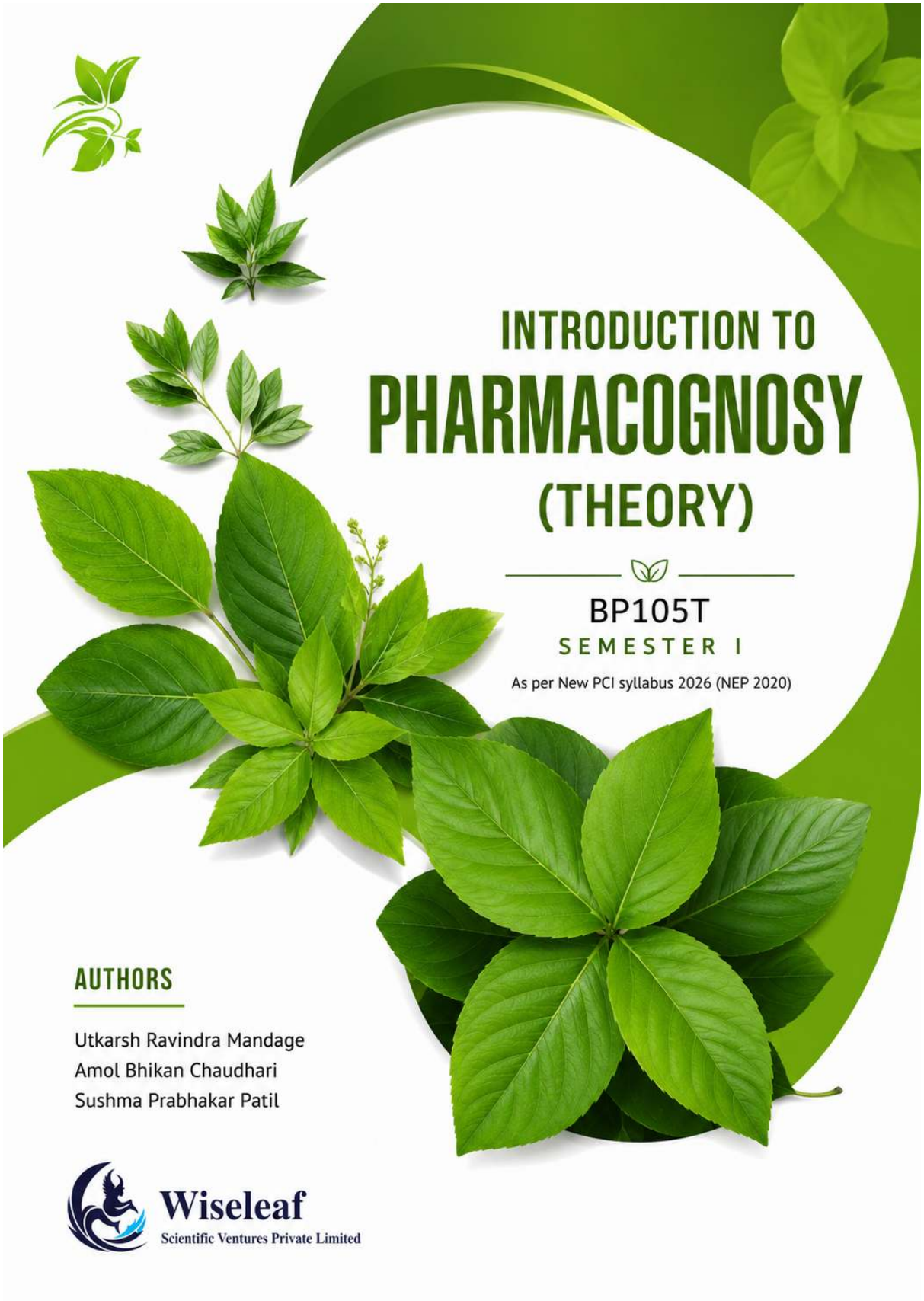

INTRODUCTION TO PHARMACOGNOSY (THEORY)

BP105T

SEMESTER I

As per New PCI syllabus 2026 (NEP 2020)

AUTHORS

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INTRODUCTION TO PHARMACOGNOSY

(THEORY)

(For First Year B. Pharmacy Candidates)
As per PCI New Syllabus 2026
Semester – I
Course Code – BP 105 T

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PREFACE

It gives us immense pleasure to present this book, **"Introduction to Pharmacognosy (Theory)"**, specially designed for the students of First Year B. Pharmacy as per the syllabus prescribed for Semester–I (BP 105 T). Pharmacognosy, being one of the foundational branches of pharmaceutical sciences, deals with the study of crude drugs obtained from natural sources such as plants, animals, minerals, and marine organisms. The subject not only connects traditional knowledge with modern pharmaceutical sciences but also plays a vital role in the discovery and development of new therapeutic agents.

The primary objective of this book is to provide students with clear, concise, and systematic knowledge of pharmacognosy in an easy-to-understand language. The contents have been prepared according to the current academic curriculum and include important topics such as sources of crude drugs, cultivation and conservation of medicinal plants, evaluation methods, classification of crude drugs, phytoconstituents, traditional systems of medicine, and therapeutic applications of natural products.

Special care has been taken to explain the concepts in a simple manner with suitable examples, tables, and updated information to help students strengthen their theoretical understanding as well as prepare effectively for university examinations and competitive studies. The book also highlights the modern advancements in pharmacognosy including biotechnology, quality control techniques, nutraceuticals, and phytotherapy, which are increasingly important in present-day pharmaceutical research.

We sincerely hope that this book will serve as a valuable guide for students, teachers, and researchers in the field of pharmacy and pharmaceutical sciences. We express our heartfelt gratitude to all the teachers, colleagues, students, and well-wishers who directly or indirectly encouraged us during the preparation of this book.

Although every effort has been made to keep the content accurate and error-free, constructive suggestions and valuable feedback from readers will always be welcomed for further improvement in future editions.

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Course Objectives

The objectives of this course are to:

1. Explain the origin, history, and classification of natural drugs.
2. Understand cultivation and conservation methods for medicinal plants.
3. Study quality control and evaluation of crude drugs.
4. Study primary and secondary metabolites with their therapeutic relevance.
5. Introduce traditional systems of medicine and phyto-therapeutic agents.

Course Outcomes (CO)

Upon successful completion of this course, the students will be able to:

1. Describe the historical development, classification, and scope of Pharmacognosy.
2. Explain cultivation, processing, and conservation techniques for medicinal plants.
3. Apply quality evaluation methods to crude drugs using organoleptic, microscopic, and chemical parameters.
4. Identify primary and secondary metabolites with their therapeutic relevance.
5. Recognize traditional systems of medicine and commonly used phyto-therapeutic agents.

Detailed Syllabus

Unit I: Fundamentals of Pharmacognosy

(a) Definition, history, present status, scope and development of pharmacognosy.
(b) Sources of drugs: Plants, animals, microbial, marine, mineral and plant tissue culture.
(c) Historical milestones in drug discovery: Morphine, quinine, aspirin, warfarin, penicillin, cephalosporin, taxol and artemisinin.
(d) Introduction to different herbal / traditional pharmacopoeias: Indian Pharmacopoeia, British Herbal Pharmacopoeia, United States Pharmacopeia – Herbal Medicines and Dietary Supplements, Ayurvedic Pharmacopoeia of India, Unani Pharmacopoeia of India and American Herbal Pharmacopoeia. (e) Official and non-official; codified and non-codified drugs. Classification of crude drugs: alphabetical, morphological, taxonomical, chemical, pharmacological and chemotaxonomic classification along with their merits and limitations.

Unit II: Cultivation, Collection, Processing and Storage of Drugs of Natural Origin

Methods of plant cultivation and Good Agricultural and Collection Practices (WHO / GAP / GCP guidelines) for medicinal plants. Factors influencing cultivation, collection and storage of medicinal plants. Plant hormones and their applications in cultivation of medicinal plants. Application of polyploidy, mutation and hybridization concepts with reference to secondary metabolites. Ex-situ and in-situ conservation and strategies for value addition of medicinal

plants. Role of eco-pharmacognosy in sustainable conservation of endangered medicinal plants such as kutki and chirata

Unit III: Quality Control of Drugs of Natural Origin (WHO Guidelines)

Adulteration of drugs of natural origin. Evaluation of drugs using organoleptic, microscopic (qualitative and quantitative), physical, chemical and biological methods. Physicochemical parameters: extractive values, moisture content, foreign organic matter, ash values, bitterness value, foaming index, haemolytic potential, swelling index, viscosity, optical rotation, refractive index, acid value and saponification value. DNA barcoding.

Unit IV: Introduction to Metabolites of Plant Origin

Definition and general properties of plant metabolites. Primary and secondary metabolites such as carbohydrates, proteins, lipids, alkaloids, glycosides, flavonoids, tannins, terpenoids, volatile oils and resins. Traditional Systems of Medicine Basic principles of treatment of diseases in different systems of medicine including AYUSH and TCM. Types of dosage forms in AYUSH medicines. Role of pharmacognosy in allopathy and traditional systems of medicine such as AYUSH and TCM.

Unit V: Phyto-therapeutic Agents

Biological source, major constituents and uses of the following classes of drugs: • Adaptogens and Immunomodulators: Ashwagandha, Tulsi, Amla • Hepatoprotectives: Milk thistle, Kutki • Cardiovascular drugs: Garlic, Arjuna • Antidiabetics: Gymnema, Fenugreek • Anti-inflammatory and analgesics: Turmeric, Boswellia • CNS drugs: Brahmi • Antimicrobial and antivirals: Giloy, Neem, Andrographis • Gastrointestinal drugs: Psyllium • Dermatological agents: Aloe • Drugs used in women's health: Chasteberry, Shatavari • Respiratory drugs: Vasaka

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UNIT-I

FUNDAMENTALS OF PHARMACOGNOSY

Chapter 01: Introduction to Pharmacognosy

Pharmacognosy is the area of pharmacy concerned with crude drugs, phytopharmaceuticals, surgical dressings, excipients, filtration aids, and the supporting media used while discovering and making medicines from natural sources.

Crude drugs: This term is used for natural products that have not been processed, such as plants, parts of plants, exudates, and extracts. Most narcotic drugs of plant origin fall in this category. A smaller number of crude drugs come from marine sources or are obtained from animals and insects, for example lard, beeswax, and honey.

HISTORY

Dioscorides, a Greek physician of the first century, wrote "De Materia Medica" in 78 A.D. In this book he described about 6000 plants having medicinal properties, and many of these are still part of present-day medicine. Drugs like opium, belladonna, colchicum, ergot, hyoscyamus, and aloe are some examples that even today are used in similar ways. Galen (131 to 200 A.D.), who was a Greek physician and pharmacist working in Rome, gave the method of preparing mixtures of medicines from plants and animals. The term "galenical" pharmacy was given as a tribute to him because of the careful manner in which he recorded his observations.

In those days, doctors used the expression materia medica, which simply means "medical materials," for substances and products obtained from natural origin. The word "pharmacognosy" is said to have been first used in the 18th century by John Adam Schmidt (1759-1809). Schmidt was a professor of general pathology, therapeutics, and materia medica at the Medicosurgical Joseph Academy at Vienna, which started in 1785. The term came into print in his book "Lehrbuch der Materia Medica," which was brought out after his death in Vienna in 1811. At that time, the knowledge about drugs was limited and could be easily covered under one subject.

Later, in 1815, C.A. Seydler in Germany used the word "pharmacognosy" formally. The name was made by joining two Greek words, "pharmakon" meaning "drug," and "gnosis" meaning "knowledge." F.A. Fluckiger, who was professor of pharmacy at Strasburg (1870), described pharmacognosy as the application of several subjects together with the aim of studying medicines from every aspect. In the 18th century, Linnaeus brought out his new method of naming and classifying plants, which gave a big push to the growth of pharmacognosy. Even though the era of drug discovery within pharmacognosy started in 1803 when F.W. Serturner obtained morphine from opium, crude drugs were still being used as powders, simple extracts, or tinctures right up to the close of the 18th century.

During the nineteenth century, after the term pharmacognosy was introduced, the subject grew beyond the limits of pure botany. So, in the broadest sense, pharmacognosy is the study of the history, distribution, growing, collection, production, identification, evaluation (both chemical and biological), preservation, and use of drugs and other commercial substances that have an effect on the health of humans and animals. Pharmacognosy forms an important part of

pharmacy education and acts as a connecting link between pharmacy and clinical pharmacy, and also between pharmacognosy and medicinal chemistry.

SCOPE AND DEVELOPMENT

Seydler in 1815 first listed pharmacognosy as a branch of pharmacy. Later, in 1909, Alexander Tschirch defined it like this: "Pharmacognosy is the name of the science that aims to understand all aspects of drugs derived from plants and animals, with the exception of physiology." In the 19th century it was the parent of all other modern pharmaceutical subjects. But once aspirin was synthesised in 1899, synthetic chemistry started becoming more and more important for making new medicines (1990).

The 19th century was the time when microscopy was first applied to test the quality of medicinal preparations made from plants. But, during the 1960s and 70s, holding on to its strong place in pharmacy education became difficult, since the use of herbal medicines in pharmacies was falling rapidly. Luckily, the development of thin layer chromatography (TLC) by Egon Stahl in 1967 brought pharmacognosists to a leading position in the study of plant materials. Because of this, gas chromatography (GC), thin layer chromatography (TLC), and high performance liquid chromatography (HPLC) became key tools to study active compounds. During the 1970s, spectrophotometric methods like mass spectrometry (MS) and nuclear magnetic resonance spectrometry (NMR) were also brought in, with the aim of finding new biologically active substances.

In 1999, a fairly large group of scientists came together for five yearly meetings, which showed that the global scientific community was getting more interested in pharmacognosy and natural product research. Attendance at the Amsterdom meeting in July 1999 was almost twice that of the previous year. The reason was the rising interest in pharmacognosy and natural product work, which can be seen from the trend in new drug discovery between 1983 and 1994. Looking at the list of approved drugs, 78% of new antibiotics and 61% of new antitumor drugs

These days, three areas attract special attention from pharmacognosists:

i. Studying new natural compounds with biological activity.
ii. Quality control of medicines obtained from natural sources.
iii. Producing drugs from natural sources by new methods such as biotechnology.

Lead Finding: After the High Throughput Screening (HTS) approach came into use, finding leads has become much easier. Through molecular targets, a very large number of samples, even up to 100,000 in just one day, can be screened for a particular activity. So, with the arrival of HTS, many plant extracts could be quickly tested for biological activity. For checking biological activity, high performance liquid chromatography (HPLC) gives another fresh approach. One more interesting screening method is plant cell culture extract, which can be obtained from rare plants so that the desired activities are produced reliably. Lead finding for drug development based on biodiversity or traditional medicine is one of the major areas where pharmacognosy can grow at a fast pace.

Biotechnology: New directions have opened up in pharmacognosy because of biotechnology. Earlier, pharmacognosy was mostly limited to plants, and microorganisms as a drug source did not get much attention. Plant cell biotechnology now offers a fresh route to obtain secondary metabolites. The pharmacognosists eagerly stepped into this area in the mid-1970s. Through genetic engineering, the production of useful drugs can be raised, for example proteins made in microorganisms (like insulin in *E. coli*) or in plants (like human serum albumin or vaccines).

Of course, these new methods also need a new kind of pharmacognosist and pharmacist. Apart from the botanical aspects of medicinal plants, a pharmacognosist must have good knowledge of phytochemistry, advanced separation methods, proteins, and molecular biology. Proteomics is a topic that pharmacologists are interested in. The molecular biology approach is useful both for characterizing medicinal plants and for keeping a check on the quality of biotechnological products.

Health claim for food (nutraceuticals): Foods or parts of foods that give medical or health-related benefits, like preventing or treating illnesses, are called nutraceuticals. Today, the world community has a much clearer idea of how diet influences human health. One of the main jobs of pharmacognosists is the biological evaluation of herbs, plant products, and other ingredients used in making nutraceuticals that claim to be useful in non-toxic treatment of diseases.

Based on chemical type and natural source, nutraceuticals are placed under nutrients, herbs, dietary supplements, and dietary fibres. The fastest growing parts of the industry are dietary supplements (20.5%), dietary fibre, and natural/herbal products (around 14.0%). Worldwide, the nutraceutical market is valued at about $115 to $120 billion.

Phytotherapy: This approach came up during the 20th century, mainly in developed countries such as North America, Europe, and Australia. Traditional medicine was already common in developing countries, but now it is being used worldwide. People in many countries, especially older people, like to use food supplements or herbal preparations (phytomedicine) for age-related problems because they feel that natural products are safer to use. This makes things difficult for medical practitioners who do not know enough about natural products. So, this is a new opportunity for pharmacognosists to provide knowledge about identification, standardization, and validation of nutraceuticals for both potency and toxicity.

In the last ten years, the general public, on its own, has been turning to herbal remedies and botanical products more than at any time in the past. This has made the subject far more relevant.

Present Status

Because of progress in the synthesis of medicinal substances, most of the active ingredients found in crude drugs are now being prepared in laboratories. It is correct that these synthetic compounds are free from impurities and unwanted natural ingredients of plant or animal drugs, but at the same time it should not be forgotten that these active ingredients were originally obtained from natural sources. The main branch of pharmacognosy, which is the study of natural medicines, is now shifting toward "Phytochemistry," which has become a separate field.

Natural medicines are a rich storehouse of moieties and remain the only source of fresh moieties (molecules). In earlier times, natural medicines have given researchers many moieties for study, and going forward, scientists expect to obtain more powerful molecules to deal with the new challenges of treating the diseases and disorders that keep getting reported. In the coming years, everybody should give attention to pharmacognosy, that is, the science of natural medicines.

Future Scope of Pharmacognosy

Using medicinal herbs to treat and manage illnesses has many advantages. Over the years, scientific studies have established the medicinal value of plants, and it is now broadly accepted that for serious diseases like AIDS and cancer, plant-based medicines and treatments are safer than synthetic ones. Many alkaloids, glycosides, tannins, and volatile oils have been discovered, isolated, and put into use as therapeutic agents.

Some examples are rutin as vitamin P, piperine as a bioavailability enhancer, artemisinin as an antimalerial, taxol as an anticancer, and forskolin as an antihypertensive. In western countries, due to growing awareness about the strength and side effects of synthetic drugs, natural products are also being used in place of semisynthetic potent drugs. There is also rising interest in plant-based therapies that follow a back-to-nature approach. For the future growth of both pharmacognosy and the herbal drug industry, dependable methods to identify the marker compounds in extracts are essential. The current way of using medicinal plants is to draw out their medicinally active components, which then helps doctors in treating different illnesses.

Chapter 02: Sources of Crude Drug Of Natural Origin

Drugs come from minerals, plants, animals, and microorganisms, both from land and from the sea. Plant tissue culture, that is, biotechnology, is now also seen as a possible source of pharmaceuticals. Plants are a part of the daily food of all living beings, and for many years scientists have been studying their nutritional and medicinal value. As Henkel et al. (1999) reported, the natural sources of about 30,000 bioactive natural compounds are animals (13%), bacteria (33%), fungi (26%), and plants (27%).

Out of more than 1.5 million fungi, only 70,000 have been identified, and out of nearly 40,000 bacteria, only 5,000 have been studied so far. This itself shows the huge variety present in both these groups. As for higher plants, only a small share of them, around 5 to 15%, has been carefully checked for the presence of physiologically active chemicals. Around 25% of prescription drugs come from plants. The WHO states that nearly 80% of people across the world depend on plants to look after their general health and to treat their diseases. On top of this, plants supply the raw material that is needed to make pharmaceuticals and other medicines.

Plants have been used since old times as the source of herbal remedies by traditional healers in indigenous medicine. Even today, new chemical entities (NCE) and medicines for newer discoveries are obtained from plants.

Sr.No.	Source	Primary Use	Example Compound
1.	Plant	Alkaloids/Glycosides	Morphine, Quinine
2.	Animal	Hormones/Enzymes	Heparin, Pepsin
3.	Microbial	Antibiotics	Tetracycline
4.	Marine	Antitumor agents	Ara-C
5.	Mineral	Adsorbents/Supplements	Iron, Calcium
6.	Tissue Culture	Rare Metabolites	Taxol

I. Plant as a Source of Drugs Herbal teas and other home remedies made from medicinal herbs are some examples of how plants are used as therapeutic resources. (Any plant that is used as raw material or as a precursor for making medicine is taken as a medicinal plant, and so is any plant used to treat, prevent, or cure disease, or to change any physiological or pathological process in living things.)

In pharmaceutical preparations, such as tinctures, fluid extracts, powders, or tablets and capsules, plants can be used as crude extracts or therapeutic fractions, and pure chemicals are also isolated from them as drugs. About 26% of the medicines given globally are obtained from plants. According to WHO, more than 125 of these active chemicals are now in actual use. Out of the 252 medicines listed as basic and essential, 11% come only from plants, while many synthetic drugs are based on plant precursors.

Example: Digoxin from *Digitalis spp*., atropine from *Atropa belladonna,* ajmalicine from *Rauwolfia spp*., artemisinin from *Artemisia spp.,* berberine from *Berberis hydrastis,* caffeine from *Camellia sinensis*, codeine from *Papaver somniferum*, podophylotoxin from *Podophyllum peltatum,* hyoscyamine from *Hyoscyamus niger*, morphine from *Papaver somniferum*, peclitaxel from *Taxus spp.,* quinine from *Cinchona ledgeriana,* reserpine from *Rauwolfia serpentina*, and vincristine and vinblastine from *Catharanthus roseus*. About 60% of antitumor and anti-infectious drugs in the market today are believed to come from natural sources, since most of them still cannot be made by synthesis. Instead, they are obtained from cultivated or wild sources.

Eastern countries like China and India have set up herbal medicine industries, while Latin American countries have been putting money into standardizing and regulating phytomedicinal products. In Germany, fifty per cent of phytomedicinal products require a doctor's prescription. In North America, phytomedicinal products are sold in the market as health foods. The National Cancer Institute, USA (NCI), has tested more than 50,000 plant samples for anti-HIV activity and over 33,000 for antitumor activity.

II. Drug Sources from Animals Many drugs use animal-derived ingredients in different forms such as tablets, injections, capsules, lotions, mixtures, and vaccines. One example is gelatin, which is collagen that has been partly hydrolyzed and is generally taken from pigs or cows. In pharmaceutical products like vaccines, gelatin works as a stabilizer and is also used to make capsule shells. The anticoagulant heparin is made from pork. Of the 252 important compounds chosen by the WHO, 8.7% come from animals, and out of the 150 prescription drugs used in the US, 27 are of animal origin.

Animals used as source of drugs in therapeutics: Modified preparations from sheep and pig thyroid glands are used in medicine as thyroid drugs. Conjugated oestrogens: These are amorphous preparations containing a water-soluble conjugated mixture of oestrogens taken from the urine of pregnant mares. They are used to treat dysmenorrhea and menopausal conditions in women.
Insulin is obtained from pigs and cattle. Oxytocin is a polypeptide hormone released by the posterior pituitary glands. Some examples of enzymes are pancreatin, tryptophan, chymotrypsin, fibrinolysin, pepsin, and hyallourinidase.

Animal extractive organs: bile, stomach, and liver preparation.

Natural products from insects: Natural compounds obtained from insects show antimicrobial, antifungal, antiviral, anticancer, antioxidant, anti-inflammatory, and immunomodulatory activity. The insects used include ants, bees, wasps, bettels, cockroaches, termites, flies, real bugs, and moths. In many parts of the world, like Korea, India, Mexico, China, Spain, Brazil, and others, entomotherapy, that is the use of insects for medicinal purposes, works as an alternative to modern medicine. Across the world, folk medicine makes

use of ants and their by-products. For example, in Northern India, a paste made by crushing black ants (Bothroponera rufipes) is applied on the skin to treat boils, wounds, and scabies.

Official Substances Derived from Animals

Cantharidin: Cantharidin is obtained from the dried beetle (*Lytta vesicatoria*) Latr., family Meloidae..

Cochineal: This is the dried female insect Dactylopius coccus costa of the family Coccidae, which contains many eggs and immature larvae. It contains carminic acid, which is used as a colouring agent and also in medicine to relieve renal capillary relaxation and urine retention.

Leeches: Hirudo medicinalis Linn (the speckled leech) and Hirudo quinquestriatus Schmarda (the Australian leech) are used to bring back intraocular pressure in cases of acute glaucoma and in cardiovascular conditions, through a chemical produced from leech saliva.

Gelatin: Gelatin is an animal protein obtained from animal skin and bones. It is used in osteoarthritis, osteoporosis, and in pharmaceutical preparations.

Galls Or Nut Galls: Galls, also known as Aleppo galls or nut galls, are an excrescence that grows on the young shoots of Quercus infectoria Olivier of family Fagaceae, and they serve as a source of tannic acid.

Ichthammol, also called ammonium bituminosulfonate, is the fossil remains of marine creatures, including fish. It is a naturally occurring compound made by dry distillation of sulfur-rich oil shale (Bituminous Schists), followed by sulfonation and then neutralisation with ammonia. It is used locally for skin conditions like psoriasis and eczema.

Apis mellifera Linn, a bee belonging to the Apidae family, deposits a sweet secretion in its honeycomb, which is used as a sweetener and as food.

Pharmaceuticals derived from pigs: Several drugs are obtained from pigs. Examples include digestive enzymes (amylase, lipase, protease, etc.), anticoagulants (heparin sodium), and vaccines (rotavirus live and attenuated vaccine, zoster virus vaccine, etc.)

Bovine: Drugs obtained include hepatitis A vaccine, Salmonella typhi live vaccine, plasma volume expander (polygeline), digestive supplements (*Lactobacillus acidophilus*, bovine colostrums, etc.), and pharmaceutical preparations like collagen, hemostatic agents, and insulin preparations (insulin, isophane, etc.).

Chinese Hamster Ovary (CHO) Cells: From these, drugs such as pituitary hormones, immunomodulators, antiplastic agents, enzyme replacement therapies, and hemostatic drugs are obtained.

Murine (mice): From mice, drugs obtained include anticoagulants (reopro), immunomodifiers (remicade, simulect, etc.), and antineoplastic medicines (avastin, herceptin, mabthera, etc.).
Eggs: A number of vaccines are made using eggs, including a pandemic vaccine, rabies vaccine, Coxiella vaccine, and the influenza virus H1N1 vaccine.

Equine (Horse): The drugs obtained from horse include antivenoms (such as antithymocyte globulin, black snake antivenom, and death adder antivenom), gonadal hormones, and hemostatic medicines. The most important ones are immunological globulins, histoplasmin, coccidioidin, chitin, lanolin, and so on.

III. Drugs from Marine Sources
The sea covers nearly 70% of the planet, and because of its huge biological variety, it is a possible source of new biologically active chemicals. Even though marine species have been getting discovered at a higher rate than land species since the 1950s, only 16% of all known species on Earth are marine. When diversity is taken into account, the ocean is more diverse than land plants and animals. Most of the marine microfauna biomass is made up of marine invertebrates such as sponges, cnidarians, and ascidians. These organisms have a wide range of biological and chemical diversity and have been the only source of biologically active compounds used to make pharmaceuticals, cosmetics, and dietary supplements.

Over the last few decades, many new biologically active substances have been identified from marine organisms. These include antibacterial, antiviral, anticoagulants, antimicrobial, antibiotics, anti-inflammatory, antianthelmintic, anticancer, antitumor, and cardiovascular active chemicals, along with cardiovascular active substances. Marine substances may belong to several pharmacological classes because they have been seen to act on a range of molecular targets. So, the worldwide search for therapeutic molecules to treat various diseases keeps getting support from pharmacological studies on marine compounds. Examples of these chemicals are polyketides, peptides, nitrogen-containing substances, terpenes, steroids, polysaccharides, and many more.

IIIa. Microorganism-Based Antibiotics: Fungi have the largest amount of natural antibacterial and antifungal chemicals. Reports show that 38 to 59% of test extracts taken from marine fungi had antifungal and antibacterial activity. The two genera of marine fungi that most often produce antimicrobial and antibacterial chemicals are Penicillium (18 strains) and Aspergillus (31 strains).

Examples
Compounds Containing Nitrogen Peptides: Desmethylation, cyclopeptides, and a few new peptides taken from mangrove fungi Astromyces cruciatus and Phomopsis species**.**

Asporyzin, which was found from Aspergillus oryzae, is one example of an indole alkaloid that works against both Gram +ve and Gram -ve bacteria. Cristatumins A, D, and E, which act against S. aureus and E. coli, were obtained from Eurotium cristatum and E. herbariorum.

Pyridines and Pyridone: The compounds called trichodin A to D, which were taken from Trichoderma species, showed antifungal action against Candida albicans, and activity against Gram+ve B. subtilis and S. epidermidis.

Pyrimidine/Pyrimidinone Alkaloids and Piperazine
Aspergicin is produced by Aspergillus species, which are epiphytic fungi found in mangroves.

Terpenoids and Steroids
Many steroids and terpenoids that have been obtained from fungi show antifungal activity against Alternaria brassicae and A. niger, and antibacterial activity against S. aureus and E. coli. Penicisteroids A, for example. Aspergillus ustus and Penicillium chrysogenum are reported to make about fifty such chemicals. Aspergiterpinoids, (-) sydonol, and (-) sydonic acid are some examples of antibacterial sequiterpenoids that were identified from Aspergillus species and *Leucostoma persoonii*.

Polyketides: Quinones, anthraquinones, xanthones, and quinine derivatives are some examples of polyketides. As a result, a large number of compounds from fungi have been described.
A few of the more than 5,300 products made from algae and sponges are listed below: The yellow marine *Pseudomonas bromoutilis* of the Altermonas species gives two quinolinols (2n-pentyl-4-quinolinol and 2n-heptyl-4-quinolinol). Aplasmomycin is a new antibiotic that is effective against Gram +ve bacteria, such as Mycobacteria in vitro and plasmodia in vivo, based on studies on the ss-20 strain of Streptomyces griseus from shallow waters.

Antibiotics from Sponges: Sponges show the highest percentage of antimicrobial activity, although many sponges with such activity are still not known. On the other side, Caribbean sponges of Agelas species have been shown to give very strong antibacterial action against S. subtilis*, E. coli,* and P. *atroventum*.

Antibiotics from Algae: Sesquiterpene phenols (Laurinterol and debromolaurinterol) are antibiotic metabolites of red algae of the genus Laurencia.

Tunicate-derived antibiotics Antibiotics from Tunicate: The genus Aplidum has been found to contain large amounts of geranyl hydroquinone. So, new marine-derived antibiotics keep coming out of the ocean.

Marine-Based Anti-Inflammatory Drugs
Marine organisms with anti-inflammatory action have been shown to contain sesquiterpenes, diterpenes, steroids, polysaccharides, alkaloids, fatty acids, proteins, and other chemical compounds. A few examples are: Algae: polyketide (6 6-bieckol), terpenoids (apo-9' Fucoxanthinone, asta-Xanthin). Alkaloids from fungi (Bis-Nnorgliovictin) and sponges (Benzamide A and B).

Antituberculosis Drugs from Marine: Tuberculosis (TB), which is mainly caused by Mycobacterium tuberculosis, is the second leading cause of death from infectious disease worldwide, after HIV/AIDS. In 2012, the World Health Organization (WHO, Geneva, Switzerland) reported almost nine million new TB cases, 1.3 million deaths from TB, and 0.3 million deaths from co-infection with HIV. The in vitro action of natural and semisynthetic chemicals taken from marine sources against Mycobacterium tuberculosis has been studied. The list of substances that have shown antituberculosis activity is given below.
Alkaloids (brevianamide S), polyketides (urdamycinone), terpenoids (asperterpenoid A, S. flavaditerpene), and terpenoid glycosides (lobophorin G).

Antiviral Substances Some of the compounds taken from sponges, soft corals, and fungi are terpenoids (L. arboreum, halistanol sulphate), terpenoid alkaloids (stachyflin), and polyketides (massarilactone-H). They are used to inhibit human herpes simplex virus, HIV protease, HIV replication, influenza virus, neuraminidase, and the H1N1 influenza virus.

Neurophysiological Agents and the Cardiovascular System: Zooxanthellamide (polyketide) and Lepadiformines A and B (alkaloid) block the cardiac inward rectifying K+ current. Rat blood vasoconstriction.

Compounds Affecting the Immune System
Demicoside, a glycosphingolipid taken from sponges, helps in the growth of spleen cells. Laminarin, a polysaccharide from algae, stops lymphocyte apoptosis. Cucumariosides (triterpene oligoglycoside) from sea cucumber activate neutrophils and lymphocytes. Soft coral has a terpenoid called lobocrassin B, which stops the activation of dendritic cells. T-lymphocyte multiplication is blocked by penicacid (polyketide), which was taken from fungus.

Compounds Affecting the Nervous System
Neuronal Ca2+ influx is increased by the peptide asteropsin A, which is obtained from sponges. C-consors peptide from cone snails brings about muscular relaxation. Convolutamydine A is an alkaloid with anti-nociceptive action and is obtained from the aquatic invertebrate phylum Bryozoa. Serinolamide B, an alkaloid taken from bacteria, has an effect on the binding of CB1 and CB2.

Marine Anti-Cancer with FDA Approval
Cytarabine, also known as cytosine arabinoside, is a drug from invertebrates and is used in chemotherapy for non-Hodgkins lymphoma and acute myeloid leukemia. It works as an inhibitor of DNA polymerase. Ziconotide, a peptide from cone snails, is used as a neuronal calcium channel modulator to bring down pain. Trabectedin is an alkaloid obtained from tunicates and has anti-cancer action. It changes the tumor microenvironments and stops the growth of cancer cells.

Eribulin mesylata (Macrolide) is an anti-breast cancer agent obtained from sponges. Bren tuximab is an antibody drug conjugate that gives good results in lymphoma and is obtained from mollusks.

IV. Tissue Culture of Plants

This has been shown to be an important source of pharmaceuticals, either through genetic modification or through organogenesis. The making of useful secondary metabolites by plant tissue culture has very high potential for use in medicines, nutraceuticals, and additives. Also, unlike traditional farming, where secondary metabolites such as alkaloids, flavonoids, terpenoids, carotenoids, saponins, steroidal alkaloids, sterols, tannins, and several others are produced, plant tissue culture production is not affected by environmental factors and changes in quality.

Because of recent advances in plant biotechnology, big progress has been made in the past ten years in raising the yield of secondary plant metabolites by controlling the parameters that affect their production and/or build-up. Some important plant-derived products are ajmaline (*Rauwolfia serpentina*), camptothecin (*Camptotheca acuminate*), codeine (*Papaver somniferum*), colchicine (*Colchicum autumnale),* elipticine (*Ochorosia elliptica),* shikonin (*Lithospermum erythrorhizon*), taxol (*Taxus brevifolia*), and vinblastine (*Catharanthus roseus*).

Example: Some food additives obtained from plant cell culture are anthocyanins, crocin, carotenoids, anthraquinones, and napthaquinones. Flavours include cocoa, coffee, garlic, and vanillin. Sweeteners (stevioside, glycyrrhizin), pungent (capsaicin). Selecting high-yielding cell lines, like Shikonin (Lithospermum erythrorhizon), Serpentine (Catharanthus roseus), Sanguinarine (Papaver somniferum), and Anthraquinone (Morinda citrifolia), can help in raising the yield of secondary metabolites.

Tissue culture works as an alternate method that gives a steady, year-round supply of the material to get over the difficulties seen in harvesting and extraction processing. Also, most of the secondary metabolites accumulate only after a certain age or maturity of the plant; for example, cinchona, rauwolfia, camptotheca, taxus, Ochrosia spp., and so on, take a few years to reach maturity and to build up the active compounds in good amounts. On top of this, increasing the area of cultivation for some species is hard, and plant growth follows its own pace. The only other source is plant cell/tissue cultivation, since natural sources are not enough to meet the always rising demand.

Chapter 03: Historical milestone in drug discovery

An important scientific discovery, invention, or development that became a clear step ahead in the way drugs are identified, developed, and applied for the treatment of diseases.

Examples of Historical Milestones

1. Penicillin was discovered by Alexander Fleming in 1928, and it became the first antibiotic to be used widely.
2. Edward Jenner developed the Smallpox Vaccine in 1796.
3. Insulin was discovered by Frederick Banting and Charles Best in 1921 for the treatment of Diabetes Mellitus.
4. Aspirin was brought in as a pain-relieving medicine by Bayer in 1899.

1. Morphine (1804) - First Alkaloid Isolated from a Plant.

Discoverer: Friedrich Sertürner
Source: Opium taken from the poppy plant (*Papaver somniferum*).
Milestone: It was the first pure active compound that was isolated from a natural product.
Importance:
It marked the beginning of alkaloid chemistry as well as modern pharmacology.
It came to be used as a strong analgesic for severe pain.

2. Quinine (1820) - First Effective Antimalarial

Discoverers: Pierre Joseph Pelletier and Joseph Bienaimé Caventou
Source: Bark of the Cinchona tree.
Milestone: It was the first treatment that worked well for malaria.
Importance:
It made it possible for Europeans to explore regions where malaria was endemic.
It led to the development of modern antimalarial drugs.

3. Aspirin (1897) - First Widely Used Synthetic Drug

Developer: Felix Hoffmann at Bayer
Chemical name: Acetylsalicylic acid.
Milestone: It was the first synthetic pharmaceutical to be produced on an industrial scale.
Importance:
It is used as an analgesic, antipyretic, anti-inflammatory, and antiplatelet drug.
It set the foundation for the modern pharmaceutical industry.

4. Warfarin (1940s-1950s) - First Major Oral Anticoagulant

Origin of discovery: It was linked to a bleeding disease seen in cattle that was caused by spoiled sweet clover.
Researched by: Scientists at the University of Wisconsin-Madison.

Milestone: It was the first oral anticoagulant drug to be widely used.

Importance:
It stops blood clots, strokes, and thrombosis.
In the beginning, it was also used as a rodenticide.

5. Penicillin (1928; clinical use 1940s) - First Antibiotic
Discoverer: Alexander Fleming
Source: Mold *Penicillium notatum.*
Milestone: The discovery of antibiotics.
Importance:
It changed the way bacterial infections were treated.
Mass production during World War II saved millions of lives.

6. Cephalosporin (1945) - New Class of Antibiotics
Discoverer: Giuseppe Brotzu
Source: Fungus *Cephalosporium acremonium***.**
Milestone: It brought in β-lactam antibiotics other than penicillin.
Importance:
It has a wider antibacterial spectrum.
It is useful for treating infections that are resistant to penicillin.

7. Paclitaxel (Taxol) (1960s-1970s) - Anticancer Drug from Plants
Source: Pacific yew tree (*Taxus brevifolia*).
Developed by: Researchers at the National Cancer Institute.
Milestone: A leading example of an anticancer therapy obtained from a natural product.
Importance:
It is used in breast, ovarian, and lung cancers.
It works by making microtubules stable and stopping cell division.

8. Artemisinin (1972) - Breakthrough Antimalarial
Discoverer: Tu Youyou
Source: The plant *Artemisia annua* (sweet wormwood).
Milestone: It was discovered from traditional Chinese medicine.

Importance:
It forms the basis of Artemisinin-based Combination Therapies (ACTs) for malaria.

Key Milestones

Sr.No.	Year (approx.)	Drug	Original Source	Therapeutic Impact
1.	1804	Morphine	Opium Poppy (*Papaver somniferum*)	The first alkaloid isolated from a plant; revolutionized pain management.
2.	1820	Quinine	Cinchona Bark (*Cinchona officinalis)*	The primary treatment for malaria for over a century.
3.	1899	Aspirin	Willow Bark (Salicylic acid)	The first synthetic version (acetylsalicylic acid) of a natural compound.
4.	1928	Penicillin	Mold (*Penicillium notatum*)	Discovered by Alexander Fleming; ushered in the "Antibiotic Era."
5.	1945/1964	Cephalosporin	Marine Fungus (Acremonium)	Broad-spectrum antibiotics discovered in sewage water off the coast of Sardinia.
6.	1948	Warfarin	Sweet Clover (Dicoumarol)	Originally a rat poison; became a life-saving anticoagulant for humans.
7.	1960	Taxol	Pacific Yew Tree (*Taxus brevifolia*)	A major breakthrough in chemotherapy for breast and ovarian cancers.
8.	1972	Artemisinin	Sweet Wormwood (*Artemisia annua*)	Discovered via ancient Chinese medicine; now the gold standard for malaria.

Chapter 04: Pharmacopoeias Of Herbal Medicine

Introduction to Different Herbal/Traditional Pharmacopoeias

An official text that lists medicinal drugs together with their description, identification, purity standards, strength and methods for quality control is called a pharmacopoeia. When such a book centres on medicinal plants, herbal drugs and traditional formulations from various medical systems, it is referred to as a herbal or traditional pharmacopoeia.

