsula (less than 2%)

Hybrid varieties are also cultivated. The two New World cotton species account for the vast majority of modern cotton production, but the two Old World species were widely used before the 1900s. While cotton fibers occur naturally in colors of white, brown, pink and green, fears of contaminating the genetics of white cotton have led many cotton-growing locations to ban the growing of colored cotton varieties.

6.14 Cultivation

Successful cultivation of cotton requires a long frost-free period, plenty of sunshine, and a moderate rainfall, usually from 60 to 120 cm (24 to 47 in). Soils usually need to be fairly heavy, although the level of nutrients does not need to be exceptional. In general, these conditions are met within the seasonally dry tropics and subtropics in the Northern and Southern hemispheres, but a large proportion of the cotton grown today is cultivated in areas with less rainfall that obtain the water from irrigation. Production of the crop for a given year usually starts soon after harvesting the preceding autumn. Cotton is naturally a perennial but is grown as an annual to help control pests. Planting time in spring in the Northern hemisphere varies from the beginning of February to the beginning of June.

The area of the United States known as the South Plains is the largest contiguous cotton-growing region in the world. While dryland (non-irrigated) cotton is successfully grown in this region, consistent yields are only produced with heavy reliance on irrigation water drawn from the Ogallala Aquifer. Since cotton is somewhat salt and drought tolerant, this makes it an attractive crop for arid and semiarid regions. As water resources get tighter around the world, economies that rely on it face difficulties and conflict, as well as potential environmental problems. For example, improper cropping and irrigation practices have led to desertification in areas of Uzbekistan, where cotton is a major export. In the days of the Soviet Union, the Aral Sea was tapped for agricultural irrigation, largely of cotton, and now salination is widespread. Cotton can also be cultivated to have colors other than the yellowish off-white typical of modern commercial cotton fibers. Naturally colored cotton can come in red, green, and several shades of brown.

6.15 Uses

Cotton is used to make a number of textile products. These include terrycloth for highly absorbent bath towels and robes; denim for blue jeans; cambric, popularly used in the manufacture of blue work shirts (from which we get the term "blue-collar"); and corduroy, seersucker, and cotton twill. Socks, underwear, and most T-shirts are made from cotton. Bed sheets often are made from cotton. It is a preferred material for sheets as it is hypoallergenic, easy to maintain and non-irritant to the skin. Cotton also is used to make yarn used in crochet and knitting. Fabric also can be made from recycled or recovered cotton that otherwise would be thrown away during the spinning, weaving, or cutting process.

While many fabrics are made completely of cotton, some materials blend cotton with other fibers, including rayon and synthetic fibers such as polyester. It can either be used in knitted or woven fabrics, as it can be blended with elastine to make a stretchier thread for knitted fabrics, and apparel such as stretch jeans. Cotton can be blended also with linen producing fabrics with the benefits of both materials. Linen-cotton blends are wrinkle resistant and retain heat more effectively than only linen, and are thinner, stronger and lighter than only cotton. In addition to the textile industry, cotton is used in fishing nets, coffee filters, tents, explosives manufacture (see nitrocellulose), cotton paper, and in bookbinding. Fire hoses were once made of cotton.

The cottonseed which remains after the cotton is ginned is used to produce cottonseed oil, which, after refining, can be consumed by humans like any other vegetable oil. The cottonseed meal that is left generally is fed to ruminant livestock; the gossypol remaining in the meal is toxic to monogastric animals. Cottonseed hulls can be added to dairy cattle rations for roughage. During the American slavery period, cotton root bark was used in folk remedies as an abortifacient, that is, to induce a miscarriage. Gossypol was one of the many substances found in all parts of the cotton plant and it was described by the scientists as 'poisonous pigment'. It also appears to inhibit the development of sperm or even restrict the mobility of the sperm. Also, it is thought to interfere with the menstrual cycle by restricting the release of certain hormones.

Cotton linters are fine, silky fibers which adhere to the seeds of the cotton plant after ginning. These curly fibers typically are less than ⅛ inch (3.2 mm) long. The term also may apply to the longer textile fiber staple lint as well as the shorter fuzzy fibers from some upland species. Linters are traditionally used in the manufacture of paper and as a raw material in the manufacture of cellulose. In the UK, linters are referred to as "cotton wool".

A less technical use of the term "cotton wool", in the UK and Ireland, is for the refined product known as "absorbent cotton" (or, often, just "cotton") in U.S. usage: fluffy cotton in sheets or balls used for medical, cosmetic, protective packaging, and many other practical purposes. The first medical use of cotton wool was by Sampson Gamgee at the Queen's Hospital (later the General Hospital) in Birmingham, England.

Long staple (LS cotton) is cotton of a longer fibre length and therefore of higher quality, while Extra-long staple cotton (ELS cotton) has longer fibre length still and of even higher quality. The name "Egyptian cotton" is broadly associated high quality cottons and is often an LS or (less often) an ELS cotton.[91] Nowadays the name "Egyptian cotton" refers more to the way cotton is treated and threads produced rather than the location where it is grown. The American cotton variety *Pima* cotton is often compared to Egyptian cotton, as both are used in high quality bed sheets and other cotton products. While Pima cotton is often grown in the American southwest, the Pima name is now used by cotton-producing nations such as Peru, Australia and Israel. Not all products bearing the Pima name are made with the finest cotton: American-grown ELS Pima cotton is trademarked as *Supima* cotton. "Kasturi" cotton is a brand-building initiative for Indian long staple cotton by the Indian government. The PIB issued a press release announcing the same.

Cottons have been grown as ornamentals or novelties due to their showy flowers and snowball-like fruit. For example, Jumel's cotton, once an important source of fiber in Egypt, started as an ornamental. However, agricultural authorities such as the Boll Weevil Eradication Program in the United States discourage using cotton as an ornamental, due to concerns about these plants harboring pests injurious to crops.

Fig. 2 Cotton in a tree

Cotton lisle, or fil d'Ecosse cotton, is a finely-spun, tightly twisted type of cotton that is noted for being strong and durable. Lisle is composed of two strands that have each been twisted an extra twist per inch than ordinary yarns and combined to create a single thread. The yarn is spun so that it is compact and solid. This cotton is used mainly for underwear, stockings, and gloves. Colors applied to this yarn are noted for being more brilliant than colors applied to softer yarn. This type of thread was first made in the city of Lisle, France (now Lille), hence its name.

6.16 Botanical description of cotton plant

The cotton plant belongs to the genus Gossypium of the family Malvaceae (mallow family); the same family as hollyhock, okra and hibiscus. It is generally a shrubby plant having broad three-lobed leaves and seeds in capsules, or bolls; each seed is surrounded with downy fiber, white or creamy in color and easily spun. The fibers flatten and twist naturally as they dry. There are different species of Cotton – Gossypium hirsutum, Gossypium barbadense, Gossypium herbaceum and Gossypium arboreum, the first two species being the most commonly cultivated.

Cotton is of tropical origin but is most successfully cultivated in temperate climates with well-distributed rainfall. All western U.S. cotton and as much as one-third of Southern cotton, however, is grown under irrigation. In the United States, nearly all commercial production comes from varieties of upland cotton (G. hirsutum), but small quantities are obtained from sea-island and American-Egyptian cotton (both belonging to the species G. barbadense). G. arboreum and G. herbaceum are cultivated species in Asia.

6.17 Taxonomy of cotton plant

Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Rosids
Order:	Malvales
Family:	Malvaceae
Subfamily:	Malvoideae
Tribe:	Gossypieae
Genus:	Gossypium

6.18 Different Parts of the Cotton Plant

Fig. 3 cotton plant

6.19 Stem &Branches

Cotton is grown between 37 degrees North at Ukraine and 30 degrees south in Australia in warm, frost-free, sunny climate. Cotton requires a lot of sunshine temperatures between 60 to 95 degrees Fahrenheit (16-35 degrees Celsius). The major cotton producing countries are United States, China, India, Pakistan, Uzbekistan, Brazil, Australia, Egypt, Argentina, Turkey, and Greece. A cotton plant starts from seeds. The seeds germinate in 5 to 10 days and the cotton plant begins its growth with two cotyledons (the seed leaves that form nodes opposite each other at the base of the main stem) until the plant forms true leaves (leaves produced subsequent to the cotyledons). Cotton has a tap root system and roots go deeper into the soil for search of nutrients. Development of a healthy root system for acquiring soil nutrients is vital to feed the growing plant.

As a cotton plant begins to grow, it develops a series of nodes up the main stem. Beginning with the fifth or sixth node, the plant begins to form fruiting branches, which bear the cotton fruit. Typically, a cotton plant will continue to add nodes and fruiting branches for a total of 16 to 22 nodes, with 12 to 16 fruiting branches. Leaves:
Leaves provide carbohydrate energy supply for adding nodes and branches and for growing bolls. Photosynthesis converts light energy into chemical energy that is stored as sugars in the plant. All plant metabolic reactions are dependent on this energy source.

6.20 Summary

Under this unit we have summarized fibers and its properties, jute, linseed oil toxicity, hemp, coir and cotton etc. Nowadays, natural fibers are used to replace synthetic fibers because of environmental concern as a reinforced material in polymer composites for engineering materials. Hybrid composites of natural and synthetic fibers are often used to enhance the mechanical strength of polymer composites. Natural fibers are the most promising reinforcements, substitute to synthetic fibers for fibers reinforced polymer composites, owing to nontoxic, nonabrasive, higher specific strength, lower density, minimal environmental impact, biodegradability besides desirable mechanical properties compared to synthetic fiber, such as glass, carbon, Kevlar fibers The natural fibers with high content of lignin exhibit high char yield, high effective heat of combustion (EHC), high activation energy of combustion (E_a) and low CO/CO_2 ratio.

