FACILITATOR GUIDE

Plant Structures and Functions

Level 2

P.O. Box 461, Hillcrest, 3650
(031) 313-3364

Title:		**Understand the Structure and Functions of a Plant**					
Applied Title:		**Understand the Structure and Functions of a Citrus Plant**					
Field:		Agriculture and Nature Conservation					
Sub-Field:		Primary Agriculture					
SETA (SGB):		AgriSETA					
Skills Area:		Plant Structures and Functions					
Context:		Citrus Production					
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Author:		Cabeton Consulting, Prof. P.J. Robbertse					

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Supported by:

Unit standard alignment and assessment tool development:
Cabeton Training and Development

Project coordinator:
Jacomien de Klerk

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Directions

1. Learning Material

This guide has developed to assist the facilitator in presenting this unit standard. The guide contains all necessary material to ensure that the facilitator will be able to assist the learner to attain the competencies required by the unit standard.

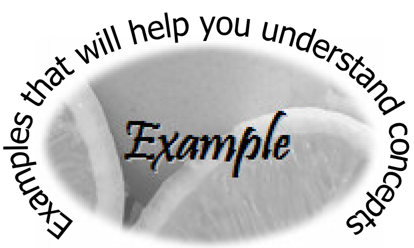
This set of learning material consists of the following guides:

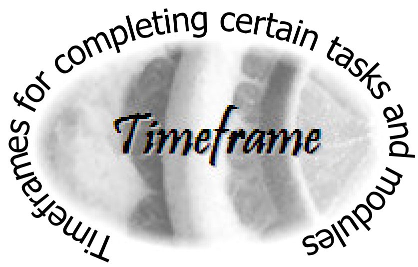
- ***Learner guide*** that contains all the information required by the learner to attain competency in this unit standard
- ***Facilitator guide*** that is a copy of the learner guide but contains additional instructions for the facilitator.
- ***Assessment Guide for Assessors and Facilitators*** that contains all the documentation needed by the assessor and facilitator to assess the competency of the learner against this unit standard.
- ***Assessment Guide for Learner and Learner Workbook*** that contains the documentation required by the learner to complete the assessment, along with the worksheets and practical exercises that the learner needs to complete as part of the formative assessment.

Please ensure that you are familiar with the contents of all of these guides before presenting this unit standard.

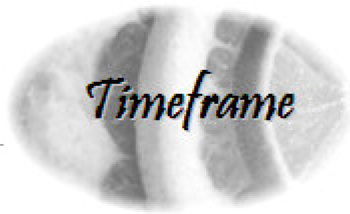
Although the learner and facilitator guide contains all the information required for attaining competency in this unit standard, references to additional resources (both printed and electronic) are provided for further study by the learner.

Information in boxes is indicated by tags that show:





2. Learning Program Timeframe



This is a summary of the timeframe for this learning program. You will be reminded of the time allowed for each module as you work through the guide.

Process	***Total Allocated Time***	***Theoretical Learning***	***Practical Learning***	***Activities***
Complete Program (Including summative assessment)	**50h**	**33h**	**17h**	**11**
Learner Orientation and Ice Breaker	30min	15min	15min	n/a
Purpose, Introduction and Learner Directions	30min	15min	15min	n/a
Introduction to Citrus Production	45min	30min	15min	n/a
Session 1 (Chapter 1)	6h	4h 30min	1h 30min activities	1-2
Session 2 (Chapter 2)	7h 15min	5h 30min	1h 45min activities	3-4
Session 3 (Chapter 3)	6h	4h 30min	1h 30min activities	5
Session 4 (Chapter 4)	8h 30min	6h 30min	2h activities	6-7
Session 5 (Chapter 5)	6h	4h 30min	1h 30min activities	8-9
Session 6 (Chapter 6)	10h	5h	2h 30min activities 2h 30min site visit to a nursery or farm to identify all the plant structures	10-11
Preparation for Assessment and revision	4h 30min	1h 30min	3h	n/a

3. Technical Program Specifications

Format	Programmed instruction workshop, combined with structured internship format as prescribed for learnership, skills program or short course.
Target Learner Description	A typical level 2 learner has functional numeracy and literacy skills, but a minimal level of experience. **EE Ratios:** 1 Male:1 Female 8 PDI:2 W 1 Employed:1 Unemployed

Articulation Options	Nil formal in place
Delivery Mode	A combination of small group mode and individual mode
Training Method and Activities	**Program Instruction:** This program forms part of an apprenticeship where coaches provide practical training in the fields requiring functional competency. The theoretical study section of the training is conducted as a 4-day workshop in the Cohort group format. Additional training activities include buzz groups, rotating role-plays, simulations, games and brainstorming sessions, and group discussions.
Learner Support Strategies	Learners are inducted by "explore strategies to learn program". Learners are supplied with all resources and aids as required by the program, including: • Objects and devices such as equipment • Manuals and guides • Visual aids

Facitator Tip

This unit standard is aimed at level 2 learners.

- A typical level 2 learner might only have been exposed to the working world for a short time.
- Explain concepts and define words in a simple, clear and concise manner throughout the learning program to help the learner where possible.
- Take special care to facilitate for ALL learners. Allow them opportunities to share experiences, prior knowledge, translate into their mother tongue for each other, and enjoy the learning process.
- The examples given in this resource guide might be for a different geographical area or commodity to what the learner is exposed to. Please adapt your examples according to the learning context.

4. Facilitator's Checklist

Facilitator Tip

This checklist has been designed to assist you in delivering the best possible facilitation to the learners. Please use it and supply whatever resources you might have in short supply at your venue of learning.

Preparation	***Yes***	***No***
Content Knowledge I have sufficient knowledge of the content to enable me to facilitate with ease.		
Application Knowledge I understand the program matrix and have prepared for program delivery accordingly.		
Ability to Respond to Learners Background and Experience I have studied the learner demographics, age group, experience and circumstances, and prepared for program delivery accordingly.		

Preparation	*Yes*	*No*
Enthusiasm and Commitment I am passionate about my subject and have prepared my program delivery to create a motivating environment with real commitment to success.		
Enterprise Knowledge I know and understand the values, ethics, vision and mission of the Citrus Academy and the service provider under whose auspices the program will be conducted, and have prepared my program delivery, reporting and administrative tasks accordingly.		
Equipment Checklist:		
Learner Guides: 1 per learner		
Learner Assessment Guides: 1 per learner		
Writing material and stationery for facilitator and learner		
White board and pens		
Flip chart paper		
Proxima projector and screen		
Notebook computer and program disk		
Documentation Checklist:		
Attendance register		
Course evaluation		
Learner course evaluation		
Portfolios of evidence		

5. Proposed Floor Plan

No floor plan is prescribed for this training module.

Introduction

1. Purpose

A learner achieving this unit standard will be able to recognise common insects, disease symptoms and weeds and apply basic control measures as per agricultural enterprise.

Learners will gain an understanding of sustainable agricultural practices as applied in the animal-, plant and mixed farming sub-fields. This unit standard focuses on the application of peat control practices in primary agriculture.

They will be able to participate in, undertake and plan farming practices with knowledge of their environment. This unit standard will instil a culture of maintenance and care for both the environment as well as for farming infrastructure and operations.

2. Learning Assumed to Be in Place

It is assumed that the learner has successfully completed the unit standards listed below:

NQF Level	***Unit Standard Number***	***Unit Standard Description***
1 (ABET 4)	Literacy and Numeracy	
1	116156	Collect agricultural data
1	116199	Demonstrate a basic understanding of the structure and function of a plant in relation to its environment

Facilitator Tip

It is important to ensure that the learners who are undertaking this learning program has already completed the correct prior learning modules, to ensure that they are not unfairly disadvantaged by the learning process, and can be supported accordingly.

Do not forget to complete the Diagnostic Assessment (Step 3 in the Assessment Guide).

Introduction to Citrus Production

Timeframe

You have to complete this section as follows:

Total time	*Theory*	*Practical*
45min	30min	15min

Facilitator Tip

While this section does not form part of the unit standard as such, it is essential for the learner's orientation to the learning context. Please take time to ensure that the learners have a thorough understanding of this section.

1. Introduction

This learning material has been developed in the context of citrus production, which means that the skills area is dealt with in terms of and as applied to citrus production. To help the learner place the material in the right context, it is necessary for the learner to understand the background to citrus production, and the manner in which a citrus plant produces fruit.

2. Background

Citrus originates from the subtropical regions of south-east Asia. In the wild, citrus trees in these regions produce fruit all year round, and the fruit are small, poorly coloured and blemished. In the absence of effective production practices, citrus trees do not produce fruit suitable for the market.

Citrus production is largely concerned with management of the practices and processes that manipulate the tree to produce high yields of marketable fruit. Production management, together with the selection of superior varieties and plant improvement, can be seen as an on-going effort to influence the natural tendencies of the tree.

Consumers want the fruit of their choice to be available at all times. Fruit should look good, be unblemished, well-coloured (superior exterior quality), taste good (high interior quality) and be of the right size. At the same time, the citrus producer wants orchards that will provide high yields over an orchard lifespan of 18 to 30 years. On top of all this, the citrus orchard must be managed in such a way that production practices have the least possible impact on the natural environment. Commercial citrus production management is about achieving these objectives efficiently and cost effectively.

3. Citrus Planting

Citrus trees are planted in rows in orchards. The planting distance, also called tree spacing or espacement, between rows and between trees within rows, is determined by numerous factors including climate, variety, and soil type. A typical tree spacing is 6m between rows by 3m between trees, meaning that 555 trees per hectare (ha) are planted (1ha = 10,000 m^2).

Once planted, trees take three or more years before bearing fruit that can be marketed. Thereafter, per tree and per hectare yields steadily increase to 40 to 70 t/ha – depending on cultivar and variety – after a further 4 to 7 years. If the trees are well looked after, this level of production will remain fairly constant until trees start to decline naturally.

Definition

Yield

Yield refers to the amount of fruit produced, and can be expressed in terms of:

Tree yield	kg per tree	kg/tree
Orchard yield	tons per hectare	t/ha
Export yield	15kg carton equivalents per hectare (10kg carton equivalents for soft citrus)	cartons/ha

4. Lifespan

The average economic lifespan of a commercial citrus orchard varies between 18 and 30 years, and can be as high as 30 to 60 years in hot, dry areas. Citrus is therefore viewed as a long-term crop. For citrus production to be profitable, the orchard must produce high yields of quality fruit every year, and do this consistently over a long period of time.

In citrus production the challenge is therefore to make production decisions and take actions to ensure high annual production of marketable fruit, while ensuring that these decisions and actions contribute to the long-term sustainability of the orchard.

5. Citrus Plant Phenology

Facilitator Tip

This is a difficult concept for level 2 learners and should be handled with care and extra attention.

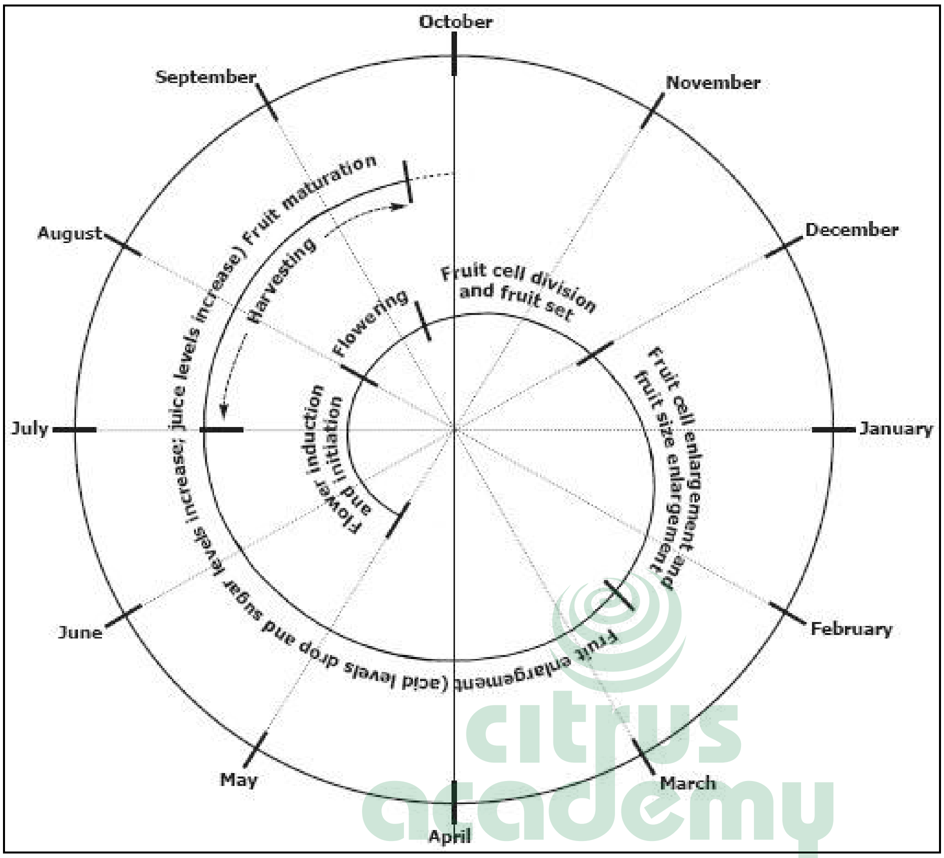
Definition

Phenology

Phenology refers to regularly recurring biological phenomena and the environmental and climatic factors that influence them. In citrus, phenology specifically refers to the annual cycle of the citrus tree.

Understanding the phenology of the citrus tree is essential to understanding the reasoning behind many of the practices and actions employed in citrus production. For example, the timing of fertiliser applications is linked to the phenology of the tree, with most fertilisers being applied at appropriate times to optimise flowering, fruiting, fruit development and fruit maturation.

The figure and table below set out the annual cycle of the citrus tree with regard to fruit production. Please note that this figure and table reflect the approximate flower and fruit development cycle of a valencia orange tree, and that the phenology of various cultivars differ.



Stage	***Description***	***Time Period***
Flower Induction and Initiation	Flower initiation is the induction and differentiation of vegetative buds into flower buds at a cellular level, and cannot be seen with the naked eye.	May to July
Flowering	Flowering or "bloom" is when blossoms appear on the tree.	August to Mid-September
Cell Division and Fruit Set	Cell division is the period when cells making up the fruit increase in number. Fruit set is the period from flowering or "bloom" until the end of fruitlet drop, after which the final fruit load is determined.	Mid-September to November
Cell Enlargement and Fruit Growth	Cell enlargement is the period during which cells making up the fruit increase in size. Fruit growth is the period during which the fruit grows and develops.	December to Mid-February
Fruit Maturation and further Fruit Growth	During this period fruit enlarges further and matures internally, meaning that the flavour, sugars and acids reach their optimum levels.	Mid-February to September
Harvest		July to September

It is important to note the term **citrus season** refers to the period from when flower initiation begins to the harvest. The season is generally from the beginning of August of one year to the end of July of the next year, although harvesting may extend to September and October for late cultivars.

6. Citrus Learning Material

The following citrus specific learning material is available from the Citrus Academy:

Skills Area	***Description***
Enterprise Selection, Planning and Establishment	Concerns itself with identifying the various components of an agricultural enterprise, and with the selection and planning processes for a new enterprise, and looks at the physical layout of a farm, with specific reference to infrastructure, orchard layout, etc.
Propagation	Concerns the various methods and requirements for the multiplication of plant material of specific varieties that possess desired qualities.
Crop Establishment	Concerns the establishment of a new citrus orchard, in terms of the physical planting of trees and the care for young trees.
Plant Structures and Functions	**Considers the structure and function of various plant parts and the manner in which nutrients, water, air and sunlight is taken up and processed.**
Plant Nutrition and Soil Management	Concerns itself with plant nutrients, in terms of the requirements of the citrus plant and the supplementation of nutrient elements through fertilisation, with specific reference to the timing and manner of application.
Water Quality	Considers the various factors that influence water quality and manners in which water quality can be measured and controlled. Considers furthermore the effect of water quality on tree and fruit growth and development, in combination with effective irrigation, fertilisation and pest control.
Plant Manipulation	Concerns various types of physical and chemical plant manipulation, with specific reference to pruning, girdling and the application of plant growth hormones, and tools and equipment used for this purpose.
Irrigation	Looks at the technical aspects of orchard irrigation, with reference to the types of irrigation systems, the installation of new irrigation systems, and the repair and maintenance of an irrigation system. Also concerns irrigation scheduling, and measures to ensure effective irrigation.
Pests, Diseases and Weeds	Concerns the identification of pests, diseases and weeds that threaten citrus production. Also considers various methods of effective control, and the planning required for this purpose.
Crop Protection	Looks at the practical application of crop protection agents through various methods, with specific reference to tools and equipment used, and health and safety requirements.
Food Safety	Concerns the requirements in terms of health and safety, and environmental control for ensuring food safety and hygiene.
Harvesting	Looks at the process of determining fruit maturity through maturity indexing, the harvesting of fruit, and the tools and equipment used for this purpose.
Conservation	Considers the impact of farming practices on the environment, with reference to the measures required to minimise this impact and protect the environment.

Skills Area	*Description*
Marketing	Concerns the factors influencing citrus marketing, and the development of an effective marketing plan.
Production Management	Concerns the actions and processes involved in effective production management, with specific reference to the coordination of the various production tasks and processes and the creation of a strategic plan for the enterprise.
Industry Overview	An overview of the citrus industry and the various institutions involved.
Packhouse Practices	Concerns the specific principles and practices that are employed in packhouse environments, and specifically: • Citrus Product Characteristics • Understanding Citrus Fruit Markets • Health and Safety in the Packhouse • Personal Hygiene Requirements for Packhouse Personnel • Understanding and Maintaining the Cold Chain • The Role of Quality Checks in the Packing Process • The Application of Fruit Treatments • The Application of Pre-Sorting Prior to Packing • Receiving Fruit into the Packhouse • Grading Fruit in the Packhouse • Packing and Packaging Materials • Palletisation of Packed Fruit • Storage of Fruit • Dispatch and Transportation of Packed Fruit • Understanding Automated Packing Solutions

Introduction to Plant Structures and Functions

Facilitator Tip

Please note that there is no separate time allocation for this section. Please treat it as part of the introduction.

Use this opportunity to establish what the learners already know. This will help you to identify areas where more time will have to be spent in facilitation during the presentation of this module.

Please note the note below, and call the attention of the learners to it. It is very important that learners internalise the scientific terms used for concepts and plant parts in this learning material, and constant attention must be paid to this aspect.

