DEEPSHIKA KALA SANSTHAN

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COLLEGE OF TECHNICAL EDUCATION

BOTANY MANUAL

Building Careers, Building the Nation

Laboratory Manual

Botany

Deepshikha College of Technical Education

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1. Preface

Botany is the scientific study of plants, encompassing their structure, function, growth, reproduction, classification, ecology, and economic importance. Practical laboratory work is an essential component of botanical education, enabling students to bridge the gap between theoretical knowledge and real-world observations. Laboratory exercises develop scientific thinking, observational skills, analytical abilities, and proficiency in handling scientific equipment and biological specimens.

This **Botany Laboratory Manual** has been prepared to provide students with systematic guidance for conducting practical experiments in various branches of botany, including plant morphology, anatomy, taxonomy, physiology, cytology, genetics, microbiology, ecology, and biotechnology. The manual presents experiments in a simple, organized, and student-friendly manner, emphasizing accuracy, safety, and scientific methodology.

Each practical exercise includes the objective, principle, materials required, procedure, observations, results, precautions, and questions for self-assessment. Illustrations, diagrams, and observation formats are included wherever appropriate to facilitate better understanding and accurate record keeping.

The manual also emphasizes laboratory safety, ethical handling of plant materials, proper use and maintenance of laboratory equipment, and environmentally responsible disposal of laboratory waste. Students are encouraged to maintain detailed laboratory records, make accurate scientific drawings, and develop the habit of critical observation and interpretation.

It is hoped that this manual will serve as a valuable resource for undergraduate students, teachers, and laboratory instructors, fostering curiosity, scientific temperament, and a deeper appreciation of plant diversity and biological sciences.

2. Objectives of the Botany Laboratory Manual

The primary objectives of this laboratory manual are to:

1. Provide practical experience that complements theoretical concepts taught in botany courses.
2. Develop skills in the safe handling and proper use of laboratory instruments, glassware, chemicals, and microscopes.
3. Train students in the preparation, observation, and interpretation of temporary and permanent microscopic slides.
4. Enhance the ability to identify, classify, and describe plant specimens based on their morphological and anatomical characteristics.
5. Develop competence in conducting experiments related to plant physiology, genetics, microbiology, ecology, and biotechnology.
6. Promote scientific observation, data collection, recording, analysis, and interpretation of experimental results.
7. Encourage accurate scientific drawing, labeling, and maintenance of practical records.

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8. Familiarize students with herbarium preparation, plant specimen preservation, and field collection techniques.
9. Instill laboratory safety practices, ethical conduct, and environmental responsibility during practical work.
10. Strengthen critical thinking, problem-solving abilities, and scientific inquiry through experimental investigations.
11. Prepare students for practical examinations, research activities, and higher studies in plant sciences.
12. Foster appreciation for plant biodiversity, conservation, and the economic importance of plants in agriculture, medicine, forestry, and industry.

3. General Laboratory Rules and Safety Guidelines

A botany laboratory is a place for scientific observation, experimentation, and learning. Adhering to laboratory rules and safety guidelines is essential for preventing accidents, protecting laboratory equipment, ensuring accurate experimental results, and maintaining a safe working environment. Every student must familiarize themselves with these guidelines before beginning practical work.

3.1 Laboratory Code of Conduct

Students are expected to maintain discipline, responsibility, and professionalism while working in the laboratory. The following rules should be observed at all times:

1. Enter the laboratory only with the permission of the instructor.
2. Read the experiment thoroughly before starting practical work.
3. Follow the instructions given by the laboratory instructor carefully.
4. Maintain silence and avoid unnecessary conversation or distractions.
5. Do not eat, drink, smoke, or chew gum inside the laboratory.
6. Keep laboratory benches clean and organized throughout the practical session.
7. Handle all laboratory equipment, chemicals, and specimens with care.
8. Do not perform unauthorized experiments.
9. Record observations honestly and accurately in the laboratory record book.
10. Return all equipment and materials to their designated places after use.
11. Report any damaged equipment, broken glassware, spills, or accidents immediately to the instructor.
12. Wash hands thoroughly after completing laboratory work.
13. Switch off microscopes, electrical equipment, lights, and water taps before leaving the laboratory.
14. Respect laboratory property and avoid wastage of reagents and plant materials.

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3.2 Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) minimizes exposure to laboratory hazards and helps prevent injuries.

Students should wear:

- A clean laboratory coat or apron during all practical sessions.
- Safety goggles while handling chemicals or glassware that may cause splashes.
- Disposable or reusable gloves when handling chemicals, stains, preservatives, or biological samples.
- Closed-toe shoes to protect feet from chemical spills and broken glass.
- Face masks when working with powders, fungal cultures, or volatile chemicals, if required.
- Long hair should be tied back, and loose clothing or dangling jewelry should be avoided. PPE should be inspected regularly and replaced if damaged.

3.3 Laboratory Safety Precautions

Although botany laboratories generally involve fewer hazards than many other science laboratories, students should always follow safe laboratory practices.

Chemical Safety

- Read labels carefully before using chemicals.
- Never taste laboratory chemicals.
- Avoid direct inhalation of chemical vapours.
- Use only the required quantity of reagents.
- Never mix chemicals unless instructed.
- Store chemicals properly after use.

Glassware Safety

- Inspect glassware for cracks before use.
- Handle glass slides and cover slips carefully.
- Dispose of broken glass only in designated containers.
- Never force glass tubing into rubber stoppers without proper lubrication.

Microscope Safety

- Carry microscopes using both hands.
- Place microscopes on stable laboratory benches.
- Clean lenses only with lens paper.
- Use coarse adjustment only under low-power objectives.
- Switch off and cover the microscope after use.

Electrical Safety

- Keep electrical equipment away from water.
- Do not touch electrical instruments with wet hands.
- Report damaged electrical cords immediately.

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- Switch off instruments after completing work.

Biological Safety

- Handle plant specimens and microbial cultures carefully.
- Wash hands after handling preserved materials.
- Avoid touching the face while working with biological samples.
- Sterilize instruments whenever required.

3.4 Emergency Procedures

Prompt and appropriate action during emergencies minimizes injury and damage.

Fire Emergency

- Remain calm and inform the instructor immediately.
- Turn off gas burners and electrical equipment if safe to do so.
- Use the appropriate fire extinguisher only if trained.
- Evacuate the laboratory through designated emergency exits.

Chemical Spill

- Inform the instructor immediately.
- Avoid touching spilled chemicals.
- Clean spills only according to laboratory instructions.
- Wash contaminated skin with plenty of water.

Glass Breakage

- Do not pick up broken glass with bare hands.
- Use a brush and dustpan for collection.
- Dispose of broken glass in designated containers.

Eye Exposure

- Flush the eyes immediately with clean running water or use the eye wash station for at least 15 minutes.
- Seek medical attention promptly.

Skin Contact

- Wash the affected area thoroughly with water.
- Remove contaminated clothing if necessary.
- Inform the instructor immediately.

Cuts and Minor Injuries

- Wash the wound with clean water.
- Apply antiseptic and a sterile dressing.
- Seek first aid if required.

Electrical Accident

- Switch off the power supply before assisting the victim.
- Do not touch the person until the power source has been disconnected.
- Inform the instructor and seek emergency medical assistance immediately.

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3.5 Waste Disposal and Environmental Safety

Proper disposal of laboratory waste protects human health and the environment.

Biological Waste

- Dispose of plant residues, microbial cultures, and biological materials in designated biological waste containers.
- Do not discard biological waste in sinks.

Chemical Waste

- Collect chemical waste separately according to laboratory instructions.
- Never pour concentrated chemicals directly into drains.
- Dispose of stains and preservatives following institutional guidelines.

Glass Waste

- Broken glass, slides, and cover slips should be placed in puncture-resistant glass disposal containers.

Plastic Waste

- Segregate disposable gloves, pipette tips, and plastic containers for appropriate disposal or recycling.

Environmental Responsibility

Students should:

- Use chemicals sparingly.
- Minimize wastage of water and electricity.
- Handle plant specimens responsibly and avoid unnecessary collection from natural habitats.
- Promote recycling and sustainable laboratory practices.
- Maintain cleanliness within and around the laboratory.

Safety Reminder

Always remember the following laboratory safety principles:

- Safety is everyone's responsibility.
- Think before performing any experiment.
- Never work alone in the laboratory.
- Follow the instructor's directions at all times.
- Report accidents immediately, regardless of how minor they may seem.
- Maintain cleanliness, discipline, and professionalism throughout every practical session.

4. Laboratory Equipment and Glassware

A well-equipped botany laboratory is essential for conducting practical experiments accurately and safely. Laboratory instruments and glassware enable students to observe plant structures, prepare specimens, measure quantities, perform physiological experiments, and analyze experimental data. Proper handling, maintenance, calibration, and storage of laboratory

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equipment ensure reliable results, extend the lifespan of instruments, and promote a safe working environment.

This chapter introduces the commonly used laboratory instruments and glassware in a botany laboratory, along with guidelines for their care, maintenance, calibration, and storage.

4.1 Common Laboratory Instruments

Botanical experiments require a variety of instruments for observation, measurement, dissection, cultivation, and analysis. Some of the commonly used instruments are described below.

1. Compound Microscope

The compound microscope is the most important instrument in a botany laboratory. It is used to observe cells, tissues, microorganisms, pollen grains, spores, and other microscopic plant structures.

Uses

- Observation of plant cells and tissues
- Study of mitosis and meiosis
- Examination of algae, fungi, and bacteria
- Identification of microorganisms

Precautions

- Carry the microscope with both hands.
- Clean lenses only with lens paper.
- Store under a dust cover after use.

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2. Dissecting (Stereo) Microscope

A dissecting microscope provides a three-dimensional view of specimens at low magnification.

Uses

- Examination of flowers and seeds
- Observation of insects associated with plants
- Dissection of plant organs

3. Hand Lens

A hand lens is a simple magnifying device used during laboratory work and field studies.

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Uses

- Observation of leaf surfaces
- Examination of floral structures
- Field identification of plants

4. Centrifuge

A centrifuge separates suspended particles from liquids by centrifugal force.

Uses

- Separation of plant extracts
- Isolation of cellular components
- Sample preparation for biochemical analysis

5. Water Bath

A water bath provides uniform heating at controlled temperatures.

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Uses

- Enzyme experiments
- Preparation of culture media
- Incubation of samples

6. Hot Plate and Magnetic Stirrer

These instruments are used for heating and mixing solutions.

Uses

- Preparation of chemical solutions
- Dissolving reagents
- Mixing nutrient media

7. Autoclave

An autoclave sterilizes laboratory equipment and culture media using steam under pressure.

Uses

- Sterilization of glassware
- Sterilization of culture media
- Decontamination of biological waste

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8. Incubator

An incubator maintains a constant temperature suitable for the growth of microorganisms and plant tissue cultures.

Uses

- Microbial culture
- Seed germination
- Plant tissue culture

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9. pH Meter

A pH meter measures the acidity or alkalinity of solutions

Uses

- Preparation of nutrient media
- Soil analysis
- Physiological experiments

10. Electronic Balance

An electronic balance measures the mass of chemicals and plant materials accurately.

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Uses

- Preparation of reagents
- Quantitative experiments

11. Oven

A laboratory oven is used for drying glassware and plant specimens.

Uses

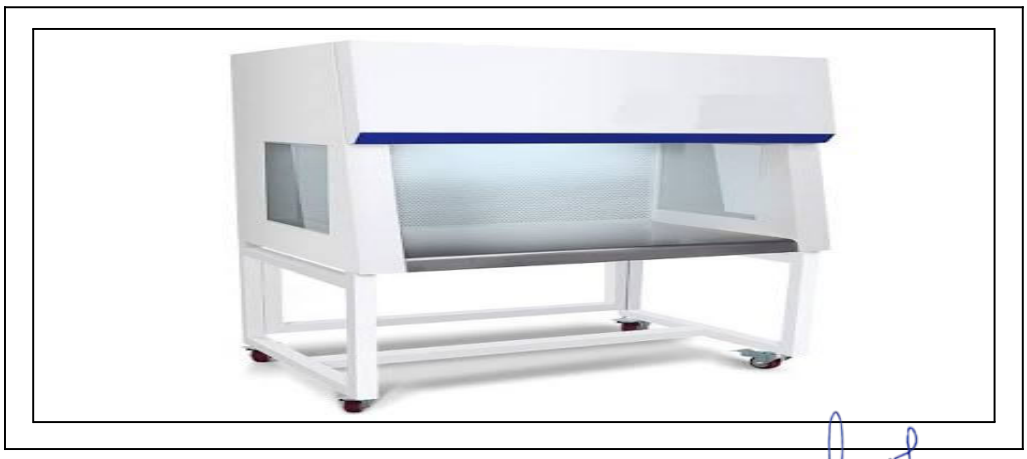
- Drying herbarium specimens
- Moisture analysis
- Sterilization of glassware

12. Refrigerator

A refrigerator preserves chemicals, biological specimens, enzymes, and culture media at low temperatures.

13. Laminar Air Flow Cabinet

This cabinet provides a sterile working environment.



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Uses

- Plant tissue culture
- Inoculation of cultures
- Sterile transfer of biological materials

14. Dissecting Instruments

These include forceps, scalpels, dissecting needles, scissors, and blades.

Uses

- Plant dissections
- Preparation of microscopic specimens
- Tissue isolation

4.2 Glassware Used in Botany Laboratories

Laboratory glassware is used for measuring, mixing, heating, storing, and transferring liquids and chemicals.

Common Glassware

- **Test Tubes**

Used for small-scale reactions, heating, and temporary storage of samples.

- **Beakers**

Used for mixing, heating, and preparing solutions.

- **Conical (Erlenmeyer) Flasks**

Used for preparing culture media, mixing solutions, and titration work.

- **Volumetric Flasks**

Used for preparing solutions of accurate concentrations.

- **Measuring Cylinders**

Used for measuring the volume of liquids.

- **Pipettes**

Used for transferring measured volumes of liquids.

- **Burettes**

Used for titration and accurate liquid dispensing.

- **Funnels**

Used for filtration and transferring liquids.

- **Watch Glasses**

Used for evaporation, covering beakers, or holding small samples.

- **Petri Dishes**

Used for culturing microorganisms and seed germination studies.

- **Glass Slides and Cover Slips**

Used for preparing temporary and permanent microscopic mounts.

- **Reagent Bottles**

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Used for storing chemicals and prepared solutions.

- **Droppers (Pasteur Pipettes)**

Used for adding small quantities of liquids.

- **Desiccators**

Used for storing moisture-sensitive materials and cooling dried samples.

4.3 Care and Maintenance of Equipment

Proper maintenance improves the accuracy, reliability, and longevity of laboratory instruments.

General Guidelines

- Clean equipment immediately after use.
- Keep laboratory benches clean and dry.
- Handle delicate instruments carefully.
- Use equipment only for its intended purpose.
- Report damaged equipment immediately.

Microscope Maintenance

- Remove dust using a soft brush.
- Clean lenses only with lens paper.
- Avoid touching lenses with fingers.
- Keep the microscope covered when not in use.
- Store in a dry, dust-free cabinet.

Glassware Maintenance

- Wash with laboratory detergent after use.
- Rinse thoroughly with distilled water.
- Dry before storage.
- Inspect for cracks or chips before use.
- Dispose of broken glass safely.

Electronic Equipment

- Keep instruments dry.
- Avoid overloading electrical circuits.
- Switch off equipment after use.
- Disconnect power before cleaning.
- Schedule periodic servicing.

Autoclave Maintenance

- Check the water level before operation.
- Clean the chamber regularly.
- Inspect pressure gauges and safety valves.
- Follow manufacturer operating instructions.

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pH Meter Maintenance

- Calibrate before use.
- Rinse the electrode with distilled water after each measurement.
- Store the electrode in the recommended storage solution.
- Avoid touching the sensitive glass bulb.

Centrifuge Maintenance

- Balance sample tubes before operation.
- Clean the rotor after use.
- Inspect for corrosion and damage.
- Never exceed the recommended speed.

4.4 Calibration and Storage

Accurate experimental results depend on properly calibrated instruments and appropriate storage conditions.

Calibration

Calibration ensures that laboratory instruments provide accurate measurements.

Instruments Requiring Regular Calibration

- Electronic balances
- pH meters
- Thermometers
- Micropipettes
- Measuring cylinders
- Incubators
- Spectrophotometers (where available)

General Calibration Procedure

1. Inspect the instrument for cleanliness and damage.
2. Use certified reference standards.
3. Adjust the instrument according to the manufacturer's instructions.
4. Verify accuracy using standard samples.
5. Record calibration details in the laboratory logbook.