Jute is a long, soft, shiny bast fiber that can be spun into coarse, strong threads. It is produced from flowering plants in the genus Corchorus, which is in the mallow family Malvaceae. The primary source of the fiber is Corchorus olitorius, but such fiber is considered inferior to that derived from Corchorus capsularis. "Jute" is the name of the plant or fiber used to make burlap, hessian or gunny cloth.

Jute is one of the most affordable natural fibers, and second only to cotton in the amount produced and variety of uses. Jute fibers are composed primarily of the plant materials cellulose and lignin. Jute fiber falls into the bast fiber category (fiber collected from bast, the phloem of the plant, sometimes called the "skin") along with kenaf, industrial hemp, flax (linen), ramie, etc.. The industrial term for jute fiber is raw jute. The fibers are off-white to brown, and 1–4 metres (3–13 feet) long. Jute is also called the "golden fiber" for its color and high cash value.

Linseed oil, also known as **flaxseed oil** or **flax oil** (in its edible form), is a colourless to yellowish oil obtained from the dried, ripened seeds of the flax plant (Linum usitatissimum). The oil is obtained by pressing, sometimes followed by solvent extraction. Linseed oil is a drying oil, meaning it can polymerize into a solid form. Owing to its polymer-forming properties, linseed oil can be used on its own or blended with combinations of other oils, resins or solvents as an impregnator, drying oil finish or varnish in wood finishing, as a pigment binder in oil paints, as a plasticizer and hardener in putty, and in the manufacture of linoleum. Linseed oil use has declined over the past several decades with increased availability of synthetic alkyd resins—which function similarly but resist yellowing

Cotton is grown commercially as an annual shrub and reaches about 1.2 metres in height. Its leaves are broad and heart-shaped with coarse veins and three to five lobes. The plant has many branches, with one main central stem. The cotton plant's taproot reaches a depth of 1.5 metres. Squares (flower buds) develop several weeks after the plant starts to grow, with flowers appearing a few weeks later. The flowers then drop, leaving a ripening seed pod that becomes the cotton boll (the fruit) after pollination. The plant also produces seeds that are contained in small capsules surrounded by fibre in the cotton bolls.

6.21 Terminal questions

Q. 1 What do you mean by natural fibers? Explain it.

Answer:---

Q. 2 Describe the cellulose regenerated fibers.

Answer:---

Q.3 Describe the semi-synthetic fibers.

Answer:---

Q. 4 Write short notes on the following.

(a) Synthetic fibers
(b) Metallic fibres

Answer:---

Q.5 Write short notes on the following.

(a) Fiberglass
(b) Silicon carbide fiber

Answer:--

Q. 6 Describe the typical properties of selected fibers.

Answer:--

Q.7. Write short notes on the following.

(a) Jute

(b) Flax

Answer:--

Q.8. Write short notes on the following.

(a) Hemp

(b) Linseed oil

Answer:--

Further readings

- Biochemistry- Lehninger A.L.
- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry and molecular biology- Wilson Walker

Unit-7: Forest Products

Structure

7.1 Introduction

A forest product is any material derived from forestry for direct consumption or commercial use, such as lumber, paper, or fodder for livestock. Wood, by far the dominant product of forests, is used for many purposes, such as wood fuel (e.g. in form of firewood or charcoal) or the finished structural materials used for the construction of buildings, or as a raw material, in the form of wood pulp, that is used in the production of paper. All other non-wood products derived from forest resources, comprising a broad variety of other forest products, are collectively described as non-timber forest products (NTFP). Non-timber forest products are viewed to have fewer negative effects on forest ecosystem when providing income sources for local community.

Globally, about 1.15 billion ha of forest is managed primarily for the production of wood and non-wood forest products. In addition, 749 million ha is designated for multiple use, which often includes production. Worldwide, the area of forest designated primarily for production has been relatively stable since 1990 but the area of multiple-use forest has decreased by about 71 million ha.

The Food and Agriculture Organization of the United Nations publishes an annual yearbook of forest products. The FAO Yearbook of Forest Products is a compilation of statistical data on basic forest products for all countries and territories of the world. It contains series of annual data on the volume of production and the volume and value of trade in forest products. It includes tables showing direction of trade and average unit values of trade for certain products. Statistical information in the yearbook is based primarily on data provided to the FAO Forestry Department by the countries through questionnaires or official publications. In the absence of official data, FAO makes an estimate based on the best information available. FAO also publishes an annual survey of pulp and paper production capacities around the world. The survey presents statistics on pulp and paper capacity and production by country and by grade. The statistics are based on information submitted by correspondents worldwide, most of them pulp and paper associations, and represents 85% of the world production of paper and paperboard.

Based on these demands, the forest products can be further explored. Pulp and paper industry has high volume demand for the wood materials including both softwood and hardwood. Wood industry can consume large volume and varieties of wood products including logs, lumbers, furniture, and other products.

Objectives

This is the seventh unit on paleobotany, palynology and economic botany. Under seventh unit, we have following objectives. These are as under:

- To know about forest product, wood and its history
- To know about growth rings, knots and rubber
- To know about gums, resins, adhesive, ink and their uses
- To discuss food industry, pharmaceutical industry and cosmetic industry

7.2 Producing Forest Product

Producers of forest products are heavily depending on the forest types and ownership. As woods are the dominant product of the forest product, the processes of producing wood products are important. The general processes for commercial land can include seedling production, site preparation, planting, applying fertilizers and herbicides, thinning (pre-commercial or commercial), and logging. The processes may vary due to different species and spatial locations. Products category may include logs, lumbers, residues, etc. For non-timber forest products, the processes can have a large variety.

Forest products trade runs the spectrum from raw wood materials, such as logs and wood chips, to highly processed products such as furniture and fine papers. Within the wood products sector some countries specialize in the production of the raw wood, others specialize in various facets of the processing, while still others produce both raw wood and processed value added. Thus, the value of wood products appears to be only a crude proxy of the amount of raw wood harvested, both domestic and imported. Nevertheless, since there are often advantages in processing located near the source of the raw material, most of the countries with large dollar values of production and exports also have large volumes of forest resources.

Sawnwood, wood milled in a sawmill and commonly referred to as lumber, is the most prevalent produce produced in the solidwood side of the forest industry and the most intensively traded globally.

Sawnwood is typically used for structural purposes in construction, as well as in furniture, flooring, and woodwork. Wood panels, such as plywood, are the second most traded wood product. Plywood is manufactured from wood veneer sheets that are glued and pressed. The United States is the largest producer of conifer plywood while Indonesia is the world's largest producer of nonconifer plywood, using tropical hardwoods in its construction. Europe is a major producer and consumer of plywood, most of it being produced from hardwoods. In addition, panels, such as particleboard and oriented strand board, made from wood fibers that are compacted and glued, are increasing in use for a variety of purposes.

The importance of forests in today's world cannot be underestimated. Whether you are living in a city or town far away from forests, you'll be surprised to realize that the majority of the things or tools used in your home come from forests. In fact, it could be from forests in a different continent as forest-sourced products are traded globally. For example, if you have a parking ticket, a shopping list, or a tissue paper, you are actually holding a product sourced from forests. Forests are significant players in everyone's and everyday life irrespective of one's location or locality. They provide ecosystem services that are not only essential for the survival of humans but also for enhancing overall welfare. Trees, for example, absorb harmful greenhouse gases, provide clean water, protect watersheds, provide food and medicine, provide habitat, and serve as a buffer in the event of natural disasters.

7.3 Wood

Wood is a porous and fibrous structural tissue found in the stems and roots of trees and other woody plants. It is an organic material – a natural composite of cellulose fibers that are strong in tension and embedded in a matrix of lignin that resists compression. Wood is sometimes defined as only the secondary xylem in the stems of trees, or it is defined more broadly to include the same type of tissue elsewhere such as in the roots of trees or shrubs. In a living tree it performs a support function, enabling woody plants to grow large or to stand up by themselves. It also conveys water and nutrients between the leaves, other growing tissues, and the roots. Wood may also refer to other plant materials with comparable properties, and to material engineered from wood, or woodchips or fiber.

Wood has been used for thousands of years for fuel, as a construction material, for making tools and weapons, furniture and paper. More recently it emerged as a feedstock for the production of purified cellulose and its derivatives, such as cellophane and cellulose acetate. As of 2005, the growing stock of forests worldwide was about 434 billion cubic meters, 47% of which was commercial. As an abundant, carbon-neutral renewable resource, woody materials have been of intense interest as a source of renewable energy. In 1991 approximately 3.5 billion cubic meters of wood were harvested. Dominant uses were for furniture and building construction.

7.4 History

A 2011 discovery in the Canadian province of New Brunswick yielded the earliest known plants to have grown wood, approximately 395 to 400 million years ago. Wood can be dated by carbon dating and in some species by dendrochronology to determine when a wooden object was created. People have used wood for thousands of years for many purposes, including as a fuel or as a construction material for making houses, tools, weapons, furniture, packaging, artworks, and paper. Known constructions using wood date back ten thousand years. Buildings like the European Neolithic long house were made primarily of wood. Recent use of wood has been enhanced by the addition of steel and bronze into construction. The year-to-year variation in tree-ring widths and isotopic abundances gives clues to the prevailing climate at the time a tree was cut.

7.5 Physical properties

7.5.1 Growth rings

Wood, in the strict sense, is yielded by trees, which increase in diameter by the formation, between the existing wood and the inner bark, of new woody layers which envelop the entire stem, living branches, and roots. This process is known as secondary growth; it is the result of cell division in the vascular cambium, a lateral meristem, and subsequent expansion of the new cells. These cells then go on to form thickened secondary cell walls, composed mainly of cellulose, hemicellulose and lignin.

