CHAPTER 3

Apical dominance

Know your fruit tree

This chapter is the most important in this book. It is my very strong view that learning to prune fruit trees is best achieved by learning how they grow. The knowledge of how tree growth occurs, how it is managed and controlled within the tree and how the tree will react to a pruning cut is critical. Pruning cannot be learned by following a template process e.g. cut each young shoot back to four buds (or some similar description). A tree is pruned because the tree needs pruning. If it does not need pruning, then do not prune it.

Pruning is only one tree management tool. There are many others. Pruning is used as an integral part of the tree management process. It is used to assist the tree’s natural growth behaviour to develop an appropriate tree framework and then to produce early and consistent crops of quality fruit.

Growth behaviour

Trees like animals are complex biological organisms. Consider the immense range of biological activities we hear about in medical science. The range of activities in plants is no less.

The growth, development and behaviour of fruit trees is the result of the balance of all the growth factors which have an influence on the tree. The most important balances in which we are interested are the balances of the naturally occurring hormones in the tree and the balances of the plant foods and nutrients.

In animals and humans we are aware of the influence of hormones in the growth and development of the individual. A hormone is a naturally
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occurring chemical produced in very small quantities in one part in the body. It is translocated to target tissues or organs where, at extremely low concentrations, it triggers and controls a growth or developmental response.

In animals there are many types of hormones produced in different glands and with different target organs. In plants there are several types of hormone as well. The most important two groups for our discussion at this point are the auxins and the gibberellins. Synthetic versions or analogs of these are marketed as plant growth regulators. These two plant hormones are involved in controlling the growth of trees. This is especially important in the spring when they control the growth response known as apical dominance.

An understanding of apical dominance is vital in the understanding of the pruning and training requirements of the fruit tree. Most examples of poor orchard design and management, of badly pruned or poorly trained trees can be traced back to a lack of this understanding.

As the tree comes out of dormancy in the spring the terminal (or apical) bud in the shoot is triggered into action and it commences the complex process of spring growth. Inside the bud is a tissue or group of cells known as a meristem. Meristems in plants are where growth is produced by the process of cell division producing new cells. As this process continues new cells are being continually added to the plant, producing the increases in length and thickness of the plant’s structure known as growth.

The most active meristems in plants are those in the tip of the shoots (shoot apical meristems) and the tips of the roots (root apical meristems). Equally important is the intercalary meristem commonly known as the cambium. This is the layer of cells which separates the bark (containing the food conducting tissue called the phloem) from the wood which contains the water and nutrient pumping tissue (known as the xylem). The cambium is the meristem which produces the new cells which increase the diameter of the stem.

Every bud contains an active or potentially active meristem. These buds are often targeted in the pruning process to be triggered into activity to produce new growth at a point and in a required direction. This means that the pruner can select the meristem which is to be activated. There are also meristems in the roots which produce branch roots as the plant grows.

When the shoot apical meristem commences activity in the spring, cell division occurs which adds new cells to the length of the shoots which then elongate to their optimum size. This produces the very obvious shoot elongation of spring. At the same time meristematic activity in the cambium is producing new layers of phloem cells (in the bark) and new xylem cells (added onto the existing wood). Under the ground, roots are increasing in length and diameter for the same reason and branch roots are developing.

As this activity begins in the shoot apical meristem it produces a hormone, a chemical known as indole-acetic-acid (I.A.) which is a naturally occurring member of the group of hormones known as auxins. Many synthetic auxins,
Figure 3.1 *Apical dominance*
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including 2,4-D, 2,4,5-TP, 2,4,5-T, N.A.A. and N.A.D. are widely used in horticulture and agriculture for a range of purposes.

In the stem the auxin moves downwards in the phloem, controlling many growth features as it does. For example it is instrumental in controlling the elongation of the new cells produced at the shoot tip. Auxins are also involved in the production and pattern of placement of the new buds on the nodes of the new shoot as it grows. More importantly from a tree training point of view, the auxin inhibits the newly developed buds from producing anything other than leaves. The apical bud or meristem is using the auxin to dominate the shoot growth and preventing any side shoot from developing and competing. The stronger the apical meristem, the higher the concentration of auxin and the more there is of this dominance. This is called apical dominance.