PLEASE NOTE: Scientific terms are used and explained in this learning material. It is important that you learn these terms, as they are used to refer to the various plant parts, processes, and other concepts in future. A glossary of these terms is provided at the end of each chapter for easy reference.

The structures of plants, also referred to plant anatomy, and the functions of plants, also referred to as plant physiology, forms the focus of this skills area.

Understanding the different parts and functions of plants enables us to understand what plants need to produce the best possible volume and quality crop. It will also make it possible for us to understand what can go wrong in the growth of a plant and how to prevent damage to a plant.

Facilitator Tip

Spend a little time in revising the basic structures and functions of the plant. The learners should be familiar with most of these concepts from level 1. It is best illustrated by showing an example of a plant such as a weed which has been pulled up gently enough to have all the structures intact.

In this learning module we look at the different parts of a plant and the scientific names used to describe them. We will also look at what each plant part consist of and how the plant part works. The plant parts that we will be looking at are:

- Seeds
- Roots
- Stems and trunks
- Leaves
- Flowers
- Fruit

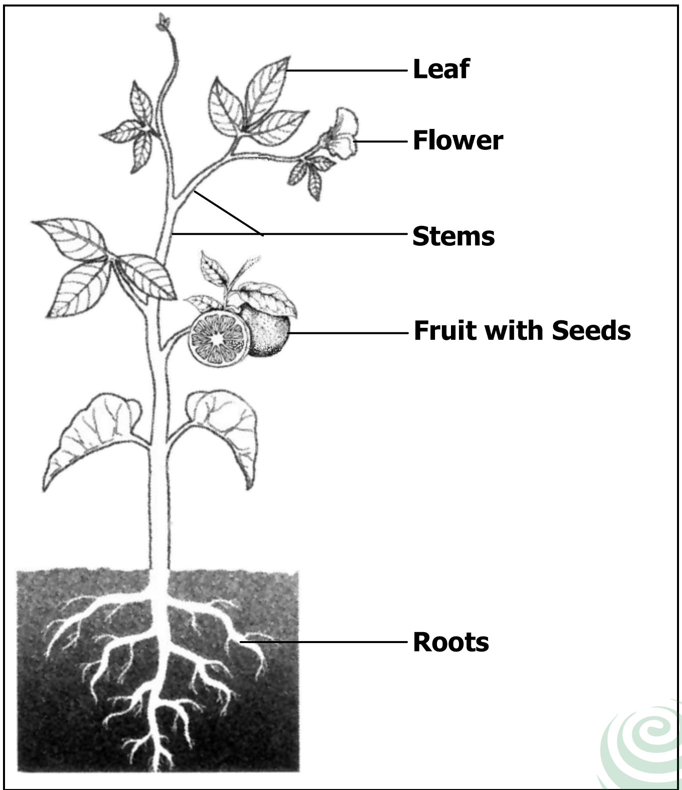


Figure I.1: Plant Parts

Chapter 1

After completing this chapter, the learner will be able to:

Identify the basic parts that make up a seed and its basic function.

Timeframe

You have to complete this section as follows:

Total time	*Theory*	*Practical*
6h	4h 30min	1h 30min activities

1. Introduction

The seed is the starting point of a plant. The seed already contains specific parts that later develop into parts of the plant, such as a radicle that later develops into the roots of a plant. Once all of these parts have developed from the seed, the plant is able to grow and perform certain processes that enable it to produce fruit, which contains more seeds.

Every plant has a unique seed, meaning that the seed of every plant is different from those of other plants. Seeds can be tiny, such as those of certain types of garden flower plants, or they can be large, such as the red seeds of a cycad plant or the seed of an avocado. They can be sticky, so that they will stick to the coats or feet of animals, or they can be light and winged, so that the wind can carry them.

2. Sexual and Asexual Propagation

Plants can propagate, or reproduce, sexually or asexually.

2.1. Sexual Propagation

Sexual propagation means that the male cells produced by the pollen, fertilises the female reproductive cells, called **ova** (singular: **ovum**) in the **ovule** and an **embryo** is formed, which is part of a **seed**. This is called plant **embryogenesis**, which literally means the creation of the embryo. The seed can eventually germinate and make a new plant.

Definition

Ovule

The ovule is a small structure inside the ovary of a seed plant that contains the female reproductive cells inside the embryo sac, and which develops into a seed after fertilisation.

Embryo

The embryo is a plant in its earliest stage of development before it becomes self-supporting. Once the embryo begins to grow out from the seed, or germinate, it is called a seedling.

When embryogenesis occurs naturally in the plant as a result of sexual fertilisation, the embryos are called **zygotic** embryos. The term zygotic embryo derives from the name for a fertilised ovum, which is called a **zygote**.

One embryo develops as a result of the fusion of the ovum inside the ovule with a male cell from the pollen. Each of these cells will have previously undergone **meiosis** and carry the genetic material of the parent. On fusion, the zygotic embryo contains the genes of both parents and is a hybrid between the two. The new plant will therefore have characteristics from both parent plants, and will be a completely unique new plant.

Facilitator Tip

This is a difficult concept for most level 2 learners and should be handled with care and extra attention. Meiosis is discussed in great detail in the level 3 learning material. At this level, learners must understand when meiosis happens and that it is part of sexual propagation.

Definition

Meiosis

Meiosis is a type of cell division in organisms that reproduce sexually, and results in cells with half the number of chromosomes of the original cell.

The ovule develops into a seed, which germinates and give rise to seedling. In animals and primitive plants such as algae, mosses, ferns and gymnosperms, fertilisation is a single process whereby a male cell fertilises an ovum to form one zygote.

In flowering plants, however, we have **double fertilisation**. The pollen tube produced by the pollen grain after pollination carries two **male sperm cells** to each ovule. The embryo sac inside the ovule contains two ova, namely the **egg cell** and the **central cell**. During fertilisation, one sperm cell fertilises the egg cell and the other one fertilises the central cell. The zygote of the fertilised egg cell will form the embryo (future seedling) and the zygote of the fertilised central cell forms the endosperm.

In the ovule, the embryo sac is contained within the **nucellus** which is surrounded by a membrane. The nucellus cells that surround the embryo are rich in various nutrients and plant growth regulator substances, often referred to as plant hormones. The nucellus acts as a nutritional source that sustains the initial embryo development.

2.2. Asexual Propagation

Asexual propagation is when plants are propagated not through seed, but through using plant parts, also referred to as scions. When a plant is propagated in this way, it has exactly the same characteristics as the plant from which the scion was taken. This process is also referred to as **vegetative propagation** or **plant tissue culture**. Plant cells are forced to form embryos during vegetative propagation. These embryos are called **somatic embryos**, which are physically formed cells derived from actual plant cells. Somatic embryos are formed from plant cells that are not normally involved in the development of embryos. Plants are propagated asexually for the following reasons:

- Preserving the genetic characteristics of a particular plant.
- Propagating plants that do not produce viable seeds, such as bananas, pineapples, and seedless grape.
- Propagating plants that produce seed that is difficult to germinate or has a very short storage life, such as cotoneaster and willow.
- Bypassing the juvenile stage of plant growth when the plants will not flower and bear fruit.

3. The Composition of Seeds

Facilitator Tip

Bring examples of different seeds to class, at least one dicot and one monocot seed. Allow learners to examine the seeds, to discuss the differences between them, and to identify the structures on each seed.

Seeds are produced through sexual propagation and are made up of two parts, being:

- A seed coat
- An embryo

3.1. Seed Coat

The seed coat is the protective outer layer of a seed. Seed coats protect the embryo from injury and from insects and diseases. Seed coats can be thin and soft, such as with avocadoes, leather-like, such as with beans, or thick and hard, such as with macadamia seeds.

There is a small opening in the seed coat, called the **micropyle**, through which the pollen tube passes before fertilisation, and through which the radicle emerges during germination.

3.2. The Embryo

Facilitator Tip

It is recommended that an illustration or microscopic photo be shown of the embryo. Remember to constantly remind the learners where the embryo is located and of its importance to the plant.

The embryo consists of the following parts:

- The radicle
- The plumule
- The cotyledon

3.2.1. Radicle

The radicle is the part of a plant embryo that forms the **root** of the young plant after germination. The radicle can be compared to an egg with the root being a chicken. The radicle is the first part of the seed to emerge from the seed coat during germination.

3.2.2. Plumule

The plumule is the rudimentary **primary shoot** of a plant embryo.

3.2.3. Cotyledon

The cotyledons are the seed leaves. Plants are classified based upon the number of cotyledons in the seed. Plants such as grasses can be monocotyledons (monocots), containing one cotyledon. Dicotyledons (dicots), such as beans and citrus, are plants that have two cotyledons.

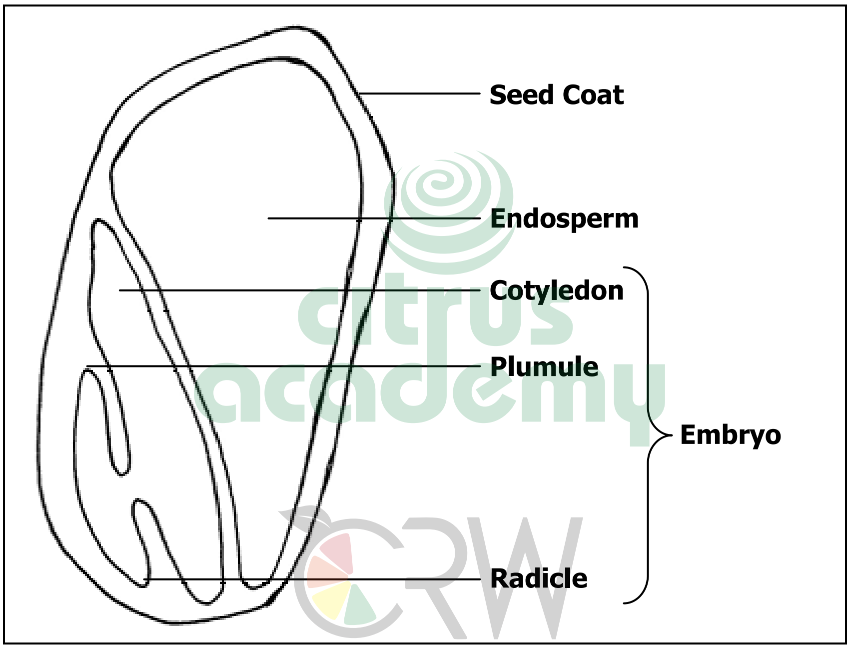


Figure 1.1: The Structure of a Monocot, Endospermous Seed

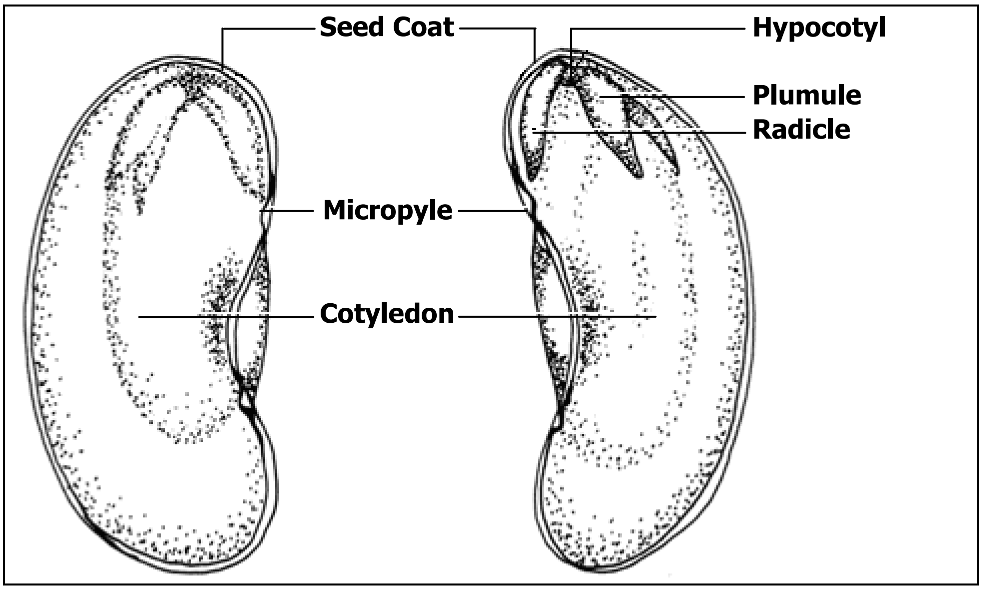


Figure 1.2: The Structure of a Dicot, Exendospermous Seed

3.2.4. Endosperm

Facilitator Tip

Ensure that learners understand that the distinction between exendospermous and endospermous seeds are not the same as between dicot and monocot seeds. The learners must understand that there are exendospermous dicot and monocot seeds, and endospermous dicot and monocot seeds. Attempt to find examples of both.

Endosperm is the nutritive tissue of a seed and may contain carbohydrates, proteins, and lipids. The endosperm is the temporary food source for the seed. As explained above, the seeds of all flowering plants start off with separate endosperm, but in some plants the endosperm is absorbed by the cotyledons of the developing embryo, leaving the mature seed without distinguishable endosperm, as is the case with the dicot seed shown in figure 1.2. Such seeds are known as **exendospermous**.

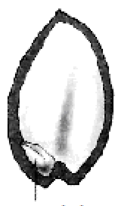
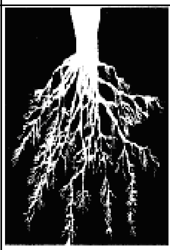
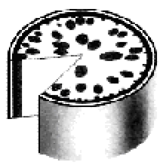
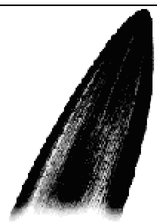
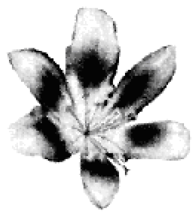
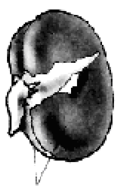
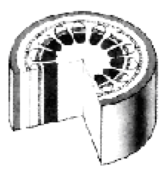
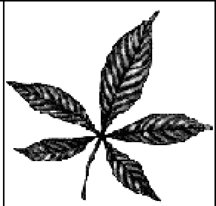
In other seeds the cotyledons remain small or thin because the endosperm is not absorbed by the cotyledons and remain separate. Such seeds are known as **endospermous** seeds.

4. Monocotyledons and Dicotyledons

Facilitator Tip

The differences between monocots and dicots are best facilitated by showing actual examples of plants and their structures.

The differences between dicots and monocots are not limited to the number of cotyledons that their seeds contain. There are differences in the roots systems, stem structures, leaf structures and flowers, as illustrated in the table below.

	Seed	Root	Stem	Leaf	Flower
Monocots	 One cotyledon in seed	 Adventitious root system	 Vascular bundles usually complexly arranged	 Leaf veins form a parallel pattern	 Flower parts in threes and multiples of three
Dicots	 Two cotyledons in seed	 Usually has taproot	 Vascular bundles usually arranged in ring	 Leaf veins form a net pattern	 Flower parts in fours or fives and their multiples

5. Seed Germination

Facilitator Tip

If time allows, have each learner germinate their own seed under different conditions to allow them to observe what seed germination is and how it is influenced by various factors. A good method of doing this is by germinating five seeds of the same type under the following conditions:

- One with correct requirement of soil, water, air and warmth
- One without adding water to the soil
- One of which the container is kept in the dark
- One of which the container is placed in the refrigerator
- One of which the seed is left as is without soil

If possible, prepare some seedlings some days prior to the facilitation and bring seedlings in the different stages to class to show to the learners.

The discussion below on seed germination relates to dicotyledonous plants. The process is similar for monocots, but there is no radicle emergence. **Seed germination** is the emergence of the radicle through the seed coat. It is the resumption the growth of the seed after a period of dormancy. Once a seed has been formed it can remain dormant, or resting, for a long period of time. The seed will only germinate when the conditions in which it finds itself are favourable for germination and growth.

The most important environmental conditions for germination are adequate water, adequate oxygen, a suitable temperature, and, in some cases, suitable light.

The specific conditions required for germination varies between different types of seeds, and is related with the conditions under which that specific plant is able to grow. Very few types of seeds will however germinate in extreme temperatures. Some seeds, such as citrus seeds, are coated with a mucilaginous compound, which is a gummy substance, on the outside. This substance contains inhibitors to germination, and has to be removed before germination takes place. Once seed germination has been triggered, the process is as follows:

- Imbibition
- Start of metabolism
- Radicle emergence
- Growth of plant parts

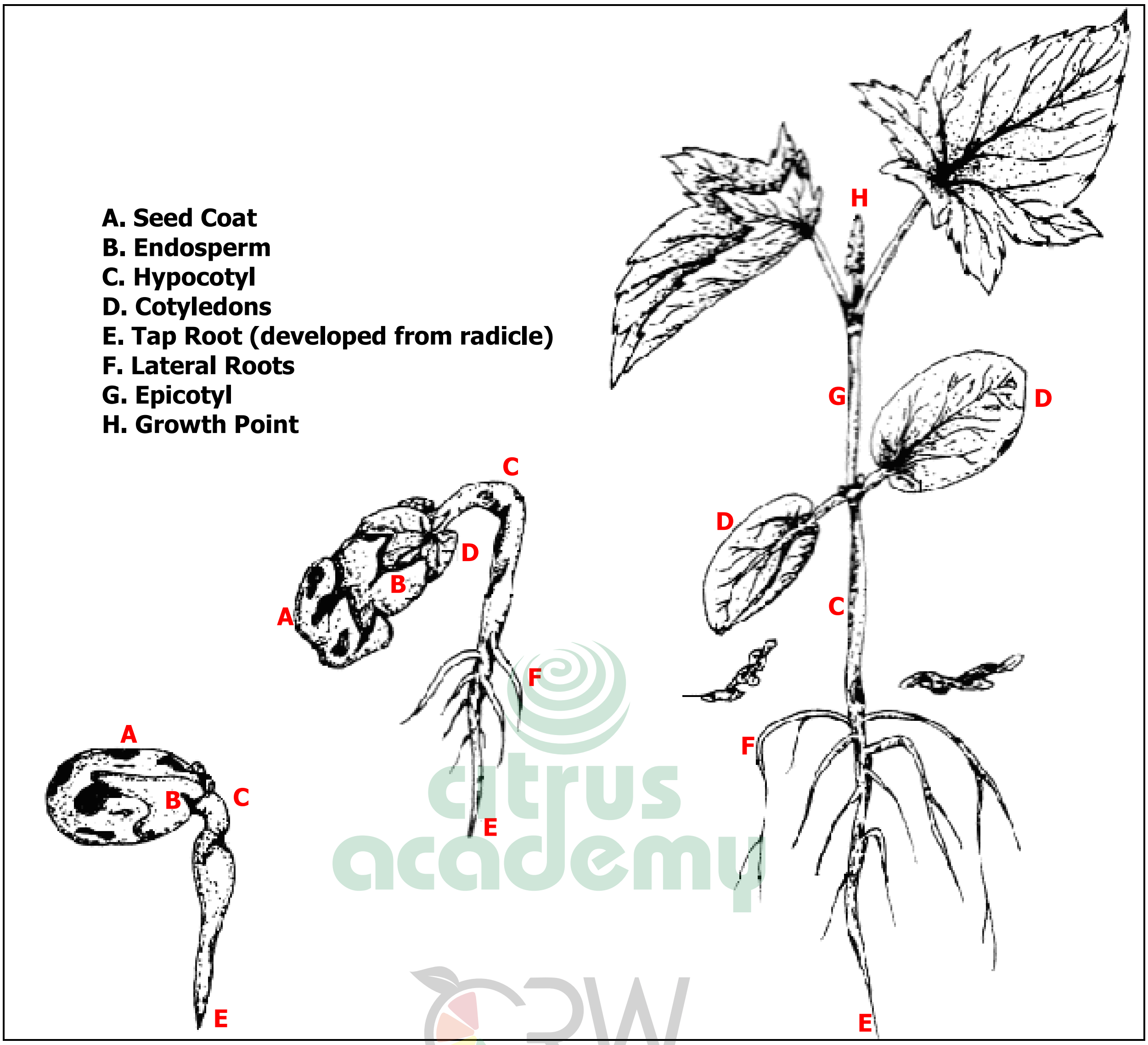


Figure 1.3: The Development of Plant Parts

5.1. <u>Imbibition</u>

Facilitator Tip

This is a difficult concept for most level 2 learners and should be handled with care and extra attention. Most learners will know that seeds need moisture to germinate, but a good question to ask is why this is so.