Where the differences between the four seasons are distinct, e.g. New Zealand, growth can occur in a discrete annual or seasonal pattern, leading to growth rings; these can usually be most clearly seen on the end of a log, but are also visible on the other surfaces. If the distinctiveness between seasons is annual (as is the case in equatorial regions, e.g. Singapore), these growth rings are referred to as annual rings. Where there is little seasonal difference growth rings are likely to be indistinct or absent. If the bark of the tree has been removed in a particular area, the rings will likely be deformed as the plant overgrows the scar.

7.5.2 Knots

As a tree grows, lower branches often die, and their bases may become overgrown and enclosed by subsequent layers of trunk wood, forming a type of imperfection known as a knot. The dead branch may not be attached to the trunk wood except at its base, and can drop out after the tree has been sawn into boards. Knots affect the technical properties of the wood, usually reducing the local strength and increasing the tendency for splitting along the wood grain, but may be exploited for visual effect. In a longitudinally sawn plank, a knot will appear as a roughly circular "solid" (usually darker) piece of wood around which the grain of the rest of the wood "flows" (parts and rejoins). Within a knot, the direction of the wood (grain direction) is up to 90 degrees different from the grain direction of the regular wood.

In the tree a knot is either the base of a side branch or a dormant bud. A knot (when the base of a side branch) is conical in shape (hence the roughly circular cross-section) with the inner tip at the point in stem diameter at which the plant's vascular cambium was located when the branch formed as a bud.

7.5.3 Structure

Wood is a heterogeneous, hygroscopic, cellular and anisotropic material. It consists of cells, and the cell walls are composed of micro-fibrils of cellulose (40–50%) and hemicellulose (15–25%) impregnated with lignin (15–30%). In coniferous or softwood species the wood cells are mostly of one kind, tracheids, and as a result the material is much more uniform in structure than that of most hardwoods. There are no vessels ("pores") in coniferous wood such as one sees so prominently in oak and ash, for example.

The structure of hardwoods is more complex. The water conducting capability is mostly taken care of by vessels: in some cases (oak, chestnut, ash) these are quite large and distinct, in others (buckeye, poplar, willow) too small to be seen without a hand lens. In discussing such woods it is customary to divide them into two large classes, *ring-porous* and *diffuse-porous*.

7.6 Rubber

Rubber, also called India rubber, latex, Amazonian rubber, ***caucho***, or ***caoutchouc***, as initially produced, consists of polymers of the organic compound isoprene, with minor impurities of other organic compounds. Thailand, Malaysia, and Indonesia are three of the leading rubber producers. Types of polyisoprene that are used as natural rubbers are classified as elastomers.

Currently, rubber is harvested mainly in the form of the latex from the rubber tree (*Hevea brasiliensis*) or others. The latex is a sticky, milky and white colloid drawn off by making incisions in the bark and collecting the fluid in vessels in a process called "tapping". The latex then is refined into the rubber that is ready for commercial processing. In major areas, latex is allowed to coagulate in the collection cup. The coagulated lumps are collected and processed into dry forms for sale.

Natural rubber is used extensively in many applications and products, either alone or in combination with other materials. In most of its useful forms, it has a large stretch ratio and high resilience and also is water-proof. Industrial demand for rubber-like materials began to outstrip natural rubber supplies by the end of the 19th century, leading to the synthesis of synthetic rubber in 1909 by chemical means.

7.7 History

The first use of rubber was by the indigenous cultures of Mesoamerica. The earliest archeological evidence of the use of natural latex from the *Hevea* tree comes from the Olmec culture, in which rubber was first used for making balls for the Mesoamerican ballgame. Rubber was later used by the Maya and Aztec cultures – in addition to making balls Aztecs used rubber for other purposes such as making containers and to make textiles waterproof by impregnating them with the latex sap.

Charles Marie de La Condamine is credited with introducing samples of rubber to the *Académie Royale des Sciences* of France in 1736. In 1751, he presented a paper by François Fresneau to the Académie (published in 1755) that described many of rubber's properties. This has been referred to as the first scientific paper on rubber. In England, Joseph Priestley, in 1770, observed that a piece of the material was extremely good for rubbing off pencil marks on paper, hence the name "rubber". It slowly made its way around England. In 1764, François Fresnau discovered that turpentine was a rubber solvent. Giovanni Fabbroni is credited with the discovery of naphtha as a rubber solvent in 1779. Charles

Goodyear redeveloped vulcanization in 1839, although Mesoamericans had used stabilized rubber for balls and other objects as early as 1600 BC.

South America remained the main source of latex rubber used during much of the 19th century. The rubber trade was heavily controlled by business interests but no laws expressly prohibited the export of seeds or plants. In 1876, Henry Wickham smuggled 70,000 Amazonian rubber tree seeds from Brazil and delivered them to Kew Gardens, England. Only 2,400 of these germinated. Seedlings were then sent to India, British Ceylon (Sri Lanka), Dutch East Indies (Indonesia), Singapore, and British Malaya. Malaya (now Peninsular Malaysia) was later to become the biggest producer of rubber.

7.7.1 Uses

Uncured rubber is used for cements; for adhesive, insulating, and friction tapes; and for crepe rubber used in insulating blankets and footwear. Vulcanized rubber has many more applications. Resistance to abrasion makes softer kinds of rubber valuable for the treads of vehicle tires and conveyor belts, and makes hard rubber valuable for pump housings and piping used in the handling of abrasive sludge. The flexibility of rubber is appealing in hoses, tires and rollers for devices ranging from domestic clothes wringers to printing presses; its elasticity makes it suitable for various kinds of shock absorbers and for specialized machinery mountings designed to reduce vibration. Its relative gas impermeability makes it useful in the manufacture of articles such as air hoses, balloons, balls and cushions.

The resistance of rubber to water and to the action of most fluid chemicals has led to its use in rainwear, diving gear, and chemical and medicinal tubing and as a lining for storage tanks, processing equipment and railroad tank cars. Because of their electrical resistance, soft rubber goods are used as insulation and for protective gloves, shoes, and blankets; hard rubber is used for articles such as telephone housings and parts for radio sets, meters, and other electrical instruments. The coefficient of friction of rubber, which is high on dry surfaces and low on wet surfaces, leads to its use for power-transmission belting, highly flexible couplings, and for water-lubricated bearings in deep-well pumps. Indian rubber balls or lacrosse balls are made of rubber.

Around 25 million tonnes of rubber are produced each year, of which 30 percent is natural. The remainder is synthetic rubber derived from petrochemical sources. The top end of latex production results in latex products such as surgeons' gloves, balloons, and other relatively high-value products. The mid-range which comes from the technically specified natural rubber materials ends up largely in tires but also in conveyor belts, marine products, windshield wipers, and miscellaneous goods. Natural rubber offers good elasticity, while synthetic materials tend to offer better resistance to environmental factors such as oils, temperature, chemicals, and ultraviolet light. "Cured rubber" is rubber that has been compounded and subjected to the vulcanisation process to create cross-links within the rubber matrix.

7.7.2 Gums and Resins

Resins and gums occupy a prime place among Non-wood Forest Produce (NWFP), and are known to mankind since time immemorial. These are perhaps the most widely used and traded NWFP's other than items consumed directly as food, fodder and medicine. Use of gums and resins for domestic consumption and sale to earn some cash is very common among the forest dwelling communities, particularly tribals in India. Thousands of forest dwellers particularly in the central and western Indian states depend on gums and resins as a viable source of income.

Resins and gums are metabolic by-products of plant tissues either in normal course or often as a result of disease or injury to the bark or wood of certain plants. There are a large number of trees in India which exude gums and resins. Some of these are of local or limited interest, while a few are used extensively all over India and also entered the export trade of the country. The total export of natural resins, gums and gum-resins during the year 2013-14 was 621246.6 tons valued Rs 12722.8 crores and total import was 37981.6 tons valued Rs 799.9 crores.

The gums and gum-resins of commercial importance collected from the forest are gum karaya, gum ghatti, salai gum, guggul, and gums from various species of Acacia, including Indian gum arabic from *Acacia nilotica* and true gum arabic from *A. senegal*. The importance of commercial resins are obtained from

Pinaceae (rosin, amber), Leguminosae (copal) and Dipterocarpaceae (dammar) families.

The uses of natural gums and resins in food, medicines and in varnishes or as protective coatings go back to very early times. The present day uses of natural gums and resins are numerous and they are employed by a large number of manufacturing industries including food and pharmaceutical industries. Some of the plant based gums and resins of commercial importance are presented here.

7.7.3 Natural Resins

Resin secretion occurs in special cavities or in many plant species. They are formed in the specialized structures called passages ducts. Resins exude or ooze out from the bark of the trees and tend to harden on exposure to air. With the exception of lac, which is produced by the lac insect (*Kerria lacca*), all other natural resins are of plant origin. Natural resins of particular importance to the furniture coatings are rosin, damar, copal, sandarac, amber and manila.

The principal characteristics of resins are:

- They are insoluble in water.
- They are soluble in ordinary solvents like alcohol, ether and turpentine.
- They are brittle, amorphous and are transparent or semi-transparent.
- They have a characteristics luster, are ordinarily fusible and when ignited,resins burn with a smoky flame.

7.7.4 Natural Gums

Gums are a group of plant products, formed primarily due to the disintegration of plant cellulose. This process is known as gummosis.Gums are produced by members of a large number of families but exploitation is restricted to of commercial a few tree species Leguminosae, Sterculiaceae and Combretaceae families. The important gum yielding trees are Acacia nilotica (babul), *A catechu* (khair), *Steruculia urens* (kullu), *Anogeissus latifolia* (dhawra), *Butea monosperma* (palas), *Bauhinia retusa* (semal), *Lannea coromandelica* (lendia) and *Azadirachta indica* (neem). Gums is also extracted from seeds of certain plants like guar, tamarind, *Cassia tora* etc. Guar gum is the prominent seed based natural gum. The principal characteristics of gums are:

- They consist of polysaccharides or their derivatives.
- They are soluble in water or at least become soft and swollen when mixed with water. However they are insoluble in alcohol and other organic solvents.
- They decompose completely on heating without melting and tend to become charred
- Most gums emanate from plants in a liquid form. They dry up into translucent,amorphous, tear-shaped bodies or flakes on contact with air.

