The availability of this product is due to the financial support of the National Department of Agriculture and the AgriSETA. Terms and conditions apply.
Dear Learner - This Learner Guide contains all the information to acquire all the knowledge and skills leading to the unit standard:

**Title:** Demonstrate a basic understanding of the physiological processes in plant growth and development  
**US No:** 116295  
**NQF Level:** 4  
**Credits:** 3

The full unit standard will be handed to you by your facilitator. Please read the unit standard at your own time. Whilst reading the unit standard, make a note of your questions and aspects that you do not understand, and discuss it with your facilitator.

This unit standard is one of the building blocks in the qualifications listed below. Please mark the qualification you are currently doing:

<table>
<thead>
<tr>
<th>Title</th>
<th>ID Number</th>
<th>NQF Level</th>
<th>Credits</th>
<th>Mark</th>
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<tr>
<td>National Certificate in Animal Production</td>
<td>48979</td>
<td>4</td>
<td>120</td>
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<td>National Certificate in Plant Production</td>
<td>49009</td>
<td>4</td>
<td>120</td>
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</table>

Please mark the learning program you are enrolled in:

- Learnership?
- Skills Program?
- Short Course?

Your facilitator should explain the above concepts to you.

This Learner Guide contains all the information, and more, as well as the activities that you will be expected to do during the course of your study. Please keep the activities that you have completed and include it in your **Portfolio of Evidence**. Your PoE will be required during your final assessment.

**What is assessment all about?**

You will be assessed during the course of your study. This is called **formative assessment**. You will also be assessed on completion of this unit standard. This is called **summative assessment**. Before your assessment, your assessor will discuss the unit standard with you.

Assessment takes place at different intervals of the learning process and includes various activities. Some activities will be done before the commencement of the program whilst others will be done during programme delivery and other after completion of the program.
The assessment experience should be user friendly, transparent and fair. Should you feel that you have been treated unfairly, you have the right to appeal. Please ask your facilitator about the appeals process and make your own notes.

Your activities must be handed in from time to time on request of the facilitator for the following purposes:

♦ The activities that follow are designed to help you gain the skills, knowledge and attitudes that you need in order to become competent in this learning module.

♦ It is important that you complete all the activities, as directed in the learner guide and at the time indicated by the facilitator.

♦ It is important that you ask questions and participate as much as possible in order to play an active roll in reaching competence.

♦ When you have completed all the activities hand this in to the assessor who will mark it and guide you in areas where additional learning might be required.

♦ You should not move on to the next step in the assessment process until this step is completed, marked and you have received feedback from the assessor.

♦ Sources of information to complete these activities should be identified by your facilitator.

♦ Please note that all completed activities, tasks and other items on which you were assessed must be kept in good order as it becomes part of your Portfolio of Evidence for final assessment.

Enjoy this learning experience!
How to use this guide …

Throughout this guide, you will come across certain re-occurring “boxes”. These boxes each represent a certain aspect of the learning process, containing information, which would help you with the identification and understanding of these aspects. The following is a list of these boxes and what they represent:

**What does it mean?** Each learning field is characterized by unique terms and definitions - it is important to know and use these terms and definitions correctly. These terms and definitions are highlighted throughout the guide in this manner.

**Activity**

You will be requested to complete activities, which could be group activities, or individual activities. Please remember to complete the activities, as the facilitator will assess it and these will become part of your portfolio of evidence. Activities, whether group or individual activities, will be described in this box.

**Examples**

Examples of certain concepts or principles to help you contextualise them easier, will be shown in this box.

**My Notes …**

You can use this box to jot down questions you might have, words that you do not understand, instructions given by the facilitator or explanations given by the facilitator or any other remarks that will help you to understand the work better.

...
What are we going to learn?

What will I be able to do?.............................................................. 6
Learning outcomes........................................................................... 6
What do I need to know?................................................................. 6
Session 1 Cell division and plant growth........................................ 7
Session 2 Transpiration and water movement in crop plants......... 10
Session 3 Plant respiration and gas exchange............................... 17
Session 4 Photosynthesis................................................................. 23
Am I ready for my test? ................................................................. 28
Checklist for Practical assessment.................................................. 29
Paperwork to be done................................................................. 30
Terms and conditions .................................................................. 31
Acknowledgements....................................................................... 32
SA Unit Standard........................................................................... 33
What will I be able to do?

When you have achieved this unit standard, you will be able to:

- The learner will be able to identify the different physiological processes involved in growth and development of a plant.
- Learners will gain specific knowledge and skills in plant physiology and anatomy and will be able to operate in a plant production environment implementing sustainable and economically viable production principles.
- They will be capacitated to gain access to the mainstream agricultural sector, in plant production, impacting directly on the sustainability of the sub-sector. The improvement in production technology will also have a direct impact on the improvement of agricultural productivity of the sector.

Learning Outcomes

At the end of this learning module, you must be able to demonstrate a basic knowledge and understanding of:

- The person is able to demonstrate a basic knowledge of:
  - Transpiration, respiration and photosynthesis.
  - Gaseous exchange, osmosis and translocation.
  - Cell division.
  - Laws of nature.

What do I need to know?

It is expected of the learner attempting this unit standard to demonstrate competence against the unit standard:

- It is assumed that a learner attempting this unit standard will show competence against the following unit standards or equivalent:
  - NQF 3: Demonstrate a basic understanding of the physiological functioning of the anatomical structures of the plant.
  - NQF 3: Incorporate basic concepts sustainable farming systems into practical farm activities.
After completing this session, you should be able to:
SO 1: Demonstrate an understanding of the processes involved in cell division with relation to growth and development of the plant.