Definition

<u>Imbibition</u>

Imbibition means the absorption of something, such as liquid or heat. In terms of seed germination, it means the absorption of water by the seed coat.

During germination water is absorbed, or imbibed, through the seed coat, which has been almost completely dry while the seed was dormant. The water causes the seed to soften and the **micropyle** to open up, enabling the seed to imbibe water faster.

The micropyle is a small opening in the seed coat, which was originally a small opening in the ovule through which the pollen passed during fertilisation.

The seed coat swells as more water is absorbed, the respiration rate and other metabolic processes increase and more oxygen is required.

5.2. Start of Metabolism

Facilitator Tip

This is a difficult concept for most level 2 learners and should be handled with care and extra attention. Ensure that learners understand that metabolism happens in every living organism, and that it is what makes the plant function.

Definition

Metabolism (Metabolic)

Metabolism means the ongoing series of chemical interactions that take place in every living organism that provides the energy and nutrients to sustain life.

The first metabolic processes of the plant take place when the food reserves contained in the endosperm is converted to simpler substances that are then transported to the embryo. At this point, growth starts taking place.

5.3. Radicle Emergence

The radicle starts to grow first through the enlargement of its cells. It appears through the micropyle and forms the tap root. The tap root develops root hairs that absorb water and attach to soil particles. The tap root grows downwards in response to gravity.

5.4. Growth of Plant Parts

Some seeds, including endospermous seeds such as castor bean and exendospermous seeds such as bean, lettuce and pumpkin, undergo **epigeal** germination.

With epigeal germination, the **hypocotyl** starts to lengthen. The hypocotyl is the part of the plant axis, or stem, between the roots and where the cotyledons are attached. The hypocotyl grows upwards, against the pull of gravity. As the hypocotyl lengthens, it pushes the plumule and cotyledon(s) above the soil.

The **epicotyl** is the part of the plant axis, or stem, above the point where the cotyledons are attached and below the growth point. The epicotyl starts to grow after the hypocotyl.

In other seed types, including exendospermous seeds such as peas, citrus, mango and avocado and endospermous grass seeds such as maize, the type of germination that takes place is called **hypogeal**.

With hypogeal germination the hypocotyl does not develop and the cotyledons remain close to the roots. The epicotyl grows and pushes the plumule above the surface of the soil.

Facilitator Tip

This is a difficult concept for most level 2 learners and should be handled with care and extra attention. Explain these terms by using examples of plants where these terms are applicable. Also ensure that learners understand that **hypo**cotyl (and epicotyl) = **epi**geal germination, and only **epi**cotyl = **hypo**geal germination.

Definition

Epigeal

Epigeal means living or growing on or right above the surface of the ground. The term is used to describe seed germination in which the hypocotyl elongates so that the cotyledons are carried above the soil.

Hypogeal

Hypogeal means remaining below ground, and refers to when the cotyledons remain below the ground while the epicotyl of the seedling grows.

The plant survives on the reserves stored in the endosperm of the seed until it develops its first leaves, at which point **photosynthesis** is initiated and the plant is able to produce food. Up to this point, the plant is referred to as a seedling.

Facilitator Tip

Most learners will have a basic understanding of the process of photosynthesis, but be alert to learners who might still be struggling with it. The concept is discussed in greater detail in the chapter dealing with leaf structure and function.

Definition

Photosynthesis

Photosynthesis literally means light production, or production by light (photo=light, synthesis=production) and is the metabolic process by which green plants turn carbon dioxide and water into food using energy obtained from sunlight.

6. The Role of Seeds in Citrus Production

Facilitator Tip

The concept of nucellar embryos will be unfamiliar and difficult to understand for learners. Emphasise that this is a unique characteristic of citrus and that only one zygotic seedling develops in other plants while more than one seedling grows from each citrus seed. Ensure that learners understand the importance of this characteristic for commercial citrus propagation.

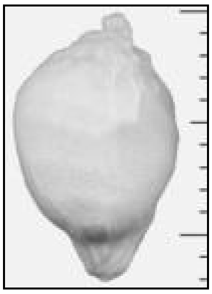


Figure 1.4: Citrus Seed

In commercial plant propagation it is very important that the nursery is able to produce plants that are true-to-type, meaning plants that are essentially the same as the mother plant. We have seen that with sexual (seed) propagation a zygotic embryo develops from which a seedling grows that has characteristics that are a combination of the characteristics of the mother and father plant.

Because the characteristics of seedlings cannot be guaranteed, seed propagation is not generally used in the commercial propagation of tree crops. Citrus rootstock is however propagated with seed in commercial citrus nurseries, because of the special structure and development of citrus seeds, which allow the grower to produce seedlings with essentially the same characteristics as the mother plant.

We have seen that the embryo is surrounded inside the seed by the nucellus. In citrus, a somewhat unusual process occurs where some of the nucellar cells develop into **nucellar embryos**. The number can vary, with up to six nucellar embryos developing in some cultivars. These cells do not undergo meiosis and contain the full set of maternal chromosomes, meaning that the nucellar embryos are deemed to be the same as the mother plant.

When the citrus seed germinates, more than one seedling grows from each seed. The zygotic embryo will always form one seedling, while the number of nucellar embryos that develop into seedlings varies. Mostly, between two and four seedlings develop from a single seed, one of them zygotic.

The zygotic seedlings differ from the nucellar seedlings, and are removed in the nursery where the rootstocks are propagated. Only true-to-type nucellar seedlings are eventually used as rootstocks.

Facilitator Tip

Revise the functions of roots, trunks and stems, and leaves, and ensure that learners understand the difference between stems and trunks. Learners should have this knowledge from level 1, but be alert to learners who struggle with these concepts. The structures and functions of these various plant parts are discussed in great detail in the following chapters.

7. The Functions of Roots

Roots are typically at the bottom end of a plant. Roots possess a root cap, have no nodes, and never bear leaves or flowers directly. Some plants roots may be used for asexual propagation.

The principal functions of roots are to:

- Absorb nutrients and water
- Anchor the plant in the soil
- Furnish physical support for the stem
- Serve as food storage organs

The structure and functions of roots are discussed in greater detail in chapter 2.

8. The Functions of Trunks and Stems

Stems are structures which support buds and leaves and serve as conduits for carrying water, minerals, and sugars. The three major internal parts of a stem are the xylem, phloem, and cambium. The xylem and phloem are the major components of a plant's vascular system. The vascular system transports food, water and minerals.

The structure and functions of stems and trunks are discussed in greater detail in chapter 3.

9. The Functions of Leaves

The principal function of leaves is to absorb sunlight for the manufacturing of plant sugars through a process called photosynthesis. Leaves have a flattened surface so that a large area is available for efficient absorption of light energy. The other important function of leaves is transpiration.

Definition

Transpiration

Transpiration means to lose water through the surface of a plant, particularly through the stomata, causing a transpiration stream of water from the roots to the leaves.

The structure and functions of leaves are discussed in greater detail in chapter 4.

Facilitator Tip

Summary

This is an opportunity to check the progress that learners have made.

Allow time for the learners to read through the summary and to gauge their own progress. Make sure that each and every learner gets and opportunity to ask questions.

Allow learners to become familiar with the use of a glossary and to refer back to it when necessary.

Chapter 1

- The seed is the starting point of a plant.
- Every plant has a unique seed, meaning that the seed of every plant is different from those of other plants.
- Plants can propagate (reproduce) sexually or asexually.
- In sexual propagation, embryogenesis occurs when the ova is fertilised by the male cells produced by the pollen, forming a zygotic embryo that is part of a seed. The plant that develops from a zygotic embryo contains half the characteristics of the mother plant and half the characteristics of the father plant.
- In flowering plants, seeds are the products of double fertilisation, which leads to the development of an embryo from which plant develops and to the development of endosperm.
- In asexual propagation, plants are propagated through using plant parts, giving rise to somatic embryos. Plants that are propagated in this manner are true-to-type.
- Seeds are produced through sexual propagation and are made up of two parts, being a seed coat and a zygotic embryo.
- The seed coat is the protective outer layer of a seed.
- The embryo consists of the radicle, the plumule, and the cotyledon.
- Some seeds also contain unabsorbed endosperm, which is the product of the second fertilisation.
- Seeds with one cotyledon are referred to as monocot (monocotyledonous) plants, and seeds with two cotyledons are called dicot (dicotyledonous) plants. The differences between monocots and dicots are not limited to the number of cotyledons in the seeds.
- Once a seed has been formed it can remain dormant, or resting, for a long period until environmental conditions for germination are favourable. The most important environmental conditions for germination are adequate water, adequate oxygen, suitable temperature, and, in some cases, suitable light.
- Once seed germination has been triggered, the germination process is imbibition, start of metabolism, radicle emergence, and growth of plant parts.
- In commercial plant propagation it is very important that the nursery is able to produce plants that are true-to-type, meaning plants that are essentially the same as the mother plant, which is why asexual propagation is often used.
- In citrus seeds, nucellus cells surrounding the embryo are stimulated to form **somatic** (asexual) embryos, which are true-to-type to the mother plant. These embryos are referred to as nucellar embryos.
- The nucellar embryos also develop into seedlings, which are then used as rootstock.
- The principal functions of roots are to absorb nutrients and moisture, anchor the plant in the soil, furnish physical support for the stem, and serve as food storage organs.
- Stems are structures which support buds and leaves and serve as conduits for carrying water, minerals, and sugars.
- The principal function of leaves is to absorb sunlight for the manufacturing of plant sugars through a process called photosynthesis.

Glossary	
Cotyledon	The cotyledons are the seed leaves. Monocotyledonous plants (monocots) have one cotyledon, and dicotyledonous plants (dicots) have two cotyledons in their seeds.
Embryo	The embryo is a plant in its earliest stage of development before it becomes self-supporting. Once the embryo begins to grow out from the seed, or germinate, it is called a seedling.

Embryo – Nucellar	Nucellar embryos are embryos that develop from the nucellar cells that surround the zygotic embryo in certain plant species, such as citrus. Nucellar embryos give rise to plants that are true-to-type to the mother plant.
Embryo – Somatic	An embryo that develops from asexual propagation, meaning when plants are propagated through tissue culture.
Embryo – Zygotic (Zygote)	An embryo that develops from sexual propagation, meaning the fertilisation of a female ovule by cells formed by the male pollen.
Endosperm	Endosperm is the nutritive tissue of a seed, deriving from the fertilisation in the ovule and may contain carbohydrates, proteins, and lipids. The endosperm is the temporary food source for the seed.
Endospermous Seeds	Seeds in which the endosperm remains separate and is not absorbed by the cotyledons.
Epicotyl	The **epicotyl** is the part of the plant axis, or stem, above the point where the cotyledons are attached and below the plumule or growth point.
Epigeal	Epigeal means living or growing on or right above the surface of the ground. The term is used to describe seed germination in which the hypocotyl elongates so that the cotyledons are carried above the soil.
Epigeal Germination	Epigeal germination refers to seed germination where the hypocotyl lengthens and pushes the plumule and cotyledons above the soil.
Exendospermous Seeds	Seeds in which the endosperm has been absorbed by the cotyledons prior to seed maturity.
Hypocotyl	The hypocotyl is the part of the plant axis, or stem, between the radicle, or roots, and where the cotyledons are attached.
Hypogeal	Hypogeal means remaining below ground, and refers to when the cotyledons remain below the ground while the epicotyl of the seedling grows.
Hypogeal Germination	Hypogeal germination refers to germination when the hypocotyl does not develop and the cotyledons remain close to the roots.
Imbibition	Imbibition means the absorption of something, such as liquid or heat. In terms of seed germination, it means the absorption of water by the seed coat.
Meiosis	Meiosis is a type of cell division in organisms that reproduce sexually, and results in cells with half the number of chromosomes of the original cell.
Metabolism (Metabolic)	Metabolism means the ongoing series of chemical interactions that take place in every living organism that provides the energy and nutrients to sustain life.
Micropyle	The micropyle is a small opening in the seed coat, which was originally a small opening in the ovule through which the pollen passed during fertilisation.
Nucellus	The nucellus surrounds the embryo sac in the ovule and acts as a nutritional source that sustains the initial development of the embryo. In some plants there is hardly any nucellus.
Ovum (P: Ova)	The ovum is the female reproductive cells that are contained in the ovule of the plant.
Ovule	The ovule is a small structure inside the ovary of a seed plant that contains the female reproductive cells inside the embryo sac, and which develops into a seed after fertilisation.

Photosynthesis	Photosynthesis literally means light production, or production by light (photo=light, synthesis=production) and is the metabolic process by which green plants turn carbon dioxide and water into food using energy obtained from sunlight.
Plumule	The plumule is the rudimentary primary shoot, or terminal bud, of a plant embryo, or the growth point.
Radicle	The radicle is the part of a plant embryo that forms the tap root of the young plant after germination.

Practical

Complete activities 1 and 2 in the **Learner Workbook**.

Facilitator Tip

Activity 1 – Make a Sketch

Hand out examples of seeds to learners and then encourage learners to draw what they see and identify the positions of specific structures. Encourage learners to draw what they see rather than to redraw the sketches used in this section.

Timeframe: 30min

Activity 2 – Discussion

Encourage learners to answer this activity as a means of checking their progress, and to answer in their own words.

Timeframe: 1h

Chapter 2

After completing this chapter, the learner will be able to: **Demonstrate an understanding of the different root systems and its basic function.**

Timeframe

You have to complete this section as follows:

Total time	*Theory*	*Practical*
7h 15min	5h 30min	1h 45min activities

1. Introduction

It is very important to understand the function and structure of roots and how these influence the growth, flowering and fruiting of the plant. The structure and growth habits of roots have a pronounced effect on the:

- Size and vigour of the plant
- Ability of the plant to adapt to certain soil types
- Response of the plant to production practices and irrigation
- Method of propagation

2. Root Systems

Facilitator Tip

Start the discussion by asking learners to find weeds and plants and pull them up gently to keep the root system intact. Identify the root systems of the examples and discuss the differences.

Root systems refer to the types of roots a plant has, and the manner in which the roots are connected. There are two main types of root systems, namely the tap root system and the adventitious root system.

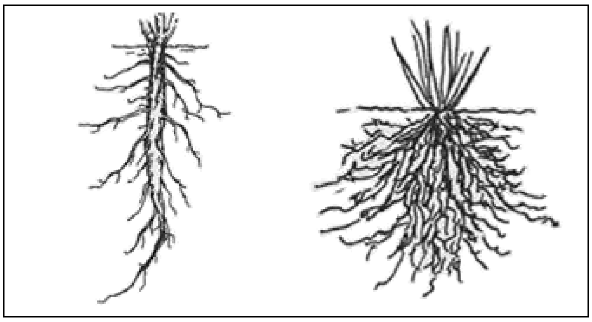


Figure 2.1: The Tap Root System (left) and Adventitious Root System (right)

2.1. Tap Root System

The tap root develops from the radicle during germination of the seed. In most dicot plants, the radicle grows and develops into the tap root that becomes the major root of the plant. Branch roots grow from the tap root. In most plants root hairs are found close to growing tips of roots.

2.2. Adventitious Root System

Definition

Adventitious

The term adventitious means developing in an unusual position. In terms of root development, it means roots that grow from the stem or leaf.

In some monocot plants, the radicle does not develop into a tap root. Roots that are all more or less the same size grow directly from the bottom end of the stem. Branch roots also grow from the adventitious roots.

In grasses and some other plants the adventitious roots are **fibrous**. They are thin and hair-like, and usually contain more fibres than other roots. The whole root system is then called a **fibrous root system**. The feeding roots of many other plants can however also be hair-like and fibrous, even if they form part of a taproot system.

3. Tap Root Structure

Facilitator Tip

Using the plants that the learners have collected that has tap root systems, identify the structures on the physical examples. Ensure that learners can identify each structure and area.

To understand the manner in which roots perform their functions, it is important to understand the structure of a root.

