A TEXT BOOK

PHARMACY INDIA PUBLICATION

INTRODUCTION TO PHARMACOGNOSY

BP105T

As per NEP 2020

Bachelor of Pharmacy

1st Semester

Author

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FULLY COLOURED BOOK

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PREFACE

Pharmacognosy is an important branch of pharmaceutical science that deals with drugs and medicinal substances obtained from natural sources. It forms a link between traditional knowledge of medicinal plants and modern pharmaceutical science.

We are pleased to present this textbook, Introduction to Pharmacognosy, prepared according to the Pharmacy Council of India syllabus under NEP 2020 for the First Semester Bachelor of Pharmacy course BP105T.

The book has been systematically organized according to the prescribed syllabus and covers the major areas of Fundamentals of Pharmacognosy; Cultivation, Collection, Processing and Storage of Drugs of Natural Origin; Quality Control of Drugs of Natural Origin; Metabolites of Plant Origin and Traditional Systems of Medicine; and Phytotherapeutic Agents.

The subject matter has been presented in a simple, concise and student-friendly manner. Important definitions, classifications, tables, illustrations, flowcharts and examination-oriented points have been included to make the concepts easy to understand and remember.

This book aims to provide students with a strong foundation in natural drugs, medicinal plants, traditional systems of medicine and phytotherapeutic agents. It is intended to fulfil the academic requirements of the PCI syllabus and support students in their university examinations and future professional studies.

Every effort has been made to ensure accuracy, clarity and completeness. Constructive suggestions from students, teachers and subject experts are always welcome and will help in improving future editions.

We sincerely hope that this book will serve as a useful and reliable learning resource for B.Pharm students.

Authors

INTRODUCTION TO PHARMACOGNOSY SYLLABUS

1. Fundamentals of Pharmacognosy — HOURS: 10

- (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 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 with merits and limitations.

2. Cultivation, Collection, Processing and Storage of Drugs of Natural Origin — HOURS: 08

- Methods of plant cultivation and Good Agricultural and Collection Practices (WHO/GAP/GCP guidelines).
- Factors influencing cultivation, collection and storage of medicinal plants.
- Plant hormones and their applications.
- Application of polyploidy, mutation and hybridization with reference to secondary metabolites.
- Ex-situ and in-situ conservation, value addition of medicinal plants.
- Role of eco-pharmacognosy in sustainable conservation of endangered medicinal plants such as Kutki and Chirata.

3. Quality Control of Drugs of Natural Origin (WHO Guidelines) — HOURS: 08

- Adulteration of drugs of natural origin.
- Evaluation using organoleptic, microscopic, 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.

4. Introduction to Metabolites of Plant Origin — HOURS: 12

- Definition and general properties of plant metabolites.
- Primary and secondary metabolites: carbohydrates, proteins, lipids, alkaloids, glycosides, flavonoids, tannins, terpenoids, volatile oils and resins.
- Traditional systems of medicine: AYUSH and TCM.
- Types of dosage forms in AYUSH medicines.
- Role of pharmacognosy in allopathy and traditional systems of medicine.

5. Phyto-therapeutic Agents — HOURS: 07

- 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.
- Women's health: Chasteberry, Shatavari.
- Respiratory drugs: Vasaka.

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1 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.

1.1 Introduction

Nature represents a remarkable system of harmony and interdependence. The living and non-living components of nature are closely associated with one another. Among these natural resources, plants occupy a very important place in human life. They provide the basic necessities such as food, clothing and shelter, along with several other useful products.

Since ancient times, nature has been considered a rich storehouse of remedies for the treatment of diseases. The knowledge of medicinal substances developed gradually over thousands of years through human observation, experience and curiosity. This accumulated knowledge later became the foundation of organized healthcare systems.

Early human beings were frequently affected by injuries and diseases. To relieve pain and suffering, they began to use the plants available in their surroundings. For many centuries, plants served as the chief source of medicine and may rightly be called man's first chemist.

At present, extensive knowledge is available regarding the therapeutic properties of plants. Various groups of plants such as thallophyta, bryophyta, pteridophyta and spermatophyta contain medicinally important species. About 3,35,000 plant species are known, and many of them provide official and unofficial medicinal products. A large number of crude drugs are obtained from higher plants, especially from different families of spermatophyta.

1.1.1 Ancient History of Herbal Medicine

The use of medicinal plants is as old as human civilization. Ancient records show that plants were used for medicinal purposes in countries such as China, India, Egypt and Greece long before the Christian era.

One of the most important ancient medical records is the Papyrus Ebers, an egyptian document dating back to the sixteenth century B.C. it is about 60 feet long and one foot wide. This document contains more than 800 formulae and mentions nearly 700 drugs. Important drugs such as acacia, castor oil and fennel are described in it. It also includes references to substances such as iron oxide, sodium chloride, sodium carbonate and Sulphur.

Many medicinal substances that were scientifically identified in the nineteenth and twentieth centuries had already been used earlier in the form of crude extracts.

1.1.2 Development of Medicine in China

In China, the use of medicinal plants dates back to about 5000 B.C. The oldest known Chinese herbal book is pen-t'sao, written by emperor Shen Nung around 3000 B.C.

This book contains 365 drugs, representing one drug for each day of the year. It is considered an important contribution to the early development of herbal medicine.

1.1.3 Development of Medicine in India

India has a rich and ancient tradition of medicinal plant use. Ancient Indian scholars studied herbs carefully and classified them into groups known as gunas.

Charaka classified medicinal plants into 50 groups, each group consisting of 10 herbs. According to him, these groups were sufficient for the needs of an ordinary physician.

Sushrutha classified about 760 herbs into 7 distinct groups according to their common properties.

Even today, a large part of the Indian population depends on Ayurveda, the traditional Indian system of medicine. Ayurveda means "the ancient science of life."

The two most important Ayurvedic texts are:

- Charaka samhita
- Sushrutha samhita

1.1.4 Dhanvantari: Father of Ayurveda

Dhanvantari is regarded as the divine founder of Ayurveda and is known as the father of Ayurveda. According to ancient belief, he appeared during the samudra manthan, or churning of the ocean. Lord dhanvantari is considered the physician of the gods. It is believed that he was born in the royal family of kashi, also known as banaras, and later became a king.

He taught ayurveda orally to his discIPle sushruta. The birth anniversary of lord dhanvantari is celebrated as dhanteras, two days before diwali, throughout India.

1.1.5 Important Contributors in the History of Medicine

1.3.3 Microbial sources

Microorganisms are an important source of antibiotics and other medicinal substances. Many antibiotics are obtained from actinomycetes, fungi, and bacteria.

1.3.4 Mineral sources

Minerals are also used as sources of drugs and pharmaceutical substances. Several mineral compounds and silicates are used in pharmacy.

These mineral substances are used for different medicinal and pharmaceutical purposes.

Table 1.6: Antibiotics and Other Drugs from Microorganisms

S. No.	Category	Microbial Source	Important Drugs / Products
1	Antibiotics from actinomycetes	Actinomycetes	Actinomycin, Amphotericin, Chloramphenicol, Erythromycin, Kanamycin, Neomycin, Gentamicin, Streptomycin, Tetracycline
2	Antibiotics from fungi	Fungi / Aspergillus group	Penicillin, Griseofulvin, Cephalosporin
3	Antibiotics from bacteria	Bacillus species	Polymyxin B, Bacitracin
4	Other microbial drugs	Fungus / Algae	Ergot alkaloids, Agar, Alginate

Table 1.7: Drugs & Their Mineral Sources

Drug	Source	Use
Kaolin	Feldspar deposits	In gastric affection
Asbestos	Hornblende	For bacterial filter
Talc	Sleatite/soap stone	Filtration
Bentonite	Mineral deposits	Emulsion, cosmetics
Fueller's Earth	Siliceous earth	Dusting powder
Prepared chalk	Calcarious remains of algae	Antacid
Kieselguhr	Fossil diatoms	Filtration aid
Calamine	Hemimorphites	Cosmetics

1.3.5 Biotechnology as a Source of Drugs

Biotechnology is a modern and important method for the production of drugs. One of the most useful techniques in biotechnology is recombinant DNA technology.

In recombinant DNA technology, DNA is cut by special enzymes called restriction endonucleases. The desired gene is then attached to rapidly multiplying DNA, such as viral DNA, bacterial DNA, or plasmid DNA. This new genetic material is inserted into bacterial cultures, where it helps in producing large quantities of useful medicinal substances.

1. Drugs Produced by Biotechnology

One of the most important examples of biotechnology-based drugs is human insulin. It may be produced either by modification of porcine insulin or by using bacteria through recombinant DNA technology.

Other important biotechnology products include:

- Somatotrophin
- Erythropoietin
- Human blood coagulation factors

2. Compounds Produced from Plant Cell Cultures

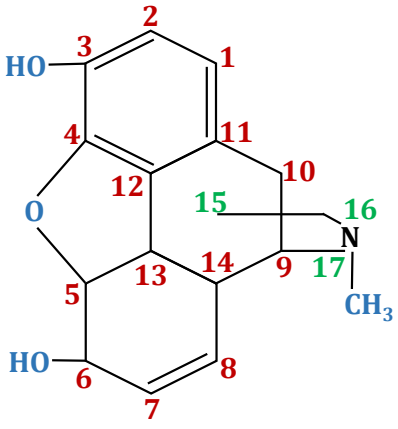
Plant cell culture techniques are also used to produce important medicinal compounds, such as:

- Scopolamine
- Podophyllotoxin
- Paclitaxel
- Rosmarinic acid
- Vanillin
- Shikonin

1.4 Historical Milestones in Drug Discovery

1.4.1 Morphine

Morphine is a landmark drug in the history of modern pharmacology and pain management. It was one of the first active medicinal compounds isolated in pure form from a natural source, opium.



- 1804–1805: Friedrich Wilhelm Adam Sertürner, a German pharmacist's assistant, isolated morphine from opium poppy (Papaver somniferum).

Table 1.9: Editions of Indian Pharmacopoeia

Edition	Year	Notes
1st	1955	~986 monographs; supplement in 1960
2nd	1966	Metric dosing introduced; supplement in 1975
3rd	1985	Two-part structure; addenda in 1989 and 1991
4th	1996	Addenda in 2000, 2002, 2005; veterinary supplement
5th	2007	First edition published by IPC; 271 new monographs; addendum 2008
6th	2010	Addendum 2012; antiretroviral, anticancer, biotech monographs
7th	2014	Addenda 2015 and 2016; published with DVD
8th	2018	Addenda 2019 and 2021; published with DVD
9th	2022	3,152 monographs; 92 new monographs; 223 general chapters
10th	2026	3,340 monographs; 121 new monographs

The IPC official history page lists editions from IP 1955 to IP 2022, and the IPC release page confirms IP 2026 as the 10th edition.

1.5.1.4 IP 2026 and its Volumes

The Indian Pharmacopoeia 2026 (IP 2026), the 10th edition, was released by Union Health Minister Shri J. P. Nadda on 2 January 2026 at the Dr. Ambedkar International Centre, New Delhi. It was described as reflecting scientific advancements, global best practices, and India's growing leadership in pharmaceutical manufacturing and regulation.

- The edition incorporated 121 new monographs, increasing the total number of monographs to 3,340.
- According to trade listings, the breakdown includes roughly 2,579 chemical monographs, 242 general chapters, and 184 excipient monographs, alongside the new additions.
- The 121 new monographs include 88 drug substances, dosage forms, and pharmaceutical aids; 5 vitamins, minerals, amino acids, and fatty acids; 2 biotechnology-derived therapeutic products; 3 human vaccines; 2 blood-related products; and 20 blood and blood component monographs.
- The edition places renewed focus on global harmonization and patient safety, introducing new categories of drugs and stronger guidelines for elemental impurities and animal ethics.
- As a member of the Pharmacopoeial Discussion Group (PDG), the IP continues to collaborate with the European, Japanese, and United States Pharmacopoeias on harmonization of monographs and general chapters, with general requirements aligned to International Council for Harmonisation (ICH) standards.

Volumes: IP 2026 is published as a 4-volume set, continuing the structure adopted since the seventh edition (2014). It is available in print along with a complementary single-user online subscription, and a separate digital version is also offered through the official IPC portal. The general arrangement typically follows the pattern of earlier four-volume editions:

- **Volume I —** Notices, preface, structure of the IPC, general chapters (e.g., apparatus, general methods of analysis, reference standards).
- **Volume II —** General notices and monographs on drug substances, dosage forms, and pharmaceutical aids (A–M).
- **Volume III —** Monographs on drug substances, dosage forms, and pharmaceutical aids (N–Z).
- **Volume IV —** Monographs on herbals, vaccines and immunological products, blood and blood-related products, biotechnology-derived therapeutic products, and other specialized categories.

1.5.1.5 Contents of Indian Pharmacopoeia

The IP is organized into several broad sections that together form a comprehensive reference for drug standards:

1. **Notices and Preface:** Introductory statements on the legal status, scope, and authority of the pharmacopoeia, along with acknowledgements and the structure of the IPC.
2. **Introduction:** Explanatory notes on how to interpret and apply the monographs, including conventions on units, abbreviations, and terminology used throughout the volumes.
3. **General Notices:** Overarching rules of interpretation that apply to all monographs unless stated otherwise — for example, definitions of terms like "percentage," "weight," "about," storage conditions, and how to handle tests and assays generally.
4. **General Chapters:** Detailed descriptions of:
   - Apparatus used in testing (e.g., dissolution apparatus, disintegration apparatus)
   - General methods of analysis (chromatography, spectrophotometry, titrimetric methods)
   - Physical and chemical tests (pH, loss on drying, sterility, microbial limits)
   - General requirements for dosage forms (tablets, capsules, injections, etc.)
   - Reference standards and their use
5. **Monographs:** The core of the IP, comprising individual standards for:
   - Drug substances (active pharmaceutical ingredients)
   - Dosage forms (tablets, capsules, injections, syrups, etc.)
   - Pharmaceutical aids and excipients
   - Vaccines and immunological products
   - Blood and blood-related products

educators, and industry representatives. This committee identifies commonly used and commercially important herbs and then prioritizes them for monograph development.