Storage of Equipment

Proper storage prevents damage and contamination.

Microscopes

- Store in dry cabinets.
- Cover with dust covers.
- Keep away from direct sunlight and moisture.

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Glassware

- Store according to type and size.
- Place fragile items on padded shelves.
- Keep clean and dry.

Chemicals

- Label all containers clearly.
- Store acids, bases, solvents, and oxidizing agents separately.
- Keep chemicals away from heat and direct sunlight.

Biological Specimens

- Preserve in appropriate fixatives or refrigeration.
- Label specimens with scientific name, collection date, and preservative used.

Electrical Equipment

- Disconnect from the power supply when not in use.
- Protect from dust and humidity.
- Store according to the manufacturer's recommendations.

5. Microscopy

Microscopy is the science of using microscopes to observe objects that are too small to be seen clearly with the naked eye. In botany, microscopy is an indispensable tool for studying the structure, organization, and function of plant cells, tissues, and organs. It enables students to examine microscopic features such as cell walls, chloroplasts, stomata, xylem, phloem, pollen grains, spores, and microorganisms associated with plants.

The compound light microscope is the most commonly used instrument in botanical laboratories because it provides sufficient magnification and resolution for routine observations. Proper handling, maintenance, and preparation of specimens are essential for obtaining accurate and clear microscopic observations.

5.1 Types of Microscopes

Different types of microscopes are used in botanical studies depending on the nature of the specimen and the level of detail required.

1. Simple Microscope

A simple microscope consists of a single convex lens used for magnifying small objects.

Uses

- Examination of seeds, leaves, flowers, and insects.
- Field observations.

Advantages

- Easy to use
- Portable
- Inexpensive

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2. Compound Light Microscope

A compound microscope uses two sets of lenses (objective and eyepiece) to produce high magnification.

Magnification

- Usually 40× to 1000×

Uses

- Observation of plant cells and tissues
- Study of mitosis and meiosis
- Examination of microorganisms

Advantages

- High magnification
- Good resolution
- Most commonly used in laboratories

3. Stereo (Dissecting) Microscope

Provides a three-dimensional view of relatively large specimens at low magnification.

Uses

- Dissection of flowers
- Observation of seeds
- Examination of mosses, fungi, and insects

5.2 Parts and Functions of a Compound Microscope

A compound microscope consists of mechanical, optical, and illumination systems.

Mechanical Parts

Part	**Function**
Base	Supports the microscope
Arm	Connects the body to the base and is used for carrying
Body Tube	Holds the eyepiece and objectives in alignment
Revolving Nosepiece	Holds objective lenses and allows switching between them
Stage	Supports the microscope slide
Stage Clips/Mechanical Stage	Holds the slide firmly
Coarse Adjustment Knob	Moves the stage rapidly for rough focusing

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Fine Adjustment Knob	Provides precise focusing
Inclination Joint (if present)	Allows tilting of the microscope

Optical Parts

Part	Function
Eyepiece (Ocular Lens)	Magnifies the image (usually 10× or 15×)
Objective Lens (4×, 10×, 40×, 100×)	Provides primary magnification
Condenser	Concentrates light on the specimen
Iris Diaphragm	Regulates the amount of light entering the specimen

Total Magnification Formula

Total Magnification = Eyepiece Magnification × Objective Magnification

Example

Eyepiece = 10×

Objective = 40×

Total Magnification = 10 × 40 = 400×

5.3 Care and Maintenance of Microscopes

Proper care ensures accurate observations and prolongs the life of the microscope.

General Precautions

- Carry the microscope with both hands—one holding the arm and the other supporting the base.
- Place it on a stable, vibration-free laboratory bench.
- Keep the microscope covered when not in use.
- Avoid sudden movements and rough handling.
- Do not expose the microscope to excessive moisture or direct sunlight.

Cleaning

- Clean lenses only with lens paper or a soft lint-free cloth.
- Never use ordinary tissue paper or cloth on optical lenses.
- Remove immersion oil immediately after using the oil-immersion objective.
- Keep the stage clean and dry.

During Use

- Begin focusing with the low-power objective.
- Use coarse adjustment only with low-power objectives.

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- Use fine adjustment for high-power objectives.
- Never allow the objective lens to touch the slide.
- Adjust the diaphragm to obtain proper illumination.

Storage

- Store the microscope in a clean, dry, dust-free cabinet.
- Rotate the low-power objective into position before storage.
- Lower the stage completely.
- Switch off the light source and unplug the microscope after use.

5.4 Preparation and Observation of Temporary and Permanent Slides

A. Temporary Slides

Temporary slides are prepared immediately before observation and are not preserved for long periods.

Common Materials

- Onion epidermal peel
- Hydrilla leaf
- Tradescantia leaf
- Pollen grains

Materials Required

- Glass slide
- Coverslip
- Forceps
- Needle
- Dropper
- Stain (Safranin, Iodine, or Methylene Blue)
- Glycerin
- Water

Procedure

1. Clean the slide and coverslip thoroughly.
2. Place a small drop of water or glycerin on the slide.
3. Transfer the specimen into the drop using forceps or a needle.
4. Add a suitable stain if required.
5. Carefully lower the coverslip at an angle to avoid air bubbles.
6. Remove excess stain or water with blotting paper.
7. Place the slide on the microscope stage.
8. Focus first under low power and then under high power.
9. Observe and record the microscopic features.

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Precautions

- Use a thin specimen.
- Avoid air bubbles beneath the coverslip.
- Do not overstain the specimen.
- Handle the coverslip gently to prevent breakage.

B. Permanent Slides

Permanent slides are prepared for long-term storage and repeated observation.

General Procedure

1. Collection of specimen
2. Fixation
3. Dehydration
4. Embedding
5. Sectioning with a microtome
6. Staining
7. Mounting with a permanent mounting medium (e.g., DPX or Canada balsam)
8. Labeling and storage

Examples

- T.S. of dicot stem
- T.S. of monocot root
- Mitosis in onion root tip
- Pollen grains
- Fungal spores

Observation of Slides

While observing a specimen under the microscope:

- Start with the low-power objective to locate the specimen.
- Adjust the light intensity using the diaphragm.
- Focus carefully using the fine adjustment knob.
- Observe the arrangement, shape, size, color, and distinguishing features of cells or tissues.
- Prepare a neat, labeled scientific diagram and record observations.

6. Preparation Techniques

Preparation techniques form the foundation of practical work in botany. Proper collection, preservation, staining, and mounting of plant specimens are essential for accurate identification, microscopic examination, and long-term storage. Well-prepared specimens not only facilitate effective teaching and learning but also serve as valuable reference materials for research, taxonomy, biodiversity studies, and herbarium collections.

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This chapter describes the standard methods used in the collection of plant specimens, herbarium preparation, preservation of plant materials, staining techniques, and mounting procedures commonly employed in botanical laboratories.

6.1 Collection of Plant Specimens

Plant specimen collection is the first step in botanical study. A well-collected specimen should accurately represent the plant in its natural condition and include sufficient morphological features for identification.

Objectives

- To obtain representative plant specimens for laboratory study.
- To facilitate identification and classification.
- To prepare herbarium sheets and teaching collections.
- To document plant biodiversity.

Materials Required

- Plant press
- Newspapers or blotting papers
- Pruning shears or scissors
- Trowel (for collecting roots)
- Field notebook
- Labels and tags
- Polythene bags
- GPS or map (optional)
- Camera (optional)

Guidelines for Collection

1. Collect healthy and disease-free specimens.
2. Include roots (where possible), stems, leaves, flowers, and fruits.
3. Collect specimens during the flowering or fruiting stage for easier identification.
4. Avoid collecting rare or endangered species without permission.
5. Minimize damage to natural vegetation.
6. Collect multiple specimens when permitted for exchange and verification.
7. Place specimens in polythene bags or between moist newspapers if immediate pressing is not possible.

Field Data to Record

- Collection number
- Scientific name (if known)
- Local/common name
- Family
- Date of collection
- Collector's name

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- Locality and habitat
- Altitude (if applicable)
- GPS coordinates (optional)
- Habit (tree, shrub, herb, climber)
- Flower and fruit colour
- Ecological observations

Precautions

- Avoid over-collection from a single population.
- Handle delicate flowers carefully.
- Do not uproot large plants unnecessarily.
- Follow institutional and legal regulations for plant collection.

6.2 Herbarium Preparation

A herbarium is a systematically arranged collection of dried and preserved plant specimens mounted on standard sheets and properly labelled. Herbarium specimens serve as permanent records for identification, teaching, and research.

Objectives

- To preserve plant specimens permanently.
- To facilitate taxonomic studies.
- To maintain reference collections.

Materials Required

- Plant press

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- Blotting paper or newspaper
- Corrugated ventilators
- Herbarium sheets (approximately 42 × 29 cm)
- Adhesive or glue
- Gummed linen tape
- Labels
- Needle and thread (if required)

Procedure

Step 1: Pressing

- Arrange the specimen naturally between newspaper sheets.
- Spread leaves and flowers to display important characteristics.
- Place specimens in a plant press.
- Tighten the straps firmly.

Step 2: Drying

- Replace damp newspapers daily until the specimen is completely dry.
- Drying usually requires 5–10 days depending on specimen thickness and humidity.

Step 3: Mounting

- Mount the dried specimen on a herbarium sheet using adhesive, linen tape, or thread.
- Ensure all important structures remain visible.

Step 4: Labelling

Attach a label at the lower right corner containing:

- Scientific name
- Family
- Common name
- Locality
- Date of collection
- Collector's name
- Habitat
- Collection number
- Remarks (if any)

Step 5: Storage

Store herbarium sheets in insect-proof cabinets under dry conditions.

Advantages

- Permanent botanical record
- Useful for taxonomic identification
- Reference material for research
- Documentation of plant diversity

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6.3 Preservation of Plant Materials

Certain plant materials cannot be dried effectively and must be preserved in liquid preservatives to retain their structural characteristics.

Objectives

- To preserve delicate plant parts.
- To prevent decomposition.
- To maintain specimens for long-term study.

Procedure

1. Clean the specimen gently.
2. Select an appropriate preservative.
3. Place the specimen in a clean, labelled glass jar.
4. Ensure the specimen is fully submerged.
5. Seal the container tightly.
6. Store in a cool, dry place away from direct sunlight.

Precautions

- Handle preservatives with care.
- Wear gloves while using formalin.
- Clearly label all preserved specimens.
- Replace preservative if it becomes cloudy.

6.4 Staining Techniques

Staining improves the visibility of cells, tissues, and microscopic structures by increasing contrast between different components.

Objectives

- To distinguish various plant tissues.
- To enhance microscopic visibility.
- To facilitate identification of cellular structures.

Characteristics of a Good Stain

- Provides clear contrast.
- Selectively stains specific tissues.
- Does not damage the specimen.
- Produces stable colour.

Common Botanical Stains

Stain	Colour Produced	Major Application
Safranin	Red	Lignified tissues, xylem
Fast Green	Green	Cellulose tissues
Methylene Blue	Blue	Nuclei and cytoplasm
Iodine Solution	Blue-black	Starch grains

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Acetocarmine	Red	Chromosomes during cell division
Aceto-orcein	Red-purple	Chromosome studies

General Staining Procedure

1. Prepare a thin section of plant material.
2. Place it on a clean slide.
3. Add a few drops of stain.
4. Allow sufficient time for staining.
5. Wash gently with water if required.
6. Mount with water or glycerine.
7. Observe under the microscope.

Double Staining

Double staining uses two different dyes to differentiate tissues.

Example

- Safranin stains lignified tissues red.
- Fast Green stains cellulose tissues green.

This technique clearly distinguishes xylem from surrounding tissues.

Precautions

- Use fresh staining solutions.
- Avoid over-staining.
- Handle stains carefully to prevent spills.
- Wash slides gently to avoid damaging sections.

6.5 Mounting Procedures

Mounting is the process of placing specimens on microscope slides using a suitable mounting medium for microscopic observation.

Objectives

- To protect the specimen.
- To improve optical clarity.
- To preserve the specimen for observation.

Types of Mounting

A. Temporary Mounting

Temporary mounts are prepared immediately before observation.

Mounting Media

- Water
- Glycerine
- Lactophenol (mainly for fungi)

Procedure

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1. Place the specimen on a clean slide.
2. Add one drop of mounting medium.
3. Lower the cover slip gently at an angle.
4. Remove excess liquid with filter paper.
5. Observe under the microscope.

B. Permanent Mounting

Permanent mounts are prepared for long-term preservation.

Common Mounting Media

- DPX (Dibutylphthalate Polystyrene Xylene)
- Canada Balsam

Procedure

1. Prepare and stain the section.
2. Dehydrate through a graded alcohol series.
3. Clear using xylene or another clearing agent.
4. Place one drop of mounting medium on the slide.
5. Carefully lower the cover slip.
6. Allow the mount to dry completely.
7. Label and store appropriately.

Removal of Air Bubbles

Air bubbles interfere with microscopic observation.

To avoid them:

- Lower the cover slip slowly at an angle.
- Avoid excessive mounting medium.
- Use clean slides and cover slips.
- Remove trapped bubbles gently with a mounted needle if necessary.

Labelling of Slides

Each prepared slide should include:

- Name of specimen
- Plant part
- Type of section (T.S., L.S., etc.)
- Stain used
- Date
- Prepared by

7. Plant Cell and Tissue Studies

The plant cell is the fundamental structural and functional unit of all plants. It is responsible for carrying out vital physiological, biochemical, and genetic activities necessary for plant growth

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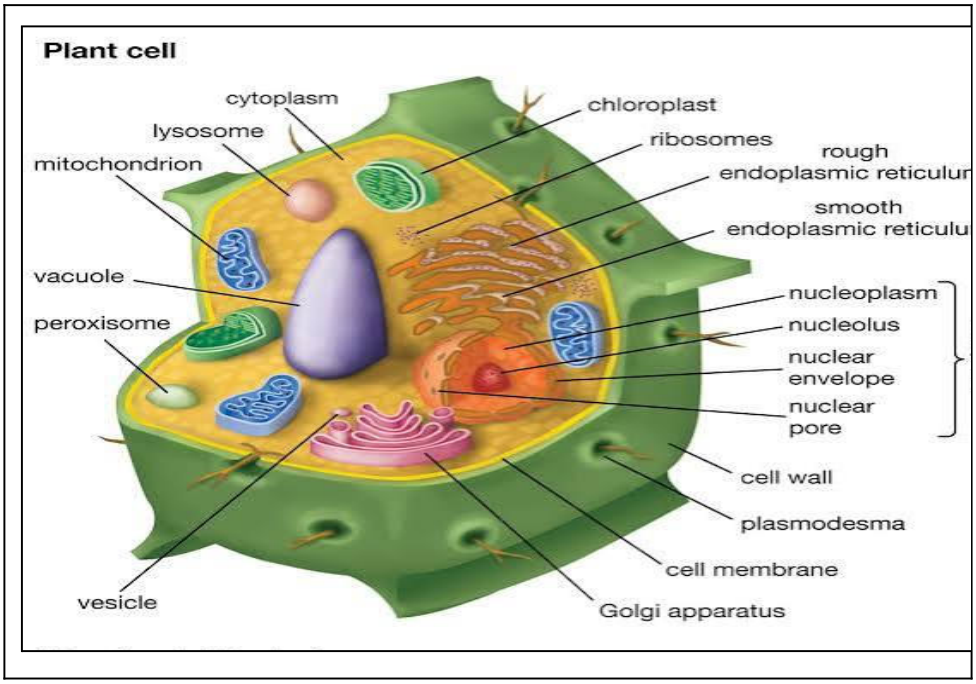
and survival. Groups of similar cells performing specific functions form tissues, which collectively constitute various plant organs such as roots, stems, leaves, flowers, and fruits.

The study of plant cells and tissues provides a foundation for understanding plant anatomy, physiology, genetics, development, and taxonomy. Practical knowledge of cell structure, organelles, cell division, and tissue organization enables students to identify plant specimens and interpret microscopic observations accurately.

This chapter introduces the structure of plant cells, describes the functions of cellular organelles, explains the processes of mitosis and meiosis, and discusses the different types of plant tissues and tissue systems.

7.1 Structure of Plant Cells

A plant cell is a eukaryotic cell enclosed by a rigid cell wall and a plasma membrane. It contains membrane-bound organelles suspended in the cytoplasm and is distinguished from animal cells by the presence of a cell wall, plastids, and a large central vacuole.