The auxin concentration declines during its flow down the stem. There are a number of reasons for this. Some is being used up by the bud inhibition process and the cell elongation process. Some is being used up by other chemical reactions in which it is involved and some is being destroyed by contact with light. At the same time as all this has been going on, other
hormones such as cytokinins and gibberellins are being produced within
the plant. Especially important for tree training purposes are the gibberellins
which are largely produced in the roots and travel upwards inside the plant.
The result is that at various points within the plant there are varying bal-
ances between the hormones.

The most important balance is that achieved at a point in the stem where
a critical balance of auxins and gibberellins is achieved. At this point the
auxin cannot quite inhibit the bud. The bud produces a shoot with a most
important feature. Because of the hormone balance situation the shoot will
grow out at a broad angle to the stem. This broad angle is critical in tree
training because not only is it a strong angle (to support the weight of a
crop of fruit) but is precisely the branch angle which initiates the induction
of fruit bud and the subsequent production of quality fruit. This shoot with
its own developing apical meristem continues to grow at an angle deter-
mined by the everchanging hormone balance within.

**Effect of pruning and training**

What does all this mean in tree training terms?

- By leaving the apical meristem on the tip of the shoot (i.e. by not
heading the shoot during pruning) the maximum shoot elongation
and maximum diameter increase (from the auxin encouraged
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...cambium) is achieved. You can grow the tree framework faster and stronger by not heading the shoot.

- By leaving the apical meristem on, shoot side branching is achieved some distance below the shoot tip at a broad branch angle. This is the strongest possible connection to the main central stem.
- The sideways growth of the side shoots produces the optimum tree shape for light penetration.
- The sideways growth will be about 60 degrees from the vertical which is the optimum branch angle to initiate the production of fruit bud.
- This angle of side growth is also the optimum to achieve the balance between fruit production and the amount of vegetative growth needed to produce optimum fruit quality.

The meristem at the tip of the developing side shoot is just like the meristem at the tip of the main leader of the tree, with one very significant difference. The shoot is not vertical but growing at some broad angle to the main shoot. This means that this meristem does not have as much dominance as the apical meristem. It is also being influenced by a higher concentration of gibberellins than the apical meristem because being lower in the tree, it is nearer to the source. For a side shoot this means that the inhibition process reduces further branching from the buds as they are produced by growth. But because the hormone balance is different from that in the main shoot or leader the buds can easily develop as flower or mixed buds.

Figure 3.5 illustrates this point. Side shoots growing in the Zone A orientation will be very vigorous producers of shoot growth but have almost no ability to grow fruit buds. Side shoots growing in Zone B1 orientation are in the transition zone where fruit buds can be induced but the shoot is still dominated by shoot growth. In Zone B2 fruit bud development is easy to induce but at the same time there is enough vegetative growth to maintain vigour in the shoot and the production of abundant food for developing fruits. Such shoots commonly bend down into Zone B3 under the weight of the fruit, and their vegetative growth will be reduced.

Shoots originally in Zone B3

Figure 3.5 Angles of growth of shoots
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are in a position where abundant fruit bud is easily produced and vegetative growth is still adequate. However, the dominance of the terminal bud is very reduced and excess small side shoots are now a possibility, creating too much shading. If the shoot bends into Zone B4 during fruit growth, elongation growth of the shoot ceases at the horizontal position and small side shoots oriented upwards will take over. This can largely be remedied during the next pruning season.

Shoots which are permanently in Zone B4 will still produce fruit but the quality of the fruit will be determined by the growth of upwards oriented shoots. This is because the terminal bud is no longer meristematic and will produce no elongation growth.

Shoots permanently in Zone C produce poor quality fruit because there will not be enough vegetative growth producing the food which the fruit needs. It is also highly likely that this wood is shaded. Such wood is of no use to the tree or grower and should appropriately pruned.

All this has been achieved by simply not pruning (heading) the leader (the main vertical shoot) of the tree. You have let the tree grow the way it wants to grow as this coincides with the most efficient tree shape. You have trained the tree by understanding the way it wants to grow and by making the decision not to prune. The result will be a strong central leader with whorls of sideways shoots (like spokes of a wheel) well below the tree’s apical meristem. Apical dominance is thus used to control the tree’s growth.

We can liken the situation to that in a political party where a very strong leader inhibits the potential competition from senior team members. This analogy will be used later to explain other facets of tree training using apical dominance.

The discussion so far has suggested that the concept of apical dominance and its use in tree training is very simple. To some extent this is true but there is more to the concept which we will now need to consider. For example, what are the factors which determine the strength of apical dominance? Clearly not all trees grow in the same way.