Some herbs are selected because of safety concerns. For example, adulteration of certain Chinese herbs with plants belonging to the family aristolochiaceae created serious safety issues, including kidney failure and cancer. In such cases, AHP works with regulatory and professional organizations to develop monographs that include authentication tests and safety information.

Another method of selection is based on direct sponsorship. Since monograph preparation requires considerable financial resources, sponsors may support the development of monographs on specific herbs. Sometimes, monographs are also prepared opportunistically when previous research or literature collection on a related plant provides useful information.

1.5.6.4 Development Process of Monographs

The development of an AHP monograph involves extensive literature research. Information is collected from scientific journals, traditional texts, clinical studies, pharmacological reports, and regulatory documents. In many cases, source materials are translated from languages such as German, French, Chinese, Japanese, Russian, and Hungarian.

After the initial writing, each section is reviewed by editors and subject experts. The complete monograph is then sent to a large group of specialists, including botanists, chemists, herbalists, pharmacists, pharmacognosists, pharmacologists, physicians, and experts in Ayurvedic, Chinese, and western medicine. This peer-review process ensures scientific accuracy, reliability, and practical usefulness.

1.5.6.5 Significance in Herbal Medicine

AHP monographs provide a strong foundation for the standardization, quality assurance, and ethical marketing of herbal medicines. They help in proper plant identification, correct harvesting methods, drying conditions, chemical analysis, therapeutic evaluation, and safety assessment.

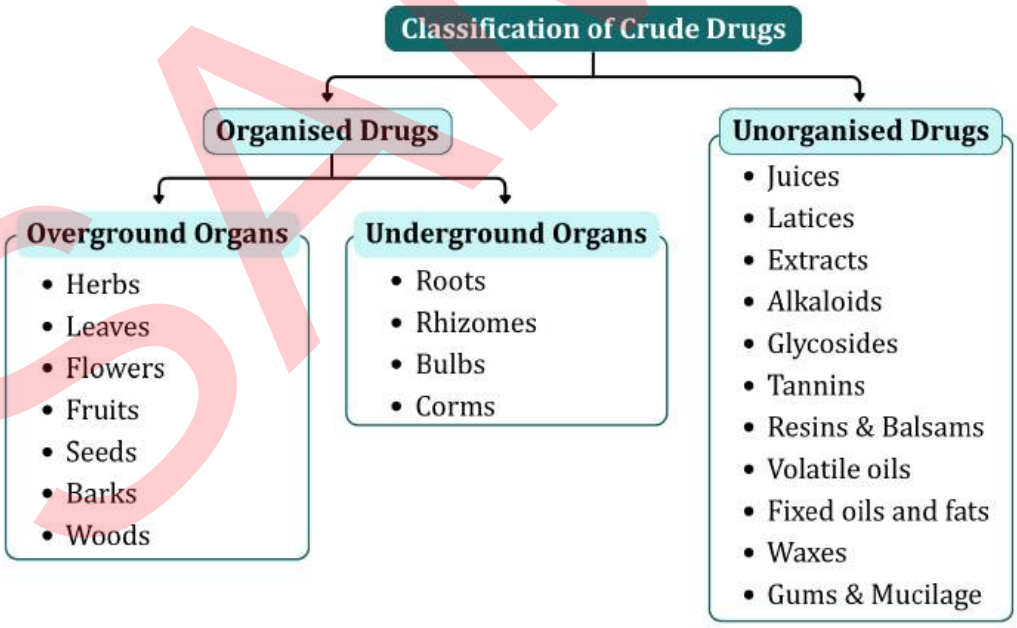
One special feature of AHP monographs is the inclusion of detailed color photographs of medicinal plants. These images are highly valuable for identification and quality control purposes.

1.6 Official And Non-Official; Codified And Non-Codified Drug

1.6.1 Classification of Crude Drugs

The term crude drug is generally used for natural substances obtained from plant and animal sources in their raw or unprocessed form. In a broader sense, this term also includes certain pharmaceutical substances obtained from the mineral kingdom, such as kaolin and bentonite, which are used in their original natural form. A crude drug may be defined as a natural product that has not undergone any process of refinement, improvement, or value addition, except those basic treatments that are necessary for its proper packing, preservation, and prevention of deterioration. Thus, crude drugs are essentially natural materials used in pharmacy and medicine with minimal processing.

On the basis of their structure, crude drugs are broadly divided into two groups:



- This method connects phytochemistry with systematic botany. Plants belonging to the same or related groups often contain similar chemical compounds such as alkaloids, glycosides, flavonoids, tannins, and terpenoids. These chemical characters help in the identification and classification of medicinal plants.
- Chemotaxonomy is useful because it provides additional evidence for understanding the chemical relationship, biological evolution, and taxonomical affinity of plants.
- For example, the alkaloid berberine is found in plants such as Hydrastis, Berberis, and Argemone, showing their chemotaxonomic relationship.
- Modern techniques like DNA hybridization, amino acid sequencing, and serotaxonomy are also used for more accurate classification.
- Thus, chemotaxonomic classification is an important method in pharmacognosy because it combines chemical, botanical, and evolutionary knowledge for the proper classification of crude drugs.

Merits

- Chemotaxonomical classification is a modern and scientific method of classifying crude drugs. In this method, plants are classified on the basis of their chemical constituents along with their taxonomical relationship.
- This method is useful in understanding the natural relationship among plants. It also helps in the study of plant classification and evolution, because closely related plants often contain similar chemical constituents.
- Chemotaxonomical classification is also helpful in the discovery of new medicinal plants. If one plant of a particular group contains important active constituents, then other plants of the same group may also be studied for similar chemical compounds and medicinal value.

Limitations

- Although this method is scientific and useful, it requires advanced knowledge of phytochemistry and plant taxonomy. Therefore, it is not suitable for routine or basic study of crude drugs.
- The chemical analysis of crude drugs may be costly, complicated, and time-consuming. Special instruments and skilled persons are required for proper identification of chemical constituents.
- Another limitation is that complete chemical information is not available for many crude drugs. Hence, the application of this method is limited in such cases.

Short Answer Type Questions

1. Define pharmacognosy. Explain the origin of the term pharmacognosy.
2. List the different natural sources of drugs with one example of each.
3. Write a short note on the present status of pharmacognosy.
4. Discuss the importance of phytochemistry in pharmacognosy.
5. Explain the role of microorganisms in drug discovery.
6. Write a short note on plant tissue culture and its applications.
7. Mention the major contributions of Charaka and Sushruta to medicine.
8. Explain the importance of the Indian Pharmacopoeia in pharmacy.
9. What are the objectives of the British Herbal Pharmacopoeia?
10. Write a short note on the historical discovery of morphine.

Long Answer Type Questions

1. Define pharmacognosy and discuss its history, present status, scope, and development.
2. Describe the different natural sources of drugs with suitable examples.
3. Explain the historical milestones in drug discovery with reference to morphine, quinine, aspirin, warfarin, penicillin, cephalosporins, Taxol, and artemisinin.
4. Discuss the importance of pharmacognosy in pharmaceutical sciences and modern drug discovery.
5. Explain the role of phytochemistry, omic technologies, and biotechnology in the advancement of pharmacognosy.
6. Describe the Indian Pharmacopoeia, including its objectives, legal status, contents, editions, and importance.
7. Explain the British Herbal Pharmacopoeia with reference to its history, structure, monographs, quality standards, and importance.
8. Discuss the cultivation, collection, conservation, quality control, and standardization of crude drugs.
9. Explain the historical development of pharmacognosy from ancient civilizations to modern molecular pharmacognosy.
10. Describe the role of pharmacognosy in the identification, evaluation, and development of herbal medicines and natural products.

2 CULTIVATION, COLLECTION, PROCESSING AND STORAGE OF DRUGS OF NATURAL ORIGIN

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.

2.1 Methods of Cultivation of Medicinal Plants

Several countries of the world possess a rich traditional heritage of herbal drugs. However, only a few countries can claim that these drugs are obtained mainly from cultivated sources. In earlier times, most crude drugs were collected from wild plants growing in their natural habitats. Recently, with the development of modern scientific knowledge, many medicinal plants have been brought under systematic cultivation.

Excessive dependence on wild sources and the absence of proper cultivation techniques have resulted in the gradual depletion of many medicinal plants from nature. Therefore, cultivation of medicinal plants has become important for ensuring a regular, reliable, and quality supply of crude drugs.

Cultivation offers several advantages over wild collection, such as better-quality control, improved yield, proper identification of plants, and continuous availability of raw material. However, cultivation may not always be economically suitable for those crude drugs that are naturally abundant in forests or wild habitats. Examples include nux vomica, acacia, and myrobalan. On the other hand, many important crude drugs are obtained from cultivated plants. These include cardamom, clove, Indian hemp, poppy latex, tea, cinchona, ginger, linseed, isabgol, Ceylon cinnamon, saffron, peppermint, and fennel.

The cultivation of vegetable drugs depends on the proper combination of agricultural and pharmaceutical factors. Important factors include soil, climate, rainfall, irrigation, altitude, temperature, fertilizers, pesticides, genetic improvement, and biochemical characteristics of medicinal plants.

When all these factors are scientifically studied and properly applied, they help in developing modern methods of cultivation. Thus, scientific cultivation technology plays an important role in improving the quality, quantity, and therapeutic value of crude drugs.

2.1.1 Advantages of Cultivation

1. Quality and Purity

Cultivation helps to produce crude drugs of uniform quality and purity. In cultivation, the correct plant source is selected and grown under proper conditions, so chances of adulteration and substitution are reduced. Examples include Digitalis, cinchona, isabgol, senna.

2. Better Yield

Cultivated plants generally give better yield than wild plants because soil, irrigation, spacing, fertilizers and pest control can be managed properly. Scientific cultivation increases the amount of useful plant material obtained from the crop. Examples include Ginger gives better rhizome yield, fennel gives better fruit yield, and peppermint gives better leaf and oil yield.

3. Regular Supply

Cultivation ensures continuous and regular supply of medicinal plant materials. This is important for pharmaceutical, herbal and cosmetic industries because they require crude drugs in large quantity throughout the year. Examples include Tea, senna, isabgol, peppermint and poppy are cultivated for regular industrial supply.

4. Improved Medicinal Value

Proper cultivation helps to maintain the required amount of active constituents in medicinal plants. Factors such as climate, soil, altitude, irrigation and harvesting stage can be controlled to improve the medicinal value of crude drugs. Examples include Cinchona contains quinine, digitalis contains cardiac glycosides, and peppermint contains menthol-rich volatile oil.

5. Use of Scientific Methods

Cultivation allows the use of scientific techniques such as selection, hybridization, mutation, polyploidy and tissue culture. These methods help to improve plant quality, yield, disease resistance and active constituent content. Examples include Tissue culture is useful for rapid multiplication, while hybridization and mutation may help in developing improved medicinal plant varieties.

6. Industrial Importance

Cultivation supplies raw materials to pharmaceutical, herbal, Ayurvedic, cosmetic and nutraceutical industries. Cultivated crude drugs are easier to process, pack, store and standardize. Examples include Aloe vera is cultivated for gel, peppermint for volatile oil, senna for leaves and pods, and isabgol for husk.

7. Conservation of Medicinal Plants

Cultivation reduces pressure on wild medicinal plants. This helps in the conservation of rare and endangered plants and prevents overexploitation from forests.

In tip layering, the tip of a young branch is bent and buried in the soil. The buried tip develops roots and shoots. After proper growth, it is separated from the parent plant. Examples include blackberry, raspberry, and dewberry. In this method, the tip of the branch forms the new plant.

Table 2.8: Summary of Types of Layering

Type of Layering	Main Method	Examples
Simple layering	Branch is bent and partly buried in soil	Jasmine, Rose, Lemon
Serpentine layering	Long branch is buried at several points	Grapevine, Jasmine
Air layering	Roots develop on aerial branch	Litchi, Guava, Lemon
Mound layering	Soil is heaped around basal shoots	Apple, Plum
Tip layering	Tip of branch is buried in soil	Blackberry, Raspberry

III. Grafting

Grafting is an asexual method of plant propagation in which two plant parts are joined together so that they grow as a single plant.

- The rooted lower part is called stock.
- The upper part attached to the stock is called scion.
- The stock provides roots, water, and minerals.
- The scion develops into the shoot system and produces flowers or fruits.

