Lesson 4.

PLANT PROPAGATION

LESSON AIM

Develop an understanding of the principles and main practices of plant propagation in horticulture.

In this lesson you will consider the following

- How to differentiate between plants produced by seed (sexual) and plants produced by vegetative propagation methods (asexual)
- Seed propagation
- Cutting propagation
- Propagation aftercare
- Layering
- Propagation tools
- Grafting
- Propagating plants in a greenhouse

SEXUAL AND ASEXUAL PROPAGATION

Growing plants from seeds and by cuttings or by separation is not difficult. Many home gardeners grow new plants from old with just a few tools and a basic knowledge of what they are doing.

In commercial horticulture, where plants are raised in their thousands, using sophisticated equipment and technology, successful propagation involves a more detailed understanding of how environmental and physiological factors affect plant growth, reproduction and development.

Sexual and Asexual Propagation

There are two methods of propagation:
1. Sexual (seed propagation)
2. Asexual (vegetative propagation)

With sexual propagation, the genetic makeup of the new plants is variable and the plants may show different characteristics to their parents.

With vegetative propagation, the genetic makeup of the new plants is identical to the parents, and can be reproduced through many generations of new plants.

Sexual Propagation (Seed Propagation)
Sexual propagation involves growing a plant from a seed or spore which has been produced by fertilisation of the female part of the plant by the male part of the plant (usually of another plant).

Plants grown this way can have some characteristics of one parent; and different characteristics from the other parent. A sexually propagated plant is not always exactly the same as the plant from which the seed or spores was taken.

Most flowering annuals, vegetables, biennials and perennials are grown this way. Ferns and some trees and shrubs are also grown sexually.

Asexual Propagation (Vegetative Propagation)
Vegetative propagation involves reproducing a new plant from only one parent. A part of an existing plant – a piece of stem, leaf or root (or possibly all three) is treated in some way so that it can produce a new plant.

Types of Vegetative Propagation

The most common form of vegetative propagation is *cutting propagation*.
The simplest form is *division* or *separation* of plants that multiply naturally.
The most technically involved form is *tissue culture*.
Other forms of vegetative propagation include *layering* and *grafting*.

GROWING PLANTS FROM SEED

Seeds can produce variable results; in other words plants grown from seeds are not necessarily a replica of the parent plant. Plants grown from the same batch of seeds may have variations in their growth habit, flower colour, leaf shape, environmental tolerances, or other characteristics. This is brought about by a random combination of genetic material from the parents. The genetic make-up of each seed is unique.

Plant breeders deliberately cross-pollinate plants that are genetically different in order to find interesting features, with the aim of producing new varieties or cultivars.


Citrus Seed

When Do We Sow Seed?
Following are some examples:

- Lawn seed is sown to create a new lawn, or to repair an established lawn.

- Vegetable and annual flower seeds are either sown directly into prepared beds or into containers. Container-grown seedlings are then transplanted into outdoor beds.
- Some tree seeds (e.g. peach, citrus, apple, maple) are sown directly into outdoor beds to produce rootstock plants for selective grafting later.
- Many seeds are sown in containers for germination in a protected environment, then separated, transplanted and potted on later.

What is required for successful germination?

In order for seeds to germinate they require:

1. water and oxygen
2. appropriate temperatures
3. sometimes light (depending on the species)
4. viable seed

Given the above, a seed will germinate readily, the embryo will develop and the plant will grow. If any of these requirements is lacking or insufficient, the seed will not germinate.

Some seeds require special treatment such as a period of cold (stratification) before it is ready to germinate; others may require soaking in hot water or abrasion (scarification) of the outer coating (testa) to assist germination.

Why Some Seeds Do Not Germinate

1. The seed is not viable – it might not have formed properly or it may have perished after trying to germinate some time previously.

2. The environmental conditions, i.e. water, temperature and light, are not suitable.

3. The seed may be dormant (e.g. some seeds have chemical inhibitors that prevent germination during dry seasons).

4. The seed (depending on species) may need the hard outer coating (testa) to be breached either by soaking in hot water or by chilling (stratification), or have the outer coating broken through mechanical or chemical abrasion (scarification).

Difficult-to-Germinate Seeds

Some types of seeds are much more difficult to germinate than others. In their natural state most species have adopted mechanisms which allow germination to occur with relative ease. For many "difficult-to-germinate seeds", it is possible to carry out some type of pre-germination treatment which will increase the chances of success.

There are two main types of seeds:

Endospermic Seeds. These have endosperm (i.e. food for the young seedling) stored inside the seed separate to the embryo. In endospermic seeds, any barrier to germination is usually physiological (e.g. a chemical within the seed which inhibits germination).

Non-Endospermic Seeds. These have food (if any) stored only within the cotyledons (i.e. the dormant first leaves within the seed). In non-endospermic seeds the barrier (if there is one) will usually be a physical one (e.g. a hard seed coat which is impermeable to water).

Treatments to Break Seed Dormancy

Soaking in Boiling Water

1. Place seed in a cup or container.
2. Pour water which has been brought to the boil over the seed. Cover the seed generously.
3. Stir.
4. Leave soaking for 24 hours. (Water is allowed to cool. Do not keep it boiling.)
5. Remove and discard any floating seeds after 24 hours (the floating seed will not usually germinate).
6. Sow the remaining seed.

Many (but not all) legume species are treated this way eg. *Gleditsia*, *Acacia.*

Stratification (also known as moist chilling)

1. If seeds are dry, soak for 24 hours in water (otherwise proceed to step 2).
2. Mix seed with slightly moistened peat moss, sphagnum or vermiculite (1 part seed to 3 parts medium).
3. Place in a polythene bag, label and tie. It is important that you use polythene...polythene is much more permeable to oxygen than some other plastics. A fungicide may be added to help protect the seed.
4. Place the bag in the bottom of a refrigerator (not the freezer).
5. At the end of the required period (this varies from plant to plant),remove seed and sow.

Species treated this way include cotoneaster, (5 weeks), apple, pear, stone fruit, ash, maple, birch, pine (3 months).

Soaking in Cold Water and other Methods
Soak the seed for 24 hours in cold water (e.g. celery, Monterey pine, Douglas fir). Other methods such as scarification or breaking hard seed coats with sandpaper or acid can be used at times by skilled propagators.

Sources of Seed
There are four main sources of seed:

- Seed collected from the wild. Seeds collected from plants growing in their natural habitat are less likely to be cross-pollinated, and you can be more certain of where they came from and how they will grow (than if you had purchased the seed).
- Seed exchanges. Many botanic gardens operate seed exchange programs, where they produce annual seed lists and swap seed with others involved with the program. Such programs are particularly valuable as a source of scarce varieties of plants. Some associations and societies also participate in exchange programs.
- Commercial seed suppliers. There are hundreds of seed companies operating throughout the world. Some breed new varieties of plants and grow seed crops to harvest. Others buy seed from collectors who collect from the wild or from gardens. Major problems of using this source include collectors identifying seed source plants incorrectly; unreliable supply (if they can't supply, it may be too late for you to collect the seed yourself); uncertainty about the quality and developing a dependence on the supplier. Major advantages of using this source include convenience; obtaining a seed source for plants which do not set seed well locally and savings on labour costs.
- Collecting seed yourself locally. You might collect seed from plants on your property, or on other nearby properties as it matures throughout the year. Seeds may also be collected from public parks and gardens or private gardens (with permission). The major advantages of this source are that you have a great deal of control over collection, storage and treatment; you can be sure you have got exactly what you want; you learn a lot more about the plants you are growing, because you see them in their mature state and you can save on cost of purchasing seed (although collecting can be time consuming, particularly if you have to travel to collection sites).

Factors that should be taken into account when sourcing seed:

Quality
- Some seed suppliers do not supply pure seed. Rubbish or weed seeds might be mixed with the seed.
- Some seeds have not been harvested at the right time, hence percentage viability is lower.
- Some seeds have not come from strong and healthy plants hence the seed may have reduced vigour.

Gene Pool
The place where a particular plant originates gives it a range of characteristics that are very specific to that area. Particular species growing in different areas may change slightly so that they adapt to match local conditions and individual habits. This is also referred to as provenance.

Seed Saving
When plants are allowed to naturally pollinate each other, produce flowers, fruit and then seed, the local conditions will determine whether the offspring of those plants are suitable for the area.

Plant varieties form other areas may not be suited to your locality without large inputs of fertilisers or pesticides. Growing your own herbs and vegetables can provide the ideal seed source for your conditions. Only collect seed from healthy plants, preferably with good yields and pleasant tasting produce. Wait until the seeds are ripe before harvesting, but do not allow the seed to over-ripen, fall out or blow away. Ideal storage is in envelopes placed in cool, dry and dark conditions. Label your seeds with species, place grown, time harvested, etc.

Seed Storage

Seeds are alive and like any living thing they can be harmed by adverse conditions. Seeds of some species do not store for very long at all, in such cases use only fresh seed (this group includes spring-ripening seeds of certain temperate zone plants). Most seeds however, when stored appropriately, will be viable for at least six months.

Factors Affecting Storage of Seed

Moisture Content

- Many short-lived seeds lose viability if they become dry (eg. citrus seed only withstands slight drying).
- Medium to long-lived seeds, on the other hand, need to be dry to survive long periods of storage (4% to 6% moisture level is ideal - higher or lower can be detrimental to viability).
- Fluctuations in moisture levels during storage will reduce longevity. For this reason, seeds keep better in dry climates than in areas of high humidity.

Temperature

Most seeds will store for longer periods at lower temperatures.

With seeds not adversely affected by low moisture, for each 1% decrease in seed moisture (between 5% and 14%) the life of the seed doubles. For each decrease of 5^{o}C between 0^{o}C and 44^{o}C, the seed storage life will double.

Storage Atmosphere

Some techniques of modifying gas levels (eg. increasing carbon dioxide) can be of value.

Ways of Storing Seed

Open Storage with No Controls: Storage in bins, sacks or paper bags.

Fumigation or insecticide/fungicide applications are sometimes necessary. Seeds of many annuals, perennials, vegetables and cereals can be successfully kept this way, apart from a few exceptions (eg. corn, onion, parsley, parsnip, delphinium, candytuft). Seeds from these groups will normally retain viability for at least a few years.

Cold Storage With or Without Humidity Control

Temperatures below 10^{o}C will improve longevity of virtually any type of seed. Cold storage of tree and shrub seed is recommended if the seed is to be held for more than one year.

Cold Moist Storage

Seed should be stored between 0^{o}C and 10^{o}C in a container containing some moisture-retaining material (e.g. peat or sphagnum moss). Relative humidity should be 80% to 90%. Examples of species requiring this type of storage are: *Acer saccharinum*, *Carya* spp., *Castanea* spp., *Corylus* spp., Citrus, *Eriobytra* (loquat), *Fagus* spp., *Juglans* spp., Litchi, *Persea* spp. (avocado) and *Quercus* spp.

SOWING SEED INDOORS

Vegetable and flower seeds are often planted in containers and germinated indoors or in a protected environment such as a greenhouse or cold frame to protect them from extreme weather conditions until conditions improve outside.

Sowing guidelines:

- Use a container with lots of holes in the bottom for good drainage.
- Wash the container in antiseptic (e.g. diluted household bleach) to kill any diseases then rinse off in hot water and let it dry.
- Use a "clean" propagating mix. An ideal mix is well drained and has no soil (this minimises disease).
- A typical propagating mix is 75% coarse sand and 25% peat moss or vermiculite.

How to Sow Seeds in Containers

1. Fill the container with propagation media and level off to approximately 5-10mm below the rim, then soak (by immersion) in water. Level the surface and firm the mix lightly, but not too hard. Over-firming will reduce the air spaces and result in over-wetting.

2. Seeds are sown evenly over the tray surface. Small seeds can be difficult to spread evenly. To spread evenly, use a pepper shaker, mix the seed with dry sand beforehand, or buy a small plastic seed sower. Sow the seed on the surface, but not too thickly.

Note:
*Thick sowing restricts air movement, which encourages disease. Overcrowding also weakens seedling growth.
*Nurseries need to maximise available propagation space; practice and experience helps to strike a balance. Seed-sowing machines (e.g. vacuum sower and hydro-seeders) used in larger nurseries help to achieve this.

3. Cover the seed with fine sand or propagation mix. Only cover to a depth equivalent to the thickness of the seed. This depends on the species as some seeds need light to germinate.

Note:
*If seeds are sown too deep the plant will be weakened or may not emerge due to the extra energy required to get to the surface.
*If sown too shallow, the roots might not take hold into the medium, possibly exposing the seed to dehydration in early growth.

4. Water the container with a fine spray from above, or place the tray in shallow water until the top of the propagation mix is damp. Remove the container and place it on a bench to help excess water drain quickly.

5. Label containers with the species name and date and determine the appropriate location to assist germination i.e. a greenhouse, cold frame. In a nursery situation, you would also keep propagation records.

6. Media must be kept moist during germination. Use an irrigation system with a timer or sensor, or for small quantities of seed, hand-water, being sure to use a very delicate touch to avoid seed disturbance.

*Once the seedlings have four leaves (for most plants) they can be removed from the pot. Carefully tease the seedling out of the potting mix, using a pointed implement. Make sure the roots are intact and hold it by the leaves only. Alternatively, gently wash the propagating mix from the roots. Do this by immersing the whole pot in water as you remove the seedlings.
*Seedlings can then be either planted individually into pots or, if conditions are good, planted outdoors.
*Don't allow potted up seedlings to get too big before planting out.

Germination
The amount of time a seed takes to germinate depends on the species and can vary greatly. Some annuals, such as pansies, germinate in a few days, parsley (a biennial) in three weeks and some tree seeds can take months.

Temperature is also important as it affects the speed and the percentage of seed that germinate. Certain seeds will germinate in a wide temperature range. Tomatoes, for example, will germinate in temperatures that range from 10℃ to 35℃ with an optimum of 26℃. Most germination lists or tables specify optimum temperatures.

Containers

A range of containers used for seed germination include:

- seed trays
- seedling containers (will hold several seedlings)
- square pots
- standard pots
- root trainers (used in tree growing)
- cell trays (able to contain up to several 100 seedlings)

Note: The types of containers used and names given to those containers will vary from one country to another.