1. Indian Pharmacopoeia (IP)

In India, the official drug-standards book is the Indian Pharmacopoeia, brought out by the Indian Pharmacopoeia Commission. The first edition came out in 1955, and since then it has been revised at regular intervals to add new drugs and updated analytical procedures.

Inside the book are monographs covering pharmaceutical substances, dosage forms and herbal products. Every monograph gives full details such as how the drug looks, the tests used to identify it, its purity limits, chemical assays, the way it should be stored and how it should be labelled.

Although the IP gives most of its attention to modern pharmaceutical drugs, it also lays down standards for some herbal drugs and plant-based preparations that the pharmaceutical industry uses. For manufacturers, drug regulators, pharmacists and quality-control labs, this book acts as both a legal and a scientific reference, and it helps ensure that medicines are safe, of good quality and effective.

2. British Herbal Pharmacopoeia (BHP)

The BHP was put together by an organisation in the United Kingdom called the British Herbal Medicine Association, and its first edition came out in the year 1971. Across Europe, this book is regarded as an important reference for herbal practice.

Within this pharmacopoeia, monographs cover a large number of medicinal plants generally seen in Western herbal practice. Each monograph carries detailed information of the following kind:

- Botanical name and family
- Description of the plant
- Parts used
- Chemical constituents
- Pharmacological actions
- Therapeutic indications
- Dosage and preparation methods

When it comes to standardising and regulating herbal medicines in the UK and several other countries, the BHP plays a major part. It assists practitioners and researchers in correctly identifying herbal drugs, using them safely and giving them in the proper dose.

3. United States Pharmacopoeia (USP) –

Herbal Medicines and Dietary Supplements

In America, official drug standards come from a book called the USP, which is brought out by the United States Pharmacopeia. Working alongside the National Formulary as the combined USP–NF, it sets the standards covering pharmaceuticals, dietary supplements as well as herbal medicines.

USP carries monographs both for herbal drugs and for dietary supplements, with guidelines that cover quality control, purity, strength and identity. As a result of these standards, any herbal supplement marketed in America must meet strict safety and quality requirements.

Apart from the standards, the USP also supplies analytical procedures, reference materials and laboratory methods for testing herbal products. Pharmaceutical companies, regulatory agencies, research institutions and healthcare workers all make use of this pharmacopoeia.

4. Ayurvedic Pharmacopoeia of India (API)

The Ayurvedic Pharmacopoeia of India is an official text that gives the standards for drugs used in Ayurveda — the traditional Indian system of healthcare. India's Ministry of AYUSH is the body that publishes it.

The API is made up of monographs covering the raw drugs that go into Ayurvedic preparations, including those of plant, mineral and animal origin. Each monograph carries detailed information of the kind shown below:

- Botanical identification and taxonomy
- Macroscopic and microscopic characteristics
- Chemical constituents
- Identification tests and analytical methods
- Standards for purity and quality

By providing this information, the Ayurvedic Pharmacopoeia helps maintain standardisation, authenticity and quality control for Ayurvedic drugs. Manufacturers of Ayurvedic medicines, researchers and regulatory bodies all rely on it widely.

5. Unani Pharmacopoeia of India (UPI)

The Unani Pharmacopoeia of India sets the official standards for drugs used in the Unani system, a traditional medical practice grounded in Greco-Arab knowledge. Like the API, this volume too comes from India's Ministry of AYUSH.

It carries monographs for both single drugs and compound formulations of Unani medicine. The kind of information given includes:

- Drug description and source Botanical identification
- Chemical composition
- Pharmacological properties
- Quality control tests

By laying down uniform standards, the Unani Pharmacopoeia helps make sure that Unani medicines remain safe, pure and effective.

6. American Herbal Pharmacopoeia (AHP)

Set up in the United States in 1995, the American Herbal Pharmacopoeia was created to develop scientifically sound standards for herbal medicines. It releases detailed monographs on medicinal plants from different parts of the world.

Each monograph includes extensive information such as:

- Botanical identification and taxonomy
- Macroscopic and microscopic features
- Phytochemical constituents
- Analytical methods for quality control
- Safety data and toxicology
- Therapeutic uses and dosage

Comparison of Scope and Authority

Sr.No.	Pharmacopoeia	Authority	Primary System
1.	IP	Government of India	Modern & Herbal
2.	BHP	British Herbal Medicine Assoc.	Western Herbalism
3.	USP-HMDS	USP Convention (Non-profit)	Dietary Supplements
4.	API / UPI	Ministry of AYUSH (India)	Traditional (AYUSH)
5.	AHP	Independent Board (USA)	Botanical Science

Standardisation, quality control and the safe use of herbal medicines all rest heavily on what herbal and traditional pharmacopoeias provide. They act as authoritative reference works for the identification, preparation, testing and therapeutic use of medicinal plants across various traditional as well as modern medical systems.

Chapter 05: Classification Of Crude Drug

1. Official vs. Non-Official Drugs

What this distinction comes down to is pharmaceutical legitimacy — whether or not a drug is recorded "on the books" of a national medical registry.

- **Official Drugs:** A drug becomes "official" when it appears in a Pharmacopoeia, that is, an official compendium of drug standards (for example, the USP in the United States or the BP in the United Kingdom). For a substance to qualify, it must meet standardised requirements covering its manufacture, purity and potency.

- **Non-Official Drugs:** Substances that do not appear in current official compendia fall under this group. The category covers:
    - **Experimental Drugs:** Compounds still in clinical trials.
    - **Obsolete Drugs:** Medicines that were used at one time but were taken off official lists, either due to safety concerns or because better alternatives became available.
    - **Illicit Synthetics:** Lab-made drugs that have never sought medical recognition.

2. Codified vs. Non-Codified Drugs

Here, the distinction is about a drug's legal status — that is, how it is treated by the criminal justice system.

- **Codified Drugs:** A drug is called codified when it is named and grouped explicitly inside some legal "Code" or "Statute" — the Controlled Substances Act, for instance. Such drugs are typically slotted into Schedules from I through V, depending upon how likely they are to be abused and how useful they happen to be in medicine.
    - **Legal Reality:** Once a drug is codified, the prosecutor only has to prove that the defendant possessed that exact molecule for a conviction**.**

- **Non-Codified Drugs:** Often known as "legal highs" or designer drugs, these substances have been chemically altered just enough to escape the banned list. They are commonly called analogues.
    - **The Loophole:** Since the exact chemical structure has not yet been written into the law (the Code), the substance sits in a gray area.
    - **Legal Reality:** To go after these compounds, the police generally fall back on so-called "Analogue Acts." Under such laws, prosecutors must show before a court that this newer compound is "substantially similar" to one already codified — and that turns into a much harder, much more expensive legal battle.

Comparative Classification of Drugs in Pharmacognosy

Sr.No	Feature	Official Drugs	Non-official Drugs	Codified Drugs
1.	Primary Definition	Recognized by current government standards/laws.	Not listed in current official compendia.	Part of a written, systematized medical system.
2.	Source of Authority	Pharmacopoeias (IP, BP, USP, etc.).	Reference books, journals, or older pharmacopoeias.	Ancient Texts (e.g., Charaka Samhita, Vedas).
3.	Documentation	Strict legal monographs (purity, ash value, etc.).	Descriptive monographs or clinical reports.	Formularies and traditional scriptures.
4.	Standardization	High; mandatory adherence to chemical/microscopic limits.	Variable; depends on the manufacturer or researcher.	Standardized based on traditional processing (Shodhana).
5.	Example (Botanical)	Atropa belladonna (IP/BP)	Sarsaparilla (once official, now mostly non-official)	Ashwagandha (Ayurvedic Pharmacopoeia)
6	Role in Research	Used as the "Gold Standard" for quality control.	Used to study potential new therapeutic agents.	Provides a lead for systematic drug discovery.

Crude Drugs:

Introduction

A wide range of diseases is treated using crude drugs sourced from various natural origins. To study them properly, they have to be arranged in a scientific and systematic way. Because they are so numerous and occur in such varied forms, putting them into a single uniform pattern is not an easy task.

For pharmacognostic study, crude drugs may be placed into one of the categories given below. In pharmacognosy, classifying crude drugs by their cellular structure is a basic way of separating them according to how they are harvested and processed.

What sets the two apart is essentially this — does the drug still retain its parent plant's or animal's anatomical form (in which case it is called Organized), or has it been extracted out from, or secreted by, those sources (then it is termed Unorganized).

Organized Drugs vs. Unorganized Drug

1. Organized Drugs

These are basically the "organs" of the plant. Place them under a microscope and you will be able to make out distinct cell walls, xylem, phloem or stomata.

- **Examples:**
    - Cinchona Bark: Used for obtaining quinine.
    - Digitalis Leaves: Used for heart conditions.
    - Nux Vomica Seeds: Containing strychnine.
    - Senna Leaves: Used as a laxative.

Feature	Organized Drugs	Unorganized Drugs
Definition	Direct parts of the plant or animal consisting of cellular tissues.	Products derived from plants/animals by extraction, incision, or distillation.
Cellular Structure	Possess a definite internal cellular structure (tissues, fibers, vessels).	-
Identification	Identified using morphological (shape, size) and microscopical features.	Identify using chemical test and physical constituent (Solublity, optical rotation)
Preparation	Usually require drying and sometimes longitudinal or transverse cutting.	Prepared by processes like expression, incision, or decoction.
Examples	Leaves, Roots, Barks, Flowers, Seeds.	Gums, Resins, Latex, Volatile oils, Extracts.

2. Unorganized Drugs

These represent the secretions or parts taken out from the biological source. Chemically they are quite varied, and they do not contain any organised living cells.

- **Examples:**
    - Opium: The dried latex collected by cutting incisions in the poppy capsule.
    - Acacia (Gum Arabic): A dried gummy exudation from the stem.
    - Castor Oil: A fixed oil obtained by expression of the seeds.
    - Agar: A dried gelatinous substance obtained from seaweed.

Feature	Organized Drugs	Unorganized Drugs
Definition	Direct parts of the plant or animal consisting of cellular tissues.	Products derived from plants/animals by extraction, incision, or distillation.
Cellular Structure	Possess a definite internal cellular structure (tissues, fibers, vessels).	Do not have a cellular structure; they are usually amorphous or semi-solid.
Identification	Identified using morphological (shape, size) and microscopical features.	Identified using chemical tests and physical constants (solubility, optical rotation).
Resparation	Usually require drying and sometimes longitudinal or transverse cutting.	Prepared by processes like expression, incision, or decoction.
Examples	Leaves, Roots, Barks, Flowers, Seeds.	Gums, Resins, Latex, Volatile oils, Extracts.

Classification of Crude Drugs

- **1. Alphabetical Classification**
  - Drugs are arranged according to their Latin or English names (for example, A for Acacia, B for Benzoin).
  - Source: IP, BP, USP.
- **2. Taxonomical (Biological) Classification**
  - Based on botanical/zoological hierarchy.
  - Path: Phylum -Order-Family-Genus-Species.
- **3. Morphological Classification**
  - Based on the physical form of the drug.
  - Organized: Parts of plants (Leaves, Roots, Barks).
  - Unorganized: Products (Gums, Resins, Dried juices, Extracts).
- **4. Pharmacological (Therapeutic) Classification**
  - Drugs are grouped on the basis of how they act on the human body.
  - Examples: Purgatives (Senna), Cardiotonics (Digitalis), Antimalarials (Cinchona).
- **5. Chemical Classification**
  - Based on the primary active chemical constituent.
  - Groups: Alkaloids, Glycosides, Volatile Oils, Tannins, Lipids.
- **6. Chemotaxonomical Classification**
  - The modern bridge between taxonomy and chemistry (e.g., presence of specific alkaloids in a specific family like Solanaceae).

1. Alphabetical Classification:

Under this method, the listing of crude drugs follows alphabetical order, going by either their Latin or English titles. A few of the pharmacopoeias and reference works which adopt this arrangement are noted as follows

1. Indian Pharmacopoeia.
2. British Pharmacopoeia.
3. United States Pharmacopoeia & National Formulary.
4. British Herbal Pharmacopoeia.
5. British Pharmaceutical Codex.
6. European Pharmacopoeia (Latin titles).
7. Encyclopaedia of common Natural ingredients used in drugs and cosmetics.

e.g.: Acacia, benzoin, cinchona, dill, ergot, fennel, gentian, hyoscyamus, ipecacuanha, jalap, kurchi, liquorice, myrrh, Nux vomica, opium, podophyllum, quassia, rauwolfia, senna, uncaria gambier, vasaka, wool fat, yellow bees wax, zedoary.

• Advantages:

The system is straightforward; finding, tracing or adding a drug is easy, and no technical expert is needed to manage it.

• Disadvantages:

• This method does not reveal the scientific nature of the drug, so one cannot tell whether it is organised or unorganised

• The system is also unable to separate drugs based on whether they come from a plant, animal or mineral source (the original source remains unclear). Examples: Acacia, Agar, Benzoin, Beeswax, Cinchona, Cinnamon, Digitalis, Datura, Ephedra, Fennel, Ginger, Isapagol, Jalap, Kino, Linseed, Mustard, Nutmeg, etc

2. Taxonomical Classification:

• Drugs in this system are classified by the plants or animals they originate from, using categories like Phylum, Orders, Families, Genera, Species, Subspecies and so on.

• A common criticism of this system is that it does not take into account whether crude drugs are organised or unorganised, nor does it consider the chemical nature of their active constituents or their therapeutic value

• Phylum – Spermatophyta
• Division – Angiospermae
• Class – Dicotyledons
• Order – Rosales
• Family - Leguminosae
• Sub-family – Papilionaceae
• Genus - Glycyrrhiza, Astragalus, Myroxylon
• Species - Glycyrrhiza glabra, Astragalus gummifer, Myroxylon balsamum.
• Phylum – Spermatophyta
• Division - Angiospermae
• Class - Dicotyledons
• Sub-class - Sympetalae
• Order - Tubiflorae
• Family – Solanaceae
• Genus - Atropa, Hyoscyamus, Datura
• Species - Atropa belladona, Hyoscyamus niger, Datura stramonium

Here drugs are placed in order based on taxonomical study — meaning they are sorted by phylum, then order, then family, then genus, then species. At its core, this is botanical or biological classification, and its use is mostly limited to crude drugs that come from plants

3. Morphological Classification:

• Crude drugs in this method are grouped by which part of the plant or animal they stand for, and they get divided into two classes — organised (cellular) drugs and unorganised (acellular) drugs.

• Organised (Cellular):

• These drugs are direct parts of the plant and are further divided into leaves, barks, wood, roots, rhizomes, seeds, fruits, flowers, stems, hairs and fibres.

• Unorganised (Acellular):

• These drugs come as products from plant, animal or mineral sources, and the subdivisions cover the following — dried latex; dried juices; dried extracts; gums; resins; fixed oils with fats; waxes; volatile oils; animal products; and minerals in solid, liquid or semi-solid form.

• Advantages:

• For practical study this kind of classification is more handy, especially in cases where the chemical nature of the drug is not yet well understood.

• It is also very helpful when one needs to identify adulterants.

Disadvantages:

• It does not give any clue about the biological source, the chemical constituents or the uses.

• Where different parts of the same plant carry different chemical constituents, fitting them into one group becomes difficult.

• Crude drugs are sorted by the parts of the plant or animal that they come from, and they fall into either organised or unorganised drugs.

• Seeds - nux-vomica, strophanthus, isabghol, castor

• Leaves - senna, digitalis, vasaka, eucalyptus

• Barks - cinchona, kurchi, cinnamom, quaillia

• Woods - quassia, sandalwood, red-sanders

• Roots - rauwolfia, ipecacuanha, aconite, jalap

• Rhizomes - turmeric, ginger, valerian, podophyllum

• Flowers - clove, pyrethrum, saffron, artemisia

• Fruits - coriander, colocynth, fennel, bael

• Entire drugs- ephedra, ergot, cantharides, belladonna

• Dried latices- opium, gutta-percha, papain

• Resins & resin combinations - balsam of tolu, myrrh, asafoetida, benzoin

• Dried juices - aloes, kino, red gum

• Gums - acacia, tragacanth, ghatti gum, guar gum

• Dried extracts- gelatin, catechu, agar & curare

4. Chemical Classification:

• In this method, crude drugs are placed into different groups on the basis of the chemical nature of the most important constituent present in the drug — the constituent to which the pharmacological or therapeutic activity of the drug is credited

• Glycosides - Digitalis, senna, cascara, liqourice

• Alkaloids - Nux vomica, ergot, cinchona, datura

• Tannins - Myrobalan, pale catechu, ashoka

• Volatile oils - Peppermint, clove, eucalyptus, garlic

• Lipids - Castor oil, bees wax, lanolin, cod liver oil, kokum butter

• Carbohydrates - Acacia, agar, guar gum, pectin, honey, ispaghula

• Resins & resin - Colophony, jalap, Balsam of Tolu

• Vitamins Yeast, Shark liver oil, Oxytocin, Hormones insulin

• Proteins - casein, gelatine, papain, trypsin This is the preferred method of classification, since the therapeutic and pharmacological importance of crude drugs depends on their chemical composition.

• Advantages :

• Chemical constituents are known,

• Medicinal uses are known

• Disadvantages :

• Drugs of different origin are placed under the same chemical heading.

• Drugs containing two different types of chemicals do not fit easily into this kind of classification.

Eg: Some drugs are found to have both alkaloids and glycosides (Cinchona), or fixed oil and volatile oil of equal importance (Nutmeg), and so they are difficult to place into a single category

5. **Pharmacological (Therapeutic) Classification:** This approach groups crude drugs by considering how the active constituents act pharmacologically, or by what they are used for therapeutically — morphology, taxonomy and chemical links are set aside. Even drugs that work through different mechanisms but bring about a similar pharmacological effect end up clubbed together here,
e.g. bulk purgatives, irritant purgatives, emollient purgatives

• Drugs acting on GIT:

Bitters - Gentian, Quassia, Cinchona

Carminatives - Dill, Mentha, Cardamom

Emetics – Ipecacuanha

Anti-amoebiasis - Kurchi, Ipecauanha

Bulk laxatives - Agar, Isapghula, Banana

Purgatives - Senna, Castor oil

Peptic ulcer - Derivatives of Glycyrrhitinic acid treatment (Liqourice and Raw banana)

Drugs acting on respiratory system

• Expectorant - Liqourice, Ipecacuanha, Vasaka

• Anti-tussives - Opium (Codeine, Noscapine)

• Bronchodilators - Ephedra, Tea (Theophylline)

Drugs acting on CVS:

• Cardiotonics - Digitalis, Squill, Strophanthus

• Cardiac depressants - Cinchona (quinidine), Veratrum

• Vaso-constrictors - Ergot (ergotamine), Ephedra • Anti-hypertensives - Rauwolfia

Drugs acting on autonomic nervous systems:

• Adrenergics - Ephedra

• Cholinergics - Physostima, Pilocarpus

• Anticholinergics - Belladona, Datura

Drugs acting on CNS:

• Central analgesics - Opium (morphine)

• CNS Stimulants - Coffee (caffeine)

• Analeptics - Nux-vomica, Lobelia, Camphor

• CNS depressants - Hyoscyamus, Belladonna, opium,

• Hellucinogenics - Cannabis, Poppy Latex

Anti-spasmodics:

• Smooth Muscle Relaxants - Opium, Datura, Hyoscyamus

• Skeletal Muscle Relaxants - Curare

Anti-cancer:

Vinca, Podophyllum, Taxus, Camptotheca

• Anti-rheumatics: Aconite, Colchicum, Guggul

• Astringents: Myrobalan, Black Catechu

6. **Chemotaxonomic Classification:** This system gives equal weight to the taxonomical position and to the chemical constituents. Certain types of chemical constituents are typically associated with certain plant classes. For example, tropane alkaloids are usually found in most members of Solanaceae. Likewise, volatile oils are commonly seen in members of Umbelliferae and Rutaceae.

UNIT-II
CULTIVATION, COLLECTION, PROCESSING AND STORAGE OF DRUGS OF NATURAL ORIGIN

Chapter 06: Cultivation Of Medicinal Plant

Cultivation

Several environmental and medicinal factors come together to support plant growth — among them rainfall, irrigation, fertilisers, pests, humidity, light and temperature. Cultivation refers to the act of growing plants when these variables are kept under careful control.

Advantages

1. Plants of better quality are produced.
2. The therapeutic activity along with the yield is improved.
3. A regular supply of herbs becomes possible.
4. Industrialisation gets supported.
5. Application of modern scientific technology becomes feasible. For instance, mutation and hybridization.

Disadvantages

1. The cost is on the higher side.
2. Ecological imbalance may give rise to losses.
3. Going for cultivation does not pay when plants can be collected in plenty from the wild.

Factors Affecting Cultivation

Compared to wild collection, growing medicinal plants under cultivation gives many benefits. Yet whether cultivation succeeds will depend on several environmental as well as biological conditions, since these decide the way a plant grows, the way it develops, and the secondary metabolites it puts out. Among the main ones are altitude; temperature; rainfall; the length of day; the strength of light; the type of soil and how fertile it is; the fertilisers applied; and the pests around.

To examine how each of these factors works, the usual method is to raise one and the same species under varying environmental settings and then observe what changes appear. To take an example, a plant kept in one particular setting may remain small physically yet still hold a richer level of active metabolites than another plant of the same species which has reached full growth in some other setting.

Nutrient supply also matters a lot. Proper nutrients can boost the production of secondary metabolites, but excessive or unbalanced nutrition often ends up reducing their levels.

- **Altitude**

  When it comes to growing medicinal plants, altitude makes a big difference, because every species has its own preferred elevation range. Take tea, cinchona and eucalyptus — these grow well at heights of around 1,000 to 2,000 metres. Cinnamon, along with cardamom, performs well between 500 and 1,000 metres. Senna, by contrast, can even be raised right at sea level.

Examples of Plants and Suitable Altitudes

Plant	Altitude (meters)
Tea	1000–1500
Cinchona	1000–2000
Camphor	1500–2000
Cardamom	600–1600

- **Temperature**

  Growth, metabolic activity and secondary-metabolite production in a plant are largely controlled by temperature. Plants do adapt to the surroundings they originate from, but most species can put up with only a narrow temperature window. Quite a few medicinal plants thrive in moderate or temperate climates, yet they cannot pull through severe cold or frost.

Optimum Temperature for Cultivation

Plant	Optimum Temperature (°F)
Cinchona	60–75
Coffee	55–70
Tea	70–90
Cardamom	50–100

- **Rainfall**

  Proper rainfall is necessary for healthy plant growth and development. The amount of water required, however, is not the same for every species. Xerophytes such as aloes need very little water, while other plants depend on steady rainfall. The effect of rainfall depends on the total annual precipitation and also on the soil's ability to hold water. When rainfall is too heavy, the level of secondary metabolites may drop because water-soluble compounds get leached away.

- **Day Length and Light**

  Both the duration of daylight (the photoperiod) and the strength of light have a marked influence on how plants grow and how they form their metabolites. When a plant gets long-day exposure, the chemical levels can come out different from what is produced under short-day conditions. With peppermint, to give one example, long days bring out menthone, menthol along with a little menthofuran, while in short-day periods only menthofuran shows up.

  Apart from photoperiod, light intensity and quality also shape plant development. In the wild, plants get optimal light naturally, but during cultivation this has to be controlled with care. Increased daylight has been found to raise alkaloid production in plants such as belladonna, stramonium and cinchona. Different kinds of radiation can also alter plant growth and chemical composition.

- **Soil**

  Soil is a basic factor in plant cultivation, since each species has its own particular soil and nutrient demands. The properties of soil can be grouped into physical, chemical and microbiological. The soil supplies structural support, water and the nutrients essential for growth.

  Soil is a mixture of air, water, minerals and organic matter. Variations in particle size give rise to different soil types — clay, sand and gravel — and these affect how much water the soil can hold. The mineral content also matters; calcium, for example, helps the growth of certain plants while having little effect on others.

  Soil pH has a strong influence on plant development as well as on microbial activity. Many plants grow best within a particular pH range. Soils rich in nitrogen are especially valuable for boosting alkaloid production in some medicinal plants. On the basis of particle size and composition, soils are divided into different categories.

  Type of soil on the basis of particle size.

Particle size (Diameter)	**Type of soil**
Less than 0.002 mm	Fine Clay
0.002-0.02 mm	Coarse clay or silt
0.02-0.2 mm	Fine sand
0.2- 2.0 mm	Coarse sand

Based on the percentage of clay they contain, soils are grouped into the following categories (see table below.)

Type of soil on the basis of percentage covered by clay.

Type of soil	**Percentage covered by clay**
Clay	More than 50 % of clay
Loamy	30-50% of clay
Silt loam	20-30% of clay
Sandy loam	10-20% of clay
Sandy soil	More than 70 % sand
Calcarious soil	More than 20 % of lime

- **Soil Fertility**

  Soil fertility refers to the soil's capacity to provide essential nutrients to plants in adequate amounts and in the right balance. When cultivation continues without restoring nutrients, fertility declines. Leaching and soil erosion can also bring it down. Fertility can be raised again by adding organic manures, using nitrogen-fixing microorganisms and applying chemical fertilisers, which give quick and dependable results.

- **Fertilizers and Manures**

  For proper growth and development, plants need nutrients. Their basic needs include carbon dioxide, sunlight, water and minerals supplied by the soil. With these inputs they

make food materials such as fruits, grains and fibres, and they also synthesise secondary metabolites like alkaloids, glycosides and oils.

- **Chemical Fertilizers**
  Chemical fertilisers deliver nutrients in a form that plants can absorb easily. About sixteen elements are essential for plants. Nitrogen, phosphorus and potassium are the primary nutrients; calcium, magnesium and sulphur are the secondary ones; while iron, copper, zinc, boron, manganese and molybdenum fall under the micronutrients. Carbon, hydrogen, oxygen and chlorine come from air and water. Each nutrient performs a specific role, and a deficiency in any of them shows up as visible symptoms in plants.

- **Manures**
  Manures are natural organic materials applied to raise soil fertility. The well-known examples are FYM (farmyard manure), compost, vermicompost, poultry manure, plus oil cakes from neem or castor. The way they work is by releasing nutrients slowly while also bettering soil structure. Some additional organic sources are bone meal, fish meal, blood meal, biogas slurry and press mud.

- **Biofertilizers**
  Biofertilisers are preparations made up of beneficial microorganisms that increase nutrient availability, mainly by fixing nitrogen from the atmosphere. They serve as a sustainable substitute for chemical fertilisers.
  Examples include *Rhizobium*, *Azotobacter*, *Azospirillum*, blue-green algae, and *Azolla*.

Microbial Pests

Microbial pests are made up of fungi, bacteria and viruses that attack plants and bring about a variety of diseases.

Fungal Diseases

A great many destructive diseases of plants trace back to fungi. A familiar one is Armillaria root rot, brought on by Armillaria mellea. After infection, plants slowly lose productivity, and they may die off in about two to four years. Signs include weak growth and shorter shoots, plus the development of dark root-shaped structures (rhizomorphs) within the soil. The fungus flourishes wherever the soil remains moist all the time.

Powdery mildew is another common fungal infection, brought on by Uncinula necator. The leaves develop yellowish (chlorotic) spots on the upper side, and on fruits a white powdery coating appears that can spread until it covers the whole surface.

Several fungal species act together in producing summer bunch rot. The list of organisms involved includes *Aspergillus niger*, *Alternaria tenuis*, *Botrytis cinerea*, *Cladosporium herbarum*, *Rhizopus arrhizus* and species of Penicillium. The outcome on the affected fruits is the development of spore masses that may be black, brown or green in colour.

Other fungal pathogens that affect medicinal plants include:

- *Fomitopsis pinicola*, which causes red-belted rot

- *Pythium pinosum*, responsible for rhizome rot
- *Septoria digitalis*, causing leaf spot
- *Phytophthora cinnamomi*, associated with little leaf disease

Bacterial Diseases

Bacteria are also behind several important plant diseases. Crown gall disease, brought on by Agrobacterium tumefaciens, leads to tumour-like swellings (galls) on stems, roots and trunks. Internally these galls are soft and irregular. The bacteria are spread through contaminated tools or through wounds made during cultivation and pruning.

Pierce's disease is another bacterial disorder, this one caused by Xylella fastidiosa. The leaf margins begin to turn yellow or red, and afterwards the edges of the leaf dry out and die.

Viral Diseases

Viruses can infect plants and bring about symptoms such as necrosis (death of tissue) in leaves, stems and petioles. Some commonly seen plant viruses are:

- Tobacco mosaic virus
- Cucumber mosaic virus
- Tobacco ringspot virus
- Yellow vein mosaic virus

These viruses generally spread through vectors or through infected plant material, and they can cause a heavy reduction in crop yield.

Control Techniques

To prevent or cut down the harm done by microbial pests, several methods are followed. These include treating the soil with chemical fumigants, spraying fungicides as well as bactericides, and pruning the diseased parts of plants on a regular basis. Keeping irrigation in proper measure and applying fertilisers in balanced doses are also important. Good sanitation, heat treatment of seeds or planting stock, plus removal of the infected portions, all work together to limit how far disease can spread. As a long-term measure, breeding plant varieties that have been genetically improved so they resist fungal as well as bacterial attack remains one of the strongest strategies.

Key Control Methods

- **Soil fumigation:** Use of chemicals to disinfect soil and eliminate harmful microorganisms.
- **Application of chemicals:** Use of fungicides and bactericides to control fungal and bacterial infections.
- **Pruning:** Removal of diseased or infected plant parts to stop further spread.
- **Proper irrigation management:** Avoid excess moisture, which favors microbial growth.
- **Balanced fertilizer use:** Ensures healthy plant growth and improves resistance to diseases.
- **Sanitation practices:** Keeping fields clean and removing plant debris to reduce infection sources.

- **Heat treatment:** Treating seeds or planting material with heat to destroy pathogens.
- **Removal of infected parts:** Cutting and destroying affected portions of plants.
- **Use of resistant varieties:** Developing and cultivating genetically improved plants that resist microbial infections.

Insect Pests

Insects fall among the major pest groups that harm plants. They feed on different parts such as roots, stems, buds and leaves, and as a result the plant's growth and yield go down.

Common Insect Pests and Their Effects

- **Ants:**
  Farm fields commonly host several types of ants. The species seen there include the Argentine ant (*Linepithema humile*), gray ants of two kinds (*Formica aerata*, *Formica perpilosa*), the pavement ant (*Tetramorium caespitum),* southern fire ant (*Solenopsis xyloni*) and thief ant (*Solenopsis molesta*).
    - They damage soil structure by building nests.
    - They feed on honeydew secreted by plants, which can indirectly promote plant damage.

- **Branch and Twig Borer (*Melalgus confertus*):**
    - These insects bore into plant stems through buds or at junctions of shoots.
    - They create deep tunnels where the insect may remain hidden.
    - Infested shoots become weak and may twist or break, especially under strong winds.

- **Click Beetle (*Limonius canus*):**
    - Feeds on plant buds.
    - Damage to buds can hinder normal plant development.

- **Cutworms (*Peridroma saucia*, *Amathes c-nigrum*, *Orthodes rufula*):**
    - Attack and damage plant buds.
    - Affected buds may fail to grow or develop properly.

- **Leafhoppers (*Erythroneura elegantula*, *Erythroneura variabilis*):**
    - Feed by sucking the contents of leaf cells.
    - Leaves show pale yellow spots due to empty cells, reducing photosynthesis.

- **Oak Twig Pruners (*Anelaphus* species):**
    - Attack shoots, twigs, and roots.
    - Cause cutting or weakening of plant parts, leading to reduced growth.

Pests and Pests
Unwanted plants or animals that cause serious harm to crops are referred to as control pests. Pests fall into several categories such as microbes, insects, non-insect pests and weeds.

Microbes
The group of microbial pests includes fungi, bacteria and viruses, all of which are capable of causing serious plant damage.
A serious fungal disease is Armillaria root rot, traced to *Armillaria mellea* of the Marasmiaceae family. Once a plant gets infected, productivity slowly falls, and within roughly two to four years death often follows. Symptoms include weak growth as well as short shoots. As things progress, dark root-shaped structures called rhizomorphs come up in the soil. The conditions this fungus likes most are soils that remain moist all the time.

Powdery mildew is yet another fungal disease, caused by Uncinula necator. Yellowish (chlorotic) spots appear on the upper surface of the leaves, while on the fruits the fungus produces white, powdery patches that may extend over the entire surface.

Summer bunch rot results from a group of fungi acting together. The organisms involved are *Aspergillus niger*, *Alternaria tenuis*, *Botrytis cinerea*, *Cladosporium herbarum*, *Rhizopus arrhizus*, plus species of Penicillium. Berries that catch the infection develop spore masses on their surface, and these masses may show up as black, brown or green.

Red-belted rot is caused by the fungus *Fomitopsis pinicola* (family Fomitopsidaceae). Other fungi attack medicinal plants too — for example, Pythium pinosum is responsible for rhizome rot, Septoria digitalis brings about leaf spot, and Phytophthora cinnamomi is the cause of little leaf disease.
Of the bacterial diseases, crown gall is brought on by Agrobacterium tumefaciens (family Controlling Techniques
To bring microbial diseases under control and reduce the harm they do to plants, growers depend on several different methods. Among these are fumigating the soil with chemicals, along with applying fungicides as well as bactericides. Pruning at regular intervals, watering the crop properly, and giving fertilisers in balanced doses all help keep the plant healthy and lower the chance of disease. Maintaining good sanitation in the field is just as important if pathogen spread is to be checked.
Other useful steps are heat treatment of planting material and the removal and destruction of infected plant parts. On top of this, breeding and growing disease-resistant plant varieties through genetic improvement can greatly cut down the damage from fungi and bacteria.

Insects
A number of insect species can attack plants and end up reducing their productivity. Common pests include ants of various kinds — for example, the Argentine ant (*Linepithema humile*), the

gray ants *Formica aerata* along with *Formica perpilosa*, the pavement ant (*Tetramorium caespitum*), the southern fire ant (Solenopsis xyloni) and the thief ant (Solenopsis molesta). The way these ants cause harm is by disturbing the soil through their nest-building, and they also feed on honeydew given off by plants or by other insects.

Damage from the **branch-and-twig borer**, Melalgus confertus, comes from the way it bores into canes — the insect usually slips in near a bud or at the point where a shoot meets the spur. Once inside, it feeds deep within and is often hard to spot. By the time the shoot has reached about 10 to 12 inches, a strong wind is enough to twist and break the weakened part.

The **click beetle** (Limonius canus) eats away at buds and affects their development. **Cutworms** — for example, Peridroma saucia, Amathes c-nigrum and Orthodes rufula — also damage buds and stop them from growing normally.

Leafhoppers, including Erythroneura elegantula and Erythroneura variabilis, suck out the contents of leaf cells. Once the cells are emptied, pale yellow spots appear on the leaves.

The **oak twig pruner** (Anelaphus species) is one more pest. It attacks shoots, twigs and roots, causing damage to all of these parts.

Rhizobiaceae). The disease leads to tumour-like growths (galls) on stems, roots, trunks and cordons. These galls can grow quite large and inside they have a soft, disorganised structure. The bacteria spread through contaminated tools or material, and they generally enter plants through wounds made during pruning or cultivation.

Controlling Techniques (Insects)

Insect pests can be managed effectively using several methods. Tilling the soil disturbs and breaks up ant nests, which lowers their numbers. Picking and destroying eggs, larvae, pupae and adult insects by hand is also helpful. To capture pests and limit their spread, insect traps may be set up.

Chemical control with insecticides is another widely used approach. Apart from this, methods that interfere with insect reproduction — for example, creating competition among males for mating — can help bring down their numbers.

For pests of the cutworm type, biological control is especially valuable. The populations of such pests are held back by their natural enemies — predator and parasitic insects, plus mammals, birds, reptiles, parasitic nematodes, and microorganisms that cause disease.

Non-Insect Pests

Non-insect pests are generally divided into vertebrates and invertebrates.

Vertebrate pests are animals such as monkeys, rats, birds and squirrels. They damage plants by feeding on them or by disturbing their growth.

Among **invertebrate pests** fall organisms like spider mites, nematodes, crabs as well as snails. The web-spinning spider mites — namely *Tetranychus pacificus*, then Eotetranychus willamettei, and Tetranychus urticae — bring about leaf discoloration along with yellow spotting.

Plant-parasitic nematodes — for example, *Meloidogyne incognita*, *Xiphinema americanum* and *Criconemella xenoplax* — interfere with plant growth by producing giant cells in the roots,

which lowers the uptake of water and nutrients. Other invertebrates such as crabs and snails are also able to damage plants.

Controlling Techniques (Non-Insect Pests)
Among the control measures used here are setting up suitable storage units like warehouses built of concrete, putting out traps, and going for biological control. Where the situation calls for it, chemical control through rodenticides and similar substances can also be applied.

Weeds
Weeds are unwanted plants that draw water, nutrients and sunlight away from the crop. The outcome is reduced growth and lower yield. By practising good weed management, both the establishment of fresh plantings and the productivity of older, settled plants stand to improve.
Weed management is influenced by several factors, soil characteristics being one of them. Soil texture and the amount of organic matter affect the kinds of weeds that grow, the frequency of cultivation that is needed, and how well herbicides work.
In light-textured soils, common weeds include puncturevine, crabgrass, horseweed and Panicum species, along with perennials like johnsongrass, nutsedge and bermudagrass. Heavier soils, by contrast, tend to support weeds such as curly dock, field bindweed and dallisgrass.
Herbicide use also changes with soil type. Sandy soils call for lower doses but may give shorter-lasting control, whereas clay soils retain herbicides for longer but dry out more slowly, which makes cultivation harder. Because of this, lighter soils generally need to be cultivated more often than heavier ones.

Common Weeds
Bermudagrass is a fast-growing perennial weed that does well in spring and summer. It spreads not only through seeds but also through rhizomes and stolons, which makes it hard to control.
Dallisgrass is also a perennial weed, and it competes strongly for nutrients and moisture, particularly in newly planted areas. It germinates during warm seasons and spreads through short rhizomes.
Other common weeds include pigweeds (*Amaranthus* species), pineapple weed (*Chamomilla suaveolens*), and nightshades (*Solanum* species).

Parasitic and Epiphytic Plants
Some plants either grow on, or depend upon, other plants for their nutrients, and this affects the host's growth in a negative way. Examples include dodder (Cuscuta species), mistletoe (Phoradendron species) and American squawroot (*Conopholis americana*). Such parasitic or epiphytic plants weaken their host and bring down its productivity.

Controlling Techniques (Weeds – Herbicide Use)
Herbicides happen to be the most widely chosen tool for weed management, and they fall mainly into two categories — those of preemergent type and those of postemergent type. The preemergent kind hit the weed seeds during germination itself; the postemergent kind go after

weeds that have already come up. There are also a few products which work effectively in both stages.

Preemergent herbicides are sprayed onto bare soil and they act on germinating weed seedlings. To work properly, they have to be carried into the soil by rainfall or irrigation. If they stay on the surface, sunlight can break them down quickly. Because of this, weeds that sprout before the herbicide has been activated may escape control.

When the goal is to kill weeds that have already emerged, postemergent herbicides come into play. They may be sprayed by themselves, mixed together with preemergent products, or used as spot treatments through the growing season. In newly planted crops, the selective postemergent type proves particularly useful against most annual or perennial grasses; they are, however, less effective when broadleaf weeds are the target.

Environmental conditions also play a part in how well a herbicide performs. Frequent soil moisture can speed up the breakdown of the chemical and reduce how long it lasts. As a rule, degradation goes on faster in warm, moist soils than in dry, cold ones.

General Methods of Pest Controls

Controlling Technique	Methods involved
Mechanical	Uses manual work along with various tools for collecting and killing pests — methods include burning, hand-picking and trapping insects, and destroying eggs, larvae and pupae.
Agricultural	Crop rotation, deep ploughing, change in environment, use of systemic insecticide.
Biological	Genetic manipulation and controlling the birth rate of insects
Chemical	Use of pesticide, herbicides, antifeedants, biopesticides

Other Factors Affecting Cultivated Plants

Air Pollution

Over the years, the release of chemicals into the atmosphere has gone up sharply, and although the full effect on plants is still not fully understood, it is clear that plant health suffers as a result. Air pollutants can slow growth and even kill plants. Both deciduous and coniferous trees are sensitive to several pollutants in the air.

These pollutants may be present as single substances or as complex compounds that form within the atmosphere. Their presence can be picked up through air analysis and through examining leaf tissues. The earliest visible signs of pollution damage tend to show up on the leaves. Common symptoms are spots between the veins, discoloration along the leaf margins and burning at the tips. How serious the damage becomes depends on the genetic makeup of the plant as well as on environmental conditions.

Herbicides

Herbicides have to be used very carefully, since wrong application can damage plants that were not the target. The total extent of such damage is not fully known, but in localised areas it can be severe.

How herbicide injury shows up depends on a number of factors — the type of chemical used, the dosage, the length of exposure, the plant species and the environmental conditions. Some herbicides bring about abnormal growth patterns such as curling or twisting of leaves, while others may cause yellowing, browning, dropping of leaves or even the death of the plant.