Factors affecting the strength of apical dominance

Several factors determine the strength of apical dominance:

1. Every fruit tree species, variety and cultivar is genetically different from every other. This results in a very large range of growth behaviour between species and within one species. Peach trees have a different growth habit from pears and Granny Smith apple trees grow differently from a Jonathon. In terms of apical dominance we can make some broad generalisations:
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- Pears have extremely strong apical dominance.
- Cherries have very strong apical dominance.
- Apples generally are also very strong but there is a big range.
- Plums have very strong dominance.
- Peaches have medium strength dominance which is stronger when the tree is young and weakens with age.

(2) The fruiting behaviour of the cultivar influences the strength of apical dominance. For example lateral bearing apples have very strong dominance but it is weaker in spur bearing varieties.

(3) The precocity (or ease with which the variety produces fruit bud early in the tree’s life) of a variety is also important. For example a tree which is normally apically dominant will lose most if not all of the dominance if it is allowed to carry too much fruit too early in the tree’s life. This commonly leads to stunted trees if the situation is not remedied.

(4) The verticality or erectness of the stem is a major factor controlling apical dominance. Dominance is greater and shoot growth is maximised if the shoot is vertical. This dominance weakens in direct proportion to the angle away from the vertical. In trees on moderate to vigorous rootstocks this vertical growth is relatively easy to achieve. In trees on dwarfing rootstocks the leader may have to be supported to maintain its vertical orientation. This is part of the reason for the need for tree support in high density orchards on dwarfing rootstocks.

(5) Leader competition reduces absolute dominance. For example if the leader of a tree is pruned back (or headed) the original dominant leader is lost. The auxin it produced is now missing so the auxin controlled inhibition of lower buds disappears. The buds closest to the point of pruning now attempt to become the new leader. Using our political party analogy, if the leader accidentally falls in front of a bus, all of the previously inhibited major contenders now compete with each other to become the new leader.

Each of the new shoots grows vertically; each has an equal share of the growing resources. So where the tree had one strong vertical shoot it now has several growing from the highest remaining buds and growing vertically competing with each other.

The grower now has to make a decision. Are all new leaders kept so that a narrow vase tree results? Or is a central leader tree re-established by keeping the top shoot and cutting its competition off? Or is the tree trained but not pruned by keeping the top shoot as the new leader and spreading the others away from the vertical thus reducing their dominance? This last choice is often made in developing a central leader tree from a newly planted tree. That is, the tree is headed after planting, the best leader kept, and the rest spread. This is a critical move if the tree is a spur type or on a weak rootstock. It is called the head and spread method.
(6) The stronger the rootstock the stronger will be the dominance. The dwarfing rootstocks now available in apples (and some other fruits) greatly reduce dominance so other strategies must be implemented to maximise the dominance which remains. These include supporting the leader and spreading the other shoots.

(7) Normal tree health and vigour influence the strength of the dominance. A healthy tree with adequate nutrition and water will have maximum dominance.

(8) Any major stress on the tree will reduce dominance. These stresses may include pests, diseases, nutrient deficiencies or imbalances, excess crop load, heat, drought and other growth factors.

(9) Any damage to the apex of the tree can have a similar effect to heading back. The damage could be physical such as wind or hail damage. It could be disease such as curl leaf or shoot blight in peaches. It could be powdery mildew in apples. It could be shoot girdling by heliothis caterpillars or a moth borer. It may be picker or machine damage. Whatever the cause, the remedy is to select a new leader as soon as possible and manage the new leader.
(10) Elevation position is important. When a new leader is chosen for any reason, the choice must be based on choosing the best candidate possible. It should be a strong shoot pointing in the best direction. Once it is chosen it must grow from the highest point on the limb. Sometimes a weak shoot will grow from the top bud and a stronger shoot from lower down. Or the tree height may be reduced by choosing a new leader lower down. In both cases the best new leader available must grow from the top of the shoot.

(11) The imposed training method will influence strength of dominance. For example any trellised system which spreads leaders away from the vertical will reduce the strength of the dominance.

(12) The use of applied plant growth regulators or pesticides which have some
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Growth regulator effects will influence dominance. Because dominance is controlled by the hormone balance within the tree, the application of any plant growth regulator may change this balance. The use of Cytolin (which contains a synthetic gibberellin and cytokinin) for example can overcome the auxin induced inhibition of buds and induce side branching where required.