3.1. External Features

The root consists of the following regions, as shown in figure 2.2:

- Root cap
- Region of cell division (meristematic region)
- Region of cell elongation
- Root hair region
- Mature region

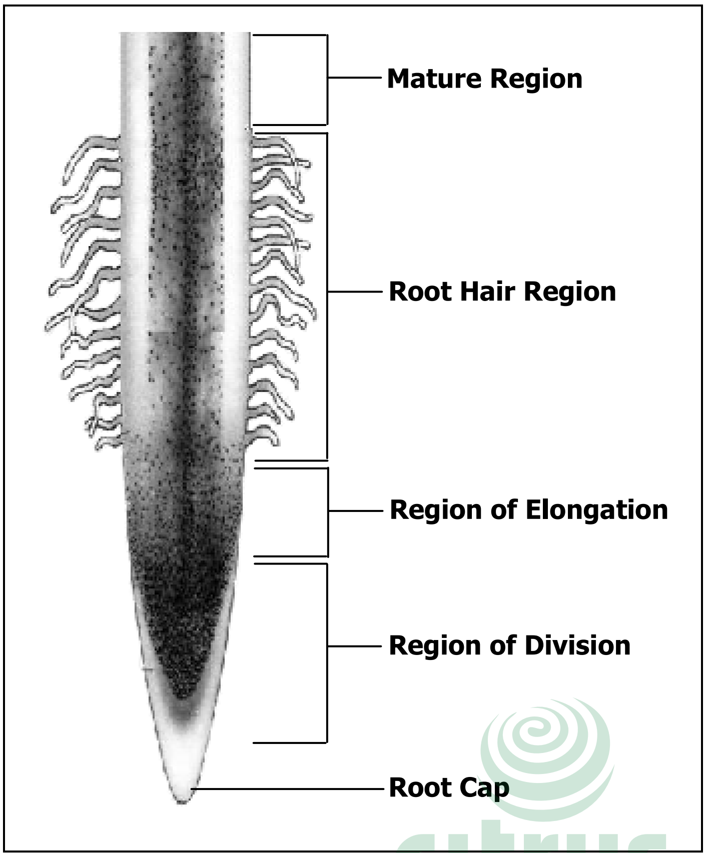


Figure 2.2: External Features of the Root

3.1.1. Root Cap

The tip of the root is covered by a cap that is shaped like a thimble. The outer cells of the root cap are continuously worn away and new cells are added to the inner portion. As these cells disintegrate, they form a strong protective cover.

The function of the root cap is to cover and protect the delicate growing tip from injury and damage as the root pushes its way through the soil.

3.1.2. Region of Cell Division (Meristematic Region)

The meristematic region is covered by the root cap. In this region, cells are dividing all the time, forming new cells that later differentiate into specialised root tissue as well as more root cap cells. The function of the meristematic region is to produce new cells, making this the primary growth region of the root.

3.1.3. Region of Cell Elongation

In this region, the cells that are formed in the meristematic region elongates, meaning that they grow rapidly in length and size. This causes the root to elongate and penetrate deeper into the soil in search for water and minerals.

The meristematic region and the region of elongation together are referred to as the region of growth.

3.1.4. Root Hair Region (Cell Differentiating Zone)

Root hairs are single, elongated epidermis cells that assist with the uptake of water and nutrients because of increasing the absorption area.

In this region the young cells start maturing into cells with specific functions. It overlaps with the region of cell enlargement. In this region the outer cell walls of the epidermis cells grow out to form root hairs to enlarge the absorption surface of the epidermis for absorbing water and nutrients form the soil. The xylem cells also start to differentiate and link up with the older part of the root in order to be able to transport the absorbed water and nutrients to the rest of the plant.

Information

Please Note

Be careful not to confuse root hairs with hair roots. Root hairs are single, elongated epidermis cells that are found close to the root tip. Hair roots are roots that resemble hair, but that have all the internal and external parts discussed in this section.

3.1.5. Mature Region

The mature region is above the root hair region where the root becomes thicker and secondary or lateral roots develop. Tertiary roots in turn grow from the secondary roots. Each lateral root has its own root cap, root hairs, meristematic region, region of elongation and mature region. The older part of the root develops a protective cork layer, referred to as the 'bark' of the root that sloughs off the epidermis.

3.2. Internal Features

Facilitator Tip

Learners might struggle with the internal features of the root. Explain to the learners that these areas are only visible through a microscope.

Be alert to learners who struggle to understand the role of cells in structures. Constantly remind learners that cells build up larger structures and systems.

If we cut a root above the root hair region and study it under a microscope, the following can be identified from the outside in, as shown in figure 2.3:

- Epidermis
- Cortex
- Vascular cylinder or stele

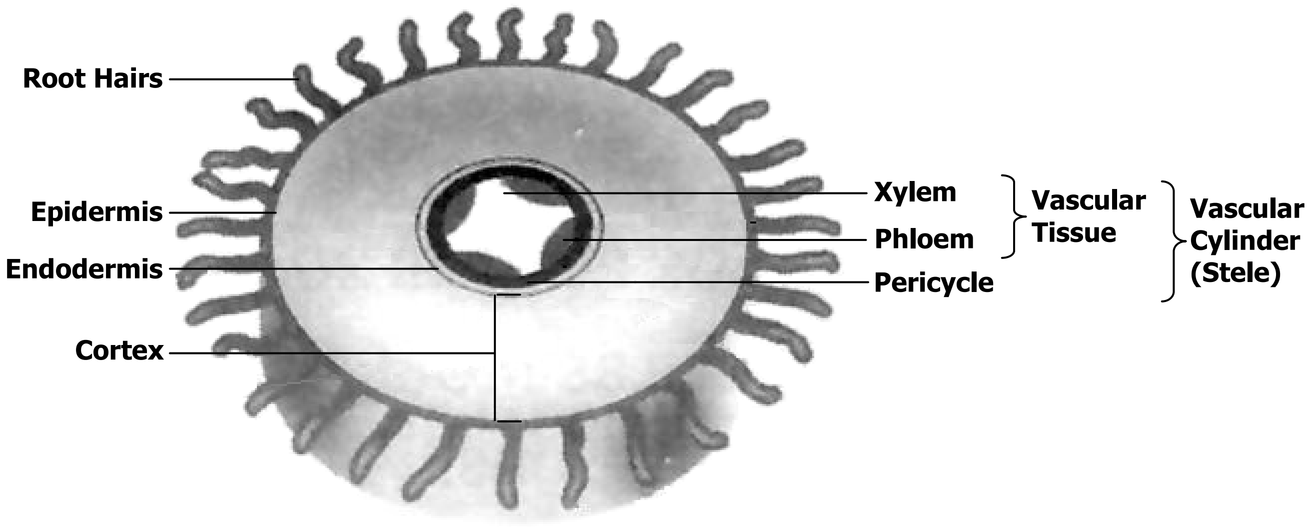


Figure 2.3: Internal Features of the Root Hair Region of the Root

3.2.1. Epidermis

Epidermis literally means "over skin" (epi = over or around, and dermis=skin). The epidermis is the outer layer of the young root. The cells of the epidermis are closely packed, thin-walled parenchyma cells. Root hairs arise from some of the epidermal cells.

Definition

Parenchyma

Parenchyma tissue is soft plant tissue made up of thin-walled cells that forms the greater part of leaves, stem pith, roots and fruit pulp.

The epidermis covers the underlying tissues of the root. The epidermal cells and the root hairs absorb water and dissolved ions.

3.2.2. Cortex

Inside the epidermis is the cortex. The cortex in roots and stems is the zone or cell layers between the epidermis and the stele, or vascular cylinder.

In many plant types, especially monocots, the cortex is divided into the **exodermis**, or outside skin, a central cortex and the **endodermis**, or inside skin. The central cortex usually consists of parenchyma cells with numerous spaces between cells.

The endodermis forms the innermost layer of the cortex. The cells of the endodermis are more rectangular in shape, the side walls being thickened with **suberin**, which is a corky substance. These thickenings are called **casparian strips**.

The cortex has several functions, including:

- Allowing for the diffusion of water, mineral salts and oxygen from the root hairs inwards.
- Storage of food reserves, especially starch.
- Transporting water and salts from the root hairs to the centre of the root.

- The endodermis, with the aid of the casparian strips, facilitates the movement of water from the cortex to the xylem, also acting as a 'security gate' to keep certain molecules out so that they cannot be transported to the rest of the plant.

3.2.3. Vascular Cylinder (Stele)

The vascular cylinder is enclosed by the endodermis, and consists of the:

- Pericycle
- Vascular tissue

3.2.3.1. Pericycle

The outermost layer of the stele is known as the pericycle, consisting of one or more layers of simple undifferentiated parenchyma cells.

3.2.3.2. Vascular Tissue

The vascular tissue consists of the xylem and phloem. In dicotyledonous roots, a vascular cambium develops between the primary xylem and phloem and gives rise to secondary xylem towards the inside and secondary phloem towards the outside. The actual cambium consists of a single layer of dividing cells.

The phloem is live cells called sieve tubes controlled by an adjacent cell called a companion cell. Sieve tubes are named as such because the cross walls between the tube-like cells have minute holes in them, like a sieve. The phloem cells transport sugars and other metabolites from the leaves.

The primary xylem alternates with the phloem, and is shaped somewhat like a star. The xylem consists mainly of cells which have become modified, have thickened walls and holes between adjacent cells of the same type, and have lost their original contents. They are thus empty cells linked together in such a way that they can carry water and nutrients from the root, through the stem to the leaves of the plant. These cells of the xylem, known as vessels also serve as strengthening units, although special strengthening cells called fibres, usually forms part of the xylem.

4. Root Functions

Roots have the following main functions:

- Anchoring the plant in the soil.
- Taking up water and nutrients from the soil.
- Transporting water and dissolved substances from the root to the stem, and carbohydrates from the stem to the root.

Some plants have developed roots that perform other functions as well, and these are discussed at the end of this section.

4.1. Stabilising and Anchoring

Roots keep plants stable and upright in the soil. Plants with tap root systems are more stable because they have a large central root that grows deep into the soil. Adventitious root systems are more common amongst monocotyledonous plants such as grasses, and occur with all plants grown from cuttings.

Root Functions

The stabilising and anchoring functions of roots are very important, as this example illustrates.

We have seen that plants that are propagated through asexual propagation methods, such as through tissue culture, develop adventitious roots because the roots grow directly from the stem, and no tap root can develop because a seed, that contains the radicle from which the tap root develops, is not used.

When plants that naturally have tap root systems are propagated through tissue culture because asexual propagation produces true-to-type seedlings, the plants are often found to be very hard to grow, because they fall over. They need the stabilising and anchoring function of the tap root.

4.2. Uptake of Water and Nutrients

Almost all the water the plant takes up from the soil enters through the youngest part of the root in the root hair region.

Water is absorbed directly through the epidermis and root hairs, which provide an enormous area for absorption. The walls of the root cells are made up of threads, referred to as **cellulose fibrils**. The open spaces between the fibrils are filled with water, which means that water can move through the cell walls from one cell to another. The **apoplast** is a network of spaces between plant cells, including the spaces in cell walls and between cells. The movement of water through the apoplast is called **apoplastic movement**.

Water can also be absorbed by the root hairs through the process of **osmosis**, where the area of high concentration is the soil and the area of low concentration is the epidermis or root hairs.

Symplastic movement refers to the movement of water and other molecules through the membranes of the cytoplasm inside the cells.

Osmosis

Osmosis is the flow of water and other liquids through a semi-permeable membrane, such as the thin membrane underneath the shell of an egg, from an area with high concentration to an area with low concentration, gradually evening out the liquid balance.

(There is an old practice that many desperate students have tried. It is said that if you put this book under your pillow, the knowledge will be absorbed into your head while your sleep, moving from the area of high concentration – the book – to the area of low concentration – inside your head. This would be learning through osmosis. However, osmosis unfortunately does not apply to knowledge.)

Water can therefore move from the soil through the cell membranes of the root hairs, through the cell walls of the cortex, and up to the endodermis where the water is blocked by the casparian strips in the endodermis. The water is then forced through the endodermis cells, through the pericycle and into the xylem vessels, which take the water through the root and stem into the leaves.

Information

Please Note

Cell **walls** and cell **membranes** are two different things. Cell walls are dead and allow free (apoplastic) movement of water. Cell membranes are alive and therefore selective, or semi-permeable, and allow symplastic movement of water such as through osmosis. Cell membranes are found, for example, underneath the cell wall.

4.3. Transportation

We have already seen that the vascular tissue (xylem and phloem) in the stele of the root transports food and water up and down the plant. Roots can not live directly from the nutrients and water that it absorbs from the soil – if you put only a root under the soil, it will not survive.

Roots transport the nutrients and water that it absorbs to the stem through the xylem, from where it is transported to the leaves. Through metabolic processes, the leaves produce food in the form of carbohydrates, which are then in turn transported back through the phloem in the stem and the root to feed the roots.

4.4. Specialised Roots

Facilitator Tip

Specialised roots are best understood by using physical examples or photos of such roots. Encourage learners to collect samples of their own.

Certain plants have developed roots that perform other functions beside the primary functions discussed above. These roots or parts of the roots have adapted to specific needs of the plant.

- ***Aerating roots*** are roots that rise above the ground or above water, as with some mangrove genera.
- ***Aerial roots*** are roots that are entirely above the ground, as with ivy or epiphytic orchids. They function as prop roots or anchor roots.
- ***Contractile roots*** pull bulbs or corms of monocots deeper into the soil by expanding radially and contracting longitudinally.
- ***Haustorial roots*** are the roots of parasitic plants, such as in mistletoe, and can absorb water and nutrients from other plants.
- ***Stilt roots*** are adventitious support roots and are common among mangroves. They grow down from lateral branches down to the soil.
- ***Storage roots*** are roots that have been modified for storage of nutrients, such as carrots, sweet potato, cassava and beetroot.
- ***Tuberous roots*** have a portion that forms into a roundish knob or sausage, called a tuber, for food storage.

5. Plant Fertilisation

In commercial agriculture, plants are provided with additional nutrients through fertilisation. Fertilisers can be applied directly to the leaves of the plant, but mostly they are applied to the soil in the form of granules or liquids. Fertilisers are also sometimes mixed with and applied through the irrigation water, a practice that is referred to as **fertigation**.

Mineral fertilisers are made up of salts. When a mineral fertiliser is applied to the soil, the salt dissolves in the soil water and breaks up into ions. Plants roots can only take up nutrients in the inonised form, such as Mg^{2+} or SO_4^{2-}, the ionised form of the salt $MgSO_4$ (magnesium sulphate). The plant cannot distinguish between ions coming from organic fertilisers or mineral fertilisers. The only difference is that organic fertilisers have to be broken down by micro-organisms before the ions can be taken up by the roots.

There are many factors that affect how easily and well plants absorb nutrients from the soil. The most important factors are:

- The form of fertiliser that is used. Inorganic, fast-release and liquid forms are absorbed faster than organic, slow-release and dry forms.
- The type of soil that the plant grows in. Clay particles and organic matter bind more nutrients than sand.
- The moisture content and temperature of the soil. Nutrient uptake is faster in moist, warm soils.
- The vigour of the plant. Plants under stress are less able to take up available nutrients due to damaged or reduced root systems.

6. Geotropism in Roots and Stems

Facilitator Tip

This is best explained by asking questions such as: "What makes roots grow downwards?" and "Why are roots not in the air?". Also mention that experiments have been done where seeds were allowed to germinate, after which the plants were turned on their side. The roots turned in response to gravity and grew downwards, even though this meant growing perpendicular to the direction in which they would normally grow. Stems turned to grow upward.

Definition

Gravitropism (Geotropism)

Gravitropism, also referred to as geotropism, is a turning or growth movement by a plant in response to gravity. *Gravi–* refers to gravity as being the force that pulls everything towards the centre of the earth, and *–tropism* means the turning in response to a stimulus.

At germination, roots grow downward due to gravitropism, the growth mechanism of plants that also causes the shoot to grow upward. Roots show positive gravitropism, meaning that they grow downward in the direction of gravitational pull and stems show negative gravitropism, meaning that they grow upwards in the opposite direction of gravitational pull.

The root cap is essential to gravitropism, because it contains the sensors that detect gravitational pull. If the root cap is removed, the root will no longer grow downwards.

The effect of gravitropism can be illustrated by planting a maize seed with the pointed end, which is the end from which the radicle will emerge, pointing upwards. At germination, the root will turn around and grow downwards. The gravitropism of stems can be illustrated by laying a potted plant on its side. The stems will grow upward, vertical to the direction in which they grew before.

In some plants, such as ivy, the roots cling to walls and structures; this is known as **thigmotropism**, or response to touch or contact. Usually thigmotropism occurs when plants grow around a surface, such as a wall, pot or trellis. Climbing plants, such as vines, contain tendrils that coil around supporting objects.

Phototropism means turning towards the light. Stems and leaves grow in response to negative geotropism and positive phototropism.

7. Root System of Citrus

Facilitator Tip

If possible, show an example of a small citrus tree and its root system or show a photo or illustration of a citrus tree. Encourage learners to identify the root system and think about the difference between citrus root systems and others seen on the weeds that was studied earlier.

The citrus tree has a tap root system, consisting of a substantial tap root and a number of lateral or side-roots that grow horizontally, referred to as **plagiotropic** growth. The root system is relatively shallow, growing only to the depth of 30cm to 60cm.

Definition

Plagiotropism

Plagiotropism is the tendency of a plant's roots, stems or branches to grow at an angle away from the vertical.

The lateral roots constitute the majority of the root system. These feeding roots are the end ramifications of the root system and are usually fibrous.

Active growth of the roots is cyclical, with growth taking place when the shoots are not actively growing. In citrus, there are usually three or more growth flushes per year.

Facilitator Tip

Summary

This is an opportunity to check the progress that learners have made.

Allow time for the learners to read through the summary and to gauge their own progress. Make sure that each and every learner gets and opportunity to ask questions.

Allow learners to become familiar with the use of a glossary and to refer back to it when necessary.

Chapter 2

- The structure and growth habits of roots have a pronounced effect on the size and vigour of the plant, the ability of the plant to adapt to certain soil types, the response of the plant to production practices and irrigation, and the method of propagation.
- There are two main types of root systems, being the tap root system and the adventitious root system.
- A root consists of the root cap, the region of cell division (meristematic region), the region of elongation, the root hair region, and the mature region.
- The internal parts of the tap root are the epidermis, cortex, and vascular cylinder (stele).
- The vascular cylinder is enclosed by the endodermis (the innermost layer of the cortex), and consists of the pericycle and vascular tissue, which consists of xylem and phloem.
- The primary functions of roots are to anchor the plant, to take up water and nutrients, and to transport water and nutrients into the stem and carbohydrates back to the roots.
- Certain plants have developed roots that perform other functions beside the primary functions.
- In commercial agriculture, plants are provided with additional nutrients through fertilisation.
- Gravitropism, also referred to as geotropism, is a turning or growth movement by a plant in response to gravity. Roots have positive gravitropism and stems have negative gravitropism.
- The citrus tree has a tap root system, consisting of a substantial tap root and a number of lateral or side-roots, which grow horizontally and are relatively shallow. The feeding roots are the end ramifications of the root system and are usually fibrous.