Collection of Medicinal Plant Materials

To get the best quality of raw materials and finished products, medicinal plants should be harvested at the right time. The level of active chemical constituents in a plant changes with its growth and development stage, and the same is true for naturally occurring toxic substances inside the plant.

The proper time of harvest should be selected on the basis of the period when desired active compounds reach maximum levels, rather than the period of maximum biomass. While the material is being collected, no direct contact with the soil should be allowed. For underground portions like roots, soil that has stuck to them must be brushed off without delay.

Collected materials are best kept in clean, well-ventilated containers like baskets or mesh bags that are free from contaminants and from leftover plant material. After harvesting, the material may be put through initial processing steps such as cleaning, washing, sorting and cutting.

It is also necessary to keep the collected material safe from insects, rodents, birds and other animals. When the collection site is far from the processing area, the material may have to be dried (either by air or in the sun) before it is transported. To prevent contamination, different plant species or different parts should always be collected and stored separately.

Time of Collection

Researchers have, in the case of many plants, carefully figured out the growth stage when medicinal value reaches its peak. To take an instance, the alkaloid content found in leaves of *Hyoscyamus niger* as well as in those of *Atropa belladonna* is at its highest right as flowering starts, whereas in *Datura stramonium* the peak comes during full bloom.

Sometimes even the time of day matters when it comes to the level of active compounds. Leaves of Datura stramonium picked in the morning, for instance, contain more alkaloids than those picked in the evening.

S.No.	Plants Parts	Time of Collection
1.	Bulb	Late autumn, long after the plant has flowered and fruited is usually best.
2.	Barks	Autumn (after leaf fall) or spring (before development of the leaves) is generally selected.
3.	Roots and rhizomes	From annuals: just before the flowering stage. From biennials: in the autumn or winter that follows the first year of growth. From perennials: in the autumn or winter that comes after the second or third year of growth.
4.	Leaves	Collection should be done in dry weather while the plant is in flower. It is usually better to collect the stems carrying the leaves first and

		then separate the leaves; gathering them in the morning is important so that the active constituents are well retained.
5.	Flowers	Collection should be affected in dry weather and towards the middle of the day, after dew has dissipated.
6.	Seeds ans Fruits	Collection should be done when the fruit is fully grown and ripe, or close to ripe. When ripening is complete the seeds are dispersed on their own; therefore, it is better to collect a little earlier — for example, at the right stage when seed loss can still be prevented.

Harvesting of Medicinal Plants

For high-quality raw materials and effective herbal products, medicinal plants need to be harvested at the right season or growth stage. The proper harvesting time changes with the plant part being collected — leaves, roots, stems, flowers or seeds. Reliable details about correct harvesting periods are usually given in pharmacopoeias, official monographs and other standard references.

The level of active chemical constituents in plants changes with the stage of growth and development. The same is true for naturally occurring toxic substances found in some plants. So harvesting should be planned around the peak concentration of the wanted active compounds, and not simply around the highest plant yield.

While harvesting, it is necessary to make sure that the collected material is free from contaminants like soil, weeds and toxic plant species. The work should be done in dry conditions, keeping away from dew, rainfall or high humidity. If plant material has to be collected when wet, it should be moved quickly to a drying facility so that microbial growth, fermentation and mould do not take hold.

Every tool and piece of equipment used for harvesting — cutting instruments, machines and so on — must be clean and well looked after, so that contamination and physical damage are kept to a minimum. These tools should be stored in clean, dry places, away from pests and domestic animals.

Care must be taken so that harvested plant material does not touch the soil directly, because that helps lower the chance of microbial contamination. As a barrier, clean cloth sheets — muslin, say — can be spread out on the ground while collection is going on. For underground organs such as roots, the moment they are dug up, any soil left clinging to them must be cleared off.

Once harvested, plant material should be moved quickly under clean and dry conditions. It can be put into baskets, sacks or other well-ventilated containers and shifted to a central collection point before being sent to the processing units. Every container has to be clean, with no residue from previously stored materials.

When plastic containers are used, care must be taken to prevent moisture from building up, because this can encourage fungal growth. When the containers are not in use, they should be kept in dry, pest-free areas, away from animals.

Mechanical damage to plant material has to be avoided. Overfilling sacks and containers, or pressing them down too hard, can cause heating, decomposition and quality loss. Any spoiled or decomposed material should be picked out and thrown away during harvesting, post-harvest handling and processing, so that product quality is maintained and contamination is prevented.

As per WHO Guidelines

1. Medicinal plants or herbal drugs ought to be collected at the stage when they have the highest quality and are most fit for their intended use.
2. Any plant parts that are damaged, diseased or below standard must be carefully sorted out and not included in the harvested material.
3. Harvesting needs to be carried out in favourable conditions, keeping away from wet soil, dew, rainfall or high humidity. If collection happens in moist conditions, suitable steps should be taken so that excess moisture does not spoil the material.
4. Cutting tools and harvesting equipment should be kept properly maintained and adjusted, so that contamination by soil and other foreign material is reduced as much as possible.
5. Harvested material should not be allowed to touch the ground directly. It must be picked up quickly and moved under clean, dry conditions.
6. While harvesting, care must be taken to see that harmful weeds or toxic plants do not get mixed up with the medicinal plant material.
7. Every container used for collection has to be clean and free from residues of earlier materials. When not being used, the containers should be kept in dry, pest-free places, away from rodents, livestock and domestic animals.
8. Physical injury as well as squeezing of the plant material has to be avoided, as these end up lowering quality. Special care must be exercised so as to prevent: (a) the bags or sacks getting overfilled, (b) too much stacking on top, which can crush the contents.
9. Freshly collected plant material must be moved to the processing unit at the earliest, so that heat and enzymatic changes do not cause deterioration.
10. The harvested material has to be kept safe from pests such as insects, rodents and other animals. Any pest control measures used should be properly recorded and documented.

Factors Influencing Cultivation of Plants

Several environmental, biological and management-related factors affect plant cultivation. Together they decide how the plant grows, the yield it gives and the quality of that yield.

1. Climate

Climate has a major part in plant cultivation. Temperature, rainfall, humidity, light intensity and wind all directly influence how a plant grows and develops. Each species needs particular climatic conditions to give its best productivity.

2. Soil Conditions

The type, texture, structure, pH and fertility of the soil have a big effect on cultivation. A well-drained, fertile soil with enough organic matter promotes better root growth and makes nutrients more available.

3. Water Availability

Plants need an adequate supply of water to grow. Both too little and too much water can hurt them. To keep soil moisture at the right level, proper irrigation and drainage are needed.

4. Nutrient Supply

For growth, plants need essential nutrients such as nitrogen, phosphorus and potassium. A shortage or imbalance in these nutrients can lower yield and harm plant health.

5. Pests and Diseases

Plants can be attacked by microorganisms (fungi, bacteria, viruses), insects and other pests, all of which lower productivity. For successful cultivation, proper pest and disease management is necessary.

6. Weeds

Weeds compete with crops for nutrients, water, light and space. To make sure plants stay healthy and yields stay high, weed control has to be done effectively.

7. Air Pollution

Pollutants present in the air can harm plant growth, leading to leaf damage, lower photosynthesis and reduced productivity.

8. Herbicide Use

When herbicides are not used properly they can damage the crop. Choosing the right product, using the correct dose and applying it the right way are all necessary to avoid injury to plants.

9. Genetic Factors

A plant's genetic makeup decides how it grows, how much it can yield, and how well it can resist pests, diseases and stress from the environment.

10. Agricultural Practices

Practices such as the time of sowing, spacing between plants, irrigation methods, fertilisation, pruning and harvesting techniques all affect overall plant growth and yield.

Chapter 07: Collection Processing And Storage

Efficient Methods of Harvesting

1. **Manual harvesting by skilled workers:** Trained labourers, working at the collection site itself, are able to pick out the right plant material while throwing away look-alike or adulterated parts. The quality you get is excellent, but the trade-off is that this approach takes more time and costs more money. For drugs such as digitalis, tea, vinca, and senna leaves, hand collection is the only practical option since machines cannot replace it.
2. **Harvesting of underground parts:** For roots, rhizomes, and tubers, mechanical implements like diggers or lifters are generally used to bring them out of the soil. Once lifted, the material is washed properly so that mud and other impurities come off.
3. **Harvesting of aerial parts:** If the whole above-ground portion of a plant has to be taken, machines such as binders are put to use. This makes the work quicker and saves money as well.
4. **Collection of flowers, seeds, and small fruits:** For these soft and small plant parts, special tools called seed strippers are employed so that they can be gathered without much loss.
5. **Beating method:** For certain drugs like cloves, the desired part is knocked off by lightly beating the plant with sticks (bamboo sticks, for example) until it falls down.
6. **Collection of insects:** In the case of cochineal insects, they are simply brushed off from the branches of cactus plants where they are found.
7. **Harvesting of seaweeds:** For agar production, seaweeds are picked up using forks fitted with long handles.
8. **Harvesting of specific crops:** Mowers are used to cut peppermint and spearmint. Plants such as fennel, coriander, and caraway are pulled up roots and all, then left to dry. Once dry, the fruits are knocked free by threshing or beating, and winnowing follows. Reaping machines are also brought in for some crops.

Primary Processing

Once a medicinal plant is harvested, it should be brought to the processing site without delay and unpacked there. Until the work begins, the material has to be guarded against rain, dampness, and any other weather condition that might cause it to spoil. Sunlight is allowed only when the drug specifically needs sun-drying.

If the plant is meant to be used fresh, it should reach the processing unit at the earliest so that fermentation and damage from heat do not set in. While in storage or during transit, the material can be kept cold under refrigeration, packed in jars or sand-filled boxes, or treated by other suitable preservation techniques. As far as possible, chemical preservatives are avoided; whenever they have to be used, they must follow regulatory rules and be properly recorded.

Each batch of plant material has to be checked carefully while processing is going on. Anything that should not be there, like discoloured pieces, mouldy bits, damaged parts, soil, stones, and similar contaminants, must be taken out either by hand or by machine.

Tools such as sieves should always be kept clean and in good working order. The processed drug must also be guarded from contamination, decay, and pests like insects, rodents, birds, and stray animals.

Drying of Medicinal Plants

Drying matters because it brings down the moisture in the drug, which in turn keeps fungi and bacteria from spoiling it. When moisture stays low, the quality and stability of the plant material are protected.

Methods of Drying

Several techniques are available for drying medicinal plants, such as:

1. Air drying carried out in shaded conditions.
2. Spreading the material in thin layers on racks, frames, or screened rooms.
3. Drying under direct sunlight, when suitable.
4. Using drying chambers, ovens, or solar dryers.
5. Applying indirect heat methods such as baking, freeze-drying (lyophilization), microwave, or infrared drying.
6. Vacuum drying.
7. Spray drying (commonly used for substances like papaya latex and pectin).

Important Considerations

Both temperature and humidity have to be watched closely, otherwise the active chemicals in the drug can get damaged. The way you dry and the temperature you pick will decide how good the final product turns out. Take leaves and flowers, for example: shade drying is preferred so that their colour is not lost, while drugs containing volatile compounds such as essential oils call for lower drying temperatures.

When natural drying is being done, the plant material should be laid out evenly in thin layers and turned every now and then. This ensures even drying and stops mould from forming. Drying racks must sit above the floor so that air moves freely beneath them. Drying directly on bare ground should not be allowed; if you have no other option, lay clean sheets or tarpaulins underneath first.

Drying spaces have to be kept safe from pests like insects, rodents, and birds. For drying done indoors, the time, temperature, and humidity settings need to be changed according to the particular plant part being handled.

If direct heat is being applied, it is better to use cleaner fuels like gas, and the temperature should usually stay at or below 60°C. The plant material must not come into contact with smoke or any harmful fumes, as these will affect its quality.

Vacuum Drying

In vacuum drying, the work is done inside tightly closed steam-heated chambers, with a pump pulling out the air. Because the pressure inside drops, moisture turns into vapour quickly even at lower temperatures, and so drying is fast and effective. Example: Digitalis

Advantages of Vacuum Drying

- Materials get dried in a short span of time
- Works at relatively low temperatures
- Keeps things hygienic and blocks contamination from dust and odours
- Outside weather has no effect on the process
- Temperature can be regulated very accurately
- Chances of fire-related accidents are reduced
- The equipment is compact, so storage space needed is less

Specific Processing

Some medicinal plant materials demand particular treatments to make them better in quality and easier to use. Such treatments help in cleaning the drug, cutting down drying time, keeping microbes and insects away, getting rid of toxic parts, and making the medicine work better.

Among the usual processing techniques you will find sorting, peeling of roots and rhizomes, boiling, steaming, soaking, pickling, distillation, fumigation, roasting, natural fermentation, lime treatment, and cutting into small pieces. Things like shaping, bundling, and the use of special drying methods can also affect the final quality.

Whenever antimicrobial treatments such as irradiation are applied, they must be openly mentioned and clearly labeled. These steps can be carried out only by trained staff using approved equipment, and they should follow standard procedures and regulatory guidelines. The residue limits laid down by authorities have to be respected at all times.

Storage of Medicinal Plant Materials

1. The storage room should have good air movement, stay dry, and be kept away from light. If needed, systems for controlling temperature and humidity should be installed, and steps should be taken to keep pests out.
2. Floors must be kept clean, smooth, and easy to maintain. Drugs should sit on shelves and not against walls so that air moves freely around them. This stops mould, decay, and pest problems. Periodic checks of the stored material are a must.
3. While the material is in storage, and just before it is packed, quality checks should be done so that anything inferior or contaminated can be taken out. Packing has to be carried out using clean, dry containers as per laid-down guidelines.
4. Packaging items should be clean, free from contaminants, and matched to the particular drug being packed. Anything fragile must go inside hard containers so it is not damaged.
5. Dried plant materials and essential oils too should be stored in dry, well-aerated places where the temperature does not swing much.
6. Fresh plant material is best kept at low temperatures, ideally somewhere between 2 and 8°C, while frozen products should sit at temperatures lower than -20°C.
7. When only small amounts of crude drug are being kept, airtight, moisture-free, and light-blocking containers like metal tins or amber glass bottles can be used.
8. Wooden boxes and paper bags do not give enough protection, so they are not appropriate when crude drugs need to be stored over a long period.

Post-Harvest Technology

The term post-harvest technology covers all the methods and steps used after crude drugs or plant materials have been collected. The aim is to keep their quality, strength, and stability intact till the time they are used or made into medicines.

Steps in Post-Harvest Technology

1. **Collection:**
   Medicinal plants are picked at the right stage of their growth to get the best possible quality and effectiveness from them.
2. **Garbling:**
   At this step, things like soil, stems, foreign matter, and any damaged or diseased pieces are pulled out from the gathered plant material.
3. **Drying:**
   The moisture in the drug is reduced so that microbes do not grow and enzymes do not break it down. This way the quality of the drug is kept safe.
4. **Packing:**
   After processing, the material is placed in suitable containers so that moisture, light, and pests cannot reach it.
5. **Storage:**
   Storage conditions like proper temperature and humidity are managed properly so that the drug retains its stability and strength.
6. **Transportation:**
   While the drug is being moved from one place to another, it has to be handled gently so that it does not get physically damaged or contaminated.

Chapter 08: Plant Growth Regulators & Genetic Approaches

Plant Growth Regulators

For healthy growth, plants depend on outside conditions like light, water, oxygen, and nutrients. These are termed extrinsic factors. Apart from them, internal factors also matter a great deal, and they are known as intrinsic factors. Genes and the chemical substances made inside the plant fall in this group.

The chemicals produced inside the plant are referred to as plant growth regulators, or PGRs in short. They are small organic molecules that the plant itself makes, and their job is to direct and coordinate growth and development.

Characteristics of Plant Growth Regulators

Plant growth regulators do not all share one chemical type. Some are gases, ethylene being one example, while others fall under groups like terpenes (such as gibberellins) or carotenoid derivatives (like abscisic acid). Phytohormones and plant hormones are other names for them. Going by what they do, they fall into the following groups:

- **Growth Promoters:** This group encourages cell division, elongation, flowering, fruit setting, and seed development. Auxins, gibberellins, and cytokinins are typical examples.
- **Growth Inhibitors:** These bring growth to a slow pace and trigger dormancy and shedding of leaves (abscission). A well-known example is abscisic acid.
- **Ethylene:** This particular hormone has the ability to behave both as a stimulator and a suppressor of growth, but most of the time its main role is that of an inhibitor.

Auxins

Discovery

The very first plant hormones to be uncovered were the auxins. Their discovery is tied to studies done by Charles Darwin and Francis Darwin. The two looked at how the coleoptiles (young shoots) of canary grass bent towards a light source, a behaviour known as phototropism. Their experiments made it clear that the bending was being controlled from the tip of the coleoptile. Some years later, F. W. Went managed to extract the first auxin from the tips of oat coleoptiles.

Types

Auxins exist in both natural and synthetic forms:

- **Natural auxins**: Indole-3-acetic acid (IAA) and Indole-3-butyric acid (IBA), which are formed in actively growing zones such as the tips of shoots and roots.
- **Synthetic auxins:** Naphthalene acetic acid (NAA) and 2,4-dichlorophenoxyacetic acid (2,4-D).

Effects of Auxins

- Bring about flowering in some plants like pineapple
- Encourage the formation of roots from stem cuttings
- Stop leaves and fruits from falling off too early

- Help in the natural shedding of old leaves and fruits
- Aid cell division and the formation of xylem tissue

Applications

- Put to use in plant propagation methods
- Trigger parthenocarpy, that is, fruit development without fertilization
- 2,4-D is applied as a herbicide to kill broadleaf weeds
- Used commonly in gardening to keep lawns free from weeds

Apical Dominance

In a number of plants, the tip of the main shoot stops the side (lateral) buds from growing. This effect is termed apical dominance. The moment you remove the apical bud, the lateral buds spring into action. Gardeners commonly use this idea while shaping plants like tea bushes and hedges.

Gibberellins

Discovery

Gibberellins came to light during research on the "bakanae" disease of rice, a condition brought about by the fungus Gibberella fujikuroi. E. Kurosawa proved that healthy rice seedlings, when treated with extracts of the fungus, started showing symptoms similar to the disease. The compound responsible was eventually identified and named gibberellic acid.

Types

Over 100 different gibberellins have so far been picked out from fungi as well as from higher plants. They are written as GA_1, GA_2, GA_3, and so on. Out of all these, GA_3 (gibberellic acid) has been studied the most.

Effects

- Causes elongation of stems and the plant axis (for example, grape stalks)
- Slows down ageing (senescence) of fruits, so they can be stored for longer
- Makes fruits like apples bigger and better in shape

Applications

- Applied during the malting step in the brewing industry
- Boosts sugarcane output by making the stems longer
- Helps conifers reach maturity faster and produce seeds earlier
- Triggers bolting, which is sudden stem growth before flowering, in crops like cabbage and beet

Cytokinins

Discovery

F. Skoog along with his team noticed that callus tissues divided rapidly only when certain compounds were added together with auxins. The active compound was later isolated by Carlos O. Miller, who gave it the name kinetin.

Types

Kinetin (which is synthetic) was the first cytokinin to be identified, and after that natural ones such as zeatin were also recognized. Such compounds are mostly present in regions where active cell division is going on, like root tips and developing buds.

Effects

- Encourage the formation of fresh leaves and chloroplasts
- Push lateral shoots to grow and help develop new shoots
- Aid in breaking apical dominance
- Slow down the ageing of leaves by helping move nutrients around

Abscisic Acid (ABA)

Discovery

Three separate substances, namely Inhibitor B, Abscission II, and Dormin, were each found independently and were later proven to be one and the same compound, which received the name abscisic acid. Its action mostly opposes that of gibberellins.

Effects

- Causes leaves to shed (abscission) and triggers dormancy
- Stops growth and prevents seed germination
- Makes stomata close during stress periods
- Builds up the plant's resistance to environmental stress, which is why it is referred to as the "stress hormone"
- Has an important part in the development and ripening of seeds
- Helps seeds get through bad conditions by putting them into dormancy

Ethylene

Discovery

The discovery of ethylene happened when researchers noticed that some gas coming off ripe fruits was making nearby unripe fruits ripen faster. That gas turned out to be ethylene, a simple gaseous hormone of plants.

Effects

- Brings about sideways growth and thickening of stems in young seedlings
- Speeds up ageing and the dropping of leaves and flowers
- Pushes up respiration during fruit ripening (the climacteric effect)
- Boosts root growth and the formation of root hairs

Applications

- Applied to break dormancy in seeds and buds (peanuts, for example)
- Encourages sprouting in potato tubers
- Aids elongation in deep-water rice
- Brings about flowering and uniform fruiting in pineapple
- Triggers flowering in mango
- Ethephon, which acts as a source of ethylene, is used to hasten ripening in fruits like apples and tomatoes
- Boosts yield in cucumbers by encouraging the formation of female flowers

- Aids in fruit thinning and abscission in crops such as cherry, walnut, and cotton

Summary of Plant Growth Regulators

Plant growth regulators have a hand in every stage of how a plant grows and develops. They can act on their own or together, and they can either push growth forward or hold it back. Together with the genetic makeup of the plant and outside conditions, they play a key part in directing the life processes of plants. Outside conditions like temperature and light too can shape plant growth through these regulators (vernalization is one such case).

Genetic Variations in Plants

- **Mutation:** A sudden alteration in the genetic material (gene).
- **Polyploidy:** The condition of having more than one set of chromosomes.
- **Hybridization:** Producing new plant types by crossing different species or varieties.

Types of Variations

1. **Phenotypic variation:** Brought about by environmental factors. It is temporary and is not passed on to the next generation.
2. **Genetic variation:** Results from changes in the genetic material itself. It is permanent and gets transferred to future generations.

Mutation

Mutation is a sudden, lasting change in the genetic material (genome) of an organism, and it is not the result of environmental factors. Such a change alters the genotype, and this in turn may affect the structure as well as the function of genes. The changes can be qualitative or quantitative in nature, and they may add to evolutionary variation.

Advantages

- Can bring about changes in plant structure, function, or chemical content
- May result in higher yields or larger amounts of useful substances

Disadvantages

- Mutated plants can become more sensitive to environmental conditions
- Greater chance of disease and slower growth may be seen

Types of Mutation

1. **Chromosomal mutation:** A change in either the structure or the count of chromosomes
2. **Point mutation:** A small change in a particular gene or DNA sequence
3. **Spontaneous mutation:** Happens on its own without any identified cause
4. **Induced mutation:** Brought about by outside agents (mutagens) like chemicals or radiation

Examples of mutagens:

- **Chemical mutagens:** Formaldehyde, nitrogen mustard, bromouracil, nitrous acid, mercuric chloride, aminopurines
- **Physical mutagens:** X-rays, gamma rays, ultraviolet rays, radio waves

Examples of Mutation

- Treating poppy seeds with cobalt-60 radiation raises their morphine content
- X-rays have been used to develop sweet lupin varieties
- Mentha piperita exposed to radiation shows resistance to diseases

- Capsicum annuum treated with chemicals shows higher capsaicin levels

Polyploidy

Polyploidy is the situation where a cell or an organism carries more than two complete sets of chromosomes (such as 3X, 4X, 5X, and so on).

Types of Polyploidy

- Triploid (3X) - example, seedless watermelon
- Tetraploid (4X) - example, cotton
- Pentaploid (5X)
- Hexaploid (6X) - example, wheat
- Heptaploid (7X)
- Octaploid (8X)
- Decaploid (10X)
- Dodecaploid (12X)

Causes of Polyploidy

1. Mistakes during cell division that cause chromosomes to separate incorrectly
2. Physical influences such as temperature shock or exposure to radiation
3. Chemical agents like colchicine, sulphanilamide, and others

Advantages

- Gives rise to new plant species
- Better fit for different surroundings
- Higher output of secondary metabolites

Colchicine

Colchicine is an alkaloid sourced from *Colchicum luteum* and *Colchicum autumnale*, both belonging to the family Liliaceae. It is widely applied for the induction of polyploidy.

Mechanism of Action

Colchicine disturbs the formation of spindle fibres while cells are dividing (especially during anaphase), which prevents the sister chromatids from separating. The chromosome count then doubles, and polyploidy is the result.

Examples

- Tetraploid *Datura stramonium* displays a higher level of alkaloids
- *Atropa belladonna* shows higher tropane alkaloids
- *Hyoscyamus niger* shows improved alkaloid levels
- *Carum carvi* shows increased volatile oil content

Extra-Chromosomal Variation

In some plants, you find one or more chromosomes over and above the usual count (for instance, 2n+1). This may push up the production of certain chemical constituents. Example: Datura stramonium with extra chromosome shows higher alkaloid content.

Chemotypes (Chemical Races)
Chemotypes are sets of plants belonging to the same species that look alike on the outside but differ in what chemicals they contain inside.

Hybridization
Hybridization is the practice of crossing two different species or varieties so that a hybrid carrying the desired characteristics can be produced.
Types
- Monohybrid - differs in one trait
- Dihybrid - differs in two traits
- Trihybrid and higher (polyhybrid) - differ in multiple traits

Advantages
- Gives rise to plants that carry desirable traits combined together
- Can result in new traits that were not present in either parent
- Helpful for boosting yield, building disease resistance, and raising chemical content

Examples
- *Mentha piperita*, a hybrid produced from *Mentha aquatica* and *Mentha spicata*, gives a higher oil yield
- Hybrid forms of *Withania somnifera* give rise to new compounds
- Crossing Digitalis purpurea with *Digitalis lanata* gives new glycosides
- Solanum hybrids show increased solasodine content

Conservation of Medicinal Plants
When it comes to plant biodiversity, India ranks among the world's richest countries and is also one of the major hubs for medicinal plant resources. Several of these plants come up naturally in forests, while many others are grown by farmers.
Conservation means looking after and protecting plant resources thoughtfully so that today's needs are met, while at the same time keeping these resources safe for the generations to come. Many plant species are now in trouble because of habitat loss, overuse, and changing environmental conditions. When populations are small and cut off, their genetic diversity goes down, which leaves them less able to handle environmental stress. So, the protection of genetic variation is needed if medicinal plants are to survive and remain available in the long run.

1.1 Threats to Medicinal Plants
Several threats hang over medicinal plants, coming from both natural causes and human activities. Among the major ones are habitat destruction caused by city expansion and forest clearing, dwindling forest cover, and unscientific or excessive harvesting of plant material. The arrival of invasive species also creates trouble, as they compete with native plants and lower their chances of survival.
There are other threats as well, like the spread of plant diseases, growth of industries, overuse of resources, shifts in farming methods, and heavy reliance on agrochemicals. Natural calamities and human-driven disturbances add further to the loss of plant diversity. Genetic erosion, where the variability inside plant populations goes down, is yet another worrying issue.

Take regions like South India, where many medicinal plant species are already labelled as threatened or endangered. So, a balance must be struck between using these plants and following sound conservation practices.

1.2 Need for Conservation of Medicinal Plants

The need for medicinal plants has gone up because they are being used in healthcare both locally and around the world. Big amounts of these plants are pulled out of natural habitats so that industrial and export demands can be met. The result has been a fast emptying of wild plant resources.

Medicinal plants matter in healthcare, give livelihood to communities, back up agroforestry systems, and add to cultural traditions and ways of life. So, looking after them is very important. Conservation is helpful in keeping biodiversity intact by safeguarding and reviving plant species along with their habitats. It also makes sure that genetic resources will be there when needed in the future. Holding on to genetic diversity matters because it lets plants adjust to environmental shifts and survive over time. Without these efforts, many useful species could be lost forever.

Secondary Metabolite Enhancement

The term secondary metabolite enhancement covers the methods used to push up the production of important bioactive substances in plants. Compounds like alkaloids, flavonoids, glycosides, and essential oils fall into this category, and they are heavily used in medicines and various industries.

Methods of Enhancement

1. **Selection of High-Yielding Plants** Plants that already carry naturally higher amounts of the wanted compounds are picked out and grown to step up overall production.
2. **Breeding and Hybridization** When different plant varieties are crossed, new strains can be developed that carry better metabolite levels and improved characteristics.
3. **Mutation and Polyploidy** Induced mutations or shifts in chromosome number can push up the amount of secondary metabolites being made.
4. **Plant Tissue Culture** With methods like callus culture, cell suspension culture, and micropropagation, metabolites can be produced under controlled lab settings.
5. **Elicitation**
   When certain chemicals or microbes are added, the plant gets stimulated to make more secondary metabolites as part of its defence reaction.
6. **Precursor Feeding** When the right starting materials (precursors) are supplied, the synthesis of the desired compounds gets a boost.
7. **Genetic Engineering** By modifying the genes that take part in metabolic pathways, the production of particular compounds can be raised.
8. **Environmental Control** Tweaking factors like light, temperature, nutrients, and stress can lift metabolite synthesis.
9. **Use of Plant Growth Regulators** Hormones such as auxins, cytokinins, and gibberellins can shape and step up metabolite production.

Chapter 9: Conversation & Eco Pharmacognosy

Conservation Strategies for Medicinal Plants

Two principal ways are followed for keeping medicinal plants safe:

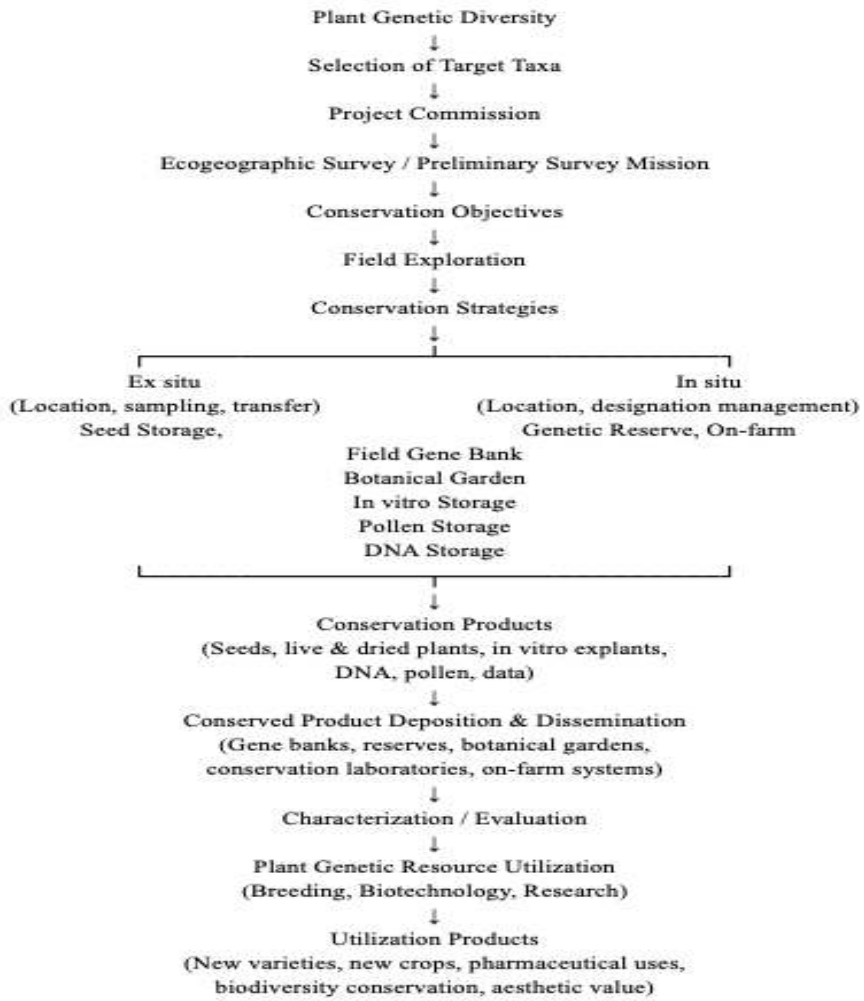
1. In situ Conservation

Under this method, plants are looked after right where they grow naturally. It involves setting up protected zones such as forests, reserves, and natural ecosystems, places where plants are free to grow and reproduce on their own.

2. Ex situ Conservation

Here, plants are protected away from the place where they grow naturally. The methods used include the following:

- Seed storage
- Field gene banks
- Botanical gardens
- Tissue culture (in vitro storage)
- Pollen and DNA preservation



Conservation Process (Simplified Steps)

- Identifying the diversity of plants
- Picking out the species that matter most (target taxa)
- Drawing up plans and projects
- Carrying out field surveys and exploration trips
- Fixing the goals for conservation
- Putting both in situ and ex situ approaches into action
- Storing and preserving plant material such as seeds, tissues, and DNA
- Sending the material out to research centres, gene banks, and conservation units
- Examining and characterizing the plant resources
- Putting the material to use in breeding, research, and pharmaceutical work

Additional Considerations

For conservation to work well, there must be proper records of how plants are used, traded, and what their population numbers look like. Sustainable harvesting techniques have to be worked out, and traditional knowledge must be safeguarded. Legal protection along with intellectual property rights also have a place here.

Bodies like the International Union for Conservation of Nature put plant species into categories based on their conservation status, ranging from extinct and endangered to vulnerable and least concern.

Conservation work should not stop at simply saving species from extinction; it should also aim at keeping the genetic diversity within each species intact. Right now in India, the steps being taken include restoring habitats, controlling pollution, banking seeds, and applying tissue culture techniques.

1.3.1 *In situ* Conservation

In situ conservation is about safeguarding and looking after plant genetic resources in the very places where they grow naturally. This covers wild species in forests as well as cultivated forms growing under traditional farming setups. Under this approach, plants keep on evolving and adjusting in their original surroundings.

The main steps that go into in situ conservation are:

- Looking at the threats faced by significant medicinal plant species
- Setting aside protected forest patches or reserves meant for medicinal plants
- Bringing local communities and stakeholders on board for the conservation work
- Carrying out botanical, ecological, trade, and ethnomedicinal surveys
- Looking into the genetic variation that exists within species
- Drawing up recovery programmes for endangered plants
- Establishing seed centres dedicated to medicinal plants

How well in situ conservation works depends a lot on whether local communities take part actively and lend their support.

1.3.2 *Ex situ* Conservation

Ex situ conservation is the practice of keeping plant species safe somewhere other than their natural surroundings. The method helps in holding on to genetic diversity in managed conditions and makes sure plant material is on hand for use later.

It makes use of techniques like seed banks, botanical gardens, and field gene banks. Ex situ conservation backs up economic, social, and environmental needs because it makes propagation, research, and assessment of plant diversity possible.

Which method is picked depends on things like the nature of the plant, geographical setting, the facilities at hand, and the people available to do the work.

1.3.2.1 In vitro Regeneration

In vitro regeneration is a method where plant pieces (explants) are made to grow under sterile conditions in a laboratory. The method gives disease-free growth, holds on to genetic material, and keeps the plant's regenerating ability intact.

Advantages

- Less space and time are needed for storing the material
- Comes in handy for species that cannot be saved through their seeds
- Makes safe exchange and transport of disease-free plant material possible

This approach is particularly handy when rare, endangered, or hard-to-propagate medicinal plants need to be multiplied quickly. As a rule, shoot tips or buds are placed on nutrient media that contain:

- Cytokinins at high levels, or
- Low auxin levels paired with high cytokinin levels

Sometimes plant tissues like embryos or buds are wrapped in gel-like substances to make artificial seeds, which then make propagation easier.

Another important step is putting the lab-grown plants back into their natural surroundings, after which they have to be watched to confirm that their original traits and chemical composition have stayed the same.

Somaclonal Variation

While tissue culture is going on, the plants regenerated from it may pick up genetic changes. These changes go by the name somaclonal variations, and they can be inherited.

They might come about because of:

- Alterations in the DNA sequence
- Changes in the chromosomes
- Rearrangements of genes
- DNA methylation or silencing of genes

Such variations are more likely to show up when a callus phase comes into the regeneration process. So, picking the culture method with care matters.

To keep genetic stability in place:

- Excess use of auxins should be steered clear of
- Plants regenerated from culture should be checked for genetic uniformity with the help of molecular markers

Value Addition Strategies for Medicinal Plants

Value addition is about lifting the quality, usability, and market worth of products made from medicinal plants.

Methods of Value Addition

1. **Proper Cleaning and Grading** Taking out impurities and sorting plant material lifts both the quality and how well it is received in the market.
2. **Drying and Processing** When scientific drying methods are followed, the active constituents stay safe and shelf life goes up.
3. **Extraction and Isolation** The active compounds are pulled out and purified so that standardized products can be made.
4. **Preparation of Herbal Formulations** When the material is turned into powders, tablets, capsules, oils, or syrups, both usability and demand go up.
5. **Packaging and Labelling** With proper packing in place, the product stays safe and its commercial value goes up.
6. **Quality Control and Standardization** This takes care of safety, purity, and consistency of the medicinal products.
7. **Storage and Preservation** When storage conditions are right, potency is held intact and spoilage is kept away.
8. **Branding and Marketing** Good branding along with awareness builds up product demand in both home and overseas markets.

Role of Eco pharmacognosy in sustainable conservation of endangered medicinal plants such as kutki and chiraita.

Ecopharmacognosy is a newer branch of pharmacognosy that gives attention to the sustainable and ethical sourcing of natural products. Rather than only checking what diseases a plant can treat, it looks at the "ecological footprint" of that plant's path from the soil to the medicine cabinet.

When it comes to threatened Himalayan herbs such as Kutki (*Picrorhiza kurroa*) and Chiraita (*Swertia chirayita*), ecopharmacognosy lays out a plan that prevents their disappearance while keeping the medicinal supply going.

1. Shift from Wild-Harvesting to Cultivation

Both Kutki and Chiraita have, for many years, been pulled out of the wild in excess, and this has caused a sharp drop in their numbers in nature.

- **The Eco-Approach:** Ecopharmacognosy pushes Good Agricultural and Collection Practices (GACP). It works out the precise climate and soil conditions required to raise these plants under managed setups (ex-situ conservation), so the strain on wild Himalayan habitats comes down.

2. Phytochemical Mapping and Quality Control

Once a plant is grown somewhere other than its natural setting, the strength of its medicinal action can shift.

- **The Role:** Through ecopharmacognosy, researchers make sure that cultivated Kutki still holds the needed amount of Picrosides and that Chiraita keeps its Amarogentin content. This way, conservation does not end up giving "weak" medicine.

3. Utilization of Alternative Plant Parts

Going by tradition, the roots of Kutki are what get used, and pulling the roots out kills the whole plant during harvesting.

- **The Role:** Ecopharmacognosy looks at whether leaves or stems hold similar bioactive compounds. If the medicinal molecules can be drawn from renewable parts (leaves) and not from the roots, the plant can be harvested in a sustainable way without wiping it out.

4. Biotechnological Interventions

If a plant is on the edge of extinction, conventional farming may be too slow to help.

- **Techniques used:**
    - **Tissue Culture:** Cloning high-quality strains of Chiraita in labs.
    - **Bioreactors:** Growing the active medicinal cells in tanks without needing the whole plant.

Strategy	Benefit to Kutki	Benefit to Chiraita
Agro-technology	Enables growth in lower-altitude "cold deserts."	Standardizes the 2-year growth cycle for farmers.
Metabolic Profiling	Ensures bitterness (potency) is maintained.	Identifies the best harvest time for maximum xanthones.
Genetic Diversity	Protects the gene pool from "genetic bottlenecking."	Identifies hardy strains resistant to climate change.

To put ecopharmacognosy into practice for Kutki and Chiraita, several Himalayan states have marked out particular Agro-Climatic Zones, with the aim of moving away from destructive wild-harvesting and towards sustainable, high-potency cultivation.

1. Kutki (*Picrorhiza kurroa*)

Kutki is an "alpine" specialist. Severe cold and high altitudes are what it needs in order to make its active hepatoprotective glycosides (Picrosides).

- **Optimal Altitude: 2,700m to 4,500m** (above sea level).
- **Active Zones: * Uttarakhand:** High-altitude regions of **Garhwal** (Johar and Chaudans Valleys) and **Pithoragarh**.
    - **Himachal Pradesh: Kullu** (at 8,000+ ft), **Lahaul & Spiti**, and **Kinnaur**.

    - **Jammu & Kashmir: Kupwara** and **Kishtwar** districts (current projects at 8,500 ft).
- **Eco-Strategy:** Ongoing projects, like the ones run by JICA and the NMPB, give preference to stolon cuttings over seeds. This route is more sustainable and makes sure the daughter plants come out genetically the same as the high-potency "mother" plants.

2. Chiraita (*Swertia chirayita*)

Chiraita is a bit more adaptable, but it does best in the "temperate" belt. It is normally raised as a biennial crop running on a 2-year cycle.

