Plant Structures and Functions

Learner Guide

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Introduction

Plants is one of the four kingdoms of the eukarya domain. From massive sequoia trees – one of the largest living organisms on earth – to tiny duckweed that float on water, from seagrass that grow in the deep oceans to the citrus trees we farm with, plants are all around us, and we depend on them for food, oxygen and many other necessities of life. What all plants have in common are certain structures that enable them to perform certain functions, such as photosynthesis and respiration.

If we have a good understanding of these structures, also called plant **anatomy**, and the functions of plants, known as their **physiology**, we will be able to understand what plants need in order to grow best, which is critical if we are involved in plant production.

information

Glossary Definitions

Before we get started, please note the following: In this module we use many difficult scientific terms, which you might not understand when you first hear them. I will give you definitions for these terms, and I will also put them into a glossary for you. Listen out for me, and please pay special attention whenever a term is placed in the glossary. You can always refer back to it if you find a term that you are uncertain of.

Plant Anatomy

Plant species have diverse structural compositions. Some plants have flowers, some don't. Some plants have massive root systems, some have tiny roots, and there are even some with no roots at all. Some plants store food in its roots, and others store water in its leaves. Some have thick, woody stems, and some have long soft bows.

In order to understand the particular plant that we work with, we need to first understand each plant part, what it looks like, and how it functions. Particularly, we will look at the following plant parts: seeds, roots, stems, leaves, flowers and fruit.

Seeds

The seed is the starting point of a plant. A seed has tiny parts that develop into the parts of the plant. Once the plant has grown it will eventually produce fruit containing more seeds.

Seeds can be tiny, such as those of vegetable or 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 and disperse them.

Seed Structure

No matter what it looks like, seeds are almost always made up of two parts, namely a seed coat and an embryo.

information

Glossary Definitions

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 forms a seedling.

The seed coat is the protective outer layer of a seed and it protects the embryo from injury and from insects and diseases. 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.

The embryo consists of three parts, namely the radicle, the plumule and the cotyledons.

information

Glossary Definitions

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 **radicle** is the part of a plant embryo that forms the tap root of the young plant after germination.

The **plumule** is the rudimentary primary shoot of a plant embryo, also known as a terminal bud or growth point.

The **cotyledons** are the seed leaves.

Plants are classified based on the number of cotyledons in the seed. Plants such as grasses are monocotyledons, or monocots, meaning the seed contains one cotyledon. Citrus seeds are dicotyledons, or dicots, and have two cotyledons.

Some seeds also have visible endosperm.

information

Glossary Definitions

Dicotyledon, or dicot, refers to a flowering plant that has a pair of cotyledons in the embryo of the seed.

Monocotyledon, or monocot, refers to a flowering plant that has only one cotyledon in the embryo of the seed.

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.

In some plants the endosperm is absorbed by the cotyledons, leaving the mature seed without separate endosperm.

Seed Germination

Seed germination happens when growth is triggered in a seed after a period of dormancy, and is marked by the radicle emerging through the seed coat. 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. The seed needs enough water and oxygen, suitable temperature, and suitable light.

As the first step in germination, the seed starts taking up water through the seed coat which was dry while the seed was dormant. This is also referred to as imbibition.

information

Glossary Definitions

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.

Imbibition causes the seed coat to soften and the micropyle to open, after which the seed can take water up faster. Metabolism now starts in the seed.

information

Glossary Definitions

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 that take place convert the food reserves in the endosperm into simpler substances that are transported to the embryo.

Now that the embryo has water and food, it starts growing. The radicle starts to grow first. It appears through the micropyle and forms the tap root of the plant, which grows downwards in response to gravity. Next, the epicotyl and – in some plants – the hypocotyl start growing upwards against gravity, pushing the plumule and the cotyledons above the surface of the growth medium.

information

Glossary Definitions

The **hypocotyl** is the part of the plant axis, or stem, between the roots and where the cotyledons are attached.

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.

Citrus Seeds

Citrus seeds have a rare characteristic that has implication for how these plants are propagated commercially.

In the case of plants that reproduce sexually, in the ovule inside the flower, the male cells produced by the pollen fertilises the female reproductive cells, called ova, and an embryo is formed.