Hygiene
Cleanliness is essential to minimise disease infecting young plants. Containers, benches, tools, spades, media bins etc should be thoroughly cleaned before use.

To clean containers:

1. Wash off any dirt in warm soapy water.
2. Then soak the containers in a solution of household bleach (20ml of the concentrate to 1 litre of water).
3. Give a final rinse in clean water.

Disease outbreaks spread quickly, particularly in artificial conditions such as greenhouses where humidity can encourage growth of fungi or bacteria. Preventing such problems from developing is the best strategy, however if they do occur, it is essential to deal with them quickly and effectively.

GENERAL CHARACTERISTICS OF SEED PROPAGATING MEDIA

Media is the term given to the solid material(s) used to grow the roots of plants in. Media must fulfil the following criteria:

- It must be relatively clean (free of disease).
- It must be chemically stable.
- It must drain freely enough to not create water-logging problems.
- It must have adequate water holding capacity.
- It must have good porosity to permit aeration and ease of root penetration.

ALSO
*Buffer capacity should be good - this is the ability of the media to resist changes in pH.
*It is preferable that the Cation Exchange Capacity (see below) is at least moderate to good.

Cation Exchange Capacity (CEC)

Cations are positively charged ions. Many important plant nutrients occur in solution as cations (i.e. potassium, calcium and magnesium). These particles will attach themselves to media particles (such as peat moss and clay) which have a negative charge, therefore staying in the media and being available to the plant roots for a longer period of time.

Organic matter, such as peat and clay, has a higher cation exchange capacity than sand and gravel. Media with a lower cation exchange capacity will require more frequent application of nutrients than ones with a higher cation exchange capacity. When nutrient solution is applied to a media with low cation exchange capacity but high water-holding capacity, the media might remain moist, but the nutrients do not remain in the media after the irrigation as much as when the media has a high cation exchange capacity.

Seed Mixes
Typical seed propagation mixes include:

1. Sand and Peat - normally 75% coarse washed sand to 25% shredded peat moss. In some cases proportions can vary down to 100% peat for fern spore, and up to 90% sand under continuous mist systems.

2. Sand and Perlite - normally 50% to 50%.

3. Peat and Perlite - normally 10% peat to 90% perlite; sometimes straight perlite.

4. Vermiculite and Sand - normally 75% sand to 25% vermiculite; never more than 40% vermiculite.

5. Rockwool - insulation-type material made by spinning fibres of molten rock. Has high ability to hold both air and water (only 3% solids).

6. Polystyrene and Peat - normally 50% to 50%. Polystyrene must only be mixed with lightweight material such as peat.

With the recent developing interest in peat-free mixes, some wood-based mixes are now appearing in the market.

SOWING SEED OUTDOORS

Seeds can be sown directly into position into garden or field beds, or into specially prepared seed beds and containers, and transplanted later. Most commercially supplied seeds come with specific instructions for sowing.

The following are general rules for sowing any seed outdoors:

- Use good quality seed.
- Sow at the right time of year. Temperature and moisture levels play an important role in successful germination.
- Do not sow too deeply. In nature seeds are generally dispersed from plants onto the ground surface.
- Do not sow too thickly. Germinating seedlings will compete for space and nutrients. Pest and disease problems are also more prevalent in dense plantings.
- Avoid sowing directly from the seed pack, particularly with fine seed, as it is very hard to get an even distribution of such seed.
- Have well-prepared soil.
- Maintain adequate moisture to aid germination but don't over water.

How to cultivate an area in preparation for seed sowing

- Cultivate to a fine tilth (i.e. no large clods or large pieces of organic matter, weeds, old crops etc). A motorised hand tiller is excellent for this job, otherwise, some good spade, pick and fork action will be required. Break up all sods and blend the soil well.
- Remove any perennial weeds.
- Incorporate (dig in) green manures (eg. cover crops or any other plant residue).
- Incorporate appropriate fertiliser if needed.
- Add ameliorants (e.g. gypsum or lime) if needed. Note: These are better applied the previous season if possible i.e. in autumn for spring planting.
- Level the area with a rake.
- Ensure soil is damp but not too wet or too dry (ideal moisture level is slightly less than field capacity).
- Ensure soil is free draining, ie. not waterlogged or impervious to oxygen. If necessary, create raised beds or drainage channels.

Sowing the Seed

1. Broadcast seed or sow into trenches, then cover seed to the correct depth according to species. Hand-held as well as mechanical seed spreaders are often used for broadcasting large quantities of field-sown seed. .

2. Irrigate, taking care to minimise disturbance to the soil surface, as soon as possible after sowing, to start the germination process. Use a fine mist spray or fine nozzle watering can.

3. Thin the emerging seedlings to the required spacing. Fill gaps with left-over seedlings.

NOTE
*Large seed can often be easily placed evenly along the furrow, however fine seed may need to be mixed with fine sand to get a more even spread.

*Very large seed (eg. melons, cucumbers and beans) can be planted by pushing (drilling) a hole with a sharp stick or dibber to the required depth and dropping seed in. When sowing is completed, lightly cover seed by replacing the soil that has been removed while making the furrow or hole. Soil should then be lightly firmed down.

How to Sow In a Straight Line

Straight rows can be marked by using a length of taut string or straight-edged piece of wood; then using a pointed or sharp-edged object make a slight furrow or trench along the row to the depth recommended for that particular vegetable seed.
Sow your seed thinly along the row.

SOWING AND TRANSPLANTING GUIDE

The following sowing and transplanting recommendations can be used as a guide for the spacing, sowing depth requirements of a variety of vegetables. (2.5cm = 1inch)

Crop	***Spacings Average(cm)***	***Depth (cm)***	***Weeks to maturity***	***Remarks***
Broccoli	50 x 70	1.5	10-16	Seed or seedlings
Brussels sprouts	"	1.5	18-25	Seed or seedlings
Beetroot	"	2.0	9-12	Seed
Silver Beet	"	2.0	8-12	Seed
Cabbage	"	1.5	8-16	Seed or seedlings
Capsicum	45 x 70	1.0	12-16	Seed or seedlings
Carrots	5 x 60	1.5	10-20	Seed
Cauliflower	40 x 70	1.5	12-26	Seed or seedlings
Celery	40 x 70	1.5	10-16	Seed or seedlings
Chicory	18 x 75	2.0	10-16	Seed or seedlings
Cucumber	25 x 140	2.0	9-14	Seed or seedlings
Eggplant	60 x 80	1.0	14- 18	Seed or seedlings
Kohlrabi	20 x80	1.0	10-12	Seed thin later

Leek	10x 40	2.0	20-24	Seed or seedlings
Lettuce	30 x 90	1.0	9-12	Seed or seedlings
Onions	10 x 40	2.0	24-40	Seed or seedlings
Parsnip	10 x 80	1.5	18-25	Seed
Potato	25 x 90	8-12	12-20	Sprouting tubers
Pumpkin	50 x 1.5	3.0	14-22	Seed or seedlings
Radish	2 x 30	1.5	4-5	Seed
Spinach	10 x 40	2.0	7-10	Seed or seedlings
Turnip	10 x 40	1.0	14-16	Seed
Tomato	40 x 100	1.5	12-16	Seed or seedlings

SEEDLINGS

Seedlings are obtained from a variety of sources:

- From special seedling beds
- Grown from seed sown in containers
- Those left over from thinning out beds
- From commercial growers

When buying and transplanting seedlings consider the following:

1. Choose only healthy-looking plants i.e. no obvious discolouring, stunted growth, signs of damage etc.
2. Reject any seedlings with obvious signs of pest or disease damage.
3. Do not buy overcrowded seedlings, or those with extensive root growth protruding from the seedling container. These seedlings are pot bound and will not transplant well.
4. Avoid small, soft seedlings. These may not have been hardened off sufficiently.

Pricking-Out or Potting-Up Seedlings

Once seeds have emerged and have developed a set of true leaves (not seed leaves/cotyledons) the seedlings should be transplanted into a new growing environment because:

a. This gives them more space to grow.

b. For quick and healthy growth they need media that has added nutrition.

The type of pots used depends on the species, for example vegetable seedlings may be pricked out into containers (e.g. small rectangular containers holding up to 12 plants). Seedlings from larger plants will be potted into small pots 4 to 10cm in diameter.

*Note: some seedlings may still be too small to prick out at the first true leaf stage. In this instance the seedlings will need to be fertilised with a dilute soluble fertiliser until they are large enough to handle without damage.

All seedlings are easily damaged so they need to be handled carefully. If the delicate root structures are damaged the plant may not be able to recover.

1. Water seedlings well before transplanting.
2. Fill plastic containers with suitable growing media to 5mm of rim.

3. Lift seedlings carefully from the communal tray by inserting a dibber (small round pointed stick) underneath the roots and carefully easing it from the media without breaking the roots.
4. Hold the seedling by the foliage (carefully) between the thumb and forefinger, taking care not to damage the terminal bud. Never hold delicate seedlings by the stem
5. Make a hole in the soil with the dibber in your other hand the length of the seedlings root system.
6. Place the seedling carefully into the hole making sure that the roots are hanging down and not curled. Very long roots may need to be reduced in size. Trim cleanly with a sharp knife or scissors.
7. Fill the hole by pushing soil in from the sides with the dibber or your fingers.
8. Place containers into a tray and water well.
9. Place the trays into an environment similar to that used for germination.
10. Seedlings need to be gradually hardened off by moving them into less sheltered environments progressively i.e. heated glass house – unheated greenhouse – shade house- open air.
11. Label containers.

*Potted seedlings need to be watered at least daily - more often during hot weather.

When taken from a clean protected propagation area and planted directly onto the ground, tender young seedlings may suffer transplant shock and in some cases be exposed to disease and other adverse environmental effects. However, healthy seedlings usually recover and eventually become vigorous.

Transplanting Seedlings Outdoors
To reduce transplant shock water the bed the day before transplanting and the containerised seedlings an hour or so before transplanting. This maintains sufficient moisture in the root zone and prevents the soil or seedling mix crumbling away during handling.

Use a dibber to make a hole then plant the seedling into the bed, firm the soil around the plant, making sure that the seedling is at the same depth as it was in the seed bed or container. Water well.

Potting a Small Plant into a Larger Pot
When you start seeing roots emerge from the bottom of your pot plant, it is time to re-pot into a larger container.
Select a pot that is slightly larger, but usually only one size larger.

1. Gently remove the plant from the smaller pot. If the plant will not come out easily, first immerse it in water, as a wet root ball will slide easier from most pots. If it is still difficult, slide an old kitchen knife around the edges of the pot. Thump the pot firmly on the ground, to loosen the roots' grip inside. If the pot is plastic, it can sometimes be squeezed to encourage roots to loosen their hold on the interior. If it still does not come out, you may have to break or cut the pot.
2. Loosen any tangled and circling roots. Prune the roots if necessary.
3. Place a layer of quality potting mix at the base of the new pot.
4. Place the plant in the centre of the new pot. The soil level should be approximately 25mm (one inch) below the top of the container.
5. Fill the sides of the container with potting mix, firming it down as you go.
6. Water thoroughly to help remove any air pockets.

7. Cut back any dead or diseased foliage and prune to shape. If you removed a large mass of root tissue, remove a proportionally large amount of foliage to compensate.
8. After the newly potted plant has begun to establish itself, the addition of have a slow-release fertiliser can be beneficial.

PROPAGATION AFTERCARE

Hardening off Young Plants

Seed grown seedlings and rooted cuttings(covered later this lesson) need to be hardened off prior to transplanting into their final position - this includes plants that are to be grown in pots indefinitely, those that will be sold as more advanced specimens or those that are to be planted in the open ground.

All plants need to hardened-off to enable them to cope with living in a harsher drier environment.

After pricking out, the cuttings/seedlings are placed back into the same environment they came out of (e.g. glass house) for a few weeks, before the hardening off process begins. This enables the young plants to settle into their individual pots and extend their roots systems. Seedlings and rooted cuttings are used to a moist and a sheltered environment - when propagated in a greenhouse or other propagating structure. Due to this they have not developed sufficient root hairs to survive a harsher, drier environment.

To lessen later transplant shock, the young plants are *gradually* moved into a drier and harsher environment.

At this point, if you gradually decrease the amount of watering the young plants receive over a 2-3 week period, they will produce a large amount of root hairs. This will increase and enhance water uptake. However, do not under-water the plants as container-grown seedlings tend to dry out quickly.

Hardening-off is a preparation process that slows growth and gives the seedlings a greater tolerance to stress, once planted in the open ground.

During 'hardening-off' the plant develops waxes and cuticles on the leaf surface, as a protection against drying out, and the plant begins to store carbohydrates to stimulate growth after transplanting.

Hardening-off methods

1. Reduce watering, i.e. water less, both in frequency and quantity.
2. Over several days move the plants from a sheltered, high temperature area to a more exposed condition for example:

✓ First - from a heated greenhouse,
✓ Second - to an unheated greenhouse,
✓ Third - to open air with greenhouse roof coverage,
✓ Fourth - finally to a sheltered, open situation

3. Apply liquid fertiliser two days before transplanting then cease fertiliser application, particularly nitrogen.
4. Harden off for approximately seven days (depending on the plants, the climate and season, and the environment of the hardening off areas).

NB. Be careful about exposing delicate seedlings to overnight frosts and freezes. However, when finally planted outdoors, hardened-off seedlings will have a higher survival rate in challenging conditions.

Problems associated with incorrect hardening-off:

1. Too rapid hardening– slows subsequent resumption of growth.
2. Lowers yields i.e. the **quantity** of fruit produced by each plant.
3. Yield **quality** may be reduced.
4. Delays yield.
5. Plants may bolt and run to seed.

Once the plants are hardened-off, further care will depend on:

- The individual species of plants
- The length of time they will be in the nursery before sales or
- The amount of time they will be in the pots before transplanting into the ground.