Glossary	
Adventitious	The term adventitious means developing in an unusual position. In terms of root development, it means roots that grow from the stem or leaf.
Apoplast	The apoplast is the network of interconnected spaces within the tissues of a plant, including spaces within the cell walls and between cells. Movement of water through these empty spaces are called **apoplastic movement**.
Cellulose Fibrils	Cellulose fibrils are the "threads" that make up the walls of root cells.
Cortex	The cortex is the internal part of the root between the epidermis and the central vascular cylinder (stele).
Endodermis	The endodermis is the "inside skin" of the cortex, and is between the cortex and the stele.
Epidermis	Epidermis literally means "over skin" (epi=over / around and dermis=skin). The outer skin of most plant parts is called the epidermis.
Exodermis	The exodermis is the "outside skin" or outer cell layer of the cortex.
Fibrous Root System	A fibrous root system consists entirely of fibrous roots, which are thin and hair-like roots that usually contain more fibres than other roots.
Gravitropism (Geotropism)	Gravitropism, also referred to as geotropism, is a turning or growth movement by a plant in response to gravity. *Gravi–* refers to gravity as being the force that pulls everything towards the centre of the earth, and *–tropism* means the turning in response to a stimulus.
Meristematic Region	The meristematic region of the root is where cell division takes place, and is immediately behind the root cap.

Osmosis	Osmosis is the flow of water and other liquids through a membrane (or skin such as a cell wall) from an area with high concentration to an area with low concentration, gradually evening out the balance.
Parenchyma	Parenchyma tissue is soft plant tissue made up of thin-walled cells that forms the greater part of leaves, stem pith, roots and fruit pulp.
Pericycle	The pericycle is the outer layer of the stele.
Phloem	Phloem is a tissue that contains sieve cells that transport carbohydrates and other metabolites from the leaves, where they are manufactured, to the rest of the plant.
Plagiotropism	Plagiotropism is the tendency of a plant's roots, stems or branches to grow at an angle away from the vertical.
Stele	The stele is the central part of the root, also called the vascular cylinder.
Suberin	Suberin is a corky substance that thickens the side walls of the endodermis cells and cork cells in the bark.
Thigmotropism	Thigmotropism is the turning or growth movement by a plant in response to touch, such as in the case of vines and climbing plants.
Tracheid	A tracheid is a xylem cell that has been modified to carry water and nutrients.
Xylem	Xylem is tissue that contains cells like vessels and tracheids that transport water and nutrients from the roots to the leaves, where it is used for food production.

Practical

Complete activities 3 and 4 in the **Learner Workbook**.

Facilitator Tip

<u>Activity 3 – Worksheet</u>

Allow learners time to revise what they have learnt about roots by answering this activity.

Timeframe: 45min

<u>Activity 4 – Class Discussion</u>

Lead a conclusive class discussion about the tropisms found in plants and encourage learners to answer the questions in their own words and as they understand it.

Timeframe: 1h

Chapter 3

After completing this chapter, the learner will be able to:

Demonstrate an understanding of different stem types.

Timeframe

You have to complete this section as follows:

Total time	*Theory*	*Practical*
6h	4h 30min	1h 30min activities

1. Introduction

A stem is a plant structure that develops from a bud to bear leaves and form buds. Stems have swellings at certain points called **nodes**, which is a point on a stem where a leaf is or was attached. The area between nodes is termed the **internode**.

Stems usually grow above the ground and are positively **phototropic**, meaning that they grow towards light, and negatively gravitropic, meaning that they grow away from the ground, except in the case of certain modified, or metamorphic, stems. The main stem develops from the plumule of the embryo, while lateral branches develop from axiliary buds or from adventitious buds. On young stems, clearly defined internodes and nodes can be distinguished.

2. Internal Structure of Dicot Stem

Facilitator Tip

Explain to learners that the internal structures of stems are mostly not visible except through a microscope. Where possible, show pictures, illustrations and photos to show these structures. Encourage learners however to collect physical examples of young and older stems, and to study the structures that are visible to the naked eye.

If a stem is cut across and studied under a microscope, the same areas can be identified as for a root, being:

- Epidermis
- Cortex
- Vascular cylinder or stele

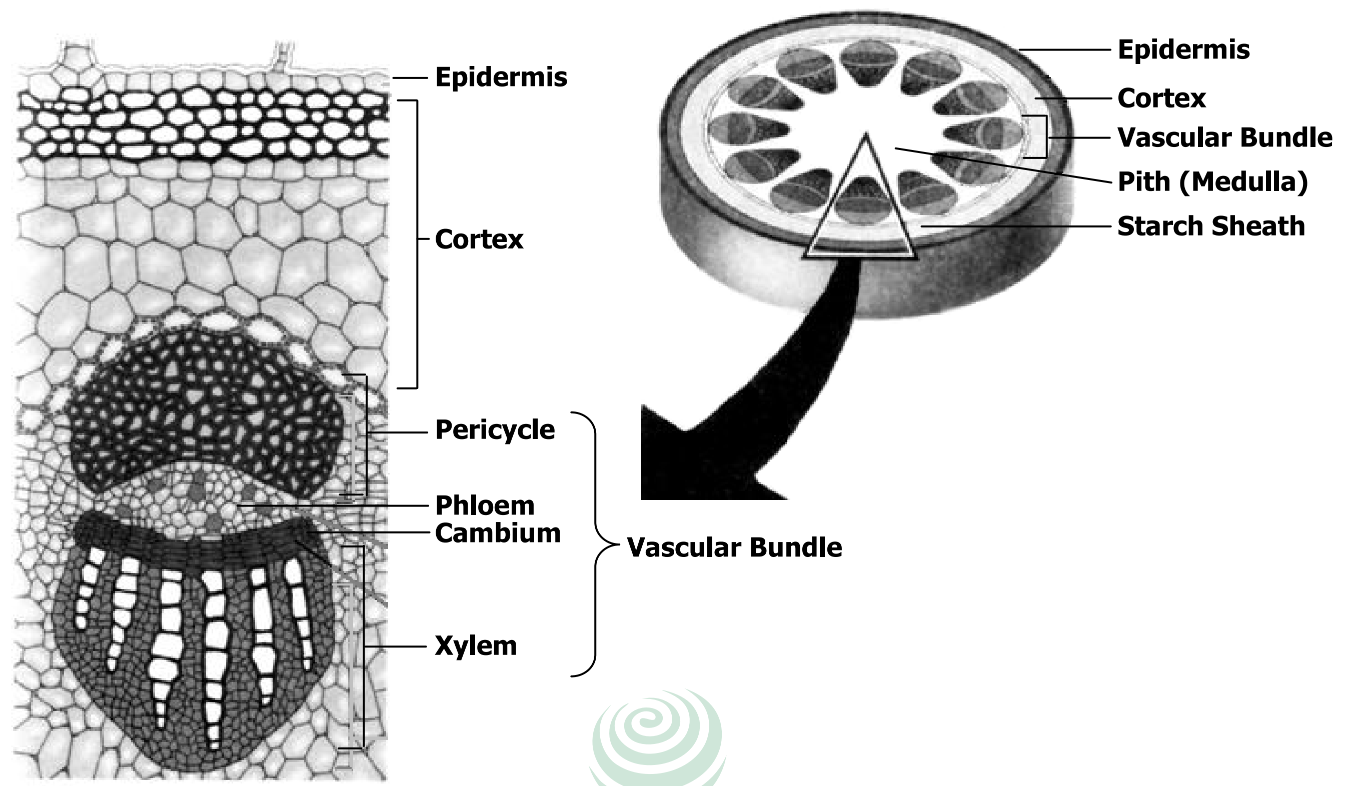


Figure 3.1: Internal Structure of Stem

2.1. Epidermis

In young stems, the epidermis consists of a single layer of living cells which are closely packed. Modified epidermal cells can be guard cells of the stomata or **trichomes**, which are epidermal hairs of various kinds.

Stomata

Stomata is the plural of stoma, which is a tiny pore surrounded by two guard cells in the epidermis of a plant leaf or stem that controls the passing of water vapour and other gasses into and out of the plant.

In the older stems of woody plants, a cork cambium develops underneath the epidermis and forms cork layers that protect the inner tissues. The outer cell walls of the epidermis are thickened and covered with a thin waterproof layer, called the cuticle. The epidermis protects the underlying tissues. The cuticle limits water loss, and stomata allow gaseous exchange for the processes of respiration and photosynthesis.

2.2. Cortex

As is the case with roots, the cortex is the layer between the epidermis and the stele of the stem. The cortex cells may also contain chloroplasts if the stem is still young. The cortex consists of the **collenchyma**, parenchyma cells and the endodermis, or starch sheath.

2.3. Vascular Cylinder (Stele) of a Dicot Stem

This region comprises the:

- Vascular bundles
- Pith, or medulla

2.3.1. Vascular Bundles

The vascular bundles are arranged in a ring on the inside of the pericycle. This distinct ring of vascular bundles is a distinguishing characteristic of dicotyledonous stems.

Between each vascular bundle is a band of parenchyma cells which runs from the cortex to the pith, also called the medulla. These are referred to as the **medullary rays**.

A mature vascular bundle consists of three main tissues, being xylem, phloem and **cambium**. The phloem is located towards the outside of the bundle and the xylem towards the centre. The cambium separates the xylem and phloem and gives rise to new phloem and xylem cells. As the tree grows, new phloem is produced towards the outside and new xylem towards the inside, creating secondary, tertiary, etc. vascular tissue, causing stems to grow thicker and forming what is commonly known as annual rings or growth rings.

The vessels and tracheids of the xylem provide a passage for water and dissolved nutrients to be transported from the root system to the leaves. The xylem fibres, xylem vessels, xylem tracheids and thick walled xylem parenchyma, collectively known as wood, strengthen and support the stem.

The phloem, with its sieve tube cells and companion cells, transports synthesised organic food from the leaves to other parts of the plant.

2.3.2. Pith (Medulla)

The pith occupies the central part of the stem. It consists of thin-walled parenchyma cells with intercellular air spaces. The medullary rays start in the pith and runs between the vascular bundles to the cortex.

The cells of the pith store water and starch and allow for the exchange of gases through the intercellular air spaces. The medullary rays transport substances from the xylem and phloem to the inner and outer parts of the stem.

3. Stem and Trunk Types

Facilitator Tip

Show physical examples, photos and illustrations of different types of stems. Encourage learners to discuss the stem or trunk types that they have come across.

There are different types of stem and trunks that perform different functions. The main types are:

- ***Herbaceous stems*** are the stems of herbs with very little secondary growth and those of most monocot plants, such as grasses, that have no secondary growth.

- ***Woody stems*** are the stems of dicot plants and have extensive secondary thickening growth. Woody stems are the product of secondary thickening growth and a source for wood. Stems of some monocot plants, such as bamboo and some palms, can also be woody, but have no secondary thickening growth.

- ***Stems of vines*** are long, slender stems that cannot support themselves and use other plants or structures to support them, such as runner beans.

- ***Tubers*** are the fleshy, terminal end of an underground stem. Tubers can be used for propagation, and some tubers are edible, such as potatoes.

- ***Rhizomes*** are swollen underground stems with distinct nodes and internodes, which is how they can be distinguished from roots. Examples are the iris and kikuju grass. Rhizomes can be used for propagation.

- ***Corms*** are swollen stem bases, as if found with gladiolus, and can be used for propagation.

- ***Bulbs*** are reduced stems with succulent leaf bases covering the growing point, such as if found with onions. Bulbs can be used for propagation and some bulbs are edible.

Stems can also be adapted as runners, tendrils, or thorns. The tendrils of grapes and virginia creeper are modified stems. Keep in mind that in some species tendrils may be modified leaves.

4. Stem Functions

Stems form the framework of the plant, exposing the leaves to the maximum available sunlight. A good example is vines that are often found in forests. They do not spend energy to develop strong stems, but rather use other supports to grow out of the forest canopy as quickly as possible to expose their leaves to the sun.

Stems contain vascular tissue like the vessels and tracheids of the xylem that transport water and dissolved minerals from the roots to other plant organs, such as the leaves, flower and fruit. The sieve tubes and sieve cells of the phloem transport organic products from the leaves to other plant organs, such as stem growing points, flowers, fruit, seed and roots where it is utilised for energy or stored as reserve food.

5. Stems of Citrus

Facilitator Tip

Hold this discussion in a citrus orchard. Ensure that all learners can identify the position of the trunk and discuss what is going on inside the trunk. Learners should have some experience with the plant manipulation technique of girdling. Discuss how girdling would affect the tree.

The concepts of the apical bud and the meristem are best explained by pointing out their location on a physical example. Also ask the following questions: "How do plants get taller?" and "How do plants develop thicker trunks?".

Above ground, the citrus tree consists of a main stem, or trunk, from which branches develop, which in turn develop a number of further and smaller branches, on which the leaves are borne. The citrus tree is therefore a complex, branched tree. This growth habit has implications for production practices.

In the case of citrus, thorns are present, especially in juvenile trees and certain groups, such as lemons. Thorns are modified stems, formed in the axils of leaves.

Initially, the citrus tree grows from the **apical bud**, but soon begins to produce lateral **meristems**, commonly known as buds, in the axils of the leaves, and the branching starts with increasing complexity as the tree ages.

Apical Bud

The apical bud is the growth point of a stem, containing the apical meristem.

Meristem

Meristems are embryonic plant tissue where cell division takes place, such as the apical meristems of stems and roots. The vascular cambium is a lateral meristem causing secondary thickening growth of stems and roots.

Summary

This is an opportunity to check the progress that learners have made.

Allow time for the learners to read through the summary and to gauge their own progress. Make sure that each and every learner gets and opportunity to ask questions.

Allow learners to become familiar with the use of a glossary and to refer back to it when necessary.

Chapter 3

- Stems usually grow above the ground and are positively phototropic, meaning that they grow towards light, and negatively gravitropic, meaning that they grow away from the force of gravity.
- On normal stems, clearly defined internodes and nodes can be distinguished.
- Internally the same areas can be identified in a stem as in a root, being the epidermis, the cortex and the vascular cylinder or stele.
- The vascular cylinder or stele consists of the pericycle, the vascular bundles and the pith, or medulla.
- The vascular bundle contains xylem and phloem.
- Stems form the framework of the plant, exposing the leaves to the maximum available sunlight.
- The vascular tissue in the stem (xylem and phloem) transports water and dissolved minerals from the roots to other plant organs.
- Above ground, the citrus tree consists of a main stem, or trunk, from which branches develop, which in turn develop a number of further and smaller branches, on which the leaves are borne.

Glossary	
Apical Bud	The apical bud is the growth point of a stem, containing the apical meristem.

Cambium	Cambium is a cylindrical layer of cells that gives rise to new cells, such as xylem and phloem cells.
Chloroplast	Chloroplasts are part of plant cells that contains chlorophyll and makes the plant part green.
Collenchyma	The collenchyma is a special kind of strengthening tissue in the cortex of many herbaceous stems.
Internodes	Internodes are the stem sections between the nodes.
Medulla	The medulla is the pith of the stem.
Medullary Rays	Medullary rays are bands of parenchyma cells that run from the cortex to the medulla between the vascular bundles in a stem.
Meristem	Meristems are embryonic plant tissue where cell division takes place, such as the apical meristems of stems and roots. The vascular cambium is a lateral meristem causing secondary thickening growth of stems and roots.
Nodes	Nodes are locations on the stem where leaves are or were attached and where vascular strands branch out to the leaves.
Phototropic	Phototropic means the turning or growing of a plant towards the light.
Rhizomes	Rhizomes are swollen underground stems that can be used for propagation.
Stomata (S: Stoma)	Stomata is the plural of stoma, which is a tiny pore surrounded by two guard cells in the epidermis of a plant leaf or stem that controls the passing of water vapour and other gasses into and out of the plant.
Trichome	A trichomes, or plant hairs, are unicellular or multi-cellular outgrowths of the epidermis. Trichomes have various shapes and functions, and include root hairs.

Practical

Complete activity 5 in the **Learner Workbook**.

Facilitator Tip

<u>Activity 5 – Worksheet</u>

Encourage learners to answer the worksheet in their own words and to check their own progress.

Timeframe: 1h 30min

Chapter 4

After completing this chapter, the learner will be able to:

The different types of leaves and the role leaves play in food production for the plant are identified.

Timeframe

You have to complete this section as follows:

Total time	Theory	Practical
8h 30min	6h 30min	2h activities

Facilitator Tip

Allow learners to collect examples of leaves and bring it to class. Encourage them to collect as many different types of leaves as possible. Hold the discussions that follow around the leaves that have been collected. Encourage learners to identify the external features on all the different types of leaves. Ensure that there are leaves of grassy plants (monocots) that do not have petioles, and other leaves with extraordinary features.

1. Introduction

The leaves, also called the foliage, of a plant are probably their most noticeable organs. Leaves grow from the stem apex or stem apical meristem, of plants. During their development, leaves can take on different forms, depending on the function that they have to perform.

2. External Leaf Structure

A typical foliage leaf consists of a large, flat leaf blade, or **lamina**, a leaf stalk, or **petiole**, and a leaf base with which the leaf is attached to the stem. The leaves of monocot plants do not have petioles, and are attached to the stem by means of a leaf sheath, which is a special kind of leaf base enclosing part of the stem above the node.

Veins are visible on the lamina of some leaves. Veins are in fact the vascular cylinders of leaves, which may continue from the petiole along the middle of the leaf to form a midrib, with smaller cylinders branching out to form veins. The vascular cylinders may also run parallel on the lamina. The way in which the veins are arranged, is referred to as the **venation** of the leaf.

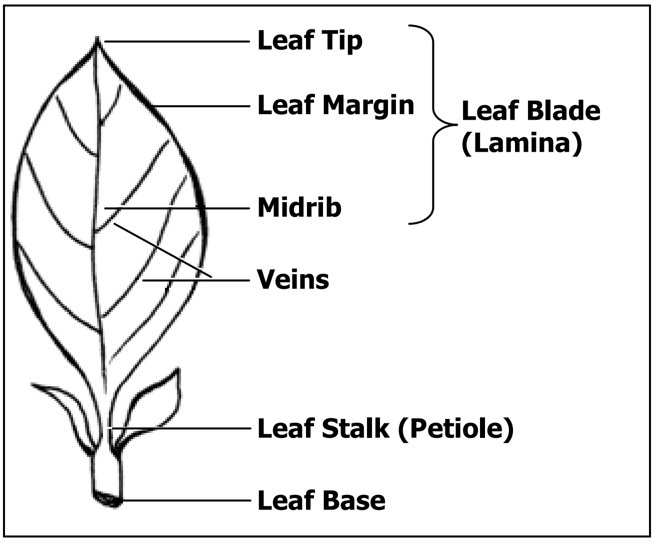


Figure 4.1: External Structure of a Leaf

3. Internal Leaf Structure

If the leaf of a citrus plant is cut the following types of tissue can be distinguished under a microscope, as can be seen in the picture below:

- Upper epidermis
- Palisade parenchyma
- Spongy parenchyma
- Vascular cylinders
- Lower epidermis with stomata

The palisade parenchyma and spongy parenchyma is collectively known as **mesophyll**. "Meso" means middle or between, and "phyll" means leaf. Mesophyll refers to the position between the upper and lower epidermis.