Major Components of a Plant Cell

1. Cell Wall

The cell wall is the outermost non-living covering composed mainly of cellulose, hemicellulose, and pectin.

Functions

- Provides shape and mechanical support.
- Protects the cell from mechanical injury and pathogens.

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- Prevents excessive water uptake.
- Facilitates communication through plasmodesmata.

2. Plasma Membrane

The plasma membrane is a selectively permeable membrane located just inside the cell wall.

Functions

- Regulates movement of substances.
- Maintains cellular homeostasis.
- Facilitates cell signaling.

3. Cytoplasm

The cytoplasm is a semi-fluid matrix in which organelles are suspended.

Functions

- Site of numerous metabolic reactions.
- Supports intracellular transport.
- Houses organelles.

4. Nucleus

The nucleus controls cellular activities and contains hereditary material (DNA).

Parts

- Nuclear envelope
- Nucleoplasm
- Chromatin
- Nucleolus

Functions

- Controls metabolism.
- Regulates cell division.
- Stores genetic information.

5. Vacuole

Plant cells possess a large central vacuole surrounded by the tonoplast.

Functions

- Storage of water, pigments, salts, and wastes.
- Maintenance of turgor pressure.
- Regulation of osmotic balance.

Characteristics of Plant Cells

- Usually rectangular or polygonal.
- Possess a rigid cellulose cell wall.
- Contain chloroplasts in photosynthetic tissues.
- Have a large permanent vacuole.

- Store food mainly as starch.

7.2 Cell Organelles

Cell organelles are specialized structures that perform specific functions within the cell which include nucleus, mitochondria, golgi body, endoplasmic reticulum, lysosomes

Types of Plastids

Chloroplasts

- Green plastids containing chlorophyll.
- Site of photosynthesis.

Chromoplasts

- Yellow, orange, or red plastids.
- Contain carotenoid pigments.
- Responsible for fruit and flower coloration.

Leucoplasts

Colourless plastids mainly involved in storage.

Types include:

- **Amyloplasts** – store starch.
- **Elaioplasts** – store oils.
- **Proteinoplasts** – store proteins.

7.3 Mitosis and Meiosis

Cell division is essential for growth, repair, reproduction, and inheritance.

A. Mitosis

Mitosis is an equational division in which one parent cell produces two genetically identical daughter cells, each with the same chromosome number.

Significance

- Plant growth
- Tissue repair
- Vegetative propagation
- Maintenance of chromosome number

Stages of Mitosis

1. Prophase

- Chromosomes become visible.
- Nuclear membrane disappears.
- Spindle fibres begin to form.

2. Metaphase

- Chromosomes align at the equatorial plate.
- Spindle fibres attach to centromeres.

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3. Anaphase

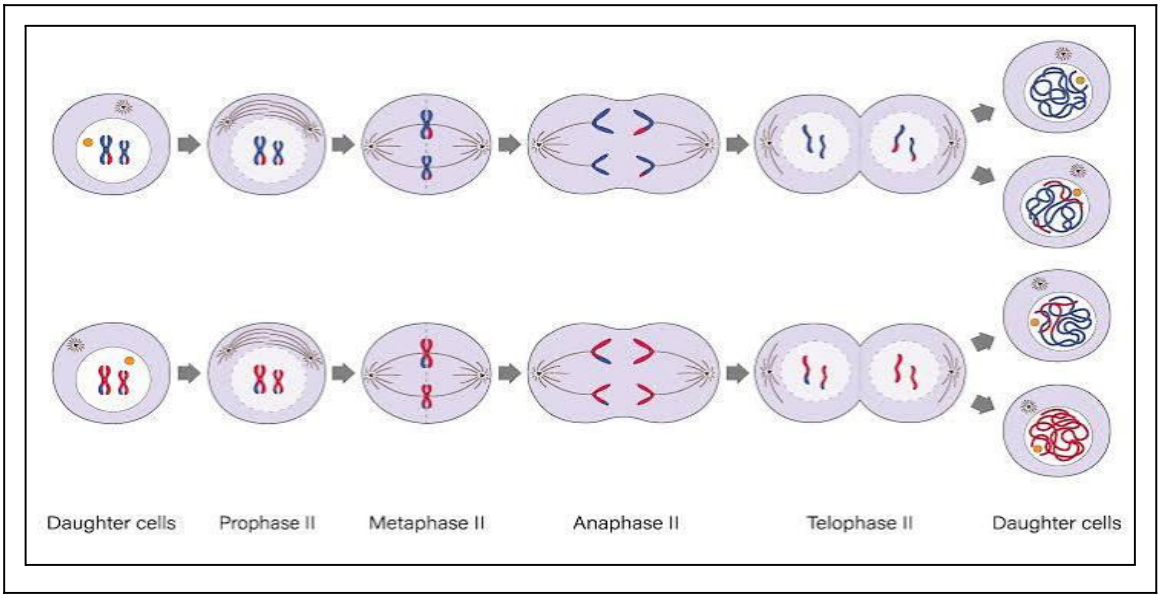
- Sister chromatids separate.
- Daughter chromosomes move toward opposite poles.

4. Telophase

- Nuclear membrane reforms.
- Chromosomes decondense.
- Two daughter nuclei are formed.

Cytokinesis

Division of the cytoplasm occurs through **cell plate formation**, resulting in two daughter cells.



B. Meiosis

Meiosis is a reductional division in which one diploid cell produces four haploid daughter cells.

Importance

- Formation of spores and gametes.
- Maintains chromosome number across generations.
- Produces genetic variation.

Meiosis I (Reductional Division)

- Prophase I
- Metaphase I
- Anaphase I
- Telophase I

Homologous chromosomes separate during this division.

Meiosis II (Equational Division)

- Prophase II

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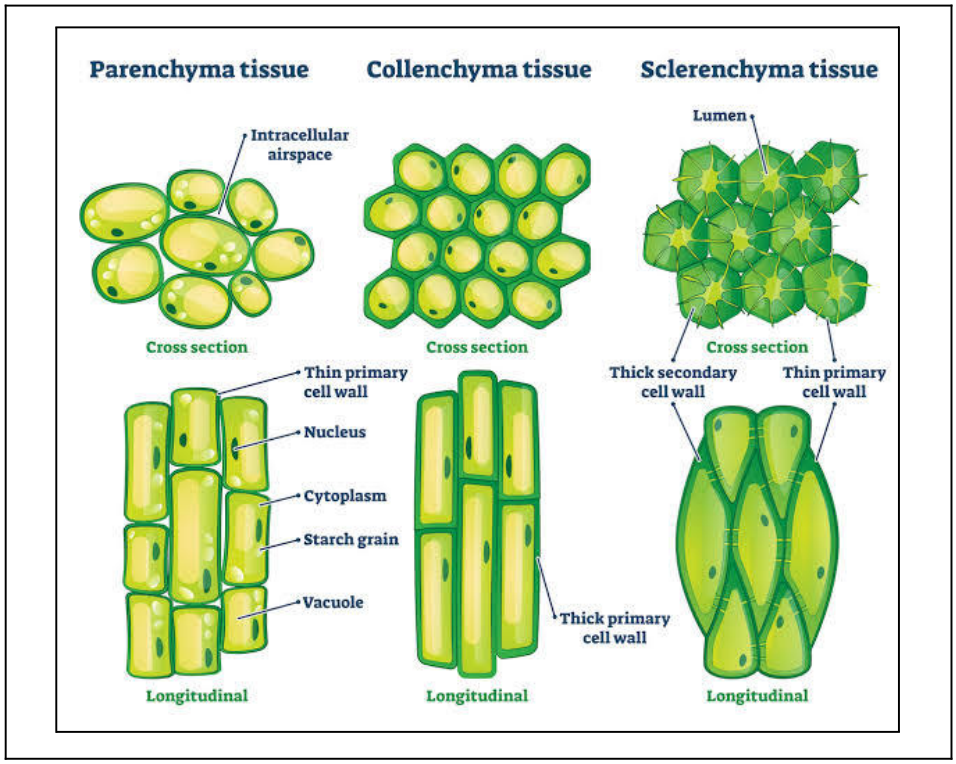
- Metaphase II
- Anaphase II
- Telophase II

Sister chromatids separate, producing four haploid cells.

7.4 Simple and Complex Tissues

Plant tissues are groups of cells having similar origin, structure, and function.



A. Simple Permanent Tissues

These tissues consist of only one type of cell.

1. Parenchyma

Characteristics

- Living cells
- Thin cell walls
- Large intercellular spaces

Functions

- Storage
- Photosynthesis (chlorenchyma)
- Secretion
- Wound healing

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2. Collenchyma

Characteristics

- Living cells
- Unevenly thickened corners
- Flexible

Functions

- Mechanical support
- Flexibility in young stems and petioles

3. Sclerenchyma

Characteristics

- Dead cells
- Thick lignified walls

Functions

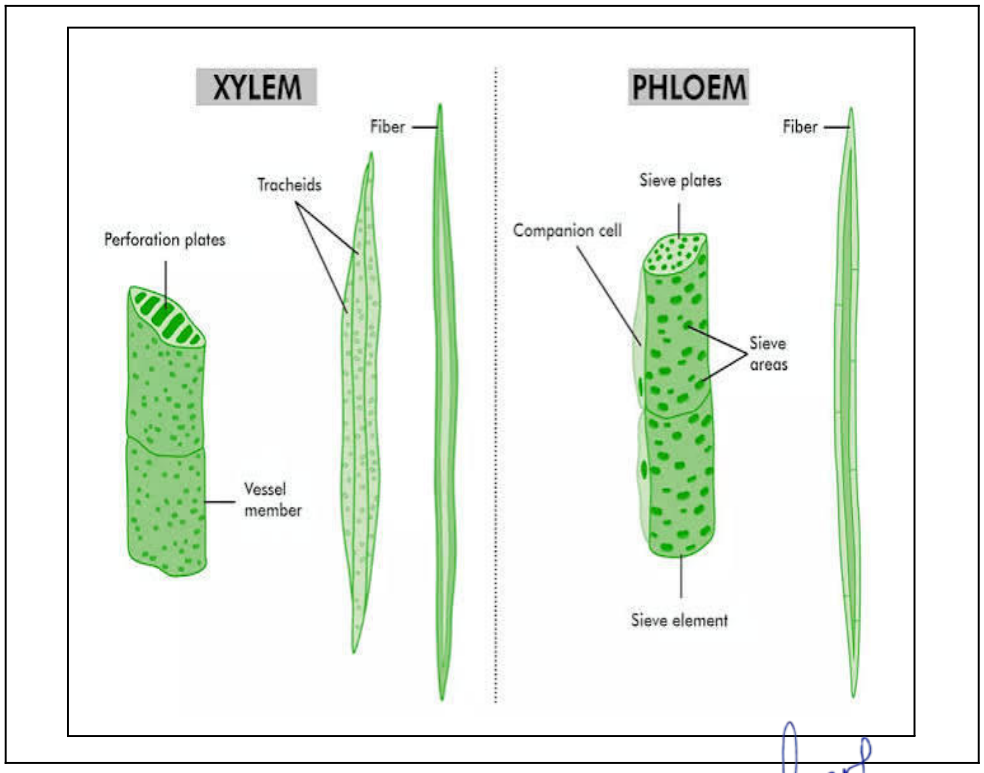
- Mechanical strength
- Protection

Types

- Fibres
- Sclereids

B. Complex Permanent Tissues

Complex tissues consist of more than one type of cell working together.



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1. Xylem

Components

- Tracheids
- Vessels
- Xylem fibres
- Xylem parenchyma

Functions

- Water transport
- Mineral conduction
- Mechanical support

2. Phloem

Components

- Sieve tubes
- Companion cells
- Phloem fibres
- Phloem parenchyma

Functions

- Transport of food
- Storage
- Support

7.5 Tissue Systems

According to Sachs (1875), plant tissues are organized into three major tissue systems.

1. Epidermal Tissue System

The epidermis forms the outer protective covering of the plant.

Components

- Epidermis
- Stomata
- Guard cells
- Trichomes
- Root hairs

Functions

- Protection
- Prevention of water loss
- Gas exchange
- Absorption in roots

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2. Ground Tissue System

The ground tissue occupies the region between the epidermis and vascular tissue.

Components

- Parenchyma
- Collenchyma
- Sclerenchyma

Functions

- Storage
- Photosynthesis
- Mechanical support

3. Vascular Tissue System

The vascular tissue system forms the conducting system of plants.

Components

- Xylem
- Phloem

Functions

- Transport of water and minerals
- Transport of food
- Mechanical support

Practical Exercises

Students should be able to:

1. Observe plant cells under the compound microscope.
2. Identify major cell organelles in prepared slides.
3. Prepare temporary mounts of epidermal peel.
4. Identify stages of mitosis using onion root tip slides.
5. Observe meiosis in suitable floral buds.
6. Identify parenchyma, collenchyma, and sclerenchyma tissues.
7. Differentiate xylem and phloem in transverse sections.
8. Draw and label observed structures accurately.

8. Plant Anatomy

Plant anatomy is the branch of botany concerned with the internal structure and organization of plant organs. It involves the study of tissues, cells, and their arrangement in roots, stems, leaves, flowers, fruits, and seeds. Anatomical studies help in understanding the functional adaptations of plants, taxonomic relationships, ecological responses, and evolutionary trends.

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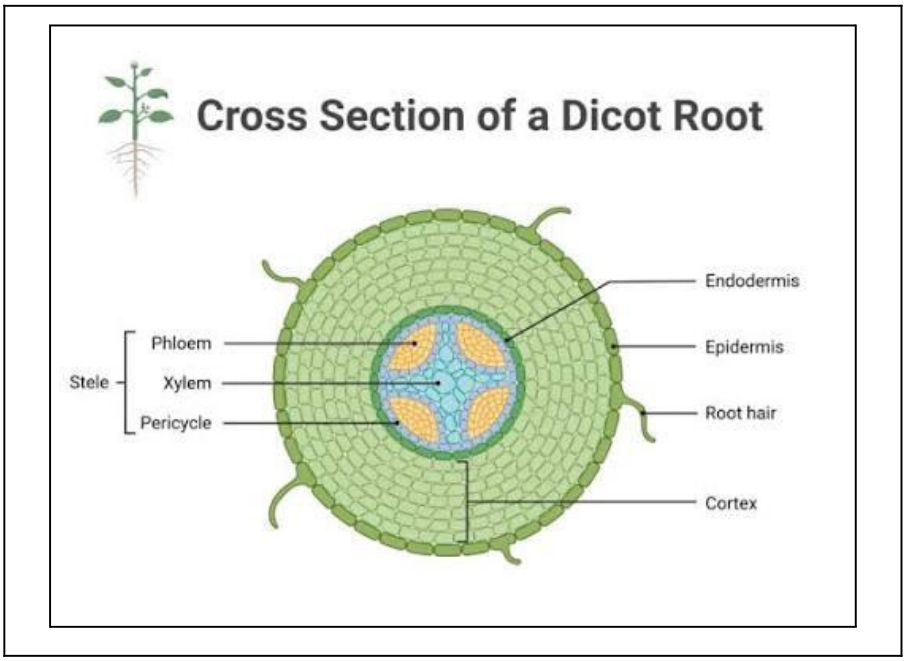
The anatomy of roots, stems, and leaves varies between monocotyledonous and dicotyledonous plants. Secondary growth, characteristic of most dicots and gymnosperms, results in an increase in girth through the activity of lateral meristems. Wood anatomy provides valuable information for taxonomy, forestry, and the identification of timber species.
This chapter introduces the anatomical structure of the root, stem, and leaf, explains the process of secondary growth in dicot stems and roots, and discusses the basic features of wood anatomy.

8.1 Anatomy of Root

The root anchors the plant, absorbs water and minerals, stores food, and conducts absorbed materials to the stem. Anatomically, roots show distinct tissue organization adapted for absorption and conduction.

A. Anatomy of a Dicot Root (e.g., Sunflower)



1. Epiblema (Piliferous Layer)

- Outermost single layer of cells.
- Lacks cuticle and stomata.
- Bears root hairs for absorption.

Function: Absorption of water and minerals.

2. Cortex

- Composed of several layers of thin-walled parenchymatous cells.
- Large intercellular spaces present.

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Function:

- Storage of food.
- Conduction of water to vascular tissues.

3. Endodermis

- Innermost layer of cortex.
- Cells possess Casparian strips.

Function:

- Regulates movement of water and minerals into the vascular cylinder.

4. Pericycle

- Single layer of parenchymatous cells beneath the endodermis.

Function:

- Gives rise to lateral roots.
- Contributes to vascular cambium and cork cambium during secondary growth.