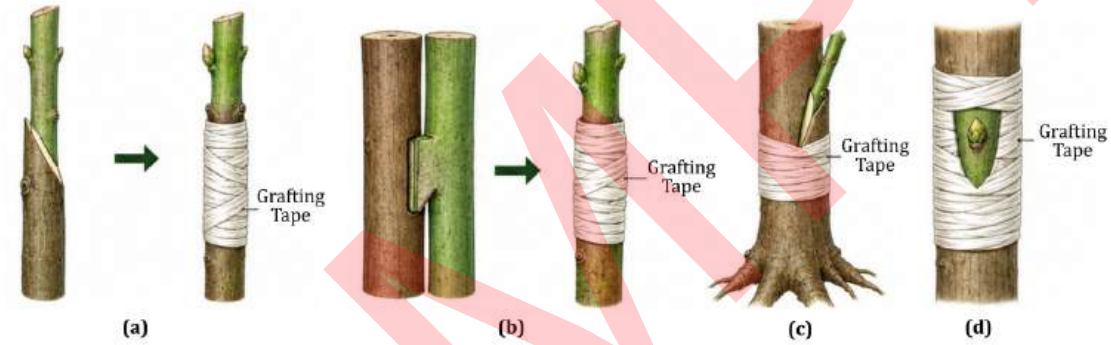


Figure 2.4: Grafting (a) Whip Grafting; (b) Tongue Grafting; (c) Side Grafting; (d) Stone Grafting

1. Whip Grafting

In whip grafting, both the stock and scion are cut obliquely or slanting. The cut surfaces are joined together and tied properly. After healing, both parts unite and grow as one plant. Examples include apple, pear, mango, and grapes. Whip grafting is suitable when stock and scion have nearly equal thickness.

2. Tongue Grafting

In tongue grafting, slanting cuts are made on both stock and scion. Then an additional small cut, called a tongue, is made on each part. These tongues fit into each other and provide strong contact between stock and scion. Examples include apple, pear, peach, and plum. Tongue grafting gives a strong union because the stock and scion interlock firmly.

3. Side Grafting

In side grafting, the scion is inserted into a cut made on the side of the stock. The stock is not cut from the top at first. After the scion establishes properly, the upper part of the stock may be removed. Examples include mango, rose, citrus plants, and cashew. Side grafting is useful when the stock is larger or thicker than the scion.

4. Stone Grafting

Stone grafting is mainly used in mango propagation. In this method, a young seedling raised from a mango stone is used as stock. A scion from a desired mango variety is grafted on the young stock. Examples include mango. Stone grafting is commonly used for rapid multiplication of mango plants.

Table 2.9: Summary of Types of Grafting

Type of Grafting	Main Method	Examples
Whip grafting	Slanting cuts of stock and scion are joined	Apple, Pear, Mango
Tongue grafting	Tongue-like cuts interlock stock and scion	Apple, Pear, Plum
Side grafting	Scion is inserted into side cut of stock	Mango, Rose, Citrus
Stone grafting	Mango seedling stock is grafted with scion	Mango

Table: 2.12 Altitude Required for Drug Cultivation

Plant	Altitude
Cardamom	600–1,600 m
Clove	Up to 900 m
Tea	1,000–1,500 m
Saffron	Up to 1,250 m
Camphor	1,500–2,000 m
Coffee	1,000–2,000 m
Cinnamon	250–1,000 m
Cinchona	1,000–2,000 m

2.3.2 Temperature

Temperature plays a major role in plant growth, metabolism, and the production of secondary metabolites. Each medicinal plant has a specific temperature range suitable for its growth. Very high or very low temperature may reduce plant development and may also affect the formation of active constituents.

Some medicinal plants grow well in temperate regions during summer but cannot tolerate frost in winter. Therefore, selection of a suitable temperature range is essential for successful cultivation.

Table: 2.13 Optimum Temperature for Drug Cultivation

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

2.3.3 Rainfall and Irrigation

Rainfall plays an important role in the growth and development of plants. However, the amount of rainfall required varies from plant to plant. Its effect depends on the total annual rainfall, distribution of rainfall throughout the year, and the water-holding capacity of the soil.

Water is essential for normal plant growth because it helps in nutrient absorption, metabolic activities, and overall development. Most medicinal plants require adequate rainfall or proper irrigation facilities for healthy growth. Well-distributed rainfall throughout the year is more beneficial than heavy rainfall for a short period.

Some xerophytic plants, such as aloe and acacia, can grow with limited water supply and require very little rainfall or irrigation. On the other hand, excessive rainfall may be harmful because it can cause waterlogging, root diseases, and leaching of water-soluble constituents from the plant. This may reduce the amount of secondary metabolites present in medicinal plants.

Therefore, irrigation should be provided according to the specific requirement of each crop. Proper irrigation maintains soil moisture, supports nutrient uptake, and improves the quality and yield of medicinal plants.

2.3.4 Day Length and Daylight

Day length has a significant effect on the production of active constituents in medicinal plants. Plants grown under long-day conditions may produce different constituents or different quantities of constituents compared with plants grown under short-day conditions.

For example, peppermint produces menthone, menthol, and traces of menthofuran under long-day conditions. Under short-day conditions, it mainly produces menthofuran.

Daylight also affects alkaloid production. Increased daylight may increase alkaloid content in plants such as belladonna, stramonium, and cinchona. The intensity and type of light also influence plant growth and metabolite formation.

2.3.5 Soil

Soil is one of the most important factors in plant cultivation. It provides mechanical support, water, air, minerals, and organic matter required for plant growth. Different medicinal plants require different types of soil and nutrients. The important properties of soil are:

1. Physical properties
2. Chemical properties
3. Microbiological properties

Soil texture depends on the size of soil particles and affects water-holding capacity. Soil minerals, pH, calcium content, and nitrogen content also influence plant growth and active constituent production. Nitrogen-rich soil may increase alkaloid production in some medicinal plants.

Table 2.14: Types of Soil Based on Particle Size

Particle Size	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

Table 2.15: Types of Soil Based on Clay Percentage

Type of Soil	Composition
Clay	More than 50% clay
Loamy soil	30–50% clay
Silt loam	20–30% clay
Sandy loam	10–20% clay
Sandy soil	More than 70% sand
Calcareous soil	More than 20% lime

The amount of organic matter also determines soil quality. Soil containing less than 0.5% organic matter is considered poor. Soil containing 0.5–1.5% humus is called intermediate soil, while soil containing 1.5–5% organic matter is considered rich.

A good soil should have proper pore spaces. Ideally, half of the pore spaces should contain water and the remaining half should contain air. Proper aeration is necessary for healthy root growth.

2.3.6 Soil pH

Table 2.36: Effect of Light Exposure on Crude Drugs

Drug/Material	Effect of Light Exposure
Ergot	Ergot alkaloids are rapidly degraded; therefore, it should be stored in light-resistant containers.
Digitalis	Glycosides may gradually deteriorate when exposed to strong light.
Peppermint, lemon, orange and clove oils	Volatile oils may oxidize or undergo colour changes after prolonged light exposure.
Turmeric and saffron	May lose their natural colour on prolonged exposure to direct sunlight.
Paprika, annatto and other naturally coloured drugs	Natural pigments may fade during improper storage.
Riboflavin-containing preparations	Highly sensitive to light and may undergo rapid degradation.

Photosensitive drugs should be stored in amber-coloured, opaque, or light-resistant containers.

4. Oxygen or Air Exposure

Oxygen present in air may cause oxidation of volatile oils, fixed oils, alkaloids, phenolic compounds, vitamins, and unsaturated substances. Oxidation may produce rancidity, resinification, discolouration, or loss of activity.

Table 2.37: Effect of Oxygen/Air Exposure on Crude Drugs

Drug/Material	Effect of Oxygen or Air Exposure
Clove oil	May oxidize and develop a resinous or unpleasant odour when stored in poorly sealed containers.
Lemon, orange, turpentine and peppermint oils	May undergo oxidation and resinification.
Linseed oil, cod-liver oil and almond oil	May become rancid after prolonged exposure to air.
Adrenaline and other catechol compounds	May darken due to oxidation.
Tannins	May oxidize and form darker, less-soluble substances.
Vitamin-containing natural products	Products containing vitamins A and C may lose activity through oxidation.

5. Microbial Contamination and Pest Infestation

Crude drugs may be attacked by bacteria, fungi, insects, mites, rodents, and other pests. Such contamination lowers quality, destroys active constituents, and may introduce harmful substances such as mycotoxins.

Table 2.38: Effect of Microbial Growth and Pest Infestation on Crude Drugs

Drug/Material	Effect of Microorganisms or Pests
Improperly dried senna leaves	May develop fungal growth and show reduced laxative activity.
Groundnuts, cereals and oil seeds	May be contaminated by Aspergillus species, resulting in aflatoxin production.
Liquorice, ginger, turmeric and rhubarb	May be attacked and damaged by beetles and other storage insects.
Gum acacia, starch and tragacanth	May suffer insect damage, particularly under humid storage conditions.
Belladonna and Digitalis leaves	May become mouldy when packed before complete drying.
Drugs stored in jute or gunny bags	Rodents may contaminate them with urine, hair and faecal matter.

Pest infestation can be controlled through proper sanitation, regular inspection, dry storage, insect-proof containers, and the use of approved pest-control or fumigation procedures. Natural repellents such as neem leaves may also be used in some traditional storage practices.

6. Packaging Material

The nature and quality of the packaging material determine the degree of protection against moisture, light, oxygen, volatile loss, contamination, and pest attack.

Table 2.39: Effect of Container and Packaging on Crude Drugs

Drug/Material	Suitable Container and Storage Requirement
Volatile oils	Store in well-filled, airtight, dark-coloured glass containers to prevent evaporation and oxidation.

Multiple Choice Questions

1. Which of the following is the major advantage of cultivating medicinal plants?
(a) Increased adulteration
(b) Better quality and regular supply
(c) Reduced medicinal value
(d) Higher dependence on wild plants

2. Which medicinal plant is mainly obtained from cultivated sources?
(a) Nux vomica (b) Acacia
(c) Peppermint (d) Myrobalan

3. Organic farming mainly avoids the use of:
(a) Compost
(b) Biofertilizers
(c) Synthetic fertilizers and pesticides
(d) Farmyard manure

4. Which principle of organic farming emphasizes maintaining the health of soil, plants, animals, and humans?
(a) Ecology (b) Fairness
(c) Care (d) Health

5. Sexual propagation of medicinal plants is also known as:
(a) Tissue culture (b) Seed propagation
(c) Vegetative propagation (d) Layering

6. Which method of seed sowing is most suitable for very small seeds?
(a) Dibbling (b) Nursery method
(c) Broadcasting (d) Grafting

7. Which of the following is an example of a plant propagated by the nursery method?
(a) Isabgol (b) Cotton
(c) Cardamom (d) Sesame

8. Which seed treatment is used to break hard seed coat dormancy?
(a) Stratification (b) Scarification
(c) Seed dressing (d) GA_3 treatment

9. Vegetative propagation through rhizomes is commonly seen in:
(a) Garlic (b) Ginger
(c) Colchicum (d) Aloe

10. Which artificial vegetative propagation method joins a stock and a scion?
(a) Cutting (b) Layering
(c) Grafting (d) Division

11. The basic principle of tissue culture is:
(a) Hybridization (b) Mutation
(c) Totipotency (d) Polyploidy

12. Which of the following is an advantage of micropropagation?
(a) High genetic variation
(b) Large-scale production of disease-free plants
(c) Low laboratory cost
(d) No sterile conditions required

13. According to GACP, medicinal plants should preferably be harvested:
(a) During heavy rainfall
(b) At the optimum season and growth stage
(c) At any convenient time
(d) After prolonged storage in the field

14. Which factor mainly influences the production of secondary metabolites in medicinal plants?
(a) Packaging material
(b) Soil, climate, and temperature
(c) Colour of containers
(d) Transport vehicle

15. Tea and cinchona grow best at:
(a) Sea level (b) High altitudes
(c) Desert regions (d) Coastal marshes

16. Which nutrient is mainly responsible for vegetative growth in plants?
(a) Phosphorus (b) Potassium
(c) Nitrogen (d) Calcium

17. Rhizobium is an example of a:
(a) Chemical fertilizer (b) Biofertilizer
(c) Herbicide (d) Fungicide

18. Which method of pest management combines biological, cultural, and chemical methods?
(a) Organic farming
(b) Crop rotation
(c) Integrated Pest Management (IPM)
(d) Hydroponics

19. Powdery mildew is caused by:
(a) Virus (b) Bacterium
(c) Fungus (d) Nematode

20. Which of the following is an example of a weed?
(a) Aloe vera (b) Bermuda grass
(c) Ginger (d) Cardamom

Answer Key

1-(b)	2-(c)	3-(c)	4-(d)	5-(b)	6-(c)	7-(c)	8-(b)	9-(b)	10-(c)
11-(c)	12-(b)	13-(b)	14-(b)	15-(b)	16-(c)	17-(b)	18-(c)	19-(c)	20-(b)

3 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.

3.1 Adulteration of Drugs of Natural Origin

3.1.1 Introduction

Drug adulteration is the practice of partially or completely replacing a genuine crude drug with an inferior, spurious, inactive, or harmful substance. The substituted material may lack the chemical constituents and therapeutic properties of the original drug.

In simple terms, adulteration refers to the lowering of the quality, purity, and medicinal value of a drug. It may occur intentionally for financial gain or accidentally because of improper identification, collection, processing, handling, or storage.

Intentional adulteration is commonly associated with the high cost, scarcity, or increased demand for a genuine drug. It is also frequently observed in illicit and contraband drugs, where foreign substances may be added to increase their weight or apparent value.

Drug adulteration may be defined as the debasement of an authentic crude drug by mixing it with, replacing it by, or adding inferior, exhausted, artificial, foreign, or harmful substances. As a result, the adulterated drug may show:

- Reduced purity

Figure 3.1: Genuine and Adulterated Senna Leaves

- Lower potency
- Altered chemical composition
- Decreased therapeutic activity
- Poor quality
- Possible toxicity

Terms Associated with Adulteration

1. Deterioration

Deterioration is the gradual loss of quality, potency, or stability of a drug due to physical, chemical, or biological factors.