In this session we explore the following concepts:

♦ Cell duplication
♦ Preprophase
♦ Prophase
♦ Prometaphase
♦ Metaphase
♦ Anaphase
♦ Telophase
♦ Cytokinesis

1.1 Cell duplication

Cells duplicate through the process of Mitosis. Mitosis is the process by which a cell duplicates its genetic information (DNA) and in the process generates two, identical daughter cells. Duplication and division of the genetic material in the nucleus is normally followed by cytokinesis. Cytokinesis is the process through which the cytoplasm divides and a new cell wall formed between the two new daughter protoplasts. The result of the process is two identical daughter cells with more or less an equal distribution of organelles originating from the mother cell. The combined phases of mitosis and cytokinesis define the mitotic phase cell cycles. Somatic cells undergo mitosis, while the sexual reproductive cells are formed by a similar process known as meiosis.

Mitosis is a regulated and sequential process consisting of phases.

These main phases of mitosis are:

♦ Preprophase
♦ Prophase
♦ Prometaphase
♦ Metaphase
♦ Anaphase
♦ Telophase
Preprophase

In plant cells prophase is preceded by a pre-prophase. The nucleus has to migrate into the center of the cell before mitosis can begin. A pre-prophase band is formed that is a ring like band of microtubules just below the plasma membrane that delimits the equatorial plane of the future mitotic spindle of the cell preparing to divide.

Prophase

In a non-dividing cell the genetic material in the nucleus is ordered in a loosely bundled coil called chromatin. When prophase is initiated the chromatin bundle becomes condensed and forms a highly ordered structure called a chromosome. At this stage the genetic material has already been duplicated and each chromosome has two sister chromatids which are bound together at the so-called centromere. The chromosomes can be seen when using a light microscope at high magnification.

Prometaphase

During prometaphase the nuclear envelope becomes disassembled and microtubules invade the nuclear space. The chromosomes now form two kinetochores at the centromere, one attached at each chromatid. The kinetochore is a protein ring which forms a moving device. This motor activity, as well as polymerisation and depolymerisation of microtubules, provides the pulling force necessary to later separate the chromosome's two chromatids. The spindle grows to a sufficient length where the _kinetochore microtubules_ begin searching for kinetochores to attach to.

Metaphase

At the same time, as the microtubules find and attach to kinetochores in prometaphase, the centromeres of the chromosomes arrange themselves along the _equatorial plane._

Anaphase

When the kinetochores are all attached to microtubules and the chromosomes have lined up along the metaphase plate, the cell proceeds to anaphase. At this stage the proteins that bind sister chromatids together are cleaved, allowing separation. The sister chromatids are then pulled apart by shortening of the kinetochore microtubules and toward the opposite sides of the cell. The end result of anaphase is the cell that has succeeded in separating identical copies of the genetic material into two distinct populations at opposite sides of the cell.

Telophase

Telophase is in effect a reversal of the events of prophase and prometaphase. The nonkinetochore microtubules lengthen, causing the elongation of the cell. Corresponding sister chromosomes attach at opposite ends of the cell. New nuclear envelopes are formed from fragments of the parent cell nuclear membrane. Both sets of chromosomes, now surrounded by new nuclei, unfold back into chromatin. Mitosis is complete, but cell division is not yet complete.
Cytokinesis

Cytokinesis begins at the same time as telophase. Cell division is driven by vesicles derived from the Golgi apparatus. The vesicles move along the microtubules to the middle of the cell. This structure forms a cell plate at the center of the nuclei and develops into a cell wall. Each of the daughter cells now has a complete copy of the genome of its parent cell as well as more or less equal parts of the cytoplasm. The importance of mitosis is that it ensures that the chromosomes or genetic information in the nuclei of the two resulting daughter cells will be alike.

Please complete Activity 1:
Group Activity
Develop a presentation in which you discuss cell duplication in plant cells

<table>
<thead>
<tr>
<th>Concept (SO 1)</th>
<th>I understand this concept</th>
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<tr>
<td>The process of mitosis is described.</td>
<td></td>
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<tr>
<td>Secondary growth in plants with reference to the development of secondary vascular tissue and growth of a plant is explained.</td>
<td></td>
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</tr>
<tr>
<td>Cell division with reference to a) germination, b) pollination, and c) fertilization is explained.</td>
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</tbody>
</table>

My Notes ...

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Session 2 Transpiration and water movement in crop plants

After completing this session, you should be able to:

SO 2: Describe the process of transpiration and its role in water uptake by a plant.

In this session we explore the following concepts:

- Osmosis
- Water transport in plants
- The role of stomata in gas exchange in plant tissues
- Transpiration and water flow in plants
- Control of transpiration

2.1 Osmosis

Osmosis is the process through which water moves (diffusion) through a membrane from an area of higher concentration to an area of lower concentration through a partially permeable or selectively permeable membrane. A selectively permeable membrane is a membrane such as the cell membrane that will selectively allow molecules to pass through it. Such a membrane may for example allow water to pass but not proteins. The movement of compounds from a higher to a lower concentration can be compared by the moving down a concentration gradient by diffusion.