In the ovule, the embryo sac is contained within the nucellus which is surrounded by a membrane.

When an embryo is made naturally in the plant by way of sexual fertilisation, the fertilised ovum is called a zygote.

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Glossary Definitions

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

The **nucellus** surrounds the embryo sac in the ovule and acts as a nutritional source that sustains the initial development of the embryo.

A **zygote** is an embryo formed when a male cell fertilises a female cell.

Because sexual propagation involves the fusion of one male cell and one female cell, the zygotic embryo has characteristics of both parents, and is a completely unique individual.

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 exactly the same as the mother plant. Because zygotic embryos have characteristics of both parents and we can therefore not guarantee that the seedlings will be the same as the mother plant, seed propagation is not generally used in the commercial propagation of tree crops.

However, true-to-type citrus rootstock is propagated with seed in commercial citrus nurseries. This is possible because citrus has an unusual characteristic. In citrus seeds, some of the nucellar cells develop into nucellar embryos.

information

Glossary Definitions

A **nucellar embryo** forms from the nucellus around the embryo sac.

Because these embryos are formed from the nucellus, they contain only the genetic material of the mother plant, which makes them true-to-type.

When a 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 grow into seedlings varies.

The zygotic seedlings are different from nucellar seedlings, and are discarded in the nursery. Only true-to-type nucellar seedlings are eventually used as rootstock plants.

Roots

Roots are typically at the bottom end of a plant. Roots have root caps and do not have nodes, and never bear leaves or flowers directly. Their main functions are to anchor the plant in the soil, absorb and transport nutrients and moisture, and store food.

Root Systems

Plants generally have either a tap root system or an adventitious root system.

Monocotyledonous plants such as grasses commonly have adventitious root systems, as do all plants propagated through asexual methods.

Dicotyledonous plants have taproot systems, because the radical in the seed develops into a tap root when the seed germinate.

information

Glossary Definitions

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

Asexual plant propagation is when plant cells or parts form new plants, such as when cuttings and tissue culture is used in commercial plant propagation.

Root Structure

In terms of its external features, a root is divided into a number of regions, which mostly have to do with how the root grows. Firstly, the root cap covers the very tip of the root and is shaped like a thimble. It protects the delicate growing tip from injury as it pushes its way through the soil.

The growing tip that is covered by the root cap is called the region of cell division, or the root meristem. This is the primary growth region of the root, where cells are dividing all the time, forming new cells that later differentiate into specialised root tissue.

information

Glossary Definitions

The **meristem** is the primary growth region and the tissue where undifferentiated plant cells, or meristematic cells, are found. Other plant parts, such as stems, also have meristems in their primary growth region.

Behind the meristematic region is the region of cell elongation, where the new cells rapidly grow in size, causing the root to lengthen and penetrate deeper into the soil.

Overlapping the region of cell elongation and extending further up the root, is the root hair region, which is also where cells are differentiated into particular functions. In this region the outer cell walls of the epidermis cells grow out to form root hairs, which makes the surface through which water and nutrients can be absorbed much larger.

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Glossary Definitions

The **epidermis** is the outer layer of tissue of all plant parts. Epidermis literally means "over skin", epi- meaning over or around, and dermis meaning skin.

Almost all the water the plant takes up from the soil enters through the root hair region, where water is absorbed directly through the epidermis and root hairs.

In the root hair region an internal vascular system develops, which contains the two types of vascular tissue. The two types of vascular tissue are xylem and phloem.

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Glossary Definitions

Vascular tissue is the plant tissue that conducts water, nutrients and sap in plants.

Xylem is plant tissue that transports water and nutrients from the roots to the leaves, where it is metabolised into food for the plant, mostly in the form of carbohydrates.

Phloem contains sieve cells that transport the food that has been metabolised by the leaves to the rest of the plant.

Behind the root hair region is the mature region of the root, where it becomes thicker and from where more roots can grow out. In some plants this region develops a cork layer, referred to as the bark of the root.