7.7.5 Gum-resins

Gum-resins are a mixture of both gums and resins and possess the properties of both the groups. They contain traces of essential oils.These are usually derived from the plant growing in dry and arid regions. Some of the commonly used gum-resins ale asafoetida, myrrh, salai, guggul etc.

7.7.6 Differences between Resins and Gums

Resins and Gums are secondary metabolic products of plants which are produced as a result of injury to the plant. They are important to us as they hold a number of commercial applications. Let us look at their differences as shown in given table:

Resins	Gums
Composition	
Resins are a mixture of organic compounds mainly composed of terpenes.	Gums are made of polysaccharides and their derivatives.
Solubility	
They are soluble in various organic liquids	They are water-soluble or rather absorb water well.

but not in water.	
Exudation	
They exude from plant passages and cavities.	They exude naturally from the stems of the plants.
Formation	
Resins are formed as oxidation products.	Gums are formed by the decomposition of cellulose and plant tissues, a process called gummosis.
Flammability	
They burn with a smoky flame, when ignited.	They decompose directly without melting on heating.
Uses	
Used as varnishes, adhesives, food glazing agent and in incense and perfumes.	Used as thickening agents, emulsifiers, gelling agents and swelling agents.
Extracted from	
Cedar, Fir, Juniper, Pine, Spruce, etc.	Acacia, Astrangalus, Sterculia, Feronia, Ceratonia, etc.
Examples	
Amber, balsam, copal	Agar, acacia gum, guar gum

7.7.7 Method of harvesting/tapping

The gum exudes from the cracks on the bark of the tree under difficult conditions such as heat,dryness, wounds, and diseases. The gum flows naturally from the bark of the trees in the form of a thick and rather frothy liquid,and speedily concretes in the sun into tears. To accelerate exudation and to improve and regulate gum production,Acacia trees are tapped by means of incisions (60 cm x 5 cm) made in their branches some weeks ahead of time. Usually mature trees, 4.5-6 m high and 5-25 years old, are tapped by making incisions in the branches and stripping away bark. The gum starts to collect in the wound within 3-8 weeks, but this depends on the weather conditions. Gum droplets are about 0.75-3 cm in diameter, and they gradually dry and harden on exposure to the atmosphere. These gum tears are manually collected. Efforts are now being made to improve gum yield by treatment of tree wounds with chemical irritant and injection of hormones.

7.7.8 Period of harvesting/collection

Collection of gum arabic takes place at intervals during the dry season from November to May. During the rainy season no gum is formed since the trees are in full bloom.

7.7.9 Yield

A tree, on an average, may yield 250 grams of gum arabic per annum, although production may range from a few grams to as high as 10 kg. The highest yields are observed on individuals aged from 7 to 12 years. A young nee usually yield 400-7000g annually. In general, the higher the average temperature, the higher is the yield of gum.Damaged trees give larger yield of gum. Gum yields are improved by natural factors that lessen the vitality of the trees such as hot weather, poor soil, lack of moisture, etc.

7.7.10 Processing and Value Addition

Just after harvest, the gum is delivered to cleaning sheds for the removal of impurities.sand, and pieces of bark. There after it is sorted to different grades based on colour and per cent of impurities. Sorted and cleaned gum arabic is usually traded as tears that are approximately 2.5 to 5 cm in size packed in 100 kg jute bags. Gum arabic is further processed in the destination countries into forms needed for incorporation into the final products. These processes include 'kibbling' (making uniform pebble size pieces), granulating, powdering and spray drying. Kibbling entails passing whole or large lumps of gum through a hammer mill and then screening it to produce smaller granules of more uniform size. These pieces are more easily dissolved in water, and under more reproducible conditions, than the raw gum and so are preferred by the end user. Powdered gum may be produced from kibbled gum but it may also be produced by a process known as spray drying. This furnishes a high.quality, free.flowing powder with even better solubility characteristics than kibbled gum. The gum is dissolved in water filtered contamination,is sprayed Gun into a stream of hot air to promote evaporation of the water. The powder is then screened to assure uniformity of particle size.

7.8 Transportation and Storage

The crude gum arabic is stored and exported either in burlap or jute sacks. The graded gum is packed in heavy duty bags of about 80 kg each. The US regulations require that only new, unused jute sacks are used. Semi-processed and processed kibbled variety, granules and powdered gum arabic is exported in drums, polyethylene lined multi-wall paper bags or polyethylene lined cardboard boxes. Gum arabic, when stored in cool (21 -24°C) and dry place, has an unlimited shelf life.

7.8.1 Quality control: The specifications that are widely used by the importers when importing raw gum arabic are as follows:

- Optical rotation: provides assurances that the gum has not come from other tree species
- Moisture content: not more than 12-14% is permitted
- Foreign matter content: no more than 3-5 % is permitted
- Color(specific parameters)
- Viscosity (specific parameters)
- Microbiological count: tests for Salmonella,Escherichia coli and Staphyloccus aureus should be negative.

An FAO specification exists for gum arabic intended for use as a food additive and in the United States, a Food Chemicals Codex specification exists. For pharmaceutical use, gum arabic appears in many pharmacopoeias, including the British Pharmacopoeia. The JECFA specification has undergone a number of revisions over the years. The present one specifies limits on such things as loss on drying, ash, acid, insoluble matter, arsenic, lead and heavy metals. A BIS specification is there for food grade gum Arabic in India.

7.8.2 Properties

- Gum arabic is a neutral or slightly acidic salt of a complex polysaccharide containing calcium, magnesium, and potassium cations.
- Gum arabic is nontoxic, odourless, and has a bland taste and it does not affect the odour, colour or taste of the system in which it is used
- The gum is some what yellowish in colour.
- It is insoluble in oils.and in most organic solvents, but usually dissolves completely in hot or cold water forming a clear,mucilaginous solution.
- Hydrolysis of gum Arabic yields L-arabinose, L-rhamnose, D-galactose and D-glucuronic acid.
- It is in the GRAS (General Recognized As Safe) list under the Federal Food, Drug and Cosmetic Act.

7.8.3 lndustrial Applications

A brief summary of the industries that use gum arabic is given in the following.

7.9 Food lndustry:

- Confectioneries:used to prevent crystallization of sugar
- Dairy Products:Used as a stabilizer in frozen products
- Bakery prodrcts: Used for its viscosity and adhesive properties
- Beverages:Used as a foam stabilizer in beer, and as a clouding agent to give opacity
- Flavour emulsifier used as an emulsifier and protective collide.
- Diabetic and dietectic product: Used because of its low level of metabolism.

7.10 Pharmaceutical Industry:

- Emulsions: Used as a stabilizer
- Tablets: Used as a binder
- Tablet coatings:Used as a mucilage
- Cough drops and syrups: Used as an emollient and demulcent

7.11 Cosmetic Industry:

- Lotions and protective creams: Used to give smooth feel
- Facial masks: Used as an adhesive
- Face powders:Used as an adhesive

7.12 Other Industries:

7.12.1 Adhesives

Used as a mucilage, as simple adhesive and glue for miscellaneous paper,glass and metal products

7.12.2 Ink

Used as a protective collide and suspending agent.

7.12.3 Lithography

Used as a sensitizers for lithographic plates, elements in the light- sensitive composition, ingredients of the fountain solution used to moisten plates during pointing, and protectors during storage of plates.

7.12.4 Paper

As a coating for speciality papers and such as a coacervate in carbonless paper.

7.12.5 Paints

Used as a protective collide, as a flocculant and emulsifier in vinyl resin emulsions.

7.12.6 Textiles

Used as sizing and finishing agents and in printing formulations for imparting designs and decorations to fabrics, also used to thicken the dye baths that are used in the printing and dyeing of fibers, fabrics and carpets.

7.13 Summary

In this unit we summarized forest product, wood, growth rings rubber gums and adhesives etc. A forest product is any material derived from forestry for direct consumption or commercial use, such as lumber, paper, or fodder for livestock. Wood, by far the dominant product of forests, is used for many purposes, such as wood fuel (e.g. in form of firewood or charcoal) or the finished structural materials used for the construction of buildings, or as a raw material, in the form of wood pulp, that is used in the production of paper. All other non-wood products derived from forest resources, comprising a broad variety of other forest products, are collectively described as non-timber forest products (NTFP). Non-timber forest products are viewed to have fewer negative effects on forest ecosystem when providing income sources for local community.

Globally, about 1.15 billion ha of forest is managed primarily for the production of wood and non-wood forest products. In addition, 749 million ha is designated for multiple use, which often includes production. Growth rings are more or less distinct in trees depending on the degree of cell differentiation within an individual growth ring. Growth rings are more easily distinguished in softwoods due to the usually marked difference in cell diameter and cell wall thickness in the earlywood and latewood growth regions. Ring porous hardwoods also exhibit distinct growth rings (Figure 9b), but growth rings are less easy to determine in the diffuse porous woods. Physical and mechanical properties also differ within growth rings due to the cell structure differences. In general the latewood regions exhibit superior mechanical properties, higher density, more shrinkage, and darker color than the earlywood regions.

The gums are part of the soft tissue lining of the mouth. They surround the teeth and provide a seal around them. Unlike the soft tissue linings of the lips and cheeks, most of the gums are tightly bound to the underlying bone which helps resist the friction of food passing over them. Thus when healthy, it presents an effective barrier to the barrage of periodontal insults to deeper tissue. Healthy gums are usually coral pink in light skinned people, and may be naturally darker with melanin pigmentation.