It may result from exposure to:

- Heat
- Moisture
- Light
- Air
- Enzymes
- Microorganisms
- Prolonged storage

2. Admixture

Admixture refers to the accidental mixing of one substance with another. It generally occurs because of carelessness, ignorance, improper collection, or faulty handling.

3. Sophistication

Sophistication is the deliberate addition of inferior or artificial materials to a genuine drug for commercial benefit.

4. Substitution

Substitution occurs when the original drug is partly or completely

Tannins	Ferric chloride solution	Blue, green, or blue-black colour
Calcium carbonate	Dilute acid	Effervescence due to carbon dioxide

These reactions help identify specific constituents present within cells and tissues.

3. Microscopy in the Detection of Adulteration

Microscopic examination is particularly valuable for detecting adulterants in powdered drugs because external morphological features are destroyed during grinding.

Examples:

- Genuine powdered cloves do not normally contain sclereids or calcium oxalate crystals, whereas these structures are found in powdered clove stalks.
- Starch is present in powdered clove fruits but is absent from genuine clove buds.
- Non-lignified vessels in powdered rhubarb may indicate the presence of foreign material.
- Uncharacteristic vessels in ginger powder may suggest adulteration.
- The presence, shape, or absence of aloin crystals may help distinguish different varieties of aloes.
- The size of starch grains may help differentiate genuine cinnamon from related species.

4. Microscopic Linear Measurements

Microscopic linear measurement involves determining the dimensions of characteristic cells and tissues with the help of a calibrated microscope.

Structures commonly measured include:

- Diameter of starch grains
- Length and width of fibres
- Size of vessels
- Dimensions of trichomes
- Size of pollen grains
- Diameter of crystals

For example, the dimensions of starch grains in Cinnamomum cassia can assist in distinguishing it from other cinnamon species or adulterants.

5. Quantitative Microscopy

Quantitative microscopy involves the numerical determination of specific microscopic characters. It provides relatively constant values that are useful for the identification and standardization of leaf drugs. Important quantitative parameters include:

- Palisade ratio
- Vein-islet number
- Vein-termination number
- Stomatal number
- Stomatal index
- Size of starch grains
- Length of fibres
- Number of characteristic cells per unit area

Differences in stomatal number and palisade ratio may be used to distinguish different varieties of senna. Similarly, the number of sclerenchymatous cells per square millimetre may help differentiate varieties of cardamom seeds.

A. Leaf Constants or Diagnostic Characters of Leaves

Leaf constants are numerical values determined microscopically from the epidermis and internal tissues of leaves. They are useful because they remain fairly constant for a particular species under normal conditions.

1. Palisade Ratio

The palisade ratio is the average number of palisade cells situated beneath a single epidermal cell. It is calculated by observing a group of epidermal cells and counting the palisade cells lying beneath them. Palisade ratio can also be determined from suitably prepared powdered leaf drugs.

2. Vein-Islet Number

The vein-islet number is the average number of small areas of photosynthetic tissue enclosed by veinlets per square millimetre of the leaf surface. It is determined in the region midway between the midrib and the leaf margin.

3. Vein-Termination Number

The vein-termination number is the average number of free veinlet endings present per square millimetre of the leaf surface. The measurement is generally made midway between the midrib and the margin.

4. Stomatal Number

The stomatal number is the average number of stomata present per square millimetre of the leaf epidermis. The value may be determined separately for the upper and lower epidermis.

5. Stomatal Index

The stomatal index is the percentage of stomata in relation to the total number of epidermal cells and stomata present in the same area. It is calculated using the following equation:

$$\text{Stomatal Index (SI)} = S/(E+S)\times 100$$

Where:

- SI = Stomatal index
- S = Number of stomata in a given area
- E = Number of ordinary epidermal cells in the same area

Each stoma is counted as one unit.

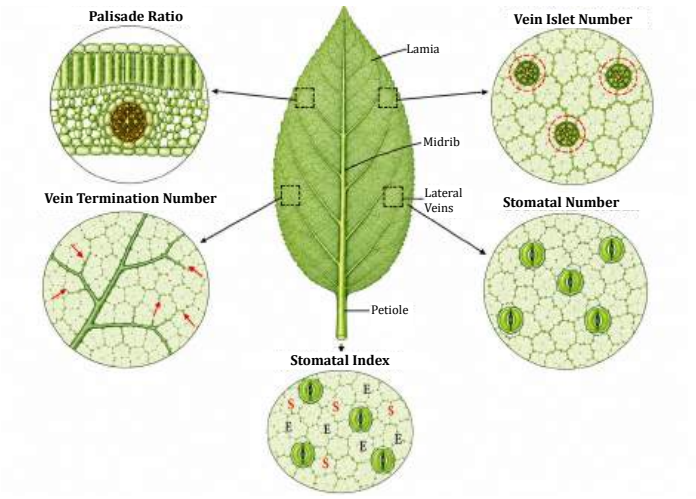


Figure 3.2: Microscopic views of Leave Constants

For ginger powder, the value of P may be taken as approximately 286,000 starch grains per milligram when the specified official method is followed.

Applications of Lycopodium Spore Method

The Lycopodium spore method may be used for the evaluation of powdered:

- Ginger
- Clove
- Cardamom
- Nutmeg
- Fennel
- Coriander
- Other umbelliferous fruits

Advantages of Microscopic Evaluation

Microscopic evaluation:

- Requires only a small quantity of the sample
- Provides rapid identification
- Is useful for whole and powdered drugs
- Detects microscopic adulterants
- Helps distinguish closely related species
- Permits quantitative measurement
- Supports pharmacopoeial standardization
- Is economical and widely applicable

Limitations

The method also has certain limitations:

- It requires trained and experienced personnel.
- Proper sectioning and staining techniques are essential.
- Closely related species may possess similar tissues.
- Processing may destroy diagnostic structures.
- Microscopy alone cannot determine the complete chemical profile.
- Quantitative results depend on proper sampling and accurate counting.

3.2.4.3 Chemical Evaluation

Chemical evaluation involves the examination of crude drugs through chemical reactions, analytical tests, and quantitative assays. It is used to establish the chemical identity, purity, strength, and quality of a drug by detecting and measuring its active constituents. This method includes:

- Preliminary phytochemical screening
- Specific identification tests
- Isolation of active constituents
- Purification and characterization of compounds
- Quantitative estimation of chemical constituents
- Determination of chemical constants
- Chromatographic and instrumental analysis

Chemical evaluation is particularly useful when the quality of a crude drug depends mainly on its chemical composition rather than its external or microscopic characteristics.

Objectives of Chemical Evaluation

The principal objectives are to:

- Identify important phytoconstituents
- Confirm the chemical identity of a crude drug
- Estimate active or marker compounds
- Detect chemical adulterants and substitutes
- Determine purity and potency
- Establish the chemical profile of a drug
- Compare different batches of crude material
- Support pharmacopoeial standardization
- Isolate and characterize therapeutically important compounds

Chemical Constants and Assay Values

Several chemical constants are used to assess natural products such as fats, oils, waxes, resins, balsams, gums, and volatile oils. Important values include:

- Acid value
- Saponification value
- Ester value
- Acetyl value
- Iodine value
- Hydroxyl value
- Sulphated ash
- Methoxy content
- Volatile acidity

Table 3.9: Applications of Chemical Constants

Natural product	Commonly determined parameters
Resins	Acid value and sulphated ash
Balsams	Acid value, ester value and saponification value
Volatile oils	Ester value and acetyl value
Fixed oils and fats	Acid, iodine and saponification values
Gums	Methoxy content and volatile acidity
Waxes	Acid, ester and saponification values

Abnormal values may indicate deterioration, substitution, improper processing, or adulteration.

Specific Chemical Tests

Specific chemical reactions are useful for identifying active constituents and detecting adulterants.

Table 3.10: Chemical Tests and their Applications

Test	Application
Copper acetate test	Detection of colophony in resins, waxes and balsams
Halphen's test	Detection of cottonseed oil
Van Urk reagent	Identification of indole alkaloids, particularly in ergot
Vitali–Morin test	Detection of tropane alkaloids
Murexide test	Identification of purine bases
Bornträger's test	Detection of anthraquinone glycosides
Legal's test	Detection of cardenolides or cardiac glycosides
Liebermann–Burchard test	Detection of steroids and triterpenoids

Table 3.14: Illustrative Biological-Activity Standards

Drug or substance	Biological activity traditionally represented by 1 IU
Digitalis	Activity present in approximately 76 mg of a standard preparation
Vitamin A	Activity equivalent to approximately 0.344 µg of a standard preparation
Vitamin D	Activity equivalent to approximately 0.025 µg of a standard preparation
Heparin	Activity present in approximately 7.7 µg of a standard preparation
Cinchona	Quinine or total quinoline alkaloids
Rauwolfia	Reserpine or total alkaloids
Ergot	Ergometrine or total ergot alkaloids

Official reference standards and current pharmacopoeial specifications should be consulted because unit definitions may be revised.

Types of Biological Assays

Biological assay methods may be broadly classified into three groups:

1. Toxic Methods

In toxic methods, the potency of a substance is determined from a toxic response produced in experimental organisms. The response may include:

- Paralysis
- Convulsions
- Respiratory failure
- Death
- Another clearly defined toxic effect

The dose producing a specified response is compared with that of a standard preparation.

2. Symptomatic Methods

In symptomatic methods, the observable symptoms or physiological changes produced by a drug are measured. Examples include:

- Changes in blood glucose
- Alteration in blood pressure
- Change in body temperature
- Sleeping time
- Convulsive response
- Inflammatory swelling
- Behavioural changes

3. Tissue or Organ Methods

In this method, the action of a drug is studied on an isolated organ, tissue, cell culture, or biological preparation. Common preparations include:

- Guinea-pig ileum
- Rabbit jejunum
- Frog rectus abdominis
- Rat phrenic nerve–diaphragm
- Isolated heart
- Cultured hepatocytes

Tissue methods generally offer better control over experimental conditions and reduce interference from whole-body physiological processes.

Biological Testing of Herbal Drugs

General Requirements

Evaluation of the biological activity of herbal drugs requires:

- A suitable experimental model
- A negative or vehicle-control group
- A standard-reference group
- One or more test-dose groups
- A validated experimental procedure
- Measurable biological parameters
- Appropriate statistical analysis
- Ethical approval for animal or human-derived material

Biological testing may be performed using in vivo, in vitro, or ex vivo methods.

A. Evaluation of Hepatoprotective Activity

Hepatoprotective activity refers to the ability of a substance to prevent, reduce, or reverse liver damage.

Liver injury may be produced experimentally by chemicals, medicines, alcohol, environmental pollutants, immunological reactions, or infectious agents. Commonly used hepatotoxic agents include:

- Carbon tetrachloride
- Paracetamol
- Ethanol
- Rifampicin
- Other experimentally validated hepatotoxic substances

Carbon tetrachloride is frequently used to produce acute hepatic injury, whereas alcohol and certain medicines may be employed in models of repeated or chronic toxicity.

In Vivo Evaluation

Albino rats or another validated animal model may be divided into:

- Normal-control group
- Hepatotoxic control group
- Standard-treatment group
- Herbal-drug treatment groups

After confirming liver injury, the test extract is administered for a defined period. Its protective activity is assessed by comparing the treated animals with the toxic-control group.

Parameters of Evaluation

1. Physiological Parameters

Changes in the metabolism of certain drugs may indicate impairment of liver function. For example, prolongation of hexobarbital-induced sleeping time can reflect reduced hepatic metabolic activity.

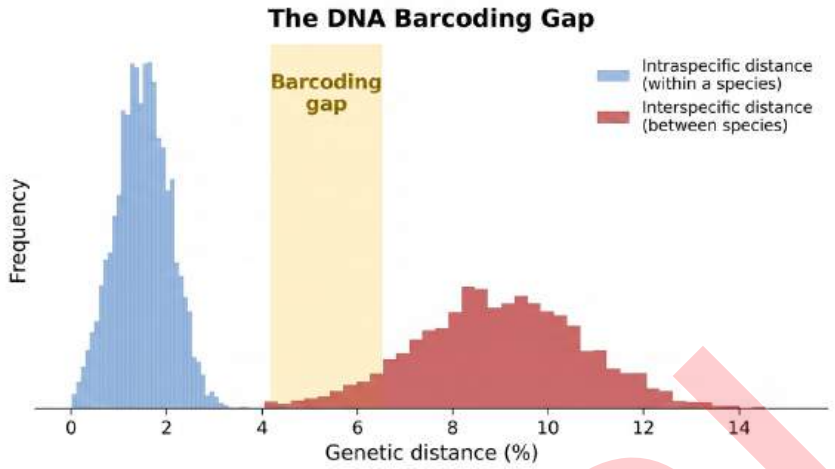


Figure 3.7: The barcoding gap: intraspecific genetic distances (blue) cluster well below interspecific distances (red), enabling reliable species discrimination.

3.4.2 Common Barcode Loci Used in Medicinal Plant Authentication

Because no single locus performs optimally across all plant families, the Consortium for the Barcode of Life (CBOL) Plant Working Group evaluated seven candidate plastid regions and recommended the two-locus combination of rbcL and matK as the core barcode for land plants, to be supplemented with nuclear ITS/ITS2 and the plastid psbA–trnH spacer where additional resolution is required.