- **Optimal Altitude: 1,200m to 3,000m**.
- **Active Zones:**
    - **West Bengal & Sikkim:** High-demand areas in **Darjeeling** and **Sikkim Himalayas**.
    - **Himachal Pradesh: Palampur** and surrounding temperate slopes (HP Krishi Vishvavidyalaya leads research here).
    - **Nepal Border Regions:** Cultivated on a wide scale in Eastern Nepal (Sankhuwasabha and Taplejung), since these areas share the same agro-climatic profile as Northeast India.
- **Eco-Strategy:** Farmers are advised to go in for organic mulching and to keep away from chemical fertilizers, so that the "bitter principle" (Amarogentin) is preserved. Rapid, artificial growth has a way of diluting it.

Project / Organization	**Focus Area**	**Impact**
National Medicinal Plants Board (NMPB)	Pan-Himalayan	Provides **50-75% subsidies** to farmers in Himalayan states for cultivating these specific species.
HP JICA Forestry Project	Himachal Pradesh	Developing "Propagation Models" for SHGs (Self-Help Groups) to grow Kutki as a cash crop.
Sami-Sabinsa Group	Kupwara, J&K	Large-scale (10+ acres) private-public partnership for Kutki cultivation to ensure an ethical supply chain.
e-CHARAK Portal	Digital / National	A "virtual market" that connects Himalayan farmers directly to pharma companies, ensuring fair trade.

UNIT III
QUALITY CONTROL OF DRUGS OF NATURAL ORIGIN (WHO RECOMMENDATION)

Chapter 10: Adulteration of Crude Drugs

Adulteration

- Adulteration is the practice where the genuine crude drug gets either partly or fully replaced by some fake material that lacks the same chemical and therapeutic strength, or shows clearly weaker properties.
- Such intentional tampering is mostly done for commercial gain, the basic goal being to earn higher profits.
- Two common reasons behind it are the limited availability of certain drugs and the steep prices these drugs command in the market.
- Although adulteration is generally a planned act, it sometimes happens by accident as well. Smuggled or contraband drugs also tend to show this problem quite often.
- The term adulteration covers practices like spoilage, inferiority, deterioration, sophistication, substitution, and admixture.

✓ Deterioration means a drop in the overall quality of the drug.
✓ Admixture means mixing one material with another, either due to an accident, lack of awareness, or carelessness.
✓ Sophistication is when adulteration is done knowingly and on purpose.
✓ Substitution refers to replacing the genuine drug with an entirely different material.
✓ Inferiority points to a drug that is below the required standard, while spoilage results from microbial attack on the drug.

❖ Several tests are run during routine quality checks to spot such adulteration. This section explains the common ways crude drugs are adulterated and the lab techniques used to identify them.

Adulteration

- Adulteration involves incorporation of impurities.
- Includes spoilage deterioration admixture.
- Genuine drugs are intentionally substituted..
- With spurious, inferior, defective or harmful substances.

Types of Adulterants

Various kinds of adulterants seen in the market are listed below.

1. **Substitution with substandard commercial varieties: In** this case, the substitute may look very similar to the original drug in appearance, chemistry, or therapeutic action, but its quality is poorer and so it is cheaper. This is by far the most frequent kind of adulteration done in trade.

2. **Substitution with superficially similar inferior drugs:** The cheaper drugs used here may carry no therapeutic or chemical benefit similar to the actual drug. Because they look much like the genuine one, traders pass them off as adulterants.

3. Substitution with artificially manufactured substances: It is sometimes seen that man-made materials are produced to imitate the original drug and then sold as substitutes. This is mostly seen with drugs that are very expensive.

4. Substitution with exhausted drugs: Here the same drug is added back, but its active medicinal ingredients have already been removed by prior extraction. This trick is often played with volatile-oil-rich drugs such as fennel, clove, coriander, and caraway. At times, traders restore the lost colour or taste of the spent drug using additives before passing it off as genuine.

5. Apart from these usual practices, synthetic chemicals are sometimes added to make the natural features of the drug appear stronger.

6. Presence of vegetative matter from the same plant: Now and then, smaller plants growing alongside the medicinal plant get mixed in with the drug because they share a similar colour, smell, or sometimes even constituents.

7. Harmful adulterants: In some cases, market wastes are picked up and mixed into the genuine drug. Such practice is mostly noted with liquid drugs and unorganised drugs.

8.Adulteration of powders: It is not just the whole drugs; powdered forms are also commonly found to be tampered with.

Detection Method

1. Physical Methods

These methods rely on plain observation or simple physical separation.

- **Visual inspection:** Looking for variations in colour, size, or shape.
    - Example: Stones in rice, papaya seeds in black pepper.
- **Microscopic examination:** A microscope is used to spot foreign material.
- **Sedimentation / floatation:** Adulterants either float or sink differently from the drug in water.
    - Example: Sand in sugar or pulses.

2. Chemical Methods

Here, particular reagents are made to react with the sample to detect adulterants.

Examples:

- **Iodine test:** Detects starch in milk or ghee.
- **Nitric acid test:** Detects artificial color in spices.
- **Hydrochloric acid test:** Used to detect certain dyes or impurities.

3. Instrumental Methods

These are higher-level laboratory methods used for precise identification.

- **Chromatography -** splits the components of a mixture apart.
- **Spectroscopy -** identifies materials through how they absorb light.
- **Mass spectrometry -** works out the chemical make-up of the sample.
- **DNA testing -** useful for spotting species-level adulteration in foods.

Such techniques are commonly seen in food testing labs.

4. Biological Methods

These methods rely on DNA or biological markers to spot adulteration.

- **DNA barcoding**
- **Immunoassays**

Useful for detecting adulteration in products like meat, honey, and milk.

5. Household Tests

Easy tests that any consumer can perform at home:

- **Milk:** Place a drop on a smooth surface; pure milk moves slowly and leaves behind a white streak.
- **Turmeric powder:** When water is added, the artificial dye dissolves at once.
- **Black pepper:** Papaya seeds float in water.

Chapter 11: Evaluation Methods I

Evaluation of Crude Drugs

Drug evaluation means verifying that a drug is what it claims to be, judging its quality and purity, and checking whether any adulteration has crept in.

Three main reasons make crude drug evaluation necessary:

(a) natural changes in chemical make-up (biochemical variation),

(b) damage caused by poor handling, drying, or storage, and (c) substitution or adulteration that occurs through carelessness, ignorance, or planned cheating.

Drug evaluation methods have come a long way over the years. Earlier, drugs were identified mostly by matching them against standard descriptions. Today, with progress in chemistry, evaluation also includes estimating the active constituents alongside morphological and microscopic study.

Thanks to better separation tools and analytical instruments, physical evaluation today gives both qualitative and quantitative data.

Pharmacological evaluation looks into the biological activity and effects of crude drug extracts.

So crude drugs end up being assessed through a mix of morphological, histological, chemical, physical, and biological approaches.

1. Morphological (Organoleptic) Evaluation

Morphological or organoleptic evaluation studies a crude drug through its sensory and physical traits, namely colour, smell, taste, size, shape, feel, and texture. It is a qualitative approach that depends on noting the outer look and sensory features of whole drugs.

Organoleptic evaluation refers to judgements made using the sense organs - sight, smell, taste, and touch.

The branch dealing with the form and structure of crude drugs is called morphology, while the elaborate written account of these forms is termed morphography.

Some unique traits make identification easier. For instance, fruits of umbelliferous plants give a characteristic aromatic odour, and liquorice tastes sweet. Likewise, distinctive shapes - the ribbon-like tragacanth, the disc-shaped nux vomica, the conical aconite, and the quill of cinnamon - act as key identifying features.

The general look of a crude drug sample tells us about its quality and whether it meets standards, as seen with the seed proportion in colocynth or the presence of stalks in clove.

Faulty drying, mainly over-drying, makes leaves and flowers brittle, so they break easily during handling and shipping, which makes morphological assessment harder.

Other notable organoleptic traits are the wavy structure of rauwolfia, the sharp pungent taste of capsicum and ginger, the brown shade of cinnamon, and the unique smell and taste of spices like asafoetida, black pepper, nutmeg, and cumin.

2. Microscopic Evaluation

Microscopic evaluation involves a careful study of crude drugs under a microscope to look at their inside structure. The technique works well for identifying organised drugs through their specific histological features. It is mainly applied for qualitative testing of crude drugs in whole as well as powdered form.

By magnifying tiny structures, the microscope allows close observation of plant tissues and helps confirm the structural details of plant-origin drugs.

For sharper results, various chemical reagents and stains are applied to bring out different cellular parts. The technique also covers microchemical (chemomicroscopic) analysis, where small amounts of powdered drug or thin sections are treated with selected chemicals to identify the constituents.

For example:

- Lignin produces a red colour when treated with phloroglucinol and concentrated hydrochloric acid.
- Mucilage stains pink with ruthenium red.
- Cellulose swells and dissolves in cuoxam solution.
- Starch and hemicellulose turn blue when treated with dilute iodine solution.

Histological work is done on very thin drug sections so that finer details such as cell walls, cell contents, starch grains, calcium oxalate crystals, fibres, vessels, and trichomes can be observed. Some microscopic features act as diagnostic clues. For example, lignified trichomes occur in nux vomica, warty trichomes in senna, wavy medullary rays in cascara bark, and glandular trichomes in mint.

Microscopy is also useful in spotting adulteration. For example:

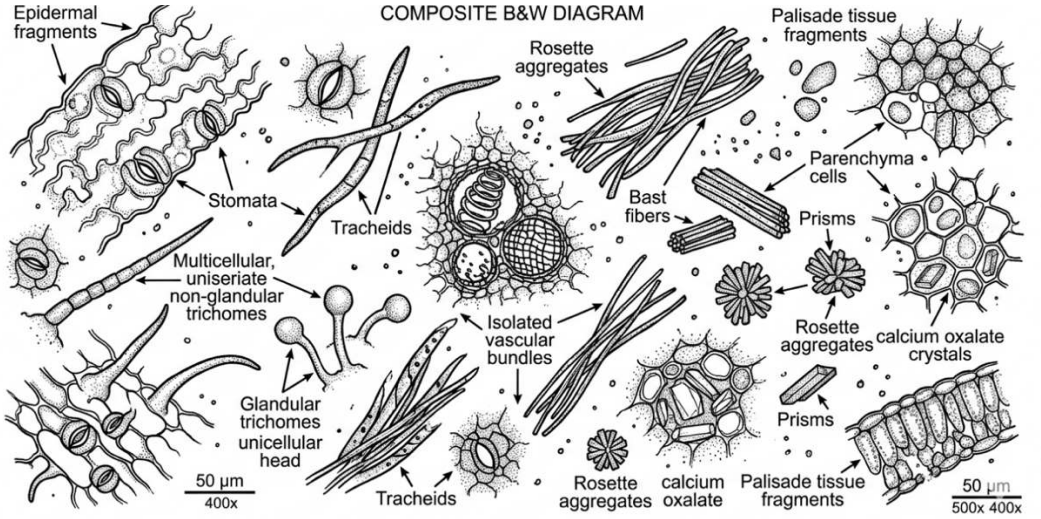
- Clove powder does not contain sclereids or calcium oxalate crystals, but these are present in clove stalks.
- Starch is found in clove fruits but not in cloves.
- The presence of non-lignified vessels in ginger powder indicates adulteration.

Another key part of the work is quantitative microscopy, where parameters like stomatal number, stomatal index, palisade ratio, vein-islet number, starch grain size, and fibre length are measured.

Such measurements help in telling drug varieties apart. For example, different types of senna can be distinguished using stomatal number and palisade ratio. The starch grain size of Cinnamomum cassia (around 10 μm) helps in spotting adulteration. In the same way, counting sclerenchymatous cells per unit area aids in differentiating cardamom seed varieties.

Powder Microscopy

Powder microscopy is one of the main pharmacognostic methods for identifying powdered crude drugs and detecting adulteration. It finds wide use in the study of medicinal plants and herbal materials.



Powdered Microscopy Of Leaf

1. Definition

Powder microscopy means studying powdered plant drugs under a microscope to examine their cellular structures, tissues, and characteristic features. It becomes especially handy when the drug is in powdered form, since the original plant parts can no longer be made out.

2. Principle

Each plant has its own microscopic features such as cell walls, fibres, starch grains, trichomes (plant hairs), calcium oxalate crystals, and vessels. Even after powdering, these structural elements stay intact, so the drug can still be identified under a microscope.

3. Method / Procedure

1. Place a small amount of the powdered drug on a clean glass slide.
2. Add a drop of mounting medium such as water, glycerin, or chloral hydrate.
3. Carefully place a coverslip over the sample.
4. Examine the preparation under a microscope using low and high magnification (10× or 40×).
5. Observe and identify the diagnostic microscopic features. Special stains may be used when required to enhance visibility of specific structures.

4. Important Reagents Used

- Iodine solution - applied to detect starch grains (gives a blue colour).
- Phloroglucinol with hydrochloric acid - shows lignified tissues such as fibres and vessels (red colour).
- Sudan III - used to identify oils and fats.
- Chloral hydrate - clears the tissues so that they become more visible.

5. Diagnostic Characters Observed

The features usually noted in powder microscopy include:

- Epidermal cells
- Starch grains
- Fibres
- Trichomes
- Calcium oxalate crystals
- Vessels and tracheids
- Sclereids (stone cells)

6. Applications

- Identification of crude drugs in powdered form
- Detection of adulteration and substitution
- Quality control of herbal formulations
- Authentication of medicinal plant materials

7. Advantages

- Simple and low-cost method
- Quick identification
- Only a small sample is needed
- Particularly handy for powdered drugs

8. Limitations

- Needs trained eyes and practical experience
- Some drugs may show similar structural features
- Less accurate than the modern analytical techniques

Stomata

- The leaf epidermis displays several features such as cuticle, stomata, trichomes, water pores, cell inclusions, and so on. A stoma is a tiny opening in the epidermis present on the aerial parts of the plant, with these characteristics: (a) one central pore, (b) two kidney-shaped guard cells of similar form which carry chloroplasts, and (c) a varying number of subsidiary (epidermal) cells lying around the guard cells.
- The chief role of stomata is gaseous exchange, with transpiration being the secondary role. Not every plant must have stomata, though.
- Submerged leaves of aquatic plants do not bear stomata. As a rule, stomata occur in the green parts of a plant (mainly leaves), but they are missing from roots. Aside from leaves, stomata are also seen on stems (ephedra), flowers (clove), and fruits (fennel).
- It is, however, generally noted that stomata are plentiful on dicot leaves. In some plants, they sit on the upper leaf surface, while in others (like coca and cherry) they are found only on the lower side.

- In yet other plants, stomata occur on both leaf surfaces (senna, belladonna, datura, etc.). The way stomata get distributed between upper and lower epidermis in dicot leaves shows a wide range of variation.

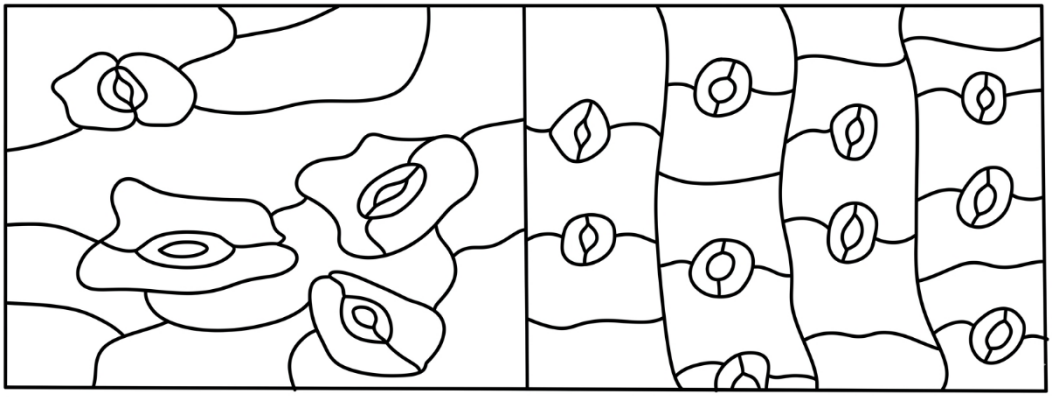
Types of stomata Based on the form of guard cells and how the subsidiary cells are arranged, stomata fall into four categories:

1. Moss type
2. Gymnosperms type
3. Gramineous type
4. Dicotyledonous type Among these, the fourth (dicotyledonous) type carries diagnostic value.

Dicotyledonous stomata are further grouped on the basis of the form and layout of subsidiary cells, as listed below.

(i) Paracytic or rubiaceous or parallel-celled stomata - These have two guard cells flanked by two subsidiary cells whose long axes run parallel to the long axis of the stoma, e.g. coca and senna leaves.

(ii) Diacytic or caryophyllaceous or cross-called stomata - The guard cells are flanked by two subsidiary cells, just like in paracytic stomata, but here the subsidiary cells lie at right angles to the long axis of the stoma, e.g. peppermint, spearmint, and vasaka.

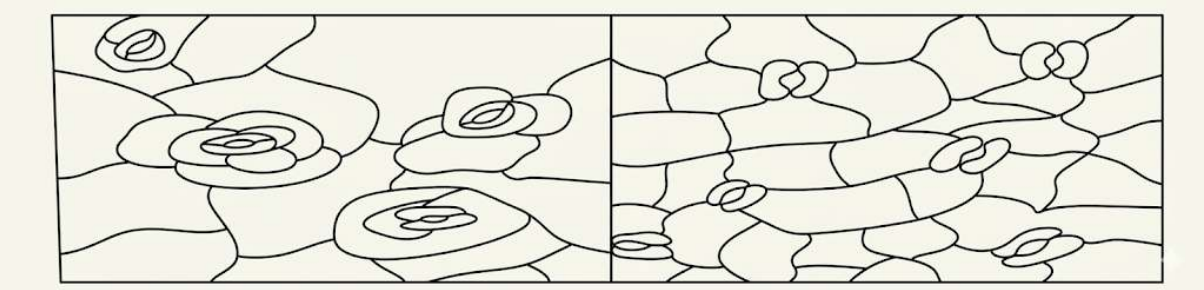


1.Paracytic **2.Diacytic**

(iii) Anisocytic or cruciferous or unequal-celled stomata - As in other types, the guard cells are two, but they are surrounded by three subsidiary cells, of which one is noticeably smaller than the remaining two, e.g. belladonna, datura.

(iv) Anomocytic or ranunculaceous or irregular-called stomata - In this kind, the stoma is surrounded by a varying count of subsidiary cells which look like the rest of the epidermal cells, e.g. digitalis and lobelia. The Indian Pharmacopoeia also recognises another type known as Actinocytic stomata.

(v) Actinocytic or radiate-celled stomata - Here the two guard cells are encircled by a ring of subsidiary cells that radiate outwards.



1.Anisocytic **2.Anomocytic**

Fig. Types of stomata

(C) Trichomes or Plant hairs

- These form another set of valuable diagnostic markers used for drug identification and for spotting adulterants. Trichomes are tubular, elongated, or glandular outgrowths from the epidermal cell. They are also called plant hairs.
- A trichome has two parts, namely the root (which lies inside the epidermis) and the body (which projects out of the epidermis).
- Trichomes appear on most plant parts such as leaves (senna and digitalis), seeds (nux vomica and strophanthus), fruits (Ladies finger), and so on. They are usually non-functional, but at times they take on secretory roles. Trichomes can give out water and, in cases like peppermint, even volatile oil.
- Trichomes are seen on most aerial parts of the plant, but they do not occur on roots.

On the basis of structure and the number of cells they contain, trichomes are placed into the groups given below:

1. Covering trichomes or non-globular trichomes or clothing trichomes
2. Glandular trichomes
3. Hydathodes or special type of trichomes.

Trichomes

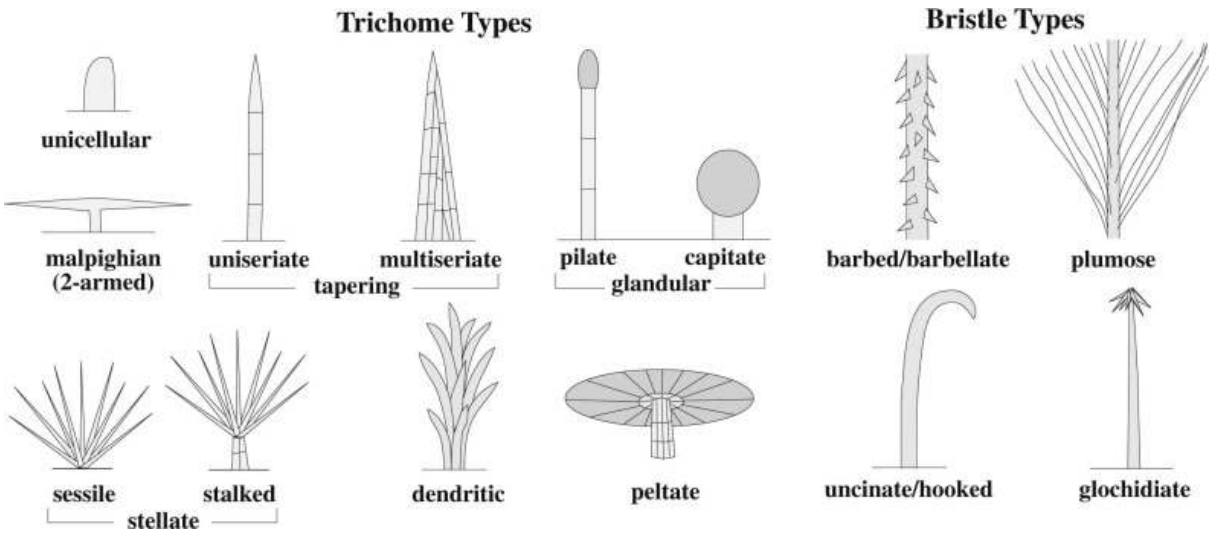
Trichomes (Plant-hairs)

- Covering or non- glandular or clothing trichomes
  a) Unicellular
  b) Multicellula

  - ✓ **Unbranched**
    Uniseriate (I)
    Biseriate (II)
    Multiseriate (III)

  - ✓ **Branched**
    - Glandular trichomes

- Hydathodes or special type of trichomes



Types of Trichomes

(d) Calcium Oxalate Crystals

- Plant drugs naturally hold many cell contents like aleurone grains, mucilage, tannin, fixed and volatile oil globules, along with inorganic substances such as calcium carbonate, calcium oxalate, and silica.
- Inorganic crystalline substances, owing to their characteristic shapes, can serve as identification markers for herbal drugs. That is why they are termed diagnostic characters of the plant.
- Special attention is given here to the various forms in which calcium oxalate crystals appear in plants.
- Calcium oxalate is a dimorphic salt and both forms occur inside plant tissue. The crystals show either monoclinic or tetragonal shapes. The two types differ from each other in features like water of hydration, optical behaviour, and so on.
- Monoclinic crystals carry just one molecule of water of crystallization, that is CaC204, while tetragonal crystals are CaC204.3H20.

Six different forms of calcium oxalate crystals occur in plants, listed below:
(1) Cubical (Prisms): As the name says, these crystals show equal height, width, and length, taking a cubical form, and possess three equal axes that are at right angles to each other.
(2) Rhombic (Diamond Shaped): These crystals also have three axes set at right angles to one another, but the axes are unequal in length.
(3) Tetragonal: This form is recognised by three axes lying at right angles to each other; two of them (the lateral axes) are equal, while the third axis - either longer or shorter - is termed the vertical or principal axis.

(4) Monoclinic: This form has three axes, all unequal. The two lateral axes lie at right angles to each other, while the third (principal) axis sits at right angles to the lateral plane. Monoclinic crystals shine more brightly than the tetragonal type.

(5) Acicular: These are very long and slender crystals with sharply pointed ends, normally seen as bundles.

(6) Rosettes (Clusters): These are aggregate crystals as well. Their shape resembles a fully-opened rose flower, which is how the name rosettes was given.

Roots

Plant roots are specialised organs meant for conduction, absorption, storage, and anchoring. Their growth runs downwards into the soil (the descending portion), which is what marks them off. They do not show nodes or internodes.

LOCATION - grows below the soil surface

TYPES OF ROOTS

1) Primary - formed straight from the axis of the embryo plant.

2) Lateral - given off from the primary

Types

Fibrous root system

A diffuse or fibrous root system is found in most monocots. It is very fine, well branched, and usually grows quite shallow.

Taproot system

Common grasses and corn are good monocot examples. The taproot system, seen in most dicots, has a thick main root running directly below the stem, with fine lateral roots branching off from it.

Feature	Taproot System	Fibrous Root System
Main Root	A single, thick **primary root**.	No main root; a cluster of **thin roots**.
Branching	Smaller **lateral roots** grow from the main root.	Roots are roughly the same size and bushy.
Soil Depth	Penetrates **deeply** into the soil.	Spreads **horizontally** near the surface.
Plant Type	Found in **Dicots** (e.g., Carrots, Mango).	Found in **Monocots** (e.g., Grass, Wheat).
Function	Excellent for deep anchorage and storage.	Excellent for preventing soil erosion.

Morphology

(1) Type / Kind - True (i.e. one that develops from the radicle or its branches) or adventitious.
Tap root, Fibrous root, Adventitious root

(2) Size and shape - tuberous, conical, cylindrical, etc.

(3) Surface characters - colour, cracks, wrinkles, annulations, lenticels, etc.
(4) Fracture and texture.
(5) Transverse section. Note whether pith is absent, whether the wood is markedly radiate or not,
and any abnormalities such as those seen in jalap and senega.

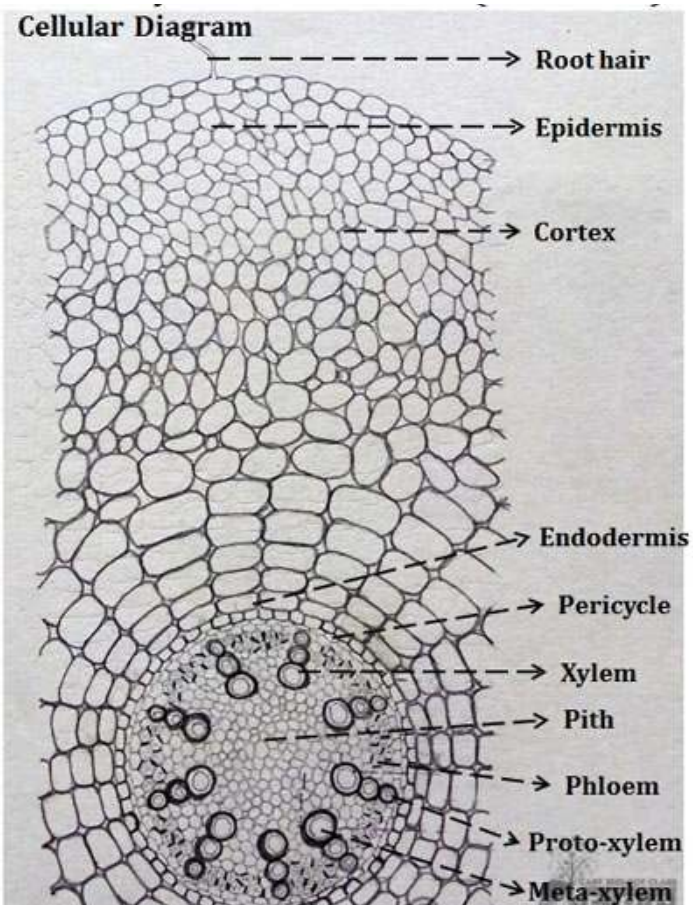
Ashwagandha Root

Liquorice root

Anatomy

A root has three basic tissue systems - the epidermis, the cortex, and the vascular tissue.

Anatomy Of Monocot Root



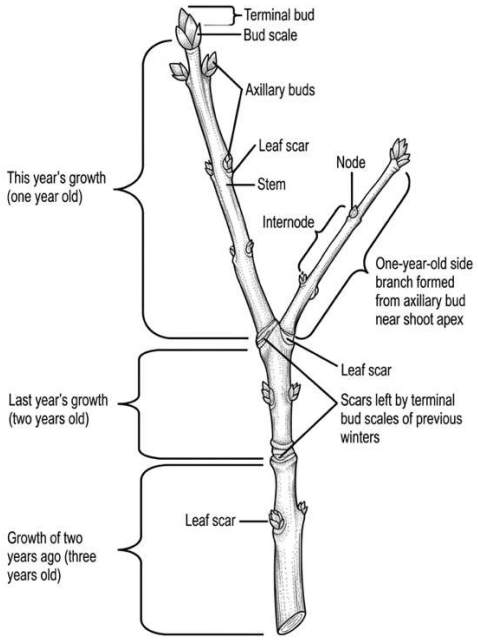
Transverse Section Of Monocot Root

Epidermis
Piliferous layer - made of a single layer of thin-walled cells, lacking cuticle, and bearing root hairs which are lateral outgrowths of the cell.
Cortex
In most annual roots, the parenchymatous cortex takes up the largest area.
Endodermis
It is the innermost layer of the cortex and made up of a single row of cells.
Stele
(vascular cylinder or stele) - The stele is the central region of the root system. It carries the xylem (which moves water and minerals from roots to shoots) and the phloem (which moves photosynthates from shoot back down to the roots).

Characteristics - Medullary rays (Ipecac, Rauwolfia, Senega)
Starch - Ashwagandha
Stem
The stem is the upward-growing axis of a plant developed from the plumule. It carries nodes, internodes, and buds, and from it grow branches, leaves, and flowers.
Stems may be aerial, sub-aerial, or underground.
Stems can be grouped into weak, herbaceous, or woody types depending on how much mechanical tissue they have.

1. Weak stems: When the stem is thin and long, it cannot stand straight on its own and so falls into one of the kinds listed below.
(a) Creepers or prostrate stems: They grow lying flat on the ground, without putting down roots, e.g. grasses, gokharu, etc.
(b) Climbers: These stems are too feeble to stand alone. They climb on a support using tendrils, hooks, prickles, or roots, e.g. Piper betel, Piper longum, Gymnema.
(c) Twinners: They wind around the support and keep growing upward. Such stems are thin and wiry, e.g. Ipomoea and Phaseolus.
2. Herbaceous or woody stems: These are normal stems and may be soft, or hard and woody, e.g. sunflower, sugarcane, ephedra, etc.

Morphology of Stem



Anatomy

The primary stem (Fig 42.1A) shows these tissues - epidermis, cortex, medullary rays, medulla, and a vascular system.

Epidermis

The epidermis is just a single layer of tightly packed cells and carries stomata.

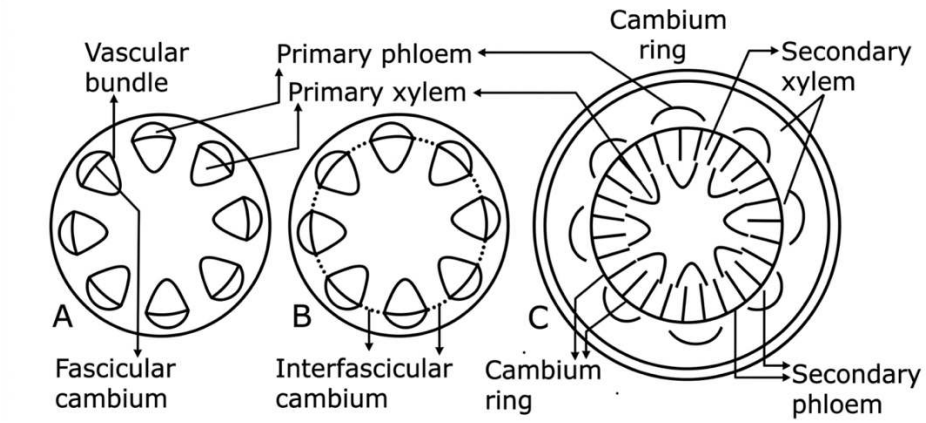
Cortex

The cortex is mostly parenchymatous; in aerial stems, the outer layers carry chloroplasts. The cortex cells just below the epidermis can be collenchymatous, forming a hypodermis.

Endodermis

In aerial stems, the endodermis is usually not clearly distinct, though a row of starch-bearing cells (the starch sheath) lying at the position of the
endodermis can be marked out.

Underground stems often look like roots, showing a fairly well-developed endodermis with characteristic Casparian strips. The pericycle may form a complete or broken ring of fibres, or stay parenchymatous and poorly defined. Pericycle fibres often sit as a cap outside each primary phloem group. Vascular bundles in the dictyostele are mostly collateral, but in some plants they are bicollateral (Cucurbitaceae, Solanaceae, Convolvulaceae).



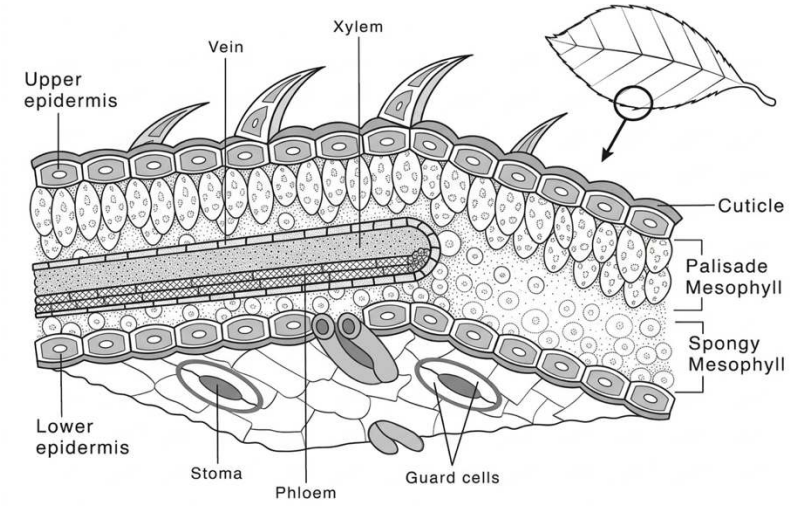
Diagrammatic illustration of stages (A, B, and C) of normal intrastelar secondary growth in a dicotyledonous stem.

Leaf

- A lateral outgrowth or appendage borne on the stem.
- It does not have nodes or internodes, and buds or lateral branches come up in its axil.

Characters:

- flattened form
thin texture
presence of chlorophyll
presence of veins

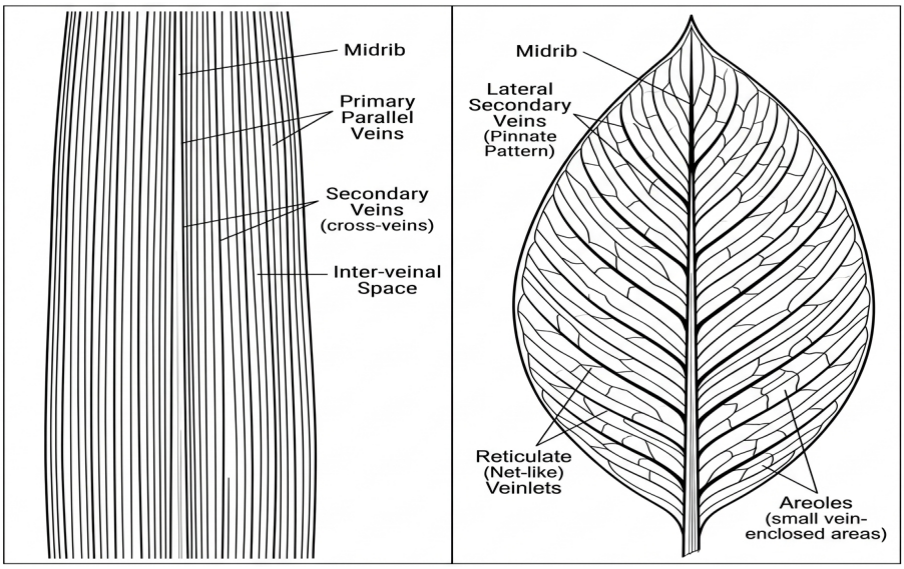


Leaf Anatomy

Leaves: Parallel veins vs. branching veins

Monocot leaves are often long and narrow and bear parallel veins.

At times, the veins go from the centre of the leaf to its margin, all running parallel to one another.

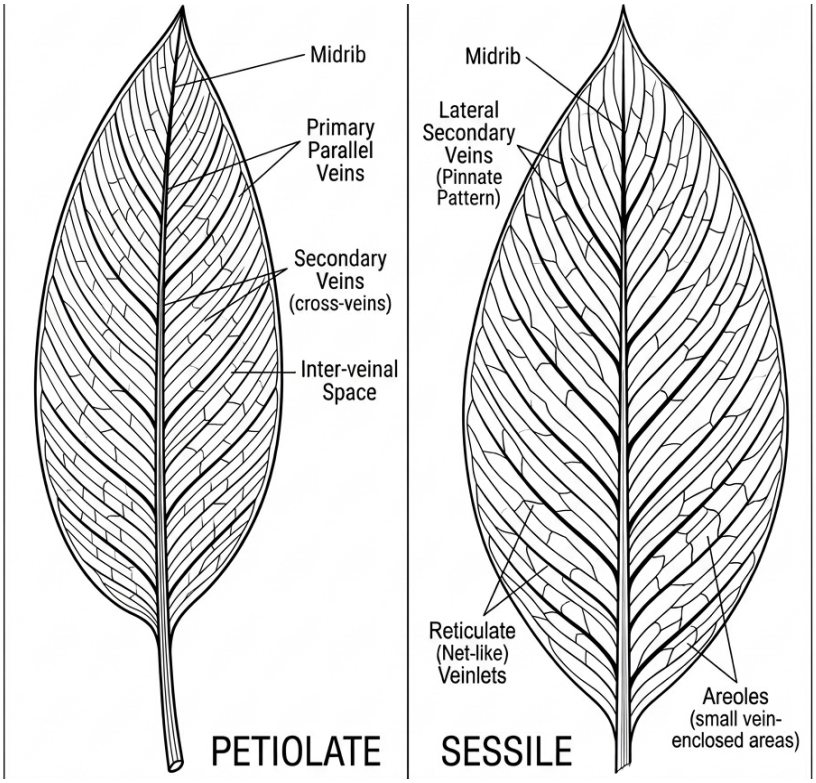


Dicots, on the other hand, have "branching veins".
Dicot leaves come in many shapes and sizes. Their veins go from the central midrib towards the leaf margin, crossing and meeting one another to form a netted pattern across the entire leaf.

Flowers:
The flower parts in monocots usually come in numbers divisible by three, often three or six.
Dicot flowers, on the other hand, generally have parts in multiples of four or five

Pollen Structure:
Monocot pollen has a single furrow or pore through the outer layer (monosulcate). Most dicots, however, descend from an ancestor that developed three furrows or pores in the pollen (tri-porate).

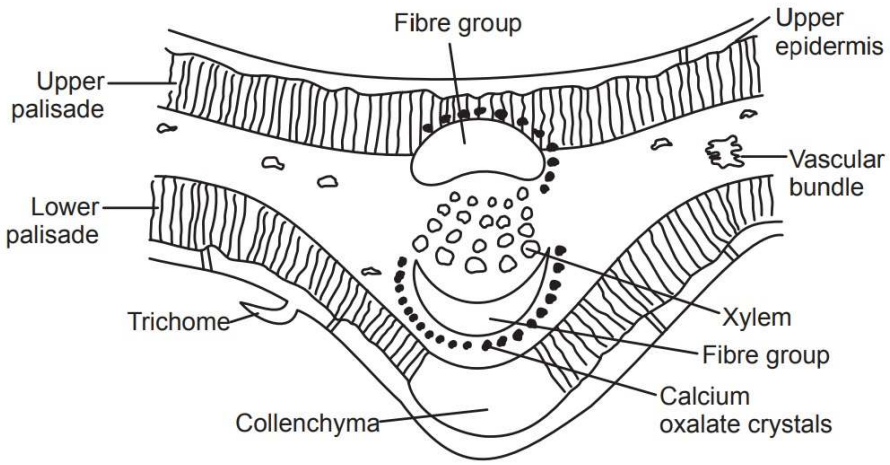
GERMINATION
When a monocot seed germinates, it puts out one leaf. The leaf is mostly long and narrow, like the adult leaf. Even when it looks somewhat round, the monocot still has only one seed leaf.
When a dicot germinates, two seed leaves come up. They hold the food for the new plant, so they are usually fatter than the actual leaves. The first true leaves are often shaped quite differently.
LEAVES OR LEAFLETS
Leaves can be described using the features given below.
Duration
Deciduous or evergreen
Leaf base - Stipulate (with outgrowths borne on either side, sometimes only one side, of the base of the leaf stalk) or exstipulate; if stipulate, describe the shape and so on:



Petiolate or sessile. If present, describe size, shape, colour, hairs, etc.

(a) Composition. If simple, note whether pinnate or palmate. If compound, note whether paripinnate (an even number of leaflets) or imparipinnate.
(b) Incision - the leaf may be more or less cleft.
(c) Shape. If drying has hidden the true shape, soak the leaf in water and lay it out on a tile. The right terms for leaf shapes can then be applied.
(d) Venation - parallel, pinnate (feather-like), palmate, or reticulate (net-veined).
(e) Margin - see Fig. for terminology.
(f) Apex - see Fig. for terminology.
(g) Base - symmetrical or asymmetrical; cordate, reniform, etc.
(h) Surface
Colour
Glabrous (free from hairs) or pubescent (hairy)
If hairy, note if hispid (rough hairs), hirsute (long distinct hairs), or with glandular hairs/punctate (dotted with oil glands).
Note any differences between the upper and the lower leaf surfaces.