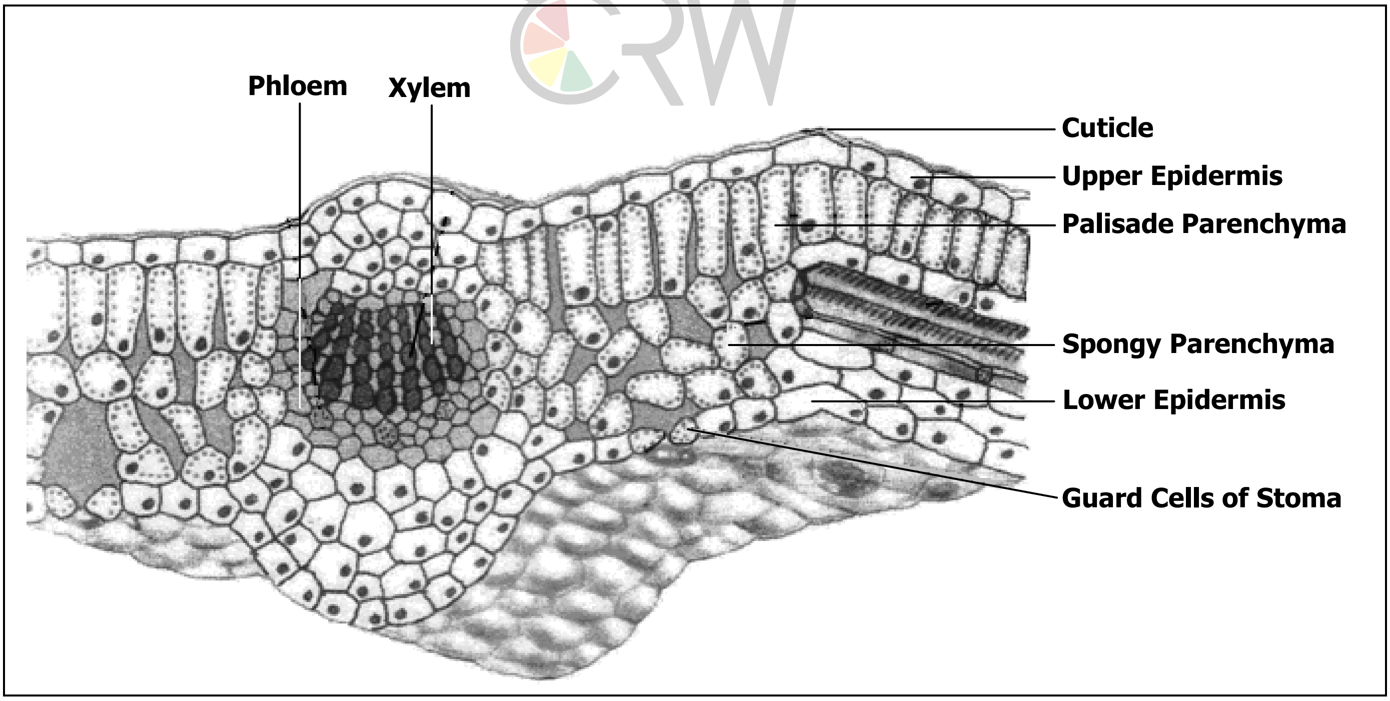


Figure 4.2: Cross Section of Bifacial Leaf of Dicot Plant

Information

Please Note

Bifacial means having two faces, and refers to the upper and lower leaf surfaces. Some leaves, such as round leaves, are unifacial.

Facilitator Tip

Remind learners that the internal structure of the leaf is only visible through a microscope. The terms used are difficult and learners could become bored with too much theoretical discussion. Constantly send the physical examples around and do experiments where the leaves are "dissected" and the differences are pointed out.

3.1. Upper Epidermis

The upper epidermis is usually only one cell layer thick. The epidermis protects the underlying tissue.

3.2. Palisade Parenchyma

The upper epidermis encloses long, vertical and tightly packed cells known as palisade cells. This layer contains an abundance of chloroplasts containing the green chlorophyll. This is the site where photosynthesis takes place.

Note that the palisade and spongy parenchyma are only differentiated in some dicot plants, such as citrus.

3.3. Spongy Parenchyma

The spongy parenchyma cells are between the palisade parenchyma cells and the lower epidermis. These are irregularly shaped cells with many air spaces between them, and the tissue is therefore spongy. The vascular system is embedded in the spongy parenchyma cells.

The spaces between the spongy parenchyma cells allows for the interchange of gasses. The spaces are connected to the stomata in the lower epidermis.

3.4. Vascular Cylinders

The vascular cylinders, or veins, contain the vascular tissue which consists of xylem and phloem. The xylem cells are situated towards the upper epidermis and the phloem towards the lower epidermis. In large veins, the vascular bundles are usually surrounded by a bundle sheath.

The xylem cells are empty, modified cells that help to strengthen the leaf. The xylem cells carry water and nutrients for the photosynthetic process to the palisade parenchyma, and are therefore the input line for the carbohydrate factory.

The phloem cells are live cells that translocate carbohydrates that have been manufactured in the palisade parenchyma to the rest of the plant. The phloem is the output line for the carbohydrate factory.

3.5. Lower Epidermis

The spongy parenchyma is enclosed by the lower epidermis. The lower epidermis has openings, referred to as stomata (singular: stoma).

3.6. Stomata

Each stoma pore is surrounded by two modified epidermal cells known as guard cells. The guard cells pull apart and cause the stoma to open when they are hydrated due to the differential thickening of their walls. When not turgid, the guard cells collapse and close the stoma.

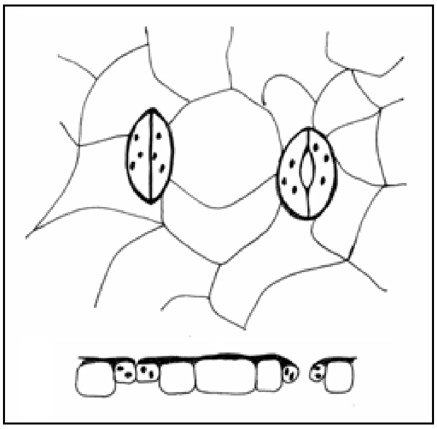


Figure 4.3: Guard Cells Opening and Closing Stomatal Pore

Stomata perform the very important functions of allowing for exchange of carbon dioxide and oxygen during photosynthesis, and for the movement of water vapour out of the leaf, referred to as **transpiration**.

The movement of water vapour out of the leaf in turn drives the movement of water from the roots to the leaves through the xylem cells, bringing with it the minerals and other compounds necessary for photosynthesis and growth.

In citrus leaves, the stomata are only found on the lower surface of the leaf, but in some plants stomata also appear in the upper epidermis and also on young stems. Stomata are also found on fruit, since the fruit develop from **carpels** that are actually modified leaves.

4. Leaf Types

Facilitator Tip

Have the learners classify the leaves that they have collected according to the types described below. Ensure that there is at least one example of each type.

Trees are classified as evergreen or deciduous, depending on whether they lose their leaves during the year or not. Evergreen trees retain their leaves for longer periods and do not lose all their leaves at the same time, while deciduous trees lose all their leaves, normally in autumn.

Leaves are classified in many different ways. The simplest classification is by:

- Composition
- Venation
- Position

4.1. Composition

The leaf blades of some plants show indentations or clefts on the outer edges. If these indentations reach all the way to the midrib so that the leaf blade is divided into a number of smaller leaflets, called pinnae, the leaf is called a compound leaf. If the leaf blade is not divided into leaflets, the leaf is termed a simple leaf.

Most monocot plants have simple leaves, while dicot plants can have simple or compound leaves. There are different types of compound leaves, where the tiny pinnae arranged in a set pattern make one compound leaf.

- Pinnate
- Twice pinnate
- Palmate
- Three-divided (trifoliate)
- Three-times-three-divided (ternate)

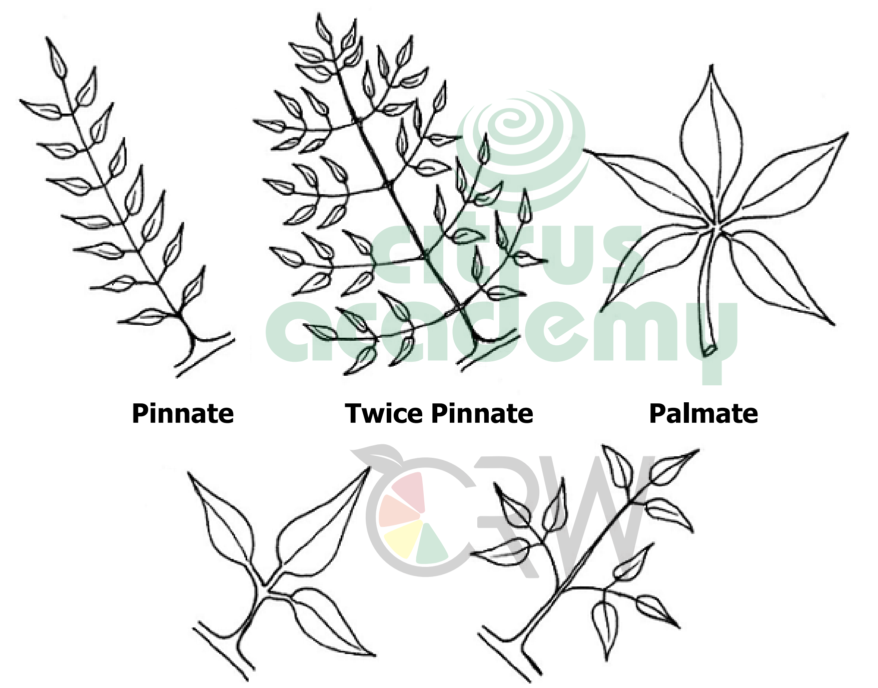


Figure 4.4: Different Types of Compound Leaves

Definition

Pinnate Pinnate means resembling a feather in appearance or structure, especially in having a central axis or stem with parts branching off.
Palmate Palmate means forming a branching pattern that spreads like fingers from a hand.

Trifoliate Trifoliate means "with three leaves", and the term is used to describe a compound leaf consisting of three pinnae that arise from the same point.
Pinnae (S: Pinna) Pinnae are the leaflets that make up a compound leaf.
Ternate Ternate means divided in three, and the term is used to describe a compound leaf that is divided into three more or less equal parts.

4.2. Venation

The manner in which the veins are arranged in the lamina is referred to as the venation of the leaf. It is described as either parallel or pinnate.

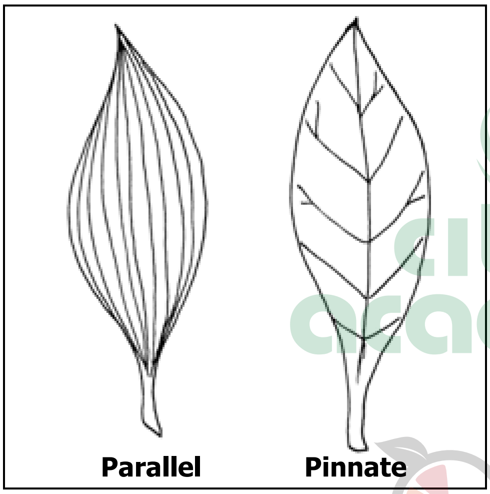


Figure 4.5: Venation of Leaves

With parallel venation, a number of vascular cylinders branch from the leaf base and run parallel on the lamina. With pinnate leaves, the vascular cylinder continues from the stem through the petiole and continues as the midrib of the leaf, and subsidiary vascular tissue branch from the midrib.

4.3. Position

Leaf position refers to the arrangement of the leaves on the stem. Figure 2.6 shows different leaf positions.

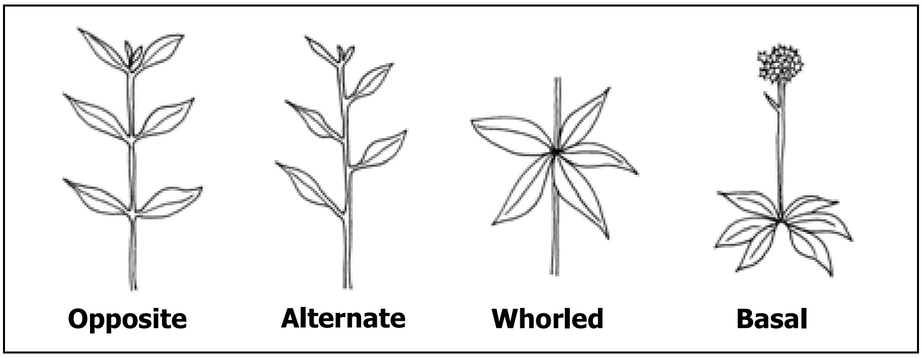


Figure 4.6: Leaf Positions

5. Leaf Functions

Facilitator Tip

These are very important concepts because it explains many of the principles used in production practices, such as irrigation and plant manipulation (specifically canopy development). It is also essential that learners understand the principles of these processes if they are to study this skills area further.

Leaves perform three very important functions, being:

- Photosynthesis
- Transpiration
- Respiration

Definition

Respiration

Respiration is an energy-producing oxidation process in cells, the complete chemical and physical process in which oxygen is delivered to plant cells and carbon dioxide and water are given off.

5.1. Photosynthesis

The leaf is possibly the most important part of the plant, as it is here that carbohydrates are produced in the process of photosynthesis. This is the energy source for further growth and development, including that of the fruit. Chlorophyll is the main pigment responsible for photosynthesis. Photosynthesis occurs throughout the lifespan of the plant.

Facilitator Tip

Some learners may find the use of the chemical notation below intimidating. Focus on what they know – such as H_2O for water – and move on to what they are not familiar with.

The formula below summarises the process of photosynthesis:

$$6CO_2 + 12H_2O \xrightarrow{\text{Light Energy}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Information

Remember That

CO_2 = Carbon dioxide

H_2O = Water
$C_6H_{12}O_6$ = Carbohydrates (sugars)
O_2 = Oxygen

This formula means that, through using light energy, the plant is able to convert six molecules of carbon dioxide and twelve molecules of water to one molecule of carbohydrates. Six molecules of oxygen and six molecules of water come free in the process.

This formula summarises the gaseous exchange that takes place and promotes plant growth. During photosynthesis, the plant absorbs CO_2 through the stomata in the leaves, and water through the roots, which is taken to the leaves by the xylem in the vascular tissue of the roots and stem. The green pigments (chlorophyll) in the chloroplast absorb sunlight and with this energy the plant manufactures sugars (carbohydrates). Oxygen and water molecules come free, and are released through the stomata.

Global Warming

Ever heard it said that the destruction of vast tracts of natural forest, especially the rain forests, contributes to there being too much carbon dioxide in the air, leading to the greenhouse effect and global warming? This is because plants are able to absorb carbon dioxide and produce oxygen during the process of photosynthesis.

5.2. Transpiration

The loss of water vapour through the stomata is known as transpiration. Transpiration helps to cool the plant, which is why more transpiration occurs during the hot summer months, leading to a greater need for water and increased irrigation.

The loss of water through the stomata also caused water to move from the roots to other plants parts. Remember that xylem cells are empty, almost like an open pipeline, and water must be "pulled" through them. When water is lost through transpiration, osmosis causes water to move from the soil into the roots, and from there the water is "pulled" through the roots and stem to the leaves.

5.3. Respiration

Not all carbohydrates made by the plant during photosynthesis are used right away. Some carbohydrates are stored. The process by which a plant uses the stored food is called respiration. Only cells with chlorophyll can carry out photosynthesis, whereas all live cells carry out respiration.

During respiration, oxygen is taken in through the stomata, and the oxygen is used to break the stored food down into energy. Respiration produces water and carbon dioxide which is released through the stomata.

6. The Effect of Environmental Conditions on Leaves

Leaves require sunlight and air, containing oxygen and carbon dioxide, to perform its functions well. In the absence of light or in greatly reduced light, leaves become yellow due to the breaking down of the chlorophyll in the chloroplasts. Leaves are then said to be **etiolated**. The green colour will however return if the plants are returned to light. Leaves are also sensitive to heat. As soon as the temperature rises above a certain level, the stomata close, and photosynthesis ceases.

Some leaves are sensitive to touch. The pinnae of the leaves of the *Mimosa pudica* close when they are touched. The leaves of the Venus Fly Trap contain sensitive hairs and when the hairs are touched by an insect, the two halves of the leaf close quickly to catch the insect. Leaf tendrils of plants such as the sweet pea will turn around a support when they make contact

7. Citrus Leaves

Although the leaves of the citrus plant look like simple pinnately veined leaves, they are actually modified trifoliate leaves where the two lateral leaflets were lost during the evolution.

Citrus trees are evergreen, but leaves in fact live only for about three years, depending on conditions such as pests and diseases. During early leaf growth, the leaves are net importers of carbohydrates, becoming contributors only once fully expanded at four to six weeks old. They reach maximum capacity after about six months.

Facilitator Tip

Summary

This is an opportunity to check the progress that learners have made.

Allow time for the learners to read through the summary and to gauge their own progress. Make sure that each and every learner gets and opportunity to ask questions.

Allow learners to become familiar with the use of a glossary and to refer back to it when necessary.

Summary

Chapter 4

- During their development, leaves can take on different forms, depending on the function that they have to perform.
- A typical foliage leaf consists of a large, flat lamina (leaf blade) with a midrib and veins, and a petiole (leaf stalk).
- The internal structure of a leaf is made up of the upper epidermis, palisade parenchyma, spongy mesophyll parenchyma, vascular cylinders, and the lower epidermis with stomata.
- The midrib and veins are the vascular cylinders inside the leaves.
- Stomata allows for exchange of carbon dioxide for photosynthesis, and for the movement of water vapour out of the leaf, referred to as transpiration.
- Leaves are classified in many different ways. The simplest classification is by shape, composition, venation, and number per node.
- Compound leaves are where the tiny pinnae are arranged in a set pattern making one compound leaf. There are different types of compound leaves, being pinnate, twice pinnate, palmate, three-divided (trifoliate), and three-times-three-divided (ternate).
- Venation of a leaf can be either parallel or pinnate.
- Leaves perform three very important functions, being photosynthesis, transpiration and respiration.
- Leaves require sunlight and air, containing oxygen and carbon dioxide, to perform its functions well.