Aftercare may include fertilising, pruning, watering, weeding and re-potting for plants to be grown to a more advanced stage before sale

ENVIRONMENTAL INFLUENCES ON PLANTS

Environmental conditions affect different species of plants in different ways. Good plant selection involves matching plant species to the environment in which they are to be grown. This process must take into account not only the existing environmental conditions, but also the changes which occur in the environment.
Some of the environmental factors that affect plants are:

- Seasonal variations, e.g. maximum and minimum temperatures.
- Changes brought about by humans, e.g. ozone depletion and climate change, location of buildings, power lines, gas and water etc. These factors may influence the microclimate.
- Changes brought about by the growth of plants themselves, e.g. taller-growing species outgrowing their smaller neighbours and shading plants that were previously in full sun.
- Light - different species react in different ways to light. Some require greater amounts of light than others. For some, the duration of sunlight exposure is important, for others light intensity is more important than the duration.
- Temperature – each plant species has an optimal range that maximises growth potential.
- Water – lack of water can impair transpiration. Too much water will impair oxygen uptake.
- Frost - frost hardiness is a complicated issue as it depends on a series of related environmental factors. Frost resistance also depends greatly on the time of year and growth stage of the plant eg. swelling buds are very susceptible to frost damage.
- Humidity - affects water movement out of the plant.
- Wind - also affects the water content of the plant, plus it may lead to mechanical damage.
- Salt tolerance.
- Chemical air pollution.

PROPAGATION FROM CUTTINGS (asexual propagation)

A cutting is a piece of vegetative growth (non-sexual i.e. not the flower or fruit) which is detached from a plant and treated in a way to stimulate it to grow roots, stems and leaves i.e. another new plant. Cutting propagation is most commonly used for shrubs, indoor plants and many herbaceous perennials. It is the most common method of asexual reproduction used by horticulturists.

Most cuttings are pieces of stem, often with some leaves left at the top of the stem. Some plants can be grown from cuttings of other tissue (e.g. a piece of leaf, or section of root, or even part of a bulb, with no stem at all).


Callistemon stem cutting


Geranium Stem Cutting

When a plant is grown from a cutting it is genetically identical to the parent plant. Cuttings are the most widely used technique for reproducing "true to type" plants. This ensures that the unique characteristics of the parent plant are passed on to the progeny.

Cuttings can often be used to propagate plants that:

- Don't produce viable seed, or produce seed at irregular times
- Have seed that is difficult to germinate
- Have seed that is difficult to collect, for example, plants that have seed pods that burst open, dispersing the seeds widely
- Produce their seed at a time when seed cannot be collected, or collection would require a further trip to the area (often very difficult for remote areas), or can only be collected with difficulty (e.g. plants whose seed matures during wet seasons when access may be limited).

Cuttings can be useful as they may avoid the problem of juvenility in the newly propagated plants. Most plants grown from seeds go through a juvenile stage, in which flowering, and hence seed production does not occur. Some plants may take five, ten, or more years before they commence flowering. Once flowering has occurred, propagation from that plant by cuttings will avoid the juvenile stage. The new plants may flower early, often within months of the cutting having been taken and rooted (struck).

Many plants also have undesirable growth forms when they are young. These include very vigorous growth, thorniness, or unattractive foliage or form. By taking cuttings from adult plants these undesirable characteristics can be avoided.

In some cases the juvenile form of a plant may have characteristics that are more desirable than those of the adult form. A good example of this is the smaller, immature foliage of the *Hedera helix* cultivars (English Ivy). For some plants cuttings will strike more readily from juvenile material.

Cuttings are usually planted into a mix of materials such as sand, peat moss, perlite, rockwool or vermiculite. Part of the tissue is usually below the surface of the mix, and some exposed above the surface.

The cuttings then needs to be kept moist, and other conditions such as light, temperature, humidity and hygiene should be kept appropriate to the requirements of the variety of plant being grown.

Chemical hormones may be applied to stimulate the formation of either roots, or foliage/shoot growth. Pesticides or disinfectants may be used to prevent diseases or pests. Heating may be used to warm the root zone (i.e. bottom heat) to encourage faster growth of roots; or periodic misting of the foliage to cool the top of the plant, or to prevent dehydration of the foliage.

Success with cuttings
There are several factors that influence the efficiency achieved in the production of rooted cuttings. Some of the more obvious factors are listed below.

Quality of work
- How well is the cutting prepared and planted?
- Has the propagator damaged the cutting material excessively? (This would increase likelihood of pest or disease damage.)
- Has the correct amount of leaf been removed?
- Has the cutting been placed in the propagating media properly?
- Has the cutting been treated in a way which will minimise drying out throughout the cutting operation?
- Have the propagating mix and tools been kept clean?
- Has the propagating mix been mixed thoroughly?

Selection of the most appropriate technique
- What time of the year is the operation carried out?
- What type of cutting is used? i.e. semi hardwood, hardwood, softwood, tip cuttings, older wood, leaf bud, leaf, root, 4cm long, 6cm?
- What type of propagating media is used? i.e. sand/peat, sand, vermiculite, rockwool, open ground, perlite bed, gravel bed, nutrient agar ...etc?

After- care
- Where are the cuttings placed after planting? (are they outside and exposed to the elements, in a glasshouse, in a cold frame, in a hot bed, in a propagator...etc?)
- How frequently are they watered? Are they watered by hand, by manual sprinklers, or by automatic sprinklers?

Growth stimulation
- Have any techniques(s) been used to stimulate root growth? i.e. hormones, bottom heat, wounding, intermittent misting?

Success Rate

- What proportion of cuttings planted actually form roots?
- How long does it take for the cuttings to form roots
- Variety being propagated. Some varieties of plants are more likely to be successful than others.

All of these factors (and others) will have a bearing on the cost of producing a cutting. Some of these factors will be more significant than others. Some may account for 10, 20 or 30% of the cost; others might only account for a very small proportion of the cost.

Improving Strike Rates

Propagators use various techniques to improve strike rate and the root growth on cuttings. These include:

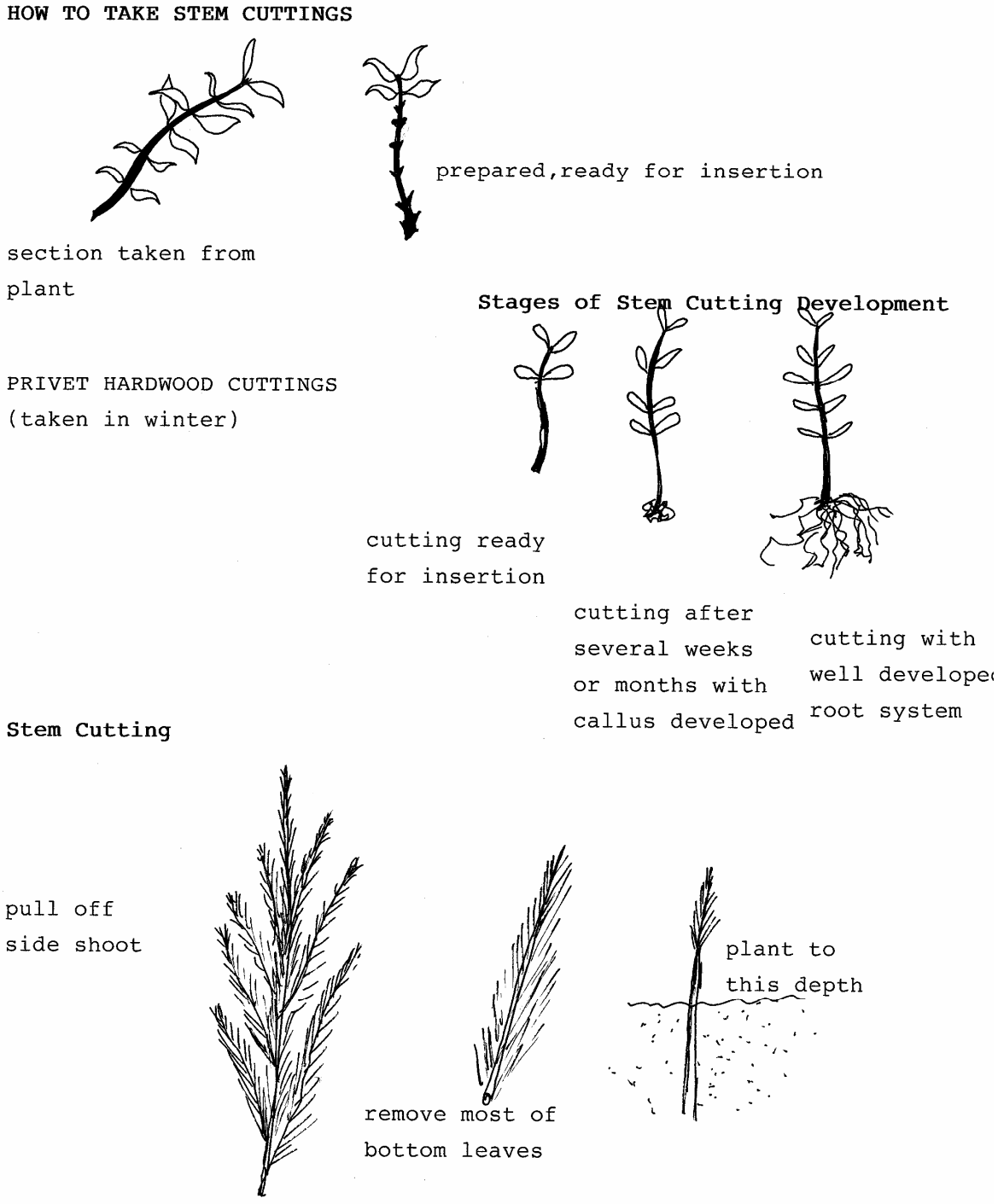
- Careful selection and preparation of cutting material i.e. age, time of year and species.
- Maximising the leaves retained on semi-hardwood and soft wood cuttings to maximise auxin content.
- Collecting cuttings in cool conditions when the cells are turgid.
- Checking stem firmness – firmness indicates a high level of energy.
- Using juvenile plants from which to collect cuttings.
- Selecting cutting material with vegetative (leaf) buds rather than flower buds.
- Taking hardwood cuttings with at least two nodes.
- Wounding the base of the cutting to increase the surface area for hormone treatment and water uptake.
- Using fungicides (when permitted) to treat the cuttings, particularly for semi-hardwood cuttings.

THE TECHNIQUES

The ease with which particular tissue can grow as a cutting depends upon the chemical and physical makeup of that tissue. These physical and chemical properties can be extremely variable at different times of the year, under different environmental conditions, and even between different varieties of the same plant species, let alone from one part of a plant to another. To become more successful at cutting propagation, you need to try and understand these subtle differences. In time, a good cutting propagator can develop an ability to make informed guesses as how to propagate a wide range of different plants.

Equipment

- ❖ Clean hygienic preparation area.
- ❖ All cuttings should be taken with a clean pair of secateurs or cuttings snips.
- ❖ Plant growth regulators (hormones) as required to improve strike rate.
- ❖ Sterilised containers or trays for prepared cuttings.
- ❖ Suitable striking media.
- ❖ Labels.
- ❖ Dibble stick for making holes (such as a small screw driver, with the end ground to a rounded off point).



TYPES OF CUTTINGS

A cutting is a section of stem, usually (but not always) with some leaves left on the top, but lower leaves removed. There should generally be a node (this is a point at which a bud emerges) at the bottom of the cutting and at least another node at the top of the cutting. There may be one or several nodes in between.

The classification of cuttings is not always the same from country to country, or even place to place within a country. Terms used in one place are sometimes different to those used

elsewhere. The term **"tip"** cutting, for example, is often used to describe a cutting taken from the end of a stem. This in effect is normally, but not always, the same as a softwood cutting.

Cuttings are commonly classified broadly in two different ways:

1. According to plant tissue being used. Example: a leaf cutting is a cutting made from just a leaf, or part of a leaf; and a stem cutting is made from a piece of stem.

2. According to the age or tenderness of the tissue used:

- Softwood cuttings (also known as 'tip' cuttings) come from tissue that is soft new season's growth taken early i.e. early to mid spring. However they can also be taken at other times of the year if suitable plant growth is available.

Note: Semi-softwood cuttings are taken from tissue that is in the process of changing from soft to semi-hardwood.

- Semi-hardwood cuttings are taken from partly mature new season's growth. The cutting material is usually green to pinkish in colour.
- Hardwood cuttings come from harder wood: the new season's growth after maturity. It usually has brown bark. Cuttings are taken in winter for deciduous plants and in late autumn to winter for evergreen species.

More on Softwood Cuttings

Although most plants produce soft new growth generally in spring, this is not necessarily true for all plants. The genus and species, in conjunction with the climate, can alter the time period. Pruning techniques used on mother-stock plants can also govern when softwood cuttings are taken.

These young shoots are tender and weak, and prone to sudden death if allowed to dry out after being removed from the plant. For this reason plant material is usually removed from the plant early in the day and placed immediately in a cool moist environment i.e. a bucket of water, or moistened and placed in a sealed polythene bag stored in a cool shaded position until ready for preparation. The plant material taken is generally larger than that which is needed – it is later cut to size during the softwood cutting process.

Soft plant tissue is easily bruised so careful handling and harvesting is essential. Extremely soft tissue that wilts the moment it is cut from the plant is not recommended as the success is often low and it often rots on the propagation bench.

Softwood cuttings are traditionally taken about 50-120mm long (2-5inches) with several nodes. With misting, fogging and base heating equipment, softwood cuttings can be taken even shorter at around 30-40mm (about 1.5 inches).

A weak concentration (1000-3000ppm) of rooting hormone in a quick dip is used which increases the success rate.

The tug test (a careful tug made near the lower part of the exposed part of the cutting) is used to indicate when the cutting has formed roots. This is when a gentle tug upwards of the cuttings is performed – if the cutting offers some resistance then the cutting has roots; if no resistance then no roots.

After rooting has occurred, watering (misting, etc) is usually progressively reduced.

Practise taking softwood cuttings using the following techniques:

1. Take a cutting (new growth) from the parent plant about 30-50mm long with several leaves attached.
2. Cut the stem with a clean sloping cut below a node.
3. Remove 2 or 3 of the lower leaves.
4. Treat with hormones.
5. Set into damp growing media.
6. Water.
7. Label and place in a humid environment i.e. glasshouse, or cover loosely with plastic.

More on Semi-hardwood Cuttings

After a growth flush has occurred, the plant tissue commences to lignify (harden). Before it attains the point of hardening, when it is still flexible but firm, the plant tissue is referred to as semi-hardwood.