(i) Texture - brittle, coriaceous, papery, fleshy, etc.



Transverse Section of Senna Leaf

Anatomy

The leaf (Fig.) is built up of a protective epidermis, a parenchymatous mesophyll, and a vascular system.

Epidermis

The shape, size, and wall structure of the epidermal cells.

The shape, spread, and the way stomata sit relative to the epidermal cells.

The shape, spread, and abundance of the epidermal trichomes are all of diagnostic value.

Mesophyll

The mesophyll may or may not be split into spongy mesophyll and palisade tissue.

The mesophyll is generally parenchymatous, but it can carry groups of collenchyma or sclerenchyma, secretion ducts or latex tissues, oil or mucilage cells, and even hydathodes (water pores).

Cells may hold inclusions like crystals or calcium oxalate, and the form, size, and spread of these can be of value.

The vascular systems

Leaf vascular systems are of two main kinds - the reticulate venation seen in dicotyledons and the parallel venation seen in monocotyledons.

When the midrib is well developed, the palisade tissue normally breaks off in the midrib region, and collenchyma often appears both above and below the midrib bundle.

The xylem lies towards the upper surface.

How the pericycle develops varies a lot - in some leaves it is parenchymatous and contains secretion cells, while in others it forms a sheath of pericyclic fibres whose long axes lie parallel to the vein.

To study the structure of a leaf, transverse sections through the lamina and the midrib are needed; pieces of the whole leaf, including the leaf margin, cleared in chloral hydrate; and surface preparations of both surfaces. The epidermis sections should be cleared if needed and stained for cellulose and lignin. In some cases, microchemical tests for mucilage, tannin, cutin, volatile oil, calcium oxalate, or carbonate may also be required.

Powdered leaves.

These features are always present - epidermis with stomata,

Cellulose parenchyma - not very plentiful, with small-sized vascular elements and chlorophyll (except in bulb leaves).

small-sized vascular elements and chlorophyll (except in bulb leaves).

Other features that often turn up are epidermal trichomes, glands, palisade cells, calcium oxalate crystals, collenchyma, and pericyclic fibres.

To tell apart leaves that closely resemble one another, it may be necessary to work out differential parameters like vein-islet number, stomatal number, stomatal index, and palisade ratio.

Fruits

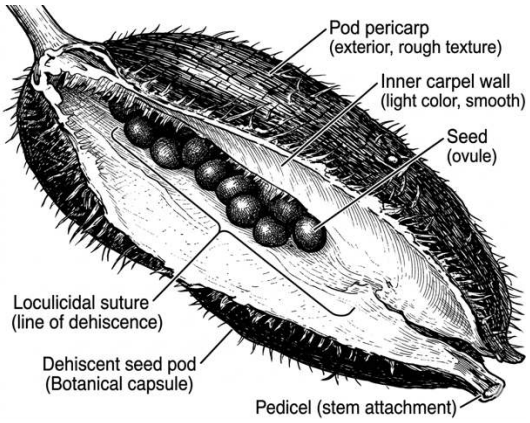
If the ovules fail to fertilize, seedless fruits develop.
On the basis of the number of carpels in the flower, fruits fall into the categories listed below:
1. Simple fruits,
2. Aggregate fruits, and
3. Compound fruits.

1. Simple fruits: These come from a single carpel or from a syncarpous gynoecium. According to whether the mesocarp is dry or fleshy, they are classed as dry fruits or fleshy fruits. Dry fruits are further split into dehiscent and indehiscent kinds.
2. Aggregate fruits: These come from many carpels, that is, from an apocarpous gynoecium.
3. Compound fruits: Here, several flowers come together and form one fruit.
4. **False fruits:** At times, besides the ovary, other floral parts like the thalamus, receptacle, or calyx also grow and become part of the fruit. Such a fruit is called a false fruit or pseudocarp. Below are a few examples of pseudocarps where parts of the flower other than the ovary play an important role in the fruit; the contributing parts are shown in brackets.
Strawberry (thalamus).
Cashew nut (peduncle and thalamus).

Apple (thalamus).
Marking nut (peduncle).

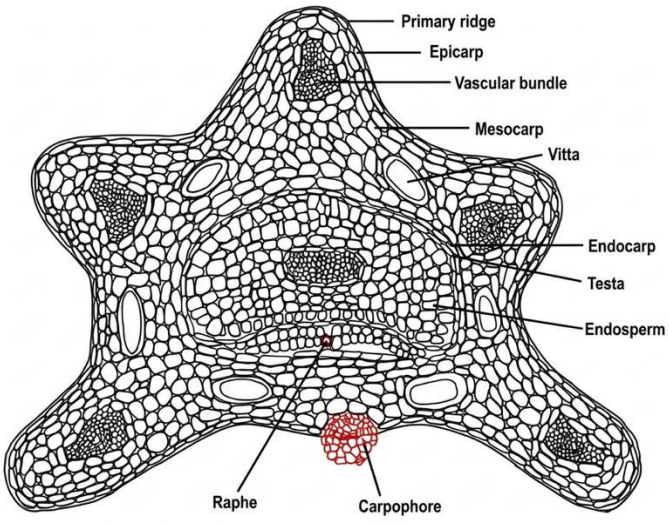
Morphology

Macroscopic study of fruits looks at the following features.
Colour
Odour
Taste
Size
Shape
Texture
Ridge - primary, secondary



Microscopy

The whole fruit is made of two zones - the pericarp; sometimes it shows three parts, namely epicarp, mesocarp, and endocarp.
The epidermis of the epicarp resembles that of leaves and shows parenchymatous cells, sclereids, oil cells, and vascular bundles.
In umbelliferous fruits, oil cells in the mesocarp form vittae.
The endocarp is oily and has oil globules, aleurone grains, and starch.



T. S. of Fennel fruit

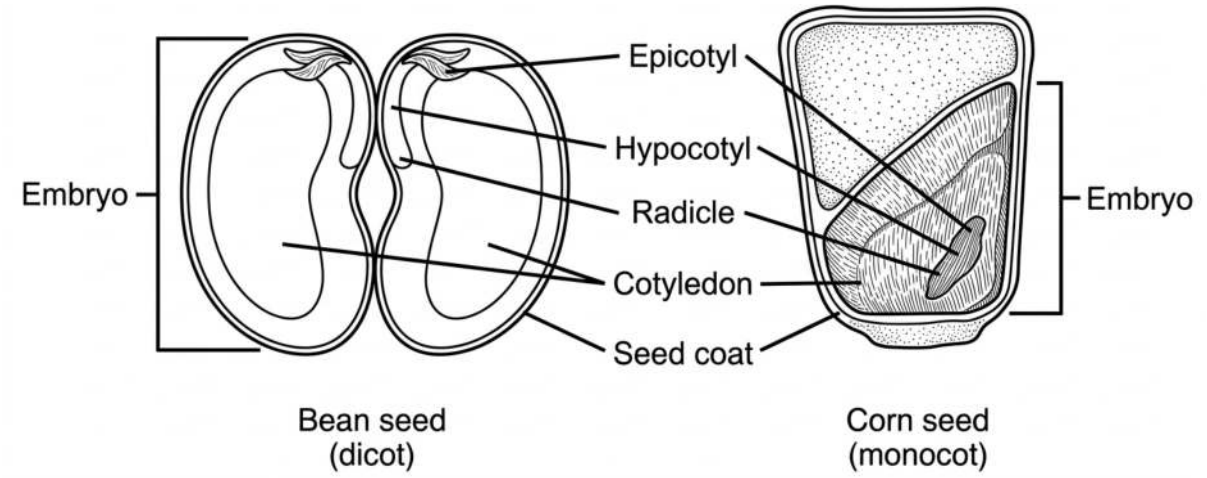
- Care must be taken to tell apart seeds from fruits or fruit parts that hold a single seed (e.g. mericarps of the Umbelliferae).
- The seed stays attached to the placenta through a stalk known as the funicle.
- The hilum is the scar that remains on the seed where it broke away from its stalk.
- The raphe is a ridge of fibrovascular tissue formed in many ovules due to the fusion of the funicle with the testa.
- The micropyle is the tiny opening in the seed coat which usually marks the position of the radicle.

Seeds

Seeds are mature, fertilized ovules. Ovules in seed plants hold the female gametophyte with the egg cell, all wrapped up by the nucellus and 1-2 integuments. In angiosperms (flowering plants), double fertilization gives rise to the diploid embryo and the triploid endosperm.
Each seed shows three parts - the embryo, the endosperm, and the seed coat.

Endosperm is the food-rich tissue that nourishes the embryo.
Endosperm may be present in some seeds and missing in others. So seeds are grouped as follows:

1. Endospermic or albuminous seeds: A part of the endosperm stays till seed germination and is partly used up by the embryo. The endosperm is clearly seen, e.g. colchicum, isapgol, linseed, nux-vomica, strophanthus, etc.
2. Non-endospermic or exalbuminous seeds: While the seed grows, the embryo absorbs the entire endosperm, so endosperm is not seen in mature seeds.
e.g. sunflower, tamarind, cotton, soyabean, etc.
3. Perispermic seeds: Here, the nucellus grows so much that it forms a large storage tissue, and the seed ends up with embryo, endosperm, perisperm, and seed coat. e.g. pepper, cardamom, nutmeg, etc.



Comparative Seeds of Dicot & Monocot

External
Seed coat (testa)
Hilum
Embryo
Cotyledon
Epicotyl / Hypocotyl
Plumule
Radicle

Seed coat (Testa)
The seed coat protects the embryo and may differ in thickness from one seed type to another.

Hilum
It is the scar/mark where the seed was tied to the ovary tissue through the funicle. Hence it is the point where the seed joined its stalk - hilum.

Embryo
The embryo is the part that grows into the new plant.
A mature embryo is made of cotyledons (seed leaves), the hypocotyl (stem-like embryonic axis below the cotyledons), and the radicle (embryonic root).

Cotyledon
The cotyledon is the first leaf to come out during germination.
It is loaded with stored food which the plant taps before it begins photosynthesis.

Some plants carry just one cotyledon (monocot), while others carry two (dicot).

Seeds Structure

Epicotyl/Hypocotyl
It forms the basis of the plant's stem. Above the cotyledon it is called the epicotyl, and below the cotyledon it is the hypocotyl. Both grow upward in response to light.

Plumule
It is the shoot tip carrying a pair of tiny leaves.

The Radicle
It is the part of the seed that develops into the root.

Raphe:
Raphe is the longitudinal mark of the adherent stalk of an anatropous ovule.

Micropyle
It is the small opening of the tubular structure through which water enters for seed germination.

Endosperm:
Food storage tissue

Special Structures:

In some seeds, besides the usual growth, extra growth also takes place in the form of appendages.

1. Aril:
Fleshy outgrowth springing from the hilum that wraps the whole seed, as seen in nutmeg (mace).

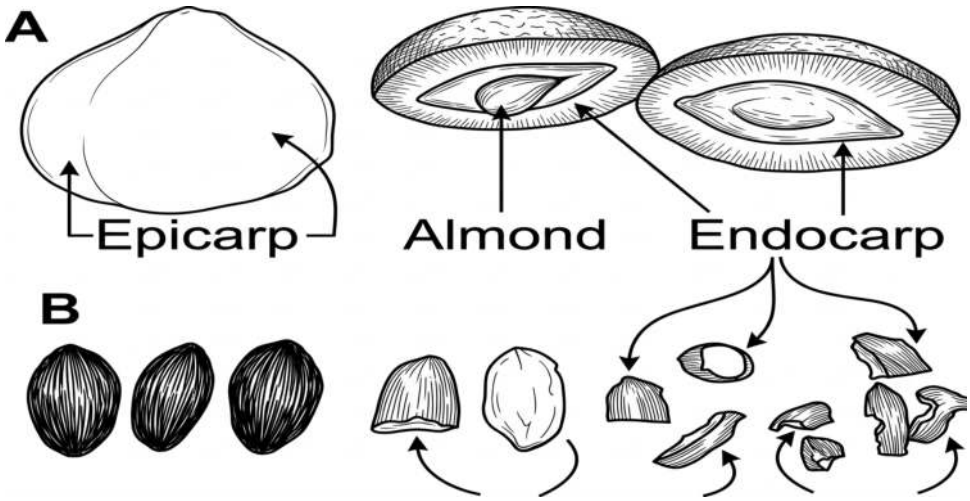
2. Arillode
Outgrowth coming from the micropyle and covering the seed, as in cardamom.

3. Arista (awn):
A stiff bristle-like appendage seen along with many flowering glumes of grasses, as in strophanthus.

4. Caruncle:
It is the warty outgrowth from the micropyle. e.g. castor, croton, viola.

5. Strophiole:
Enlarged funicle, e.g. Datura fastuosa and colchicum seed.

6. Hairs
Gossypium and Calotropis show this kind of outgrowth.
These appendages sometimes carry out special roles. For example,
Hairs and awns of seeds aid in their dispersal.



A seed can be described in the following order:

Size, shape, colour, odour, and taste

Features such as funicle, raphe, hilum, and micropyle can be noted.

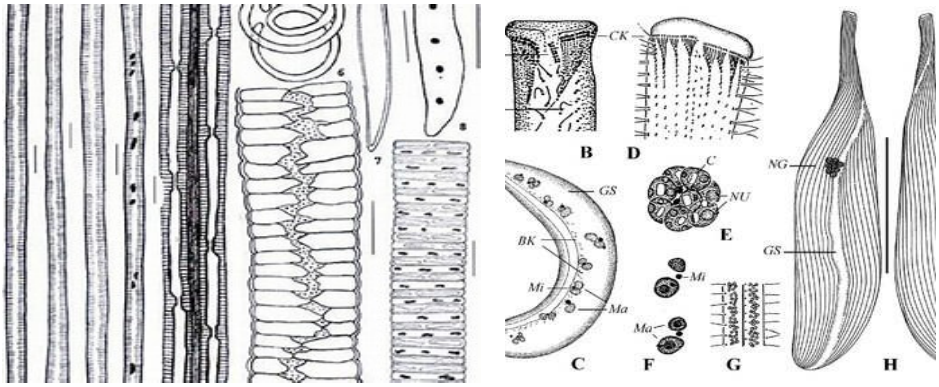
Bark

Study of the morphology and histology of bark.

The bark is made up of the secondary external tissues that lie outside the cambium in the stem or root of dicotyledonous plants.

Botanically, the bark is made of the periderm and all the tissues lying outside it - that is, cork, phellogen, and phelloderm.

A young bark (Fig.) is built of the following tissues.



(1) Epidermis:

A layer of tightly fitting cuticularised cells with stomata at intervals.

(2) Primary cortex:

A zone usually made of chlorophyll-containing collenchyma and parenchyma.

(3) Endodermis: (or the inner layer of the cortex)

It often holds starch.

(4) Pericycle:

It may be made up of parenchyma or fibres. Groups of fibres are often seen lying opposite each phloem group.

(5) Phloem:

It is made of sieve tubes, companion cells, and phloem parenchyma, separated by radially running medullary rays.

Chapter 12: Quantitative Microscopy

Lycopodium Spore Method for Determining Percentage Purity

The Lycopodium spore method is a useful quantitative tool for analysing powdered crude drugs. It comes in handy in cases where chemical or other evaluation routes fail to give dependable findings.

Lycopodium spores are easy to spot because of their typical shape and uniform size of about 25 µm. Each milligram of Lycopodium powder holds nearly 94,000 spores, which makes them ideal as a counting reference standard.

The technique is suited for powdered drugs that contain:

- Clearly identifiable particles that can be counted, such as starch grains or pollen grains.
- Single-layered tissues or cells whose area can be measured under a microscope.
- Structures of consistent thickness whose dimensions can be measured to calculate their area.

Formula for Percentage Purity (Example: Ginger Powder)

Powdered ginger purity is worked out using the formula given below:

Percentage Purity = (N * W * 94000 * 100) / (S * M * P)

Where:

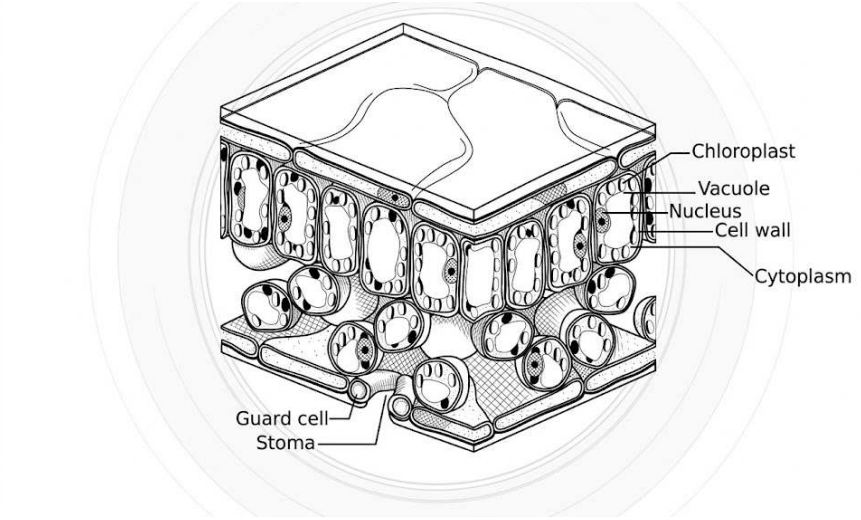
- **N** = Number of characteristic structures (e.g., starch grains) observed in 25 fields
- **W** = Weight (in mg) of Lycopodium powder used
- **S** = Number of Lycopodium spores counted in the same 25 fields
- **M** = Weight (in mg) of the sample (on a dry basis at 105°C)
- **P** = Standard value (2,86,000 for ginger starch grains)

The same approach also works for analysing powdered drugs like clove, cardamom, nutmeg, and fruits from the umbelliferous family.

Leaf Constants (Diagnostic Features of Leaves)

1. Palisade Ratio

Palisade ratio is the average count of palisade cells lying just below a single epidermal cell. It acts as a key diagnostic value for plant material identification, and the same can be measured even on powdered leaf samples.



2. Vein-islet number is the count of vein-islets per square mm of leaf surface, taken halfway between the midrib and the leaf margin. Vein-islet numbers for many dicot leaves were worked out by Levin in 1929.

3. Vein-termination number means the count of veinlet endings per square mm of leaf surface, again taken midway between the midrib and the margin.

4. Stomata number gives the count of stomata per square mm of the leaf epidermis. 5. Stomata index represents the ratio (in percentage) of stomata to the sum of stomata plus epidermal cells, where each stoma is taken as one cell.

It is calculated by using the following equation: SI=S/E +S * 100

where,

SI= Stomatal Index

S= Number of stomata per unit area

E= Number of epidermal cells in the same unit area

5. Micrometers

Micrometers are instruments used for **measuring the size of microscopic objects**.
Two types are commonly used.

5.1 Stage Micrometer

A **stage micrometer** is a special microscope slide on which a **scale is engraved**.
Characteristics:

- Total length = **1 mm**
- Divided into **100 equal divisions**
- Each division = **10 micrometers (µm)**

It is used for **calibrating the ocular micrometer**.

5.2 Ocular Micrometer

An ocular micrometer is a **glass disc with a scale placed inside the eyepiece of the microscope**.

Characteristics:

- The scale has **no fixed value**
- Must be **calibrated using a stage micrometer**

Calibration of Micrometer

1. Place the stage micrometer on microscope stage.
2. Insert ocular micrometer into eyepiece.
3. Focus the microscope.
4. Superimpose the two scales.
5. Determine how many ocular divisions correspond to stage divisions.
6. Calculate the value of one ocular division.

6. Measurement of Starch Grains

Starch grains are **reserve carbohydrate materials stored in plant cells**.

Example:

Solanum tuberosum (potato).

Structure

Starch grains consist of:

- **Hilum** – central point
- **Lamellae** – concentric layers of starch deposition

Procedure

1. Take powdered drug on slide.
2. Add **iodine solution**.
3. Place cover slip.
4. Observe under microscope.
5. Measure the diameter using ocular micrometer.

7. Measurement of Aleurone Grains

Aleurone grains are **protein storage bodies present in the endosperm of seeds**.

Example:

Ricinus communis.

Structure

Each aleurone grain consists of:

- Protein matrix
- Crystalloid
- Globoid

8. Measurement of Phloem Fibres

Phloem fibres are **elongated thick-walled supportive cells present in the phloem tissue of plants**.

Examples include fibres present in:

- Cinnamomum verum bark
- Linum usitatissimum stem

The length and width of fibres are measured using a calibrated micrometer.

9. Measurement of Calcium Oxalate Crystals

Calcium oxalate crystals are inorganic crystalline deposits present in plant tissues.
They occur in plants such asAtropa belladonna.

Types

1. Prismatic crystals
2. Raphides (needle-shaped bundles)
3. Rosette crystals
4. Acicular crystals

These crystals are **diagnostic features used in identification of crude drugs**.

10. Importance of Quantitative Microscopy

Quantitative microscopy is important for:

- Identification of powdered drugs
- Detection of adulteration
- Determination of purity
- Standardization of herbal drugs
- Quality control in pharmacognosy laboratories

Mountants, Clearing Agents and Chemomicroscopic Reagents

In pharmacognostic studies, microscopic examination of crude drugs requires **special chemical substances** to prepare the sample. These include **mountants, clearing agents, and chemomicroscopic reagents**.
These substances help in:

- Proper mounting of plant tissues
- Clearing and making tissues transparent
- Detecting specific chemical constituents in plant cells

1. Mountants

Definition

Mountants are **liquids used to mount the specimen on a microscope slide for microscopic observation**.
They help to:

- Hold the specimen in place
- Preserve plant tissues
- Improve visibility of structures under microscope

Mountants may be **temporary or permanent**.

Types of Mountants

1. Temporary Mountants

These are used for **short-term observation**.

Examples

1. Water

- Simplest mountant.
- Used for **fresh plant materials**.
- Does not preserve tissues for long time.

2. Glycerin (Glycerol)

- Most commonly used mountant in pharmacognosy.
- Prevents drying of specimen.
- Provides clear visibility of tissues.

3. Glycerin Jelly

- Semi-solid mounting medium.
- Provides better support for delicate tissues.

2. Permanent Mountants

These are used for **long-term preservation of slides**.

Examples:

- **Canada balsam**
- **DPX mountant**

These mountants preserve the preparation for **many years**.

Characteristics of a Good Mountant

A good mountant should:

- Be **transparent**
- Have **appropriate refractive index**
- Preserve tissues without distortion
- Prevent drying or shrinkage of specimen

2. Clearing Agents

Definition

Clearing agents are chemicals used to make plant tissues transparent by removing coloring matter or cell contents.

This helps in clear observation of internal structures under microscope.

Common Clearing Agents

1. Chloral Hydrate

One of the **most widely used clearing agents in pharmacognosy**.

Properties:

- Removes pigments such as chlorophyll
- Makes tissues transparent
- Swells cell walls slightly

Uses:

- Clearing powdered crude drugs
- Examination of leaf structures
- Identification of crystals and fibres

2. Sodium Hydroxide (NaOH)

- Used to soften and clear plant tissues.
- Dissolves cytoplasmic contents.

3. Potassium Hydroxide (KOH)

- Used to clear hard tissues.
- Helps remove cellular contents.

4. Lactic Acid

- Used for clearing tissues without damaging cell walls.
- Often used in fungal studies.

Procedure of Clearing

1. Plant material is placed in clearing solution.
2. Heat may be applied gently.
3. Pigments are removed.
4. The tissue becomes **transparent**.
5. The cleared specimen is mounted for microscopic observation.

3. Chemomicroscopic Reagents

Definition

Chemomicroscopic reagents are chemical reagents used to identify specific chemical constituents in plant tissues under the microscope.

They produce characteristic color reactions with certain plant components.

This method is known as chemomicroscopy.

Purpose

Chemomicroscopy is used to detect:

- Starch
- Lignin
- Alkaloids
- Tannins
- Oils
- Proteins
- Calcium oxalate crystals

Important Chemomicroscopic Reagents

1. Iodine Solution

Used for detection of **starch**.

Reaction:

Starch + Iodine → **Blue or blue-black color**

Example: starch grains in
Solanum tuberosum.

2. Phloroglucinol + Hydrochloric Acid

Used to detect **lignified tissues**.

Reaction:

Lignin → **Pink or red coloration**

Used for identifying **lignified fibres and vessels**.

3. Sudan III or Sudan IV

Used for detection of **fixed oils and fats**.

Reaction:

Oils → **Orange-red coloration**

Used in seeds such as
Ricinus communis.

4. Ferric Chloride Solution

Used for detection of **tannins**.

Reaction:

Tannins → **Blue, green or black color**

5. Dragendorff's Reagent

Used to detect **alkaloids**.

Reaction:

Alkaloids → **Orange or reddish-brown precipitate**

6. Ruthenium Red

Used to detect **mucilage and gums**.

Reaction:

Mucilage → **Pink or red coloration**

7. Ninhydrin Reagent

Used to detect **proteins and amino acids**.

Reaction:

Proteins → **Purple or blue color**

Chemo microscopic Tests

Reagent	Constituent detected	Observation
Iodine	Starch	Blue/black color
Phloroglucinol + HCL	Lignin	Pink/red color
Sudan III	Fixed Oils	Orange-red color
Ferric chloride	Tannin's	Green/ blue Color
Dragendroff's Reagent	alkaloids	Orange precipitate
Ruthenium red	Mucilage	Pink color
Ninhydrin	Proteins	Purple

3. CHEMICAL EVALUATION

- This category covers a range of chemical tests and assays. Methods such as isolating, purifying, and identifying active constituents fall under chemical evaluation. Qualitative chemical tests like acid value and saponification value are also part of this technique.
- Preliminary phytochemical screening forms a part of chemical evaluation. The qualitative chemical tests are useful in detection of adulteration.
- Some specific examples include Halphen's test for cottonseed oil, Van Urk's reagent for ergot, Vitali's test for tropane alkaloids, and the murexide test for purine bases.
- Chemical evaluation also includes phytochemical screening, which helps establish the chemical profile of a crude drug.

The extracts are then put through qualitative tests so that the various plant constituents can be identified.

1. **Detection of alkaloids:** Small portions of the solvent-free chloroform, alcoholic, and water extracts are stirred separately with a few drops of dilute hydrochloric acid, and the mixture is filtered. The filtrate is then carefully tested using different alkaloidal reagents - Mayer's reagent (cream precipitate), Dragendroff's reagent (orange-brown precipitate), Hager's reagent (yellow precipitate), and Wagner's reagent (reddish-brown precipitate).

2. Detection of carbohydrates and glycosides

(a) Take small portions (200 mg) of the alcoholic and aqueous extracts, dissolve each in 5 ml of distilled water, and filter. The filtrate can then be checked through Molisch's test for the presence of carbohydrates.

(b) Take another small piece of the extract, hydrolyse it with dilute HCl on a water-bath for a few hours, and then run Liebermann-Burchard's and Borntrager's tests to check for the various glycosides.

(c) Take a small bit of extract, dissolve it in water, and treat it with Fehling's and Benedict's reagents to test for the different sugars.

3. Detection of phytosterols: The petroleum ether, acetone, and alcoholic extracts are refluxed separately with alcoholic potassium hydroxide solution till saponification is complete. The saponified mixture is then diluted with distilled water and shaken with ether. The ether layer is

evaporated, and the residue (unsaponifiable matter) is checked by Liebermann's and Burchard's tests.

4. Detection of fixed oils and fats: A little of the petroleum ether and benzene extracts is squeezed separately between two filter papers. If oily stains appear on the paper, fixed oil is present.

5. Detection of saponins: Roughly 1 ml each of the alcoholic and aqueous extracts is diluted with distilled water up to 20 ml in a graduated cylinder and shaken for 15 minutes. A foam layer of about 1 cm tells us saponins are present.

6. Detection of phenolic compounds and tannins: Small amounts of the alcoholic and aqueous extracts in water are checked for phenolic compounds and tannins by treating with dilute ferric chloride (5 per cent), 10% lead acetate, and aqueous bromine solutions.

7. Detection of proteins and free amino acids: Small portions of the alcoholic and aqueous extracts are dissolved in a few ml of water and then tested using Millon's, Biuret, and Ninhydrin tests.

8. Detection of gums and mucilages: Around 10 ml of the aqueous extract is added slowly to 25 ml of absolute alcohol with constant stirring. The precipitate that forms is air-dried, then checked for swelling property and the presence of carbohydrate.

9. Detection of volatile oil: Take roughly 50 g of the powdered material in a volatile oil estimation apparatus and run hydro-distillation to detect the volatile oil. The distillate is collected in the graduated tube of the assembly, where the aqueous layer separates automatically from the volatile oil (if any) and gets returned back to the distillation flask.

Chapter 13: Physiochemical Evaluation

PHYTOCHEMICAL INVESTIGATIONS

Looking at plant material in a phytochemical way is a step-by-step process that runs through four stages.

1. Sourcing the raw material along with quality control.
2. Pulling out the constituents of pharmaceutical interest, purifying and characterizing them, plus running in-process quality control.
3. Studying the biosynthetic pathways leading to particular compounds, and
4. Quantitative evaluation.

- EXTRACTION is the term used for the routine technique by which the active substance is taken out from a crude drug, and it makes use of various solvents.
- The plant material picked for extraction must first be properly authenticated or identified. Which plant is chosen depends on its nature and on the components that one wants to isolate.
- For extraction, dried powdered plant material is the form most commonly used.
- When fresh plant parts are taken, they are homogenized or macerated with a solvent like alcohol. Alcohol pulls many possible constituents out, but later it makes the removal of pigments, resins, and similar matter difficult.
- Light petroleum, being water-immiscible, is the solvent of choice when fixed oils, essential oils, steroids, and aglycones have to be extracted.
- For separating alkaloids and quinines, chloroform and ether are the usual solvents.
- If a water-immiscible solvent is being applied to extract organic bases like alkaloids, the plant material generally has to be made basic first; on the other hand, aromatic acids and phenols may need acidification.
- Glycosides dissolve in water and alcohol, but they will not dissolve in non-polar solvents.
- Tannins, being phenolic in nature, dissolve in water, alcohol, and ethyl acetate. The actual extraction can be carried out by repeated maceration with shaking, by percolation, or by continuous extraction in a Soxhlet extractor.

Preliminary Phytochemical Screening

- A plant works like a biosynthetic factory. It makes not just food substances such as carbohydrates, proteins, and lipids that humans eat, but also a wide range of compounds like glycosides, alkaloids, volatile oils, tannins, and others which produce physiological and therapeutic effects.
- The medicinal action of a drug is mostly due to its secondary metabolites. So, a complete study of a crude drug needs careful look at both primary and secondary metabolites that the plant produces during its metabolism. The plant material is first run through preliminary phytochemical screening to detect the various plant constituents along the lines given below.

- Successive solvent extraction: The air-dried, powdered plant material is taken in a Soxhlet assembly and extracted one after the other with petroleum ether, benzene, solvent ether, chloroform, acetone, ethanol, and methanol.
- Lastly, the drug is macerated using chloroform water. Before moving on to each new solvent, the powdered material is dried in a hot-air oven at a temperature below 500 °C.
- Each extract is concentrated by distilling off the solvent, then taken to dryness on a water-bath.
- Each solvent extract is weighed. Its yield is worked out as a percentage of the air-dried weight of the plant material. The colour and consistency of every extract are also recorded.
- Another way is to prepare extracts by successive maceration (co-extraction) of the powdered drug, working through solvents in order of rising polarity.
- A general scheme for taking out different constituents from a fresh plant is shown in the chart below.

PHYSICAL EVALUATION

Wherever possible, physical standards should be set for drugs. They are seldom truly constant for crude drugs, yet they help during evaluation - especially with parameters like moisture content, specific gravity, density, optical rotation, refractive index, melting point, viscosity, and solubility in different solvents. A few of these are explained below.

(i) Moisture content: For crude drugs, the percentage of active chemical constituents is always given on an air-dried basis.

- So, the moisture content has to be measured and kept under control. Keeping moisture as low as possible is important to stop crude drugs from breaking down by chemical change or by microbial spoilage.
- Moisture content is found by heating the drug in an oven at 105°C until it gives a constant weight.
- e.g. Aloes - not more than 10% w/w
  Starch - NMT 15% w/w
  Acacia - NMT 15% w/w

(ii) Viscosity: At a fixed temperature, the viscosity of a liquid stays constant and reflects its make-up. So it can be applied as a way of standardizing liquid drugs.
Examples. Liquid paraffin - Kinematic viscosity not less than 64 centistokes at 37.8°.
Pyroxylin - Kinematic viscosity, 1100-2450 centistokes

(iii) Melting point: Melting point is one of the values used to test the purity of crude drugs. For pure chemicals or phytochemicals, the melting point is sharp and constant. But crude drugs from animal or plant sources contain mixed chemicals, so they are quoted with a certain range of melting point.
Examples
Bees wax - 62-65 °C

Cocoa butter - 30-35 °C

(iv) Solubility: The presence of an adulterant in a drug can sometimes be picked up through solubility studies.

- Castor oil dissolves only in three volumes of 90 per cent alcohol; an adulterated sample, however, may dissolve more readily in alcohol.
- Asafoetida dissolves in carbon disulphide. Alkaloidal bases dissolve in
- chloroform, while alkaloidal salts dissolve in polar solvents.

(v) Ash Values and Extractives: As mentioned earlier, evaluating a drug mainly calls for its identification, and this can be carried out using morphological or microscopic features.

Quite often, even after the drug is identified, it turns out to be of poor quality due to either bad collection or wrong storage.

So, to confirm that it is fit for use as a drug, the tests listed below can be applied wherever they apply.

(a) Ash content: The residue that remains after burning is called the ash content of the drug. It simply stands for the inorganic salts that occur naturally in the drug, stick to it from outside, or are added on purpose as a kind of adulteration.

Physicochemical Evaluation

Physicochemical evaluation means the determination of physical and chemical constants of crude drugs by standard laboratory methods, so that quality, purity, and authenticity can be assured.

Physicochemical Parameters

1. **Moisture content (Loss on drying)**
2. **Ash values**
    - Total ash
    - Acid-insoluble ash
    - Water-soluble ash
3. **Extractive values**
    - Alcohol-soluble extractive
    - Water-soluble extractive
4. **Foreign organic matter**
5. **Volatile oil content**
6. **Crude fiber content**
7. **pH value**

1. Extractive Values

Definition: The percentage of active constituents pulled out from a drug using a particular solvent (water, alcohol, etc.).

Purpose:

- Measures **solubility of phytoconstituents**
- Indicates **drug quality**

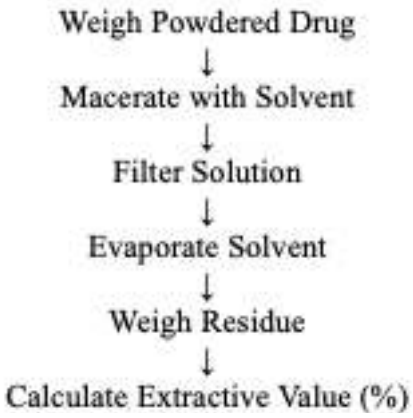
Procedure (Brief):

- Weigh powdered drug -> Macerate with solvent -> Filter -> Evaporate -> Weigh residue

Formula:

$$\textbf{Extractive value (\%)} = \frac{\textbf{Weight of drug}}{\textbf{Weight of extract}} \times 100$$

Example Solvents: Water, Alcohol, Hydroalcoholic



2. Moisture Content (Loss on Drying)

Definition: Percentage of water held in crude drugs, which decides storage stability.

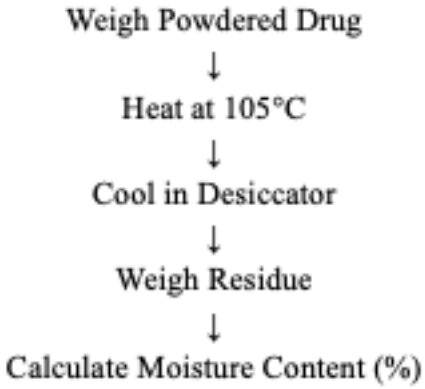
Purpose:

- Stops microbial growth
- Avoids **chemical degradation**

Procedure:

Weigh drug -> Heat at 105°C -> Cool in desiccator -> Reweigh

$$\textbf{Moisture (\%)} = \frac{\textbf{Initial weight} - \textbf{Final weight}}{\textbf{Initial weight}} \times 100$$



3. Foreign Organic Matter

Definition: The percentage of foreign matter such as dust, soil, or other plant parts present in crude drugs.

Purpose:

- Indicates the purity of the drug

Procedure:

- Separate foreign matter manually -> Weigh -> Calculate the percentage

Foreign matter (%)= $\frac{\text{Weight of foreign matter}}{\text{Total weight}} \times 100$

4. Ash Values

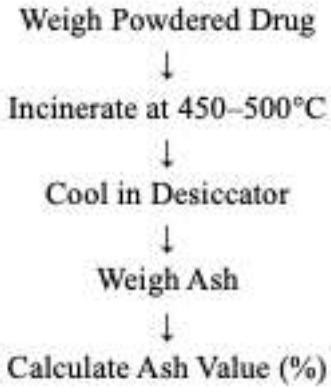
Definition: The residue left after a crude drug is fully burnt; it represents the total mineral content.

Types:

Type	Definition	Purpose
Total ash	Total inorganic matter	General purity check
Acid-insoluble ash	Silica or sand content	Detect earthy contamination
Water-soluble ash	Soluble mineral salts	Quality assessment

Procedure:

- Weigh -> Incinerate at 450-500°C -> Cool -> Weigh residue
- Ash value (%)=$\frac{\text{Weight of ash}}{\text{Total Weight}} \times 100$



5. Bitterness Value

Definition: A measure of the intensity of bitter constituents, mainly alkaloids.

Procedure:

- Pull out the active principle -> Dilute -> Compare against a standard (caffeine solution or quinine).

6. Foaming Index

Definition: The highest dilution of an aqueous extract that gives stable foam; applied for saponin-containing drugs.

Procedure:

- Shake the aqueous extract -> Note the foam height -> Stable foam over 1 cm shows saponins.

7. Hemolytic Potential

Definition: The ability of a drug extract to lyse red blood cells.

Purpose:

- Mostly used for saponin-containing drugs

Procedure:

- Mix the extract with RBC suspension -> Note hemolysis

8. Swelling Index

Definition: The volume (mL) to which 1 g of powdered drug swells when soaked in water.

Purpose:

- Indicates the mucilage or gum content

Procedure:

- 1 g powdered drug -> Add water -> Allow to stand for 1 h -> Read the final volume.

Swelling index = (mL/g)

9. Viscosity

Definition: The resistance of a solution or extract to flow when a force is applied.

Purpose:

- Useful for **gums, mucilage, and plant resins**

Procedure:

- Measured using a **capillary viscometer** at standard temperature

10. Optical Rotation

Definition: The rotation of plane-polarised light by optically active compounds (e.g. sugars, essential oils).

11. Refractive Index

Definition: The ratio of the speed of light in air to the speed of light in the drug solution or oil.

Formula:

$$n=\frac{c}{v}$$

Where:

- c = Speed of light in air
- v = Speed of light in sample

Purpose:

- Used for **essential oils, fixed oils, and syrups**

12. Acid Value

Definition: The mg of KOH needed to neutralize the free fatty acids present in 1 g of oil or fat.

Formula:

$$\text{Acid value}=\frac{56.1\times V\times N}{W}$$

Where:

- V = Volume of KOH (mL)
- N = Normality of KOH
- W = Weight of sample (g)

13. Saponification Value

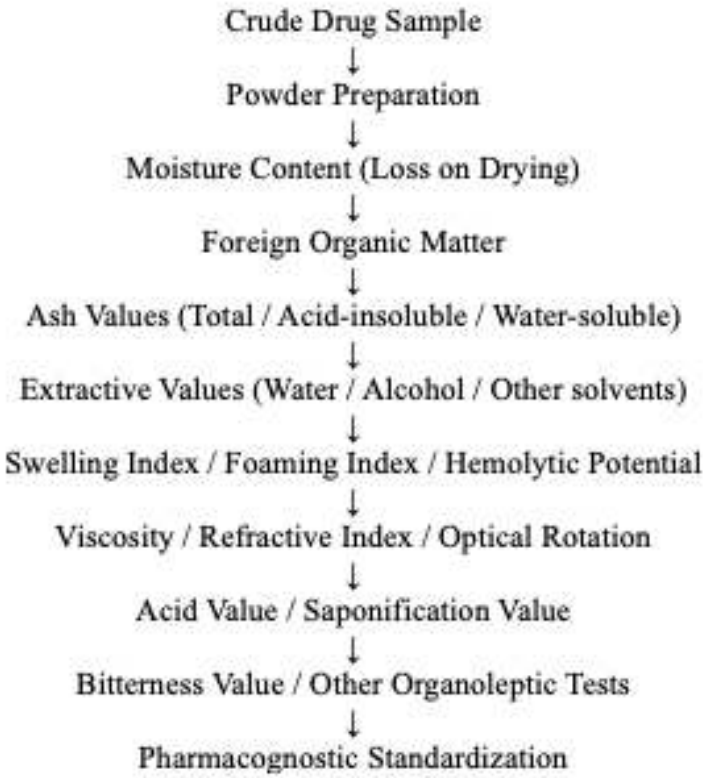
Definition: The mg of KOH needed to saponify 1 g of oil or fat.