Table 3.26: Common DNA Barcode Loci Used for Plant Species Identification

Locus	Genome / Type	Key Features	Limitations
rbcL	Plastid, coding	Easy to amplify and align; highly conserved; part of CBOL core barcode	Low interspecific variability; poor resolution in closely related species
matK	Plastid, coding	Higher discriminatory power than rbcL; part of CBOL core barcode	Difficult universal primer design; variable amplification success
ITS / ITS2	Nuclear ribosomal DNA	High interspecific divergence; good species-level discrimination; short and easily amplified (ITS2)	Paralogy from incomplete concerted evolution; fungal contamination risk
psbA–trnH	Plastid, intergenic spacer	Highly variable, useful supplementary marker; easy amplification	Length variation and mononucleotide repeats complicate alignment

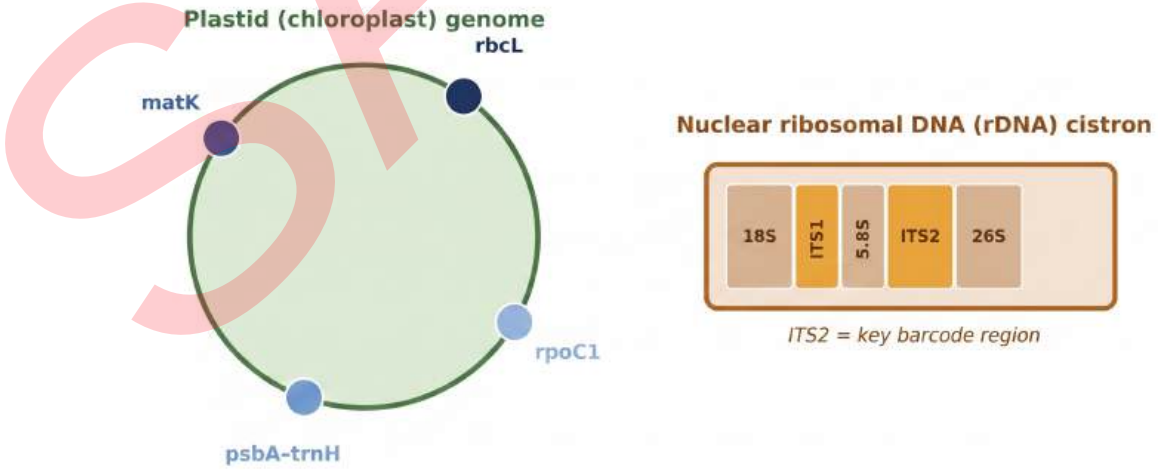


Figure 3.8: Approximate genomic location of the common plastid and nuclear barcode loci used in medicinal plant authentication (schematic, not to scale).

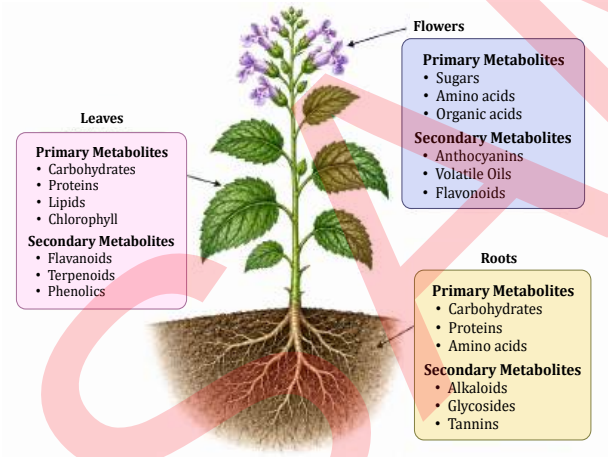
4 INTRODUCTION TO METABOLITES OF PLANT ORIGIN

4.1 Definition and General Properties of Plant Metabolites

4.1.1 Introduction

The understanding of plant metabolism is built upon the fundamental division of metabolic processes into primary and secondary metabolism. This classification was introduced by H. Kossel in 1891 and remains an important concept in plant biochemistry. Metabolites are naturally occurring organic substances produced within living organisms through enzyme-controlled biochemical reactions known as metabolic pathways. Primary metabolites are directly involved in vital processes such as plant growth, development, respiration, and reproduction. Since these functions are essential for survival, primary metabolites are commonly found in nearly all plants.

Secondary metabolites, however, are not directly required for basic growth and are distributed selectively among different plant species. They usually perform specialized ecological and protective roles. Many secondary metabolites are responsible for the characteristic colour, aroma, and taste of plants. They also help plants interact with their surroundings by attracting pollinators, defending against herbivores, resisting pathogens, and competing with neighbouring organisms.



4.1.2 General Properties of Plant Metabolites

Plant metabolites are naturally occurring chemical substances produced through enzyme-controlled biochemical reactions in plant cells. Collectively, these compounds form the plant metabolome and play important roles in plant growth, development, reproduction, defence, signalling and adaptation to environmental conditions. Plant metabolites are broadly classified into primary metabolites and secondary or specialized metabolites. Primary metabolites are directly involved in essential cellular functions, whereas specialized metabolites mainly contribute to ecological interactions, defence and environmental adaptation.

Chemical Diversity

Plants produce more than 500,000 chemical compounds, broadly classified as primary and secondary metabolites. Primary metabolites, including carbohydrates, proteins, lipids, and nucleic acids, are essential for plant growth, energy production, structural development, and genetic functions. Secondary metabolites, such as alkaloids, terpenoids, and phenolic compounds, are not directly involved in basic growth but help plants defend against pests and pathogens, tolerate environmental stress, attract pollinators, and communicate with other organisms. This chemical diversity also makes plants valuable sources of food, nutrients, and medicines.

Molecular Size

Plant metabolites are mainly small organic molecules whose molecular masses generally lie between about 50 and 3,000 Da. Their size, structure and biological roles differ according to whether they belong to primary or specialized metabolism. Primary metabolites are commonly less than 900 Da and participate directly in essential physiological activities, including energy production, respiration, cellular growth, division and reproduction. Amino acids, simple carbohydrates, organic acids and fatty acids are typical examples of this group. Secondary metabolites, also known as specialized metabolites, are often more structurally complex and usually occur within an approximate molecular-mass range of 300 to 3,000 Da. Instead of supporting basic cellular metabolism directly, these substances help plants defend themselves, communicate with other organisms, produce colour and fragrance, attract pollinators and tolerate environmental stress. Important secondary metabolites include alkaloids, phenolic compounds such as flavonoids and anthocyanins, and terpenoids ranging from small C5 compounds to larger C40 molecules.

Polarity and Solubility

The solubility of plant metabolites depends mainly on their polarity. Polar compounds such as glycosides, polysaccharides, amino acids, and organic acids dissolve readily in water or methanol and are commonly extracted by maceration, infusion, or decoction. Semi-polar constituents, including flavonoids, phenolic compounds, and many alkaloids, are better extracted with ethanol, acetone, ethyl acetate, or hydroalcoholic mixtures. Alkaloidal salts are generally water-soluble, whereas free alkaloidal bases dissolve more readily in organic solvents. Non-polar metabolites such as terpenoids, steroids, oils, waxes, and essential oils require solvents like hexane, petroleum ether, or chloroform. Volatile oils are usually isolated by steam distillation or hydrodistillation.

Volatility

Plant volatile metabolites are small, lipophilic compounds with low molecular weight and high vapour pressure, allowing them to evaporate easily into the atmosphere. They act as chemical signals that attract pollinators and seed-dispersing organisms, produce characteristic plant aromas and flavours, and protect against her-

Chemically, carbohydrates are defined as Polyhydroxy aldehydes, polyhydroxy ketones, or compounds that produce such substances upon hydrolysis. Carbohydrates may therefore contain several hydroxyl groups along with either an aldehyde or a ketone functional group.

Biological and Pharmacognostical Importance

- Carbohydrates are among the earliest organic compounds formed during photosynthesis. They constitute a major portion of plant biomass and perform several essential structural and physiological functions.
- Cellulose forms the rigid framework of plant cell walls and provides mechanical strength to plant tissues. Starch serves as an important reserve food material and supplies energy when required by the plant.
- In pharmacognosy, carbohydrates are particularly important because sugars combine with various non-sugar compounds to form glycosides and several secondary metabolites. These compounds often possess significant medicinal and pharmacological properties.
- Mucilages, such as those found in marshmallow root and psyllium seeds, absorb and retain large quantities of water. They are commonly used as soothing, protective, suspending, and bulk-forming agents.
- Gums and mucilages are similar in their chemical composition and physical properties. However, mucilages are generally produced during the normal growth of plants, whereas gums are usually formed as a result of injury, stress, or pathological changes. Gums commonly appear as solidified exudates and are mainly composed of sugar units and uronic acids.
- The cell walls of brown seaweeds and the middle lamellae of higher plant tissues also contain polysaccharides rich in uronic acid components.

General Physical Properties

Carbohydrates show different physical properties depending on their molecular weight. Low-molecular-weight carbohydrates are generally:

- Crystalline in nature
- Sweet in taste
- Readily soluble in water
- Examples include glucose, fructose, and sucrose.

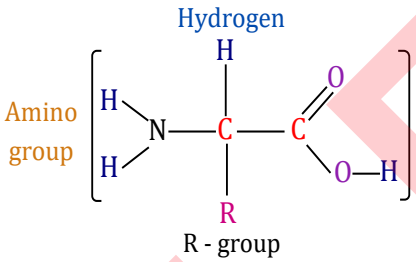
High-molecular-weight carbohydrates or polysaccharides are generally:

- Amorphous in nature
- Tasteless
- Less soluble or insoluble in water
- Examples include starch, cellulose, and inulin.

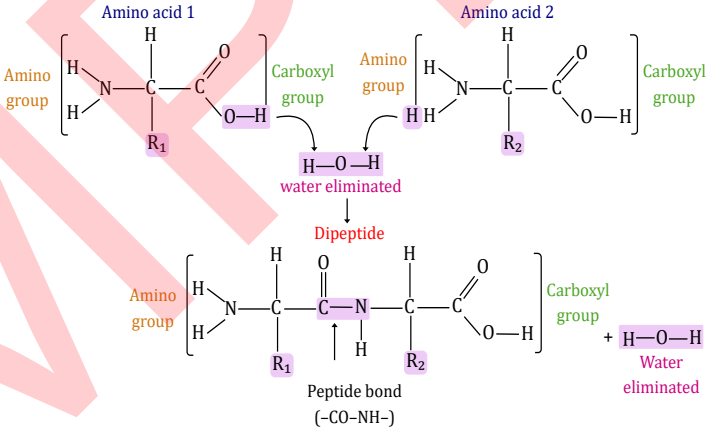
4.2.1.4 Proteins

Proteins are complex organic macromolecules with high molecular weights. They are composed of amino acids linked together through peptide bonds. The word protein is derived from the Greek word "protos," meaning first or of primary importance, indicating their essential role in living organisms.

Each amino acid contains an amino group (-NH_2), a carboxyl group (-COOH), a hydrogen atom, and a variable side chain (R group) attached to a central alpha carbon. The nature of the side chain determines the properties of each amino acid.



Amino acids are joined together by peptide bonds. A peptide bond is formed between the amino group of one amino acid and the carboxyl group of another amino acid with the elimination of one molecule of water. Long chains of amino acids form polypeptides, which fold into specific three-dimensional structures to form functional proteins.



Proteins are fundamental components of every living cell and are required for maintaining cellular structure and carrying out biological functions. Many proteins act as enzymes or form functional components of enzymes, while others serve structural and mechanical roles. Structural proteins contribute to the formation of the cytoskeleton, connective tissues, muscles, skin, hair, and other biological frameworks. They also participate in cellular communication and tissue signalling.

Sources and Occurrence

Proteins are obtained from both plant and animal sources. In plants, reserve proteins are commonly stored in seeds in the form of aleurone grains. These protein-containing structures are particularly abundant in the outer layers of cereal grains and in many oilseeds. In animals, proteins occur as important structural and functional components, including:

- Collagen in connective tissues
- Keratin in hair, wool, feathers, nails, and horns
- Elastin in elastic connective tissues
- Casein in milk
- Haemoglobin in red blood cells
- Plasma proteins in blood

waxes contain high-molecular-weight monohydric alcohols. Common alcohols found in waxes include:

- Cetyl alcohol
- Ceryl alcohol
- Myricyl alcohol
- Melissyl alcohol

Certain waxes may also contain sterols, hydrocarbons, free fatty acids, and free alcohols.

Table 4.5: Difference Between Fats and Waxes

Fats and fixed oils	Waxes
Glycerol	Long-chain monohydric alcohol
Triacylglycerols	Esters of fatty acids and higher alcohols
Readily saponified by aqueous or alcoholic alkali	Generally require prolonged heating with alcoholic alkali
Generally digestible	Usually poorly digested
Important energy source	Limited nutritional significance
Energy storage	Protective and water-repellent coating

Waxes are more resistant to hydrolysis than fats and oils. Human digestive enzymes have limited ability to hydrolyse many wax esters; therefore, most waxes are not suitable as major dietary substances.

4.2.2 Secondary Metabolites

Secondary metabolites are organic compounds produced by plants, microorganisms, fungi, and other organisms that are not directly involved in the normal growth, development, or reproduction of the organism (unlike primary metabolites such as carbohydrates, proteins, lipids, and nucleic acids). Features of the secondary metabolites are:

- They are synthesized during the secondary metabolism pathway, often derived from primary metabolic pathways (e.g., shikimic acid pathway, mevalonate pathway).
- Generally produced in specific tissues, at specific developmental stages, or in response to environmental stress, stimuli, or attack.
- Not essential for the survival of the producing organism on a day-to-day basis, but provide ecological and adaptive advantages.
- Often species-specific or even strain-specific, unlike primary metabolites which are universal.
- Examples: alkaloids, terpenoids, phenolics, glycosides, etc.