In order for osmosis to occur, two solutions must be separated by a membrane that will only let the solvent (water in the case of cells) pass through it. Another prerequisite is that the concentration of the water must be higher in one of the separated solutions. This can be achieved by having a sugar solution as one solution and plain water on the other side. In this way the water molecules will move into the sugar solution down a concentration gradient.
The water will continue to migrate through the membrane until the two solutions are in equilibrium, meaning that the relative concentrations at both sides of the membrane are the same. In the example the membrane is permeable to only the water, thus only will the water move but the sugar will not migrate, remaining at one side of the membrane.

Selectively or partially permeable membranes are found mostly in living organisms: e.g. Cell membranes and the membrane lining of an egg shell. Osmosis is thus clearly a critical process in living beings. The process controls the constitution of cells and therefore of living tissues. It is important that as little water as possible moves in or out of cells because if too much water enters a cell, it could swell and burst and if too much water exits the cell, the protoplast will shrink and the plasmalemma (outer cell membrane) will pull away from the cell wall (plasmolysis).

### 2.2 Water transport in plants

Plant stems have two major functions. The first is to produce and carry the leaves and ‘hold’ the leaves up to the sunlight and to produce and carry buds and flowers. The second is to hold the vascular system through which sugars and water is transported.
Simplified, a cross and longitudinal section of the stem reveals that a stem is made up of an outer protective tissue layer, ground (filling) tissue and the vascular system.

The vascular system consists of two tissue systems; the phloem through which SUGARS are transported from the leaves (source) to where they are stored or used (sink or target) and the xylem transporting water and mineral nutrients.

Primary tissues deriving from the growing point (apical meristem) of the stem:

- The epidermis (Protective tissue). Epidermis in young stems or periderm in older stems.
- The ground tissue. (Cotex and pith) Live parenchyma cells, and collenchyma.
- Transport system:
  - Primary Xylem – consists of strengthening tissue (dead xylem fibres), transporting tissue (dead xylem vessels) and live cells (xylem parenchyma).
  - Primary Phloem system – consists of transporting tissue (live sieve elements). Live phloem parenchyma and sometimes strengthening tissue (dead phloem fibres).

Secondary tissues deriving from the vascular cambium and cork cambium:

Vascular cambium (only found in Dicots – no secondary thickening growth in most Monocots) Cylinder of embryonic (dividing) cells producing secondary xylem towards the inside and secondary phloem towards the outside of the stem or root:

- Secondary xylem (secondary xylem vessels, secondary xylem fibres and secondary xylem parenchyma) in xylem rays and axial xp.
- Secondary phloem (secondary phloem sieve elements or sieve tubes, companion cells, secondary phloem fibres, secondary phloem parenchyma).
Cork cambium (phellogen) producing:

- Dead cork tissue (phellem) towards the outside
- Live parenchyma cells (phelloderm) towards the inside
- (Phellem + phellogen + felloderm collectively known as periderm, a very important protective tissue)
- Periderm + secondary phloem commonly known as the bark of a tree, easily breaks off from the wood (secondary xylem) at the vascular cambium when debarking trees

2.3 The role of stomata in gas exchange in plant tissues

Stomata are found in the epidermis of leaves, young stems and fruit. Stomata allow gas exchange into and out of the leaf. Water vapour moves out of the leaf and carbon dioxide is allowed in for photosynthesis. If the stomata are closed, transpiration is reduced and photosynthesis is limited. The plant thus has to constantly balance these two processes ensuring metabolism is optimised.

In most plants the stomata are primarily or solely found on the underside of a leaf’s surface but may also be present in young stems and fruit. At times of extreme heat (such as at midday) they will close thereby reducing water loss.

2.4 Transpiration and water flow in plants

Transpiration is a biological process in which water evaporates from a plant. The exchange of water vapour from leaves through the stomata is the primary driving force of the process. Transpiration is critical to the metabolic processes in the plant and thus the survival of the plant.

Water flow

All living organisms need water to survive. Plants need water to maintain the internal pressure or turgidity in cells and tissues. Water is also needed to transport dissolved minerals and elements materials from the soil that may be required for metabolic process to continue.

Water, containing dissolved minerals enters the plants roots via root hairs, and is transported via the xylem vessels up the stem to the leaves and actively growing and metabolising part of the plant.
In order to maintain a flow though the xylem system, water evaporates from the leaves via the stomata into the surrounding atmosphere. As the water evaporates from the leaf surface, more water enters the roots to replace the evaporated water. This causes a sucking system allowing water to be drawn from the roots-to-leaves in a continuous stream through the plant. This capillary suction action is known as the transpiration stream or transpiration tension and is similar to the suction effect found in a wick. Much of this water will not enter cells, but will pass by the cells and exit the plant directly.

### Wilting

Wilting is the loss of rigidity or turgidity of non-woody plant parts. Plant cells and tissues lose turgidity when the turgor pressure in the cells decreases towards zero. The pressure is reduced when the volume of water in the cell decreases below the ideal. Permanent wilting leads to plant death.

Decreased cell water content occurs due to:

- Drought, where soil moisture decreases below that which plants can maintain water uptake
- High salinity, which causes water to diffuse out of plant cells
- Saturated soil conditions, where roots are unable to obtain sufficient oxygen or infections that may clog the vascular systems.

### 2.5 Control of transpiration

Because water is not always abundant, most plants must control transpiration in order to prevent excess water loss. The surface of plant leaves are covered in a waxy, semi-waterproof coating called the cuticle. This layer ensures a minimal loss of water (evaporation) though the cuticle of epidermal cells. The stomatal pore is flanked by two specialised bean-shaped guard cells. The guard cells’ inner walls are thicker and firmer than their outer walls. When a plant begins to wilt through excess transpiration, the guard cells become flaccid due to the lack of water, straightens and so doing, closes the pore.