The vascular system – the xylem and phloem – that starts in the root hair region links up with the system in the older part of the root running though the stele. The stele connects to the vascular system that runs through the rest of the plant.

information

Glossary Definitions

The **stele** is the central part of the root, also called the vascular cylinder.

Root Functions

The nutrients and water that the roots absorb are transported through the xylem in the vascular system of the roots and stem to the leaves. The leaves produce food in the form of carbohydrates through metabolic processes, which are then in turn transported back through the phloem in the vascular system to feed other plant parts, including the roots. The roots can use these carbohydrates to grow, but they can also store some of it for later use.

Citrus Roots

The citrus tree has a tap root system, with a large tap root and a number of lateral roots, or side roots. The root system is relatively shallow, growing only to a depth of between 30cm and 60cm. The lateral roots make up most of the root system.

Citrus roots don't grow actively all year round; in fact, the roots only grow when shoots are not actively growing. There are usually three or more growth flushes every year. Root growth also depend on soil temperature – they stop growing as soon as the temperature in the soil drops below 10°C.

Trunk and Stems

The main stem, or trunk, of a tree plant grows from the plumule of a seed. Lateral branches and stems grow from buds to bear leaves and form more axillary buds or adventitious buds.

information

Glossary Definitions

An **axillary bud** develops in the axil of a leaf on a stem. Axillary buds sprout new stems. On some of the new stems, flowers and eventually fruit develop.

Adventitious buds are subnormal buds found at points along a stem.

Stem Structure

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.

The major internal parts of a stem are the vascular system, which also consist of xylem and phloem and connects to the vascular system in the roots, and cambium.

information

Glossary Definitions

Cambium is a tissue layer that contains undifferentiated cells for plant growth.

Stem Growth

Stems usually grow above the ground and are positively phototropic. Some stems are thigmotropic in response to touch, such as the stems of climbing plants. In most stems the meristem, which you may remember means the primary growth region, is apical. This results in apical dominance.

information

Glossary Definitions

Phototropic means turning or growing of a plant towards the light.

Thigmotropic means turning or growing towards a touch stimulus.

In most stems the meristem, which you may remember means the primary growth region, is apical. This results in apical dominance.

information

Glossary Definitions

Apical means at the apex, in this case the tip or end.

Apical dominance means growing faster at the apex, or tip, which results in lengthening.

This is called primary growth. Tree stems continue to grow until the apical meristem falls below the horizontal, at which point it stops growing longer and growth energy is directed into younger stems. This is why tree branches stop growing longer when they become lateral.

Cutting off the apical meristem of a stem or branch also stops the branch from growing longer. It directs growth energy into buds along the stem or branch, causing them to start growing. This can be seen clearly in the nursery, when

young trees are topped. Removing the apical meristem of the main stem of the tree causes it to stop growing taller and to develop side branches, which is how the tree canopy starts developing.

Bending is another method that can be used to break apical dominance. This means simply bending a stem or branch so that its tip is below the horizontal and securing it.

Stems thicken through secondary growth. The cambia in the stem is made up of undifferentiated cells, and as the stem gets older, these cells differentiate into xylem, phloem, cork and other woody tissue. This causes the stem to thicken.

Stem Functions

Stems and trunks form the framework of the plant. The stems support buds and leaves, and serve as conduits for water and nutrients. One of their most important functions is to expose leaves to the maximum available sunlight.

Citrus Trunks and Stems

Citrus trees have main trunks from which lateral branches grow. A number of smaller branches grow from the lateral branches, on which the leaves grow. The citrus tree is referred to as a complex, branched tree.

In citrus, as is the case in other fruit trees, water shoots also develop. Water shoots, also called water sprouts, are stems that grow from dormant buds buried in old branches, often on the inside of the tree canopy. The shoots grow quickly and vigorously towards the light, feeding on the plentiful nutrients and water in the old wood. This fast growth causes the shoot to be thin and weak. The joint to the branch is also often weak. Water shoots are not ideally suited for bearing fruit and they are usually removed during pruning.

These growth habits have implications for production practices, and in particular for pruning. Removing deadwood and water shoots, improving light interception inside the tree canopy, and getting a good balance between vegetative growth and fruit production are the main aims of pruning.