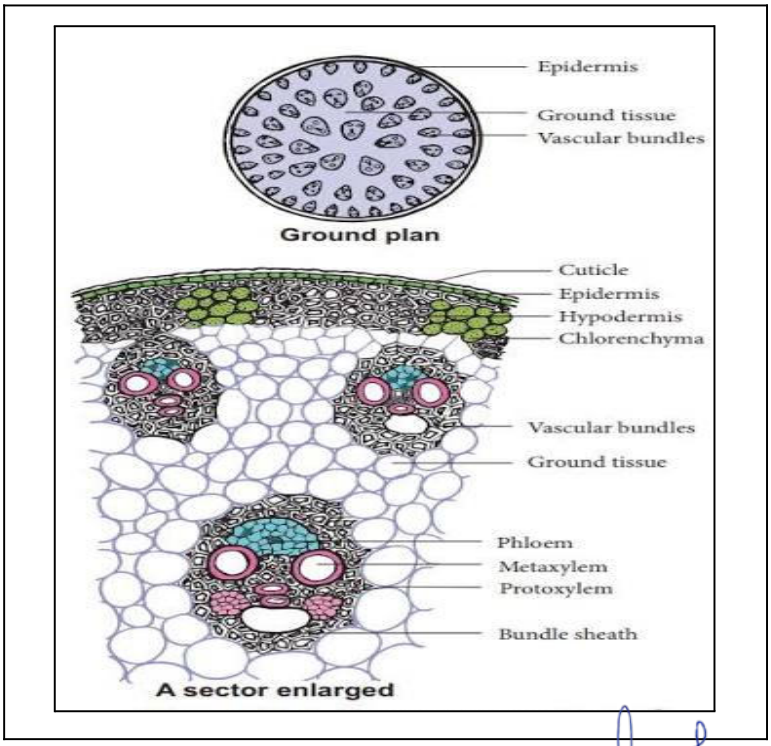
5. Vascular Tissue

- Xylem and phloem arranged alternately (radial arrangement).
- Xylem is **exarch**, with protoxylem towards the periphery.

6. Pith

- Small or absent in dicot roots.
- Composed of parenchymatous cells.

B. Anatomy of a Monocot Root (e.g., Maize)



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Distinctive Features

- Wide cortex.
- Large and well-developed pitch.
- Polyarch xylem (many xylem bundles).
- No secondary growth.

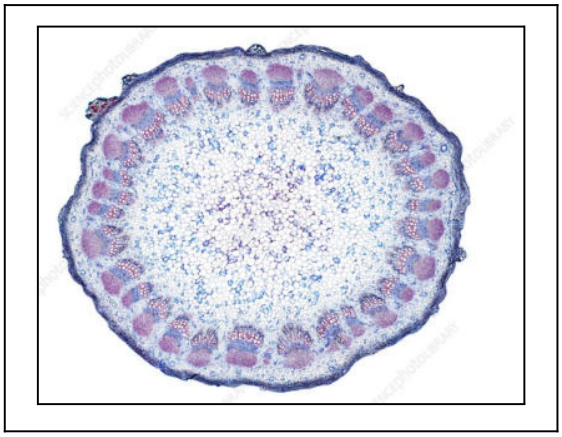
Differences Between Dicot and Monocot Roots

Character	Dicot Root	Monocot Root
Xylem	Diarch to hexarch	Polyarch
Pith	Small or absent	Large
Cambium	Develops	Absent
Secondary growth	Present	Absent

8.2 Anatomy of Stem

The stem supports aerial plant parts and conducts water, minerals, and food between roots and leaves.

A. Anatomy of a Dicot Stem (e.g., Sunflower)



1. Epidermis

- Single layer of cells.
- Covered by a cuticle.
- May bear multicellular hairs.

Function: Protection and reduction of water loss.

2. Hypodermis

- Usually collenchymatous.

Function: Mechanical support.

3. Cortex

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- Parenchymatous cells with intercellular spaces.

Function: Storage and photosynthesis.

4. Endodermis

- Innermost cortical layer.
- Rich in starch (starch sheath).

5. Pericycle

- Often composed of sclerenchyma.

Function: Mechanical support.

6. Vascular Bundles

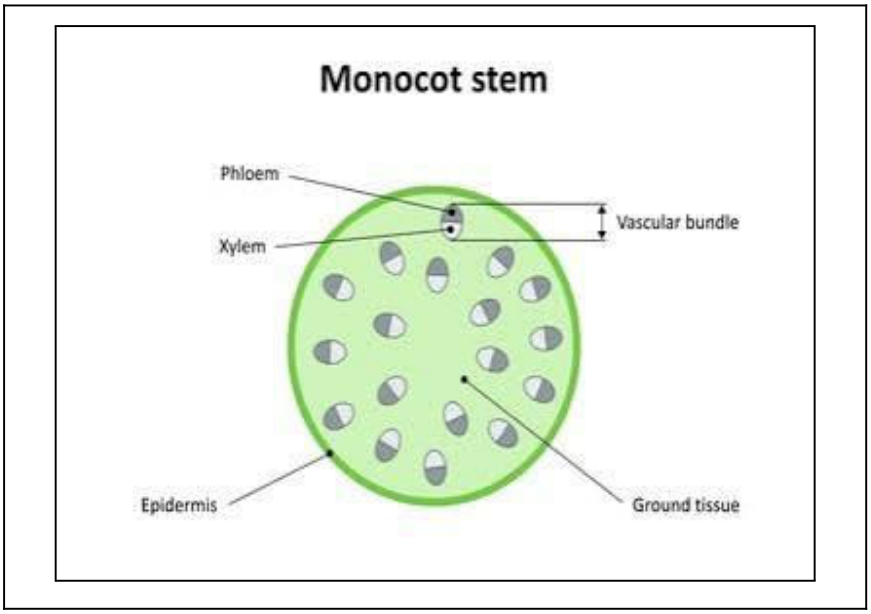
- Arranged in a ring.
- Conjoint, collateral, and open.
- Cambium present between xylem and phloem.

7. Pith

- Large central region.
- Composed of parenchyma.

Function: Storage.

B. Anatomy of a Monocot Stem (e.g., Maize)



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Characteristics

- Epidermis with thick cuticles.
- Sclerenchymatous hypodermis.
- Ground tissue undifferentiated.
- Numerous scattered vascular bundles.
- Closed vascular bundles (no cambium).
- No secondary growth.

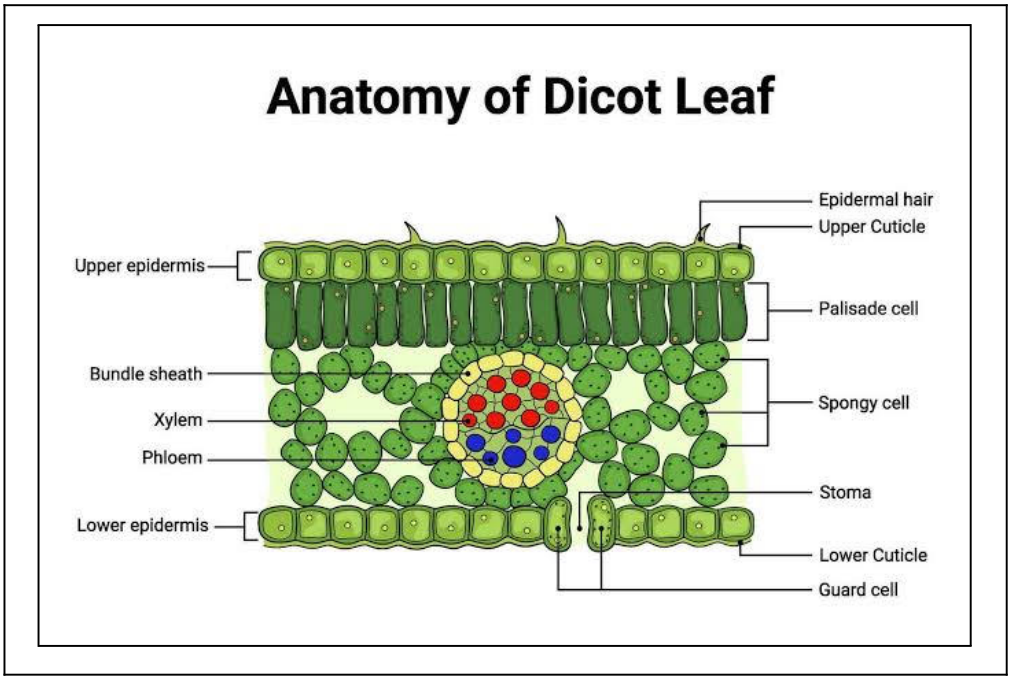
Differences Between Dicot and Monocot Stems

Character	Dicot Stem	Monocot Stem
Vascular bundles	Ring arrangement	Scattered
Cambium	Present	Absent
Secondary growth	Present	Absent
Ground tissue	Differentiated	Undifferentiated

8.3 Anatomy of Leaf

Leaves are specialized organs primarily responsible for photosynthesis, transpiration, and gaseous exchange.

A. Dicot (Dorsiventral) Leaf



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Upper Epidermis

- Covered with cuticles.
- Few or no stomata.

Mesophyll

Differentiated into:

Palisade Parenchyma

- Elongated cells rich in chloroplasts.

Function: Photosynthesis.

Spongy Parenchyma

- Loosely arranged cells with air spaces.

Function:

- Gas exchange.
- Photosynthesis.

Lower Epidermis

- Numerous stomata.
- Guard cells regulate gas exchange.

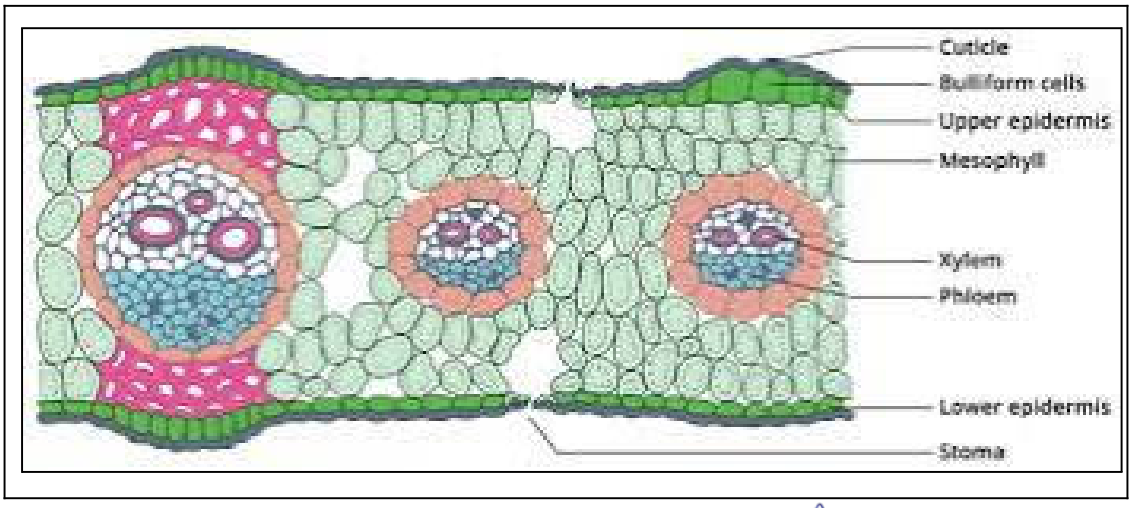
Vascular Bundle

- Xylem towards the upper side.
- Phloem towards the lower side.

B. Monocot (Isobilateral) Leaf

Characteristics

- Similar upper and lower epidermis.
- Stomata on both surfaces.
- Mesophyll not differentiated.
- Bulliform (motor) cells present.
- Parallel venation



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Practical Exercises

Students should be able to:

1. Prepare transverse sections (T.S.) of dicot and monocot roots.
2. Identify tissues in dicot and monocot stems.
3. Observe dorsiventral and isobilateral leaf anatomy.
4. Identify vascular bundles and tissue systems.
5. Study prepared slides showing secondary growth.
6. Observe annual rings, vessels, fibres, and medullary rays in wood sections.
7. Draw neat, labelled diagrams of observed specimens.

9. Plant Morphology

Plant morphology is the branch of botany that deals with the external form, structure, and appearance of plants and their organs. It includes the study of roots, stems, leaves, flowers, fruits, and seeds, along with their modifications and adaptations. Morphological characteristics are fundamental for plant identification, classification, taxonomy, ecological studies, and understanding plant evolution.

The study of plant morphology enables students to recognize distinguishing features of different plant groups, understand adaptive modifications, and identify economically important species. This chapter introduces the morphology of roots, stems, leaves, inflorescences, flowers, fruits, and seeds, emphasizing their structural diversity and biological significance.

9.1 Root Systems

The root is the descending, generally underground part of a plant that develops from the radicle of the embryo. It anchors the plant, absorbs water and minerals, stores food, and conducts absorbed substances to the shoot.

Functions of Roots

- Anchorage of the plant.
- Absorption of water and mineral nutrients.
- Conduction of absorbed materials.
- Storage of food.
- Synthesis of plant growth regulators.
- Symbiotic association with microorganisms.

Types of Root Systems

A. Tap Root System

The tap root develops directly from the radicle and gives rise to secondary and tertiary branches.

Characteristics

- One prominent primary root.
- Common in dicotyledonous plants.

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- Penetrates deeply into the soil.

Examples

- Mustard (*Brassica*)
- Pea (*Pisum*)
- Mango (*Mangifera Indica*)

B. Fibrous Root System

The primary root is short-lived and replaced by numerous roots of similar size arising from the base of the stem.

Characteristics

- No dominant primary root.
- Dense network of roots.
- Common in monocotyledonous plants.

Examples

- Wheat (*Triticumaestivum*)
- Rice (*Oryza sativa*)
- Maize (*Zea mays*)

C. Adventitious Root System

Roots arise from parts of the plant other than the radicle, such as stems, leaves, or branches.

Examples

- Banyan (*Ficusbenghalensis*)
- Sugarcane (*Saccharumofficinarum*)
- Money plant (*Epipremnumaureum*)

9.2 Underground Stem Modifications

Rhizome

A horizontal underground stem with nodes and internodes.

Examples

- Ginger (*Zingiberofficinale*)
- Turmeric (*Curcuma longa*)

Tuber

A swollen underground stem storing food.

Example

- Potato (*Solanumtuberosum*)

Bulb

A condensed stem surrounded by fleshy scale leaves.

Examples

- Onion (*Allium cepa*)
- Garlic (*Allium sativum*)

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Corm

A short, solid underground stem.

Examples

- Colocasia
- Gladiolus

Subaerial Stem Modifications

- Runner – Cynodon (Doob grass)
- Stolon – Strawberry
- Offset – Pistia
- Sucker – Mint, Chrysanthemum

These modifications aid in vegetative propagation.

Aerial Stem Modifications

Stem Tendrils

Provide support for climbing.

Examples

- Grapevine (*Vitis*)
- Passiflora

Thorns

Modified stems for protection.

Examples

- Citrus
- Bougainvillea

Phylloclades

Flattened green stems performing photosynthesis.

Examples

- Opuntia
- Euphorbia

Cladodes

Small, leaf-like green stems.

Example

- Asparagus

9.3 Leaf Morphology

The leaf is the principal photosynthetic organ of the plant.

Parts of a Typical Leaf

- Leaf base
- Petiole
- Lamina (leaf blade)

- Stipules (when present)

Types of Leaves

Simple Leaf

The lamina is undivided.

Examples

- Mango
- Guava

Compound Leaf

The lamina is divided into leaflets.

Pinnately Compound

- Neem
- Rose

Palmately Compound

- Silk cotton
- Cassava

Leaf Arrangement (Phyllotaxy)

- Alternate – Hibiscus
- Opposite – Calotropis
- Whorled – Nerium

Leaf Modifications

Tendrils

For climbing.

Example

- Pea

Spines

For protection and reduced transpiration.

Examples

- Cactus
- Agave

Storage Leaves

Store food or water.