When thousands of stomata shut on a leaf, the rate of transpiration is drastically reduced. The plant though, continues to absorb water via the roots, replenishes the plant cells to a point where they swell and become turgid. As the guard cells swell, the thin, outer wall stretches and become curved, resulting in the widening of the stomatal pore between them. More water vapour passes through the open stomata and transpiration increases until the plant begins to wilt again. This self-adjusting system regulates the plant's water loss by means of transpiration. The concentration of the plant hormone, abscisic acid, also increases when the leaves of a plant wilt as it causes the guard cells to close the stomata.
Please complete Activity 2.1

**Individual activity**

In the illustration below you are provided with two solutions separated by a partially permeable membrane. The membrane in the example is permeable to water and sodium, but not sugar. Further, the membrane separates two solutions; a sodium solution in water (left) and a sugar solution in water (right). Assume that the solvent concentration is lower in the sugar solution.

1. Identify all the concentration gradients that exist at time zero i.e. just after all solutions were introduced.
2. What would the nett result of osmosis be at equilibrium?

![Diagram of a partially permeable membrane separating solutions](image)

Please complete Activity 2.2

**Groups of two**

Develop a presentation in which you explain the movement of water from roots to leaves in a plant.

Please complete Activity 2.3

**Groups of two**

Develop a presentation in which you discuss:
What is the involvement of stomata in the process of transpiration?

Please complete Activity 2.4

**Individual activity**

Develop a presentation in which you discuss the transpiration in relation to water use efficiency in the plant.
### Concept (SO 2)

<table>
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<th>Concept (SO 2)</th>
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<td>The movement of water from the root to the leaves is explained and illustrated.</td>
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<td>The role of the stomata with reference to transpiration is explained.</td>
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<td>The concept of wilting is explained.</td>
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Session 3

Plant respiration and gas exchange

After completing this session, you should be able to:
SO 3: Describe the process of respiration in relation to gaseous exchange in the plant.
SO 5: Demonstrate an understanding of the maturity and ripening of fruit.

In this session we explore the following concepts:
- Respiration
- Fruit growth and development
- Fruit ripening
- Climacteric and non-climacteric fruit

3.1 Respiration

The main energy source of plants for growth is carbohydrates which are formed during photosynthesis (see later). During the respiration the energy trapped in the carbohydrates is released in a usable form for the plant. The process of respiration takes place in the plant cell organelles called Mitochondria.

Mitochondria are sub-cellular compartments that contain enzymes and membrane systems that are required to control the biochemical processes which are involved in converting of sugars (trapped energy) to Adenosine tri phosphate (ATP) (usable energy) during respiration. ATP is the universal energy-carrying molecule in all living organisms (bacteria, fungi, plants, animals). Every plant cell contains hundreds of mitochondria, the equivalent of small power generators feeding into a grid, providing energy for the cell. The sugars that are produced in the leaves during photosynthesis are transported to other organs such as growing shoot tips, roots or fruits. The sugar is supplied to every cell in the plant otherwise these cells will die. The sugars are essential because they are consumed during respiration releasing energy. During a series of biochemical reactions in the mitochondria sugar is combined with oxygen, releasing carbon dioxide, water and energy. The energy, which is released, is captured in the molecule called ATP. ATP is then in turn used to "drive" a number of other cellular processes aimed at maintenance (e.g. repair), functions (e.g. nutrient uptake and transport) and growth of plant tissues. From the sugar produced during photosynthesis, approximately half is consumed during respiration. The amount of carbohydrates used per day dependents on
environmental conditions. Throughout the respiration process, enzymes which are protein catalysts are involved with the reactions.

The respiration process can be summarised as:

Sugar (C₆H₁₂O₆) + oxygen (6O₂) renders → carbon dioxide (6CO₂) + water (6H₂O) + energy

Respiration can be separated into distinct phases. During the first step the sugar glucose (6 carbon carbohydrate) is oxidised (where oxygen is added) to form two molecules of pyruvic acid (3 carbon organic acids). This process is known as Glycolysis (‘Glyco’ refers to sugar and ‘lysis’ meaning splitting) and is set out schematically below.

<table>
<thead>
<tr>
<th>1st sugar phosphorylation</th>
<th>Glucose</th>
</tr>
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<tbody>
<tr>
<td>ATP</td>
<td>↓</td>
</tr>
<tr>
<td>ADP</td>
<td>↓</td>
</tr>
<tr>
<td>Glucose 6 - Phosphate</td>
<td>↓</td>
</tr>
<tr>
<td>Fructose 6 - phosphate</td>
<td>↓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2nd sugar phosphorylation</th>
<th>Fructose 1,6-biphosphate</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATP</td>
<td>↓</td>
</tr>
<tr>
<td>ADP</td>
<td>↓</td>
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Sugar cleavage

<table>
<thead>
<tr>
<th>Pyruvic acid formation</th>
<th>Glyseraldehyde 3-phosphate</th>
<th>Dihydroxyacetone phosphate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of nucleotide</td>
<td>NAD</td>
<td>Oxidation of triose</td>
</tr>
<tr>
<td></td>
<td>NADH</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phosphorylation of ADP</th>
<th>Pyruvic acid (Pyrovate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 ADP</td>
<td></td>
</tr>
<tr>
<td>2 ATP</td>
<td></td>
</tr>
</tbody>
</table>