Changes in color, particularly increased redness, together with swelling and an increased tendency to bleed, suggest an inflammation that is possibly due to the accumulation of bacterial plaque. Overall, the clinical appearance of the tissue reflects the underlying histology, both in health and disease. When gum tissue is not healthy, it can provide a gateway for periodontal disease to advance into the deeper tissue of the periodontium, leading to a poorer prognosis for long-term retention of the teeth. Both the type of periodontal therapy and homecare instructions given to patients by dental professionals and restorative care are based on the clinical conditions of the tissue.

7.14 Terminal questions

Q. 1 What do you mean by growth rings? Explain it.

Answer:---

Q. 2 Describe the natural resins.

Answer:---

Q.3 Differences between resins and gums.

Answer:---

Q.4 Write short notes on the following.

(a) Natural resins

(b) Natural gums

Answer:---

Q.5 Write short notes on the following.

(a) Lithography

(b) Cosmetic industry

Answer:--

Q.6 Describe the food industry and pharmaceutical industry.

Answer:--

Q.7 Write short notes on the following.

(a) Paper

(b) Paints

Answer:--

Q.8 Write short notes on the following.

(a) Textiles

(b) Ink

Answer:--

Further readings

- Biochemistry- Lehninger A.L.
- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry and molecular biology- Wilson Walker

Unit-8: Medicinal Plants

Structure

8.1 Introduction

The term "**medicinal plant**" include various types of plants used in herbalism ("herbology" or "herbal medicine"). It is the use of plants for medicinal purposes, and the study of such uses. The word "**herb**" has been derived from the Latin word, *"herba"* and an old French word *"herbe"*. Now a days, herb refers to any part of the plant like fruit, seed, stem, bark, flower, leaf, stigma or a root, as well as a non-woody plant. Earlier, the term "herb" was only applied to non-woody plants, including those that come from trees and shrubs. These medicinal plants are also used as food, flavonoid, medicine or perfume and also in certain spiritual activities.

Plants have been used for medicinal purposes long before prehistoric period. Ancient Unani manuscripts Egyptian papyrus and Chinese writings described the use of herbs. Evidence exist that Unani Hakims, Indian Vaids and European and Mediterranean cultures were using herbs for over 4000 years as medicine. Indigenous cultures such as Rome, Egypt, Iran, Africa and America used herbs in their healing rituals, while other developed traditional medical systems such as Unani, Ayurveda and Chinese Medicine in which herbal therapies were used systematically.

Objectives

This is the eighth unit on paleobotany, palynology and economic botany. Under eighth unit, we have following objectives. These are as under:

- To know about importance of some herbs with their medicinal values
- To know about rauwolfia, reserpine and belladona
- To know about cultivation, distribution of quinine
- To discuss about beverages, opium, ephedra and their uses

Traditional systems of medicine continue to be widely practised on many accounts. Population rise, inadequate supply of drugs, prohibitive cost of treatments, side effects of several synthetic drugs and development of resistance to currently used drugs for infectious diseases have led to increased emphasis on the use of plant materials as a source of medicines for a wide variety of human ailments.

Among ancient civilisations, India has been known to be rich repository of medicinal plants. The forest in India is the principal repository of large number of medicinal and aromatic plants, which are largely collected as raw materials for manufacture of drugs and perfumery products. About 8,000 herbal remedies have been codified in AYUSH systems in INDIA. Ayurveda, Unani, Siddha and Folk (tribal) medicines are the major systems of indigenous medicines. Among these systems, Ayurveda and Unani Medicine are most developed and widely practised in India. Recently, WHO (World Health Organization) estimated that 80 percent of people worldwide rely on herbal medicines for some aspect of their primary health care needs. According to WHO, around 21,000 plant species have the potential for being used as medicinal plants.

As per data available over three-quarters of the world population relies mainly on plants and plant extracts for their health care needs. More than 30% of the entire plant species, at one time or other were used for medicinal purposes. It has been estimated, that in developed countries such as United States, plant drugs constitute as much as 25% of the total drugs, while in fast developing countries such as India and China, the contribution is as much as 80%. Thus, the economic importance of medicinal plants is much more to countries such as India than to rest of the world. These countries provide two third of the plants used in modern system of medicine and the health care system of rural population depend on indigenous systems of medicine.

Treatment with medicinal plants is considered very safe as there is no or minimal side effects. These remedies are in sync with nature, which is the biggest advantage. The golden fact is that, use of herbal treatments is independent of any age groups and the sexes.

The ancient scholars only believed that herbs are only solutions to cure a number of health related problems and diseases. They conducted thorough study about the same, experimented to arrive at accurate conclusions about the efficacy of different herbs that have medicinal value. Most of the drugs, thus formulated, are free of side effects or reactions. This is the reason why herbal treatment is growing in popularity across the globe. These herbs that have medicinal quality provide rational means for the treatment of many internal diseases, which are otherwise considered difficult to cure.

Medicinal plants such as *Aloe, Tulsi, Neem, Turmeric* and *Ginger* cure several common ailments. These are considered as home remedies in many parts of the country. It is known fact that lots of consumers are using Basil (*Tulsi*) for making medicines, black tea, in *pooja* and other activities in their day to day life. In several parts of the world many herbs are used to honour their kings showing it as a symbol of luck. Now, after finding the role of herbs in medicine, lots of consumers started the plantation of tulsi and other medicinal plants in their home gardens.

Medicinal plants are considered as a rich resources of ingredients which can be used in drug development either pharmacopoeial, non- pharmacopoeial or synthetic drugs. A part from that, these plants play a critical role in the development of human cultures around the whole world. Moreover, some plants are considered as important source of nutrition and as a result of that they are recommended for their therapeutic values. Some of these plants include ginger, green tea, walnuts, aloe, pepper and turmeric etc. Some plants and their derivatives are considered as important source for active ingredients which are used in aspirin and toothpaste etc.

Apart from the medicinal uses, herbs are also used in natural dye, pest control, food, perfume, tea and so on. In many countries different kinds of medicinal plants/ herbs are used to keep ants, flies, mice and flee away from homes and offices. Now a days medicinal herbs are important sources for pharmaceutical manufacturing. Recipes for the treatment of common ailments such as diarrhoea, constipation, hypertension, low sperm count, dysentery and weak penile erection, piles, coated tongue, menstrual disorders, bronchial asthma, leucorrhoea and fevers are given by the traditional medicine practitioners very effectively.

Over the past two decades, there has been a tremendous increase in the use of herbal medicine; however, there is still a significant lack of research data in this field. Therefore since 1999, WHO has published three volumes of the WHO monographs on selected medicinal plants.

8.2 Importance of some herbs with their medicinal values

- Herbs such as black pepper, cinnamon, myrrh, aloe, sandalwood, ginseng, red clover, burdock, bayberry, and safflower are used to heal wounds, sores and boils.
- Basil, Fennel, Chives, Cilantro, Apple Mint, Thyme, Golden Oregano, Variegated Lemon Balm, Rosemary, Variegated Sage are some important medicinal herbs and can be planted in kitchen garden. These herbs are easy to grow, look good, taste and smell amazing and many of them are magnets for bees and butterflies.
- Many herbs are used as blood purifiers to alter or change a long-standing condition by eliminating the metabolic toxins. These are also known as 'blood cleansers'. Certain herbs improve the immunity of the person, thereby reducing conditions such as fever.
- Some herbs are also having antibiotic properties. Turmeric is useful in inhibiting the growth of germs, harmful microbes and bacteria. Turmeric is widely used as a home remedy to heal cut and wounds.
- To reduce fever and the production of heat caused by the condition, certain antipyretic herbs such as *Chirayta*, black pepper, sandal wood and safflower are recommended by traditional Indian medicine practitioners.
- Sandalwood and Cinnamon are great astringents apart from being aromatic. Sandalwood is especially used in arresting the discharge of blood, mucus etc.

- Some herbs are used to neutralize the acid produced by the stomach. Herbs such as marshmallow root and leaf. They serve as antacids. The healthy gastric acid needed for proper digestion is retained by such herbs.
- Indian sages were known to have remedies from plants which act against poisons from animals and snake bites.
- Herbs like Cardamom and Coriander are renowned for their appetizing qualities. Other aromatic herbs such as peppermint, cloves and turmeric add a pleasant aroma to the food, thereby increasing the taste of the meal.
- Some herbs like aloe, sandalwood, turmeric, sheetraj hindi and khare khasak are commonly used as antiseptic and are very high in their medicinal values.
- Ginger and cloves are used in certain cough syrups. They are known for their expectorant property, which promotes the thinning and ejection of mucus from the lungs, trachea and bronchi. Eucalyptus, Cardamom, Wild cherry and cloves are also expectorants.
- Herbs such as Chamomile, Calamus, Ajwain, Basil, Cardamom, Chrysanthemum, Coriander, Fennel, Peppermint and Spearmint, Cinnamon, Ginger and Turmeric are helpful in promoting good blood circulation. Therefore, they are used as cardiac stimulants.
- Certain medicinal herbs have disinfectant property, which destroys disease causing germs. They also inhibit the growth of pathogenic microbes that cause communicable diseases.

- Herbal medicine practitioners recommend calmative herbs, which provide a soothing effect to the body. They are often used as sedatives.
- Certain aromatic plants such as Aloe, Golden seal, Barberry and Chirayata are used as mild tonics. The bitter taste of such plants reduces toxins in blood. They are helpful in destroying infection as well.
- Certain herbs are used as stimulants to increase the activity of a system or an organ, for example herbs like Cayenne (Lal Mirch, Myrrh, Camphor and Guggul.
- A wide variety of herbs including Giloe, Golden seal, Aloe and Barberry are used as tonics. They can also be nutritive and rejuvenate a healthy as well as diseased individual.
- Honey, turmeric, marshmallow and liquorice can effectively treat a fresh cut and wound. They are termed as vulnerary herbs.