Generally this occurs between late spring and summer, to early autumn, but it is also dependent on the species of the plant and the local climatic conditions.

Very soft tips of these semi-hardwood cuttings are generally removed as this soft tissue can desiccate during the rooting period, and increase chances of disease. Additionally this limp soft tip may interfere with water penetration to the rooting media.

Cuttings are usually taken 80 -150mm (3-6 inches) long with the lower leaves (half to two-thirds of leaves) removed.

Top leaves can be trimmed to reduce water loss, or to facilitate handling, but there is conflicting evidence as to the benefits of this practice.

Hormone treatment is recommended to maximise root uniformity and success. Concentration of any solution or mixture will be dependant on the species being propagated.

Practise taking semi-hardwood cuttings using the following techniques:

1. Take a cutting (firmer growth without woody bark, test: cutting should snap like a bean when bent) from the parent plant up to 200mm long (depending on species, each cutting should have at least three nodes on the stem.)
2. Remove the soft growing tip.
3. Cut the base just below a node.
4. Remove half to a third of the leaves.
5. Treat the bottom 15mm with rooting hormone.
6. Set in damp propagating mix.
7. Water.
8. Label and place in a humid environment i.e. glasshouse, or cover loosely with plastic.

More on Hardwood Cuttings

The cutting needs to be thick enough to store ample ‘food’ reserves for over-wintering. As the cutting has no roots, it will be relying on what is stored in its stem. Around pencil thickness is usually adequate for cuttings.

Treatment of the cutting is variable – the technique chosen will depend on plant species, and the cultural methods used by the propagator. Hormones are usually used in the range of 2000-5000ppm.

Some of the more common techniques include:

Bottom heat:-
Tops of cuttings are exposed to cooler temperatures but roots are kept warm, commonly at around 18 – 23^{o}C. Cuttings are hormone treated, left for about 4 weeks and transplanted after callusing occurs, but before bud break.

Plastic bag:-
Cuttings are treated with hormone then sealed in a plastic bag and placed in the dark at around 10^{o}C (50^{o}C). Cuttings are planted out after callusing.

Winter treatment:-
Cuttings are bundled together and planted up-side-down in the soil outdoors, completely covered. In spring the bundles are dug up and planted the right way up.

Warm temperature:-
Cuttings are treated with hormone, kept moist at around 21^{o}C (70^{o}F) for up to 5 weeks. After this treatment, the cuttings are usually stored until spring and planted out.

Outdoor ground beds:-
Cuttings are taken and treated with hormone then planted into outdoor base-heated (to 21^{o}C (70^{o}F) in-ground beds.

Variations on Cuttings
Stem cuttings can be taken from different parts of a stem. They might be taken from the very tip, with the terminal (end) bud left attached (or in some cases removed). They might be taken from sections of stem lower down, with the soft growing tip removed. In this case, several cuttings might be made from one single section of stem. Another alternative is to pull a short side shoot, from a stem, with some older tissue still attached to the base. This older tissue is called a heel.

Some plants will even grow from sections of old stem (i.e. wood that is two or more years old.)

Some cuttings might contain different types of tissue in the one cutting. A heel cutting, for example, can contain wood that has grown recently at the top (still soft); wood that is semi -hard in the middle, and a small section of hard wood (from last years growth) attached at the bottom.

Herbaceous Cutting
These are leafy stem cutting taken from a soft wooded (non-woody) plant such as a *Chrysanthemum, Aster, Coleus, Dianthus, Geranium, Pelargonium* and many perennials and herbs. These can be taken virtually at any time of the year.

Tip Cuttings
Stem cutting taken from the growing tip of a plant. Softwood cuttings are often tip cuttings. This plant material is very soft and prone to limp quickly (eg. *Weigela, Callistemon, Azalea*).

Heel Cuttings
A stem cutting of 1-year-old wood which has a small section of 2-year-old wood attached to the base. This section of older wood is called a heel; normally prepared by carefully pulling off side shoots from a small branch or stem. The torn section is then trimmed neatly with a pair of secateurs or a knife (e.g. *Abelia, Cotinus, Actinidia*).

Nodal Cuttings
This is a stem cutting without a heel, where the base of the cutting is made as a cut, just below a node (i.e. where the leaf joins the stem).

A single node cutting (also called leaf bud cutting) utilises a single node and a leaf as part of the cutting. The node may have one or two buds depending on the species being propagated.

Examples of plants grown by single bud node cuttings include: *Vitis, Magnolia, Passiflora, Camellia.* Double bud nodes plants include: *Lonicera, Clematis, Pandorea.*

Double node cuttings are made from plants where two leaves emerge at the same point along the stems length, but on opposite sides of the stem. The cutting retains two pairs of buds that are opposite each other. Double node cuttings are popular for climbing plants in that if one bud fails to shoot, the other might succeed. *Lonicera, Clematis* and *Jasminum* are commonly propagated by these methods.

Basal Cuttings
Stem cutting where the base of the cutting is made at the point where the young shoot joins the older branch. At this point there is often some swelling in the stem. The basal cutting does not necessarily contain any older wood, as does the heel cutting. Plants that benefit from this type of cutting treatment include *Acer, Cornus, Prunus*.

Cane Cuttings
A small section of cane from the plant, containing only one or two nodes and no leaves, is inserted horizontally (instead of vertically – as is usual), with a bud showing just above the surface of the media. This is used with plants such as *Saccharum* (Sugar Cane), *Cordyline*, *Dracaena* and *Dieffenbachia,* where it is difficult to obtain large quantities of cutting material. Heating and misting are usually essential for commercial success.

LEAF CUTTING TECHNIQUES

Leaf Bud Cuttings
A full leaf (leaf blade and stalk) with a small piece of the stem the leaf was attached to. At the junction of the stem, there is a bud (which is retained). This technique is most commonly used when large numbers of plants need to be produced, but the quantity of propagating material available is limited. Plants which can be grown this way include:
Camellia, *Cissus*, Citrus, *Clematis armandii, Delphinium* cultivars, *Dracaena*, *Ficus*, *Fuchsia*, *Hedera* (Ivy), *Hoya*, *Mahonia*, *Monstera*, *Philodendron*, *Rosa* (Rose), *Rhododendron* (some species and varieties), *Rubus*, *Scindapsus*, *Sedum, Syngonium.*

Leaf Cuttings

Either a section of a leaf, or a full leaf including the leaf stalk (petiole), is used to produce a new plant. In the case of a section of a leaf being used (e.g. *Begonia, Gloxinia* or *Peperomia*), the cutting must include part of a major leaf vein. New growth (a shoot and roots) will normally grow

from the base of the cutting (i.e. the base of the leaf stalk, or the base of the leaf vein). *Saintpaulia* are commonly grown from full leaves. Leaf cuttings (and sections of leaves) are commonly inserted vertically, or at a small angle (base downwards) into the propagation media.

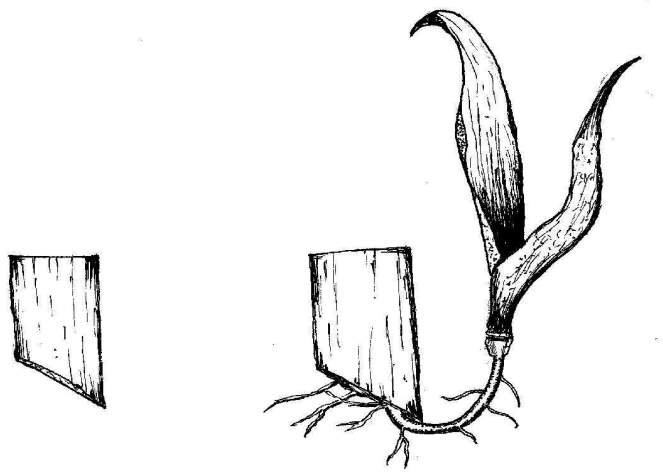
Large leaves of some plants however, (e.g. *Begonia*) can have each of the main veins cut with a sharp knife or similar tool and the leaf placed horizontally down on the surface of the propagation media. The leaf might be lightly weighed down with a small pebble or two, or some of the propagating mix to ensure it keeps in good contact with the mix beneath. New plantlets will form where the leaf's main veins have been cut.

Some bulbs (e.g. *Lachenalia* and *Muscari*) can be grown via leaves being chopped into sections along their length – in this case be sure to maintain correct polarity with the lower part of the cut leaf section being planted.

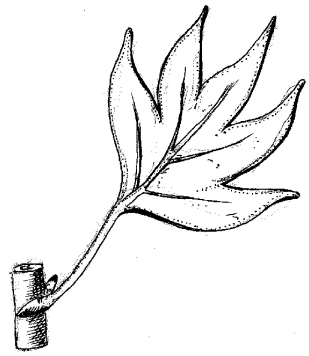
Practise taking leaf cuttings using the following techniques:

- Choose a plant species that can be propagated from leaf cuttings such as *Asplenium bulbiferum*, *Tolmiea menziesii* (or other suitable species).
- Place the leaf into propagating media at the base of the plant, making sure that some of the petiole (stem) is attached.
- Leaves will develop roots quite quickly and a new plantlet will form.
- Choose a leaf such as *Begonia rex.*
- Cut through the large veins beneath the leaf.
- Place leaf on top of propagating mix, roots and new shoots will develop at each cut.
- Plants propagated by this technique include:

Achimenes, *Boea hygromatica*, *Bryophyllum*, Cacti, *Conandron*, *Crassula*, *Echeveria*, *Hyacinthus* (Hyacinth), *Primula* (many but not all), *Sanseviera***,** *Streptocarpus, Tolmiea.*



Leaf Cutting
Sansevieria



Leaf Bud Cutting
Ivy (*Hedera*)

ROOT CUTTINGS

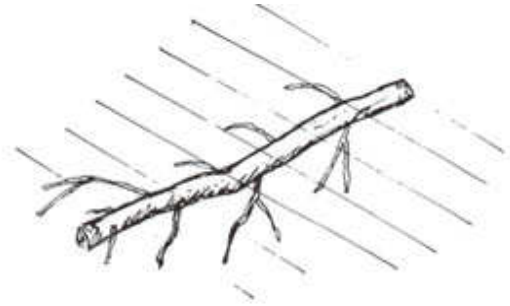
Sections of relatively young (1-3-year-old) root, 2-10cm long are taken, preferably from young plants. Cuttings are planted horizontally, 2-4cm deep, in the propagation media. Small delicate roots should be shorter and planted shallower (maybe a 1cm layer of sand over the top). Larger roots can be longer, and planted deeper.

Many herbaceous plants are grown commercially from root cuttings in some parts of the world, but only a few woody species. Root cuttings may grow from many woody trees and shrubs, such as *Albizzia,* some *Daphne, Malus*, some *Populus, Rhus, Liquidambar, Syringia*, and *Wisteria*, but they are only occasionally used commercially. Generally, any plants that commonly produce suckers can also be grown by root cuttings.

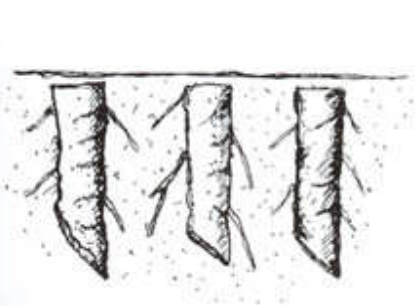
Most plants that produce suckers can be grown by root cuttings; however, in many instances, other propagation methods are also effective and are preferred.

For most root cuttings, it is important that you maintain an awareness of the proximal and distal ends of the cutting; and plant the cutting with the proximal end upwards.

Note:
*Proxima*l refers to end of cutting closest to the stem.
Distal refers to end of cutting furthest from the stem



Thin root cuttings are normally laid horizontally beneath a thin layer of media.



Root cuttings
Thick root cuttings are normally inserted into media with proximal end up and with top of cutting lightly covered.

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There are five distinct types of root cutting propagation

1. *Natural Suckering without Division*
The type of plant that produces root suckers close to the stem or trunk.

2. *Natural Suckering with Division*
This includes plants (mostly shrubs) that sucker from roots that have NOT been damaged. They tend to sprout new shoots from roots naturally, then connecting roots die back leaving the new plant independent of the parent.

3. *Induced Suckering*
This type shoots a new stem from a root that has been damaged (perhaps by weeding, cultivation, lawn mowing, or even an animal or insect).

4. *In-situ Whole Root Cuttings*
These plants produce a shoot from a section of root that has been severed from the parent plant, and left in situ, until a shoot emerges from the proximal end (i.e. cut roots around a stock plant, and severed sections of root that have no shoots attached will grow). Once the growth has become sufficiently established, the new plants can be dug up.

5. *Ex-situ Detached Root Cuttings*
Here roots are dug up, cut into short sections, then planted either in the open ground, or in containers.

Stock Plants for Root Cuttings
Stock plants are those plants from which you take cuttings.

- Young plants are best as stock for root cuttings, as disease sometimes builds up in the lower parts of a plant as it ages.
- For most plants, collect roots late autumn through winter, when growth is slow or dormant.
- Some plant cultivars e.g. variegated plants that consist of a periclinal chimera (cells of more than one genotype present near the apical layer), may not come true if propagated by root cuttings.
- Plants grown as grafts on rootstocks will not grow true from root cuttings.

- Some species that do not sucker in nature can still be grown by root cuttings.

When taking root cuttings, consider the following:

- Thick sections of root generally produce roots more readily than thin sections.
- Cuttings should be planted with the proximal end upwards.
- It is always best to treat root cuttings with fungicide.
- After cuttings are taken, they can be stored in a moist, well-aerated-media over winter until plants start to grow at the end of winter or spring. It is usually best to plant/stick the cuttings as soon as growth starts in order to minimise the risk of rotting. Most types are planted in containers and put into a greenhouse in late winter or early spring (If placed on a hotbed they might be started earlier). Some are struck in unheated cold frames through spring. Some of the easiest varieties can be planted straight into open beds.
- The propagating media should be moist but well-drained. If the roots get too wet, they can rot before producing shoots.

Practise taking root cuttings using the following techniques:

- Lift a stock plant suitable for root cuttings.
- Remove soil from roots.
- Cut away required roots.
- Prune mother plant and re-plant.
- Inspect for damage and disease and use only best quality cuttings material.
- Trim to suitable size according to species - 75mm for smaller species 200mm for trees.
- Place cuttings right end up (i.e. the end closest to the original trunk should point up) in media and cover.