During the first phase no oxygen was involved and is therefore called the anaerobic phase that takes place in the ground substance of the cytoplasm and not in the mitochondria. During the second, aerobic phase of respiration taking place inside the mitochondria, the newly formed pyruvic acid is converted into 2 acetaldehyde molecules. These then enter the organic acid cycle of respiration.
Demonstrate a basic understanding of the physiological processes in plant growth and development

Primary Agriculture
NQF Level 4
Unit Standard No: 116295

One step missing? Pyrovate → Acetyl-CoA

Entrance of carbon into acid cycle
- ↑ oxaloacetate
- ↑ malate
- ↑ Fumarate ←

Organic acid cycle
- ↑ Citrate
- ↑ CO₂
- ↑ α-ketoglutarate
- ↑ ADP + Pi
- ↓ Succinate
- ↓ ATP

Eight hydrogen (H) atoms are liberated; two to from malate conversion to oxaloacetate; two to from succinate conversion to fumarate; two to from α-ketoglutarate conversion to Succinate and two to from isocitrate conversion to α-ketoglutarate

Final stages of respiration
Electron transport
ADP + Pi → ATP

And Oxidative phosphorylation
ADP + Pi → ATP
ADP + Pi → ATP
2H⁺ + ½ O₂ → H₂O

ATP available for work in cell
3.2 Fruit growth and development

Seeds develop inside the ovary wall where various hormones are induced in the fruit for specific growth metabolic processes.

First cytokinins are produced. Cytokinins are released from the seed to stimulate cell division in the ovary wall. This leads to the thickening of the wall of the fruit.

The next hormone produced is gibberellic acid. This hormone is released to the ovary wall where it induces rapid expansion of individual cells. This combination of increased number of cells and the expansion of cells leads to drastic increases in the size of the ovary.

At the same time the mother plant produces the hormone abscisic acid. Abscisic acid causes the embryo inside the developing seeds to become dormant, ensuring that the seed does not sprout whilst inside the warm, moist fruit.

Where seedless fruit types have been developed, a solution of gibberellic acid can be applied to the fruit to ensure that full-sized fruit develops. The number of applications required and the stage of treatment may differ between cops. Important to note is that without these treatments the fruits will not reach the market sizes required.

3.3 Fruit ripening

An unripe fruit is generally hard, green, sour, lacks scent; its starch content is high and therefore has no taste. Fruit will ripen once a “ripening signal” has been received. This signal is a rapid increase or burst in ethylene production which lead to metabolic changes, causing the fruit to ripen. Ethylene is a simple gas CH₂ that is produced within the fruit. The gas is discarded into the atmosphere. Often ethylene production is initiated when a fruit is injured e.g. during picking process.

As a result of the ethylene burst, enzymes are produced that are essential in the ripening process. These enzymes may include hydrolases that aid in breaking down specific chemicals in the fruits, amylases that are required to hydrolyse starch into sugar and pectinases that catalyze the degradation of pectin (the substance that glues cells together). The combined action of these enzymes alters the composition characteristics of the fruit.

Responses that occur may include:

- Chlorophyll is broken down
- New pigments are formed that colour the fruit
• Acids are degraded, thus changing the fruit from sour to neutral.
• Starch is degraded to sugar.
• Pectin is degraded, thus separating the cells resulting in a softer fruit.
• Often the degradation of organic compounds occurs, leading to volatile compounds being formed which escape the fruit, leaving an aroma.

As a producer, one can manipulate fruit ripening because of the way the ripening process is initiated. This is extremely important in the case of bananas as they ripen very unevenly and over an extremely long time on the mother plant. In addition, ripe bananas have an extremely short shelf live. Because of this, they are picked and shipped green. Once the consignment arrives at the destination, the crop is treated with ethylene in specialised warehouses. This causes even coordinated ripening, where all bunches will ripen at the same time, making it easier to market the produce.

Citrus, for export purposes, is harvested when still green.

3.4 Climacteric and non-climacteric fruit

Climacteric fruit can be picked from the tree at maturity, but before they are fully ripe and can continue the ripening process later. In general there will be an increase in quality during the picking-to-ripening stage. Ripening is controlled by the fruit producing their own ethylene together with a significant increase in CO₂ production.

Non climacteric fruit on the other hand, will maintain the quality they had at harvest without much beneficial change as these fruit produce little or no ethylene with only small changes in CO₂ production. Non-climacteric fruit therefore can only be harvested when fully ripe.
Please complete Activity **3.1 – 3.3:**
3.1. Develop a presentation in which you discuss the role of respiration in relation to cell metabolism.
3.2 Develop a presentation in which you explain the physiology of fruit ripening.
3.3 Discuss climacteric versus non-climacteric fruit.