Leaves

The leaves of plants, also called foliage, are probably their most noticeable structures. Leaf buds develop at the apex of stems and form nodes on the stem once the stem has grown longer. Leaves grows from the leaf buds. Leaves can take different forms, depending on the function that they have to perform.

Leaf Types

There are different types of leaves, classified according to their composition, venation and position on the stalk. Simple leaves just have a simple blade, but compound leaves have indentation on the edge that can sometimes reach to the centre midrib, which divides the leaf into leaflets. Leaf composition is about how leaflets are arranged around the midrib in compound leaves. The most common compositions are pinnate, twice pinnate, palmate, trifoliate and ternate leaves.

Leaf venation refers to the manner in which the veins are arranged on the leaf blade. The most common venation is parallel and pinnate.

Leaf position refers to where on the stem the leaves grow and their arrangement on the stem. The most common leaf positions are opposite, alternate, whorled and basal.

Leaf Structure

A typical simple, pinnate foliage leaf consists of a large, flat lamina, a petiole, and a leaf base with which the leaf is attached to the stem.

information

Glossary Definitions

The **lamina** is the blade of the leaf.

The **petiole** is the leaf stalk.

The leaves of monocot plants do not have petioles, and are attached to the stem by means of a leaf sheath.

The midrib and veins on the leaf blade are the vascular cylinders of the leaf. It runs from the stem through the petiole to the midrib and into the veins.

On the surface of the leaf there are stomata.

information

Glossary Definitions

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.

Leaf Functions

Leaves perform three very important functions, namely photosynthesis, transpiration and respiration. We will discuss this in more detail in the next section, when we look at plant functions.

Citrus Leaves

Citrus trees are evergreen. Leaves live only for about three years, depending on conditions. During early leaf growth, the young leaves use more carbohydrates than what they produce, becoming contributors only once fully grown at four to six weeks old. They reach maximum production capacity after about six months.

Flowers

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

Flower Structures

Flowers consist of whorls of flower parts that fit into one another. From the bottom, or outside, the flower consists of the pedicel, receptacle, perianth, stamen, and pistil.

information

Glossary Definitions

The **pedicel** is the stalk of the flower.

The **receptacle** is a set of very closely spaced nodes to which the whorls are attached.

The **perianth** is the outer structure of a flower, also sometimes referred to as the flower envelope, consisting of the sepals and petals.

The **stamens** form the third whorl inside the corolla and are the male reproductive organs of a flower.

Some flowers, such as citrus, have more than one whorl of stamens. The stamen typically consists of a filament and an anther.

The pistil is made up of the stigma, style and ovary. The ovary will become a fruit after the ovules are fertilised, and the ovules will become the seeds.

information

Glossary Definitions

The **filament** is a slender, flexible stalk that supports the anther.

The **anther** bears the pollen in pollen sacs. Pollen grains contain the male reproductive cells.

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

The **stigma** is the top part of the pistil that receives the male pollen grains.

The **style** is an extension of the ovary, shaped like a stalk. It supports the stigma and connects it to the ovary.

The **ovary** contains one or more chambers, which contain ovules.

Flower Functions

Flowers are the reproductive parts of plants and produce male sex cells contained in pollen grains, and female sex cells contained in ovules. Some flowers are brightly coloured and produce nectar to attract pollinators, such as birds, butterflies, bees and mosquitoes.

Citrus Flowers

The citrus flower is reasonably typical. It is composed of sepals at the base, which remains on the fruit as the calyx.

This is followed by white petals, which enclose the stamens and pistils. This is known as a complete flower, meaning that both female and male reproductive structures are present.

Fruit

Fruit develops from the ovaries contained in flowers, and normally contains seeds with zygotic embryos. The fruit protects seeds and in some cases helps them to disperse.

Fruit Structures

Fruit normally consists of a pericarp and one or more seeds. The pericarp in fleshy fruit consists of the exocarp, mesocarp, and endocarp.

information

Glossary Definitions

The **pericarp** is the part that surrounds the seed or seeds, and includes the skin and flesh of fleshy fruit.

The **exocarp** is the outer fruit covering.

The **mesocarp** is the middle fruit covering.