*They may also be laid flat - several buds will develop along the cuttings which can then be cut up and replanted individually.

PLANTS THAT CAN BE PROPAGATED SUCCESSFULLY BY ROOT CUTTINGS

A small selection of plants commonly propagated by root cuttings:

Acacia (some species – those that tend to sucker when disturbed, like the Blackwood) (*A. melanoxylon*)
Acanthopanax species
Actinidia deliciosa
Aesculus parviflora #
Ailanthus altissima #
Albizzia julbrissin #
Amelanchier species #
Amorpha species
Anchusa #
Arabis #
Aralia species #
Aristolochia species
Aronia species
Asclepias
Asimina triloba
Austromyrtus
Banksia (some species)
Bauhinia species
Berberis species
Bignonia species #
Bombax
Boronia pinnata
Breynia species
Broussonetia papyrifera #
Brunfelsia species
Calycanthys species #
Camellia species
Campsis radicans #
Caragana species #
Carya species
Catalpa species #
Celastrus species #
Chaenomeles species #
Cladrastis species #
Clematis species
Clerodendrum species #

Clethra alnifolia	*Commersonia*	*Comptonia peregrina* #
Corylus maxima	*Cotinus* species	*Crambe cordifolia* #
Cretagus species	*Cupaniopsis* species	*Cydonia oblonga*
Cyrilla racemiflora	*Dampiera* species	*Daphne* species
Decaisnea fargesii #	*Dendromecon rigida* #	*Dicentra spectabilis* #
Echinops #	*Eleagnus* species	*Elliottia racemosa*
Embothrium coccineum #	*Eryngium* #	*Euonymous* species
Exocarpos	*Fatsia* species	*Ficus carica*
*Forsythi*a species	*Fothergilla* species	*Gardenia* species
Gleditsia triacanthos	*Gymnocladus dioica* #	*Halesia* species #
Hippophae rghamnoides	*Hydrangea quercifolia*	*Hypericum calycinum* #
Ilex species	*Illicium floridanum*	*Incarvillea* #
Indigofera species	*Kalopanax septemlobus* #	*Koelreuteria paniculata*
Lagerstraemia indica	*Laurus nobilis*	*Leitneria floridana*
Liquidambar styraciflua	*Lonicera* species	*Maackia amurensis*
Macaranga tanarius	*Maclura pomifera* #	*Malus* species
Melaleuca (some species)	*Melia azedarach*	*Meliosma* species
Morisia monantha #	*Morus* species	*Myrica* species
Nandina domestica	*Oenothera* #	*Orixa japonica*
Paliurus species	*Papaver orientale* #	*Paulownia tomentosa* #
Pelargonium (some)	*Phellodendron amurense* #	*Phlox paniculata* #
Picrasma quassioides #	*Populus* species #	*Primula denticulata* #
Prunus species	*Pterocarya* species	*Pulsatilla vulgaris* #
Pyracantha coccinea	*Pyrus calleryana*	*Rhododendron* species
Rhodotypos scandens	*Rhus* species #	*Ribes* species
Robinia pseudoacacia, hispida, kelseyi #	*Romneya coulteri* #	*Rosa* species
Rubus species #	*Rulingia*	*Sambacus* species #
Saponaria ocymoides #	*Sassafras albidum* #	*Scaevola* species
Sophora japonica	*Sorberia sorbarifolia*	*Spiraea* species
Staphylea species	Statice #	*Stokesia laevis* #
Symphoricarpos species	*Symphytum*	*Syringia vulgaris* #
Tetradium (syn. *Euodia*)	*Toona*# syn. *Cedrela sinensis*)	*Trollius europeus*
Ulmus species	*Vaccinum* species	*Verbascum* species #
Viburnum species	*Wisteria* species	*Xanthocerus sorbifolium* #
Xanthorhiza simlicissima	*Zanthoxylum* species #	*Zizyphus jujuba*

= May be more appropriate for serious propagation by root cuttings

BULB CUTTINGS

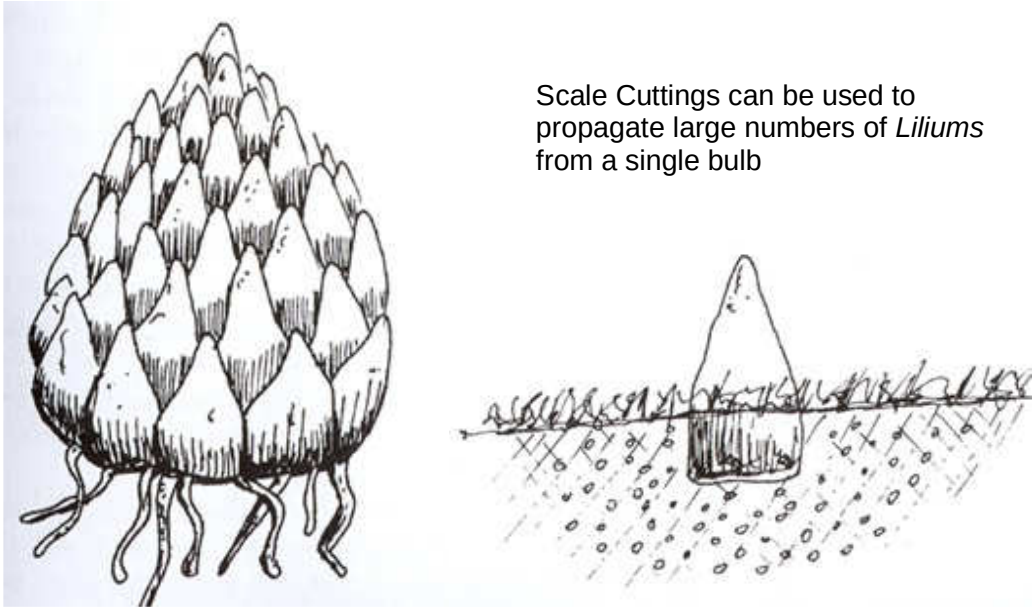
Different types of bulbs require different cutting propagation techniques. True bulbs are plants that have a series of scales (like an onion). There are two types of true bulbs: tunicate and non-tunicate. Tunicate bulbs have a sheath (or a covering called a tunic) that encases the bulb. Non-tunicate bulbs have no tunic.

Other plants that also develop swollen underground sections are often loosely grouped with, and called, bulbs, but they are not true bulbs because they are not made up of scales. These include such things as corms (e.g. gladioli), tubers (e.g. potato) and rhizomes (e.g. some iris). The main requirement for propagating these types of plants is that each cutting has a bud (i.e. “eye) from which a shoot can emerge. Gladioli, potatoes and dahlias are just a few plants that can be grown this way.

There are four main techniques used for bulb cuttings: scaling, twin scaling, sectioning and basal cuttage.

Scaling
This involves removing individual scales from scaly (non-tunicate) bulbs. The segments may be treated with a fungicide (e.g. sulphur powder) to control disease, before being planted in pots or trays of propagating media or placed in a moist bag of sphagnum or peat moss and put in a dark, cool location. Roots and one or more new bulblets will form at the base of the scale where it was broken from the bulb.

Plants grown this way include *Crinum* (some), *Lilium* and *Narcissus.*



Scale Cuttings can be used to propagate large numbers of *Liliums* from a single bulb

Twin Scaling
This technique is used for non-scaly (tunicate) bulbs. A large healthy bulb is first prepared by removing the outer brown tunic. The top section of the bulb is then normally cut off – this allows easier separation of segments later. This can be done with a sharp spoon-like implement, scooping out the top of the bulb. The bulb is then cut vertically into 8 or 10 sections, each having part of the basal plate. Each of these sections can be further divided by cutting down between the scales, in effect leaving two scales connected to a small segment of basal plate. Treating cut bulbs with a sulphur dust fungicide is recommended. The bulb sections are then placed in a bag of moist vermiculite or similar material until bulblets form – in about 3 months. At this stage they can then be planted into trays and grown on.

Narcissus are commonly propagated by this method.

Sectioning
This involves cutting a bulb vertically so that each section of bulb has pieces of scale attached to the basal plate. Depending on the size of the bulb, you might obtain anything from 4 to 8 or more cuttings from one bulb.

Plants grown this way include *Albuca, Chasmanthe, Cooperia, Crinum* (some types), *Priophys (Eurycles), Haemanthus, Hippeastrum, Hymenocallis, Lycoris, Narcissus, Nerine, Pancratium, Scilla, Sprekelia, Urceolina.*

Basal Cuttage
This involves making cuts to expose tissue at the bottom of a bulb. From these cuts root and stem (or bulblet) growths may emerge, given the right conditions. There are three main methods:

- Scoring - involves making cuts across the basal plate of a bulb. The cuts must be deep enough to destroy the dormant flower bud in the centre of the bulb.
- Scooping - involves removing almost the entire basal plate, by scooping it out of the bottom of the bulb (including the flower bud in the centre), leaving just a thin rim of basal plate.
- Coring - involves cutting the central core and flower bud out of the basal plate.

Any of these techniques will result in the energies of the remaining tissues going completely into vegetative growth, and the production of several, sometimes many, new bulblets. Any cut surfaces should be treated with a fungicide to minimise rot.

You can plant any bulb cuttings vertically into a propagation tray with just the tips showing, irrespective of the type of cutting.

Plants grown this way include Hippeastrum, Hyacinth, Iris reticulata, Lycoris, Scilla, Sprekelia, Vallota**.**

LAYERING
Layering involves developing roots on a stem while it is still attached to the parent plant. Layering can occur naturally or may be induced by propagators. Once roots form on the stem it can be detached to provide a new plant. There are important advantages in this technique:

- The parent plant supplies the new plant with food, water and hormones while the new roots are being formed. Compared to cuttings which frequently die through moisture stress, this significantly increases the propagating success rate.
- The technique is simple and does not require expensive equipment or expertise.

Not all plants can be layered successfully, despite the fact that this technique is more successful than others such as cuttings. Usually any plant which can be grown from a cutting can also be propagated from layering.

Layering is a relatively time-consuming method of propagating plants and for this reason, other less labour-intensive techniques are usually preferred.

Root formation will be faster if the area around the rooting zone has the following conditions:

- It should always be moist. Never let the rooting zone dry out!
- There is ample aeration in rooting zone. It should not be allowed to become so wet that there is no oxygen present for the developing roots.
- The temperatures in the rooting zone should be moderate and never allowed to get too hot or too cold. A medium such as wood-shavings, rockwool, sphagnum moss or sawdust around the rooting zone will provide most of these requirements.

Root development can sometimes be further encouraged by:

- Cutting the stem. A slit in the stem exposing the cambium tissue (i.e. the layer between the bark and the inside wood) will in most cases speed up the development of roots.
- Use of root-promoting hormones. Products available to professional and amateur growers will vary in different countries. For example, where available, Indole butyric acid (IBA) can be applied to cuts (as above) either in liquid or powder form. (*Seradix* is a commercial form of IBA).

Types of Layering

Tip Layering

The tip or end of a stem is bent down to the ground and pegged just below the surface. This shoot will grow down into the soil until roots begin to form, after which it will turn and grow back upwards. Many of the berry fruit reproduce naturally this way, including blackberry, raspberry, boysenberry, dewberry and loganberry.

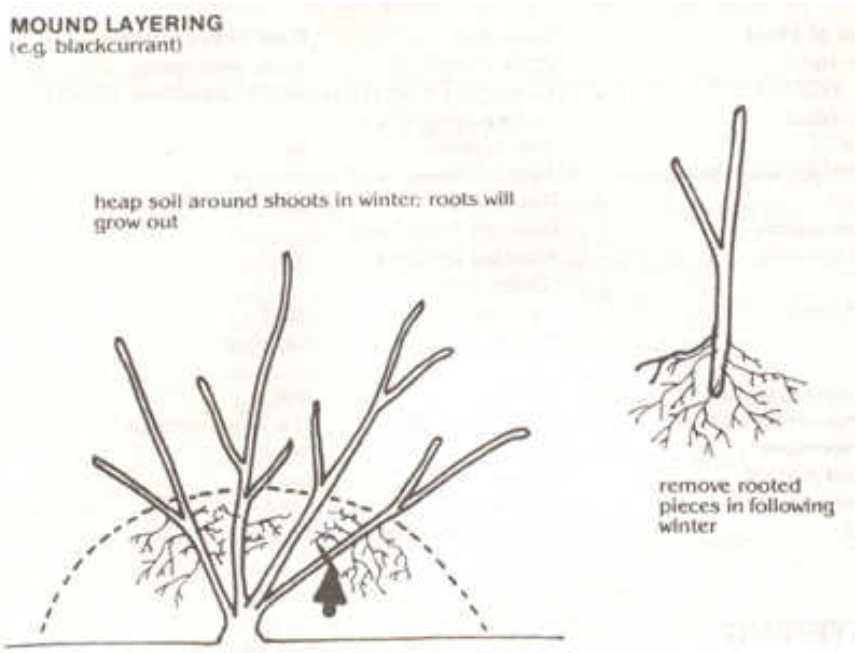
Tip layers are best done in early autumn. Make holes 8-10cm deep and peg the tip into the hole. Cover with soil and keep it moist. The roots will then form very quickly. The layer can usually be dug up and planted between 2 and 4 months after starting (late autumn or early spring).