Formula:

$$\text{Saponification value}=\frac{56.1\times(Vb-Vs)\times N}{W}$$

Where:

- VbV_bVb = Volume of KOH for blank
- VsV_sVs = Volume of KOH for sample
- N = Normality of KOH
- W = Weight of sample


Crude Drug Sample
Powder Preparation
Moisture Content (Loss on Drying)
Foreign Organic Matter
Ash Values (Total / Acid-insoluble / Water-soluble)
Extractive Values (Water / Alcohol / Other solvents)
Swelling Index / Foaming Index / Hemolytic Potential
Viscosity / Refractive Index / Optical Rotation
Acid Value / Saponification Value
Bitterness Value / Other Organoleptic Tests
Pharmacognostic Standardization

Chapter 14: Modern Quality Control Technique

1. DNA Barcoding of Medicinal Plants

Definition:

DNA barcoding is a method based on molecular biology that uses a small section of DNA to recognise and confirm plant species, even when the material is in powder form or has been processed.

Purpose:

- Detect **adulteration or substitution**.
- Confirm **authenticity of medicinal plants**.
- Useful when **morphological features are absent**.

Principle:

- A **standard DNA region** is amplified using **PCR**.
- Sequence is compared with **reference database** (GenBank, BOLD).

Common Barcode Regions:

Gene	Location	Features
rbcL	Chloroplast	Easy amplification, low variability
matK	Chloroplast	High variability, species-level discrimination
ITS	Nuclear DNA	Highly variable, useful for closely related species

Procedure (Brief):

1. **DNA Extraction** → Isolate DNA from plant material.
2. **PCR Amplification** → Amplify barcode region.
3. **Sequencing** → Determine nucleotide sequence.
4. **Sequence Comparison** → Match with database.
5. **Species Identification** → Confirm genuine plant or detect adulterants.

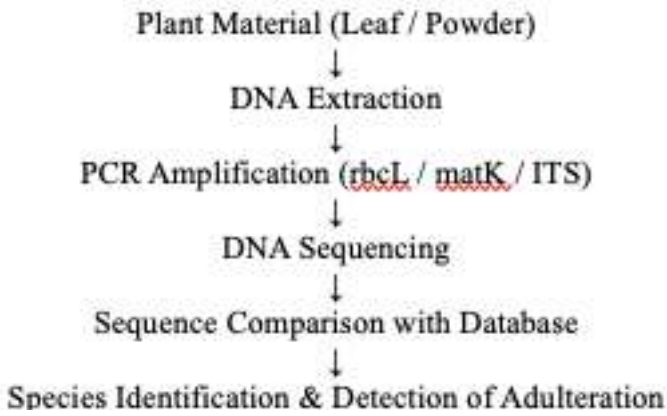
Advantages:

- Accurate, reproducible
- Works on processed/powdered drugs
- Detects closely related species

Limitations:

- Requires molecular lab and equipment
- Costly for routine use
- Does not indicate chemical quality

DNA Barcoding

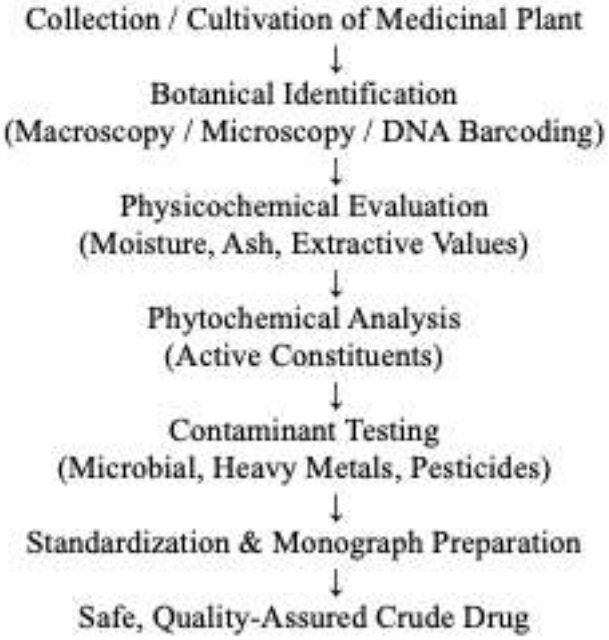


2. WHO Guidelines for Quality Control of Crude Drugs and Medicinal Plants

Objective:

To make sure that herbal medicines are safe, pure, effective, and of good quality.

Step	Description
Plant Identification	Correct botanical name, family, species; use **macroscopy, microscopy, DNA barcoding**.
Good Agricultural & Collection Practices (GACP)	Proper cultivation, harvesting, drying, storage; avoid contamination.
Physicochemical Evaluation	Moisture, ash, extractive values, bitterness, foaming index.
Phytochemical Analysis	Screening for active constituents (alkaloids, saponins, tannins, etc.).
Microbial & Contaminant Testing	Check for microbial load, heavy metals, pesticides, aflatoxins.
Standardization	Reference standards for active compounds; ensure consistent quality.
Documentation & Monograph	Botanical description, physicochemical data, chemical markers, traceability.



Parameter	Traditional Pharmacognosy	DNA Barcoding	WHO Guidelines
Purpose	Identification by morphology, microscopy	Molecular species identification	Standardization, quality, purity, safety
Material	Whole plant, leaf, powder	Fresh, dried, or powdered plant tissue	Fresh, dried, or processed crude drugs
Methods	Macroscopy, microscopy, physicochemical tests	PCR, sequencing, database comparison	Identification, physicochemical & phytochemical tests, contaminant analysis
Advantages	Simple, low cost	Accurate, works on powders	Comprehensive quality assurance
Limitations	Subjective, may fail in powders	Requires lab, expensive	Requires multiple tests, time-consuming

Standardisation Protocol of Crude Drugs

Standardisation is a planned, step-by-step process that keeps the quality, purity, safety, and effectiveness of a crude drug at a consistent level. The drug is checked through different scientific methods, and proper limits or standards are then fixed for it.

1. Identification (Authentication)

The very first step is to make sure the drug is genuine. For this, the following methods are used:

- Looking at outer features such as size, shape, colour, smell and taste
- Examining inner tissues with the help of a microscope
- Confirming the botanical (plant) source from which the drug has come

2. Detection of Foreign Matter
The sample is checked to see if it has any unwanted things mixed in it, such as dust, insects or parts of other plants. The quantity of such impurities is then expressed as a percentage of the whole.

3. Organoleptic Evaluation
Here the drug is examined with the help of sense organs. The following points are noted:

- Colour
- Smell
- Taste
- Texture
  This is a fast way to get an early idea about the drug.

4. Physical Evaluation
Several physical parameters of the drug are measured. The main ones are:

- Moisture content (so that the drug does not spoil during storage)
- Ash values (which help in finding inorganic impurities)
- Extractive values (which give a rough idea of the active constituents that dissolve in water or alcohol)

5. Chemical Evaluation
Chemical reactions are carried out so that active constituents like alkaloids, glycosides, tannins and flavonoids can be identified and their amounts measured. Modern tools such as chromatography are also used at this stage.

6. Biological Evaluation
In this step, the pharmacological activity of the drug is checked through bioassays or animal experiments. This proves whether the drug really gives the expected therapeutic effect.

7. Microbiological Evaluation
The drug is also tested for contamination by microbes such as bacteria and fungi. The aim is to keep harmful organisms within the safe limits given in the pharmacopoeia.

8. Toxicological Evaluation
This part of the work makes sure that the drug does not contain harmful substances such as:

- Heavy metals
- Pesticide residues
- Toxic compounds such as aflatoxins

9. Analytical Techniques
Newer methods like Thin Layer Chromatography (TLC), High Performance Liquid Chromatography (HPLC) and spectroscopy are applied to confirm the identity and purity of the drug by giving its chemical profile.

10. Stability Studies

The drug is kept under different conditions of temperature, light and humidity, and then studied. From these results, its shelf life and proper storage conditions are decided.

11. Reference Standards

All the values obtained are matched against the official limits given in pharmacopoeias such as the Indian Pharmacopoeia or in WHO guidelines.

UNIT IV
INTRODUCTION TO PLANT METABOLITES OF NATUAL ORIGIN & TRADITIONAL SYSTEMS OF MEDICINE

Chapter 15: Primary Metabolites

Definition

Primary metabolites are the chemical compounds made by living organisms that are needed for their normal growth, development and reproduction. They take part directly in the basic metabolic pathways of the body, and without them the organism cannot survive.

Carbohydrates as Primary Metabolites

Definition

Carbohydrates are organic compounds built from carbon, hydrogen and oxygen. They form a major class of primary metabolites because they supply energy and also give structural support to living organisms.

Characteristics

- General formula: $(CH_2O)n$
- In plants they are formed during photosynthesis
- Simple sugars usually dissolve in water
- Mono- and disaccharides have a sweet taste

Functions

- Act as the main fuel for energy
- Stored as energy reserves (starch in plants, glycogen in animals)
- Provide structure (cellulose builds the plant cell wall)

Sources

- Rice, wheat, potatoes, fruits, sugar

Chemical Tests for Carbohydrates

1. Molisch's Test (General test)

- Add Molisch reagent + concentrated H_2SO_4
- Observation: Violet/purple ring at junction
- Result: Presence of carbohydrates

2. Benedict's Test (Reducing sugars)

- Heat with Benedict's reagent
- Observation: Green → yellow → orange → brick-red precipitate
- Result: Presence of reducing sugars (e.g., glucose)

3. Fehling's Test

- Heat with Fehling's solution A & B
- Observation: Brick-red precipitate
- Result: Reducing sugars present

4. Iodine Test (Starch test)

- Add iodine solution
- Observation: Blue-black colour
- Result: Presence of starch

Carbohydrates are key primary metabolites that give the body energy and also help in building structures, and their presence in a sample can be checked through specific chemical tests.

Proteins as Primary Metabolites

Definition

Proteins are big organic molecules formed by joining amino acids together. They count as essential primary metabolites because they are required for growth, repair of tissues and almost every metabolic activity in living organisms.

Characteristics

- Made up of C, H, O, N (sometimes sulfur as well)
- Built from amino acids joined by peptide bonds
- Found in every living cell
- Have a complex structure

Functions

- Help in the growth and repair of body tissues
- Function as enzymes (the catalysts of biological reactions)
- Help in formation of hormones and antibodies
- Keep the structure and function of cells in order

Sources

- **Plant:** Pulses, soybean, legumes
- **Animal:** Milk, eggs, meat

Chemical Tests for Proteins

1. Biuret Test

- Add sodium hydroxide (NaOH) and copper sulfate ($CuSO_4$)
- Observation: Violet/purple colour
- Result: Presence of proteins

2. Ninhydrin Test

- Heat sample with ninhydrin reagent
- Observation: Blue or purple colour
- Result: Presence of amino acids/proteins

3. Xanthoproteic Test

- Add concentrated nitric acid and heat
- Observation: Yellow colour (turns orange with alkali)
- Result: Presence of aromatic amino acids

4. Millon's Test

- Add Millon's reagent and heat
- Observation: Red colour
- Result: Presence of tyrosine (protein)

Proteins are important primary metabolites that build the body, run its functions and take part in metabolism, and they can be detected by carrying out specific chemical tests.

Lipids as Primary Metabolites

Definition

Lipids are organic compounds which do not dissolve in water but dissolve well in organic solvents. They serve as important primary metabolites because they are involved in the storage of energy and in the formation of cell structure.

Characteristics

- Mainly built up of carbon, hydrogen and oxygen
- They are hydrophobic in nature
- Group includes fats, oils and waxes
- Carry a high amount of energy

Functions

- Serve as the main reserve store of energy
- Form a structural part of cell membranes (phospholipids)
- Give protection by acting as insulation and as a cushion around organs
- Help the body absorb the fat-soluble vitamins (A, D, E, K)

Sources

- **Plant sources:** Groundnut oil, coconut oil, seeds
- **Animal sources:** Butter, ghee, fish oil

Chemical Tests for Lipids

1. Grease Spot Test

- Lipid sample is placed on filter paper
- Observation: Permanent translucent (greasy) spot
- Result: Indicates presence of lipids

2. Sudan III Test

- Add Sudan III dye to the sample
- Observation: Red/orange coloration

- Result: Confirms lipids

3. Saponification Test

- Heat lipid with alkali (NaOH/KOH)
- Observation: Formation of soap and glycerol
- Result: Indicates presence of fats/oils

4. Emulsion Test

- Shake lipid with alcohol, then add water
- Observation: Milky white emulsion
- Result: Presence of lipids

Lipids are key primary metabolites which give energy, offer protection and help in cell structure, and their presence can be confirmed using definite chemical tests.

Chapter 16: Secondary Metabolite-I

Secondary metabolites are a varied group of organic compounds produced by plants, fungi and microorganisms. They are not strictly required for immediate survival of the organism (that is, for growth, development or reproduction), but they help in long-term fitness and in dealing with the environment.

Primary metabolites are present everywhere in the plant kingdom and take part in the basic energy-related cycles. Secondary metabolites, on the other hand, are usually specialised and are made when the plant is under specific ecological pressures.

Core Characteristics

- **Taxonomic Specificity:** Many of these compounds are limited to a particular species or family. Because of this, they serve as good chemical markers for botanical identification and chemotaxonomy.
- **Ecological Utility:** They mainly act as "chemical signals" or "defence weapons" of the plant. Their roles include:
    - **Antifeedants:** To deter herbivores.
    - **Phytoalexins:** To provide antimicrobial or antifungal protection.
    - **Allelochemicals:** To inhibit the growth of competing plant species.
    - **Attractants:** To draw in pollinators or seed dispersers.
- **Metabolic Origin:** They are synthesised from primary metabolic starting materials such as acetyl-CoA or amino acids, through specialised pathways like the Shikimic acid pathway, the Mevalonate pathway, or the Acetate-malonate pathway.

Alkaloids

Alkaloids are organic compounds occurring in nature, mainly in plants, including marine algae, and at times in animals also, for example in the toxic secretions given out by fire ants, ladybugs and toads. Within plants, they are mostly seen in seed-bearing types, especially in parts such as berries, bark, fruits, roots and leaves. From a structural point of view, an alkaloid usually carries at least one nitrogen atom inside a heterocyclic ring. This nitrogen gives the molecule a basic (alkali-like) character, and from this property the term "alkaloid" is derived.

These compounds show strong physiological effects in humans and other animals, and they are the active principles of many medicinal plants and plant-derived drugs. Among natural products, alkaloids stand out because of their structural variety and their wide range of physiological actions. A number of important drugs used in medicine and also in recreational use are natural alkaloids, for example atropine, strychnine, caffeine, nicotine, morphine, codeine and cocaine.

Receptors that respond to several alkaloids have also been detected in humans and other animals, which suggests that alkaloids may have an evolutionary part in physiological functions. Alkaloids are fairly stable substances, and they accumulate as by-products of different biosynthetic routes that mostly start from common amino acids such as tryptophan, lysine, ornithine and tyrosine. Although these compounds are usually colourless, some coloured alkaloids have been reported, for example berberine which is yellow, sanguinarine salt which is copper-red, and betanidin which is red (Kokate et al., 2005). They are crystalline

solids carrying a ring system, with definite melting points and a bitter taste. According to Biswas and Sharia (1978), Tanahashi et al. (2000) and Kashiwaba et al. (2000), alkaloids are seldom present in plants in glycosidic form; they may exist in the free state, as a salt, or as an N-oxide. Most alkaloids contain oxygen along with carbon, hydrogen and nitrogen. Some are oxygen-free, for example nicotine from tobacco and coniine from hemlock. With their salts the picture is generally reversed; for example, strychnine hydrochloride is more soluble in water than in organic solvents, but the free bases dissolve poorly in water and easily in organic solvents. Because most alkaloids carry a tertiary nitrogen in the structure, they are optically active. As a result, the different isomeric forms have different physical, chemical and pharmacological properties. For example, (+)-tubocurarine, isolated from Chondrodendron tomentosum (Bisset, 1992), shows muscle relaxant action, while its laevo isomer is much less active. The structural formulas of a few common alkaloids of plant origin are given in Figures 1 and 2.

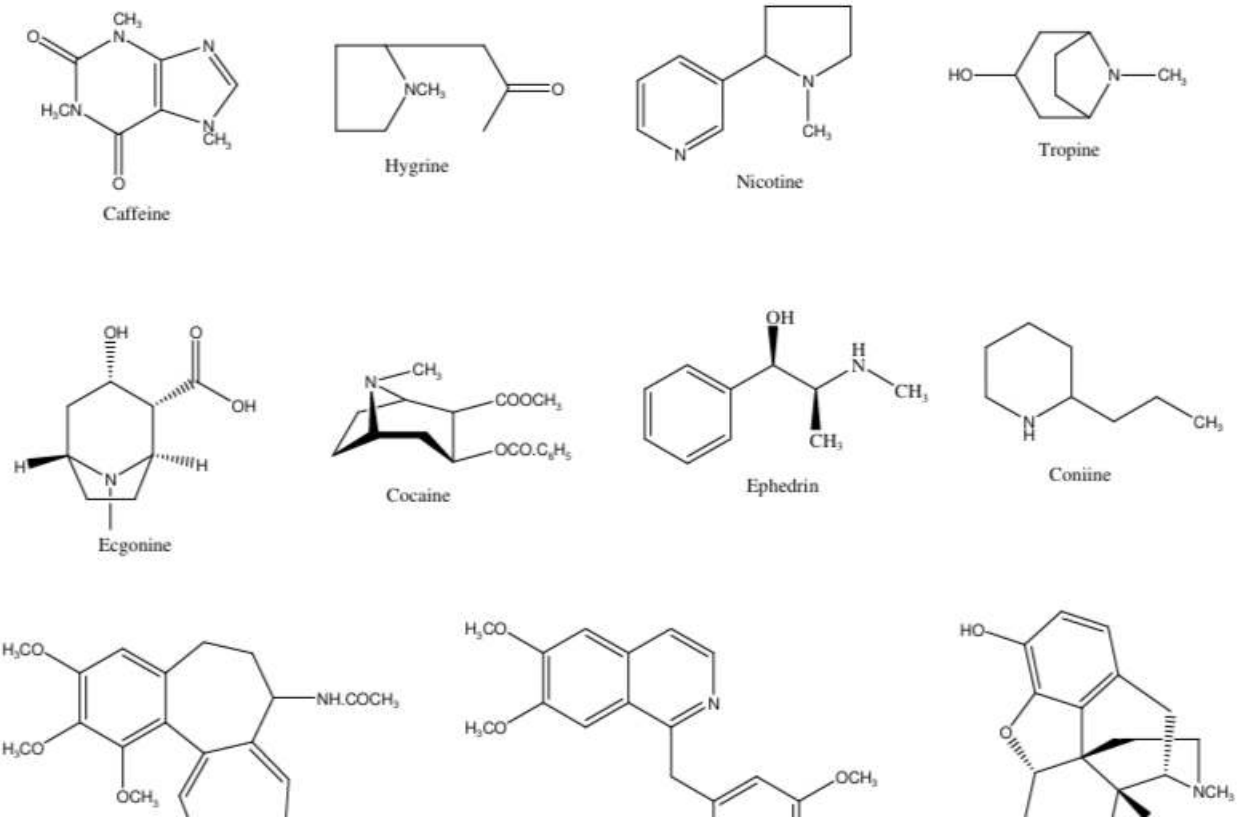


Fig. 1

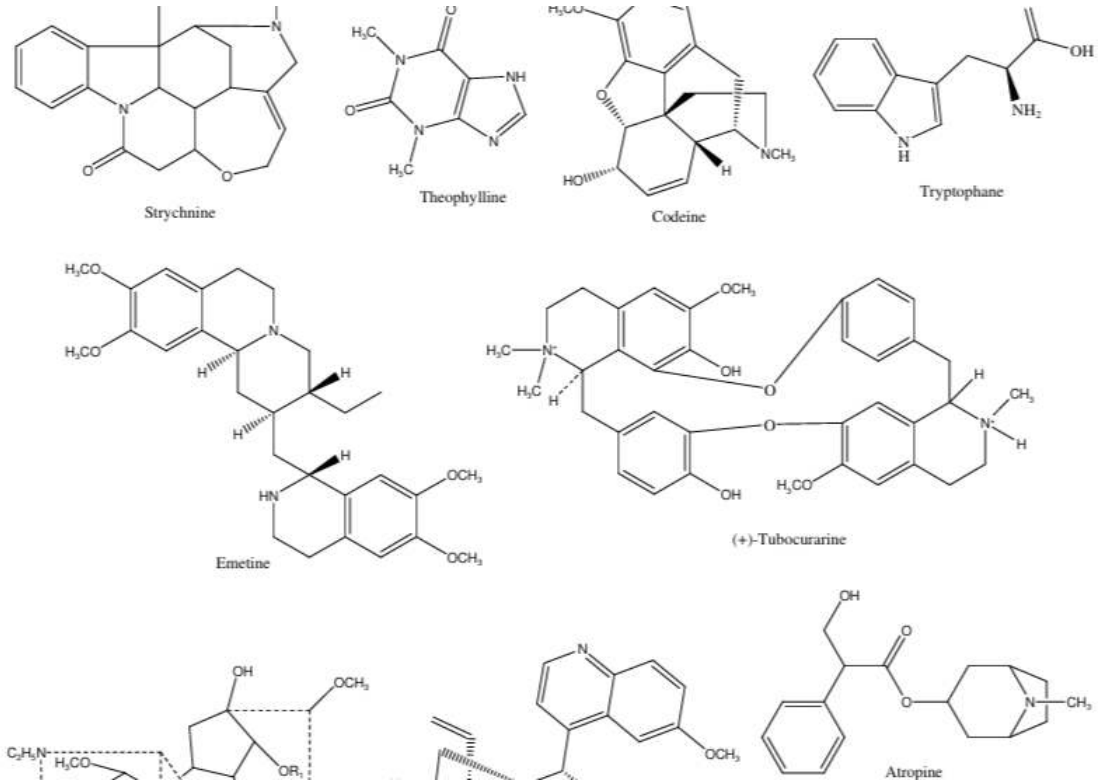


Fig. 2

DISTRIBUTION/ OCCURRENCE

Alkaloids are usually spread throughout all parts of a plant; sometimes, however, they get concentrated in certain organs and are absent from others. For instance, the edible tubers of the potato plant carry no alkaloid, whereas the green parts contain a toxic alkaloid called solanine. One should remember that the place where the alkaloid collects is not always the place where it is made. In tobacco, nicotine is produced in the roots and is then carried to the leaves where it gets stored.

Work on alkaloids started in the early 19th century. The French apothecary Derosne isolated narcotine in 1803, and Serturner isolated morphine in 1806. Since that time, more than 10,000 alkaloids have been reported from various natural sources. They are widely spread among plant groups, especially in orders like Centrospermae, Magnoliales, Ranunculales, Papaverales, Rosales, Rutales, Gentianales, Tubiflorae and Campanulales. True alkaloids are seldom found in lower plants. However, certain biologically active alkaloids have been reported in Pteridophytes and Gymnosperms, for example those from Lycopodium, Ephedra and Taxus. Fungi are also known to produce alkaloids such as lysergic acid and the sulphur-containing compound gliotoxin.

Alkaloids are not only found in plants and fungi; animals also produce them. Around 300 different alkaloids belonging to more than 24 structural classes have been detected in the skin of amphibians, and many of them are toxic. Highly poisonous neurotoxic alkaloids have been isolated from frogs of the genus Phyllobates. Antimicrobial alkaloids have also been reported from the skin of reptiles. Apart from that, certain indole and isoquinoline alkaloids, including some compounds similar to morphine, have been detected in mammals.

Classification of Alkaloids

Alkaloids may be grouped in several ways, depending on their source, structure or biological action. The main systems of classification are described below:

1. Taxonomical Classification

This system is based on the plant family in which the alkaloid is found. For example, the alkaloids occurring in the family Solanaceae are termed solanaceous alkaloids, while those of the family Papilionaceae are called papilionaceous alkaloids. In some cases the alkaloid is named after the genus in which it is commonly found, for example Ephedra or Cinchona.

2. Biosynthetic Classification

This grouping is based on the precursor from which the alkaloid is biosynthesised in the plant. Alkaloids that come from the same precursor are placed together, even if they differ in chemical structure or in biological activity. For example, the indole alkaloids derived from tryptophan form one group. In a similar way, alkaloids built from amino acids like ornithine, lysine, tyrosine, phenylalanine and tryptophan are placed in their respective groups.

3. Pharmacological Classification

Here alkaloids are placed in groups according to their action on living organisms, mainly animals. The categories include CNS stimulants or depressants, sympathomimetic agents, analgesics, purgatives and so on. This system looks only at the biological action and pays no attention to the chemical structure. It should be noted that alkaloids with similar structure may show very different effects. For example, morphine works as a narcotic analgesic, while quinidine acts as a cardiac depressant.

4. Chemical Classification

This is the most accepted and the most widely followed system, and it is based on the chemical structure of the alkaloid. The alkaloids are placed in three main groups:

- **True Alkaloids:** These have nitrogen inside a heterocyclic ring and are derived from amino acids.
- **Proto Alkaloids:** These come from amino acids but the nitrogen is not part of a heterocyclic ring (e.g., colchicine).
- **Pseudo Alkaloids:** These have nitrogen inside a heterocyclic ring, but they are not built from amino acids; instead they originate from compounds like terpenoids or purines.

S.No.	Class of Alkaloids	Basic Ring Structure (Simplified)	Example	Biological Source
1.	Pyrrole & Pyrrolidine	5-membered ring with 1 nitrogen (–NH)	Nicotine, Hygrine	*Erythroxylum coca*, Tobacco
2.	Pyridine & Piperidine	6-membered ring with 1 nitrogen	Piperine, Coniine	Black pepper, Hemlock
3.	Tropane	Bicyclic structure (tropane nucleus)	Atropine, Cocaine	*Atropa belladonna*, *Erythroxylum coca*
4.	Quinoline	Benzene fused with pyridine ring	Quinine	*Cinchona* bark
5.	Isoquinoline	Benzene fused with pyridine (different position)	Morphine, Berberine	Opium poppy, *Berberis*
6.	Indole	Benzene + pyrrole ring	Reserpine, Strychnine	*Rauwolfia*, *Strychnos*
7.	Imidazole	5-membered ring with 2 nitrogen atoms	Pilocarpine	*Pilocarpus*
8.	Purine	Fused imidazole + pyrimidine ring	Caffeine, Theobromine	Tea, Coffee, Cocoa
9.	Steroidal Alkaloids	Alkaloids Classification and Structures	Solanine	Potato, *Solanum*
10.	Terpenoid Alkaloids	Derived from terpenes (complex ring system)	Aconitine	Aconitum
11.	Quinazoline	Benzene fused with pyrimidine	Vasicine	*Adhatoda vasica*

Chemical Tests for Alkaloids

Most of the chemical tests for the detection of alkaloids depend on their property of forming salts with organic acids, which then come down as a precipitate. Alkaloids may also react with certain heavy metal compounds, such as those of mercury, gold and platinum, giving insoluble precipitates. However, a few alkaloids like caffeine are very soluble in water and may not give a positive response with these common reagents.

Reagents used for the detection of alkaloids

S.No	Name of Reagent	Chemical Composition	Colour Obtained	Example
1	Mayer's reagent	Potassium mercuric iodide solution	Cream	Common Alkaloids
2	Wagner's reagent	Solution of iodine in potassium iodide	Reddish-brown	Common Alkaloids
3	Dragendorff's reagent	Potassium bismuth iodide solution	Reddish-brown	Common Alkaloids
4	Hager's reagent	Saturated solution of picric acid	Yellow	Common Alkaloids
5	Picrolonic acid	Solution of picrolonic acid	Yellow	Common Alkaloids

6	Tannic acid	Solution of tannic acid	Precipitate	Common Alkaloids
7	Murexide test	Potassium chlorate + HCl + NH_3	Purple	Caffeine (Purines)
8	Mineral acids	Phosphotungstic / Phosphomolybdic acid	Yellow	Colchicine
9	Acidic p-dimethyl aminobenzaldehyde	p-Dimethyl-aminobenzaldehyde + H_2SO_4	Bluish-violet to red	Indole Alkaloids
10	Nitric acid	Dilute nitric acid	Orange-red	Morphine

Pharmacological Actions of Alkaloids

Alkaloids form a varied group of natural compounds and they show strong physiological effects on humans and animals. From very old times, plants containing alkaloids have been used both for medicinal and for poisonous purposes. History gives us striking examples; the Greek philosopher Socrates, for instance, died after taking hemlock that contained coniine, while Cleopatra is said to have used plant extracts containing atropine to make her pupils dilate.

Because of this strong biological activity, alkaloids hold an important place in modern medicine. They are used in many therapeutic areas, for example as analgesics (pain killers), stimulants, sedatives, muscle relaxants, anaesthetics, antimalarials, antimicrobials, antidiabetics and anticancer agents. A number of alkaloids also show antioxidant and antiviral effects.

Some plant-derived alkaloids show very useful pharmacological effects. For instance, compounds like proaporphines and crotsparine display hypotensive and anticancer activity, while some alkaloids isolated from certain plants act as molluscicides. Alkaloids such as caffeine and nicotine are popular stimulants and are taken in beverages and in tobacco respectively.

Several alkaloids show narcotic, analgesic or hallucinogenic actions. Some examples are:

- Morphine is a strong analgesic given for the relief of severe pain, particularly in terminal illness.
- Codeine has similar effects but is less potent.
- Quinine is widely used as an antimalarial drug.
- Atropine acts as a smooth muscle relaxant and is used in ophthalmology to dilate pupils.

Some alkaloids are used as templates for designing synthetic drugs, while others are linked with abuse because of their addictive nature. Cocaine, obtained from coca leaves, works both as a stimulant and as a local anaesthetic, but it is also strongly addictive. Heroin, which is a derivative of morphine, is another powerful and addictive substance.

A few alkaloids are extremely toxic and have no medicinal use. Coniine and strychnine are good examples; even small amounts of these can produce severe poisoning.

Several alkaloids also show specialised pharmacological effects, for example:

- Papaverine relaxes smooth muscles and is useful in treating spasms.
- Ergotamine, often combined with caffeine, is effective in managing migraines.
- Alkaloids from plants like Rauwolfia are used as sedatives and antihypertensive agents.
- Compounds from Tylophora and other genera have shown anticancer potential.
- Alkaloids from Holarrhena species are used in the treatment of dysentery.

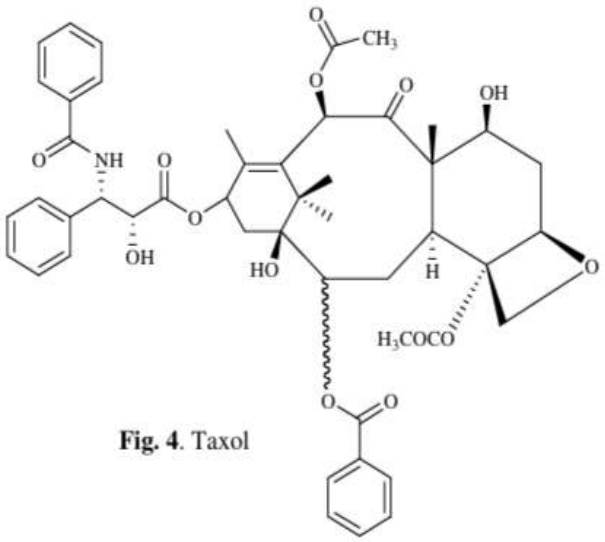


Fig. 4. Taxol

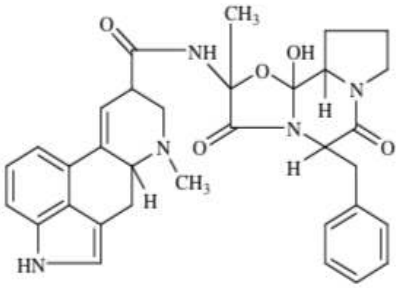


Fig. 5. Ergotamine

Extraction and Isolation of Alkaloids

The isolation of alkaloids is mostly based on their basic character and on the fact that they show different solubilities in different solvents. A few general methods are commonly used for their extraction:

1. Defatting and Stas–Otto Method

In this method the plant material (mostly seeds and leaves) is first treated with a non-polar solvent like petroleum ether so that fats and other lipid-soluble matter are removed. After the defatting step, the residue is taken up in a polar solvent. The extract is concentrated under reduced pressure, then made alkaline so that the alkaloids change into their free base form. These free bases are next taken into an organic solvent. This procedure is generally known as the Stas–Otto process and is commonly used for extracting alkaloids such as ergotamine.

2. Lime Treatment Method

Here the powdered drug is first wetted with water and mixed with lime, that is calcium hydroxide. The lime reacts with acids, tannins and phenolic substances and at the same time releases the alkaloids from their salt forms. The mixture is then taken with organic solvents like ether or petroleum spirit. The organic layer is shaken with dilute acid, so that the alkaloids pass into the aqueous phase as their salts, while the unwanted impurities stay back in the organic layer.

3. Acidic Extraction Followed by Precipitation

In this approach the plant material is extracted with acidified water or with aqueous alcohol. This makes the alkaloids dissolve as their salts. Unwanted matter such as pigments is then removed by shaking with organic solvents (for example, chloroform). The alkaloids are next changed into free bases by adding alkaline reagents like sodium bicarbonate or ammonia, and they come down as a precipitate. The precipitate may be collected by filtration or taken up further by solvent extraction.

4. Liberation of Free Bases and Solvent Extraction

In this method the extract that contains alkaloid salts is treated with ammonia, which converts them into free bases. These free alkaloids are then taken into organic solvents such as ether, chloroform or benzene. This method, however, cannot be used for quaternary alkaloids, because such alkaloids do not give free bases.

5. Reineckate Formation and Ion Exchange Method

In this method the alkaloids in the extract are made to react with Reinecke's reagent, which produces insoluble complexes called reineckates. The complexes are then dissolved in acetone and passed through an ion-exchange column. This step gives alkaloids in a highly purified form.

General Scheme for Extraction of Alkaloids

1. **Drying and Powdering** The crude plant material is first dried and then ground into a fine powder so that the surface area available for extraction goes up.
2. **Defatting (Removal of Lipids)** The powdered drug is shaken with a non-polar solvent such as petroleum ether to take out fats, waxes and other non-polar impurities.
3. **Extraction with Acidic Solvent** The defatted drug is now extracted with a dilute acid (for example, dilute hydrochloric acid or sulphuric acid). Since alkaloids are basic, they form water-soluble salts and pass into the aqueous layer.
4. **Filtration**
   The extract is filtered so that the insoluble plant residues are removed.
5. **Removal of Impurities** The acidic extract is shaken with organic solvents such as chloroform or ether. This step removes pigments, resins and other unwanted matter.
6. **Basification**
   The purified acidic solution is treated with an alkali (for example, ammonia or sodium carbonate). The alkaloid salts are now converted into free bases.
7. **Extraction with Organic Solvent** The free alkaloids are taken into organic solvents like chloroform, ether or benzene.
8. **Evaporation of Solvent** The organic solvent is then evaporated, and the crude alkaloids are obtained.
9. **Purification**
   Final purification is done by recrystallization, by chromatography, or by any other suitable method.

Further Purification of Crude Alkaloid Extract

Once the alkaloids have been extracted, the crude material is purified by different methods according to its chemical nature. The methods commonly used are:

1. Direct Crystallization

This is the easiest way of purification. The alkaloids are made to crystallise out from a suitable solvent through fractional crystallization. This approach, however, does not work well when the extract contains a complex mixture of several alkaloids.

2. Steam Distillation

This technique is mainly applied to volatile alkaloids like coniine, sparteine and nicotine. In the procedure, the aqueous extract is first made alkaline with sodium carbonate or caustic soda. The alkaloids are then carried over with steam and are collected after the vapours condense. The method, however, is not suitable for alkaloids that are non-volatile or have a high molecular weight.

3. Gradient pH Method

Different alkaloids show different degrees of basicity, and this property is used as the basis for separation. The crude mixture is dissolved in a weak acid, for example tartaric acid, and shaken first with an organic solvent so that the neutral or weakly basic compounds are removed. The pH of the solution is then raised step by step in small intervals (about 0.5 unit at a time), and at each step extraction is carried out. In this way the alkaloids get separated according to their increasing basic strength, with the strongly basic alkaloids coming out at higher pH values.

4. Chromatographic Techniques

Among all the methods, chromatography is one of the most efficient ways for separating and purifying alkaloids from complex mixtures. It always uses a stationary phase and a mobile phase.

a. Paper Chromatography (PC)

- A simple and widely used method for separation and identification.
- Works on both **partition and adsorption principles**.
- The stationary phase is the hydrophilic paper surface, while the mobile phase is a suitable solvent or solvent mixture.
- Non-polar solvents are used for non-polar alkaloids, while polar solvents are used for polar alkaloids.
- The paper is usually pre-treated to remove impurities.
- After development, spots are detected under UV light or by spraying reagents.
- Identification is based on **Rf values** and color of spots.

b. Thin Layer Chromatography (TLC)

- A highly useful method for **separation, identification, and purity testing** of alkaloids.
- Common stationary phases include **silica gel, alumina, or cellulose**, with silica gel being most widely used.
- It provides good resolution even with small sample quantities.
- Alkaloids are identified based on their movement (Rf value) in a solvent system and their response to detecting reagents or UV light.
- TLC can also be used for **preparative purposes** to isolate compounds.

Common Solvent Systems for Alkaloid Separation (TLC/PC)

Different solvent combinations are chosen depending on the polar or non-polar nature of the alkaloids. Some of the solvent systems often used are:

1. Benzene : Ethyl acetate : Diethylamine (5 : 4 : 1) with 8% methanol
2. Chloroform : Acetone : Diethylamine (7 : 2 : 1) with 8% methanol
3. Dimethylformamide : Diethylamine : Ethanol : Ethyl acetate (1 : 1 : 6 : 12)
4. Cyclohexane : Diethylamine (9 : 1 or 1 : 1)
5. Chloroform : Ethanol (9 : 1 or 8 : 2)
6. Xylene : Butanol : Methanol : Diethylamine (5 : 5 : 7 : 3)
7. Benzene : Ethyl acetate : Diethylamine (5 : 4 : 1 or 7 : 2 : 1)
8. Chloroform : Acetone : Diethylamine (7 : 2 : 1)
9. Chloroform : Methanol : Acetic acid (6 : 1 : 3)
10. Benzene : Chloroform : Acetone (14 : 3 : 3)
11. Chloroform : Diethyl ether : Water (7 : 1 : 2)
12. Hexane : Carbon tetrachloride : Diethylamine (5 : 4 : 1)

Detection of Alkaloids on TLC Plates

Once the development of the TLC plate is over, the plate is sprayed or dipped in a suitable visualising reagent in order to detect the alkaloids.

Many alkaloids can be seen straight away in daylight, while quite a few of them give a typical fluorescence under UV light at 365 nm, which makes their identification easier.

Common Visualizing Reagents for Alkaloids

The reagents listed below are commonly used for spotting alkaloids on chromatograms:

- **Dragendorff's reagent** – gives orange or reddish-brown spots
- **Acidified iodine solution** – produces brown-colored spots
- **Iodoplatinate reagent** – forms colored complexes
- **Antimony (III) chloride** – useful for specific alkaloids
- **Cerium sulfate in sulfuric acid** – general detection reagent
- **Cerium sulfate in phosphoric acid** – also used for visualization

Specific Reagents for Particular Alkaloids

- **Papaverine-type alkaloids** → produce **red coloration** when exposed to hydrogen chloride vapors
- **Rauwolfia alkaloids** → give color reactions with:
  - ferric chloride + perchloric acid mixture
  - iodine vapors
- **Phenylalkylamine alkaloids** → detected using **ninhydrin reagent**
- **Indole alkaloids** → visualized using **cinnamaldehyde–hydrochloric acid reagent**
- **Purine alkaloids and betaines** → detected with **sulfuric acid**
- **Ergot alkaloids** → identified using **Van Urk reagent**

Advanced Chromatographic Techniques for Alkaloid Purification

a. Preparative Thin Layer Chromatography (Preparative TLC)

In preparative TLC, the adsorbent layer is coated thicker, generally about 1 mm, in comparison with analytical TLC. After development, the bands of separated compounds are scraped off the plate, and the compounds are then recovered with the help of suitable solvents.