Examples

- Onion
- Aloe

Insectivorous Leaves

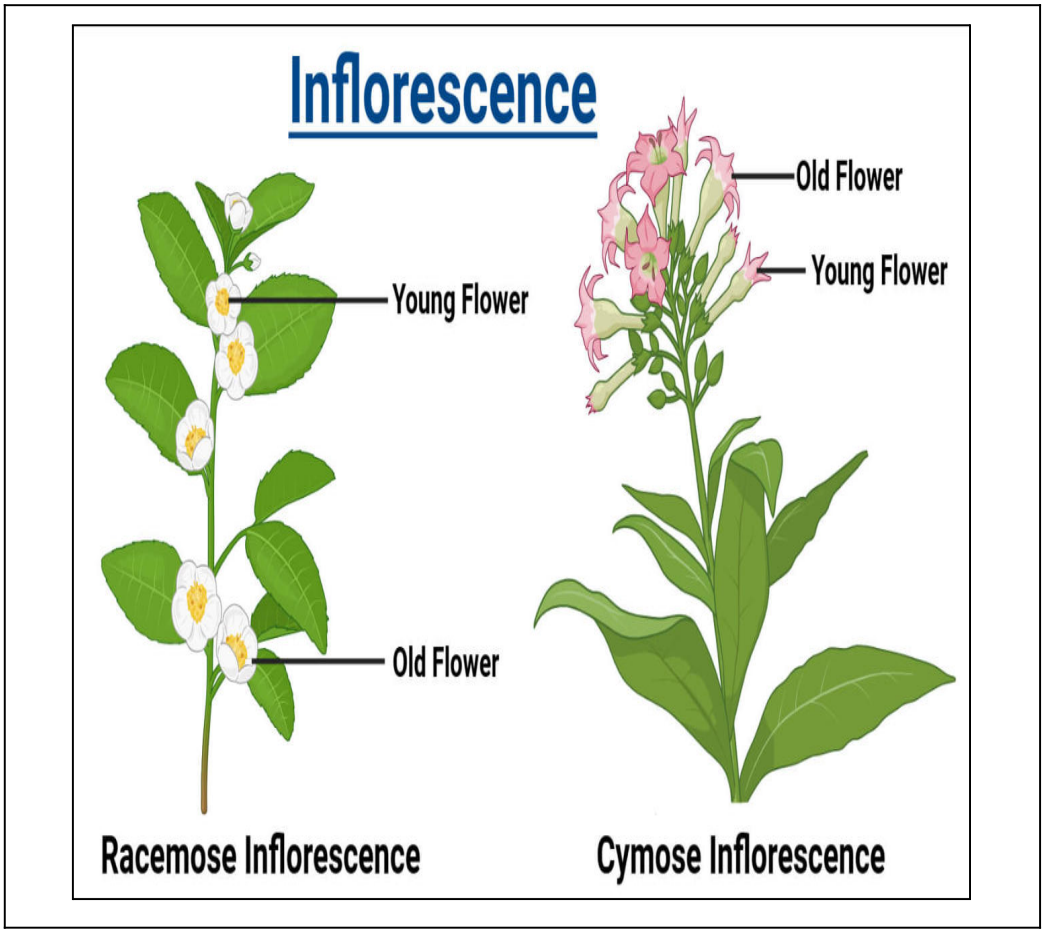
Modified to trap insects.

Examples

- Pitcher plant (*Nepenthes*)

- Venus flytrap (*Dionaea*)
- Sundew (*Drosera*)

9.4 Inflorescence Types



An inflorescence is the arrangement of flowers on the floral axis.

A. Racemose Inflorescence

The main axis continues to grow, and flowers develop in **acropetal succession** (older flowers at the base, younger towards the apex).

Types

- Raceme – Mustard
- Spike – Achyranthes
- Spadix – Colocasia
- Catkin – Mulberry
- Corymb – Iberis
- Umbel – Coriander

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- Capitulum (Head) – Sunflower
- Panicle – Oats

B. Cymose Inflorescence

The main axis terminates in a flower, and subsequent flowers develop in **basipetal succession**.

Types

- Monochasial cyme
- Dichasial cyme
- Polychasial cyme

Special Types of Inflorescence

- Cyathium – Euphorbia
- Verticillaster – Ocimum
- Hypanthodium – Fig (*Ficus*)
- Coenanthium – Dorstenia

9.5 Floral Morphology

The flower is the reproductive structure of angiosperms.

Parts of a Typical Flower

1. Pedicel
2. Thalamus (Receptacle)
3. Calyx
4. Corolla
5. Androecium
6. Gynoecium

Floral Symmetry

- Actinomorphic (Radial) – Mustard, Hibiscus
- Zygomorphic (Bilateral) – Pea, Cassia

Completeness

- Complete flower – Contains all four floral whorls.
- Incomplete flower – Lacks one or more floral whorls.

Sexuality

- Bisexual (Perfect)
- Unisexual (Imperfect)

Position of Ovary

Hypogynous

Superior ovary.

Examples

- Mustard
- Hibiscus

Perigynous

Half-inferior ovary.

Example

- Rose

Epigynous

Inferior ovary.

Examples

- Guava
- Cucumber

Placentation

- Marginal
- Axile
- Parietal
- Free-central
- Basal

Floral Formula and Floral Diagram

Students should learn to:

- Interpret floral formulae.
- Draw floral diagrams.
- Identify floral parts and aestivation.

9.6 Fruit and Seed Types

A fruit is a mature ovary developed after fertilization. Seeds develop from ovules and contain the embryo.

Types of Fruits

A. Simple Fruits

Develop from a single ovary.

Fleshy Fruits

- Berry – Tomato
- Drupe – Mango

- Pepo – Cucumber
- Hesperidium – Orange
- Pome – Apple

Dry Fruits

Dehiscent

- Legume
- Capsule
- Follicle
- Siliqua

Indehiscent

- Achene
- Caryopsis
- Cypsela
- Samara
- Nut

Schizocarpic

- Cremocarp
- Lomentum
- Carcerulus
- Regma

B. Aggregate Fruits

Develop from many free carpels of a single flower.

Examples

- Strawberry
- Custard apple

C. Multiple (Composite) Fruits

Develop from an entire inflorescence.

Examples

- Pineapple
- Jackfruit
- Mulberry

Types of Seeds

Dicot Seed Eg. Pea,Bean

Characteristics

- Two cotyledons

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- Endosperm usually absent at maturity
- Large embryo

Monocot Seed Eg. Maize,Wheat

Characteristics

- One cotyledon (Scutellum)
- Endosperm persistent
- Embryo small

Seed Dispersal

By Wind

Examples:

- Cotton
- Drumstick

By Water

Examples:

- Coconut
- Lotus

By Animals

Examples:

- Xanthium
- Mango

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By Explosive Mechanism

Examples:

- Balsam
- Castor

Practical Exercises

Students should be able to:

1. Identify different root systems and modifications.
2. Observe and identify stem modifications.
3. Study various leaf types, venation, phyllotaxy, and modifications.
4. Identify racemose and cymose inflorescences.
5. Describe floral parts and determine floral symmetry and ovary position.
6. Write floral formulae and draw floral diagrams.
7. Identify different fruit and seed types.
8. Prepare labelled diagrams of all observed specimens.

10. Plant Taxonomy

Plant taxonomy is the branch of botany that deals with the identification, nomenclature, classification, and description of plants. It provides a systematic framework for recognizing, naming, and organizing plant diversity based on their similarities, differences, and evolutionary relationships. Taxonomy plays a vital role in agriculture, forestry, horticulture, ecology, conservation biology, pharmacognosy, and biodiversity research.

Modern plant taxonomy integrates evidence from morphology, anatomy, embryology, cytology, palynology, phytochemistry, molecular biology, and DNA sequencing to establish natural relationships among plants. Knowledge of taxonomy enables students to identify unknown plants, understand their classification, and appreciate the diversity of the plant kingdom.

This chapter introduces the principles of plant classification, botanical nomenclature, methods of plant identification using floras and keys, the study of major plant families, and the preparation of identification keys.

10.1 Principles of Classification

Plant classification is the systematic arrangement of plants into groups based on shared characteristics and evolutionary relationships.

Objectives of Classification

- Organize plant diversity in a systematic manner.
- Facilitate identification of plants.
- Indicate natural and evolutionary relationships.
- Provide a universal system of communication.

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- Aid research, conservation, and utilization of plant resources.

Taxonomic Hierarchy

Plants are arranged in hierarchical categories known as taxonomic ranks.

Taxonomic Rank	**Example (*Mangiferaindica*)**
Kingdom	Plantae
Division	Magnoliophyta (Angiosperms)
Class	Magnoliopsida (Dicotyledons)
Order	Sapindales
Family	Anacardiaceae
Genus	*Mangifera*
Species	*Mangiferaindica*

The **species** is the basic unit of classification.

Systems of Classification

1. Artificial System

Plants are grouped using one or a few easily observable characters.

Advantages

- Simple to use.
- Useful for beginners.

Limitations

- Does not reflect natural relationships.

Example

- Sexual System of Classification by Carl Linnaeus.

2. Natural System

Plants are classified using many morphological and anatomical characters.

Advantages

- Reflects overall similarities.
- More reliable than artificial systems.

Example

- Bentham and Hooker System of Classification.

3. Phylogenetic System

Plants are classified according to evolutionary relationships and common ancestry.

Advantages

- Reflects evolutionary history.
- Supported by molecular evidence.

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Examples

- Engler and Prantl System
- Angiosperm Phylogeny Group (APG) Classification

Criteria Used in Plant Classification

Modern classification is based on multiple lines of evidence:

- Morphological characters
- Anatomical features
- Embryological evidence
- Cytological characteristics
- Palynological studies
- Phytochemical data
- Molecular and DNA evidence
- Ecological adaptations

10.2 Botanical Nomenclature

Botanical nomenclature is the scientific system of naming plants according to internationally accepted rules.

The naming of plants is governed by the **International Code of Nomenclature for Algae, Fungi, and Plants (ICN)**, ensuring that each plant has one universally accepted scientific name.

Binomial Nomenclature

The system of binomial nomenclature was introduced by **Carl Linnaeus** in 1753.

Each scientific name consists of two words:

1. **Genus name**
2. **Specific epithet (species name)**

Example

Mangiferaindica L.

where:

- *Mangifera* = Genus
- *indica* = Specific epithet
- **L.** = Author citation (Linnaeus)

Rules of Botanical Nomenclature

1. Scientific names are written in Latin or are Latinized.
2. The genus name begins with a capital letter.
3. The species name begins with a lowercase letter.

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4. Both genus and species names are written in italics (or underlined separately when handwritten).
5. Only one correct scientific name is accepted for each species.
6. The earliest validly published name generally has priority (Principle of Priority).
7. Every species is represented by a designated type specimen.

Type Concept

A **type specimen** serves as the permanent reference for the application of a scientific name.
Common categories include:

- Holotype
- Isotype
- Lectotype
- Neotype
- Paratype

Advantages of Scientific Names

- Universal recognition.
- Avoid confusion caused by common names.
- Reflect taxonomic relationships.
- Facilitate scientific communication worldwide.

10.3 Identification Using Floras and Keys

Correct identification is the first step in any botanical investigation.

Flora

A flora is a systematic account of the plants occurring in a particular geographical region.
A flora generally includes:

- Scientific names
- Botanical descriptions
- Identification keys
- Distribution
- Habitat
- Flowering and fruiting periods
- Illustrations or photographs (in many modern floras)

Herbarium

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A herbarium is a collection of dried, mounted, and labelled plant specimens used for reference and identification.

Herbaria support:

- Plant identification
- Taxonomic research
- Biodiversity documentation
- Teaching and conservation

Identification Keys

Identification keys help distinguish among taxa through a series of paired contrasting statements.

Types of Keys

1. Dichotomous Key

Consists of two contrasting statements (couplets) at each step.

Example:

1a. Leaves simple ..... Go to 2

1b. Leaves compound ..... Go to 5

2. Polyclave (Multiple Access) Key

Uses several characters simultaneously and is often computer-assisted.

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Procedure for Plant Identification

1. Observe the plant carefully.
2. Record morphological characters.
3. Compare with descriptions in a flora.
4. Use an identification key.
5. Confirm the identification with herbarium specimens or authenticated references.

Important Characters Used for Identification

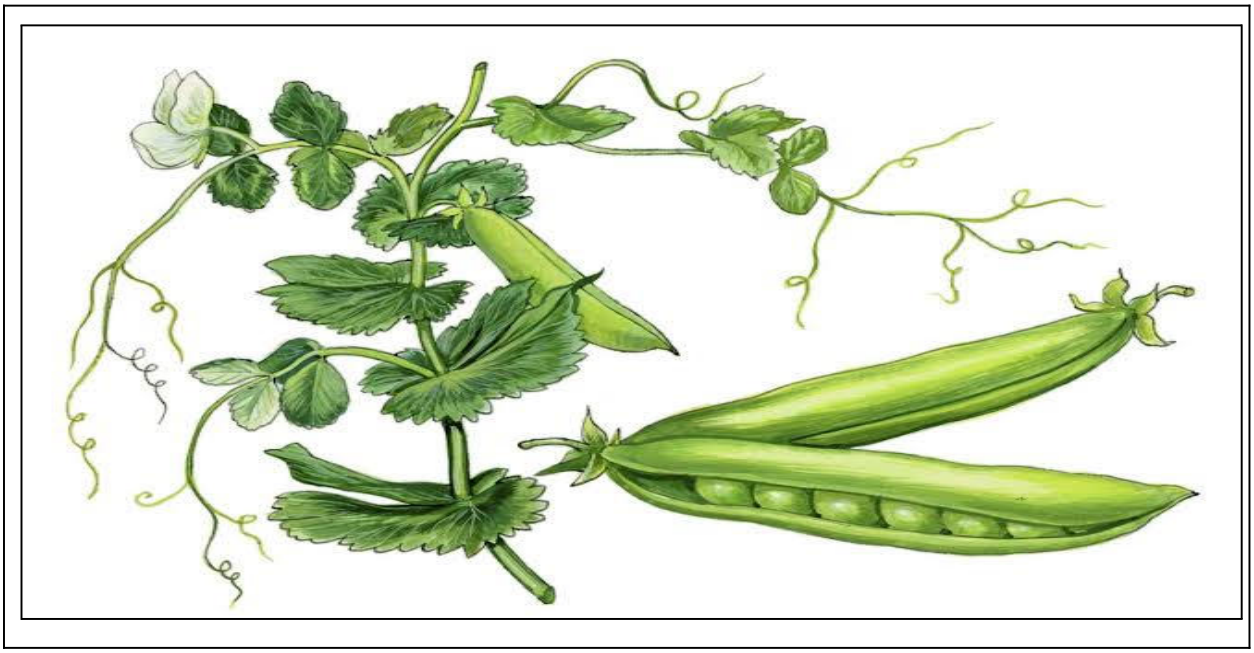
- Habit (herb, shrub, tree, climber)
- Root system
- Stem characteristics
- Leaf arrangement and venation
- Inflorescence type
- Floral structure
- Fruit type
- Seed characteristics

10.4 Study of Major Plant Families

The study of economically important plant families is an essential component of botanical practical work.

Students should study the morphology, floral characteristics, floral formula, floral diagram, and economic importance of representative species.

1. Fabaceae (Leguminosae)



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Diagnostic Features

- Herbs, shrubs, or trees
- Compound leaves
- Papilionaceous corolla
- Ten stamens (often diadelphous)
- Superior ovary
- Fruit a legume

Examples

- Pea (*Pisumsativum*)
- Gram (*Cicer Arietinum*)
- Soybean (*Glycine max*)

2. Solanaceae

Diagnostic Features

- Herbs or shrubs
- Alternate leaves
- Pentamerous flowers
- Five epipetalous stamens
- Superior ovary
- Fruit berry or capsule

Economic Importance

- Vegetables
- Medicinal plants
- Ornamental species

3. Brassicaceae (Cruciferae)

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Diagnostic Features

- Herbs
- Four free petals arranged in a cross
- Six stamens (tetradynamous)
- Superior ovary
- Fruit siliqua or silicula

Examples

- Mustard (*Brassica juncea*)
- Radish (*Raphanussativus*)
- Cabbage (*Brassica oleracea*)

Economic Importance

- Oilseeds
- Vegetables
- Condiments

4. Poaceae (Gramineae)

Diagnostic Features

- Herbs
- Fibrous roots
- Hollow stems with nodes
- Parallel venation
- Spikelets as inflorescence

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- Fruit caryopsis

Examples

- Rice (*Oryza sativa*)
- Wheat (*Triticumaestivum*)
- Maize (*Zea mays*)

Economic Importance

- Cereals
- Fodder
- Sugar industry
- Biofuel production

5. Lamiaceae (Labiatae)

Diagnostic Features

- Aromatic herbs
- Quadrangular stems
- Opposite leaves
- Bilabiate corolla
- Four didynamous stamens
- Superior ovary

Examples

- Tulsi (*Ocimumtenuiflorum*)
- Mint (*Mentha* spp.)