Table 4.6: Classification of Secondary Metabolites

Major Group	Classification / Subclasses	Examples
A. Terpenoids (Terpenes/Isoprenoids)	Monoterpenes (C_{10})	Menthol, limonene, geraniol
	Sesquiterpenes (C_{15})	Artemisinin, farnesol
	Diterpenes (C_{20})	Gibberellins, taxol
	Triterpenes (C_{30})	Squalene, saponins
	Tetraterpenes (C_{40})	Carotenoids, β-carotene, lycopene
	Polyterpenes	Rubber, gutta
B. Phenolic Compounds (Phenolics)	Simple phenols and phenolic acids	Caffeic acid, gallic acid, salicylic acid
	Flavonoids	Anthocyanins, flavones, flavonols, isoflavones
	Tannins	Hydrolysable tannins, gallotannins, condensed tannins
	Lignans and lignin	Lignans, lignin
	Coumarins	Coumarins
	Stilbenes	Resveratrol
C. Alkaloids	Pyrrolidine alkaloids	Hygrine
	Tropane alkaloids	Atropine, cocaine
	Pyridine/Piperidine alkaloids	Nicotine, coniine
	Isoquinoline alkaloids	Morphine, codeine
	Indole alkaloids	Reserpine, vincristine

Sesquiterpenoids	3	15	$C_{15}H_{24}$
Diterpenoids	4	20	$C_{20}H_{32}$
Sesterterpenoids	5	25	$C_{25}H_{40}$
Triterpenoids	6	30	$C_{30}H_{48}$
Tetraterpenoids	8	40	$C_{40}H_{64}$
Polyterpenoids	More than 8	More than 40	$(C_5H_8)_n$

The general formulae shown represent the basic hydrocarbon forms. The actual molecular formula may differ because of cyclisation, oxidation, reduction, rearrangement, or the introduction of functional groups.

Pharmacological and Commercial Importance

Terpenoids possess considerable medicinal and industrial importance. They may exhibit:

- Antimicrobial activity
- Antiviral activity
- Anti-inflammatory activity
- Antimalarial activity
- Anticancer activity
- Expectorant activity
- Analgesic activity
- Sedative activity
- Antioxidant activity
- Insecticidal activity

Important medicinal examples include:

- Artemisinin as an antimalarial sesquiterpenoid
- Paclitaxel as an anticancer diterpenoid
- Menthol as a cooling and topical soothing agent
- Camphor as a counterirritant
- Thymol as an antimicrobial agent
- Squalene as a pharmaceutical and cosmetic ingredient

Terpenoids are also widely used in perfumes, cosmetics, flavouring agents, food products, pharmaceuticals, pesticides, and the rubber industry.

4.2.2.7 Volatile Oils

Volatile oils are aromatic, naturally occurring substances obtained mainly from plants. They readily evaporate when exposed to air at ordinary temperatures and are therefore known as volatile oils. They are also called essential oils because they contain the characteristic fragrance or "essence" of the plant from which they are obtained. The older term ethereal oils refers to their volatile nature and solubility in ether.

Volatile oils are responsible for the characteristic odour and, in many cases, the flavour of aromatic plants. They are widely used in pharmaceutical preparations, perfumes, cosmetics, foods, beverages, and traditional medicines.

Although most volatile oils are obtained from plants, a small number of aromatic substances may also be derived from animal or microbial sources.

Occurrence in Plants

In most cases, volatile oils are already present in the living plant and are stored in specialized secretory tissues or structures, including oil cells, oil glands, secretory cavities, secretory ducts, glandular trichomes, resin canals, and epidermal or subepidermal tissues.

Examples of their occurrence include:

- Oil ducts in the fruits of Apiaceae plants, such as fennel and coriander
- Oil glands in the peel of lemon and orange
- Oil-containing cavities in eucalyptus leaves
- Glandular trichomes in mint, basil, and other aromatic plants
- Secretory cells in cinnamon bark and ginger rhizome

Volatile oils may occur in various plant parts, including leaves, flowers, fruits, seeds, bark, wood, roots, rhizomes, and peels. The quantity and chemical composition of an essential oil may vary according to the plant species, plant organ, age, season, geographical region, climate, soil conditions, time of collection, and method of processing.

Table 4.12: Classification of Volatile Oils

Groups	Drugs	Condensed tannins
Hydrocarbons	Turpentine oil	Polymers of flavonoid-related units
Alcohols	Peppermint oil, Pudina, Sandalwood oil, etc.	Not readily hydrolysed
Aldehydes	Cymbopogon species, Lemongrass oil, Cinnamon, Cassia and Saffron	Phlobaphenes on treatment with acids
Ketones	Camphor, Caraway, Dill, Jatamansi, Fennel, etc.	Mainly carbon–carbon bonds
Phenols	Clove, Ajowan, Tulsi, etc.	Green or greenish-black colour
Phenolic ethers	Nutmeg, Calamus, etc.	Catechol derivatives
Oxides	Eucalyptus, Cardamom and Chenopodium oil	Catechol tannins or proanthocyanidins
Esters	Valerian, Rosemary oil, Garlic, Gaultheria oil, etc.	Catechu, kino and cinchona

5 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.

5.1 Basic Principles of Treatment of Diseases in Different Systems of Medicine Including Ayush and TCM

5.1.1 Introduction

The term AYUSH represents the traditional and complementary systems of healthcare officially recognised in India. The acronym stands for:

- A – Ayurveda
- Y – Yoga and Naturopathy
- U – Unani
- S – Siddha and Sowa-Rigpa
- H – Homoeopathy

These systems include the Indian systems of medicine as well as Homoeopathy. They are practised throughout the country according to regional traditions, public preferences, availability of trained practitioners, and healthcare infrastructure.

Figure 5.1: Ayush System

Each system has its own principles of diagnosis, prevention, treatment, and health promotion. AYUSH systems commonly emphasise holistic well-being, maintenance of health, disease prevention, lifestyle regulation, and the use of natural or traditional therapeutic approaches.

Ayurveda

Ayurveda is regarded as one of the oldest organised systems of medicine. It has a long documented history and has been practised in India for several thousand years.

The term Ayurveda is derived from two Sanskrit words: Ayus, meaning life, and Veda, meaning knowledge or science. Thus, Ayurveda literally means the science or knowledge of life. Thus, Ayurveda may be described as the science of life. It focuses on maintaining balance among the body, mind, senses, and environment.

Ayurveda is practised extensively across many parts of India, particularly in Kerala, Maharashtra, Himachal Pradesh, Gujarat, Karnataka, Madhya Pradesh, Rajasthan, Uttar Pradesh, Delhi, Haryana, Punjab, Uttarakhand, Goa, and Odisha.

Kerala is especially well known for its established Ayurvedic traditions, specialised therapies, medicinal plants, educational institutions, and treatment centres.

Yoga and Naturopathy

Yoga is a traditional discipline that promotes physical, mental, and spiritual well-being through practices such as postures, breathing exercises, meditation, and regulated lifestyle.

Naturopathy is based on the principle that the body possesses an inherent capacity for self-healing. It commonly employs natural approaches such as diet regulation, fasting, hydrotherapy, exercise, massage, exposure to sunlight, mud therapy, and lifestyle modification.

Yoga and Naturopathy are widely used for health promotion, stress management, disease prevention, rehabilitation, and improvement of quality of life.

Unani System of Medicine

The Unani system is based on principles developed from the medical traditions of ancient Greece and subsequently enriched by Arab, Persian, and Indian scholars.

It emphasises the maintenance of balance among the bodily humours and considers factors such as diet, environment, lifestyle, temperament, and physical activity in the prevention and management of disease.

The Unani system is practised mainly in Andhra Pradesh, Karnataka, Jammu and Kashmir, Bihar, Maharashtra, Madhya Pradesh, Uttar Pradesh, Delhi, and Rajasthan. Its therapies may include medicines of plant, animal, and mineral origin, along with dietary regulation, regimental therapy, and lifestyle modification.

Siddha System of Medicine

Siddha is one of the ancient traditional systems of medicine developed mainly in South India. It is closely associated with Tamil culture and the teachings of the Siddhars.

The system gives importance to maintaining harmony among the body, mind, and environment. It uses herbal, mineral, metallic, and animal-derived preparations, together with dietary and lifestyle measures.

It is associated with movement and communication within the body.

Its traditional functions include:

- Movement of the body and limbs
- Respiration
- Circulation and transport
- Elimination of wastes
- Speech
- Sensory and motor activity
- Transmission of impulses
- Regulation of other Doshas

Vata is traditionally considered the driving force behind bodily activity because it governs movement.

Pitta Dosha

Pitta is predominantly associated with the qualities of fire, together with a limited water component. It represents transformation, digestion, and metabolism.

Its traditional functions include:

- Digestion of food
- Metabolic transformation
- Regulation of body heat
- Formation of colour and complexion
- Vision
- Intellect and understanding
- Appetite and thirst

Pitta therefore represents the transformative processes occurring within the body.

Kapha Dosha

Kapha is predominantly composed of the qualities of water and earth. It is associated with structure, stability, nourishment, and lubrication.

Its traditional functions include:

- Maintenance of body structure
- Strength and stability
- Lubrication of joints and tissues
- Moisture and cohesion
- Growth and nourishment
- Immunological resistance in the traditional sense
- Emotional calmness and endurance

A balanced state of Vata, Pitta, and Kapha is regarded as essential for health.

Table 5.2: Relationship Between Elements and Doshas

Dosha	Predominant elements	Principal functional concept
Vata	Space and air	Movement and communication
Pitta	Fire with water	Digestion and transformation
Kapha	Water and earth	Structure, stability and lubrication

IV. Sapta Dhatu: The Seven Body Tissues

Ayurveda describes seven fundamental body tissues known as the Sapta Dhatu. These tissues are considered to support the structure, nourishment, development, and functioning of the body. The seven Dhatus are:

1. Rasa – nutritive fluid or primary nourishing tissue
2. Rakta – blood tissue
3. Mamsa – muscle tissue
4. Meda – adipose or fatty tissue
5. Asthi – bone tissue
6. Majja – marrow and related filling tissue
7. Shukra or Artava – reproductive tissue

According to Ayurvedic theory, digested nutrients are progressively transformed and used to nourish these tissues. Proper formation and balance of the Dhatus are regarded as essential for strength, immunity, growth, reproduction, and general well-being.

Figure 5.5: Saptadhatus

V. Mala: Excretory Products

The waste products formed during digestion and tissue metabolism are known as Malas. The three principal Malas are:

- Purisha – faeces
- Mutra – urine
- Sveda – sweat

Their proper formation and elimination are considered important for maintaining health. Excessive retention, deficiency, or abnormal elimination of these wastes is traditionally associated with disease.

In addition to the major Malas, Ayurveda describes specific metabolic by-products associated with different body tissues.

5.1.2.3 Ayurvedic Concept of Health

Ayurveda defines health as a balanced and coordinated state of the doshas, dhatus, malas, digestive and metabolic activities, sensory and motor functions, mind, and consciousness.

Health is therefore not understood merely as the absence of disease. It includes physical balance, efficient digestion and elimination, mental stability, appropriate sensory functions, and a satisfactory state of well-being.

Prakriti: Individual Constitution

Every individual is believed to possess a characteristic constitutional pattern called Prakriti. It is established at conception and reflects the relative predominance of Vata, Pitta, and Kapha. The

Spiritual relaxation refers to a deeper state of inner peace in which a person develops awareness of the inner self and a connection with a higher spiritual reality.

Through yoga postures, breathing exercises, meditation and self-reflection, the practitioner may develop:

- Inner contentment
- Positive thinking
- Emotional stability
- Self-awareness
- Harmony of body, mind and spirit

Complete yogic relaxation is therefore not merely physical rest; it involves relaxation of the body, calming of the mind and development of inner tranquillity.

II. Proper Exercise in Yoga

The physical exercises of Yoga are known as asanas. They are practised with controlled breathing, awareness and proper alignment. Unlike forceful physical exercise, yoga postures are generally performed slowly and steadily.

The selection of asanas should be based on the practitioner's age, flexibility, health condition and physical capacity. Beginners should practise difficult postures only under the supervision of a trained yoga instructor.

Important Yoga Postures

Figure 5.9: Yoga Postures

1. Malasana – Garland Pose

Malasana is a deep squatting posture that stretches the hips, groin and lower body. This posture may improve hip mobility, stretch the ankles and lower back, strengthen the lower body, and help improve posture and flexibility. However, individuals with knee, hip, or lower-back problems should practise it carefully.

2. Surya Namaskar – Sun Salutation

Surya Namaskar is a coordinated sequence of postures performed with rhythmic breathing. It engages several major muscle groups and promotes whole-body movement.

This practice may improve flexibility and circulation, strengthen different parts of the body, develop coordination between movement and breathing, produce warmth and energy, and help calm and focus the mind.

3. Chaturanga Dandasana – Four-Limbed Staff Pose

Chaturanga Dandasana resembles a low plank and requires considerable strength and alignment.

This posture may strengthen the arms and shoulders, activate the abdominal and core muscles, improve upper-body stability, and prepare the body for more advanced postures.

Beginners should practise it under guidance to avoid excessive pressure on the shoulders and wrists.

4. Utkatasana – Chair Pose

Utkatasana is performed by bending the knees and lowering the hips as though sitting on an imaginary chair.