Through this method, enough quantity of pure compound can be obtained for further studies, for example spectral analysis. The technique has been used successfully for the isolation of alkaloids such as cryptopleurine and related compounds, on alumina-coated plates with appropriate solvent systems.

b. Column Chromatography (CC)

Column chromatography is one of the methods most often used for the separation and purification of alkaloids from complex plant extracts.

- It involves a column packed with a **stationary phase (adsorbent)** and a **mobile phase (solvent)**.
- The selection of adsorbent and solvent depends on the **chemical nature of the compounds**.

Common adsorbents:

- Silica gel (most commonly used)
- Neutral alumina
- Others: kieselguhr, cellulose, starch, dextran gels (Sephadex), bentonite, zirconium compounds, etc.

Elution principle:

- Non-polar compounds are eluted first using **non-polar solvents**
- Polar compounds require **more polar solvents**

Common solvents in increasing order of polarity: Petroleum ether → n-hexane → cyclohexane → carbon tetrachloride → benzene → chloroform → ether → ethyl acetate → alcohols → water

Typical solvent systems:

- Petroleum ether : chloroform
- n-hexane : chloroform
- Benzene : chloroform
- Methanol : chloroform
- Methanol : ethyl acetate
- Petroleum ether : ethyl acetate : diethylamine

c. Gas Liquid Chromatography (GLC)

GLC is applied for the separation of alkaloids that are volatile and thermally stable.

- A gaseous mobile phase carries the sample through a liquid stationary phase.
- Suitable for alkaloids such as those found in opium, tobacco, and belladonna.

Derivatization:

In order to improve volatility and stability, alkaloids are often modified chemically (for example, by silylation). Some of the common derivatising agents are:

- Trimethylchlorosilane

- Hexamethyldisilazane
- N,O-bis(trimethylsilyl)acetamide

d. High Performance Thin Layer Chromatography (HPTLC)

HPTLC is an improved form of TLC and gives:

- Better resolution
- Faster analysis
- Lower solvent consumption

The main difference from ordinary TLC lies in the smaller particle size of the adsorbent and in the better quality of the layer used.

It is used for both **qualitative and quantitative analysis** of alkaloids and other natural products.

HPTLC is widely applied for profiling compounds such as **berberine, quinine, morphine, colchicine, and many others**.

e. High Performance Liquid Chromatography (HPLC)

HPLC is one of the most powerful and dependable techniques used in alkaloid analysis.

- Separation is based on interaction between compounds and the **stationary phase** along with their **UV absorption properties**.
- It provides **high sensitivity, accuracy, and reproducibility**.

Applications:

- Quantitative and qualitative analysis of alkaloids like morphine, codeine, papaverine, emetine, and ergot alkaloids
- Widely used in pharmaceutical and research laboratories

Advantages:

- Fast and precise
- Highly sensitive
- Suitable for complex mixtures

S.No	Test Name	Reagent	Observation	Principle
1	Mayer's Test	Potassium mercuric iodide solution	Cream-colored precipitate	Alkaloids form insoluble complexes with mercuric ions
2	Dragendorff's Test	Potassium bismuth iodide solution	Orange-red precipitate	Alkaloids react with bismuth ions to form insoluble salts
3	Hager's Test	Saturated picric acid solution	Yellow precipitate	Alkaloids form insoluble salts with picric acid
4	Wagner's Test	Iodine in potassium iodide solution	Reddish-brown precipitate	Alkaloids react with iodine to give insoluble iodides

5	Tannic Acid Test	1% Tannic acid solution	White or pale precipitate	Alkaloids form insoluble complexes with tannic acid

Glycosides

Glycosides are organic compounds occurring in plants or in animals which, on enzymatic or acidic hydrolysis, give one or more sugar units along with a non-sugar fragment. The sugar part is termed the glycone, while the non-sugar part is known as the aglycone or genin.

Structurally, a glycoside is a sugar unit joined to another group through its anomeric carbon by a glycosidic bond. This bond is a particular kind of chemical link that connects a sugar molecule to a non-sugar molecule.

Properties of Glycosides

- Inside plants, glycosides are made and broken down with the help of specific enzymes.
- They may occur in either crystalline or amorphous form.
- Glycosides usually dissolve in water or in alcohol, but they do not dissolve in non-polar organic solvents like benzene and ether.
- The aglycone fraction, on the other hand, is generally soluble in organic solvents such as benzene or ether.
- They can be hydrolysed by water, by acids or by enzymes.
- Glycosides show optical activity, which means they can rotate the plane of polarised light.
- Glycosides as such do not reduce Fehling's solution; however, the simple sugars set free during hydrolysis do reduce it and give a red precipitate of cuprous oxide.
- The sugars present in glycosides may exist as α and β isomers, but in most natural glycosides the β-form of the sugar is found.
- The word "glycoside" is a broad term and covers every combination of a sugar (glycone) part with a non-sugar (aglycone) part.

Classification of Glycosides

Glycosides may be grouped on the basis of (1) the kind of glycosidic bond, (2) the type of sugar (glycone) involved, and (3) the kind of non-sugar (aglycone or genin) attached.

1. Type of Glycosidic Bond

- **C-glycosides:**
  These are seen in some anthraquinone glycosides, for example the cascarosides (from cascara) and aloin (from aloe). Here the sugar is joined directly to a carbon atom of the aglycone.
- **Reaction: Glycone-OH + HC-Aglycone → Glycone-C-Aglycone + H_2O**
- **O-glycosides:**
  These are common in higher plants like senna and rhubarb. In them the sugar is linked to the aglycone through an oxygen atom.
- **Reaction: Glycone-OH + HO-Aglycone → Glycone-O-Aglycone + H_2O**

- **S-glycosides:**
  These occur in compounds such as sinigrin (an isothiocyanate glycoside). They are formed when the hydroxyl group of the sugar reacts with a sulphhydryl group on the aglycone.
- **Reaction: Glycone-OH + HS-Aglycone → Glycone-S-Aglycone + H_2O**
- **N-glycosides:**
  The nucleosides are typical examples of this group. Here the sugar reacts with an amino group of the aglycone, and a nitrogen-linked glycosidic bond is formed. **Reaction: Glycone-OH + NH-Aglycone → Glycone-N-Aglycone + H_2O**

2. Type of Glycone (Sugar) Part

- The name of the glycoside is decided by the sugar portion present:
  - **Glucose → glucoside**
  - **Fructose → fructoside**
  - **Glucuronic acid → glucuronide**
- In living systems, toxic compounds are frequently joined to glucuronic acid so that they become more water-soluble. The glucuronides so formed can then be removed from the body.

3. Type of Aglycone/Genin (Non-Sugar) Part

- Steroidal glycosides (Cardiac glycosides): In this group the aglycone fragment carries a steroidal nucleus.
  - Found in plants like **Digitalis, Scilla, and Strophanthus**.
  - These glycosides are used in medicine for treating heart conditions like congestive heart failure and arrhythmias.

Identification Tests for Glycosides

Glycosides are made up of a sugar fragment (the glycone) joined with a non-sugar fragment (the aglycone). Different chemical tests are applied for their identification, depending on their structure and class.

1. General Test (Hydrolysis Test)

Glycosides can be split into a sugar and an aglycone by heating with dilute acids.

Method:

The drug extract is boiled with dilute hydrochloric acid or with sulphuric acid. After hydrolysis, the solution is neutralised, and then it is tested for the presence of sugar.

Result:

If reducing sugars are formed, as confirmed by the Fehling's test or the Benedict's test, the presence of glycosides is indicated.

2. Tests for Cardiac Glycosides

Keller–Killiani Test

This test is used to detect the deoxy sugars present in cardiac glycosides.

Method:
The extract is treated with glacial acetic acid containing ferric chloride. After this, concentrated sulphuric acid is added carefully along the side of the test tube.
Result:
A brown ring shows up at the junction of the two layers, and a bluish-green colour may appear in the upper layer. This confirms a positive test.

Legal's Test
Method:
The extract is mixed with sodium nitroprusside and pyridine, and then made alkaline.
Result:
The development of a pink to red colour confirms the presence of cardiac glycosides.

Baljet Test
Method:
The extract is treated with sodium picrate solution.
Result:
Development of an orange color indicates a positive test.

3. Tests for Anthraquinone Glycosides
Borntrager's Test
Method:
The drug is boiled with dilute acid and then taken into an organic solvent like benzene or chloroform. Ammonia solution is added afterwards to the organic extract.
Result:
A pink to red colour appearing in the alkaline (ammonia) layer shows that anthraquinone glycosides are present.

Modified Borntrager's Test
This is used for glycosides that are not easily hydrolyzed.
Method:
The sample is first treated with ferric chloride and hydrochloric acid; it is then extracted and tested as in the Borntrager's test.
Result:
The appearance of a red colour confirms the presence of such glycosides.

4. Tests for Saponin Glycosides
Foam Test
Method:
The extract is shaken vigorously with water.
Result:
If a stable foam forms which lasts for several minutes, it points to the presence of saponins.

Hemolysis Test
Method:
The extract is added to a blood sample on a slide.
Result:
If the red blood cells break down, the presence of saponins is confirmed.

5. Test for Cyanogenic Glycosides
Sodium Picrate Test
Method:
A strip of sodium picrate paper is exposed to the extract.
Result:
A change in colour from yellow to brick-red indicates the release of hydrogen cyanide and confirms the presence of cyanogenic glycosides.

6. Tests for Flavonoid Glycosides
Shinoda Test
Method:
The extract is treated with magnesium turnings and concentrated hydrochloric acid.
Result:
Development of a pink, red or orange colour indicates the presence of flavonoids.

Alkaline Reagent Test
Method:
The extract is treated with sodium hydroxide solution.
Result:
A yellow colour that disappears when acid is added confirms the presence of flavonoids.

Flavonoids

Definition
Flavonoids form a big group of polyphenolic compounds occurring naturally in plants. They give the colour to many flowers, fruits and leaves. Their basic structure carries two aromatic benzene rings linked by a three-carbon bridge, and this bridge usually closes into a pyran ring.

Classification of Flavonoids
Flavonoids are placed in different groups according to their chemical structure, especially the oxidation state of the central pyran ring.

1. Flavones
- **Structure:** Double bond between C2 and C3, ketone at C4
- **Examples:** Apigenin, Luteolin

- **Sources:** Parsley, celery

2. Flavonols

- **Structure:** Similar to flavones but with an additional hydroxyl group at C3
- **Examples:** Quercetin, Kaempferol
- **Sources:** Tea, onions, apples

3. Flavanones

- **Structure:** Saturated bond between C2 and C3
- **Examples:** Hesperidin, Naringenin
- **Sources:** Citrus fruits

4. Flavanols (Flavan-3-ols)

- **Structure:** No double bond and no ketone group
- **Examples:** Catechin, Epicatechin
- **Sources:** Green tea, cocoa

5. Anthocyanidins

- **Structure:** Positively charged oxygen (flavylium ion)
- **Examples:** Cyanidin, Delphinidin
- **Sources:** Berries, grapes

6. Isoflavones

- **Structure:** B-ring attached at position 3 of C-ring
- **Examples:** Genistein, Daidzein
- **Sources:** Soybean

7. Chalcones

- **Structure:** Open-chain structure (no central ring)
- **Examples:** Phloretin
- **Sources:** Apples, tomatoes

Identification Test

S. No.	Test Name	Procedure	Observation	Inference
1	Shinoda Test	Add magnesium ribbon and concentrated HCl to alcoholic extract	Pink, red, or orange color	Presence of flavonoids (flavonols, flavones)
2	Alkaline Reagent Test	Add NaOH solution to extract, then add dilute acid	Yellow color turns colorless on adding acid	Presence of flavonoids
3	Lead Acetate Test	Add lead acetate solution to extract	Yellow precipitate	Confirms flavonoids

4	Ferric Chloride Test	Add $FeCl_3$ solution to extract	Green, blue, or black coloration	Presence of phenolic compounds including flavonoids
5	Zinc–HCl Reduction Test	Add zinc dust and HCl to extract	Red coloration	Presence of flavonoids
6	Ammonia Test	Add ammonia solution and observe under UV light	Yellow fluorescence	Presence of flavonoids
7	Sulfuric Acid Test	Add concentrated H_2SO_4 to extract	Orange or yellow color	Indicates flavonoids

Tannins

Tannins are polyphenolic compounds of high molecular weight which occur naturally in plants. They have the property of bringing down proteins from solution and also of forming complexes with them.

They are responsible for the **astringent taste** of many plant materials and play a protective role in plants.

Classification of Tannins

Tannins are mainly classified into the following types:

1. Hydrolysable Tannins

Definition:

These are tannins which can be split by acids or by enzymes into simpler products like gallic acid or ellagic acid, along with sugar.

Subtypes:

- **Gallotannins** → yield **gallic acid**
- **Ellagitannins** → yield **ellagic acid**

Examples:

- Tannic acid
- Myrobalan

Properties:

- Easily hydrolyzed
- Less complex structure

2. Condensed Tannins (Non-hydrolysable tannins)

Definition:

These tannins are not easily broken down by hydrolysis, and they are formed by polymerisation of flavonoid units.

Also called: Proanthocyanidins

Examples:

- Catechin
- Quebracho tannin

Properties:

- Resistant to hydrolysis
- On strong heating, give **red insoluble products (phlobaphenes)**

3. Complex Tannins

Definition:

These tannins carry both hydrolysable and condensed tannin units in the same molecule.

Examples:

- Some plant tannins that contain both **gallic acid and catechin units**

Identification Test

S. No.	Test Name	Procedure	Observation	Inference
1	Ferric Chloride Test	Add neutral $FeCl_3$ solution to the extract	Blue-black (hydrolysable) or greenish-black (condensed) color	Presence of tannins and differentiation of type
2	Gelatin Test	Add 1% gelatin solution with NaCl to extract	White precipitate	Presence of tannins (protein precipitation)
3	Lead Acetate Test	Add lead acetate solution to extract	White or bulky precipitate	Confirms tannins
4	Potassium Dichromate Test	Add potassium dichromate solution to extract	Yellow precipitate	Presence of tannins
5	Goldbeater's Skin Test	Treat skin with HCl, dip in extract, then add $FeSO_4$	Brown or black coloration	Positive test for tannins
6	Matchstick (Catechin) Test	Dip matchstick in extract, dry, add HCl and warm	Red color	Indicates condensed tannins

Definition of Tannins

Tannins are polyphenolic compounds occurring naturally, mostly in plants, and they have the property of precipitating proteins and of forming complexes with macromolecules such as cellulose and with minerals. They are responsible for the astringent taste of many plant materials, and they also help the plant in defence against herbivores and microorganisms.

Classification of Tannins

Tannins are mainly placed into two large groups, based on their chemical structure and behaviour:

Class	Sub-type	Characteristics	Examples	Sources
Hydrolysable Tannins	Gallotannins	Yield gallic acid on hydrolysis	Tannic acid	Gall nuts, sumac
	Ellagitannins	Yield ellagic acid on hydrolysis	Ellagic acid derivatives	Pomegranate, oak bark

Condensed Tannins (Non-hydrolysable)	Proanthocyanidins	Do not hydrolyze easily; give red color on heating with acids	Catechin, epicatechin	Tea, cocoa, bark
Complex Tannins	—	Contain both hydrolysable and condensed tannin units	Mixed structures	Some medicinal plants

Identification Tests

S.No.	Test Name	Procedure	Observation	Inference
1.	Ferric Chloride Test	Add few drops of ferric chloride solution to the extract	Blue-black or greenish-black color	Presence of tannins (type indicated)
2.	Gelatin Test	Add 1% gelatin solution with sodium chloride to the extract	White precipitate forms	Presence of tannins
3.	Lead Acetate Test	Add lead acetate solution to the extract	Bulky white precipitate	Presence of tannins
4.	Potassium Dichromate Test	Add potassium dichromate solution to the extract	Yellow or brown precipitate	Presence of tannins
5.	Goldbeater's Skin Test	Treat skin with HCl, rinse, add extract, then add ferrous sulfate	Brown or black coloration	Presence of true tannins
6.	Matchstick Test	Dip matchstick in extract, dry, add conc. HCl, and warm	Red coloration on matchstick	Presence of condensed tannins
7.	Vanillin-HCl Test	Add vanillin reagent with hydrochloric acid to the extract	Pink or red color develops	Presence of catechin-type tannins

Chapter 17: Secondary Metabolites-II

Secondary metabolites are organic compounds made by plants, microorganisms or animals which do not directly take part in normal growth, development or reproduction. Even so, they have important jobs in defence, protection and ecological interactions.

Terpenoids

Terpenoids form a large class of natural organic compounds. They are built from isoprene units which have been chemically changed, for example through oxidation or rearrangement of carbon skeletons.

Classification of Terpenoids

S.No.	Class	Number of Isoprene Units	Carbon Atoms	Examples
1.	Hemiterpenoids	1	C_5	Isoprene
2.	Monoterpenoids	2	C_{10}	Menthol, Limonene
3.	Sesquiterpenoids	3	C_{15}	Farnesol, Artemisinin
4.	Diterpenoids	4	C_{20}	Phytol, Retinol
5.	Sesterterpenoids	5	C_{25}	Geranylfarnesol
6.	Triterpenoids	6	C_{30}	Squalene, Lanosterol
7.	Tetraterpenoids	8	C_{40}	Carotenoids (β-carotene)
8.	Polyterpenoids	Many	$>C_{40}$	Natural rubber

Identification Tests for Terpenoids

S.No.	Test Name	Procedure	Observation	Inference
1.	Salkowski Test	Add chloroform to extract, then carefully add concentrated sulfuric acid	Reddish-brown coloration at interface	Presence of terpenoids
2.	Liebermann–Burchard Test	Add acetic anhydride and concentrated sulfuric acid to extract	Blue-green or reddish color develops	Presence of terpenoids/steroids
3.	Copper Acetate Test	Add copper acetate solution to the extract	Emerald green color appears	Presence of diterpenes
4.	Sulfur Test	Heat extract with sulfur	Formation of characteristic odor	Indicates presence of terpenoids
5.	Carr-Price Test	Add antimony trichloride in chloroform to the extract	Blue color develops	Presence of carotenoids (tetraterpenoids)

Volatile Oils (Essential Oils)

Volatile oils are aromatic substances that evaporate quickly. They are obtained mainly from plants and a few animal sources. Since they vaporise even at room temperature, they are also called volatile or ethereal oils. Because they hold the typical smell and many of the active constituents of the plant, the name essential oils is used as well.

In most plants these oils are kept inside special structures. They may be stored in oil ducts (for example in fruits of umbelliferous plants), in oil glands (such as those seen in the peels of citrus fruits like lemon and orange), in mesophyll cells (e.g., eucalyptus leaves) and in glandular trichomes.

Sometimes the volatile oil is not present in a free form; it is produced through enzyme action. A good example is black mustard seed, which has no noticeable smell at first. But the moment the seeds are crushed in the presence of water, the enzyme myrosinase acts on the glycoside sinigrin and releases allyl isothiocyanate, which has a sharp smell. The reason is that the enzyme and its substrate are kept in different parts of the plant cell, and they meet only when the cell is broken.

Volatile oils dissolve well in organic solvents like ether, chloroform and alcohol, but they are practically insoluble in water. They have the ability to dissolve other plant constituents such as fixed oils, resins, camphor and free alkaloids.

Chemically, volatile oils are mostly made of terpenes (mainly monoterpenes and sesquiterpenes) along with their oxygenated derivatives. Usually they are colourless liquids with a typical aroma. Most of them float on water (though some, like clove oil, are heavier), they show a high refractive index, and they are optically active.

When kept in air or light, volatile oils slowly oxidise and may turn darker in colour. Unlike fixed oils, they do not leave a permanent oily stain on paper, and they cannot be turned into soap, that is, they are non-saponifiable.

Classification of Volatile Oils

Volatile oils may be grouped on the basis of their chemical composition, the functional groups they carry, and their biosynthetic origin.

1. Classification Based on Chemical Composition

Class	Description	Examples
Hydrocarbons	Contain only carbon and hydrogen	Limonene, Pinene
Oxygenated Compounds	Contain oxygen along with hydrocarbons	Linalool, Menthol
Sulphur-containing Compounds	Contain sulphur atoms	Mustard oil, Garlic oil
Nitrogen-containing Compounds	Contain nitrogen atoms	Bitter almond oil
Class	Description	Examples

2.Classification Based on Functional Groups

Functional Group	Description	Examples
Alcohols	Contain –OH group	Menthol, Geraniol
Aldehydes	Contain –CHO group	Citral, Cinnamaldehyde
Ketones	Contain carbonyl group (C=O)	Camphor, Carvone
Phenols	Aromatic compounds with –OH	Eugenol, Thymol
Esters	Formed from acid + alcohol	Linalyl acetate
Oxides	Contain oxygen bridge	Cineole
Lactones	Cyclic esters	Coumarin

3. Classification Based on Biosynthetic Origin

Class	Description	Examples
Terpenoid Oils	Derived from isoprene units	Menthol, Camphor
Phenylpropanoid Oils	Derived from phenylpropane structure	Eugenol, Cinnamaldehyde
Class	Description	Examples

4. Classification Based on Consistency

Type	Description	Examples
Liquid Oils	Remain liquid at room temperature	Peppermint oil
Semi-solid Oils	Partially solidify	Rose oil
Solid Oils (Stearoptenes)	Solid components separated from oil	Camphor

Identification test

Test Name	Procedure	Observation	Inference
Spot Test (Filter Paper Test)	Place a drop of the oil on filter paper and allow it to evaporate.	No permanent greasy stain remains.	Confirms volatile nature (distinguishes from fixed oils).
Odour Test	Smell a small quantity of the oil.	Characteristic pleasant aroma is detected.	Indicates presence of volatile (essential) oil.
Solubility Test	Add oil to alcohol (90% or higher).	Oil dissolves completely in alcohol.	Volatile oils are soluble in alcohol.
Sudan III Test	Add a few drops of Sudan III reagent to the oil.	Red coloration appears.	Indicates presence of oil (lipid nature).
Steam Volatilization Test	Heat the oil with water and pass steam.	Oil vaporizes with steam and condenses separately.	Confirms volatile nature of oil.

Reaction with Alkali (Saponification Test)	Treat oil with alcoholic KOH.	No soap formation or only slight reaction.	Differentiates volatile oils from fixed oils (which form soap).
Iodine Test	Add iodine solution to the oil.	Slight or no decolorization.	Shows low unsaturation compared to fixed oils.
Refractive Index Test	Measure refractive index using refractometer.	Specific range for each oil.	Helps in identification and purity assessment.

Resins

Resins are amorphous, solid or semi-solid natural substances obtained from plants. They are formed mainly as the oxidation products of terpenoids. Resins do not dissolve in water, but they dissolve in organic solvents such as alcohol, ether and chloroform. On heating they soften first and then melt completely.

Classification of Resins

Resins are divided into types mainly on the basis of their chemical make-up and the substances that occur along with them:

1. True Resins

- Made up of resinous matter only, with no other component
- Generally hard, brittle and clear in appearance
- **Example:** Colophony (Rosin)

2. Oleoresins

- A mixture of resin together with volatile oil
- Soft in consistency and have a typical odour
- **Example:** Turpentine

3. Gum Resins

- Made up of resin along with gum
- Partly soluble in water because of the gum portion
- **Example:** Gamboge

4. Oleo-gum Resins

- Contain resin, gum and volatile oil together
- They show the properties of all three components
- **Example:** Asafoetida, Myrrh

5. Balsams

- Resins which contain benzoic acid, cinnamic acid or their esters

- Have a pleasant smell and useful medicinal properties
- **Example:** Benzoin, Tolu balsam

6. Glycoresins (Resin Glycosides)

- Resins joined with sugar units (glycosides)
- Many of them show a purgative action
- **Example:** Jalap

Class	Composition	Characteristics	Examples
True Resins	Only resin	Hard, brittle, amorphous, insoluble in water	Colophony (Rosin)
Oleoresins	Resin + Volatile oil	Soft, aromatic, semi-liquid	Turpentine
Gum Resins	Resin + Gum	Partially soluble in water, sticky	Gamboge
Oleo-gum Resins	Resin + Gum + Volatile oil	Show combined properties of all components	Asafoetida, Myrrh
Balsams	Resin + Benzoic/Cinnamic acid or esters	Pleasant odor, medicinal value	Benzoin, Tolu balsam
Glycoresins	Resin + Sugar (glycoside)	Often show purgative action	Jalap

Identification Tests

Test Name	Procedure	Observation	Inference
Solubility Test	Dissolve resin in water and organic solvents (alcohol, ether).	Insoluble in water, soluble in organic solvents.	Confirms resin nature.
Heat Test	Heat a small quantity of resin.	Softens, melts, and may burn with smoky flame.	Indicates resinous substance.
Alcohol Test	Add resin to alcohol and shake.	Forms a clear or slightly turbid solution.	Shows solubility in alcohol.
Ferric Chloride Test	Add $FeCl_3$ solution to alcoholic extract.	Yellow, green, or brown coloration.	Indicates presence of phenolic groups in resins.
Acetone Test	Dissolve resin in acetone.	Readily dissolves.	Confirms resin property.
Water Test	Add resin to water.	Forms a turbid mixture or sinks without dissolving.	Shows water insolubility.
Alkali Test	Treat with dilute alkali (NaOH/KOH).	Resin dissolves forming a clear solution.	Indicates presence of resin acids.

Chapter 18: Traditional System Of Medicine

Traditional Systems of Medicine

As defined by the World Health Organization (WHO), traditional medicine covers a broad set of beliefs, knowledge, and healthcare practices. It includes remedies derived from plants, animals, and minerals, together with spiritual treatments, manual techniques, and bodily exercises. People use these methods to keep themselves healthy and also to prevent, identify, and treat various illnesses.

Types Of TSM (AYUSH)

•A-AYURVEDA
•Y-YOGA T NATUROPATHY
•U-UNANI
•S-SIDDHA
•H-HOMEOPATHY

Ayurveda

Ayurveda is a natural healing tradition that began in India over 3,000 years ago. The word itself comes from two Sanskrit roots — ayur (life) and veda (science or knowledge) — so Ayurveda means the science of life. It views illness as resulting from imbalance or stress within a person's consciousness, and so it suggests lifestyle changes and natural therapies that bring back harmony among body, mind, spirit, and surroundings.

Principle:

- Ayurveda's principle rests on five fundamental elements known as the Panchamahabuthas — Prithvi (Earth), Jala (Water), Teja (Fire), Vayu (Air), and Akash (Space/Ether) — together with the three doshas: Vata, Pitta, and Kapha.
- Apart from these three humours, the body is described as having seven essential tissues called sapthadhatus — Rasa, Rakta, Mamsa, Meda, Asthi, Majja, and Shukra — along with three waste materials (mala): faeces, urine, and sweat.
- These elements come together in balanced proportions that suit each structure and function of the body matrix and its parts. Growth and development of this matrix depend on its nutrition, that is, on food. The food itself is also made up of these same elements.
- Diagnosis is carried out by treating the patient as a whole — through what is called the ten-fold examination. In this approach, the physician evaluates the following parameters in the patient:
  - Psychosomatic constitution
  - Disease susceptibility
  - Quality of tissues
  - Body build Anthropometry
  - Adaptability
  - Mental health
  - Digestive powers
  - Exercise

- Age
- Apart from this, the doctor also checks pulse, urine, stool, tongue, voice and speech, skin, eyes, and the patient's general appearance.

Siddha Medicine

- The word 'Siddha' comes from the root 'Siddhi', which carries the meaning of perfection or an object that has to be attained.
- Siddha medicine traces its origin to the medicinal practices and ideas developed by a group of Tamil sages known as the Siddhars, often called 'perfected ones' or 'holy immortals'.
- They held a strong belief that the deathless physical body could remain in tune with the spiritually immortal soul.
- **Basic Human Principles -** 96 Thathuvas Five Elements
  The primordial elements are called panchamahabootham, namely mann(earth), Agni Prithavi Jala
  • neer(water), . thee (fire),
  • kattru(air)
  • aagayam(space)
  • Vayu Akash .

Three Humours

- For easy regulation of the living body, these five primordial elements were summarised into three humours: vazhi (vadham or air), azhal (pittam or heat), and Iyyam (kapha or cold). When these humours stay in their natural balance and harmony, the person enjoys excellent health.
- The first one-third of life is regarded as the vazhi period, during which a person develops physically, mentally, emotionally, and spiritually.
- The middle one-third of life is taken as the azhal period, where the body is treated as being in its physiological maintenance phase.
- The final one-third of life corresponds physiologically to the Iyyam period, also called the senile or destructive phase.

Five Sheaths (Kosham)

- Being human involves both physical and psychological dimensions, and these together work as a single complete system.
- The kosham concept describes various dimensions seen as layers of a person's subjective experience.
- These are paruvaudambu — annamayakaosham (food-apparent physical sheath), valiudmambu — pranaamayakosham (air-apparent sheath), manaudambu — manomayakosham (mind-apparent sheath), arivudambu — vijnanamayakosham (wisdom-apparent intellectual sheath), and inbaudambu — anandamayakosham (bliss-apparent sheath).

Ten Pranic Air (Vayus)

- These secondary vayus do not just take care of physiological work; they also play a part in psychological and spiritual functioning.
- **Siddha Therapy:** When the three humours go out of balance or illness occurs, the first remedy given is usually of herbal origin.

Homeopathy

- The term 'Homeopathy' comes from two Greek words — Homois, meaning similar, and pathos, meaning suffering.
- Homeopathy basically means treating a disease using remedies given in very small doses — remedies that, when taken by healthy people, can produce symptoms resembling that disease. The system follows the natural healing law 'Similia Similibus Curantur', which translates to 'Likes are cured by likes'.
- Homeopathy is a particular form of drug therapy in which a natural disease is treated by giving medicines. It started in the late 1700s and was developed by a German physician, Samuel Hahnemann.

Definition & Meaning

- Homoeopathy is a branch of medical science that follows the principle of 'Similia similibus curentur', meaning like cures like — in other words, the symptoms shown by the patient and those produced by the medicine are similar. This is also referred to as the LAW OF SIMILA.

Fundamental Principles Of Homeopathy

1. Law of Similia
2. Law of Simplex
3. Law of Minimum
4. Doctrine of Drug proving
5. Theory of Chronic disease
6. Theory of Vital force
7. Doctrine of Drug-dynamization

Principle

The cause behind a disease itself can serve as its cure — this is the Law of Similar, the foundational principle of homeopathy. Hahnemann held that diseases are inborn and arise from gene mutations.

These toxic or poisonous agents that cause gene mutation are called Miasms. There are three kinds of Miasms — Psora, Psychosis, and Syphilis.

These Miasms remain in a dormant or sleeping condition inside a person. While they are inactive, the person stays free of disease because of natural resistance. But once any one of them gets activated, that resistance is lost and the related illness develops. Because of this, homeopathy is termed a Genetic medicine.

Homeopathy in India

- According to data from the World Health Organization (WHO), Homeopathy now ranks as the second largest medical system in the world.
- Homeopathy reached India in 1810, when Dr. John Martin Honigberger, a French traveller who had learnt the system from Dr. Hahnemann himself, came to India and began treating patients.
- He treated Maharaja Ranjit Singh, the then ruler of Punjab, who was suffering from paralysis of the vocal cords, with the homeopathic medicine Dulcamara.
- **Babu Rajendra Lal Dutt (1818–1889) is regarded as the Father of Indian Homeopathy.**

Unani Medicine

- Unani has had a long and notable history in India. The system was brought into India by Arabs and Persians around the eleventh century.
- The name Unani is taken from the word 'Ionian', which has its roots in Greece. Like every other branch of medical science, Unani works towards finding the best ways for a person to live a healthy life with little or no illness.

Principles & Concepts

- As per Unani's basic principles, the body is composed of four primary elements — earth, air, water, and fire — each carrying its own temperament: cold, hot, wet, and dry. When these four elements mix and react, a new compound is formed with a new temperament, namely hot-wet, hot-dry, cold-wet, and cold-dry.
- The body contains both simple and compound organs, and these get their nourishment — the substances needed for growth, health, and well-being — through four humours: Blood, phlegm, yellow bile, and black bile.
- Each humour also carries a temperament: blood is hot and wet, phlegm is cold and hot, yellow bile is hot and dry, while black bile is cold and dry.
- Phlegm is cold and hot — it is the thick, sticky, stringy mucus released by the mucous membrane of the respiratory tract, particularly during a cold or any other respiratory infection. Yellow bile is hot and dry — a yellow or greenish viscid fluid, generally alkaline, secreted by the liver, which then enters the intestines and assists digestion.
- Black bile is cold and dry — it was once thought to be produced by the kidneys or spleen, and was believed to bring about feelings of sadness.
- Unani medicine focuses on promoting health, preventing disease, and curing illness. Human health, according to this system, depends on six essentials:
- Atmospheric air
- Physical activity and rest
- Drinks and foods
- Sleep and wakefulness –
- Excretion and retention
- Mental activity and rest

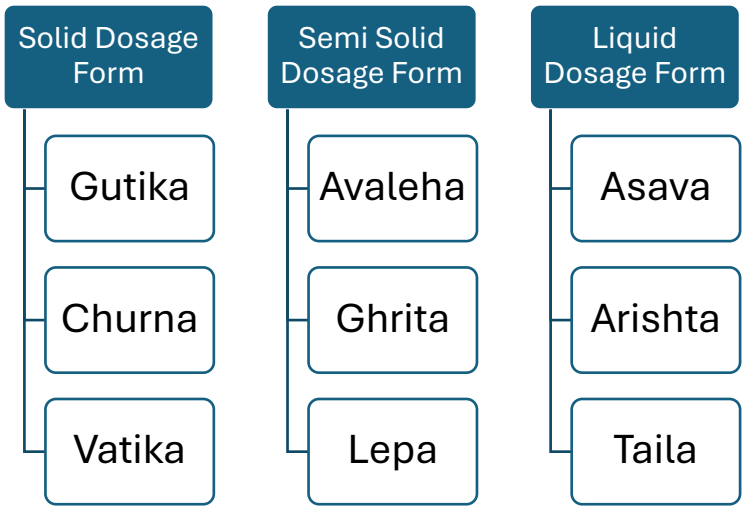
Naturopathy System Of Medicine

- Naturopathy is a traditional healing approach grounded in the natural laws that govern life, living, and good health.
- References to such principles appear in scriptures such as the Vedas and Upanishads, and also in epics like the Ramayana and Mahabharata.
- Naturopathy is described as a drugless system of healthcare, supported by sound philosophy and well-established practices.
- Its central focus is a holistic view of health, taking in not just the physical side but also mental, moral, and spiritual aspects.

Ayurvedic formulations

- Various solvents (Menstruum) are used while preparing Ayurvedic formulations, including water, oils, milk, ghee, cow's urine, and others.
- It is also quite common in Ayurvedic preparations to use sweetening agents, binders, colourants, flavouring agents, and other adjuvants.

Classification of Ayurvedic dosage form



Aristas

These preparations are made by allowing the main decoction substance to ferment for a fixed period after it has been boiled and mixed with sugar or jaggery.

Asavas

These are made by adding powdered drug to the substance solution along with sugar or jaggery, and then letting the mixture ferment for a fixed time.

1. Preparation of Asava

Asava is made from fresh herbal juice or cold infusion, and no boiling is done.

Steps

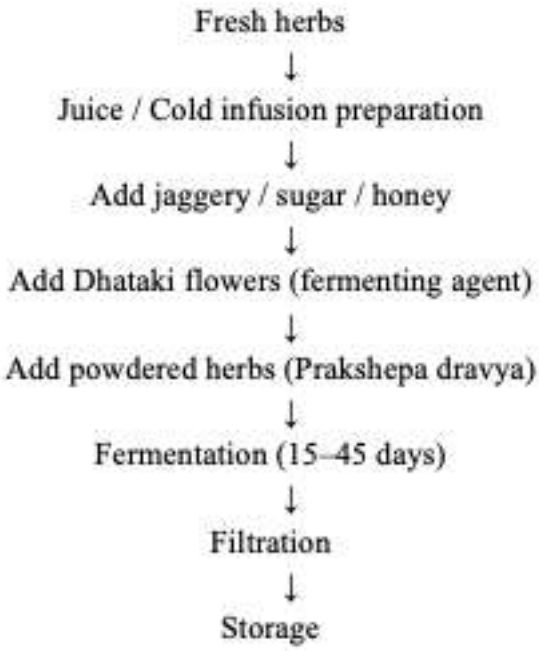
1. **Preparation of herbal juice**
    - Fresh herbs are crushed to extract swarasa (juice), or alternatively soaked in water to prepare a cold infusion known as hima.
2. **Addition of sweetening agents**
    - Add **jaggery, sugar, or honey** to the liquid.
3. **Addition of fermentation starter**
    - Add **Dhataki flowers** (*Woodfordia fruticosa)* or yeast-like natural fermenting agents.
4. **Addition of powdered herbs (Prakshepa dravya)**
    - Fine powders of aromatic or supportive herbs are mixed.
5. **Fermentation**
    - The mixture is placed in a **clean earthen or wooden vessel**.
    - The vessel is then sealed off and stored in a warm place for around 15–45 days.
6. **Filtration and storage**
    - After fermentation, the liquid is filtered and stored in **airtight containers**.

Key Point

- **No boiling is involved** in Asava preparation.

Example

- Kumaryasava
- Lohasava



2. Preparation of Arishta

Arishta is prepared from **herbal decoction (Kwatha)** followed by fermentation.

Steps

1. **Preparation of decoction**
    - Coarse herbal drugs are boiled with water to prepare **Kwatha (decoction)**.
2. **Filtration and cooling**
    - The decoction is filtered and allowed to cool.
3. **Addition of sweetening agents**
    - Add **jaggery or sugar**.
4. **Addition of fermentation initiator**
    - Add **Dhataki flowers** or similar fermenting agents.
5. **Addition of Prakshepa dravya**
    - Fine powders of specific herbs are added.
6. **Fermentation process**
    - The mixture is transferred to **fermentation vessels** and sealed.
    - Kept in a warm place for **15–45 days**.
7. **Filtration and storage**
    - After fermentation, it is filtered and stored properly.

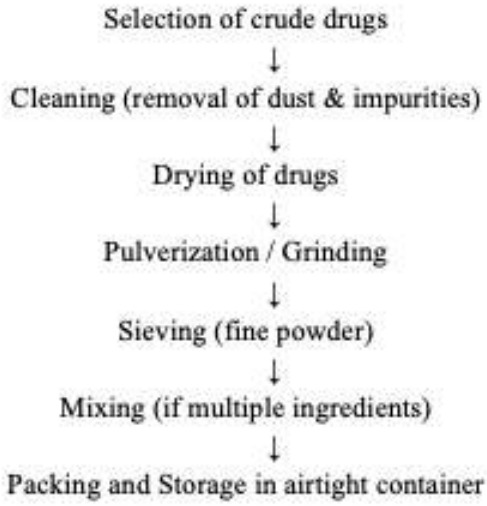
Ghutika & vati

• Medicines prepared in the form of tablet known as vati

• Medicines prepared in the form of pills known as ghutika

Churna

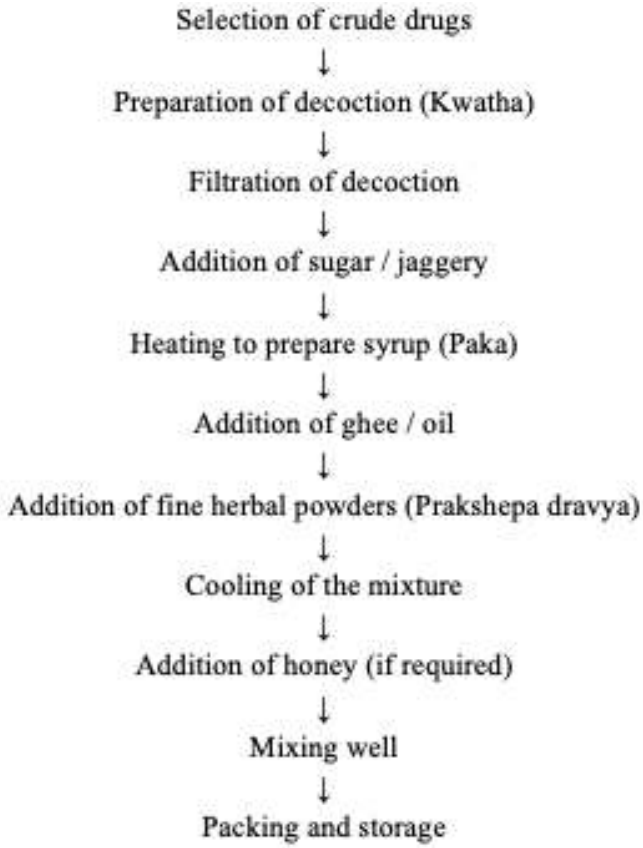
• Churna is a fine powder of drugs.