Economic Importance

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- Essential oils
- Medicinal plants
- Culinary herbs

10.5 Preparation of Identification Keys

An identification key is a practical tool used to distinguish plant species based on observable characters.

Characteristics of a Good Key

- Uses clear and contrasting characters.
- Employs easily observable features.
- Avoids ambiguous terminology.
- Progresses from general to specific characters.
- Leads accurately to the correct identification.

Steps in Preparing a Dichotomous Key

1. Select the plant species to be identified.
2. List important diagnostic characters.
3. Arrange characters from general to specific.
4. Write paired contrasting statements (couplets).
5. Test the key using actual specimens.
6. Revise and simplify if necessary.

Example of a Simple Dichotomous Key

1a. Leaves simple ..... Go to 2
1b. Leaves compound ..... Go to 3
2a. Venation parallel ..... Monocot
2b. Venation reticulate ..... Dicot
3a. Flowers papilionaceous .....Fabaceae
3b. Flowers actinomorphic ..... Other family

Applications of Identification Keys

- Botanical surveys
- Herbarium work
- Biodiversity assessment
- Ecological studies
- Forestry
- Agricultural research

- Conservation programmes

Practical Exercises

Students should be able to:

1. Identify plants using standard floras.
2. Use dichotomous keys for identification.
3. Study herbarium specimens of major plant families.
4. Identify diagnostic characters of representative species.
5. Write floral formulae and prepare floral diagrams.
6. Construct simple dichotomous identification keys based on observable characters.
7. Record scientific names according to the rules of botanical nomenclature.

11. Plant Physiology Experiments

Plant physiology is the branch of botany that deals with the study of vital life processes occurring in plants. These processes include water absorption, mineral nutrition, photosynthesis, respiration, transpiration, enzyme action, growth, and movement. Practical experiments in plant physiology help students understand the physiological mechanisms governing plant growth and development through observation and experimentation.

The experiments described in this chapter provide hands-on experience in studying osmosis, diffusion, plasmolysis, photosynthesis, transpiration, respiration, enzyme activity, and water relations. These experiments develop scientific skills in observation, measurement, data recording, analysis, and interpretation.

General Laboratory Guidelines

Before conducting physiological experiments, students should:

- Wear a laboratory coat and appropriate personal protective equipment (PPE).
- Handle chemicals and glassware carefully.
- Use fresh plant materials whenever possible.
- Record observations immediately.
- Repeat experiments for accuracy.
- Clean apparatus after use.
- Dispose of chemicals according to laboratory safety guidelines.

11.1 Experiment: Osmosis and Diffusion

Aim

To demonstrate the processes of diffusion and osmosis using plant materials.

Principle

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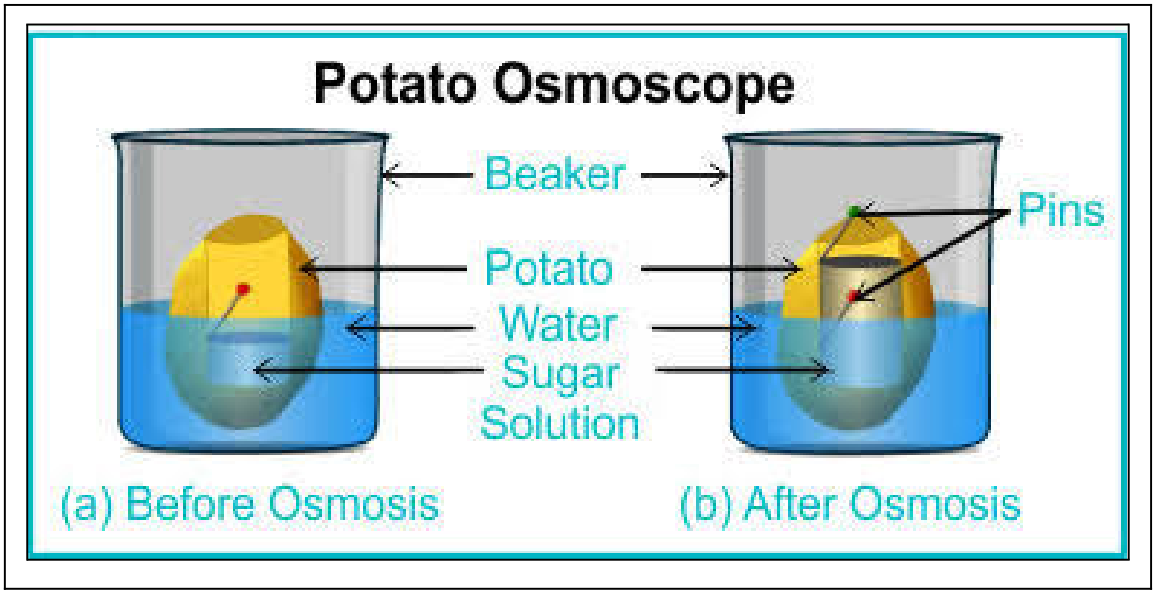
Diffusion is the movement of molecules from a region of higher concentration to a region of lower concentration until equilibrium is reached.

Osmosis is the movement of water molecules through a selectively permeable membrane from a region of higher water potential to a region of lower water potential.

Materials Required

- Potato osmometer or dialysis tubing
- Beaker
- Sugar solution
- Distilled water
- Measuring cylinder, Knife



Procedure

1. Prepare a potato cup or dialysis tubing filled with concentrated sugar solution.
2. Place it in a beaker containing distilled water.
3. Mark the initial level of the solution.
4. Observe the level after 30–60 minutes.

Observations

- Rise in solution level inside the potato cup.
- Water enters through the semipermeable membrane.

Result

The rise in liquid level demonstrates osmosis.

11.2 Experiment: Plasmolysis and Deplasmolysis

Aim

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To observe plasmolysis and deplasmolysis in plant cells.

Principle

Plasmolysis occurs when a plant cell loses water in a hypertonic solution, causing the protoplast to shrink away from the cell wall.

Deplasmolysis is the reverse process, in which water re-enters the cell when placed in distilled water.

Materials Required

- Epidermal peel of *Rhoeo* or onion
- Sodium chloride solution (10%)
- Distilled water
- Microscope
- Glass slides
- Cover slips

Procedure

1. Prepare an epidermal peel.
2. Mount it in water and observe.
3. Replace water with sodium chloride solution.
4. Observe plasmolysis.
5. Wash with distilled water.
6. Observe recovery (deplasmolysis).

Observations

- Cytoplasm shrinks during plasmolysis.
- Cytoplasm regains its original position during deplasmolysis.

Result

Hypertonic solutions cause plasmolysis, while hypotonic solutions restore turgidity.

11.3 Experiment: Photosynthesis

Aim

To demonstrate that photosynthesis requires light and chlorophyll and produces starch.

Principle

Photosynthesis is the process by which green plants synthesize carbohydrates from carbon dioxide and water using light energy in the presence of chlorophyll.

Experiment A: Test for Starch

Materials Required

- Destarched potted plant
- Iodine solution
- Ethanol

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- Water bath
- Beaker
- Forceps

Procedure

1. Keep the plant in sunlight for several hours.
2. Remove a leaf.
3. Boil in water.
4. Decolorize in hot ethanol.
5. Wash with warm water.
6. Add iodine solution.

Observation

The leaf turns blue-black.

Result

Starch is produced during photosynthesis.

Experiment B: Necessity of Light

Procedure

1. Cover part of a leaf with black paper.
2. Expose the plant to sunlight.
3. Test the leaf for starch.

Observation

Only the exposed portion turns blue-black.

Result

Light is essential for photosynthesis.

Experiment C: Necessity of Chlorophyll

Use a variegated leaf and perform the iodine test.

Observation

Only green portions stain blue-black.

Result

Chlorophyll is essential for photosynthesis.

11.4 Experiment: Transpiration

Aim

To demonstrate transpiration in plants.

Principle

Transpiration is the loss of water in the form of water vapour from the aerial parts of plants, mainly through stomata.

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Materials Required

- Potted plant
- Polythene bag
- Thread
- Cobalt chloride paper (optional)

Procedure

1. Cover a leafy branch with a transparent polythene bag.
2. Tie the bag securely.
3. Keep the plant in sunlight.
4. Observe after one to two hours.

Observations

Water droplets collect inside the bag.

Result

Water vapour released by leaves condenses inside the bag, demonstrating transpiration.

11.5 Experiment: Respiration

Aim

To demonstrate respiration in germinating seeds.

Principle

Respiration is the oxidation of food to release energy, producing carbon dioxide and water.

Materials Required

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- Germinating seeds
- Conical flask
- Cork
- Test tube containing lime water, Delivery tube

Procedure

1. Place germinating seeds in a flask.
2. Connect the flask to a test tube containing lime water.
3. Leave the setup for several hours.

Observations

Lime water turns milky due to the formation of calcium carbonate.

Result

Carbon dioxide released during respiration turns lime water milky.

11.6 Experiment: Enzyme Activity

Aim

To study the activity of the enzyme catalase.

Principle

Catalase catalyzes the decomposition of hydrogen peroxide into water and oxygen.

$2H_2O_2 \rightarrow 2H_2O + O_2$

Materials Required

- Fresh potato or liver extract

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- Hydrogen peroxide
- Test tubes
- Dropper

Procedure

1. Place potato extract in a test tube.
2. Add hydrogen peroxide.
3. Observe the reaction.

Observations

Rapid effervescence due to oxygen bubbles.

Result

Catalase breaks down hydrogen peroxide into water and oxygen.

Effect of Temperature on Enzyme Activity

Enzyme activity changes with temperature, increasing up to an optimum level before declining due to denaturation.

11.7 Experiment: Water Relations

Aim

To study water absorption and movement in plants.

Principle

Water moves through plants because of differences in water potential and is transported mainly through the xylem.

Experiment A: Demonstration of Water Uptake

Materials Required

- Fresh twig with leaves
- Coloured water (eosin or safranin solution)
- Beaker

Procedure

1. Place the cut end of the twig in coloured water.
2. Leave it for several hours.
3. Cut transverse sections of the stem.

Observation

The xylem vessels become coloured.

Result

Water is conducted through the xylem.

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Experiment B: Imbibition

Materials Required

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- Dry seeds
- Water
- Measuring cylinder

Procedure

1. Measure the initial volume of dry seeds.
2. Soak the seeds in water.
3. Measure the volume after several hours.

Observation

The seeds swell considerably.

Result

Water is absorbed by imbibition.

12. Genetics Experiments

Genetics is the branch of biology that deals with the study of heredity, variation, and the transmission of genetic information from one generation to the next. It explains how traits are inherited, how genes are expressed, and how genetic variation contributes to biodiversity and evolution. In plants, genetics forms the basis of plant breeding, crop improvement, biotechnology, conservation, and evolutionary studies.

Practical experiments in genetics enable students to understand the principles of inheritance, chromosome structure and behavior, genetic variation, and basic pedigree analysis. Through observation, data analysis, and problem-solving, students develop skills in interpreting genetic ratios, identifying chromosomal stages, and analyzing inheritance patterns.

This chapter describes laboratory exercises related to Mendelian genetics, chromosome studies, genetic variations, and basic pedigree analysis.

12.1 Experiment: Mendelian Genetics

Aim

To study the principles of inheritance using Mendelian genetic crosses.

Principle

Gregor Mendel demonstrated that hereditary traits are controlled by discrete units called genes. During gamete formation, alleles segregate and assort independently, producing predictable inheritance patterns.

The three fundamental laws of Mendelian inheritance are:

1. Law of Dominance
2. Law of Segregation
3. Law of Independent Assortment

Experiment A: Monohybrid Cross

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Objective

To study inheritance involving one pair of contrasting characters.

Example

Tall pea plant (**TT**) × Dwarf pea plant (**tt**)

F_1 Generation

All plants are **Tall (Tt)**.

F_2 Generation

Obtained by self-pollination of F_1 plants.

Genotype	**Ratio**
TT	1
Tt	2
tt	1

Phenotypic Ratio

3 Tall : 1 Dwarf

Experiment B: Dihybrid Cross

Objective

To study inheritance involving two pairs of contrasting characters.

Example

Round Yellow (**RRYY**) × Wrinkled Green (**rryy**)

F_1 Generation

All plants:

Round Yellow (RrYy)

F_2 Generation

Phenotypic Ratio

9 : 3 : 3 : 1

Phenotype	Ratio
Round Yellow	9
Round Green	3
Wrinkled Yellow	3
Wrinkled Green	1

Verification Using Chi-square (χ^2) Test

The Chi-square test is used to compare observed and expected genetic ratios.

Formula

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[
\chi^2=\sum \frac{(O-E)^2}{E}
]
where:

- **O** = Observed frequency
- **E** = Expected frequency

Interpretation

- Small χ^2 value: observed data fit the expected ratio.
- Large χ^2 value: observed data differ significantly from the expected ratio.

Materials Required

- Pea seed data or genetic charts
- Calculator
- Graph paper
- Record sheets

Observations

Record observed phenotypes and compare them with expected Mendelian ratios.

Result

The experimental data support the Mendelian laws of inheritance when observed ratios closely match expected ratios.

12.2 Experiment: Chromosome Studies

Aim

To observe chromosomes during mitosis and meiosis.

Principle

Chromosomes carry hereditary information in the form of DNA. During cell division, chromosomes undergo characteristic changes that can be observed under a microscope.

Experiment A: Mitosis in Onion Root Tip

Materials Required

- Onion root tips
- Carnoy's fixative (or suitable fixative)
- Hydrochloric acid (1 N)
- Acetocarmine or aceto-orcein stain
- Microscope
- Slides and cover slips

Procedure

1. Collect actively growing onion root tips.
2. Fix the root tips.
3. Hydrolyze in warm hydrochloric acid.
4. Stain with acetocarmine.
5. Prepare a squash mount.
6. Observe under the microscope.

Identify the Stages

- Interphase
- Prophase
- Metaphase
- Anaphase
- Telophase

Experiment B: Meiosis in Flower Buds

Materials Required

- Young flower buds (e.g., lily or onion)
- Acetocarmine stain
- Microscope
- Glass slides

Procedure

1. Remove young anthers.

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2. Prepare a squash mount.
3. Stain with acetocarmine.
4. Observe meiotic stages.

Observe

- Prophase I
- Metaphase I
- Anaphase I
- Telophase I
- Meiosis II stages

Observations

Students should identify:

- Chromosome condensation
- Chromosome alignment
- Chromosome separation
- Cytokinesis

Result

Characteristic stages of mitosis and meiosis are observed, demonstrating chromosome behavior during cell division.

12.3 Experiment: Genetic Variations

Aim

To study different types of genetic variation in plant populations.

Principle

Genetic variation arises due to mutation, recombination, crossing over, independent assortment, and environmental influences. Variation provides the raw material for evolution and plant improvement.

13. Plant Biotechnology

Plant biotechnology is an interdisciplinary branch of science that combines plant biology with modern biotechnological techniques to improve crop productivity, quality, disease resistance, and environmental sustainability. It involves the manipulation of plant cells, tissues, and genetic material under controlled laboratory conditions to produce improved plants and valuable biological products.

One of the most important tools of plant biotechnology is **plant tissue culture**, which is based on the principle of **totipotency**—the ability of a single living plant cell to regenerate into a complete plant under suitable environmental and nutritional conditions. Tissue culture techniques are widely used for rapid multiplication of elite plants, production of disease-free

planting material, conservation of rare and endangered species, genetic transformation, and production of secondary metabolites.

This chapter introduces the basic concepts of plant tissue culture, preparation of culture media, sterilization techniques, micropropagation, and callus culture.

General Laboratory Guidelines

Before performing biotechnology experiments, students should:

- Wear laboratory coats, gloves, masks, and safety glasses.
- Work in a sterile environment whenever possible.
- Sterilize all instruments before and after use.
- Label all culture vessels clearly.
- Avoid unnecessary exposure of culture media to the atmosphere.
- Dispose of biological waste according to biosafety guidelines.

13.1 Introduction to Tissue Culture

Aim

To understand the principles and techniques of plant tissue culture.

Principle

Plant tissue culture is the **aseptic cultivation of plant cells, tissues, organs, or embryos on a defined nutrient medium under controlled environmental conditions**.

The technique is based on the principle of **cellular totipotency**, proposed by **Gottlieb Haberlandt (1902)**, which states that every living plant cell has the genetic potential to regenerate into a complete plant.

Objectives of Tissue Culture

- Rapid multiplication of plants.
- Production of disease-free planting material.
- Conservation of endangered plant species.
- Germplasm preservation.
- Plant breeding and genetic improvement.
- Production of secondary metabolites.
- Genetic transformation and biotechnology research.