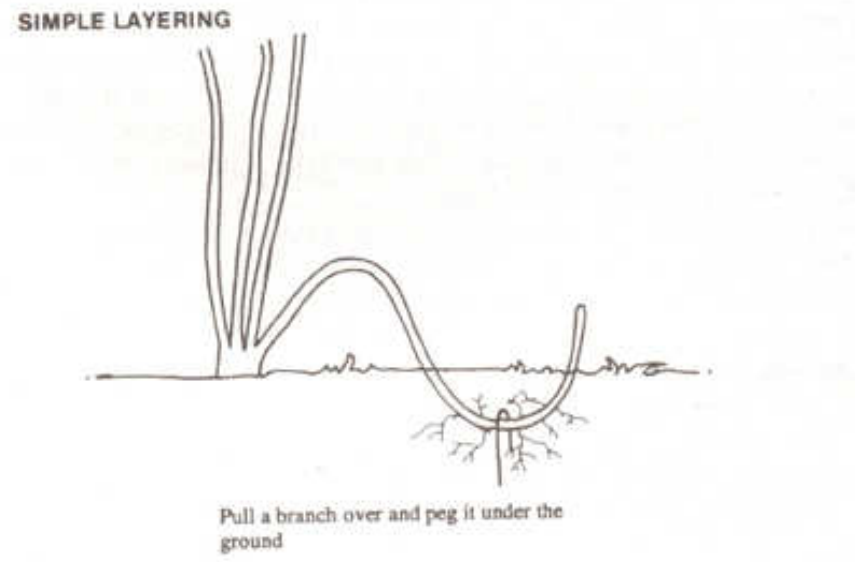
Mound Layering

This involves cutting a plant back to ground level when it is dormant (over winter) and then mounding up earth around the portion left above the ground. Several new shoots form and grow through the mound, each developing its own root system. In the following winter, the mounded soil can be pulled back and the rooted layers removed. The remaining root system and stubs of growth can be covered again and the whole process repeated over the next season. A series of plants in a bed used for this purpose is sometimes called a 'stool bed'. A stool bed can sometimes be used for up to 20 years before new plants are needed. The mother plants are usually spaced 30 to 35cm apart with the distance between rows varying from 1 to 2 metres.

When a stool bed is first planted, plants are usually allowed to grow for one season (to establish a root system) before any layering starts.

Certain rootstock plants are grown this way for budding and grafting onto eg. apples, cherries, currants and gooseberries. In parts of the USA, sawdust has been used almost exclusively for forming the mounds for this type of layering.





Simple Layering
This is a very similar to tip layering except that the end of the stem is left out of the ground (i.e. the part which is buried is a few centimetres down the stem behind the tip). Often the sharp bending of the stem is all that is needed to induce rooting, although cutting or notching of the underside of the stem is often practised. A wooden peg, bent piece of wire or a stone may be used to hold the stem layer in place.

The usual time for simple layering is early spring. With some broad-leaved evergreens, e.g. *Rhododendron* and *Magnolia*, the layering is done a little later, after new season's growth has formed on the plant. Rooted layers are usually dug out and moved in the following autumn.

Compound Layering
This is basically the same as simple layering except that the same stem is alternately covered and exposed along its length making it possible to obtain several new plants from just one stem during the course of a year. This method is used on grape vines, *Wisteria*, *Clematis*, *Philodendron* and *Syngonium*.

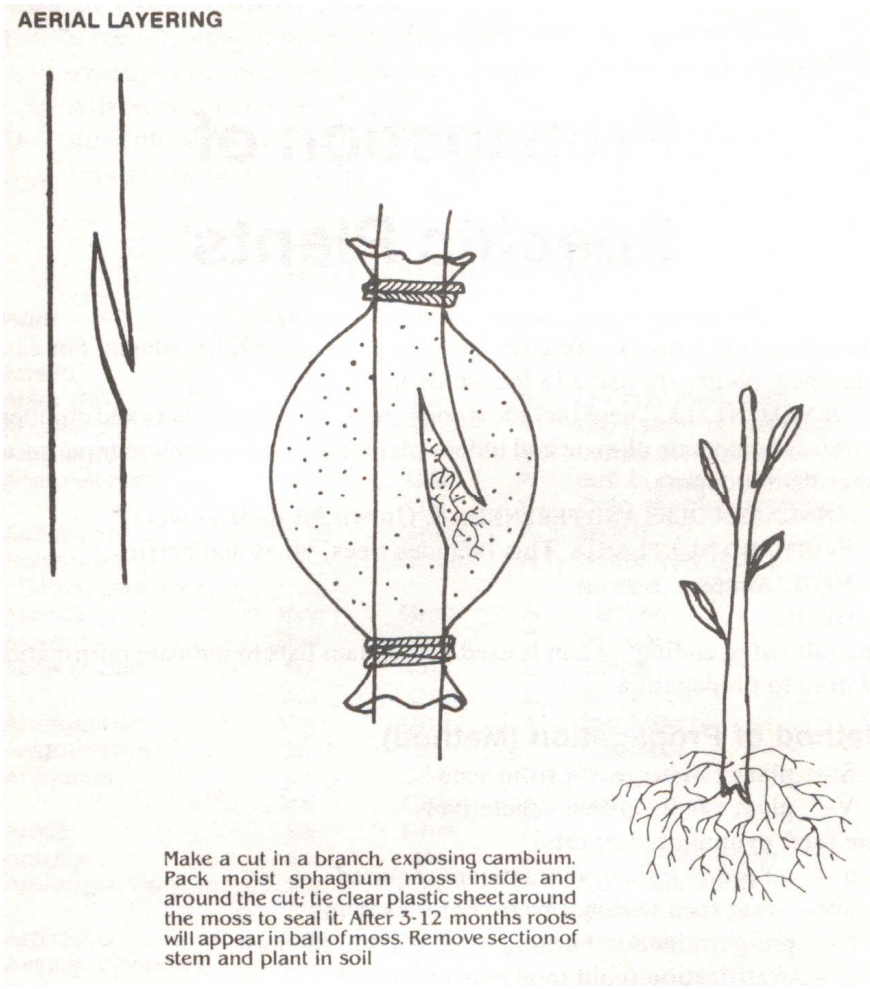
Aerial Layering
With this technique, roots form on an above-ground part of a stem which is enclosed with some type of rooting medium. Usually this involves packing moist sphagnum moss (or some similar material) around a cut section of stem. The whole area is sealed (made air-tight) to keep the moss moist, and then left for the roots to develop.

The ancient Chinese practised aerial layering using clay to form a ball around the wound. This would then be covered with moss to hold it together. Some type of receptacle above (perhaps a piece of bamboo) would hold water from which a string would dangle, to keep the area continuously moist. Today the layer is almost exclusively wrapped in polythene film (preferably clear).

Aerial layering is usually carried out in spring on one-year-old growth (i.e. new wood). Older growth can be used but root formation is usually not as satisfactory. Apart from this, the larger plants are usually more difficult to handle after rooting. If clear plastic is used, it is possible to observe when the roots begin to appear. Approximately two handfuls of moistened sphagnum moss is a normal quantity for an aerial layer. A piece of polythene about 25cm square should be adequate.

Plants which can be grown by aerial layers include *Litchi*, Persian Lime, *Azalea*, *Camellia*, *Magnolia*, *Ilex, Syringia, Philodendron*, *Monstera*, *Rhododendron* and *Ficus*.

When you remove the rooted section, remember to keep the relationship between the top growth and the new root system in proportion. It is not very good to have a small root system with an enormous top. You may need to cut the top back to ensure a good chance of survival.



Natural Layering

Suckers
A sucker is a shoot which grows up from below ground level on a plant. Suckers can be dug out and cut away from the parent plant with a section of root attached. They are usually removed in winter. Plants which are grown from a sucker tend to sucker more themselves. If suckering is desirable (eg. with raspberries) this is a valid technique for propagating, but where suckering is not desirable (eg. poplars) this is not a very worthwhile way of propagating plants.

Runners
A runner is a special type of stem which grows horizontally along the ground forming new plants at its nodes. Strawberries grow easily from runners, but due to the high incidence of virus diseases in strawberries in many countries, gardeners and growers alike are often advised to not propagate their own plants. Virus-free strawberry plants are sometimes propagated in areas isolated from this disease, under government Department of Agriculture supervision. Other plants which can be grown from runners include *Ajuga*, *Saxifraga* and *Chlorophytum*. Rooted daughter plants can be dug up whenever they have formed sufficient roots.

Offset

This is a special type of branch which develops from the base of the main stem of certain plants. Usually this is a shortened thickened stem. Many bulbs reproduce this way, producing offset bulblets at their base. The date palm and the pineapple are just two plants that produce offsets. Lateral shoots from rhizomes (as with banana and orchids) are also called offsets.

The offset is removed by cutting close to the main stem with a sharp knife. As many roots as possible should be removed at the same time. It might also be necessary to cut back the top of the plant to balance the amount of top growth with root growth.

Crown division
The crown of a plant is the point at which new growth arises at soil level. In some plants the crown is like a large ball or swelling. Below it are the roots and from it several shoots grow upwards. The crown is cut and divided with a sharp blade so that each section has least one of the shoots or stems, plus some of the roots.

Many herbaceous perennials as well as some woody shrubs and some indoor/tropical plants can be grown by crown division. Other plants grown this way include *Aster*, *Dianthus*, *Hemerocallis* and *Chrysanthemum.*

PROPAGATION USING PARTS OF SPECIALISED STEMS AND ROOTS

Several plants have specialised vegetative structures including bulbs, corms, rhizomes, tubers, tuberous roots, and pseudo-bulbs. These structures serve two main purposes:

- Organs of food storage
- Organs of vegetative reproduction.

Propagation involves simply detaching one or part of these structures from the parent plant. This method of propagation is called 'separation' and/or 'division'. These different structures can be distinguished as follows:

- Bulbs: consist of a basal plate, adventitious roots attached below, and scales attached above, encompassing a number of growth buds (eg. onion, daffodil, *Lilium*).
- Corms: do not have scales (they are solid right through). Corms are solid shortened stems with several buds over their surface (eg. gladiolus).
- Tuber: consist of a swollen stem structure which develops below the surface of the ground (eg. potato and caladium).
- Rhizome: is a special type of stem which grows just below ground level. Leaves arise from the stem breaking the soil and the rhizome is covered with both buds and roots (eg. Iris).
- Tuberous root: Differ from true tuber in that buds are only present at the crown (eg. dahlia, tuberous begonia).
- Pseudobulb: large fleshy section of stem occurring on some types of orchids (eg. Dendrobium, Cattleya, Cymbidium).

Propagating Bulbs by Offsets

Many types of bulbs are very easy to propagate by simply removing the naturally produced bulblets from the mother bulb. Tulip, Daffodil, Bulbous Iris, Grape Hyacinth, and other bulbs are produced this way. Lily, Hyacinth and Amaryllis can be grown like this but are usually slow, therefore other techniques are preferred.

Bulblet Formation on Scales
Liliums (lilies) can be broken into many scales mid to late summer. Each scale can be planted so that about 2/3 is below the level of the soil. This is usually planted into a well drained soil mix in either boxes or pots. New bulblets will develop at the base of each scale. The bulblets will usually take a couple of months to form. The following spring each new bulblet is planted out individually. It can take up to a few years before these new plants flower well.

Stem Cuttings
Liliums can be propagated by stem cuttings. Instead of roots and shoots forming, new bulblets will form at the points where the leaves join the stem below the media.

Bulbils
These are small bulblets which form in the leaf axis (i.e. the points where the leaves join the stems) on some types of lilies. These can be removed and grown to produce full-sized bulbs.

Basal Cuttage and Scooping
This involves cutting the base plate of a bulb prior to planting (plant in a pot or seedling tray in a well drained sterile-clean medium). The cutting might involve scooping out a circular cup-shaped section or perhaps a series of v-shaped cross-cuts. New bulblets will form along the edges of the cuts. This technique is most commonly used with *Hyacinth*, although it can also be used with *Scilla* and some other types of bulbs.

Corm Division
Large corms can be cut into sections retaining a bud on each. After cutting, these sections are best dusted with a fungicide (e.g. Bordeaux) before planting. Each section should develop into a new corm.

Tuber Division
A tuber can be cut into several sections, just like a corm. Provided each section contains an 'eye' (i.e. bud), each division will develop into a new plant.

Dividing Tuberous Roots
Once again the most important thing is to ensure each divided piece contains an 'eye' or bud.

Dahlia Tip Cuttings
The young growth can be taken from a dahlia tuberous root a month or so after the shoot emerges. This shoot can then be struck as a cutting using the same method as that of stem cuttings from woody plants.

Division of Rhizomes
Cut the rhizome with a sharp knife, retaining at least one 'eye' to each piece. This can be done with bamboo, Iris, Lily of the Valley, Banana, Sugar cane and some grasses including Couch, Kikuyu and Buffalo.

Culm Cuttings
The aerial shoots (or culm) of some rhizomes (eg. banana) can be used as cuttings in the same way that stem cuttings are used for woody shrubs.

Pseudobulbs (Back Bulbs)
At the end of a season's growth, the leaves of a *Cymbidium* pseudobulb will die down as a new growth emerges from the base of that pseudobulb. This old 'bulb' or 'back bulb' can be removed

and planted again. If this is done, a second new shoot will develop from it. When available, treatment by soaking in an Indole Butyric Acid solution (about 500ppm for 5 min.) has been found to be beneficial.

Division of Orchids
During the dormant growing season some types of orchids can be cut with a sharp knife, each section containing four or five pseudobulbs. These sections are then potted; each developing into a new plant (eg. *Cattleya*, *Odontoglossum*).

Dividing and Separating Perennials (herbaceous and non herbaceous)
Plants with modified stems or roots, i.e. rhizomes, tubers, corms or bulbs, can be easily separated or divided by digging up and separating during the dormant period after the foliage has died back. Tunicated bulbs are dug up and the offsets (new bulbs) that formed from within the scales of the mature bulb are separated from the original bulb once they are mature. The bulbs should be stored until the correct planting time at 18–20℃.

Rhizomes are divided by lifting from the ground washing, and cutting it into sections (each of which should have one but preferably several buds or “eyes”) e.g. Bearded Iris. Tops should be cut back to about one-third and the cut section dusted with a fungicide before re-planting.

Some perennials such as grasses and herbaceous plants are simply lifted and split into smaller clumps in early spring late autumn.

Use a sharp knife to cut into smaller (disease and weed free) clumps; alternatively use two garden forks centred into the crown (back to back) then ease the forks into opposite direction to the outside of the crown. Discard the old, woody centres. Most herbaceous plants divide easily using this method. After trimming back any damaged roots, the separated portions can then be re-planted straight into a well-composted, moist garden bed or potted up into appropriate sized pots.

For non-herbaceous type plants it is usually necessary to cut back the foliage by at least half to prevent too much moisture loss and transplant shock.

PROPAGATION TOOLS

Secateurs
Every horticulturist, whether in a production growing, growing-on or retail nursery, or in garden maintenance, needs a pair of secateurs.