Lehya

Defination

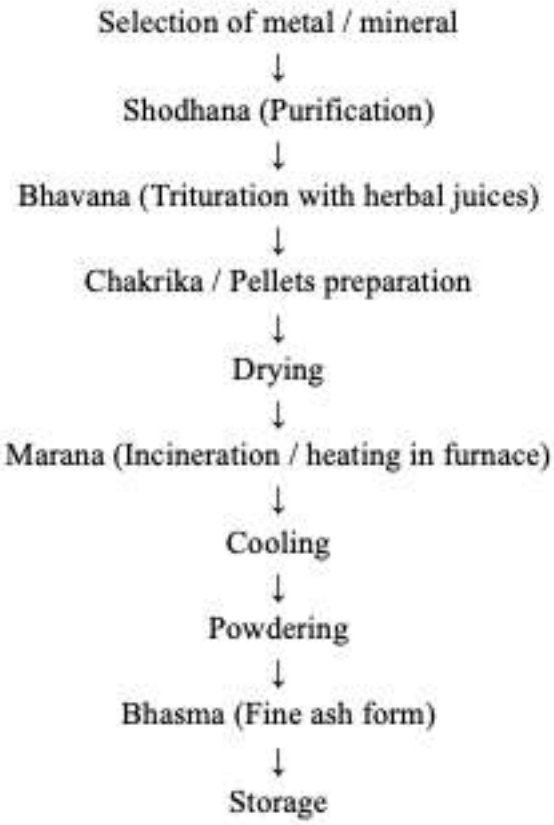
Avaleha or lehya is a semi-solid drug preparation, made by adding jaggery, sugar, or sugar candy and then boiling with the prescribed drug juice or decoction. They go by several other names too, such as modaka, guda, khanda, rasayana, and leha.



Bhasma

Definition

Bhasmas are powdered substances produced by calcination. The technique is used on metals, minerals, and animal-based products, which are first treated by two specialised steps — Sodhana and Marana — done inside closed crucibles placed in pits along with cow dung cakes (puta).



Sodhana:

In Ayurveda, the purification step is known as sodhana. Different drugs require different types of purification, depending upon the kind of drug being used.

There are two kinds — the first is Samanya sodhana and the second is Visesa sodhana. Samanya sodhana is suitable for most metals or minerals, where thin sheets are heated and then immersed in gomutra, taila, takra, and similar liquids in order to remove toxicity. Visesa sodhana, on the other hand, is meant only for certain drugs and for specific preparations.

Marana:

•This stage is regarding the preparation of bhasma.

The drug, after being purified through sodhana, is then ground in a khalva (mortar and pestle) along with juices of the specified plants or with decoctions of drugs prescribed for that particular mineral or metal.

After the prescribed time, small cakes called cakrikas are shaped and dried thoroughly under sunlight. These dried cakes are then placed in a single layer on a shallow earthen plate and covered with another plate.

The edges of the two plates are then bound with clay-smeared cloth in seven successive layers and allowed to dry.

This sealed earthen container is placed inside a pit which has been half filled with cow dung.

Once the container is inside, the rest of the pit is packed with dung cakes and fire is set on every side. After the burning is complete, the setup is left to cool, and the earthen container is then taken out.

The material from the earthen container is removed and ground into fine powder using a khalva. Marana is then repeated for as many cycles as the procedure prescribes. The final fine powders are stored in airtight glass or earthen containers.

Role in Allopathy and Traditional Systems:

Pharmacognosy is important in drug discovery, in identifying medicinal plants, in isolating active constituents, in maintaining quality control, and in scientifically validating natural medicines used in modern (allopathic) medicine as well as in traditional systems such as AYUSH (promoted by the Ministry of AYUSH) and Traditional Chinese Medicine.

It serves as a link connecting traditional knowledge with modern pharmaceutical research, supporting the development of safe, effective, and standardised medicines drawn from natural origins.

Role of Pharmacognosy in Allopathy

1. Drug Discovery from Natural Sources

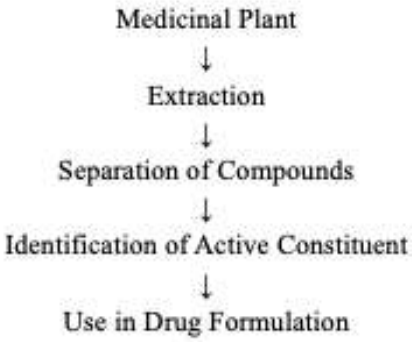
Through pharmacognosy, scientists are able to find new medicines from plants, animals, and microbes. A large number of present-day drugs come from medicinal plants.

Examples:

- Morphine from Papaver somniferum
- Quinine from Cinchona
- Aspirin from Salix alba

2. Isolation of Active Constituents

Active chemical compounds that give medicinal effects — like alkaloids, glycosides, tannins, and flavonoids — are identified and isolated through pharmacognosy.

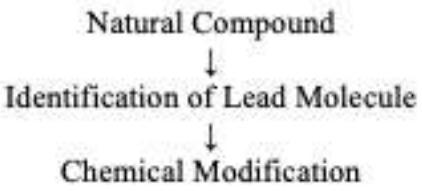


3. Quality Control and Standardization

Pharmacognosy makes sure that herbal drugs used in pharma industries meet the required standards of purity, safety, and quality.

4. Development of Semi-Synthetic Drugs

Compounds from natural sources can serve as lead molecules, which through chemical modification give rise to better drugs.



UNIT-V
PHYTOTHERAPUTIC AGENTS

Chapter 19: ADAPTOGEN & IMMUNOMODULATORS

Definition

Adaptogens are plant-derived natural substances that boost the body's tolerance to physical, chemical, and biological stress, and help keep regular body functions (homeostasis) intact. They work as modifiers of the stress response, allowing the body to better cope with unfavourable conditions and that too without producing harm.

ASHWAGANDHA

Synonyms

Withania root. Ashwagandha, Clustered Wintercherry.

Biological Source

It is made up of the dried roots together with the stem bases of *Withania somnifera Dunal*, a plant of the family Solanaceae.

Geographical Source

Ashwagandha grows mostly in dry, subtropical zones, and is found across:

- **India** (major cultivation areas: **Madhya Pradesh**, **Rajasthan**, **Gujarat**, **Uttar Pradesh**, **Punjab**)
- **Pakistan**
- **Sri Lanka**
- **Mediterranean region**
- Parts of **Africa**

History

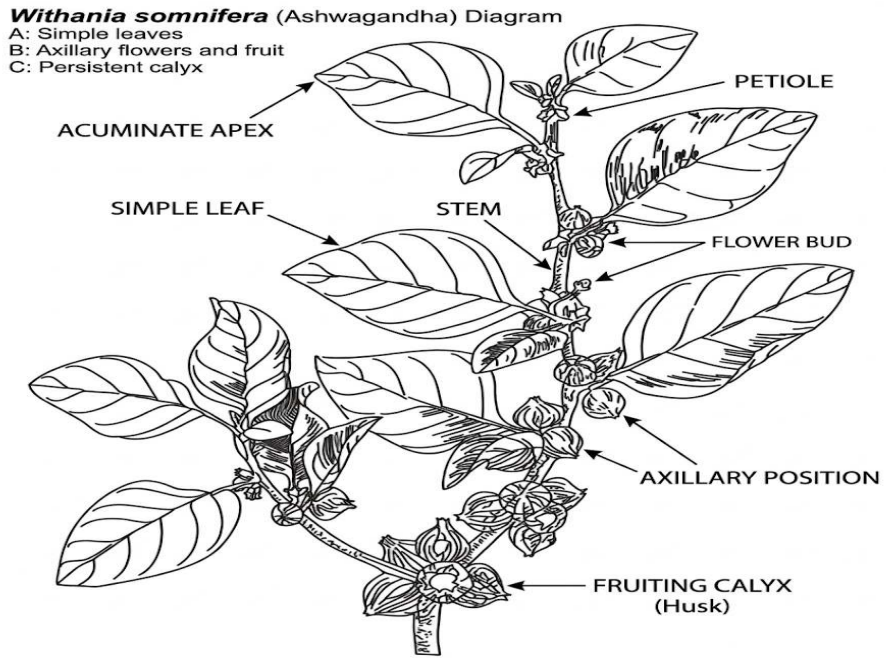
Ashwagandha has been used in Ayurvedic medicine for over 3,000–4,000 years, going back to the teachings of the respected rishi (sage) Punarvasu Atriya. Sacred Ayurvedic texts such as the Charaka and Sushruta Samhitas describe it in detail, praising it widely as a tonic, particularly for emaciation in people of every age — even babies — and for boosting the reproductive function in both men and women.

Cultivation and Collection

Withania somnifera can be propagated by division, by cuttings, or by seed, and seed is the most preferred way. When sown on moist sand at 20°C, the seeds germinate in about 14–21 days. The plant grows best with full sun to partial shade and a well-drained, slightly alkaline soil mix. Soil pH between 7.5 and 8.0 gives the best results. A mix made of two parts sandy loam to one part sand works better. Between waterings, the plants must be allowed to dry completely. In container plantings, excess water can lead to root rot. The plants are given a balanced fertiliser only once a year.

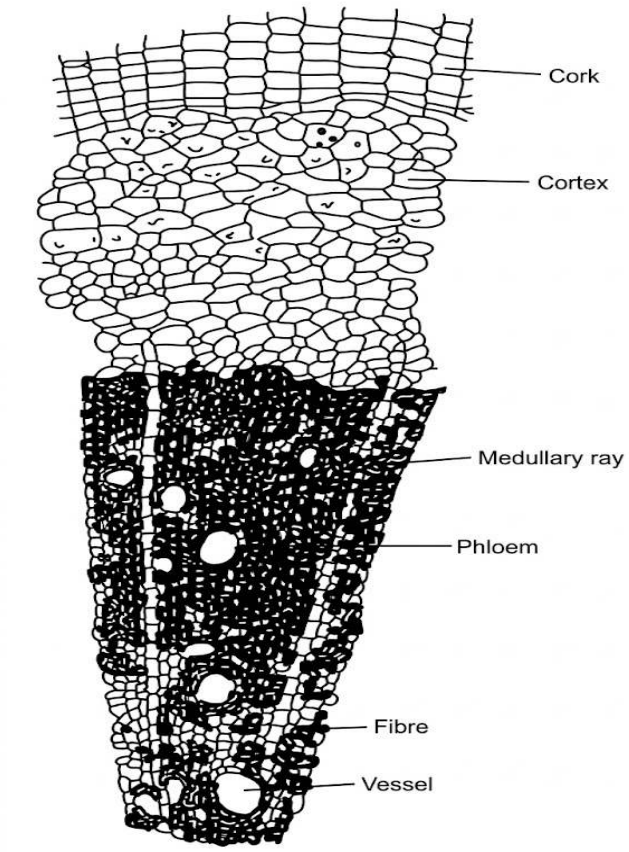
Characteristics

It is a low-growing plant, usually only 1–2 ft tall but at times reaching up to 6 ft. Although perennial in nature, it can also be cultivated as an annual. The plant and its fruits look quite similar to its relatives — the ground cherry and the Chinese lantern. Young roots are conical, straight, unbranched, and come in pieces of varying lengths. Their thickness depends on age and is generally 5–12 mm just below the crown. The outer surface appears buff to yellow with longitudinal wrinkles. The taste is bitter and mucilaginous.



Microscopy

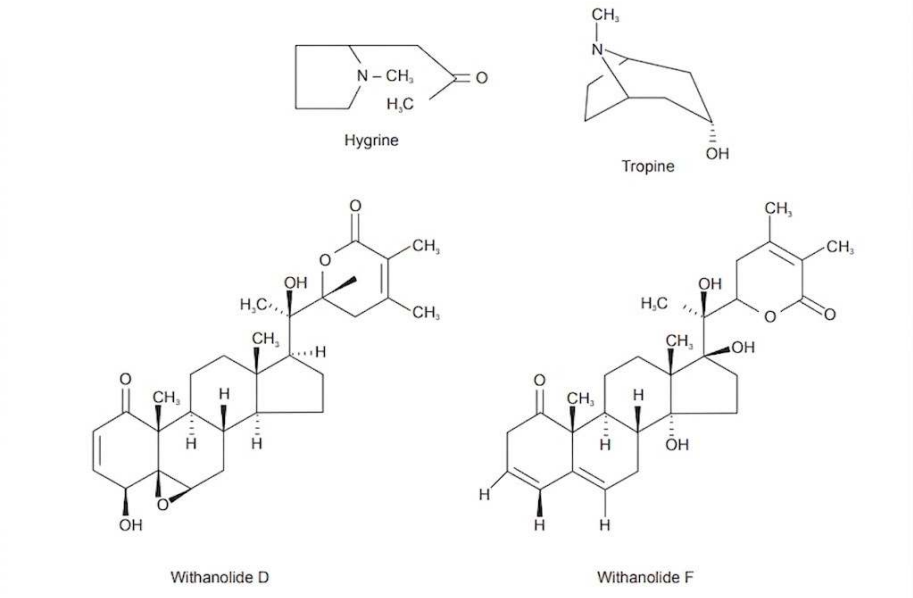
A transverse section of the root shows the cork in an exfoliated or crushed form; whenever present, it is isodiametric and non-lignified. The cork cambium consists of two to four loosely arranged rows of cells. The secondary cortex is formed of about twenty layers of compact parenchymatous cells. The phloem contains sieve tubes, phloem parenchyma, and companion cells. The cambium contains four to five rows of tangentially elongated cells. The secondary xylem is hard and forms a closed vascular ring, separated by multiseriate medullary rays along with a few xylem parenchyma.



Transverse section of Withania root

Chemical Constituents

The plants mainly contain the alkaloid withanine, alongside somniferine, pseudowithanine, tropine, pseudotropine, hygrine, isopellederine, anaferine, anahygrine, and steroid lactones. The leaves carry a steroid lactone group commonly referred to as withanolides.



Uses

Every part of the plant is utilised — the roots, bark, leaves, fruit, and seed — and these are used in the treatment of nervous disorders, intestinal infections, and leprosy. Among Indian tranquillisers, Ashwagandha is one of the most widely used, holding a status comparable to that of ginseng in China. Its action is mainly directed at the reproductive and nervous systems, giving the body a rejuvenative effect; it is therefore used to enhance vitality and to support recovery after long-standing illness. It is also given for nervous exhaustion, weakness, insomnia, wasting diseases, failure to thrive in children, impotence, infertility, multiple sclerosis, and so on. Externally, it is applied as a poultice on boils, swellings, and other painful areas. Since Withania is regarded as an adaptogen, it finds use in numerous diseases.

Marketed Products

It is included as one of the ingredients in formulations such as Abana, Geriforte, Mentat, Mentat syrup, Reosto, Tentex forte, AntiStress Massage Oil, Nourishing Baby Oil, Nourishing Skin Cream, Anxocare, Galactin Vet, Geriforte Aqua, Geriforte Vet, Immunol, Speman forte Vet, Tentex forte Vet, Ashvagandha tablet (Himalaya Drug Company), Balarishta (Baidyanath), and Aswagandha tablet (BAPS AMRUT).

TULSI

Synonyms Sacred basil, Holy basil.

Biological Source

Tulsi is made up of the fresh and dried leaves of *Ocimum sanctum* Linn., a plant belonging to the family Labiatae.

Geographical Source

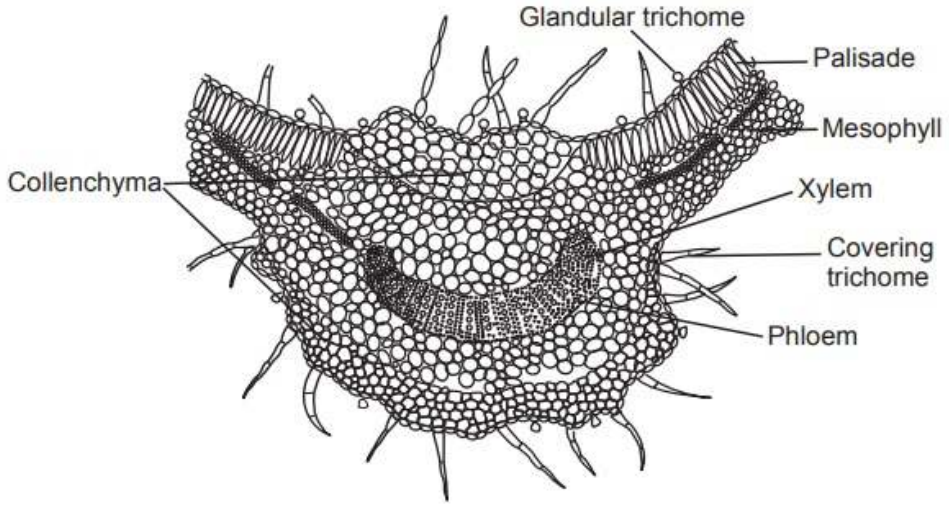
It is a herbaceous, much-branched annual plant growing throughout India, and is regarded as sacred by Hindus. The plant is commonly grown in gardens and is also planted near temples. Propagation is by seeds. Today Tulsi is also cultivated on a commercial scale for its volatile oil.

Characteristics

It is a small, much-branched herb of about 30 to 75 cm in height. Almost every part of tulsi has medicinal use, especially the fresh and dried leaves. The leaves are oblong, acute, with margins that are entire or serrate, pubescent on both surfaces, and finely gland-dotted. They are green in colour, aromatic in flavour, and slightly pungent in taste. Flowers appear purplish, arranged as racemes. Nutlets are subglobose, slightly compressed, and pale brown or red. Seeds are reddish-black and subglobose.

Microscopy

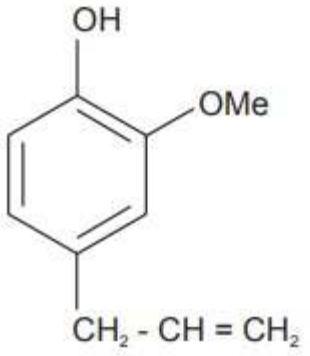
The Tulsi leaf is dorsiventral. Stomata are of the diacytic type and are particularly numerous on the lower surface. Epidermal cells have wavy walls and a thin cuticle. Just below the upper epidermis, a single layer of elongated palisade cells is present. The mesophyll has four to six layers of spongy parenchymatous cells, with intercellular spaces and oil glands. Both covering and glandular trichomes occur on the leaf; the covering trichomes are uniseriate, multicellular, and often quite long (100–400 μ). Glandular trichomes are sessile and have a radiate head made up of eight cells, all sharing a common cuticle that forms a bladder — the typical labiate trichome type.



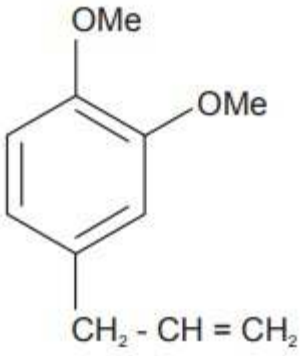
Transverse section of Tulsi leaf

Chemical Constituents

Tulsi leaves yield a bright, yellow-coloured, pleasant-smelling volatile oil (0.1 to 0.9%). The amount of oil varies with the variety, place of cultivation, and the season of collection. The oil is obtained by steam distillation from the leaves and flowering tops. Roughly 70% of it is eugenol, with about 3% carvacrol and 20% eugenol-methyl-ether. Caryophyllin is also present. The seeds yield a fixed oil that has good drying qualities. The plant has also been reported to contain alkaloids, glycosides, saponin, tannins, a fairly good amount of vitamin C, and small quantities of maleic, citric, and tartaric acids.



Eugenol



Methyleugenol

Uses

The fresh leaves, their juice, and the volatile oil are put to several uses. The oil works as an antibacterial and insecticidal agent. Leaves serve as a stimulant, aromatic, spasmolytic, and diaphoretic. The juice is used as an antiperiodic and is also a component of many preparations meant for skin diseases and even for treating earache. An infusion of the leaves acts as a stomachic. Overall, this drug is a strong immunomodulatory agent.

Marketed Products

It is one of the constituents of preparations such as Abana, Diabecon, Diakof, and Koflet (Himalaya Drug Company); Respinova (Lupin Herbal Laboratory); Amulcure (Aimil Pharmaceuticals); Nomarks (Nyle Herbals); Sualin (Hamdard); and Kofol syrup (Charak Pharma Pvt. Ltd.).

HEPATOPROTECTIVES

MILK THISTLE

Synonyms

- **Common names:** Milk Thistle, Holy Thistle, Marian Thistle, St. Mary's Thistle
- **Botanical synonym:** *Silybum marianum (L.) Gaertn.*

Biological Source

- **Botanical name:** Silybum marianum (L.) Gaertn.
- **Family:** Asteraceae (Compositae)
- **Part used:** Seeds (fruits/achenes)

Family

- **Family:** Asteraceae (Compositae)

Geographical Distribution & Cultivation

- Native: Mediterranean region (Southern Europe, North Africa)
- Cultivated: Europe, North America, India, Middle East

- Climate: Dry, sunny; well-drained soil

Macroscopy

- Seed:
    - Oblong or ovoid, 3–5 mm long, 2–3 mm wide
    - Greyish-brown with whitish veins
    - Hard, smooth, oily
- Fruit (achene): 4–6 mm long, compressed, smooth surface
- Plant:
    - Erect, branched, 1–2 m tall
    - Leaves: large, spiny, white-veined
    - Flowers: Purple, in capitula

Microscopy

- Epidermis: Single layer, thickened, lignified walls
- Endosperm: Cells rich in oil and proteins
- Embryo: Large cotyledons occupying most of the seed
- Trichomes: Simple unicellular hairs on seed coat

Chemical Constituents

- **Flavonolignans (Silymarin complex):**
    - Silybin (major), Silychristin, Silydianin, Isosilybin
- **Others:**
    - **Fatty acids:** Linoleic, oleic acids
    - Proteins, carbohydrates, phenolic compounds
- **Major pharmacological action:** Hepatoprotective, antioxidant, choleretic

Collection & Storage

- **Collection:** Seeds collected when fully ripe (late summer/autumn)
- **Drying:** Shade-dried to preserve active constituents
- **Storage:** Airtight containers, away from moisture & light

Uses

- **Hepatoprotective:** Treats liver disorders (hepatitis, cirrhosis)
- **Antioxidant:** Protects liver cells from oxidative stress
- **Cholagogue/choleretic:** Increases bile production
- **Supportive therapy**: For jaundice, liver damage from drugs/alcohol

Marketed Products

- **Forms:** Capsules, tablets, powders, tinctures, standardized extracts
- **Standardization:** Usually standardized to 70–80% silymarin
- **Common products:** “Silymarin capsules,” “Milk Thistle extract tablets”

KUTKI

Synonyms

- Kutki
- Katuka
- Katuki
- Picrorhiza
- Hellebore (Indian Gentian)

Biological Source

Kutki is made up of the dried rhizomes and roots of *Picrorhiza kurroa* Royle ex Benth., a plant of the family Scrophulariaceae (some classifications place it under Plantaginaceae).

Geographical Source

- Native to **Himalayan regions**
- Found in:
    - India (Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim)
    - Nepal
    - Tibet
- Grows at high altitudes (3000–5000 meters)

Macroscopy (Morphology)

- **Rhizome**:
    - Small, cylindrical, straight or slightly curved
    - 2–8 cm long, 0.5–1 cm thick
    - Surface: Rough with longitudinal wrinkles and root scars
    - Color: Greyish-brown to dark brown
- **Fracture**: Short and brittle
- **Odour**: Slight
- **Taste**: Intensely bitter

Microscopy

- **Cork**: Several layers of rectangular cells
- **Cortex**: Parenchymatous cells with starch grains
- **Vascular bundles**: Scattered
- **Xylem**: Well-developed with vessels
- **Phloem**: Present outside xylem
- **Starch grains**: Abundant
- **Calcium oxalate crystals**: Present

Chemical Constituents

- **Iridoid glycosides**:
    - Picroside I
    - Picroside II
    - Kutkoside
- **Other constituents**:
    - Apocynin
    - D-mannitol
    - Vanillic acid

Uses

- Hepatoprotective (protects liver)
- Used in **jaundice and liver disorders**
- Anti-inflammatory
- Antioxidant
- Digestive stimulant
- Mild laxative
- Used in **fever and skin diseases**

Marketed Products

- Kutki capsules/tablets (various Ayurvedic brands)
- Liv-52 (contains Kutki as one of the ingredients)
- Arogyavardhini Vati
- Kutki churna (powder form)

Chapter 20: Cardio Vascular & Antidiabetic Drugs

Definition:
Cardiovascular drugs are agents that work on the heart and blood vessels in order to prevent, control, or treat circulatory disorders such as hypertension, heart failure, and arrhythmias.
They help in:

- Regulating heart rate and rhythm
- Improving blood circulation
- Lowering blood pressure
- Preventing clot formation

GARLIC

Synonyms

- Garlic
- Lahsun / Lasuna
- Rasona
- Allium

Biological Source
Garlic is made up of the bulbs (cloves) of *Allium sativum* Linn., a plant of the family Amaryllidaceae (earlier placed under Liliaceae).

Geographical Source

- Native to **Central Asia**
- Cultivated worldwide:
    - India
    - China
    - Egypt
    - USA

Macroscopy (Morphology)

- **Bulb**:
    - Compound bulb made of 8–20 cloves
    - Covered with papery white or pinkish skin
- **Cloves**:
    - Small, curved, and fleshy
- **Odour**: Strong, characteristic
- **Taste**: Pungent

Microscopy

- **Epidermis**: Single layer of cells
- **Parenchyma**: Large cells containing oil droplets
- **Vascular bundles**: Scattered
- **Calcium oxalate crystals**: Present
- **Sulfur-containing cells**: Responsible for odour

Chemical Constituents

- **Sulfur compounds**:
  - Alliin
  - Allicin (active principle)
  - Ajoene
- **Volatile oil**
- **Enzymes**: Alliinase

Uses

- Antihypertensive
- Hypolipidemic (reduces cholesterol)
- Antimicrobial
- Antiplatelet (prevents clotting)
- Used in cardiovascular disorders

Marketed Products

- Garlic oil capsules
- Garlic pearls
- Odorless garlic tablets
- Herbal heart-care formulations

ARJUNA

Synonyms

- Arjuna
- Arjun tree
- Terminalia bark
- Kakubha

Biological Source

Arjuna is made up of the dried bark of *Terminalia arjuna* (Roxb.) *Wight & Arn*., a tree belonging to the family Combretaceae.

Geographical Source

- Widely found in **India**
- Also in:
  - Sri Lanka
  - Bangladesh
  - Myanmar
- Grows along river banks and moist areas

Macroscopy (Morphology)

- **Bark**:
  - Flat or curved pieces
  - Outer surface: Smooth, grey
  - Inner surface: Pinkish or reddish
- **Fracture**: Fibrous
- **Odour**: Slight
- **Taste**: Astringent

Microscopy

- **Cork**: Multiple layers
- **Cortex**: Parenchymatous cells
- **Phloem fibers**: Present
- **Medullary rays**: Prominent
- **Calcium oxalate crystals**: Abundant

Chemical Constituents

- Triterpenoids:
  - Arjunolic acid
  - Arjunic acid
- Flavonoids
- Tannins
- Glycosides

Uses

- Cardioprotective
- Used in **heart diseases and hypertension**
- Antioxidant
- Hypolipidemic
- Wound healing

Marketed Products

- Arjuna tablets/capsules
- Arjunarishta
- Cardiac herbal tonics
- Heart support formulations

Antidiabetic Drugs

Definition:

Antidiabetic drugs are medicines used to keep blood glucose under control in diabetic patients, either by improving insulin action, raising insulin secretion, or by lowering glucose production or absorption.

They help in:

- Maintaining normal blood sugar levels
- Preventing complications of diabetes
- Improving insulin sensitivity

GYMNEMA

Synonyms

- Gymnema
- Gurmar ("sugar destroyer")
- Meshashringi
- Madhunashini

Biological Source
Gymnema consists of the dried leaves taken from *Gymnema sylvestre* R.Br., a plant of the family Apocynaceae (earlier classified under Asclepiadaceae).

Geographical Source
- Native to **tropical regions of India**
- Also found in:
    - Sri Lanka
    - Africa
    - Australia
- Common in forests of Central and Southern India

Macroscopy (Morphology)
- **Leaves**:
    - Opposite, simple
    - Shape: Elliptical to ovate
    - Margin: Entire
    - Color: Green
- **Odour**: Slight
- **Taste**: Initially bitter, later suppresses sweet taste

Microscopy
- **Epidermis**: Single layer with cuticle
- **Stomata**: Present (mostly paracytic)
- **Mesophyll**:
    - Palisade and spongy parenchyma
- **Calcium oxalate crystals**: Present
- **Vascular bundles**: Well developed

Chemical Constituents
- **Triterpenoid saponins**:
    - Gymnemic acids
- **Gurmarin (peptide)**
- Flavonoids
- Tannins

Uses
- Antidiabetic (reduces blood sugar)
- Suppresses sweet taste sensation
- Helps in weight management
- Hypolipidemic

Marketed Products
- Gymnema capsules/tablets
- Diabetic herbal formulations
- Sugar-control powders

FENUGREEK

Synonyms

- Fenugreek
- Methi
- Trigonella
- Greek hay

Biological Source

Fenugreek is composed of the dried, ripe seeds of *Trigonella foenum-graecum* Linn., a plant of the family Fabaceae.

Geographical Source

- Cultivated widely in:
    - India
    - Egypt
    - Mediterranean region
    - China

Macroscopy (Morphology)

- **Seeds**:
    - Small, hard, yellowish-brown
    - Rhomboidal shape
    - Deep furrow present
- **Odour**: Strong, characteristic
- **Taste**: Bitter

Chemical Constituents

- **Alkaloids**:
    - Trigonelline
- **Saponins**:
    - Diosgenin
- **Mucilage**
- Proteins and fibers

Uses

- Antidiabetic
- Hypocholesterolemic
- Digestive aid
- Galactagogue (increases milk production)

Marketed Products

- Methi powder
- Fenugreek capsules
- Diabetic care formulations
- Herbal supplements

Chapter-21: Anti-Inflammatory, analgesics, CNS, Antimicrobial and antiviral Drugs

TURMERIC

Synonyms: Haldi, Curcuma, Indian saffron

Biological Source: Dried rhizomes obtained from *Curcuma longa* (Family: Zingiberaceae)

Geographical Source: India (the major producer), along with China and Indonesia

Macroscopy:

- Yellowish-brown rhizomes
- Aromatic odor, bitter taste
- Rough surface with annulations

Microscopy:

- Parenchymatous cells with starch grains
- Oleoresin cells containing curcumin
- Fibrovascular bundles scattered

Chemical Constituents:

- Curcuminoids (curcumin)
- Volatile oil (zingiberene, turmerone) (Praag Bio Science)

Uses:

- Anti-inflammatory, antioxidant
- Wound healing, arthritis
- Hepatoprotective (jscholaronline.org)

Marketed Products:

- Curcumin capsules, Haldi powder, Ayurvedic formulations

BOSWELLIA

Synonyms: Salai guggul, Indian olibanum

Biological Source: Oleo-gum-resin obtained from *Boswellia serrata* (Burseraceae)

Geographical Source: India (Rajasthan and Madhya Pradesh), and Africa

Macroscopy:

- Yellowish resin tears
- Aromatic, bitter taste

Microscopy:

- Resin ducts
- Oil globules in parenchyma

Chemical Constituents:

- Boswellic acids (AKBA)

Uses:

- Anti-inflammatory (arthritis)
- Analgesic

Marketed Products:

- Shallaki tablets, Boswellia extract capsules

BRAHMI

Synonyms: Jal Brahmi, Water hyssop
Biological Source: The whole plant of *Bacopa monnieri* (Plantaginaceae)
Geographical Source: India, Nepal, and Sri Lanka

Macroscopy:

- Small creeping herb
- Fleshy leaves
- White flowers

Microscopy:

- Thin-walled cells
- Vascular tissues
- Oil globules

Chemical Constituents:

- Bacosides A & B

Uses:

- Memory enhancer
- Anti-anxiety, CNS tonic

Marketed Products:

- Brahmi syrup, capsules

GILOY

Synonyms (Giloy)
Tinospora cordifolia
Guduchi
Amrita
Giloe
Heart-leaved Moonseed

Biological Source
Giloy is made up of the dried stem of *Tinospora cordifolia,* a plant belonging to the family Menispermaceae.

Morphology (Macroscopic Characters)
Stem: Long, cylindrical, succulent climbing shrub
Surface grey-brown with warty lenticels
Transversely cut surface shows radial medullary rays

Leaves: Heart-shaped (cordate),Long petiole,Smooth green surface
Taste: Bitter

Odour: Odourless

Microscopy

Microscopic characters of stem:
Cork: Thin layer of rectangular cells
Cortex: Parenchymatous cells containing starch
Pericycle: Fibres present
Vascular bundles: Scattered and conjoint
Medullary rays: Prominent and radial
Calcium oxalate crystals and starch grains present

Geography (Distribution)
Widely distributed in India, Sri Lanka, Myanmar, and Bangladesh.
In India it is common in tropical forests, hedges, and roadsides.

Chemical Constituents
The stem of Tinospora cordifolia contains several important compounds:

- Alkaloids
- Berberine
- Magnoflorine
- Tinosporine
- Palmatine
- Diterpenoid lactones
- Tinosporide
- Cordifolide
- Cordifol
- Glycosides
- Tinocordiside
- Cordioside
- **Other constituents**
- Steroids
- Polysaccharides
- Starch
- Resin

Chemical Tests (Identification)
Some common pharmacognostic tests:
Alkaloid test:
Dragendorff's reagent → orange precipitate
Starch test:
Iodine solution → blue colour
Calcium oxalate crystals:
Visible under microscope
Uses (Medicinal Uses)
In Ayurveda, Giloy is considered a very important medicinal plant.

Main uses:

Immunomodulator (boosts immunity)
Antipyretic (reduces fever)
Anti-diabetic
Anti-inflammatory
Antioxidant
Used in treatment of Dengue Fever, Malaria, and Typhoid (supportive therapy)

NEEM

Synonyms: Margosa, Indian lilac
Biological Source: Leaves and seeds taken from *Azadirachta indica* (Meliaceae)
Geographical Source: India and other tropical regions
Macroscopy:

- Compound leaves
- Bitter taste

Microscopy:

- Epidermal cells
- Oil glands
- Fibers

Chemical Constituents:

- Azadirachtin, nimbin

Uses:

- Antibacterial, antifungal
- Blood purifier
- Skin diseases

Marketed Products:

- Neem oil, soap, capsules

ANDROGRAPHIS

Synonyms: Kalmegh, Bhui neem
Biological Source: Whole plant of *Andrographis paniculata* (Acanthaceae)
Geographical Source: India, Sri Lanka
Macroscopy:

- Erect herb
- Bitter taste

Microscopy:

- Epidermis with stomata
- Parenchyma cells

Chemical Constituents:

- Andrographolide

Uses:

- Hepatoprotective
- Antiviral, antipyretic

Marketed Products:

- Kalmegh tablets, liver toni

Chapter-22: System-Wise Therapeutic agent

1. Gastrointestinal Agents
Definition:
Medicines used for treating digestive system disorders such as acidity, ulcers, constipation, and diarrhoea.
Categories & Examples:
- **Antacids:** Neutralize stomach acid (e.g., magnesium hydroxide)
- **Laxatives:** Promote bowel movement (e.g., senna, ispaghula)
- **Antidiarrheals:** Control diarrhea (e.g., loperamide)
- **Digestives/Carminatives:** Improve digestion and relieve gas (e.g., ginger, fennel)

Uses:
- Peptic ulcer, indigestion, constipation, diarrhea

2. Dermatological Agents
Definition:
Medicines applied on the skin to manage infections, inflammation, and other dermatological conditions.
Categories & Examples:
- **Antiseptics:** Prevent infection (e.g., neem, turmeric)
- **Anti-inflammatory agents:** Reduce swelling (e.g., aloe vera)
- **Antifungals:** Treat fungal infections (e.g., clotrimazole)
- **Emollients:** Moisturize skin (e.g., coconut oil)

Uses:
- Acne, eczema, wounds, fungal infections

3. Women's Health Drugs
Definition:
Medicines that are used to support female reproductive health and to treat related disorders.
Categories & Examples:
- **Uterine tonics:** Strengthen uterine function (e.g., ashok, lodhra)
- **Hormonal agents:** Regulate menstrual cycle (e.g., estrogen, progesterone)
- **Galactagogues:** Increase milk production (e.g., fenugreek)
- **Antispasmodics:** Relieve menstrual cramps

Uses:
- Menstrual disorders, menopause symptoms, lactation support

4. Respiratory Agents
Definition:
Drugs used for treating diseases of the respiratory tract.
Categories & Examples:
- **Expectorants:** Help remove mucus (e.g., vasaka, liquorice)
- **Bronchodilators:** Open airways (e.g., theophylline)
- **Antitussives:** Suppress cough (e.g., codeine)
- **Decongestants:** Relieve nasal congestion (e.g., pseudoephedrine)

Uses:
- Asthma, cough, bronchitis, cold

5. Urogenital Agents
Definition:
Drugs used for disorders of urinary and reproductive systems.
Categories & Examples:
- **Diuretics:** Increase urine output (e.g., punarnava)
- **Urinary antiseptics:** Treat infections (e.g., cranberry extract)
- **Aphrodisiacs:** Improve sexual function (e.g., ashwagandha)

Uses:
- Urinary tract infections, kidney disorders, reproductive health issues

6. Agents for Metabolic Disorders
Definition:
Medicines given for managing metabolic conditions such as diabetes, obesity, and lipid disorders.
Categories & Examples:
- **Antidiabetic agents:** Control blood glucose (e.g., insulin, gymnema)
- **Hypolipidemic agents:** Reduce cholesterol (e.g., statins)
- **Anti-obesity agents:** Help weight management

Uses:
- Diabetes mellitus, hyperlipidemia, obesity

About the Authors

Mr. Utkarsh Ravindra Mandage is a dynamic and forward-thinking academician, researcher, and author in the field of pharmaceutical sciences, currently serving as an Assistant Professor in the Department of Pharmacognosy at Ravindra Vidya Prasarak Mandal's Institute of Pharmacy, Nashik. Renowned for his passion for teaching and innovation, he actively mentors students while driving impactful research in natural products, medicinal plants, and herbal drug development. He has an impressive academic portfolio, having authored 6 pharmacy books, including 1 international publication, along with 17 research papers and over 40 review articles published in reputed national and international journals. An accomplished innovator, he holds 5 Indian patents and 1 UK patent in pharmaceutical sciences. His excellence in academia has been recognized through prestigious honors such as the Best Teacher Award, Young Researcher Award, and multiple Best Article Awards. Further strengthening his professional stature, he serves as an editorial board member for 7 journals and publication houses and has been nominated as an external expert scientist for two institutes. With a strong vision for advancing pharmaceutical education and research, Mr. Mandage continues to inspire, innovate, and contribute significantly to the scientific community.

Mr. Amol Bhikan Chaudhari is an emerging pharmaceutical academician and research enthusiast currently associated with Shram Sadhana Bombay Trust's (SSBT) Institute of Pharmacy, Bambhori, Jalgaon, affiliated with PCI and MSBTE. He completed his B.Pharm from Gangamai College of Pharmacy, Nagaon, Dhule (KBC North Maharashtra University, Jalgaon) in 2022 and earned his M.Pharm degree from Shree Sureshdada Jain Institute of Pharmaceutical Education and Research (SSJIPER), Jalgaon, in 2024. He has already demonstrated remarkable research potential through 5 research publications, 1 review article, and 1 patent contribution. He has also actively participated in 18 conferences and 3 seminars, reflecting his continuous engagement in scientific learning and professional development. Passionate about Pharmacognosy and pharmaceutical research, Mr. Chaudhari is dedicated to exploring innovative approaches in herbal medicine and advancing pharmaceutical education through research-oriented academic contributions.

Ms. Sushma Prabhakar Patil is an enthusiastic young researcher and emerging academician in the field of pharmaceutical sciences, known for her keen interest in Pharmacognosy and herbal drug research. Currently associated with Shram Sadhana Bombay Trust's (SSBT) Institute of Pharmacy, Bambhori, Jalgaon, she has built a strong academic foundation through her B.Pharm from Arunamai College of Pharmacy, Mamurabad, Jalgaon, and M.Pharm from Tapi Valley Education Society's Hon'ble Loksevak Madhukarrao Chaudhari College of Pharmacy, Faizpur, both under KBC North Maharashtra University, Jalgaon. Her scholarly contributions include 3 review articles and 1 patent, reflecting her growing involvement in innovative pharmaceutical research. She has actively participated in various conferences and seminars, continuously expanding her scientific knowledge and professional expertise. Driven by curiosity, dedication, and a vision to contribute to natural medicine and healthcare innovation, Ms. Patil aspires to make meaningful contributions to the advancement of pharmaceutical education and research.

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