As our lifestyle is now getting techno-savvy, we are moving away from nature. While we cannot escape from nature because we are part of nature. As herbs are natural products they are free from side effects, they are comparatively safe, eco-friendly and locally available. Traditionally there are lot of herbs used for the ailments related to different seasons. There is a need to promote them to save the human lives.

Fig. 1 Rauwolfia serpentina fruit

These herbal products are today are the symbol of safety in contrast to the synthetic drugs, that are regarded as unsafe to human being and environment. Although herbs had been priced for their medicinal, flavouring and aromatic qualities for centuries, the synthetic products of the modern age surpassed their importance, for a while. However, the blind dependence on synthetics is over and people are returning to the naturals with hope of safety and security. It's time to promote them globally.

8.3 Rauwolfia

Rauwolfia supplements are generally available in tablets and capsules. Whole and crude forms are also available, but because dosing is more difficult to establish and monitor, the use of these forms is not recommended. Adult daily dose is usually 600 mg of rauwolfia or 6 mg of reserpine. Thus, the daily dose may be about 7 mg/kg of rauwolfia supplement, or 0.07 mg/kg of reserpine. While this dose may be appropriate for adolescents, children should start much lower. It is preferable to purchase the tablet preparations for use with children, since these can be scored to begin with a low dose. Because rauwolfia is sedating, it may be better to take the compound at night.

Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Clade:	Asterids
Order:	Gentianales

Family:	Apocynaceae
Subfamily:	Rauvolfioideae
Tribe:	Vinceae
Subtribe:	Rauvolfiinae Benth. & Hook.f.
Genus:	Rauvolfia

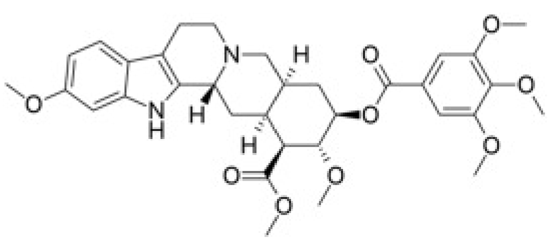
Rauwolfia serpentina (serpentwood) is known in India for its tranquilizing effects. Biomolecules found in rauwolfia include:

(1) weak basic indole alkaloids,

(2) intermediate basic indole alkaloids, and

(3) strong anhydronium bases.

The plant contains more than 50 different types of alkaloids, but the principal alkaloids are the indole alkaloids (reserpine, rescinnamine, and deserpidine). Other bioactive biomolecules present in the plant include other alkaloids (tetrahydroserpentine, raubasine, and ajmalicine). Nonactive alkaloids in *R. serpentina* include Ajmaline, isoajmaline, and raueolfinine.



8.4 Reserpine

Reserpine blocks vesicular storage of monoamines, prolonging monoamine presence in cytoplasm and exposing them to degradation by MAO, leading to depletion of monoamine store in synaptic terminals of central and peripheral neurons, so that little or no neurotransmitter is available for release on arrival of action potential to the nerve terminal. This effect results in depression of activity of such neurons.

8.5 Effects of biomolecules in Rauwolfia serpentina

Rauwolfia was used primarily for the treatment of hypertension and as an antipsychotic biomolecule. It elicits its action by reducing dopamine and monoamine available for release from axonal nerve terminal. In schizophrenia, reserpine decreases thought disturbance, agitation, and hostility, and suspiciousness . The antihypertensive effect of *Rauwolfia* rests on its ability to deplete monoamines in the chromaffin cells and sympathetic ganglia, and perhaps CNS neurons .

8.6 Belladonna

Atropa belladonna has a long history of use as a medicine, cosmetic, and poison. Known originally under various folk names (such as "deadly nightshade" in English), the plant was baptized *Atropa belladonna* by Carl Linnaeus when he devised his classification system. Linnaeus chose the genus name *Atropa* because of the poisonous properties of these plants. Atropos (lit. "unturning one"), one of the Three Fates in Greek mythology, is said to have cut a person's thread of life after her sisters had spun and measured it. Linnaeus chose the species name *belladonna* ("beautiful woman" in Italian) in reference to the cosmetic use of the plant during the Renaissance, when women used the juice of the berries in eyedrops intended to dilate the pupils and make the eyes appear more seductive.

Extracts of plants in the deadly nightshade family have been in use since at least the 4th century BC, when *Mandragora* (mandrake) was recommended by Theophrastus for treatment of wounds, gout, and sleeplessness, and as a love potion. In the first century BC, Cleopatra used Atropine-rich extracts from the Egyptian henbane plant (another nightshade) for the above-mentioned purpose of dilating the pupils of her eyes. The use of deadly nightshades as a poison was known in ancient Rome, as attested by the rumor that the Roman empress Livia Drusilla used the juice of *Atropa belladonna* berries to murder her husband, the emperor Augustus.

In the first century AD, Dioscorides recognized wine of mandrake as an anaesthetic for treatment of pain or sleeplessness, to be given prior to surgery or cautery. The use of nightshade preparations for anesthesia, often in combination with opium, persisted throughout the Roman and Islamic Empires and continued in Europe until superseded in the 19th century by modern anesthetics.

The modern pharmacological study of *Atropa belladonna* extracts was begun by the German chemist Friedlieb Ferdinand Runge. In 1831, the German pharmacist Heinrich F. G. Mein succeeded in preparing a pure crystalline form of the active substance, baptized *atropine*.

The name "belladonna" means "beautiful lady," and was chosen because of a risky practice in Italy. The belladonna berry juice was used historically in Italy to enlarge the pupils of women, giving them a striking appearance. This was not a good idea, because belladonna can be poisonous. Since 2010, the FDA has been cracking down on homeopathic infant teething tablets and gels. These products may contain inaccurate doses of belladonna. Serious side effects including seizures, breathing problems, tiredness, constipation, difficulty urinating, and agitation have been reported in infants taking these products.

Though widely regarded as unsafe, belladonna is taken by mouth as a sedative, to stop bronchial spasms in asthma and whooping cough, and as a cold and hay fever remedy. It is also used for Parkinson's disease, colic, inflammatory bowel disease, motion sickness, and as a painkiller. Belladonna is used in ointments that are applied to the skin for joint pain, pain along the sciatic nerve, and general nerve pain. Belladonna is also used in plasters (medicine-filled gauze applied to the skin) for mental disorders, a behavior disorder that involves hyperactivity and inability to concentrate, excessive sweating, and asthma. Belladonna is also used as suppositories for hemorrhoids.

Fig. 2: Atropa belladonna

8.7 Description

Atropa belladonna is branching herbaceous perennial rhizomatous hemicryptophyte, often growing as a subshrub from a fleshy rootstock. Plants grow to 2 m (7 ft) tall with ovate leaves 18 cm (7 in) long. The bell-shaped flowers are dull purple with green tinges and faintly scented. The fruits are berries, which are green, ripening to a shiny black, and approximately 1.5 cm (0.6 in) in diameter. The berries are sweet and are consumed by animals that disperse the seeds in their droppings, even though they contain toxic alkaloids (see *Toxicity*). There is a pale-yellow flowering form called *Atropa belladonna* var. *lutea* with pale yellow fruit.

Belladonna is sometimes confused with the much less poisonous black nightshade, Solanum nigrum, belonging to a different genus within Solanaceae. A comparison of the fruit shows that the black nightshade berries grow in bunches, whereas the deadly nightshade berries grow individually. Another distinction is black nightshade flowers have white petals.

8.8 Distribution

Atropa belladonna is native to temperate southern, Central and Eastern Europe; North Africa, Turkey, Iran and the Caucasus, but has been cultivated and introduced outside its native range. In southern Sweden it was recorded in Flora of Skåne in 1870 as grown in apothecary gardens near Malmö. In Britain it is native only on calcareous soils, on disturbed ground, field margins, hedgerows and open woodland. More widespread as an alien, it is often a relic of cultivation as a medicinal herb. Seed is spread mainly by birds. It is naturalized in parts of North America, where it is often found in shady, moist locations with limestone-rich soils. It is considered a weed species in parts of the world, where it colonizes areas with disturbed soils.

8.9 How does it work?

Belladonna has chemicals that can block functions of the body's nervous system. Some of the body functions regulated by the nervous system include salivation, sweating, pupil size, urination, digestive functions, and others. Belladonna can also cause increased heart rate and blood pressure.

8.10 Cultivation

Atropa belladonna is rarely used in gardens, but, when grown, it is usually for its large upright habit and showy berries. Germination of the small seeds is often difficult, due to hard seed coats that cause seed dormancy. Germination takes several weeks under alternating temperature conditions, but can be sped up with the use of gibberellic acid. The seedlings need sterile soil to prevent damping off and resent root disturbance during transplanting.

8.11Quinine

Quinine is a medication used to treat malaria and babesiosis. This includes the treatment of malaria due to *Plasmodium falciparum* that is resistant to chloroquine when artesunate is not available. While sometimes used for nocturnal leg cramps, quinine is not recommended for this purpose due to the risk of serious side effects. It can be taken by mouth or intravenously. Malaria resistance to quinine occurs in certain areas of the world. Quinine is also the ingredient in tonic water that gives it its bitter taste.

Common side effects include headache, ringing in the ears, trouble seeing, and sweating. More severe side effects include deafness, low blood platelets, and an irregular heartbeat. Use can make one more prone to sunburn. While it is unclear if use during pregnancy causes harm to the baby, treating malaria during pregnancy with quinine when appropriate is still recommended. Quinine is an alkaloid, a naturally occurring chemical compound. How it works as a medicine is not entirely clear.