This posture may strengthen the thighs and legs, activate the core muscles, improve balance and endurance, and generate warmth and energy in the body.

5. Utthita Trikonasana – Extended Triangle Pose

This standing posture involves extending the legs and arms while bending the upper body sideways.

This posture may stretch the legs, hips, and sides of the trunk, improve balance and flexibility, strengthen the legs and back, and promote expansion of the chest.

Beginners may place the lower hand on the shin or a yoga block instead of forcing it towards the floor.

6. Adho Mukha Svanasana – Downward-Facing Dog Pose

In this posture, the body forms an inverted V-shape, with the hands and feet placed on the floor.

This posture may stretch the shoulders, hamstrings, and calves, strengthen the arms and legs, lengthen the spine, activate several major muscle groups, and help reduce stiffness and physical fatigue.

7. Virabhadrasana – Warrior Pose

Virabhadrasana includes a group of strong standing postures that develop stability and concentration.

This posture may strengthen the legs and core muscles, improve balance and stamina, open the hips and chest, and promote confidence, focus, and determination.

8. Ardha Matsyendrasana – Half Lord of the Fishes Pose

This is a seated spinal-twisting posture.

This posture may improve spinal mobility, stretch the back and shoulders, stimulate the abdominal region, support healthy digestion, and help reduce stiffness in the trunk. The twist should be

5.2 Types of Dosage Forms in Ayush Medicines.

5.2.1 Ayurvedic Dosage Forms

Ayurvedic pharmaceutical preparations can be classified into four major groups according to their physical form.

Table 5.13: Classification of Ayurvedic Dosage Forms

Type of Dosage Form	Examples
Solid dosage forms	Vatika, Vati, Gutika and Guggulu preparations
Semisolid dosage forms	Kalka Ghirta, Lepa, Malam and Avaleha
Liquid dosage forms	Asava, Arishta, Swarasa, Hiama, Kwath, Taila, Arka and Taila
Powder dosage forms	Churna, Bhasma, Parapatii, Kakipak rasayana and Khsar
Rasa Chenduram	Processed red mercury preparation

1. Asava and Arishta

Asavas and Arishtas are fermented liquid Ayurvedic preparations. They are prepared by allowing medicinal drugs to ferment in an aqueous solution containing sugar, jaggery or honey for a specified period.

During fermentation, a small quantity of alcohol is naturally produced. This self-generated alcohol extracts alcohol-soluble active constituents from the drugs, improves the extraction of medicinal components, acts as a preservative, and enhances the stability of the formulation.

The main difference between the two preparations is that Arishta is prepared from a decoction, whereas Asava is generally prepared without making a decoction.

Table 5.14: Difference Between Asava and Arishta

Asava	Arishta
Water, expressed juice or infusion	Medicinal decoction or Kashaya
Usually not subjected to decoction	Drugs are boiled to prepare a decoction
Fine powder, juice or infusion	Coarsely powdered drugs used for decoction
Natural fermentation occurs after adding a fermentable sweetening substance	Natural fermentation occurs after adding a fermentable sweetening substance
Arvindasava, Kumaryasava, Vasakasava	Dashamularishta, Ashwagandharishta, Ashokarishta
Night	Day
Substance	Function

Method of Preparation of Arishta

1. Preparation of the Drugs

The medicinal drugs prescribed in the formula are cleaned, dried and converted into a coarse powder.

2. Preparation of Kashaya

The coarsely powdered drugs are boiled with the prescribed quantity of water to prepare a decoction known as Kashaya or Kwatha.

The prepared decoction is filtered and transferred into a clean fermentation vessel.

3. Addition of Sweetening Substance

During fermentation, a small quantity of alcohol is naturally produced. This self-generated alcohol helps extract alcohol-soluble active constituents from the drugs, improves the extraction of medicinal components, acts as a preservative, and enhances the stability of the formulation. The liquid is allowed to cool before fermentation begins.

4. Addition of Prakshepa Dravyas

The aromatic or supplementary drugs mentioned as Prakshepa Dravyas are finely powdered and added to the mixture. These drugs may contribute to the therapeutic action, aroma, taste, and stability of the preparation.

5. Addition of Dhataki Flowers

When prescribed in the formula, properly cleaned Dhataki Pushpa is added. It traditionally supports the fermentation process.

6. Sealing of the Vessel

The mouth of the fermentation vessel is covered with a suitable lid. Traditionally, the edges are sealed with a clay-smeared cloth applied in seven successive layers.

This prevents the entry of dust and contaminants, excessive exposure to air, loss of alcohol and aroma, and disturbance of the fermentation process.

7. Fermentation

The sealed vessel is kept in a place where a relatively constant temperature can be maintained.

Traditionally, the vessel may be kept in a specially prepared room, an underground chamber, or within a heap of paddy. Major variations in temperature should be avoided, as they may accelerate, delay, or disturb the fermentation process.

8. Examination and Filtration

After the prescribed fermentation period, the vessel is opened and the contents are examined to determine whether Sandhana, or fer

6 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

6.1 Introduction

Phytotherapeutic agents are standardized herbal medicines obtained from medicinal plants and used for the prevention or treatment of diseases. Modern phytotherapy focuses on scientific, evidence-based herbal preparations with defined active constituents, purity, safety, and therapeutic efficacy.

6.2 Adaptogens & Immunomodulators

Adaptogens

Adaptogens are natural substances that increase the non-specific resistance of the body against different types of stress. The drug-induced state of resistance against harmful or stressful stimuli is known as adaptogenic activity, and the substances producing this effect are called adaptogens.

Adaptogens act as metabolic regulators and improve the ability of the body to adapt to environmental changes and stress conditions. The concept and use of adaptogens have been accepted by medical scientists and health authorities in many developed countries.

Natural products having immunomodulatory, rasayana, and adaptogenic properties are Withania somnifera, Ocimum sanctum, Sida cordifolia, Panax ginseng, Eleutherococcus senticosus, and Schizandra chinensis are important medicinal plants commonly used in traditional and herbal medicine.

Immunomodulators

Immunomodulatory medicinal plants are a relatively new concept in pharmacognosy. In many disease conditions, the immune response becomes weak or disturbed. Therefore, maintaining a disease-free state may require modulation of the immune system either by stimulation or suppression.

Immunomodulators can act as supportive therapy along with chemotherapy. Although the human immune system is naturally capable of defending the body against various infections, certain bacteria and viruses can adversely affect it. In addition to infectious agents, factors such as poor living conditions, chronic diseases, environmental pollution, and stress can also weaken immune responses.

Immunosuppressants are already used in transplantation surgery. Similarly, non-specific immune stimulation or immunopotentiation can be achieved through certain medicinal plants. Ayurvedic concepts of preventive healthcare also show a close relationship with non-specific immunostimulation produced by medicinal plants. Examples include Arnica montana, Calendula officinalis, Matricaria recutita, Echinacea purpurea, Panax ginseng, Serenoa serrulata, Tinospora cordifolia, Withania somnifera, Azadirachta indica, Asparagus racemosus, and Allium sativum are important medicinal plants widely used in traditional and herbal medicine.

6.2.1 Ashwagandha

Synonyms

Withania root, Asgandh, Indian Ginseng

Biological Source

Ashwagandha consists of the dried roots and stem bases of Withania somnifera (Linn.) Dunal, a plant belonging to the family Solanaceae. On a dried basis, it should contain not less than 0.02% of the combined amount of withanolide A and withaferin A.

Figure 6.1: Withania somnifera

is widely cultivated in southern Europe, Iran, China, the United States and India.

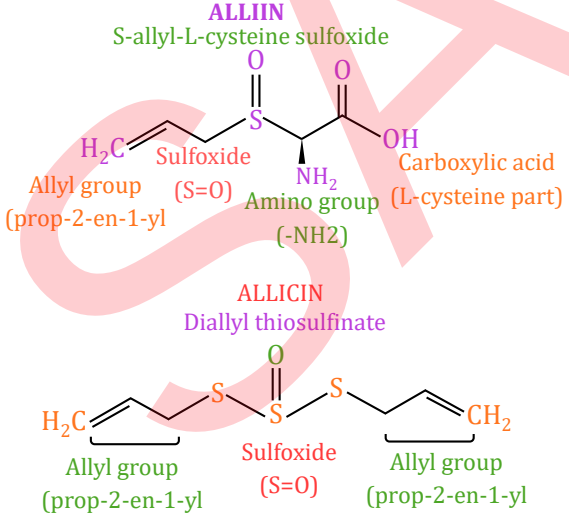
In India, garlic is grown in almost all states as an important spice, condiment and medicinal crop. China is one of the largest producers of garlic worldwide.

Figure 6.7: Allium sativum

Chemical Constituents

Garlic contains numerous biologically active compounds, particularly organosulphur constituents. The fresh bulb contains carbohydrates, proteins, small quantities of fats, mucilage, volatile oil, minerals, amino acids, flavonoids, phenolic compounds, saponins and polysaccharides.

Its volatile oil content is approximately 0.06–0.1% and is chiefly responsible for the characteristic odour and medicinal activity of garlic. The major sulphur-containing constituents include alliin, allicin, ajoene, diallyl sulphide, diallyl disulphide, diallyl trisulphide, allyl propyl disulphide, vinyl dithiins, S-allyl cysteine, S-methyl cysteine sulphoxide, S-propyl cysteine sulphoxide and gamma-glutamyl peptides. Alliin, chemically known as S-allyl-L-cysteine sulphoxide, is an odourless constituent present in intact garlic cloves.



When the cloves are cut, crushed or injured, the enzyme alliinase comes into contact with alliin and rapidly converts it into allicin. Allicin is a yellow, unstable liquid responsible for the characteristic pungent odour of freshly crushed garlic. It possesses marked antibacterial and antifungal activities and is soluble in alcohol, ether and benzene, but decomposes on heating or distillation.

The amino acids reported in garlic include leucine, methionine, S-allyl cysteine, S-methyl cysteine, S-propyl-L-cysteine and several related cysteine sulphoxides. Garlic polysaccharides are composed mainly of fructose, along with smaller quantities of glucose and galactose.

It also contains several phenolic constituents, including β-resorcylic acid, pyrogallol, gallic acid, protocatechuic acid, rutin and quercetin. Important mineral constituents include phosphorus, iron and copper. Purple varieties of garlic generally contain larger quantities and a greater variety of saponins than white varieties.

Uses

Garlic exhibits several important pharmacological properties, including antibacterial, antifungal, anthelmintic, antioxidant, antihypertensive, hypolipidaemic, antiplatelet, carminative, expectorant, mild diuretic, stimulant and rubefacient activities.

Garlic is widely used as a spice, flavouring agent and condiment. Medicinally, it is employed as a carminative and appetite stimulant in the management of indigestion, flatulence and abdominal discomfort. Owing to its expectorant and antimicrobial properties, it is also used in traditional preparations for cough, cold, chronic bronchitis and other respiratory infections.

Garlic may help reduce elevated blood pressure and serum cholesterol levels and is therefore used as a supportive dietary agent in hypertension, hyperlipidaemia, atherosclerosis and certain cardiovascular disorders. Its organosulphur compounds inhibit platelet aggregation and may contribute to the prevention of abnormal blood-clot formation. The antioxidant constituents of garlic also protect body tissues against oxidative damage caused by free radicals.

Garlic oil has traditionally been used as an anthelmintic against intestinal parasites and externally as a rubefacient. Fresh garlic has also been used as a preventive remedy against amoebic dysentery and certain gastrointestinal infections. Traditional systems of medicine employ garlic in the management of asthma, fever, constipation, rheumatism, menstrual discomfort, skin diseases, urinary tract infections, wounds and general weakness. Garlic has also been investigated for its possible role in supporting immune function, improving physical performance, protecting nervous tissue and reducing the accumulation of certain heavy metals; however, these uses require further clinical confirmation.

Garlic is generally considered safe when consumed in normal dietary quantities. However, excessive consumption or the use of concentrated preparations may cause gastric irritation, heartburn, nausea, diarrhoea, sweating, dizziness, strong breath and body odour, allergic reactions and an increased tendency to bleed. Direct application of raw garlic to the skin may cause irritation, blistering or burns, particularly in sensitive individuals.

Garlic may enhance the effects of anticoagulant and antiplatelet medicines and thereby increase the risk of bleeding. Particular caution is required in patients taking warfarin or related

enzymes, LOX enzymes, and NF-κB pathways. They help reduce pain and inflammation with potential supportive therapeutic value.

Important pharmacognostic examples include Turmeric, Boswellia, Ginger, Clove, Willow bark, and Aloe, which are traditionally used for pain, arthritis, swelling, wounds, and inflammatory disorders

6.6.1 Turmeric

Synonyms

Turmeric, Curcuma, Haldi, Indian Saffron and Rhizoma Curcumae.

Biological Source

Turmeric consists of the fresh or dried rhizomes of Curcuma longa Linn., formerly known as Curcuma domestica Valeton, belonging to the family Zingiberaceae.

The dried drug should contain not less than 1.5% curcumin.

Geographical Source

Turmeric is believed to be native to South and Southeast Asia. It is extensively cultivated in India, China, Pakistan, Sri Lanka, Indonesia, Malaysia and other tropical countries.

India is one of the leading producers and exporters of turmeric. The major turmeric-growing states include Telangana, Andhra Pradesh, Tamil Nadu, Maharashtra, Karnataka, Odisha, Kerala, West Bengal and Assam. Turmeric cultivated in Kerala and certain southern regions is particularly valued for its rich colour, characteristic aroma and high curcumin content.