There are three main types of secateurs:

By-pass secateurs
By-pass secateurs use a scissor-type action and have a sharp upper blade which cuts against a sharp lower blade to make a clean, precise cut.

Anvil secateurs
Anvil secateurs have a sharp upper blade that cuts against a lower anvil. These secateurs can crush woody material if they are blunt.

Parrot-beak secateurs
Have rounded blades that use a scissor-like action. Use these with care, as they can be dangerous

How to cut
All cuts should be made at a sharp angle in relation to the ground. This prevents water from collecting on the cut surface, thus reducing the likelihood of disease problems. Where possible, cuts should be made just above a node (where the leaves and/or flower stems are, or have been, attached to the plant stem). This reduces the likelihood of dieback along the stem. It is also important to only cut material that is not too thick for the secateurs (ideally no more than 1-1.5cm depending on the secateurs), otherwise you will find the cutting to be a strain on both the secateurs and yourself, and the final cut is likely to be rough, torn or uneven. When using anvil secateurs you should always cut down onto the anvil.

It is important to sharpen the secateur's cutting blade regularly with a sharpening stone:
...on anvil types the blade should be sharpened on both sides.
...on scissor cut types, the blade should only ever be sharpened on one side (i.e. the outer edge - the side which is furthest away from the other blade when a cut is made).

Knives
Knives can be used for a variety of jobs in a garden or nursery including budding and grafting, preparing cuttings, layering, dividing plants and pruning. Because it is a small and convenient tool, many horticulturists carry a knife at all times, just in case they need it for these or any other jobs. With practice, a skilled horticulturist can do most things with a knife for which other gardeners might need a pair of secateurs.

It is best to use the appropriate knife for the job at hand, and there are many different types of knives. Knives can have either fixed blades, folding blades or disposable blades.

Folding Blade Knives
This is the most common type of knife used in nurseries. A normal pocket knife or even a Swiss army type knife might look like a propagation knife, but it isn't designed, nor should be used, for propagating plants. Different folding blade knives are designed for different tasks, so either use several different types of knives, or choose a knife designed specifically for the task for which it will be most often used.

Fixed Blade Knives
The main advantage is that the blade can't move when it is being used, so there is less chance of an accident damaging either human flesh or plant tissue.

Disposable Blade Knives
These came with both fixed and protractible blades. Protractible types allow a "sectioned" blade to be slid inside a handle for safety when not being used, and slid out when needed. When the blade becomes blunt a section can be snapped off and the next piece extended for use.

Characteristics of Knives
*Type of Metal
Stainless steel knives are often cheaper, and do not keep their edge as well as do more expensive knives, made with higher quality steel. Expert propagators need tools to suit their skills if they are to perform to the best of their ability, but unskilled labour will probably misuse and not get any significant value out of more expensive knives.

*Single or double-angled blade
Single-angled blades are ground on one side only so one side of the blade is sloped and the other is flat. These can only be used to cut with the flat side against what is being cut. Most specialist knives are single-angled.

Double-angled blades are sloped on both sides and cuts can be made any way. Knives for "T" budding are made this way.

*Weight
Knives are more efficient if most of the weight is in the handle. You can test where most of the weight is by balancing the knife on your finger.

*Handle
The handle should be comfortable in the user's hand. If it is to be used for hours on end, this will become extremely important.

*Attachment between blade and handle
This is a weak point and on less expensive knives the blade may become loose.

Applications
*For dividing large clumps of perennial plants, a large sturdy knife may be most appropriate. It will usually come in for rough treatment, coming in contact with soil, and will need to be sharpened regularly
*For budding, a lightweight folding knife with a spatula on the end (for handling buds and lifting bark) is the traditional tool. Some nurseries find these knives are expensive and frequently go missing, so they have been replaced successfully with cheaper alternatives such as razor blades in a protractible plastic holder.
*Grafting knives come with both curved and straight blades, though straight-edged blades are preferred.
*Pruning knives are traditionally larger knives with curved blades used for de-heading (eg. cutting the tops off perennials at the end of the season), or taking the tops off rootstocks before grafting.

INTRODUCTION TO GRAFTING

Grafting involves joining parts of plants in a way that they will grow together and remain united as one plant. The part of the graft combination which becomes the upper part of the new plant is called the *scion*. The part which becomes the bottom part is called the *rootstock* or *stock*. All methods of joining two plants together this way are forms of grafting, however, when the scion is only a small piece of bark containing a single bud, the technique is called *budding*.

Reasons for Budding and Grafting

1. Maintaining a variety of plant which cannot be easily grown using other propagating techniques.

2. To obtain different "special" growth forms (e.g. Standard Roses, Weeping Cherries).

3. Obtaining an influence from a rootstock. For example, grafting a scion which is susceptible to certain rots onto a root-rot tolerant stock will create a plant which has the

desired top growth but greater resistance to disease. Or, grafting a tall-growing plant onto a smaller growing rootstock can produce a stunting effect on the top growth.

4. Obtaining benefits from *intermediate* stocks. Here a scion is grafted to a stock then another scion is grafted to the top of the first scion. If the ultimate tip scion is not compatible with the very bottom scion, it is sometimes possible to graft a different variety in between the two which is compatible with both.

5. Repairing damaged trees. If bark is stripped, or if ringbarking occurs, it is possible to graft across the damaged section aiding sap flow and hastening healing.

How a Graft Forms

There is a mass of growth cells in any plant between the bark layer and the inside wood of the plant. That layer is called the cambium layer. The cambium is the region where growth is happening and, as such, when you graft you MUST ENSURE THAT THE CAMBIUM OF THE STOCK CONTACTS THE CAMBIUM OF THE SCION! **This is the single-most important thing to learn about budding and grafting.**

The usual sequence in the formation of a graft is as follows:
1st Freshly cut cambium tissue of a scion is brought into contact with freshly cut tissue of a stock.
2nd The section where the union has been made is sealed (possibly with plastic tape...maybe with wax or grafting mastic). This sealing does two things: it holds the graft in place, and it prevents drying out of the cut tissue.
3rd The outer cells in the cambium region grow together, producing a callus.
4th New cambium tissue is produced between the two different varieties.
5th When growth is seen to have taken place; the plastic tie or seal on the graft union may be removed.

Factors That Influence Healing of a Graft

Compatibility: The varieties of plants being grafted together need to be compatible with each other. If plants are closely related, chances of success may be high.

Type of Plant: Some plant types are much easier to graft than others. Difficult ones include oaks and beeches.

Temperature: Temperature has a big effect on formation of callus (eg. with apples, little callus is formed below 0℃ or above 40℃). Research has shown that for most plants, 25 to 30℃ is the ideal for formation of callus.

Moisture: Air moisture levels below saturation point inhibit callus formation. Unless a completed graft union is kept at a relatively high humidity, chances of success are low. Often root grafts are stored in moist moss, some grafts are irrigated (i.e. a supply of water is provided), but most are simply sealed to prevent drying.

Polarity: Generally polarity must be maintained with grafting material (i.e. the part of the scion which comes from the point closest to the top of the plant must be grafted so it remains to the top...don't use stocks or scions upside down!)

Grafting Hints - General

- Keep Records
  - The stage in the plant's lifecycle is critical.
  - Root and scion maturity is critical.
  - The correct technique is critical.
  - After-care is critical.
  - Keep your reel of grafting tape tied around your neck. It can become contaminated if it is left lying on a bench or put down on the ground in the field.

- Don't graft wet plants (a dry scion and dry rootstock give the best results). When you graft wet material, you are more likely to get bacterial soft rots and other problems.

- Grafting young onto old works but grafting old onto young does not work.

- Information on grafting theory is abundant but information on grafting practice is scarce.

New grafters should aim to start with 200 grafts per day, concentrating on accuracy rather than speed, then build from there.

Carpentry of Grafting

- Take time to set up an arrangement of tools in the workplace.
- Hold the knife with a relaxed grip. (This is essential if the hand is to avoid tiredness.)
- When you slice, use the sharpness and the full length of the blade to achieve the cut (slide the blade rather than pushing).
- When you cross cut, rotate the blade around the circumference of the plant.
- Be careful not to scoop when you cut...this occurs when you lose control over your cut by the wrist moving forward as the cut is being made. The hand should move, but the wrist should remain still.

What Can be Grafted Onto What

Generally speaking, plants need to be very closely related to each other to be successfully grafted.

- A variety of plant can usually be grafted onto another plant of the same species e.g. *Acer palmatum dissectum* can be grafted onto a seedling of *Acer palmatum*.
- In many cases a variety of plant can be grafted onto a plant of the same genus but a different species, eg. *Banksia prionotes* can be grafted into *Banksia serrata.*
- In a few cases a variety of plant can be grafted onto a plant of the same family but a different genus, e.g. *Syringia* (Lilac) can be grafted onto *Ligustrum* (Privet).

Examples of compatible rootstocks and scions

ORNAMENTALS

Scion	***Rootstock***
Acer japonicum cv, *A.palmatum* cv.	*Acer palmatum*
Alnus sp., cv.	*Alnus glutinosa*
Betula sp., cv.	*Betula pendulosa*
Camellia japonica cv, *C.reticulata*	*Camellia japonica*
Clematis cv.	*Clematis vitalba*
Crateagus sp., cv.	*Crataegus mongyna*
Cytisus sp.	*Laburnum anagyriodes*

Hibiscus (low vigour varieties)	*Hibiscus* "Ruth Wilcox"
Ilex aquifolium cv.	*Ilex aquifolium*
Magnolia grandiflora, M.stellata	*Magnolia kobus*
Pittosporum sp.	*Pittosporum tenuifolium*
Rapholepsis x *delacourii*	*Crateagus monogyna*
Rhododendron hybrids	*Rhododendron ponticum*
Rosa cv.	*Rosa canina*
Syringia cv. *vulgare*	*Syringia*, *Ligustrum vulgaris*
Viburnum x *burkwoodii,* V.*carlesii*	*Viburnum lantana*
CONIFERS	
Scion	***Rootstock***
Chamaecyparis cv.	*Chamaecyparis lawsoniana*
Cupressus sp., cv.	*Cupressus macrocarpa*
Cedrus atlantica glauca	*Cedrus deodara*
FRUIT AND NUTS	
Scion	***Rootstock***
Apple cv.	Seedlings: Delicious, McIntosh, Rome Beauty Clonal: *Malus pumila* cv., including Malling series
Cherry	Seedlings: *Prunus avium*, *P. mahaleb* Mazzard Clonal: Stockton Morello
Citrus *C.aurantium*	*Citrus sinensis* (Sweet Orange), (Sour *orange), C.limon (Lemon) Trifoliate orange (Poncirus trifoliata* – dwarfing stock), Citranges cv.
Macadamia (*M.integrifolia*)	*Macadamia tetraphylla*
Olive (*Olea europea*)	*Olea europea* seedlings
Passionfruit (*Passiflora .edulis*)	Seedling *P.edulis*
Peach, Nectarine (*Prunus persica*)	Seedlings: Elberta, Halford, Lovell, *P.armenica* (Apricot seedlings)
Pear (*Pyrus communis*)	Seedlings: *Pyrus communis*, *P.callryana*, Quince (*Cydonia oblonga*)
Plum (*Prunus* sp.)	*Prunus cerasifera* cv. (Myrobalan plum – Used for Japanese and European plums); *P.persica P.armenica, P.dulcis* (Almond)
Walnut (*Juglans regia*)	*J.regia, J.hindsii, J.nigra*

TYPES OF GRAFTS

Budding

Budding is a type of graft where a "single" bud is all that is being grafted onto the stock. There are many ways of attaching a bud, and several different ways of cutting a bud. Normally a bud is cut with a sharp knife, taking a small amount of wood and bark from the stem behind the bud. The wood taken can sometimes be peeled away from the bark to expose more of the cambium layer behind the bud. With more cambium tissue exposed, the bud will have a greater chance of "taking".

Budding is normally performed in early autumn. The bud is usually bound with a strip of plastic budding tape after being placed in position.

Whip and Tongue Graft
This is perhaps the most common form of grafting. It is usually performed in late winter when plants are beginning to enter a rapid growth period. This method is most commonly used in propagating new varieties onto the top of a one year-old seedling or cutting-grown plant.

Top Graft and Side Graft
These are normally used for changing the variety of an existing plant (eg. an existing seedling apple tree may be grafted with a Jonathan apple so as to make it into a more desirable and useful tree).

Approach Grafting
This technique is used in cases where you want to eliminate the risk of losing propagation material because a graft does not "take".

The scion is grafted onto the side of the stock while it is still attached to its own root system. The scion is not cut away from its roots until the graft has "taken".

Irrigated Graft
Here the base of the scion is placed in a bottle of water. This assists the scion to remain alive until the graft "takes".

Nurse Seed Graft
This technique can be used to help establish roots on a cutting by grafting the cutting onto the roots of a newly-germinated seedling.

Root Grafting
Root grafting is the use of a section of plant root, or an entire root system taken from a seedling rootstock, rooted cutting or layered plant. The root pieces are generally small, so the whip and whip tongue grafts are the most commonly used and this type of graft is usually undertaken in the cooler months with the scion wood being collected usually in autumn and stored in a cool place until needed.

The rootstock pieces are lifted in late autumn and stored in a cool moist place, or in temperate climates, lifted just prior to use. Fungal drenches and disinfectants are sometimes used in an attempt to reduce pest and disease problems.

Lilac Graft
One of the plants most commonly grown by root grafting is the lilacs (*Syringia* spp.). These are commonly grown in the northern hemisphere by bench grafting the lilac scion onto green ash (*Fraxinus* spp) root pieces using the whip graft. The completed grafts are packed, usually in polythene or moist sawdust or peat, and stored in a cool place until ready for planting in the field. The green ash pieces act as a nurse graft. The graft union is placed deep into the ground so that if a good graft union is made, the rootstock will feed the scion until it has put out is own roots; when this occurs the nurse rootstock is generally rejected. String is popular as a binding agent as this allows roots to penetrate from the base of the scion where they are most likely to form. This may be a problem with plastic tape.