Quinine was first isolated in 1820 from the bark of a cinchona tree, which is native to Peru, and its molecular formula was determined by Strecker in 1854. The class of chemical compounds to which it belongs is thus called the cinchona alkaloids. Bark extracts had been used to treat malaria since at least 1632 and it was introduced to Spain as early as 1636 by Jesuit missionaries returning from the New World. It is on the World Health Organization's List of Essential Medicines. Treatment of malaria with quinine marks the first known use of a chemical compound to treat an infectious disease.

8.12 Beverages

Quinine is a flavor component of tonic water and bitter lemon drink mixers. On the soda gun behind many bars, tonic water is designated by the letter "Q" representing quinine. Tonic water was initially marketed as a means of delivering quinine to consumers in order to offer anti-malarial protection. According to tradition, because of the bitter taste of anti-malarial quinine tonic, British colonials in India mixed it with gin to make it more palatable, thus creating the gin and tonic cocktail, which is still popular today. While by drinking significant amounts of tonic water, an individual may temporarily be able to achieve sufficient quinine levels to offer anti-malarial protection, this is not a sustainable long-term means of protection.

In France, quinine is an ingredient of an *apéritif* known as *quinquina*, or *"Cap Corse,"* and the wine-based *apéritif* Dubonnet. In Spain, quinine (also known as "Peruvian bark" for its origin from the native cinchona tree) is sometimes blended into sweet Malaga wine, which is then called *"Malaga Quina"*. In Italy, the traditional flavoured wine Barolo Chinato is infused with quinine and local herbs, and is served as a *digestif*. In Scotland, the company A.G. Barr uses quinine as an ingredient in the carbonated and caffeinated beverage Irn-Bru. In Uruguay and Argentina, quinine is an ingredient of a PepsiCo tonic water named Paso de los Toros. In Denmark, it is used as an ingredient in the carbonated sports drink Faxe Kondi made by Royal Unibrew. As a flavouring agent in drinks, quinine is limited to less than 83 parts per million in the United States, and 100 $^{mg}/_{l}$ in the European Union.

8.13 Scientific

Quinine (and quinidine) are used as the chiral moiety for the ligands used in Sharpless asymmetric dihydroxylation as well as for numerous other chiral catalyst backbones. Because of its relatively constant and well-known fluorescence quantum yield, quinine is used in photochemistry as a common fluorescence standard.

8.14 Contraindications

Because of the narrow difference between its therapeutic and toxic effects, quinine is a common cause of drug-induced disorders, including thrombocytopenia and thrombotic microangiopathy. Even from minor levels occurring in common beverages, quinine can have severe adverse effects involving multiple organ systems, among which are immune system effects and fever, hypotension, hemolytic anemia, acute kidney injury, liver toxicity, and blindness. In people with atrial fibrillation, conduction defects, or heart block, quinine can cause heart arrhythmias, and should be avoided. Quinine can cause hemolysis in G6PD deficiency (an inherited deficiency), but this risk is small and the physician should not hesitate to use quinine in people with G6PD deficiency when there is no alternative.

8.15 Adverse effects

Quinine can cause unpredictable serious and life-threatening blood and cardiovascular reactions including low platelet count and hemolytic-uremic syndrome/thrombotic thrombocytopenic purpura (HUS/TTP), long QT syndrome and other serious cardiac arrhythmias including torsades de pointes, blackwater fever, disseminated intravascular coagulation, leukopenia, and neutropenia. Some people who have developed TTP due to quinine have gone on to develop kidney failure. It can also cause serious hypersensitivity reactions including anaphylactic shock, urticaria, serious skin rashes, including Stevens–Johnson syndrome and toxic epidermal necrolysis, angioedema, facial edema, bronchospasm, granulomatous hepatitis, and itchiness.

The most common adverse effects involve a group of symptoms called cinchonism, which can include headache, vasodilation and sweating, nausea, tinnitus, hearing impairment, vertigo or dizziness, blurred vision, and disturbance in color perception. More severe cinchonism includes vomiting, diarrhea, abdominal pain, deafness, blindness, and disturbances in heart rhythms. Cinchonism is much less common when quinine is given by mouth, but oral quinine is not well tolerated (quinine is exceedingly bitter and many people will vomit after ingesting quinine tablets). Other drugs, such as Fansidar (sulfadoxine with pyrimethamine) or Malarone (proguanil with atovaquone), are often used when oral therapy is required. Quinine ethyl carbonate is tasteless and odourless, but is available commercially only in Japan. Blood glucose, electrolyte and cardiac monitoring are not necessary when quinine is given by mouth. Quinine has diverse unwanted interactions with numerous prescription drugs, such as potentiating the anticoagulant effects of warfarin.

8.16 Uses

8.16.1 Medical

As of 2006, quinine is no longer recommended by the World Health Organization (WHO) as a first-line treatment for malaria, because there are other substances that are equally effective with fewer side effects. They recommend that it be used only when artemisinins are not available. Quinine is also used to treat lupus and arthritis.

Quinine was frequently prescribed as an off-label treatment for leg cramps at night, but this has become less common due to a warning from the US Food and Drug Administration (FDA) that such practice is associated with life-threatening side effects. Quinine can also act as a competitive inhibitor of monoamine oxidase (MAO), an enzyme that removes neurotransmitters from the brain. As an MAO inhibitor, it has potential to serve as a treatment for individuals with psychological disorders stemming from neurotransmitter deficits.

8.16.2 Available forms

Quinine is a basic amine and is usually provided as a salt. Various existing preparations include the hydrochloride, dihydrochloride, sulfate, bisulfate and gluconate. In the United States, quinine sulfate is commercially available in 324-mg tablets under the brand name Qualaquin. All quinine salts may be given orally or intravenously (IV); quinine gluconate may also be given intramuscularly (IM) or rectally (PR). The main problem with the rectal route is that the dose can be expelled before it is completely absorbed; in practice, this is corrected by giving a further half dose. No injectable preparation of quinine is licensed in the US; quinidine is used instead.

8.16.3 Opium

Opium (or poppy tears, scientific name: *Lachryma papaveris*) is dried latex obtained from the seed capsules of the opium poppy *Papaver somniferum*. Approximately 12 percent of opium is made up of the analgesic alkaloid morphine, which is processed chemically to produce heroin and other synthetic opioids for medicinal use and for the illegal drug trade. The latex also contains the closely related opiates codeine and thebaine, and non-analgesic alkaloids such as papaverine and noscapine. The traditional, labor-intensive method of obtaining the latex is to scratch ("score") the immature seed pods (fruits) by hand; the latex leaks out and dries to a sticky yellowish residue that is later scraped off and dehydrated. The word "meconium" (derived from the Greek for "opium-like", but now used to refer to newborn stools) historically referred to related, weaker preparations made from other parts of the opium poppy or different species of poppies.

Fig. 3 poppy seeds on wooden surface

Fig. 4 Poppy heads with seeds

Opium is one of the oldest recreational and medicinal drugs in the world. Extracted from the unripe pods of the poppy flower, opium serves as the raw material for production of numerous drugs, both legal (morphine, codeine, hydromorphone, oxycodone, hydrocodone, etc.) and illegal (heroin). Modern production and use of opium in the Western world has declined dramatically over the past century, with the epicenters of opium production now centered in Afghanistan. In 2004, 87% of the world illicits opium production was in Afghanistan, making up an estimated 60% of the country's GDP. Morphine and codeine are the constituent opiates responsible for the pharmacological effects of opium, and act via binding to opioid receptors throughout the body. The entire class of drugs derived from opium has a very high addictive potential, and are among the most frequently abused prescription medications.

Opium was apparently introduced in India by the Arabs around the ninth century AD. Thereafter, use of opioids gradually spread over northern India, especially among the nobility. Use of opioids in the form of raw opium (*afeem*) and poppy husk (*doda*) became ethnographically acceptable (Ganguly, Sharma, & Krishnamachari, 1995). Opium use became acceptable not only for men but also for women and children in limited amounts. As the British took over India, they realized the potential of selling the opium grown in India to China, extracting lucrative profits. Such a trade seemed to be inimical to the interests of Chinese rulers and resulted in opium wars between the British and Chinese. Locally in India, many farmers would be given opium during the harvest season to alleviate fatigue and to enhance productivity. A proportion of opiate-addicted individuals continued to use opium in limited quantities over decades. After the independence of India, controlled supply of opium was attempted through establishing "opium registries" as a means of harm reduction. Gradually the use of raw opium gave way to other illicit opioids.

The production methods have not significantly changed since ancient times. Through selective breeding of the *Papaver somniferum* plant, the content of the phenanthrene alkaloids morphine, codeine, and to a lesser extent thebaine has been greatly increased. In modern times, much of the thebaine, which often serves as the raw material for the synthesis for oxycodone, hydrocodone, hydromorphone, and other semisynthetic opiates, originates from extracting *Papaver orientale* or *Papaver bracteatum*. For the illegal drug trade, the morphine is extracted from the opium latex, reducing the bulk weight by 88%. It is then converted to heroin which is almost twice as potent, and increases the value by a similar factor. The reduced weight and bulk make it easier to smuggle.

Opium has been known for millennia to relieve pain and its use for surgical analgesia has been recorded for several centuries. The Sumerian clay tablet (about 2100 BC) is considered to be the world's oldest recorded list of medical prescriptions. It is believed by some scholars that the opium poppy is referred to on the tablet. Some objects from the ancient Greek Minoan culture may also suggest the knowledge of the poppy. A goddess from about 1500 BC shows her hair adorned probably with poppy-capsules and her closed eyes disclose sedation. Also juglets probably imitating the poppy-capsules were found in that period in both Cyprus and Egypt. The first authentic reference to the milky juice of the poppy we find by Theophrastus at the beginning of the third century BC.