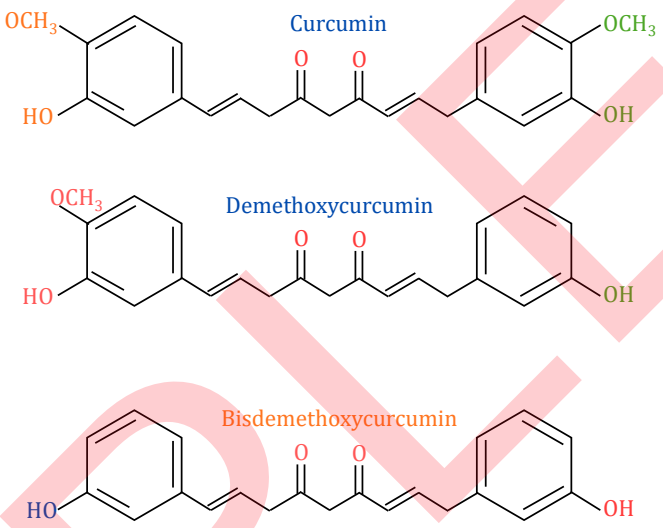
The genus Curcuma comprises several species of rhizomatous herbs distributed mainly throughout tropical and subtropical regions of Asia. Commercially important species include Curcuma longa, Curcuma aromatica, Curcuma amada, Curcuma angustifolia, Curcuma caesia and Curcuma zedoaria. Among these, Curcuma longa is the most important species because of its extensive use as a spice, colouring agent and medicinal drug.

Figure 6.11: Curcuma longa

Chemical Constituents

Turmeric rhizomes contain curcuminoids, volatile oil, starch, carbohydrates, proteins, resins, polysaccharides, peptides, vitamins and several minor constituents. The yellow colouring matter of turmeric consists of a group of phenolic compounds collectively known as curcuminoids.

The principal curcuminoids are curcumin, demethoxycurcumin and bisdemethoxycurcumin. Curcumin, chemically known as diferuloylmethane, is the major colouring and biologically active constituent and generally constitutes about 50–60% of the total curcuminoid fraction.



The total curcuminoid content of the rhizome may range from approximately 3–5%, depending on the variety, geographical source and processing conditions. Other related compounds include dihydrocurcumin, tetrahydrocurcumin, hexahydrocurcumin and cyclocurcumin. These curcuminoids are mainly responsible for the characteristic yellow-orange colour and much of the antioxidant and anti-inflammatory activity of turmeric.

Turmeric contains approximately 1–6% volatile oil, although its quantity and composition vary according to the source and variety. Important components of the volatile oil include ar-turmerone, α-turmerone, β-turmerone or curlone, zingiberene, germacrone, atlantone, curcumenol, dehydrocurdione, β-sesquiphellandrene, α-phellandrene, sabinene, borneol, cineole, α-pinene, β-pinene, camphor, camphene, α-curcumene and β-curcumene. The volatile oil contributes to the characteristic odour, flavour and several biological activities of the drug.

The rhizome also contains abundant starch grains and sugars such as glucose, fructose and arabinose. Several acidic polysaccharides have been isolated from turmeric and may contain L-arabinose, D-xylose, D-galactose, D-glucose, L-rhamnose and D-galacturonic acid. A water-soluble peptide known as turmerin has also been reported. Other constituents include resins, proteins, fixed oil, caprylic acid, vitamin C, pyridoxine, minerals, p-α-dimethylbenzyl alcohol and 1-methyl-4-acetyl-1-cyclohexene.

Uses

Turmeric and its constituents exhibit several important pharmacological properties, including anti-inflammatory, antioxidant, antimicrobial, antiseptic, carminative, stomachic, cholagogue, choleretic, hepatoprotective, wound-healing, analgesic, antiallergic, hypolipidaemic and immunomodulatory activities.

Curcumin is well known for its anti-inflammatory activity and may influence several mediators and biochemical pathways involved in inflammation. Turmeric is traditionally used in the management of joint pain, arthritis, muscular discomfort, sprains, local

5. Describe Amla with reference to its biological source, chemical constituents, pharmacological actions, therapeutic uses, and importance as a rasayana.
6. Discuss hepatoprotective phytotherapeutic agents in detail with special reference to Milk Thistle and Kutki.
7. Explain cardiovascular phytotherapeutic agents with detailed accounts of Garlic and Arjuna.
8. Discuss antidiabetic phytotherapeutic agents with special reference to Gymnema and Fenugreek, including their chemical constituents, mechanism of action, and therapeutic uses.
9. Explain anti-inflammatory and analgesic phytotherapeutic agents with detailed accounts of Turmeric and Boswellia.
10. Discuss about Brahmi and Giloy with their biological sources, active constituents, pharmacological actions, and therapeutic uses.

Multiple Choice Questions

1. Phytotherapeutic agents are:
(a) Synthetic drugs used in chemotherapy
(b) Standardized herbal medicines used for prevention and treatment of diseases
(c) Homeopathic medicines only
(d) Mineral-based medicines

2. Adaptogens primarily help the body to:
(a) Increase blood glucose levels
(b) Improve resistance to stress and environmental changes
(c) Destroy microorganisms directly
(d) Increase appetite only

3. Which of the following is an important adaptogenic medicinal plant?
(a) Senna (b) Isabgol
(c) Withania somnifera (d) Aloe vera

4. Which of the following medicinal plants is widely used as an immunomodulator?
(a) Tinospora cordifolia (b) Papaver somniferum
(c) Digitalis purpurea (d) Rauwolfia serpentina

5. Ashwagandha belongs to the family:
(a) Lamiaceae (b) Solanaceae
(c) Fabaceae (d) Asteraceae

6. The major alkaloid present in Ashwagandha is:
(a) Eugenol (b) Curcumin (c) Withanine (d) Allicin

7. Tulsi belongs to the family:
(a) Apiaceae (b) Lamiaceae
(c) Euphorbiaceae (d) Burseraceae

8. The major constituent of Tulsi volatile oil is:
(a) Curcumin (b) Allicin (c) Eugenol (d) Trigonelline

9. Amla is one of the richest natural sources of:
(a) Vitamin A (b) Vitamin B_{12}
(c) Vitamin C (d) Vitamin D

10. Which Ayurvedic formulation contains Amla as an important ingredient?
(a) Dashamoola (b) Triphala
(c) Hingvashtaka Churna (d) Sitopaladi Churna

11. The principal active constituent of Milk Thistle is:
(a) Boswellic acid (b) Curcumin
(c) Silymarin (d) Gymnemic acid

12. Kutki is obtained from the dried rhizomes of:
(a) Picrorhiza kurroa (b) Curcuma longa
(c) Bacopa monnieri (d) Tinospora cordifolia

13. Allicin is formed when:
(a) Curcumin is oxidized
(b) Alliin is acted upon by alliinase
(c) Eugenol is hydrolysed
(d) Gymnemic acid is reduced

14. Arjuna is mainly used as a:
(a) Hepatoprotective agent (b) Cardiotonic agent
(c) Laxative (d) Antimalarial agent

15. Gymnema suppresses the perception of:
(a) Saltiness (b) Sourness (c) Sweetness (d) Bitterness

16. The principal alkaloid of Fenugreek is:
(a) Trigonelline (b) Piperine (c) Berberine (d) Nicotine

17. The principal active constituent of Turmeric is:
(a) Allicin (b) Curcumin (c) Withaferin A (d) Azadirachtin

18. The principal anti-inflammatory constituents of Boswellia are:
(a) Gymnemic acids (b) Boswellic acids
(c) Silymarin (d) Bacosides

19. The major active saponins responsible for the memory-enhancing activity of Brahmi are:
(a) Picrosides (b) Bacosides A and B
(c) Curcuminoids (d) Sitoindosides

20. The principal active constituent of Kalmegh responsible for its hepatoprotective activity is:
(a) Andrographolide (b) Quercetin
(c) Azadirachtin (d) Cordifolioside

Answer Key

1-(b)	2-(b)	3-(c)	4-(a)	5-(b)	6-(c)	7-(b)	8-(c)	9-(c)	10-(b)
11-(c)	12-(a)	13-(b)	14-(b)	15-(c)	16-(a)	17-(b)	18-(b)	19-(b)	20-(a)

SCREENING PATHWAY FOR THE PHYTOCHEMICAL NATURE OF NATURAL DRUGS

Test solution: Depending upon the type of natural drug under examination, the test solution may be an aqueous extract or alcoholic extract or extract in specific menstruum like petroleum ether.

Chloroform, ethyl acetate, etc. for the tests to be performed. For testing, as far as possible clear, transparent solution should be used.

1. Acidic Compounds

(a) Alcoholic extract of the drug after treatment with sodium bicarbonate produces effervescence.

(b) Treat alcoholic extract of the drug with warm water and filter. Test the filtrate with litmus paper, it turns blue.

2. Aleurone Grains

(a) Add few drops of alcoholic iodine solution to aqueous test solution, yellowish brown to brown colour indicates presence of aleurone grains.

(b) To the sample add few drops of alcoholic trinitrophenol (picric acid), aleurone grains take yellow colour.

(c) To the sample add 1ml of mercuric nitrate solution, brick red colour indicate presence of aleurone grains.

3. Alkaloids

(a) Dragendorff's reagent: Alkaloids give reddish brown precipitate with Dragendorff's reagent (Potassium bismuth iodide solution).

(b) Mayer's reagent: Alkaloids give cream colour precipitate with Mayer's reagent (Potassium mercuric iodide solution).

(c) Wagner's reagent: Alkaloids give reddish brown precipitate with Wagner's reagent (Iodine-potassium iodide solution).

(d) Hager's reagent: Alkaloids give yellow precipitate with Hager's reagent (Saturated solution of picric acid).

(e) Tannic acid test: Alkaloids give buff colour precipitate with tannic acid solution.

(f) Picrolonic acid test: Alkaloids give yellow colour precipitate picrolonic acid.

4. Amino Acids

(a) Millon's test: To the test solution add about 2ml of Millons reagent, white precipitate indicates presence of amino acids.

(b) Ninhydrine test: To the test solution add Ninhydrine solution, boil, violet colour indicates presence of amino acid.

5. Bitterness Value:

Medicinal plant materials that have a strong bitter taste ("bitters") are employed therapeutically, mostly as appetizing agents. Their bitterness stimulates secretions in the gastrointestinal tract.

Especially of gastric juice. The bitter properties of plant material are determined by comparing the threshold bitter concentration of an extract of the materials with that of a dilute solution of quinine hydrochloride.

The bitterness value is expressed in unit's equivalent to the bitterness of a solution containing of Quinine hydrochloride R (R - Reference material)

Bitterness value calculated in units per g using the following formula:

$$\text{Bitterness value} = \frac{(2000 \times c)}{(a \times b)}$$

where,

(a) The concentration of the stock test solution (ST) (mg/ml)

(b) The volume of test solution ST (in/ml) in the tube with the threshold bitter concentration,

(c) The volume of Quinine hydrochloride R (in\mg) in the tube with the threshold bitter concentration.

6. Carbohydrates (with aqueous test solution)

(a) Molisch's test: To the test solution add few drops of alcoholic a-naphthol, and then add few drops of concentrated sulphuric acid through sides of test tube; purple to violet colour ring appears at the junction.

(b) Barfoed's test: 1 ml of test solution is heated with 1mlof Barfoed's reagent on water bath, if red cupric oxide is formed, monosaccharide is present. Disaccharides on prolong heating (about \ min)may also cause reduction, owing to partial hydrolysis to monosaccharides.

(c) Selivanoff's test (Test for ketones): To the test solution add crystals of resorcinol and eq. volume of concentrated hydrochloric acid and heat on a water bath, rose colour is produce (eg. Fructose, honey)

(d) Test for pentoses: To the test solution add equal volume of hydrochloric acid containing c small amount of phloroglucinol and heat, red colour is produced.

(e) Osazone formation test: Heat the test solution with solution of phenylhydrazine hydrochloride, sodium acetate and acetic acid. Examine the yellow crystals formed under microscope. These crystals are of characteristic shape for particular sugars. (Osazones are the crystalline derivatives of sugars having particular shapes. Glucose and fructose form the same osazone-glucosazone, m.p. (205°C

7. Cellulose:

(a) To the thin section of the sample add 1-2 drops of iodinated zinc chloride solution, wait for a minute. Add 1 drop of iodine and then add 1 drop of sulphuric acid, cell walls (cellulose) stain blue or blue-violet.

(b) To the thin section of the sample add (0.1\M) iodine solution and sulphuric acid, cell walls (cellulose) turns blue-violet. If cuoxam test solution is added to, cell walls swell and gradually dissolve.

(c) Thionine test: Treat thin section of the sample with thionine solution, wash with alcohol after 15\min, cell wall turns blue.

8. Fats and Fixed Oils (Petroleum ether extract):

Fixed oils and fats can be confirmed by chemical tests for glycer-

Author Profile

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Prof. (Dr.) Daksh Bhatia, M.Pharm., PhD (Pharmacognosy), is a seasoned academic leader with 20 years of teaching, research and administrative experience. Currently, serving as Professor & Associate Dean at KIET School of Pharmacy, he has also held at various other administrative positions. His expertise spans pharmacognosy, herbal drug technology, and pharmaceutical biology, with research interests in ethnopharmacology and phytopharmaceutical standardization. He holds multiple granted patents, has published over 20 research papers, and has authored a book on Pharmacognosy. Recognized with awards for teaching and administration, he has coordinated many events, seminars, and contributed significantly to academic excellence and innovation.

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