Some Species that may be Root Grafted

Scion	Rootstock
Apples (*Malus* sp.)	Clonal stocks of *Malus* sp.
Clematis (*Clematis* sp.)	*C.flammula, C.vitalba, C.viticella*
Crabapple (*Malus baccata*)	*Malus ioensis* and other *Malus* sp.
Gooseberry (*Ribes* sp.)	Vigorous rooting cultivars
Hawthorn (*Crataegus* sp.)	Various *Crataegus* sp.
Kiwi fruit (*Actinidia chinensis*)	Seedlings of *A.chinensis*
Lilac (*Syringia* sp.)	*Fraxinus* sp., *Ligustrum* sp, *Syringia* sp
Passionfruit (*Passiflora* sp.)	*Passiflora edulis*
Pears (*Pyrus* sp.)	*Pyrus* sp., *Cydonia oblonga*
Tree Peony (*Paeonia* sp.)	*P. lactiflora*

Soft Tissue Grafting

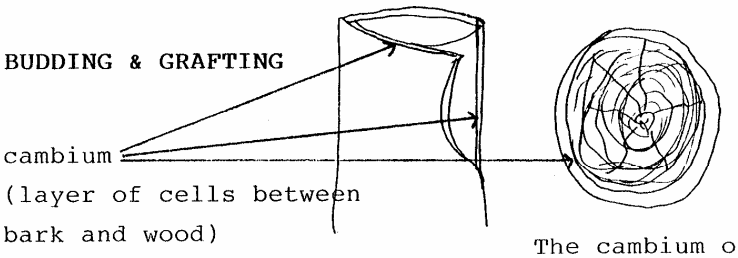
Soft tissue or herbaceous grafting is a grafting method using material that is soft, succulent and prone to damage. Such grafting is usually undertaken for research purposes, for commercial production of some cucurbits, and has been undertaken for the propagation of some woody perennials, with various degrees of success. These grafts are generally undertaken at the seedling stage, just after germination, often using a splice graft by making a diagonal cut just above the cotyledon (seed leaves). A similar matching cut is made in the scion and these are held together snugly by a thin walled piece of polythene tubing that has been slipped over the top of the rootstock, so that the cut surfaces match as best as possible. Callusing usually takes 10-14 days when the plastic tubing is removed.

When grafting older herbaceous material, some leaves may be retained below the graft position and a cleft or splice graft may be used. The lower leaves are generally removed once the graft has healed and new growth is established in the scion. These grafts need to be well protected to prevent damage or drying out.

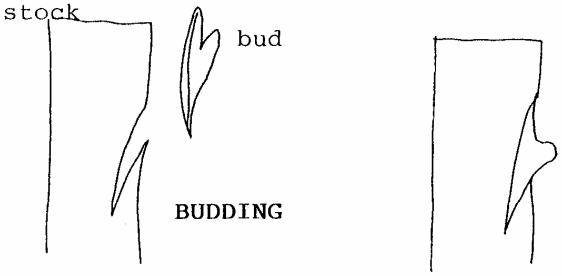
Grafting Tapes

Grafts require firm tying so that a solid contact of cambium is obtained and retained between rootstock and scion. There are many tapes on the market, though some are electrostatic which makes them difficult to use and manage. Some tapes reviewed are:

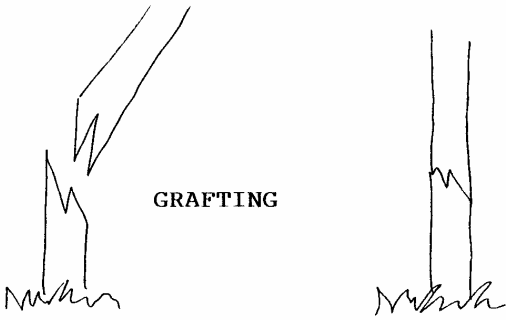
- Stericrepe - thick but sticks well to itself, can be moulded around the graft to give support; a type of self-adhesive bandage.
- Thin plastic bags - thin when stretched, strong, do not stick to themselves; similar to those in supermarkets.
- Plastic lunch wrap - very thin but sticks well to itself, will break if overstretched, best for soft delicate stem work.
- Florist's tape - thin when stretched, can be cut into strips, seals well due to waxy characteristics.
- Teflon tape - very thin, strong, stretchable but highly electrostatic makes it difficult to work with.
- Parafilm and Nescofilm - stretches well, sticks to itself, can be cut into strips, seals well due to waxy characteristics.



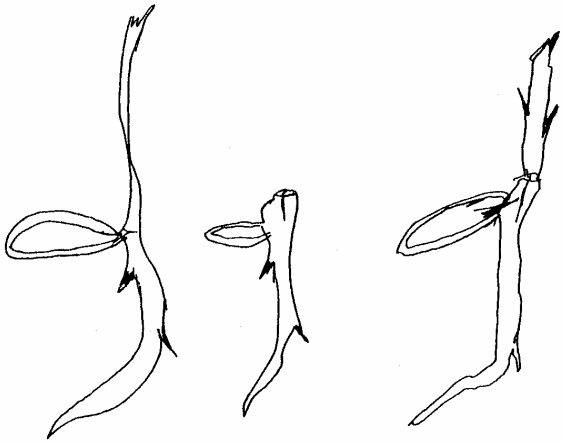
The cambium of the scion must connect with the cambium of the stock.



In budding,only an individual bud is attached.



In grafting,a piece of wood containing several buds is attached.
Shown here is a whip & tongue graft.



NURSE SEED GRAFT

PROPAGATING PLANTS IN A GREENHOUSE

You can grow all sorts of plants in a greenhouse, and achieve all types of things, which otherwise you might not be able to achieve. However the greenhouse is only a tool that enables you to alter the growing environment a little. To succeed you must know what conditions the plant needs, and create those conditions within your greenhouse.

Greenhouses are very labour intensive and require careful management. In the summer this may mean monitoring it every day, particularly if the greenhouse does not have automatic watering and ventilation systems.

You need to be aware that different plants have different requirements. It may not be possible to grow a variety of plants in the greenhouse and get the very best out of each one, if each of those plants has different growth requirements.

What Can You Grow?
A greenhouse may be heated or unheated and have a fully manual ventilation system. The unheated greenhouse is the simplest to manage. However it must be remembered that although a cold greenhouse will trap heat from the sun during the day, thereby extending the growing season, temperatures within the structure overnight can be as cold as the temperature outside. Plants that are frost-sensitive cannot be grown in an unheated house over winter. Heating systems will add to the cost of running a greenhouse, although simple systems are available for the small grower. Ensuring that the temperature within the house does not fall below 5-7º Celsius will extend the range of crops that can be grown.

Greenhouses are normally used for one of the following. There may be other uses, but these are the main ones:

- To propagate new plants in - provide the ideal conditions for seeds to germinate or cuttings to initiate the growth of roots.
- To grow tropical and sub-tropical plants in cooler climates.
- To protect plants that are cold or frost-sensitive over winter.
- To grow vegetables, cut flowers or berry fruits out of season or earlier than they would be able to grow outside.
- To grow nursery container plants over winter when there may not be much growth in the outside environment.

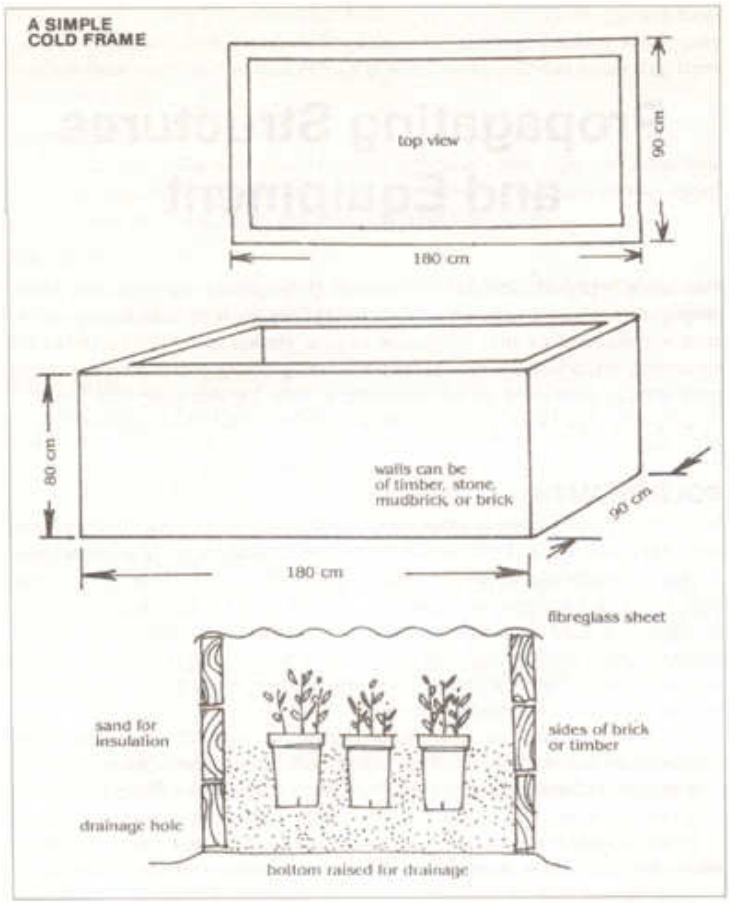
It is not usually advisable to try to use the greenhouse for more than one of the above purposes. This may be acceptable for the hobbyist, but not for the commercial grower.

Cold Frames
Cold frames are in effect mini-greenhouses. They are most commonly used by home gardeners, but can also be effectively used in a nursery. The frame can be used to:
- grow seedlings
- propagate cuttings
- provide a protected environment for budding and grafting

The frame is a simple structure, usually box-like with a hinged top. The walls of the frame can be either a transparent material, such as polyflute/polycarbonate, or non-transparent such as timber. The top is at an angle (so water can run off, and the sun enters at nearly right angle) and can be opened and closed for access and to allow air in, depending on the weather. Opening and closing the lid also controls the temperature and humidity.

The advantage that a frame has over a glasshouse is that you get more ground space covered for less material used. A frame can be moved around to find the best spot, or changed from a sunny position to shade depending on the season. It can be designed so that new frames can be added on, making a multiple unit. The disadvantages are that one is working at ground level

and not at a bench, also, because of the smaller internal volume, the frame can heat up and cool down faster, and so it needs to be watched more closely.



Cuttings and seed can be placed in a cold frame when propagating. The frame acts in a similar way to a glasshouse, by keeping the young plants protected.

Heated Propagators

Professional growers often use heated plant propagation systems when growing from seed or cuttings. Heated propagation guarantees a higher germination rate and a much faster growth rate. Using a heated propagator allows plants to be propagated out of season.

Propagators are available in various sizes from small backyard hobby units, to large bench-style systems. The following are just some of the systems available:

- Vacuum moulded propagators. Made from tough, water-resistant plastic material with a plastic element that distributes heat evenly without hotspots or lines of high temperatures.
- Fibreglass propagation tray. Trays are available with heating only or fitted with both heating and misting. They are made of rigid fibreglass, reinforced plastic completely enclosing a 240volt heating element, making them safe, long-lasting and maintenance free. Various sizes are available.
- Flexible heat mats. Insulated heating mats that can be bought by the metre at various widths, are available with or without a thermostat.

- Heated cable on mesh. This system has been available for many years and is still widely used today. The mesh has a 240v cable mounted on mesh and is available in various sizes to the customer's specifications.
- On-bench tubed heating systems. Similar to the heated cable system but uses hydroponic heating through a series of tubes placed under wire mesh on the benches.
- Germination/Propagation chambers. Thermostatically controlled, electrically-heated chamber mounted on wheels. The chamber has a stainless steel heated water tank that creates the necessary humidity inside the chamber. Sides are removable for easy loading and unloading. This is a sophisticated system that would ordinarily only be used by the large grower.

SET TASK

1. Collect at least 10 different types of seed. You must collect and clean seed from a living plant yourself. Do not use pre-packaged bought seed. Describe the seeds and name the plants from which they were collected (do not send the seed).

2. Sow the seed you collected for the previous question, and germinate it. Write a description of how you germinated it, and take a photograph of the germinated seedlings. (As it might take some time to get the photo, this can be included in this or a future assignment if you wish.)

3. Write your own definitions for the following terms and submit them with this lesson's assignment:
- Budding
- Grafting
- Layering
- Cutting Propagation
- Separation
- Division
- Vegetative propagation
- Seed propagation
- Physical dormancy
- Physiological dormancy

4. Research (using the internet, libraries, propagation professionals) ways in which propagation practices can affect the environment and the health and safety issues involved.

ASSIGNMENT

1. Using 3 examples (stating scientific and common names) briefly describe the characteristics of plants that are propagated by seed and those that are propagated vegetatively.
Why would you choose one method of propagation over the other?
What are the advantages and disadvantages of the two methods?
(Write no more than half a page)

2. Summarize the factors that can affect the success or failure of raising plants from seed.
a. in containers in a protected environment and
b. in the open.
What sort of conditions would be appropriate for raising seeds in a protected growing environment? What aftercare is required for seeds sown in containers? What factors need to be considered for growing seed in the open and what aftercare is appropriate? (List at least 10 plants for each situation i.e. protected and open and their requirements)
(Write no more than one page)

3. Name two different methods for overcoming physical and physiological dormancy in seeds. Write one sentence to briefly define each of these two methods.

4. Describe the seed harvesting techniques you used appropriate for one of the seed types you harvested in Set Task 1.
What are the seed storing conditions relevant to these seeds?
What effect could storage have on each of these seeds?
(Write one paragraph only)

5. Write approximately 500 words (in total) explaining procedures you would use to propagate a range of cuttings including at least one from each of the following categories:
a. stem cuttings
b. root cuttings
c. leaf cuttings
Give named examples for each. Describe the equipment you require, the environmental requirements needed for each? How could improve the striking rate of these cutting? What aftercare you would give?

6. Describe a layering technique. What physiological factors need to be fulfilled to successfully propagate by layering? What after care is required?
If you prefer, answer this with labelled illustrations.
(Answer this in half a page)

7. Describe a methods you would use, and the conditions needed, to successfully propagate a plant by division, including the aftercare.
(Write one paragraph only)

8. Explain why budding and grafting are sometimes preferred as propagating techniques.
(Answer in one or two sentences)

9. Describe the type of health and safety practices that would be used in propagating plants and list ways that propagation practices can impact on the environment and methods of controlling this impact. *(Write no more than half a page)*
Don't forget to submit your seven plant review sheets