**Using apical dominance to manage the tree**

Looking closer at the "ideal" central leader tree discussed earlier, we will observe that as soon as the side bud is no longer inhibited from developing by the downward flowing auxin, it develops a new shoot with its own leader and apical bud. The growth of this shoot and the development of the the apical bud is still influenced firstly by the hormone balance at the bud and then by the changing hormone balance created by the new developing leader. The strength of the dominance of this new leader is determined by its genetics and its verticality. This will vary from one cultivar to another.

If the side shoot becomes too dominant and too vertical it may start to compete with the original leader. Too large a proportion of the tree's vegetative growth is from the base of the tree rather than the top. This is called basitonic growth and it is typical of some apple cultivars such as Red Chief Red Delicious. The answer with a basitonic tree is to protect the main leader and to spread the side shoots to weaken their dominance. This

![Diagram](image)

**Figure 3.9 Strong and weak apical dominance due to branch orientation**
is the head and spread technique developed by Don Heineckie (previously from Washington State University).

Because of the relative weakness of the leader of the side shoot, fruit bud development is easy to initiate. So by not pruning but controlling the side shoots, trees can be persuaded very easily to crop. The cropping itself will then influence tree development. So spreading and cropping are two ways of training trees without pruning.

In the light of this concept we can examine more closely what happens to the side shoot if it is pulled down by the weight of the fruit to horizontal or even below.

As shown in Figure 3.10, when the side shoot bends under the weight of the fruit, the angle begins changing from the 60 degrees to the vertical towards 90 degrees from the vertical. At this angle (that is, horizontal) the apical meristem has lost its dominance powers. The shoot will not produce elongation growth. As the shoot bends below horizontal the bud at the tip of the shoot is no longer the dominant bud. The dominant bud is that one at the highest point on the bend of the shoot. Because the apical bud is producing no auxin this bud is not inhibited at all so it will begin to grow a shoot. If nothing else now changes this shoot will be vertical and very strong. This type of growth is commonly called a water shoot. Water shoots are a problem because they grow strongly and vertically inside the tree canopy producing crowding and shading.

The water shoot develops because apical dominance control has been lost on the side shoot as its apical bud drops below horizontal. If the side
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Figure 3.11 Watershoot management

shoot (especially the apical bud) has been prevented from dropping below horizontal then the water shoot is very unlikely to develop. If it does develop then clearly it must be removed completely.

If the side shoot continues to drop under the weight of the developing crop what happens is that as every bud on the bowed part of the shoot becomes the highest (hence dominant) bud, it develops a shoot. But before this shoot develops, another bud takes over as the new top bud and another weak shoot develops. The result is a bowed main side shoot with a number of short shoots developed on it. The correct remedial procedure is to prune the end from the side shoot back to the best positioned and oriented of the weak shoots (Figure 3.11) (about 60 degrees from the vertical), which will become the side shoot’s new leader. This procedure may need to be repeated at intervals (Figure 3.12).

This means that the fruit bearing side shoots are largely renewed on a regular basis. But the renewal pruning must only be done when it is necessary. The overall long term aim is to maintain the fruiting arms (the side shoots) at an angle of about 30 to 60 degrees from the vertical. This angle is important because it is wide enough to prevent the side shoot ever competing with the tree’s leader. The angle is also steep enough to allow for some strength of the apical bud so that it may impose its own apical dominance on that shoot. This allows for some continuing vegetative growth to retain the vigour of the shot which will in turn optimise fruit size and quality (Figure 3.13).

Similar sorts of problems can occur at the tip of the tree where the tree’s
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Figure 3.12 Limb angles can be used to reduce or encourage shoot growth fruitfulness

Figure 3.13 Dormant pruning of low angle branches
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Figure 3.14 Peach tree showing a side shoot which has been pulled down to horizontal by the weight of a crop of fruit.

Figure 3.15 The peach tree in Figure 3.14 after pruning.
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Figure 3.16 Loss of apical dominance because of fruit weight. The final stage shows the effect of remedial pruning.

Figure 3.17 Reduction of the height of the tree while maintaining apical dominance control.
Figure 3.18 Central leader apple tree where the central leader has been encouraged to grow vertically for five years, controlling the tree’s development. When the tree was large enough the leader was allowed to bend under the weight of the crop. As it bent and lost its dominance, another leader developed from lower in the tree. The tree’s height has been controlled by training not pruning.