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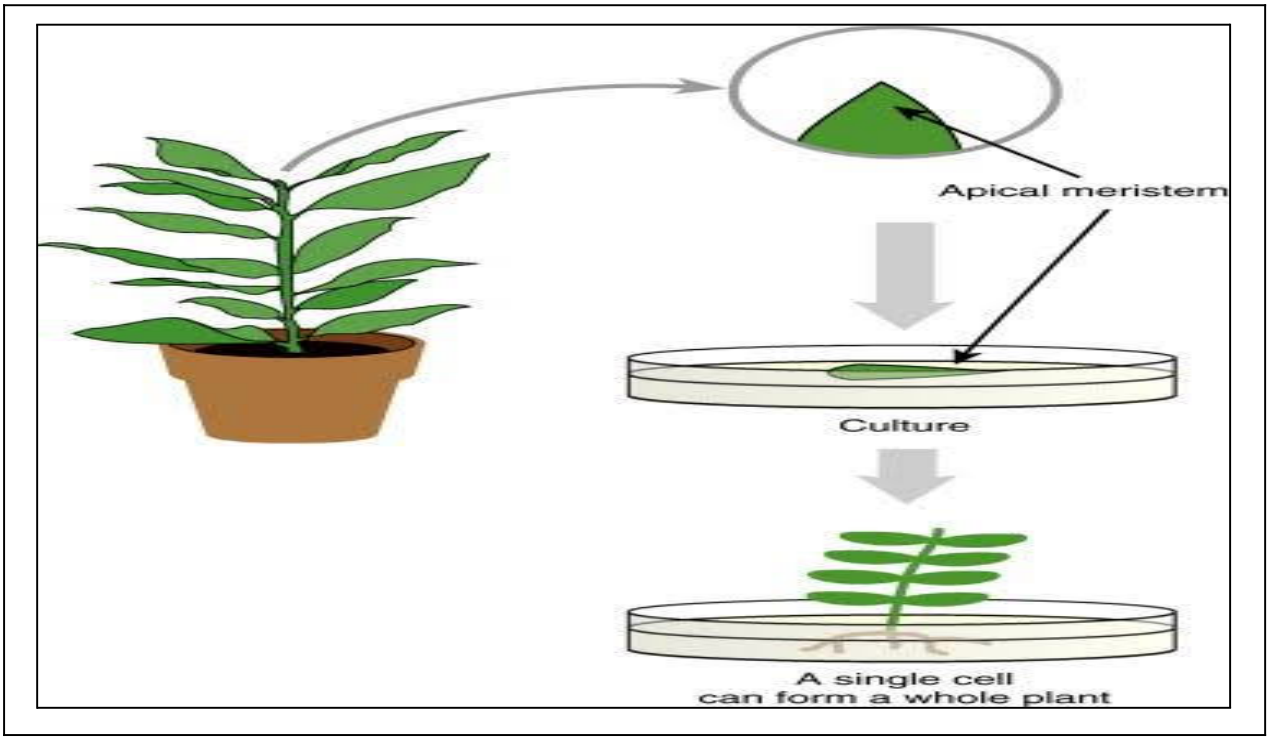

Requirements for Tissue Culture

- Healthy explant
- Sterile nutrient medium
- Growth regulators
- Sterile culture vessels
- Controlled temperature
- Appropriate light conditions
- Humidity control

Common Explants

- Shoot tip
- Apical meristem
- Axillary bud
- Leaf segment
- Stem segment
- Root tip
- Embryo
- Anther
- Pollen
- Cotyledon

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Applications

- Commercial plant propagation
- Virus-free plant production
- Haploid production
- Synthetic seed technology
- Cryopreservation
- Production of transgenic plants

13.2 Preparation of Culture Media

Aim

To prepare a sterile nutrient medium suitable for plant tissue culture.

Principle

Plant cells require a balanced supply of nutrients, vitamins, carbohydrates, growth regulators, and water for growth under in vitro conditions.

The most widely used medium is the **Murashige and Skoog (MS) Medium**, developed in 1962.

Components of Culture Medium

1. Macronutrients

- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Calcium (Ca)
- Magnesium (Mg)
- Sulphur (S)

2. Micronutrients

- Iron (Fe)
- Zinc (Zn)
- Manganese (Mn)
- Boron (B)
- Copper (Cu)
- Molybdenum (Mo)
- Cobalt (Co)
- Iodine (I)

3. Vitamins

- Thiamine (Vitamin B_1)
- Nicotinic acid
- Pyridoxine
- Myo-inositol

4. Carbon Source

Usually:

- Sucrose (20–30 g/L)

5. Plant Growth Regulators

Auxins

- IAA
- IBA
- NAA
- 2,4-D

Functions

- Root induction
- Callus formation
- Cell elongation

Cytokinins

- BAP (BA)
- Kinetin
- Zeatin

Functions

- Shoot induction
- Cell division
- Bud formation

6. Gelling Agent

Usually:

- Agar (7–8 g/L)

Preparation Procedure

1. Prepare stock solutions of nutrients.
2. Measure required quantities.
3. Add sucrose.
4. Adjust pH to approximately **5.7–5.8**.
5. Add agar (for solid media).
6. Dispense into culture vessels.
7. Sterilize by autoclaving.
8. Cool and store until use.

13.3 Sterilization Techniques

Aim

To understand methods of sterilization used in plant tissue culture.

Principle

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Successful tissue culture requires complete elimination of microorganisms that may contaminate cultures.

Types of Sterilization

A. Sterilization of Glassware

Methods:

- Hot air oven (160–180°C for about 2 hours)
- Autoclaving

B. Sterilization of Culture Media

Autoclaving:

- 121°C
- 15 psi pressure
- 15–20 minutes

C. Sterilization of Instruments

- Flaming
- Ethanol (70%)
- Glass bead sterilizer
- Autoclaving

D. Surface Sterilization of Explants

Common sterilizing agents:

E. Sterile Working Area

Cultures should be transferred inside a **laminar airflow cabinet** under aseptic conditions.

Precautions

- Work close to the flame or inside a laminar airflow cabinet.
- Sterilize instruments before each transfer.
- Avoid touching sterile surfaces.
- Keep culture vessels open only briefly.
- Label cultures immediately after inoculation.

13.4 Micropropagation

Aim

To study the process of rapid multiplication of plants using tissue culture.

Principle

Micropropagation is the rapid production of genetically identical plants (clones) through tissue culture techniques under aseptic conditions.

Advantages

- Rapid multiplication.
- Production of disease-free plants.
- Uniform planting material.
- Year-round propagation.

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- Conservation of rare species.

Stages of Micropropagation

Stage I – Selection and Establishment

- Selection of healthy explant.
- Surface sterilization.
- Inoculation onto culture medium.

Stage II – Shoot Multiplication

- Multiple shoots develop through cytokinin activity.
- Repeated subculturing increases shoot numbers.

Stage III – Root Induction

- Shoots transferred to auxin-containing medium.
- Root development occurs.

Stage IV – Hardening (Acclimatization)

- Plantlets are gradually adapted to greenhouse conditions.
- Finally transferred to field conditions.

Applications

- Banana
- Sugarcane
- Potato
- Orchids
- Bamboo
- Medicinal plants
- Forestry species

13.5 Callus Culture Demonstration

Aim

To demonstrate callus induction from plant explants.

Principle

A **callus** is an unorganized mass of actively dividing parenchymatous cells produced when plant tissues are cultured on nutrient media containing suitable growth regulators, particularly auxins.

Materials Required

- Sterile explants
- MS medium
- Auxins (commonly 2,4-D)
- Cytokinins (if required)
- Laminar airflow cabinet
- Culture bottles
- Forceps and scalpel

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Procedure

1. Select a healthy explanation.
2. Wash thoroughly with running water.
3. Surface sterilize the explant.
4. Rinse with sterile distilled water.
5. Place the explant on sterile MS medium.
6. Seal the culture vessel.
7. Incubate under controlled conditions (about 25 ± 2°C).

Observations

- Swelling of the explanation.
- Cell proliferation.
- Formation of cream, white, or green callus after 2–4 weeks.

Applications of Callus Culture

- Plant regeneration.
- Genetic transformation.
- Production of secondary metabolites.
- Somatic embryogenesis.
- Artificial seed production.
- Germplasm conservation.
- Mutation studies.

14. Microbiology

Microbiology is an important branch of botany that deals with the study of microscopic organisms associated with plants and their environment. It includes bacteria, algae, fungi, cyanobacteria, and lichens, many of which play vital roles in nutrient cycling, plant growth, decomposition, nitrogen fixation, and symbiotic relationships. This section introduces students to basic microbiological techniques and the identification of important microbial groups relevant to plant sciences.

Learning Objectives

After completing this section, students will be able to:

- Understand the importance of microorganisms in plant biology.
- Learn aseptic techniques used in microbiology laboratories.
- Prepare and maintain microbial cultures.
- Identify common algae, fungi, lichens, and cyanobacteria.
- Recognize the ecological and economic significance of these organisms.

Experiment 14.1: Microbial Culture Techniques

Aim

To learn the basic techniques for culturing microorganisms under aseptic conditions.

Principle

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Microorganisms are cultured on nutrient media under sterile conditions to prevent contamination. Proper aseptic techniques ensure the growth of pure cultures for study and experimentation.

Materials Required

- Nutrient agar or Potato Dextrose Agar (PDA)
- Petri dishes
- Test tubes
- Inoculating loop
- Spirit lamp/Bunsen burner
- Autoclave
- Incubator
- Microbial culture

Procedure

1. Sterilize all glassware and culture media.
2. Flame the inoculating loop before and after use.
3. Transfer the microbial sample onto the sterile culture medium.
4. Incubate at the appropriate temperature.
5. Observe colony growth after 24–72 hours.

Observations

- Colony colour
- Shape
- Size
- Margin
- Elevation
- Texture

Result

Pure microbial colonies are obtained using aseptic culture techniques.

Precautions

- Maintain aseptic conditions throughout the experiment.
- Sterilize instruments before and after inoculation.
- Do not expose culture plates unnecessarily.

Experiment 14.2: Study of Algae

Aim

To study the morphology and identify common algae.

Principle

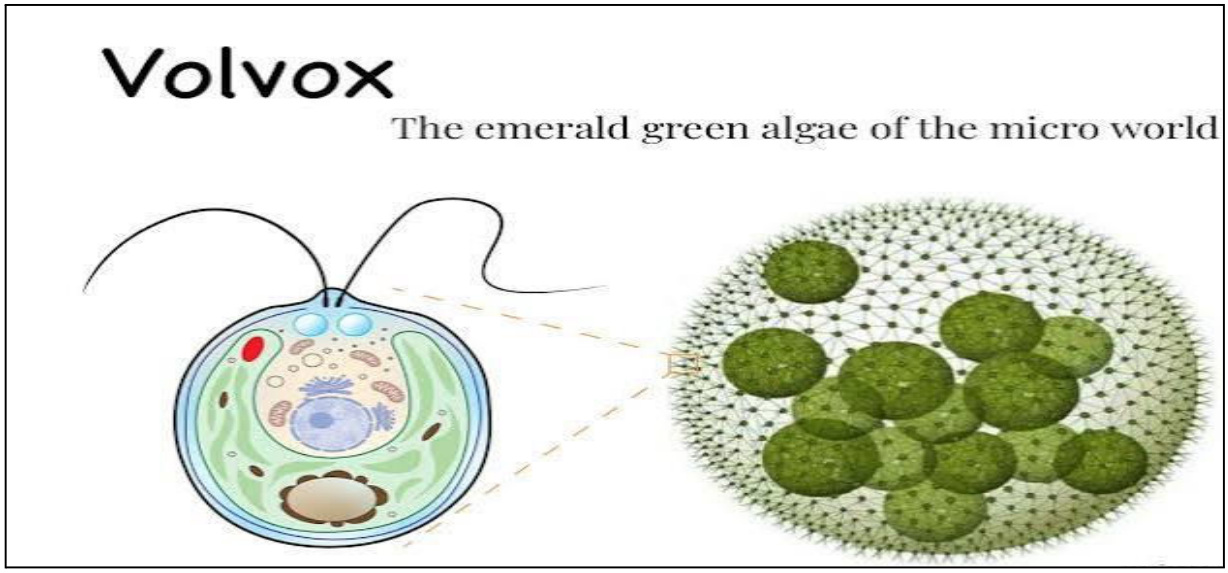
Algae are chlorophyll-bearing, photosynthetic organisms found in aquatic and moist habitats. They vary from unicellular to multicellular forms.

Materials Required

- Permanent slides or fresh algal specimens
- Compound microscope
- Glass slides and coverslips

Specimens

- *Chlamydomonas*
- *Volvox*
- *Spirogyra*
- *Ulothrix*
- *Oedogonium*



Procedure

1. Place the algal specimen on a slide.
2. Add a drop of water if necessary.
3. Cover with a coverslip.
4. Observe under low and high power of the microscope.
5. Draw labelled diagrams.

Observations

- Cell organization
- Chloroplast type
- Reproductive structures
- Colony or filament arrangement

Result

The algal specimen is identified based on its morphological characteristics.

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Precautions

- Avoid air bubbles while mounting.
- Handle specimens gently.

Experiment 14.3: Study of Fungi

Aim

To study the morphology and reproductive structures of common fungi.

Principle

Fungi are non-chlorophyllous organisms that obtain nutrition by absorption. They reproduce by spores and play important ecological roles.

Materials Required

- Fungal cultures or preserved specimens
- Compound microscope
- Lactophenol cotton blue stain
- Slides and coverslips

Specimens

- *Rhizopus*
- *Mucor*
- *Aspergillus*
- *Penicillium*
- *Yeast*

Procedure

1. Prepare a temporary mount using lactophenol cotton blue.
2. Observe under the microscope.
3. Identify hyphae, spores, and reproductive structures.
4. Draw labelled diagrams.

Observations

- Hyphal structure
- Septation
- Spore type
- Fruiting bodies

Result

Fungal specimens are identified based on microscopic characteristics.

Precautions

- Handle fungal cultures carefully.
- Avoid inhalation of spores.

Experiment 14.4: Study of Lichens

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Aim

To study the morphology and classification of lichens.

Principle

Lichens are symbiotic associations between fungi and algae or cyanobacteria. They are excellent indicators of environmental pollution.

Materials Required

- Lichen specimens
- Hand lens
- Compound microscope

Types of Lichens

- Crustose
- Foliose
- Fruticose

Procedure

1. Observe external morphology.
2. Prepare a thin section if required.
3. Identify fungal and algal components.
4. Draw labelled diagrams.

Observations

- Growth form
- Colour

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- Attachment
- Internal organization

Result

The lichen specimen is identified based on morphological features.

Precautions

- Handle specimens carefully.
- Use sharp blades cautiously while preparing sections.

Experiment 14.5: Study of Cyanobacteria

Aim

To study the morphology of common cyanobacteria.

Principle

Cyanobacteria are photosynthetic prokaryotes capable of nitrogen fixation. They are important in agriculture and ecosystem productivity.

Materials Required

- Permanent slides or fresh cultures
- Compound microscope

Specimens

- *Nostoc*
- *Anabaena*
- *Oscillatoria*
- *Gloeocapsa*

Procedure

1. Place the specimen on a clean slide.
2. Observe under the microscope.
3. Identify vegetative cells, heterocysts, and akinetes where present.
4. Draw labelled diagrams.

Observations

- Colony organization
- Presence of heterocysts
- Filament arrangement
- Cell shape

Result

The cyanobacterial specimen is identified based on its microscopic features.

Precautions

- Use clean slides.
- Avoid contamination of cultures.

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15. Plant Ecology

Plant Ecology is the branch of botany that studies the relationships between plants and their environment. It examines how environmental factors such as climate, soil, water, light, and other living organisms influence plant growth, distribution, adaptation, and community structure. Practical studies in plant ecology provide students with hands-on experience in field sampling, vegetation analysis, soil examination, and biodiversity assessment, enabling them to understand ecosystem dynamics and conservation strategies.

Learning Objectives

After completing this section, students will be able to:

- Understand the ecological adaptations of plants to different habitats.
- Study the structure and composition of plant communities.
- Learn the quadrat method for vegetation sampling.
- Analyze important physical and chemical properties of soil.
- Assess biodiversity using standard ecological indices and field techniques.

Experiment 15.1: Ecological Adaptations

Aim

To study various ecological adaptations in plants growing in different habitats.

Principle

Plants develop structural and physiological adaptations that enable them to survive under specific environmental conditions such as drought, aquatic environments, saline soils, or epiphytic habitats.