The **endocarp** is the inner covering, in many cases the stiff or hard covering of the seed.

The exocarp, mesocarp and endocarp take on different roles in different types of fruit. In fleshy fruit the pericarp develops into these three layers around the seeds as the fruit ripens. In a mango and peach, for instance, the exocarp is what we know as the skin, and the mesocarp is the flesh. In stone fruit such as peaches, plums, apricots and mangos, the endocarp is known as the stone. The seed is normally enclosed in the endocarp.

In dry fruit, such as nuts, grains and legumes, you cannot distinguish between these three layers.

Citrus Fruit

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.

In citrus, the exocarp – also called the flavedo – is a few cells thick, has a waxy cuticle on the outer side. It contains pigments which give it the green or orange colour and oil glands.

The mesocarp contains loosely packed cells with many air spaces, which later become the albedo.

The endocarp contains the segments and juice vesicles, and becomes the edible part of the fruit. The seeds, if present, are found within the endocarp.

information

Glossary Definitions

The **flavedo** is the coloured outer peel layer of citrus fruits, also called the zest.

The **albedo** is the whitish inner portion of the rind of citrus fruit, also called the pith.

The **vesicles** in citrus fruit contain the juice of the fruit, and is also called the pulp.

Plant Functions

Plants perform many complex functions, but at the basis of it are the three metabolic processes that are fundamental to plant growth, namely photosynthesis, transpiration and respiration.

Photosynthesis

The principal function of leaves is to absorb sunlight to manufacture carbohydrates through photosynthesis. Think of leaves as the food factory of the plant.

information

Glossary Definitions

Photosynthesis literally means production through light, and it is the metabolic process by which green plants turn carbon dioxide and water into food in the form of carbohydrates using energy from sunlight.

This formula shows the process that takes place during photosynthesis. The plant absorbs water through the roots and it is taken to the leaves through the xylem in the vascular tissue. Through the stomata in the leaves, the plant absorbs carbon dioxide, for which the chemical formula is CO_2. The green pigments, or chlorophyll, in the leaves absorb sunlight and with this energy the plant manufactures carbohydrates in the form of sugar, with the chemical formula $C_6H_{12}O_6$. The remaining oxygen and water molecules are released through the stomata.

information

Glossary Definitions

Chlorophyll is a green pigment, present in all green plants, which is responsible for the absorption of light to provide energy for photosynthesis.

The carbohydrates that are manufactured by the leaves are transported back through the phloem to the other plant parts where it is stored until it is needed for plant growth and to produce fruit and flowers.

Transpiration

The loss of water vapour through the stomata is known as transpiration.

information

Glossary Definitions

Transpiration means to lose water through the surface of a plant, particularly through the stomata.

As we can see from the photosynthesis formula above, about half the water that is absorbed by the roots are lost through the leaves during transpiration. Transpiration helps to cool the plant, which is why the transpiration rate is higher during hot summer months, and why plant growth speeds up. It is also why irrigation must increase during the summer.

The loss of water through the stomata causes water to move from the roots to other plants parts. 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, from where it is "pulled" through the roots and stem to the leaves.

information

Glossary Definitions

Osmosis is a process by which a substance, usually a gas or fluid, moves from an area where there is a lot of it to an area where there is less of it, in order to equalise the concentrations in the areas.

Respiration

Carbohydrates made by the plant during photosynthesis are not used directly. The process by which a plant converts carbohydrates to growth energy is called respiration.

information

Glossary Definitions

Respiration is an oxidation process through which energy is produced in cells.

Only cells with chlorophyll can carry out photosynthesis, but all live cells carry out respiration.

During respiration, oxygen is taken in through stomata, and the oxygen is used to break the stored food down into energy. Water and carbon dioxide is released back into the atmosphere through the stomata, and the energy is used for plant growth.

Conclusion

That is the whole picture of the more common plants. There are of course plants that are exceptional in that they do not have some of these parts, or plant parts in strange positions, or parts with modified functions. However, if you understand and remember everything that we learnt in this module, it will put you in a position to understand how most plants are put together and how they grow, and it will definitely help you to grow citrus plants more productively.