<table>
<thead>
<tr>
<th>Concept (SO 3)</th>
<th>I understand this concept</th>
<th>Questions that I still would like to ask</th>
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<tr>
<td>The transfer of gases between the plant and its external environment is described.</td>
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<tr>
<td>The process of respiration and when it occurs in plants is explained.</td>
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<tr>
<td>The process of respiration in relation to climacteric and non-climacteric fruit is described.</td>
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<tr>
<td>The influences of respiration on the ripening of fruit are discussed.</td>
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<tr>
<td>The process of cell division and differentiation in fruit is explained.</td>
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<td>The role of ethylene in fruit maturity and ripening is explained.</td>
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<tr>
<td>The function of ethylene in the manipulation of fruit ripening and harvesting is explained.</td>
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<tr>
<td>The storage of fruit is explained with reference to ethylene and atmospheric factors.</td>
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</table>
Demonstrate a basic understanding of the physiological processes in plant growth and development

Primary Agriculture          NQF Level 4          Unit Standard No: 116295

**Session 4**

Photosynthesis

After completing this session, you should be able to:

**SO 4: Demonstrate an understanding of the process of photosynthesis.**

In this session we explore the following concepts:

- Photosynthesis

### 4.1 Photosynthesis

The primary source of energy for all living organisms on earth is the sun, 150 million kilometres from earth. Energy is generated from light and heat. Heat energy cannot be captured directly by either plants or animals, but light energy is captured by green plants. It is this captured energy that is used by animals via plants, to meet all their needs. To obtain this energy, an animal requires food from plants, which can be broken down in the animal's body to provide the necessary energy for the animal's life processes. Only plants can however capture light energy directly and they do this through the process of photosynthesis.

Photosynthesis is the process through which plants trap light energy and converts it into chemical energy which is then released by means of respiration. Life on earth, as we know, cannot exist without the process of photosynthesis.

During photosynthesis plants convert light energy into stored energy. Plants thus have the ability to manufacture their own food. Photosynthesis is possible because plants have an energy-capturing green pigment substance called chlorophyll, which also gives plants their green colour. Photosynthesis also occurs in seaweed and other algae, mosses and not only in vascular plants.

A plant's chlorophyll captures the light energy and uses it to manufacture carbohydrates from the raw materials water (hydrogen and oxygen), carbon dioxide (carbon and oxygen). These raw materials are sourced through the plant's roots and leaves. Water, containing minerals, enters the plants through the roots and is channelled up the stem and into the veins of the leaves in the vascular system, and the carbon dioxide enters the leave trough the stomata.
Demonstrate a basic understanding of the physiological processes in plant growth and development

Primary Agriculture

NQF Level 4

Unit Standard No: 116295

Figure 4.1: Diagram indicating the transport of water through the plant.

Photosynthesis has as its final product carbohydrates. Carbohydrates are compounds composed of carbon, hydrogen and oxygen atoms such as sugar, glucose and fructose (simple carbohydrates). Starch and cellulose are also carbohydrates, but these are complex carbohydrates. A simple carbohydrate is made up of a few carbon, hydrogen and oxygen atoms while complex carbohydrates are made up of many of each of the three basic atoms. Glucose for example consists 6 atoms of carbon, 12 atoms of hydrogen and 6 atoms of oxygen. The formula for glucose is usually written as $C_6H_{12}O_6$. The plant uses glucose for the production of more complex carbohydrates.

The photosynthetic process can be summarised as:

Carbon Dioxide + Water + Chlorophyll and Sunlight = Oxygen + Sugar

The sugar produced is mixed with water and sent to other parts of the plant where it is used by the plant as food. The oxygen is released into the air through the stomata. The figure below shows the basic structure of a plant leaf.

Figure 4.2: A diagram of a cross section of a plant leaf showing its basic structure.
Photosynthesis takes place in the leaf cells containing tiny lens shaped structures called chloroplasts. Each chloroplast consists of green chlorophyll containing grana within the stroma (Figure 4.3).

**Figure 4.3:** A diagram of the basic structure of the chloroplast.

The steps as they follow on one another in the photosynthetic path are summarised in the diagram below.

1. Light energy passes into the leaf and reaching the chloroplast inside an individual cell.
2. The chlorophyll inside the grana captures the light energy.
3. Inside the grana some of the energy is used to split water into hydrogen and oxygen, the oxygen is released into the air.
4. The hydrogen is transported to the stroma along with the grana's remaining light energy.

5. Carbon dioxide enters the leaf and passes into the chloroplast.

6. In the stroma the remaining light energy is used to combine hydrogen and carbon dioxide to produce carbohydrates.

7. The energy rich carbohydrates are carried to other plant cells and used by the cells to drive the plant's life processes.

Figure 4.4: A diagram showing the light capturing process within the chloroplasts.

My Notes ...

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Demonstrate a basic understanding of the physiological processes in plant growth and development

Primary Agriculture
NQF Level 4
Unit Standard No: 116295

**Figure 4.5**: A diagram of the photosynthetic splitting of water, carbon dioxide and the fixation and production of sugars.

Why is respiration explained in more depth than photosynthesis?

Please complete Activity 4.
Develop a presentation in which you explain the process of photosynthesis.

<table>
<thead>
<tr>
<th>How am I doing?</th>
<th>I understand this concept</th>
<th>Questions that I still would like to ask</th>
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<tbody>
<tr>
<td>Concept (SO 4)</td>
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<tr>
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<td>The light phase of photosynthesis is discussed and described.</td>
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Demonstrate a basic understanding of the physiological processes in plant growth and development

Primary Agriculture  
NQF Level 4  
Unit Standard No: 116295

Am I ready for my test?

♦ Check your plan carefully to make sure that you prepare in good time.
♦ You have to be found competent by a qualified assessor to be declared competent.
♦ Inform the assessor if you have any special needs or requirements before the agreed date for the test to be completed. You might, for example, require an interpreter to translate the questions to your mother tongue, or you might need to take this test orally.
♦ Use this worksheet to help you prepare for the test. These are examples of possible questions that might appear in the test. All the information you need was taught in the classroom and can be found in the learner guide that you received.