Materials Required

- Fresh plant specimens or herbarium samples
- Hand lens
- Field notebook
- Camera (optional)

Specimens

- Xerophytes (*Opuntia*, *Calotropis*, *Nerium*)
- Hydrophytes (*Hydrilla*, *Eichhornia*, *Nelumbo*)
- Mesophytes (*Hibiscus*, *Mangifera*)
- Halophytes (*Avicennia*, *Salicornia*)
- Epiphytes (*Orchid*, *Vanda*)

Procedure

1. Observe plants from different habitats.
2. Record external morphological features.

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3. Identify adaptive characteristics.
4. Compare adaptations among habitat types.
5. Draw labelled diagrams of representative specimens.

Observations

- Root system
- Stem modifications
- Leaf characteristics
- Cuticle thickness
- Presence of stomata
- Water storage structures

Result

Different ecological groups exhibit specialized adaptations that enable survival in their respective habitats.

Precautions

- Handle specimens carefully.
- Record observations immediately.
- Identify plants correctly before noting adaptations.

Experiment 15.2: Vegetation Analysis

Aim

To study the composition and structure of plant communities.

Principle

Vegetation analysis provides quantitative information regarding the distribution, abundance, and dominance of plant species within a community.

Materials Required

- Quadrat frame
- Measuring tape
- Field notebook
- Plant identification guide

Procedure

1. Select a representative study area.
2. Lay quadrats randomly.
3. Record all plant species within each quadrant.
4. Count individuals of each species.
5. Calculate ecological parameters.

Parameters Studied

- Frequency
- Density
- Abundance

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- Relative Frequency
- Relative Density
- Relative Dominance
- Importance Value Index (IVI)

Observations

Prepare a table with:

- Species name
- Number of individuals
- Frequency
- Density
- Abundance

Result

The vegetation structure and dominant species of the study area are determined.

Precautions

- Randomly place quadrats.
- Avoid duplicate counting.
- Correctly identify plant species.

Experiment 15.3: Quadrat Method

Aim

To estimate plant population characteristics using the quadrat method.

Principle

The quadrat method is a standard ecological sampling technique used to estimate plant density, frequency, abundance, and distribution within a community.

Materials Required

- Quadrat (1 m × 1 m or appropriate size)
- Measuring tape
- Rope
- Field notebook
- Calculator

Procedure

1. Select the sampling site.
2. Place quadrats randomly or systematically.
3. Count individuals of each plant species.
4. Repeat observations in several quadrats.
5. Calculate ecological parameters.

Calculations

Frequency (%)

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Frequency=Number of quadrats in which species occursTotal quadrats studied×100\text{Frequency} = \frac{\text{Number of quadrats in which species occurs}}{\text{Total quadrats studied}} \times 100Frequency=Total quadrats studiedNumber of quadrats in which species occurs×100

Density

Density=Total individualsTotal quadrats studied\text{Density} = \frac{\text{Total individuals}}{\text{Total quadrats studied}}Density=Total quadrats studiedTotal individuals

Abundance

Abundance=Total individualsQuadrats where species occurs\text{Abundance} = \frac{\text{Total individuals}}{\text{Quadrats where species occurs}}Abundance=Quadrats where species occursTotal individuals

Observations

Record:

- Quadrat number
- Species present
- Number of individuals
- Frequency
- Density
- Abundance

Result

Population characteristics of the selected plant community are determined.

Precautions

- Use quadrats of uniform size.
- Avoid disturbing vegetation.
- Count accurately.

Experiment 15.4: Soil Analysis

Aim

To study important physical and chemical properties of soil.

Principle

Soil properties determine nutrient availability, water retention, aeration, and ultimately plant growth and productivity.

Materials Required

- Soil sample
- pH meter or pH paper
- Distilled water
- Beakers
- Sieve
- Balance

Parameters Studied

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- Soil texture
- Soil colour
- Soil moisture
- Soil pH
- Organic matter
- Water holding capacity

Procedure

1. Collect soil samples from the study site.
2. Remove stones and debris.
3. Measure soil pH.
4. Determine moisture content.
5. Observe texture and colour.
6. Record observations.

Observations

- Colour
- Texture
- pH
- Moisture content
- Organic matter
- Water holding capacity

Result

The physical and chemical characteristics of the soil are determined.

Precautions

- Collect representative samples.
- Avoid contamination.
- Use clean equipment.

Experiment 15.5: Biodiversity Assessment

Aim

To assess plant biodiversity in a selected ecosystem.

Principle

Biodiversity assessment measures the variety, richness, and abundance of plant species present in an ecosystem and helps evaluate ecosystem health.

Materials Required

- Quadrat
- Measuring tape
- GPS (optional)
- Field notebook

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- Plant identification manual

Procedure

1. Select the study site.
2. Record all plant species within the sampling area.
3. Count individuals of each species.
4. Calculate species richness and diversity indices.
5. Prepare a checklist of plant species.

Parameters Studied

- Species richness
- Species diversity
- Species evenness
- Dominant species
- Rare species

Observations

Prepare a table including:

- Scientific name
- Common name
- Family
- Number of individuals
- Habitat

Result

The biodiversity status of the study area is evaluated based on species composition and abundance.

Precautions

- Identify species accurately.
- Record field observations carefully.
- Avoid repeated counting.

16. Economic Botany

Economic Botany is the branch of botany that deals with the study of plants of economic importance and their uses for food, medicine, industry, agriculture, forestry, and commerce. It provides knowledge of economically valuable plants, their botanical characteristics, cultivation, products obtained, and their significance in human welfare. Practical studies in Economic Botany help students identify important crop plants and understand their commercial applications.

Learning Objectives

After completing this section, students will be able to:

- Identify important economic plants based on their morphological characteristics.

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- Classify plants according to their economic uses.
- Understand the botanical names, families, useful parts, and products obtained from various crops.
- Recognize the importance of medicinal, timber, fibre, spice, and beverage plants.
- Appreciate the role of economic plants in agriculture and industry.

Experiment 16.1: Study of Cereals

Aim

To study the morphology and economic importance of major cereal crops.

Principle

Cereals are members of the family **Poaceae** and constitute the principal source of carbohydrates for humans and livestock.

Materials Required

- Fresh or preserved cereal specimens
- Seeds and grains
- Herbarium sheets
- Hand lens

Specimens

Common Name	Botanical Name	Family	Economic Product
Rice	*Oryza sativa*	Poaceae	Grain
Wheat	*Triticumaestivum*	Poaceae	Grain
Maize	*Zea mays*	Poaceae	Grain
Barley	*Hordeumvulgare*	Poaceae	Grain
Sorghum	*Sorghum bicolor*	Poaceae	Grain

Procedure

1. Observe vegetative and floral characters.
2. Study the grain and inflorescence.
3. Record botanical name, family, useful part, and economic importance.
4. Draw labelled diagrams.

Result

The important cereal crops are identified along with their economic uses.

Experiment 16.2: Study of Pulses

Aim

To study important pulse crops.

Principle

Pulses are rich in proteins and belong mainly to the family **Fabaceae**.

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Specimens

Common Name	Botanical Name	Family	Useful Part
Gram	*Cicerarietinum*	Fabaceae	Seeds
Pea	*Pisumsativum*	Fabaceae	Seeds
Green gram	*Vignaradiata*	Fabaceae	Seeds
Black gram	*Vignamungo*	Fabaceae	Seeds
Pigeon pea	*Cajanuscajan*	Fabaceae	Seeds

Procedure

1. Observe seed and plant morphology.
2. Identify diagnostic characters.
3. Record economic importance.

Result

Common pulse crops are identified based on their morphological features.

Experiment 16.3: Study of Oilseed Crops

Aim

To study important oil-yielding plants.

Principle

Oilseed crops provide edible and industrial oils obtained from seeds or fruits.

Specimens

Common Name	Botanical Name	Family	Product
Mustard	*Brassica juncea*	Brassicaceae	Edible oil
Groundnut	*Arachishypogaea*	Fabaceae	Edible oil
Sunflower	*Helianthus annuus*	Asteraceae	Edible oil
Sesame	*Sesamumindicum*	Pedaliaceae	Edible oil
Castor	*Ricinuscommunis*	Euphorbiaceae	Industrial oil

Procedure

1. Examine seeds and fruits.
2. Identify botanical characteristics.
3. Record uses.

Result

Major oilseed crops are identified along with their products.

Experiment 16.4: Study of Fibre Plants

Aim

To study economically important fibre-producing plants.

Principle

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Plant fibres are obtained from stems, leaves, fruits, or seeds and are used in textile and paper industries.

Specimens

Common Name	Botanical Name	Family	Fibre Type
Cotton	*Gossypiumhirsutum*	Malvaceae	Seed fibre
Jute	*Corchoruscapsularis*	Malvaceae	Bastfibre
Flax	*Linumusitatissimum*	Linaceae	Bastfibre
Hemp	*Cannabis sativa*	Cannabaceae	Bastfibre
Sisal	*Agave sisalana*	Asparagaceae	Leaf fibre

Procedure

1. Observe fibre source.
2. Identify the plant.
3. Record industrial uses.

Result

The important fibre plants and their economic uses are studied.

Experiment 16.5: Study of Medicinal Plants

Aim

To identify common medicinal plants and their therapeutic uses.

Principle

Medicinal plants contain bioactive compounds used in traditional and modern medicine.

Specimens

Common Name	Botanical Name	Family	Medicinal Use
Neem	*Azadirachtaindica*	Meliaceae	Antibacterial
Tulsi	*Ocimumtenuiflorum*	Lamiaceae	Respiratory ailments
Aloe vera	*Aloe vera*	Asphodelaceae	Skin disorders
Ashwagandha	*Withaniasomnifera*	Solanaceae	General tonic
Turmeric	*Curcuma longa*	Zingiberaceae	Anti-inflammatory

Procedure

1. Observe morphological characters.
2. Record botanical name and family.
3. Note medicinal uses.

Result

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Common medicinal plants are identified with their therapeutic importance.

Experiment 16.6: Study of Timber Plants

Aim

To study economically important timber-yielding plants.

Principle

Timber plants provide durable wood used in construction, furniture, and other industries.

Specimens

Common Name	Botanical Name	Family	Uses
Teak	*Tectonagrandis*	Lamiaceae	Furniture
Sal	*Shorearobusta*	Dipterocarpaceae	Construction
Deodar	*Cedrusdeodara*	Pinaceae	Building timber
Eucalyptus	*Eucalyptus globulus*	Myrtaceae	Timber and paper
Sandalwood	*Santalum album*	Santalaceae	Timber and perfume

Procedure

1. Observe wood samples or specimens.
2. Identify based on bark and leaves.
3. Record economic uses.

Result

Important timber plants are identified.

Experiment 16.7: Study of Spices and Beverages

Aim

To study important spice and beverage plants.

Principle

Spices are aromatic plant products used for flavouring food, while beverages are prepared from plant products consumed as drinks.

Specimens

Spices

Common Name	Botanical Name	Family	Useful Part
Black Pepper	*Piper nigrum*	Piperaceae	Fruits
Cardamom	*Elettariacardamomum*	Zingiberaceae	Fruits
Clove	*Syzygiumaromaticum*	Myrtaceae	Flower buds
Cinnamon	*Cinnamomumverum*	Lauraceae	Bark
Coriander	*Coriandrumsativum*	Apiaceae	Fruits

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Beverages

Common Name	Botanical Name	Family	Product
Tea	*Camellia sinensis*	Theaceae	Tea leaves
Coffee	*Coffeaarabica*	Rubiaceae	Coffee beans
Cocoa	*Theobroma cacao*	Malvaceae	Cocoa powder

Procedure

1. Observe specimens.
2. Identify botanical names and families.
3. Record useful parts and economic importance.

Result

Common spices and beverage plants are identified based on their morphological and economic characteristics.

17. Field Study and Excursions

Field studies and botanical excursions are an integral part of botanical education, providing students with opportunities to observe plants in their natural habitats. They bridge the gap between theoretical knowledge and practical application by enabling students to study plant diversity, ecological interactions, habitat characteristics, and conservation issues. During field visits, students learn scientific methods of plant collection, specimen preservation, field documentation, and plant identification while developing observational and analytical skills.

Learning Objectives

After completing this section, students will be able to:

- Conduct botanical field surveys using standard scientific methods.
- Collect plant specimens ethically and responsibly.
- Record accurate field notes and environmental data.
- Identify common plant species using field guides and taxonomic keys.
- Observe ecological relationships and habitat characteristics.
- Prepare herbarium specimens for future reference.

17.2 Collection Techniques

Aim

To learn standard methods for collecting plant specimens during botanical field studies.

Principle

Proper collection techniques ensure that plant specimens are preserved in a condition suitable for identification, herbarium preparation, and scientific study while minimizing damage to natural populations.

Materials Required

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- Plant press
- Newspapers or blotting sheets
- Field notebook
- Polythene bags
- Pruning shears or secateurs
- Digging tool (for small herbs)
- Labels and tags
- Permanent marker
- GPS device or mobile phone (optional)
- Camera (optional)

Procedure

1. Select healthy and representative plant specimens.
2. Collect complete specimens whenever possible, including roots (for herbs), stems, leaves, flowers, and fruits.
3. Avoid collecting rare, endangered, or protected species without permission.
4. Place specimens between newspaper sheets and press them immediately.
5. Label each specimen with a unique collection number.
6. Record collection details in the field notebook.
7. Transport specimens carefully for herbarium preparation.

Observations

Record:

- Collection number
- Date and time
- Scientific/Common name (if known)
- Habit (herb, shrub, tree, climber)
- Flowering/Fruiting stage
- Habitat type
- Collector's name

Result

Representative plant specimens are collected and preserved using standard botanical techniques.

Precautions

- Do not over-collect specimens.
- Follow local conservation regulations.
- Handle specimens carefully to avoid damage.
- Keep labels with the correct specimen at all times.

17.3 Field Notes

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Aim

To record accurate observations made during botanical field studies.

Principle

Field notes provide permanent scientific records that support plant identification, ecological interpretation, and herbarium documentation.

Result

Complete and systematic field records are prepared for future reference.

Precautions

- Record observations immediately.
- Use waterproof ink or pencil in wet conditions.
- Write clearly and accurately.

17.4 Plant Identification

Aim

To identify collected plant specimens using taxonomic characters.

Principle

Plant identification is based on observable morphological features and comparison with standard floras, field guides, taxonomic keys, and herbarium specimens.

Materials Required

- Collected plant specimens
- Hand lens
- Flora or field guide
- Taxonomic keys
- Herbarium specimens (if available)

Procedure

1. Observe vegetative and reproductive characters.
2. Record diagnostic features.
3. Compare with identification keys.
4. Confirm the scientific name, family, and common name.
5. Verify identification using herbarium specimens or reference books.

Observations

Record:

- Habit
- Root type
- Stem characteristics
- Leaf arrangement
- Flower characters
- Fruit type

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- Family
- Scientific name

Result

Plant specimens are identified based on morphological and taxonomic characteristics.

Precautions

- Use flowering or fruiting specimens whenever possible.
- Observe all diagnostic characters carefully.
- Confirm identification using multiple references.

17.5 Ecological Observations

Aim

To study ecological conditions and plant-environment interactions in the field.

Principle

Ecological observations help explain how environmental factors influence plant distribution, adaptation, and community composition.

Materials Required

- Quadrat frame
- Measuring tape
- Soil sampling tools
- Thermometer
- Compass
- Field notebook
- Camera (optional)

Parameters to Observe

- Habitat type
- Vegetation type
- Species composition
- Dominant species
- Plant density
- Soil characteristics
- Light intensity
- Moisture conditions
- Human disturbances
- Signs of pollution or degradation

Procedure

1. Survey the selected study area.
2. Record habitat characteristics.
3. Observe dominant and associated plant species.
4. Note environmental factors affecting vegetation.

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5. Record evidence of ecological interactions such as competition, grazing, or pollination.

Result

Ecological characteristics of the study area are documented, providing insights into plant distribution, community structure, and environmental influences.

Precautions

- Minimize disturbance to natural habitats.
- Avoid trampling vegetation.
- Follow safety guidelines during fieldwork.
- Respect protected areas and wildlife.

Field Excursion Report Format

Students should prepare a field excursion report including the following:

1. Title of the Field Visit
2. Date and Location
3. Objectives
4. Description of the Study Area
5. List of Plant Species Observed
6. Methods of Collection
7. Ecological Observations
8. Photographs or Sketches (if available)
9. Herbarium Specimen Details
10. Results and Discussion
11. Conclusion
12. References

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