Apical dominance should be strong. If the top of the shoot bends for any reason (a common one is fruit on a shoot which is too weak to carry it), as the terminal bud moves away from the vertical its dominance declines in proportion. As the terminal bud approaches horizontal its dominance disappears completely. The dominant bud now is the one at the top of the bend. So it will grow a vertical shoot. If the bending continues (as discussed previously) then several new vertical shoots may develop. To regain control of the tree the most suitable leader must be chosen and the top of the tree cut back to it. Any competing leaders must be removed (Figure 3.16).

The same concept can be used to reduce the height of the tree while still maintaining apical dominance control. Simply cut the top back to a suitable candidate for leader. This candidate should preferably be close to vertical, fairly strong and at the required height. Having cut back to it (i.e. electing it as the new leader) then all possible competing leaders must be removed (Figure 3.17).

Tree height control especially in central leader trees often occurs naturally when the leader is permitted to bear fruit, and bend below the horizontal; new vertical shoots develop and a new leader must be chosen.
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It should now be clear that choosing an unheaded leader either at the top of the tree or on the side shoots which are the fruiting arms leaves the pruner in control of the tree. By constantly heading during the pruning process, apical dominance and control is lost and the regrowth will be uncontrolled. Heading always produces a number of shoots (the competing new leaders) increasing shading problems and increasing the pruning which will be needed in the next season. If heading back is needed then head back to a shoot no matter how weak. It will then dominate in the next season, producing growth in the direction you have chosen. Heading back may be necessary for a number of reasons but the most common is to reduce excess fruit bud or excess height/length. In either case head back to a newly elected leader which is pointing in the direction you want the regrowth to develop in.
1. The most important balance is that achieved at a point in the stem where a critical balance of \[ \text{...} \] is achieved. At this point the lateral bud can grow.
   a. Auxins and cytokinins
   b. Auxins and gibberellins
   c. Gibberellins and cytokinins
   d. Auxins and ethylene

2. Heading back may be necessary for a number of reasons except
   a. To reduce excess fruit bud
   b. To reduce length of shoots
   c. To reduce apical dominance
   d. To remove the undesirable shoots

3. Which of the following sentences is False
   a. Plums have weak apical dominance
   b. Peaches have medium strength apical dominance
   c. Cherries have very strong apical dominance.
   d. Pears have extremely strong apical dominance.

4. Depending on the following figure answer the following 4 questions.

5. Shoots originally in \[ \text{...} \] are in a position where abundant fruit bud is easily produced and vegetative growth is still adequate
   a. Zone B2
   b. Zone B4
   c. Zone B3
   d. Zone A

6. Shoots which are permanently in \[ \text{...} \] will still produce fruit but the quality of the fruit will be determined by the growth of upwards oriented shoots
   a. Zone B4
   b. Zone B3
   c. Zone B2
   d. Zone C

7. Shoots permanently in \[ \text{...} \] produce poor quality fruit because there will not be enough vegetative growth producing the food which the fruit needs
   a. Zone B1
d. Zone B4
   b. Zone A
   c. Zone B2

8. Side shoots growing in the \[ \text{...} \] orientation will be very vigorous producers of shoot growth but have almost no ability to grow fruit buds.
   a. Zone B1
d. Zone B3
   b. Zone A
   c. Zone B2

9. To control the apical dominance, the most important balance is that achieved at a point in the stem where a critical balance of \[ \text{...} \] is achieved
   a. Cytokinin and gibberellins
   b. Auxins and cytokinin
c. Auxins and gibberellins
   d. Auxins and ethylene

True or False
1. Any major stress on the tree will increase the apical dominance
2. Apical dominance is greater and shoot growth is maximized if the shoot is vertical
3. As the shoot bends below horizontal the bud at the tip of the shoot is no longer the dominant bud. The dominant bud is that one at the highest point on the bend of the shoot
4. The dwarfing rootstocks greatly increase apical dominance
5. The fruiting behaviour of the cultivar influences the strength of apical dominance. For example, lateral bearing apples have very weak dominance but it is stronger in spur bearing varieties.

6. The early growth of the apical shoot tends to inhibit lateral budbreaks. This effect is greatly enhanced when chilling is incomplete, because apical buds require more chilling than lateral buds.

7. The stronger the apical meristem, the lower the concentration of auxin and the more there is of the apical dominance.

8. Tree height control especially in central leader trees often occurs naturally when the leader is permitted to bear fruit, and bend below the horizontal; new vertical shoots develop and a new leader must be chosen.

9. One method of inducing additional branches is to notch above a bud before bloom.

10. Horizontal shoots tend to produce more flowers than verticals.