1. I am sure of this and understand it well
2. I am unsure of this and need to ask the Facilitator or Assessor to explain what it means

<table>
<thead>
<tr>
<th>Questions</th>
<th>1. I am sure</th>
<th>2. I am unsure</th>
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</thead>
<tbody>
<tr>
<td>1. What is Mitosis?</td>
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<tr>
<td>2. Define Osmosis?</td>
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<td>3. Discuss the movement of water from plant roots to the leaves.</td>
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<td>4. How do plant wilt?</td>
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<td>5. How are stomata involved in transpiration control?</td>
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<tr>
<td>6. What is respiration?</td>
<td></td>
<td></td>
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<tr>
<td>7. What is Photosynthesis?</td>
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</table>
Use the **checklist** below to help you prepare for the part of the practical assessment when you are observed on the **attitudes and attributes** that you need to have to be found competent for this learning module.

<table>
<thead>
<tr>
<th>Observations</th>
<th>Answer Yes or No</th>
<th>Motivate your Answer (Give examples, reasons, etc.)</th>
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<tbody>
<tr>
<td>Can you identify problems and deficiencies correctly?</td>
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<tr>
<td>Are you able to work well in a team?</td>
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<td>Do you work in an organised and systematic way while performing all tasks and tests?</td>
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<td>Are you able to collect the correct and appropriate information and / or samples as per the instructions and procedures that you were taught?</td>
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<td>Are you able to communicate your knowledge orally and in writing, in such a way that you show what knowledge you have gained?</td>
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<tr>
<td>Can you base your tasks and answers on scientific knowledge that you have learnt?</td>
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<tr>
<td>Are you able to show and perform the tasks required correctly?</td>
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<tr>
<td>Are you able to link the knowledge, skills and attitudes that you have learnt in this module of learning to specific duties in your job or in the community where you live?</td>
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</table>

- The assessor will complete a checklist that gives details of the points that are checked and assessed by the assessor.
- The assessor will write commentary and feedback on that checklist. They will discuss all commentary and feedback with you.
- You will be asked to give your own feedback and to sign this document.
- **It will be placed together with this completed guide in a file as part of you portfolio of evidence.**
- The assessor will give you feedback on the test and guide you if there are areas in which you still need further development.
# Paperwork to be done …

Please assist the assessor by filling in this form and then sign as instructed.

<table>
<thead>
<tr>
<th>Learner Information Form</th>
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<tbody>
<tr>
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Acknowledgements

- **Project Management:**
  IMPETUS Consulting and Skills Development

- **Donors:**
  Citrus Academy

- **Developer:**
  Mr R H Meinhardt

- **Authenticator:**
  Prof P J Robbertse

- **OBE Formatting:**
  Ms B Enslin

- **Design:**
  Didacsa Design SA (Pty) Ltd

- **Layout:**
  Ms A du Plessis
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SOUTH AFRICAN QUALIFICATIONS AUTHORITY

REGISTERED UNIT STANDARD:

Demonstrate a basic understanding of the physiological processes in plant growth and development

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PURPOSE OF THE UNIT STANDARD

The learner will be able to identify the different physiological processes involved in growth and development of a plant.

Learners will gain specific knowledge and skills in plant physiology and anatomy and will be able to operate in a plant production environment implementing sustainable and economically viable production principles.

They will be capacitated to gain access to the mainstream agricultural sector, in plant production, impacting directly on the sustainability of the sub-sector. The improvement in production technology will also have a direct impact on the improvement of agricultural productivity of the sector.

LEARNING ASSUMED TO BE IN PLACE AND RECOGNITION OF PRI OR LEARNING

It is assumed that a learner attempting this unit standard will show competence against the following unit standards or equivalent:

- NQF 3: Demonstrate a basic understanding of the physiological functioning of the anatomical structures of the plant.
- NQF 3: Incorporate basic concepts sustainable farming systems into practical farm activities.

UNIT STANDARD RANGE

Whilst range statements have been defined generically to include as wide a set of alternatives as possible, all range statements should be interpreted within the specific context of application.
Range statements are neither comprehensive nor necessarily appropriate to all contexts. Alternatives must however be comparable in scope and complexity. These are only as a general guide to scope and complexity of what is required.

UNIT STANDARD OUTCOME HEADER
N/A

Specific Outcomes and Assessment Criteria:

SPECIFIC OUTCOME 1
Demonstrate an understanding of the processes involved in cell division with relation to growth and development of the plant.

OUTCOME RANGE
Cell division refers to the process of mitosis. Growth and development refers to the development of secondary vascular bundles.

ASSESSMENT CRITERIA

ASSESSMENT CRITERION 1
The process of mitosis is described.

ASSESSMENT CRITERION RANGE
Refers to the process of cell division.

ASSESSMENT CRITERION 2
Secondary growth in plants with reference to the development of secondary vascular tissue and growth of a plant is explained.

ASSESSMENT CRITERION RANGE
Secondary vascular tissue refers to secondary xylem and phloem development.

ASSESSMENT CRITERION 3
Cell division with reference to a) germination, b) pollination, and c) fertilization is explained.

SPECIFIC OUTCOME 2
Describe the process of transpiration and its role in water uptake by a plant.

OUTCOME RANGE
Water uptake refers to but it is not limited to the process of osmosis and translocation.

ASSESSMENT CRITERIA

ASSESSMENT CRITERION 1
The concept of osmosis and how it occurs is explained.

ASSESSMENT CRITERION 2
Osmosis is illustrated.

ASSESSMENT CRITERION 3
The movement of water from the root to the leaves is explained and illustrated.