Glossary	
Etiolated	Etiolated is a terms used to describe a plant that is deficient in the green pigment chlorophyll owing to the lack of light.

Lamina	The lamina is the blade of the leaf.
Mesophyll Parenchyma	Irregularly shaped cells with large intercellular spaces that fill the space between the palisade parenchyma and the lower epidermis.
Palisade Parenchyma	The long, tightly-packed parenchyma cells enclosed by the upper epidermis of the leaf. The site for photosynthesis.
Palmate	Palmate means forming a branching pattern that spreads like fingers from a hand.
Petiole	The petiole is the stalk of the leaf. Some leaves do not have a petiole and are therefore **sessile**.
Pinnae (S: Pinna)	Pinnae are the leaflets that make up a compound leaf.
Pinnate	Pinnate means resembling a feather in appearance or structure, especially in having a central axis or stem with parts branching off.
Respiration	Respiration is an energy-producing oxidation process in cells, the complete chemical and physical process in which oxygen is delivered to plant cells and carbon dioxide and water are given off.
Ternate	Ternate means divided in three, and the term is used to describe a compound leaf that is divided into three more or less equal parts.
Transpiration	Transpiration means to lose water through the surface of a plant, particularly through the stomata.
Trifoliate	Trifoliate means "with three leaves", and the term is used to describe a compound leaf consisting of three pinnae that arise from the same point.

Practical

Complete activities 6 and 7 in the **Learner Workbook**.

Facilitator Tip

Activity 6 – Worksheet

Encourage learners to answer this worksheet in their own words and to check their own progress.

Timeframe: 1h

Activity 7 – Practical

Encourage learners to answer this question according to the crop they are most familiar with and to draw what they see rather than re-draw technical sketches used in this section.

Timeframe: 1h

Chapter 5

After completing this chapter, the learner will be able to:

Identify the different parts of the flower and their basic functions.

Timeframe

You have to complete this section as follows:

Total time	***Theory***	***Practical***
6h	4h 30min	1h 30min activities

Facilitator Tip

Allow learners to collect examples of different flowers. Use these samples throughout to illustrate the discussions that follow.

1. Introduction

Plants have flowers of many different shapes and sizes, with many variations in colour, number of flower parts and the arrangements of these parts. On fruit producing plants, such as citrus, flowers are also referred to as blossoms.

Flowers are the reproductive parts of plants and are responsible for the production of sex cells, or gametes. After fusion of the male and female gametes, a zygote is produced which develops into an embryo within the seed. The seed gives rise to a new flowering plant of the same kind.

2. Structure of a Flower

Facilitator Tip

Have the learners dissect a flower and identify its main parts. Alert learners to the male and female parts.

Flowers consist of whorls, which can be described as flower parts that fit into one another. From the bottom, or outside, the flower consists of the following main parts, as can be seen in figure 5.1:

- Pedicel
- Receptacle

- Perianth
- Stamen
- Pistil

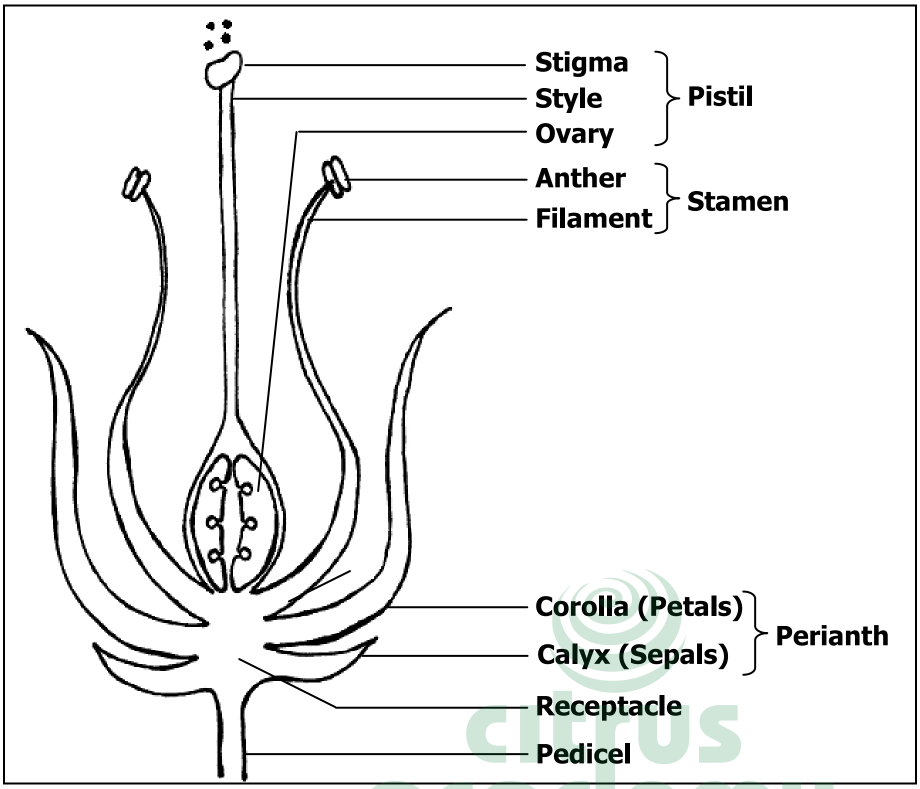


Figure 5.1: Cross-Section of a Citrus Blossom

2.1. Pedicel

The pedicel is the stalk of the flower.

2.2. Receptacle

The receptacle is a set of very closely spaced nodes to which the whorls of flower parts, or leaves, are connected.

2.3. Perianth

The perianth is the outer structure of a flower, also sometimes referred to as the flower envelope. The perianth normally consists of the:

- Calyx
- Corolla

2.3.1. Calyx

The calyx is the outermost whorl of a flower, a group of **sepals**, usually green, around the outside of a flower that encloses and protects the inner structures of the flower bud. Sepals are modified leaves that form the calyx. They are leaf-like structures located beneath the petals of a flower and are usually green.

2.3.2. Corolla

The corolla is the second whorl of the flower. Collectively, the **petals** form the corolla of a flower and form a ring around the reproductive organs.

The corolla is usually the most conspicuous part in the flower because it is usually white or brightly coloured and not green like the rest of the plant, except in wind pollinated flowers where the corolla is reduced and green as in grasses.

Petals are much larger than sepals. The petals may be separated from each other or become partly or completely fused. If the petals are completely fused they form a **corolla tube**.

The brightly-coloured corolla attracts agents of pollination such as insects and birds. The corolla also encloses and protects the stamens and pistil.

In flowers of monocots it is usually not possible to distinguish between petals and sepals and they are called tepals.

2.4. Stamen

The stamens form the third whorl on the inside of the corolla and are the male reproductive organs of a flower. Some flowers, such as citrus, have two or more whorls of stamens.

The stamen typically consists of a **filament** and an **anther**. The filament is a slender, flexible stalk that supports the anther that bears the pollen in pollen sacs. Pollen grains contain the male reproductive cells.

2.5. Pistil

The pistil is the fourth and the innermost whorl of the flower, and the female reproductive organ of the flower.

The pistil is made up of one or more carpel leaves and generally consists of the following parts:

- Stigma
- Style
- Ovary

2.5.1. Stigma

The stigma is the top part of the pistil that receives the male pollen grains. The stigma has a hairy and / or sticky surface, to retain the pollen deposited on it. The stigma may be receptive for from a few hours to some days after the flower opening.

2.5.2. Style

The style is an extension of the ovary, shaped like a stalk, and supports the stigma. The style can be solid or may have canals, or tubes, that lead from the stigma to the ovary. After pollination and fertilisation, the style begins to degenerate and abscises, meaning it falls off, where it is connected to the ovary.

2.5.3. Ovary

The ovary consists of one or more parts, or carpel leaves, forming one or more chambers, containing the ovules. The ovary will become the fruit after fertilisation of the ovules.

The chambers that contain the ovules are called **locules**, and the wall surrounding each locule is called a **carpel**. In citrus, each fruit segment is a carpel. The locules within the carpels later become filled with the juice vesicles and developing seeds if the flower was fertilised.

3. Flowers of Monocot and Dicot Plants

Facilitator Tip

Show examples of flowers of monocot and dicot plants. Discuss the differences between the structures of the flowers.

The flowers of monocot and dicot plants differ in a number of ways. The flower parts of monocot plants normally occur in multiples of three, while the flower parts of dicot plants normally occur in multiples of four or five.

In monocot plants, the calyx and corolla cannot be distinguished in the perianth, while they are differentiated in dicot plants.

4. Flower Types

Facilitator Tip

Ensure that learners understand the sexual function of the different types of plants and that they can identify the type of flower through looking at the male and female parts.

The stamens and pistils are essential whorls and usually occur in the same flower. A flower bearing both the essential whorls is bisexual. Sometimes a flower has only the stamens or only the pistils, in which case it is referred to as a unisexual flower. Female flowers, being flowers lacking stamens, are called **pistillate**, while male flowers, being flowers lacking pistils, are called **staminate**.

The calyx and the corolla are referred to as the non-essential whorls, since they are not responsible for the formation of gametes and seeds. Seed formation can occur in the absence of the outer whorls.

A flower in which all four whorls are present is said to be a complete flower. If any one of the non-essential whorls is not present, the flower is incomplete.

5. Flower Functions

The sole function of the flower, which is generally the showiest part of the plant, is sexual reproduction. Fragrance and colour are devices to attract pollinators that play an important role in the reproductive process.

Pollination is the transfer of pollen from an anther to a stigma. This may occur by wind or with the assistance of pollinators, such as insects, animals, or birds. Wind-pollinated flowers lack showy floral parts and nectar since they don't need to attract a pollinator.

The stigma ' recognises' the pollen and supplies water to the pollen grains, causing them to germinate and to form long tubes that grow down the channel inside the style to the ovules inside the ovary. Each pollen tube carries two immobile sperm cells that are released into the embryo sac, inside the ovule. Double fertilisation takes place. The first is the union of one male sperm cell and the female egg, and the second is the union of the other sperm cell with the central cell inside the embryo sac in the ovule. If fertilisation is successful, the ovule will develop into a seed.

6. Citrus Flowers

Figure 5.2: Citrus Blossom

The citrus flower has characteristics common with most typical flowers. It is composed of sepals at the base, which remains as small green leaf-like structures on the fruit, followed by the white petals, which enclose the reproductive structures. Citrus is known as a complete flower, in that both female and male components are present.

Normally, flower parts are present in citrus blossoms in multiples of five. The calyx usually consists of five sepals, with the corolla consisting of between four and eight petals, but again usually five. The usually white petals have a glossy waxed appearance and contain oil glands, as do the sepals.

The flower usually contains twenty to forty stamens, with yellow anthers at the ends of the filaments. Pollen is however not always produced in large qualities, and the pollen grains may often be degenerate. This is a characteristic of citrus, where for many years selection has been done to produce seedless fruit, resulting in trees being selected where sterility is present. This may be in the form of pollen sterility.

Facilitator Tip

Summary

This is an opportunity to check the progress that learners have made.

Allow time for the learners to read through the summary and to gauge their own progress. Make sure that each and every learner gets and opportunity to ask questions.

Allow learners to become familiar with the use of a glossary and to refer back to it when necessary.

Summary

Chapter 5

- Flowers are the reproductive parts of plants and are responsible for the production of sex cells, or gametes.
- From the bottom, or outside, the flower consists of the pedicel, receptacle, perianth, stamen and pistil.

- Flowers are also said to consist of four or more whorls, being the calyx, the corolla, one or more whorls of stamens and the pistil. The calyx and the corolla make up the perianth.
- The perianth is the outer structure of a flower, and normally consists of the calyx (group of sepals) and the corolla (group of petals).
- The pistil generally consists of the stigma, the style and the ovary.
- The flowers of monocot and dicot plants differ in a number of ways, mostly in the multiples in which flower parts are present.
- A flower in which all four whorls are present is said to be a complete flower. If any one of the non-essential whorls is not present, the flower is incomplete.
- The sole function of the flower, which is generally the showiest part of the plant, is sexual reproduction.
- The citrus flower has characteristics common with most typical flowers. Citrus has a complete flower, in that it has both female and male components.

Glossary	
Anther	The anther is a male flower part that bears the pollen in pollen sacs.
Calyx	The calyx is the outermost whorl of a flower, a group of **sepals**, usually green, around the outside of a flower that encloses and protects the flower bud.
Carpel	Modified leaves that form the pistil, including stigma, style and ovary.
Corolla	The corolla is the second whorl of modified leaves of the flower. The corolla is the **petals** of a flower collectively and forms a ring around the reproductive organs.
Filament	The filament is a slender stalk that supports the anther.
Locule	A locule is a small cavity of chamber in a plant part. In the ovary, the chambers containing the ovules are called locules.
Pedicel	The pedicel is a stalk of a flower.
Perianth	The perianth is the collective name for the calyx and corolla.
Pistil	The pistil is the innermost whorl of the flower, and the female reproductive organ of the flower.
Pistillate	Pistillate refers to female flowers that contain one or more pistils but no stamens.
Pollination	Pollination is the transfer of pollen from an anther to a stigma.
Receptacle	The receptacle is a set of very closely spaced nodes to which the whorls of flower parts, or modified leaves, are connected.
Sepal	Sepals are modified leaves that form the calyx.
Stamen	The stamens form the third whorl of modified leaves on the inside of the corolla and are the male reproductive organs of a flower.
Staminate	Staminate refers to male flowers that contain one or more stamens but no pistils.
Stigma	The stigma is the top part of the pistil that receives the male pollen grains.
Style	The style is an extension of the ovary, shaped like a stalk, and supports the stigma.

Practical

Complete activities 8 and 9 in the **Learner Workbook**.

Facilitator Tip

Activity 8 – Make a Sketch Encourage learners to make the drawing from an example that they have found and to draw what they see. **Timeframe:** 45min
Activity 9 – Worksheet Encourage learners to answer this worksheet in their own words and to check their own progress. **Timeframe:** 45min

Chapter 6

After completing this chapter, the learner will be able to:

Demonstrate an understanding of the different types and parts of a fruit.

Timeframe

You have to complete this section as follows:

Total time	***Theory***	***Practical***
10h	5h	2h 30min activities 2h 30min site visit to a nursery or farm to identify all the plant structures

1. Introduction

The fruit develops from the ovary contained in the flower. The fruit normally contains the seeds that contain the zygotic embryos. The fruit protects the seed and guarantee their dispersal.

2. Structure of Fruit

Facilitator Tip

Bring as many different fruit as possible as examples. First look at their external differences and then cut the fruit open to discuss their internal differences. Use these fruit in the discussions that follow.

Fruit normally consists of a **pericarp** and one or more seeds. The pericarp is the fruit wall, the part of a fruit that surrounds the seed or seeds, including the skin and flesh in the case of fleshy fruit. The pericarp in fleshy fruit in turn consists of the:

- Exocarp
- Mesocarp
- Endocarp

In dry fruit it is not possible to distinguish between these three layers.

The pericarp develops into the parts around the seed(s) as the fruit ripens. The exocarp, mesocarp and endocarp take on different roles in different types of fruit.

The exocarp is the outer covering. In a mango and peach, for instance, it is what we know as the skin. The mesocarp is the middle covering what we call the flesh in a mango or peach. The endocarp is the inner covering, in many cases the stiffened part covering the seed. In all stone fruit types such as peach, plum, apricot and mango, it is commonly know as the stone. The seed is normally enclosed in the endocarp.

3. Fruit Classification and Types

The classification below includes most of the common types of fruits. Please note that this only highlights some of the classification types. Fruit is classified in major groups as follows:

- Single fruit
- Aggregate fruit
- Multiple fruit

3.1. Single Fruit

Single fruit are fruit that develops from a single ovary from a single flower. There are two major classifications for single fruit, being:

- Single fleshy fruit
- Single dry fruit

3.1.1. Single Fleshy Fruit

The pericarp of single fleshy fruit is soft and fleshy. Single fleshy fruit is further classified as:

- Drupe or stone fruit
- Berry
- Pepo
- Pome

3.1.1.1. Drupe or Stone Fruit

In drupe or stone fruit, such as peach and mango, the exocarp forms the peel, the mesocarp forms the soft edible part, and the endocarp is a hard, stone- or leather-like layer surrounding the seed. These fruits develop from a single carpel and from flowers with superior ovaries.

3.1.1.2. Berry Fruit

Berry fruit are also fleshy, but the mesocarp and endocarp are both fleshy and, in most cases, not distinguishable from each other, for instance grape berry, tomatoes, papayas, avocado, blueberries and gooseberries.

In other berry fruit, such as citrus, the exocarp forms the skin, the mesocarp forms the **albedo**, which is the spongy white tissue inside the skin, and the endocarp forms the fleshy, juicy tissue that is divided into segments by **septa (singular: septum)**.

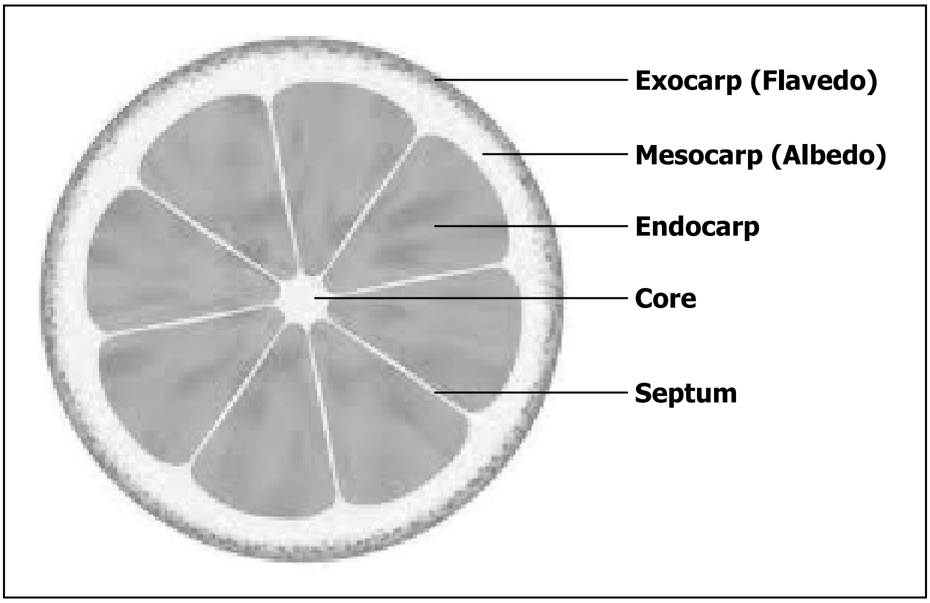


Figure 6.1: Citrus Fruit

3.1.1.3. Pepo Fruit

Pepo fruit is a fruit of the gourd family such as a melon, squash, pumpkin, or cucumber that typically has a firm or hard rind, a large number of flat seeds, and soft watery flesh. Pepo fruit are actually also berries, but the carpels are imbedded in the concave receptacle, also referred to as an inferior ovary, that takes part in the formation of the fruit wall.