In the first century the opium poppy and opium was known by Dioscorides, Pliny and Celsus and later on by Galen. Celsus suggests the use of opium before surgery and Dioscorides recommended patients should take mandrake (contains scopolamine and atropine) mixed with wine, before limb amputation. The Arabic physicians used opium very extensively and about 1000 AD it was recommended by Avicenna especially in diarrhoea and diseases of the eye. Polypharmacy, including a mixture of nonsensical medications were often used. Fortunately for both patients and physicians many of the preparations contained opium. The goal was a panacea for all diseases. A famous and expensive panacea was theriaca containing up to sixty drugs including opium. Simplified preparations of opium such as tinctura opii were used up to about 2000 in Denmark. In the early 1800s sciences developed and Sertürner isolated morphine from opium and was the founder of alkaloid research. A more safe and standardized effect was obtained by the pure opium. Several morphine-like drugs have been synthesized to minimize adverse effects and abuse potential. Opioid receptors were identified and characterized in binding assays and their localization examined. However, the complexity of the system including interaction with several neurons and transmitters indicate the goal of nonaddictive opiates to be elusive. Combination therapy, innovative delivery systems and long-acting formulations may improve clinical utility.

8.16.4 Ephedra

Ephedra is a genus of gymnosperm shrubs. The various species of Ephedra are widespread in many arid regions of the world, ranging across southwestern North America, southern Europe, northern Africa, southwest and central Asia, northern China and western South America. It is the only extant genus in its family, **Ephedraceae**, and order, **Ephedrales**, and one of the three living members of the division Gnetophyta alongside Gnetum and Welwitschia.

In temperate climates, most Ephedra species grow on shores or in sandy soils with direct sun exposure. Common names in English include joint-pine, jointfir, Mormon-tea or Brigham tea. The Chinese name for Ephedra species is mahuang (simplified Chinese; traditional Chinese; pinyin: máhuáng; Wade–Giles: ma-huang; lit. 'hemp yellow'). Ephedra is the origin of the name of the stimulant ephedrine, which the plants contain in significant concentration.

8.16.5 Description

The family Ephedraceae, of which Ephedra is the only genus, are gymnosperms, and generally shrubs, sometimes clambering vines, and rarely, small trees. Members of the genus frequently spread by the use of rhizomes. The stems are green and photosynthetic. The leaves are opposite or whorled. The scalelike leaves fuse into a sheath at the base and this often sheds soon after development. There are no resin canals. The plants are mostly dioecious: with the pollen strobili in whorls of 1–10, each consisting of a series of decussate bracts. The pollen is furrowed. The female strobili also occur in whorls, with bracts which fuse around a single ovule. Fleshy bracts are white (such as in Ephedra frustillata) or red. There are generally 1–2 yellow to dark brown seeds per strobilus.

8.16.6 Taxonomy

The genus Ephedra was first described in 1753 by Carl Linnaeus, and the type species is Ephedra distachya. The family, Ephedraceae, was first described in 1829 by Dumortier.

8.16.7 Evolutionary history

The oldest known members of the genus are from the Early Cretaceous around 125 million years ago, with records being known from the Aptian-Albian of Argentina, China, Portugal and the United States. The fossil record of Ephedra outside of pollen disappears after the Early Cretaceous. Molecular clock estimates have suggested that last common ancestor of living Ephedra species lived much more recently, during the Early Oligocene around 30 million years ago. However, pollen modified from the ancestral condition of the genus with branched pseudosulci (grooves), which evolved in parallel in the living North American and Asian lineages is known from the Late Cretaceous, suggesting that the last common ancestor is at least this old.

8.16.8 Distribution

The genus is found worldwide, in desert regions, but not in Australia.

8.16.9 Ecology

Ephedraceae are adapted to extremely arid regions, growing often in high sunny habitats, and occur as high as 4000 m above sea level in both the Andes and the Himalayas.

8.16.10 Drug and supplement uses

The *Ephedra* alkaloids, ephedrine and pseudoephedrine – constituents of *E. sinica* and other members of the genus – have sympathomimetic and decongestant qualities, and have been used as dietary supplements, mainly for weight loss. The drug, *ephedrine*, is used to prevent low blood pressure during spinal anesthesia. In the United States, ephedra supplements were banned from the market in the early 21st century due to serious safety risks. Plants of the genus *Ephedra*, including *E. sinica* and others, were used in traditional medicine for treating headache and respiratory infections, but there is no scientific evidence they are effective or safe for these purposes. Ephedra has also had a role as a precursor in the clandestine manufacture of methamphetamine.

8.16.11 Adverse effects

Alkaloids obtained from the species of *Ephedra* used in herbal medicines, which are used to synthetically prepare pseudoephedrine and ephedrine, can cause cardiovascular events. These events have been associated with arrhythmias, palpitations, tachycardia and myocardial infarction. Caffeine consumption in combination with ephedrine has been reported to increase the risk of these cardiovascular events.

8.16.12 Economic botany and alkaloid content

The earliest uses of *Ephedra* species (mahuang) for specific illnesses date back to 5000 BC. Ephedrine and its isomers were isolated in 1881 from *Ephedra dystachia* and characterized by the Japanese organic chemist Nagai Nagayoshi. His worked to access *Ephedra's* active ingredients to isolate a pure pharmaceutical substance led to the systematic production of semi-synthetic derivatives thereof is relevant still today. Three species, *Ephedra sinica*, *Ephedra vulgaris*, and to a lesser extent *Ephedra equisetina*, are commercially grown in Mainland China as a source for natural ephedrines and isomers for use in pharmaceuticals. *E. sinica* and *E. vulgaris* usually carry six optically active phenylethylamines, mostly ephedrine and pseudoephedrine with minor amounts of norephedrine, norpseudoephedrine as well as the three methylated analogs. Reliable information on the total alkaloid content of the crude drug is difficult to obtain. Based on HPLC analyses in industrial settings, the concentrations of total alkaloids in dried *Herba Ephedra* ranged between 1 and 4%, and in some cases up to 6%.

For a review of the alkaloid distribution in different species of the genus *Ephedra* see Jian-fang Cui. Other American and European species of *Ephedra*, e.g. *Ephedra nevadensis* (Nevada Mormon tea) have not been systematically assayed; based on unpublished field investigations, they contain very low levels (less than 0.1%) or none at all.

8.17 Summary

Under this unit we summarized importance of some herbs with medicinal values, rauwolfia, reserpine, belladonna, beverages, epedra and their uses.

Economic botany is the study of the relationship between people (individuals and cultures) and plants. Economic botany intersects many fields including established disciplines such as agronomy, anthropology, archaeology, chemistry, economics, ethnobotany, ethnology, forestry, genetic resources, geography, geology, horticulture, medicine, microbiology, nutrition, pharmacognosy, and pharmacology. This link between botany and anthropology explores the ways humans use plants for food, medicines, and commerce.[

Plants have been used for medicinal purposes long before prehistoric period. Ancient Unani manuscripts Egyptian papyrus and Chinese writings described the use of herbs. Evidence exist that Unani Hakims, Indian Vaids and European and Mediterranean cultures were using herbs for over 4000 years as medicine. Indigenous cultures such as Rome, Egypt, Iran, Africa and America used herbs in their healing rituals, while other developed traditional medical systems such as Unani, Ayurveda and Chinese Medicine in which herbal therapies were used systematically. Traditional systems of medicine continue to be widely practised on many accounts. Population rise, inadequate supply of drugs, prohibitive cost of treatments, side effects of several synthetic drugs and development of resistance to currently used drugs for infectious diseases have led to increased emphasis on the use of plant materials as a source of medicines for a wide variety of human ailments.

A **drink** (or **beverage**) is a liquid intended for human consumption. In addition to their basic function of satisfying thirst, drinks play important roles in human culture. Common types of drinks include plain drinking water, milk, juice, smoothies and soft drinks. Traditionally warm beverages include coffee, tea, and hot chocolate. Caffeinated drinks that contain the stimulant caffeine have a long history. In addition, alcoholic drinks such as wine, beer, and liquor, which contain the drug ethanol, have been part of human culture for more than 8,000 years. Non-alcoholic drinks often signify drinks that would normally contain alcohol, such as beer, wine and cocktails, but are made with a sufficiently low concentration of alcohol by volume. The category includes drinks that have undergone an alcohol removal process such as non-alcoholic beers and de-alcoholized wines.

Ephedra is a naturally-occurring herb, its main active ingredient ephedrine can also be synthesized as a medication. Synthetic ephedrine compounds, such as pseudoephedrine, are widely used in over-the-counter cold remedies and are regulated as a drug. This is unlike the regulation of ephedrine alkaloids derived from the herb itself. These are regulated as dietary supplements. It is important to note that ephedrine-containing products are banned from amateur sporting events, and evidence of ephedra on drug testing will likely disqualify athletes from competition.

8.18 Terminal questions

Q.1 What do you mean by economic botany? Explain it.

Answer:---

Q.2 Describe the importance of some herbs with their medicinal values**.**

Answer:---

Q.3 Describe the beverages with examples.

Answer:---

Q.4 Write short notes on the following.

(a)Alkaloids

(b) Opium

Answer:---

Q.5 Write short notes on the following.

(a) Belladona

(b) Quinine

Answer:--

Q. 6 Describe the drugs with examples.

Answer:--

Q.7 Write short notes on the following.

(a) Rauwolfia

(b) Reserpine

Answer:--

Q.8 Write short notes on the following.

(a) Beverages

(b) Ephedra

Answer:--

Q.9 Describe the effects of biomolecules in *Rauwolfia serpentine.*

Answer:---

Further readings

- Biochemistry- Lehninger A.L.
- Text book of Botany – Singh -Pande-Jain.
- The elements of Botany- James Hewetson Wilson
- Textbook of Biotechnology –H. K. Das
- Biochemistry and molecular biology- Wilson Walker
- Economic Botany- B.P.Pandey.

NOTE