ASSESSMENT CRITERION 4
The role of the stomata with reference to transpiration is explained.

**ASSESSMENT CRITERION 5**  
The role of transpiration in relation to water use efficiency of the plant is explained.

**ASSESSMENT CRITERION 6**  
The concept of wilting is explained.

**SPECIFIC OUTCOME 3**  
Describe the process of respiration in relation to gaseous exchange in the plant.

**OUTCOME RANGE**  
Gaseous exchange refers to but is not limited to osmosis and respiration.

**ASSESSMENT CRITERIA**

**ASSESSMENT CRITERION 1**  
The transfer of gases between the plant and its external environment is described.

**ASSESSMENT CRITERION 2**  
The process of respiration and when it occurs in plants is explained.

**ASSESSMENT CRITERION 3**  
The process of respiration in relation to climacteric and non-climacteric fruit is described.

**ASSESSMENT CRITERION 4**  
The influences of respiration on the ripening of fruit are discussed.

**SPECIFIC OUTCOME 4**  
Demonstrate an understanding of the process of photosynthesis.

**OUTCOME RANGE**  
Photosynthesis refers to the process that occurs in green plants. Photosynthesis is the process by which complex molecules are produced from plant nutrients, water and gases through a physiological process.

**ASSESSMENT CRITERIA**

**ASSESSMENT CRITERION 1**  
The effect environmental factors have on the process of photosynthesis is demonstrated and explained.

**ASSESSMENT CRITERION 2**  
The light phase of photosynthesis is discussed and described.

**ASSESSMENT CRITERION 3**  
The dark phase of photosynthesis is discussed and described.

**SPECIFIC OUTCOME 5**  
Demonstrate an understanding of the maturity and ripening of fruit.

**OUTCOME RANGE**  
Maturity and ripening refers to but is not limited to cell division, respiration, etc.

**ASSESSMENT CRITERIA**
ASSESSMENT CRITERION 1
The process of cell division and differentiation in fruit is explained.

ASSESSMENT CRITERION 2
The role of ethylene in fruit maturity and ripening is explained.

ASSESSMENT CRITERION 3
The function of ethylene in the manipulation of fruit ripening and harvesting is explained.

ASSESSMENT CRITERION 4
The storage of fruit is explained with reference to ethylene and atmospheric factors.

UNIT STANDARD ACCREDITATION AND MODERATION OPTIONS
The assessment of qualifying learners against this standard should meet the requirements of established
assessment principles.

It will be necessary to develop assessment activities and tools, which are appropriate to the contexts in
which the qualifying learners are working. These activities and tools may include an appropriate
combination of self-assessment and peer assessment, formative and summative assessment, portfolios and
observations etc.

The assessment should ensure that all the specific outcomes; critical cross-field outcomes and essential
embedded knowledge are assessed.

The specific outcomes must be assessed through observation of performance. Supporting evidence should
be used to prove competence of specific outcomes only when they are not clearly seen in the actual
performance.

Essential embedded knowledge must be assessed in its own right, through oral or written evidence and
cannot be assessed only by being observed.

The specific outcomes and essential embedded knowledge must be assessed in relation to each other. If a
qualifying learner is able to explain the essential embedded knowledge but is unable to perform the specific
outcomes, they should not be assessed as competent. Similarly, if a qualifying learner is able to perform
the specific outcomes but is unable to explain or justify their performance in terms of the essential
embedded knowledge, then they should not be assessed as competent.

Evidence of the specified critical cross-field outcomes should be found both in performance and in the
essential embedded knowledge.

Performance of specific outcomes must actively affirm target groups of qualifying learners, not unfairly
discriminate against them. Qualifying learners should be able to justify their performance in terms of these
values.

• Anyone assessing a learner against this unit standard must be registered as an assessor with the
relevant ETQA.

• Any institution offering learning that will enable achievement of this unit standard or assessing this unit
standard must be accredited as a provider with the relevant ETQA.

• Moderation of assessment will be overseen by the relevant ETQA according to the moderation guidelines
in the relevant qualification and the agreed ETQA procedures.

UNIT STANDARD ESSENTIAL EMBEDDED KNOWLEDGE
The person is able to demonstrate a basic knowledge of:

• Transpiration, respiration and photosynthesis.
• Gaseous exchange, osmosis and translocation.
• Cell division.
• Laws of nature.

**UNIT STANDARD DEVELOPMENTAL OUTCOME**
N/A

**UNIT STANDARD LINKAGES**
N/A

**Critical Cross-field Outcomes (CCFO):**

**UNIT STANDARD CCFO IDENTIFYING**
Problem Solving: Relates to all outcomes.

**UNIT STANDARD CCFO WORKING**
Teamwork: Relates to all outcomes.

**UNIT STANDARD CCFO ORGANIZING**
Self-Management: Relates to all outcomes.

**UNIT STANDARD CCFO COLLECTING**
Interpreting Information: Relates to all outcomes.

**UNIT STANDARD CCFO COMMUNICATING**
Communication: Relates to all outcomes.

**UNIT STANDARD CCFO SCIENCE**
Use Science and Technology: Relates to all outcomes.

**UNIT STANDARD CCFO DEMONSTRATING**
The world as a set of related systems: Relates to all outcomes.

**UNIT STANDARD CCFO CONTRIBUTING**
Self-development: Relates to all outcomes.

**UNIT STANDARD ASSESSOR CRITERIA**
N/A

**UNIT STANDARD NOTES**
N/A

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