3.1.1.4. Pome Fruit

Pome fruit is a fleshy fruit that has a central core typically containing five seeds, for example an apple or pear. Pome fruit also derives from an inferior ovary with the receptacle taking part in the formation of the fleshy fruit wall, but it also has a firm, partly woody endocarp surrounding the seeds.

3.1.2. Single Dry Fruit

In single dry fruits, the pericarp in the mature fruit is a dry, leathery or papery structure and the exocarp, mesocarp and endocarp are not differentiated. Single dry fruit includes:

- Nuts
- Achenes
- Capsules
- Pods or legumes

3.1.2.1. Nuts

Nuts are indehiscent (not opening) fruit consisting of a single carpel, for instance the nuts falling from oak trees.

3.1.2.2. Achenes

An achene fruit is a dry single-seeded fruit that does not open to release its seed. Dandelions and sunflowers have achenes.

3.1.2.3. Capsules

Capsule fruit is a single, dry dehiscent fruit, usually consisting of more than one carpel. The mature fruit dehisces, meaning it opens by itself, and the seeds are distributed, for example the Strelitzia fruit.

3.1.2.4. Pods or Legumes

Pods or legumes are also a dehiscent fruit, but consists of one carpel only, for instance pea pods, beans, soybeans, and most of the acacias.

Definition

Dehiscent Dehiscent means to burst open, releasing seeds, pollen, or spores.
Indehiscent Indehiscent means not opening up to release seeds when ripe.

3.2. Aggregate Fruit

Aggregate fruit derive from a single flower, but is made up of a number of separate ovaries on the same receptacle, for example the strawberry which consist of an aggregation of small drupelets.

3.3. Multiple Fruit

Multiple fruit are actually a collection of fruit on a common inflorescence axis. An example of a multiple fruit is the pineapple, which is a collection of fleshy fruit and flower parts collected on a common axis.

4. Citrus Fruit

Facilitator Tip

Spend time examining examples of citrus fruit and point out how it differs from the other fruit. Pay specific attention to its shape and the location of the external and internal structures thereof.

Citrus fits into the category fleshy single fruit, because the pericarp is fleshy and juicy when mature, and a sub-category called a berry, because the pericarp is fleshy throughout. There are some further specialised types of berries, with citrus called a **hesperidium**. This is characterised by a leathery exocarp and mesocarp, which forms the fruit rind, and a juicy endocarp divided into segments.

In citrus, the exocarp is a few cells thick, has a waxy cuticle on the outer side, contains pigments which give it the green or orange colour, and contains oil glands. The mesocarp contains loosely packed cells with many air spaces, which later become the albedo, being the white tissue under the outer exocarp cells. The endocarp contains the segments and juice vesicles, and becomes the edible portion. Segments are actually the insides of separate carpels and are divided by membranes referred to as septa, which form the margins of the folded carpels. The juice vesicles are outgrowths of the endocarp. The seeds, if present, are found within the endocarp.

While it is normally necessary for pollination and fertilisation to take place for the ovary to develop into a fruit, in some fruits, which includes some forms of citrus to varying extents, this is not necessary. The ovary may be able to develop further without fertilisation. This is called **parthenocarpy**.

Facilitator Tip

At the end of this session, arrange a site visit to either a citrus farm or a citrus nursery where learners can revise and see all the structures discussed in this module on citrus plants. Encourage learners to ask questions and share knowledge during this session.

Facilitator Tip

Summary

This is an opportunity to check the progress that learners have made.

Allow time for the learners to read through the summary and to gauge their own progress. Make sure that each and every learner gets and opportunity to ask questions.

Allow learners to become familiar with the use of a glossary and to refer back to it when necessary.

Summary

Chapter 6

- The fruit normally contains the seeds that contain the zygotic embryos. The fruit protects the seed and guarantee their dispersal.
- Fruit normally consists of a pericarp and a seed. The pericarp in turn consists of the exocarp, mesocarp and endocarp.
- The pericarp develops into the parts around the seed(s) as the fruit ripens.
- Fruit is classified in major groups as single fruit, aggregate fruit or multiple fruit.
- There are two major classifications for single fruit, being single fleshy fruit and single dry fruit.
- Single fleshy fruit is further classified as drupe or stone, berries, pepo, and pome.
- Single dry fruit includes nuts, achenes, capsules, and pods or legumes.
- Citrus fits into the category fleshy single fruit, because the pericarp is fleshy and juicy when mature, and a sub-category called a berry, because the pericarp is fleshy throughout.

Glossary	
Achene Fruit	An achene fruit is a dry single-seeded fruit that does not open to release its seed. Dandelions and sunflowers have achenes.
Albedo	Albedo is the spongy white tissue inside the skin of a citrus fruit.
Dehiscent	Dehiscent means to burst open, releasing seeds, pollen, or spores.
Drupe Fruit (Stone)	A drupe fruit has a thin outer skin, soft pulpy middle, and hard stony central part enclosing a seed.

Endocarp	The innermost layer or the fruit wall, or pericarp.
Exocarp	The outer layer or the fruit wall, or pericarp.
Hesperidium	Hesperidium fruit are a sub-type of berry fruit, and is a fruit, for example citrus, made up of a thick leathery rind and soft segmented pulp.
Indehiscent	Indehiscent means not opening up to release seeds when ripe.
Mesocarp (Mericarp)	The middle layer or the fruit wall, or pericarp.
Parthenocarpy	Parthenocarpy means the production of fruits without fertilisation or seeds.
Pepo Fruit	Pepo fruit is a fruit of the gourd family such as a melon, squash, pumpkin, or cucumber that develops from an inferior ovary and typically has a firm or hard rind, a large number of flat seeds, and soft watery flesh.
Pericarp	The pericarp is the fruit wall, the part of a fruit that surrounds the seed or seeds, including the skin, flesh, and stone if present.
Pome Fruit	Pome fruit is a fleshy fruit that has a central core typically containing five seeds, for example an apple or pear. They derive from inferior ovaries and the receptacle forms part of the fleshy part.
Septum	Septum in a thin partition or membrane. In citrus fruit, septum partitions the segments in the fruit.

Practical

Complete activities 10 and 11 in the **Learner Workbook**.

Facilitator Tip

Activity 10 – Practical

Encourage learners to answer this question individually and to look at fruit other than citrus when answering it.

Timeframe: 1h

Activity 11 – Make a Sketch

Encourage learners to answer this question from their experience in the orchards or during the site visit. Encourage them to draw what they see and include as much information as possible.

Timeframe: 1h 30min

Facilitator Tip

Call the attention of the learners to the glossary and encourage them to refer to it until they are familiar with the terms.

Concise Glossary

Achene Fruit	An achene fruit is a dry single-seeded fruit that does not open to release its seed. Dandelions and sunflowers have achenes.
Adventitious	The term adventitious means developing in an unusual position. In terms of root development, it means roots that grow from the stem or leaf.
Albedo	Albedo is the spongy white tissue inside the skin of a citrus fruit.
Anther	The anther is a male flower part that bears the pollen in pollen sacs.
Apical Bud	The apical bud is the growth point of a stem, containing the apical meristem.
Apoplast	The apoplast is the network of interconnected spaces within the tissues of a plant, including spaces within the cell walls and between cells. Movement of water through these empty spaces are called apoplastic movement.
Calyx	The calyx is the outermost whorl of a flower, a group of sepals, usually green, around the outside of a flower that encloses and protects the flower bud.
Cambium	Cambium is a cylindrical layer of cells that gives rise to new cells, such as xylem and phloem cells.
Carpel	Modified leaves that form the pistil, including stigma, style and ovary.
Cellulose Fibrils	Cellulose fibrils are the "threads" that make up the walls of root cells.
Chloroplast	Chloroplasts are part of plant cells that contains chlorophyll and makes the plant part green.
Collenchyma	The collenchyma is a special kind of strengthening tissue in the cortex of many herbaceous stems.
Corolla	The corolla is the second whorl of modified leaves of the flower. The corolla is the **petals** of a flower collectively and forms a ring around the reproductive organs.
Cortex	The cortex is the internal part of the root between the epidermis and the central vascular cylinder (stele).
Cotyledon	The cotyledons are the seed leaves. Monocotyledonous plants (monocots) have one cotyledon, and dicotyledonous plants (dicots) have two cotyledons in their seeds.
Dehiscent	Dehiscent means to burst open, releasing seeds, pollen, or spores.
Drupe Fruit (Stone)	A drupe fruit has a thin outer skin, soft pulpy middle, and hard stony central part enclosing a seed.
Embryo	The embryo is a plant in its earliest stage of development before an organism becomes self-supporting. Once the embryo begins to grow out from the seed, or germinate, it is called a seedling.
Embryo – Nucellar	Nucellar embryos are embryos that develop from the nucellar cells that surround the zygotic embryo in certain plant species, such as citrus. Nucellar embryos give rise to plants that are true-to-type to the mother plant.

Embryo – Somatic	An embryo that develops from asexual propagation, meaning when plants are propagated through tissue culture.
Embryo – Zygotic (Zygote)	An embryo that develops from sexual propagation, meaning the fertilisation of a female ovule by cells formed by the male pollen.
Endocarp	The innermost layer or the fruit wall, or pericarp.
Endodermis	The endodermis is the "inside skin" of the cortex, and is between the cortex and the stele.
Endosperm	Endosperm is the nutritive tissue of a seed, deriving from the fertilisation in the ovule and may contain carbohydrates, proteins, and lipids. The endosperm is the temporary food source for the seed.
Endospermous Seeds	Seeds in which the endosperm remains separate and is not absorbed by the cotyledons.
Epicotyl	The **epicotyl** is the part of the plant axis, or stem, above the point where the cotyledons are attached and below the plumule or growth point.
Epidermis	Epidermis literally means "over skin" (epi=over / around and dermis=skin). The outer skin of most plant parts is called the epidermis.
Epigeal	Epigeal means living or growing on or right above the surface of the ground. The term is used to describe seed germination in which the hypocotyl elongates so that the cotyledons are carried above the soil.
Epigeal Germination	Epigeal germination refers to seed germination where the hypocotyl lengthens and pushes the plumule and cotyledons above the soil.
Etiolated	Etiolated is a terms used to describe a plant that is deficient in the green pigment chlorophyll owing to the lack of light.
Exendospermous Seeds	Seeds in which the endosperm has been absorbed by the cotyledons prior to seed maturity.
Exocarp	The outer layer or the fruit wall, or pericarp.
Exodermis	The exodermis is the "outside skin" or outer cell layer of the cortex.
Fibrous Root System	A fibrous root system consists entirely of fibrous roots, which are thin and hair-like roots that usually contain more fibres than other roots.
Filament	The filament is a slender stalk that supports the anther.
Gravitropism (Geotropism)	Gravitropism, also referred to as geotropism, is a turning or growth movement by a plant in response to gravity. Gravi– refers to gravity as being the force that pulls everything towards the centre of the earth, and –tropism means the turning in response to a stimulus.
Hesperidium	Hesperidium fruit are a sub-type of berry fruit, and is a fruit, for example citrus, made up of a thick leathery rind and soft segmented pulp.
Hypocotyl	The hypocotyl is the part of the plant axis, or stem, between the radicle, or roots, and where the cotyledons are attached.
Hypogeal	Hypogeal means remaining below ground, and refers to when the cotyledons remain below the ground while the epicotyl of the seedling grows.
Hypogeal Germination	Hypogeal germination refers to germination when the hypocotyl does not develop and the cotyledons remain close to the roots.
Imbibition	Imbibition means the absorption of something, such as liquid or heat. In terms of seed germination, it means the absorption of water by the seed coat.
Indehiscent	Indehiscent means not opening up to release seeds when ripe.
Internodes	Internodes are the stem sections between the nodes.

Lamina	The lamina is the blade of the leaf.
Locule	A locule is a small cavity of chamber in a plant part. In the ovary, the chambers containing the ovules are called locules.
Medulla	The medulla is the pith of the stem.
Medullary Rays	Medullary rays are bands of parenchyma cells that run from the cortex to the medulla between the vascular bundles in a stem.
Meiosis	Meiosis is a type of cell division in organisms that reproduce sexually, and results in cells with half the number of chromosomes of the original cell.
Meristem	Meristems are embryonic plant tissue where cell division takes place, such as the apical meristems of stems and roots. The vascular cambium is a lateral meristem causing secondary thickening growth of stems and roots.
Meristematic Region	The meristematic region of the root is where cell division takes place, and is immediately behind the root cap.
Mesocarp (Mericarp)	The middle layer or the fruit wall, or pericarp.
Mesophyll Parenchyma	Irregularly shaped cells with large intercellular spaces that fill the space between the palisade parenchyma and the lower epidermis.
Metabolism (Metabolic)	Metabolism means the ongoing series of chemical interactions that take place in every living organism that provides the energy and nutrients to sustain life.
Micropyle	The micropyle is a small opening in the seed coat, which was originally a small opening in the ovule through which the pollen passed during fertilisation.
Nodes	Nodes are locations on the stem where leaves are or were attached and where vascular strands branch out to the leaves.
Nucellus	The nucellus surrounds the embryo sac in the ovule and acts as a nutritional source that sustains the initial development of the embryo. In some plants there is hardly any nucellus.
Osmosis	Osmosis is the flow of water and other liquids through a membrane (or skin such as a cell wall) from an area with high concentration to an area with low concentration, gradually evening out the balance.
Ovule	The ovule is a small structure inside the ovary of a seed plant that contains the female reproductive cells inside the embryo sac, and which develops into a seed after fertilisation.
Ovum (P: Ova)	The ovum is the female reproductive cells that are contained in the ovule of the plant.
Palisade Parenchyma	The long, tightly-packed parenchyma cells enclosed by the upper epidermis of the leaf. The site for photosynthesis.
Palmate	Palmate means forming a branching pattern that spreads like fingers from a hand.
Parenchyma	Parenchyma tissue is soft plant tissue made up of thin-walled cells that forms the greater part of leaves, stem pith, roots and fruit pulp.
Parthenocarpy	Parthenocarpy means the production of fruits without fertilisation or seeds.
Pedicel	The pedicel is a stalk of a flower.
Pepo Fruit	Pepo fruit is a fruit of the gourd family such as a melon, squash, pumpkin, or cucumber that develops from an inferior ovary and typically has a firm or hard rind, a large number of flat seeds, and soft watery flesh.
Perianth	The perianth is the collective name for the calyx and corolla.
Pericarp	The pericarp is the fruit wall, the part of a fruit that surrounds the seed or seeds, including the skin, flesh, and stone if present.

Pericycle	The pericycle is the outer layer of the stele.
Petiole	The petiole is the stalk of the leaf. Some leaves do not have a petiole and are therefore sessile.
Phloem	Phloem is a tissue that contains sieve cells that transport carbohydrates and other metabolites from the leaves, where they are manufactured, to the rest of the plant.
Photosynthesis	Photosynthesis literally means light production, or production by light (photo=light, synthesis=production) and is the metabolic process by which green plants turn carbon dioxide and water into food using energy obtained from sunlight.
Phototropic	Phototropic means the turning or growing of a plant towards the light.
Pinnae (S: Pinna)	Pinnae are the leaflets that make up a compound leaf.
Pinnate	Pinnate means resembling a feather in appearance or structure, especially in having a central axis or stem with parts branching off.
Pistil	The pistil is the innermost whorl of the flower, and the female reproductive organ of the flower.
Pistillate	Pistillate refers to female flowers that contain one or more pistils but no stamens.
Plagiotropism	Plagiotropism is the tendency of a plant's roots, stems or branches to grow at an angle away from the vertical.
Plumule	The plumule is the rudimentary primary shoot, or terminal bud, of a plant embryo, or the growth point.
Pollination	Pollination is the transfer of pollen from an anther to a stigma.
Pome Fruit	Pome fruit is a fleshy fruit that has a central core typically containing five seeds, for example an apple or pear. They derive from inferior ovaries and the receptacle forms part of the fleshy part.
Radicle	The radicle is the part of a plant embryo that forms the tap root of the young plant after germination.
Receptacle	The receptacle is a set of very closely spaced nodes to which the whorls of flower parts, or modified leaves, are connected.
Respiration	Respiration is an energy-producing oxidation process in cells, the complete chemical and physical process in which oxygen is delivered to plant cells and carbon dioxide and water are given off.
Rhizomes	Rhizomes are swollen underground stems that can be used for propagation.
Sepal	Sepals are modified leaves that form the calyx.
Septum	Septum in a thin partition or membrane. In citrus fruit, septum partitions the segments in the fruit.
Stamen	The stamens form the third whorl of modified leaves on the inside of the corolla and are the male reproductive organs of a flower.
Staminate	Staminate refers to male flowers that contain one or more stamens but no pistils.
Stele	The stele is the central part of the root, also called the vascular cylinder.
Stigma	The stigma is the top part of the pistil that receives the male pollen grains.
Stomata (S: Stoma)	Stomata is the plural of stoma, which is a tiny pore surrounded by two guard cells in the epidermis of a plant leaf or stem that controls the passing of water vapour and other gasses into and out of the plant.
Style	The style is an extension of the ovary, shaped like a stalk, and supports the stigma.

Suberin	Suberin is a corky substance that thickens the side walls of the endodermis cells and cork cells in the bark.
Ternate	Ternate means divided in three, and the term is used to describe a compound leaf that is divided into three more or less equal parts.
Thigmotropism	Thigmotropism is the turning or growth movement by a plant in response to touch, such as in the case of vines and climbing plants.
Tracheid	A tracheid is a xylem cell that has been modified to carry water and nutrients.
Transpiration	Transpiration means to lose water through the surface of a plant, particularly through the stomata.
Trichome	A trichomes, or plant hairs, are unicellular or multi-cellular outgrowths of the epidermis. Trichomes have various shapes and functions, and include root hairs.
Trifoliate	Trifoliate means "with three leaves", and the term is used to describe a compound leaf consisting of three pinnae that arise from the same point.
Xylem	Xylem is tissue that contains cells like vessels and tracheids that transport water and nutrients from the roots to the leaves, where it is used for food production.

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Subject Matter Experts:

B. Harington BSc Agric – Viticulture and Oenology
C. Harington (OBET)

Illustrations:

M. Botha