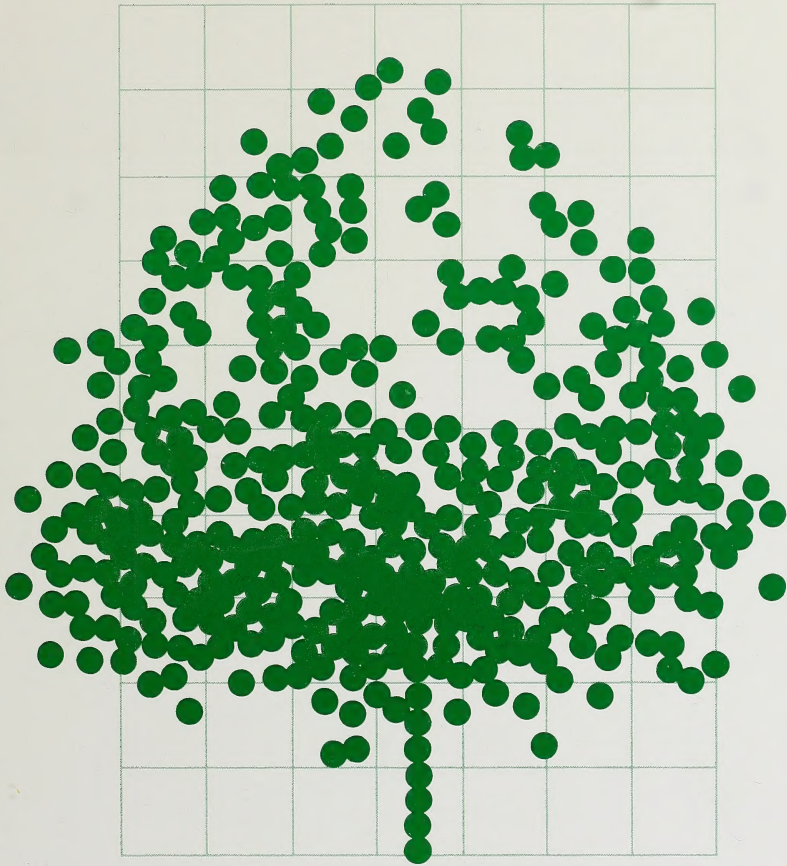


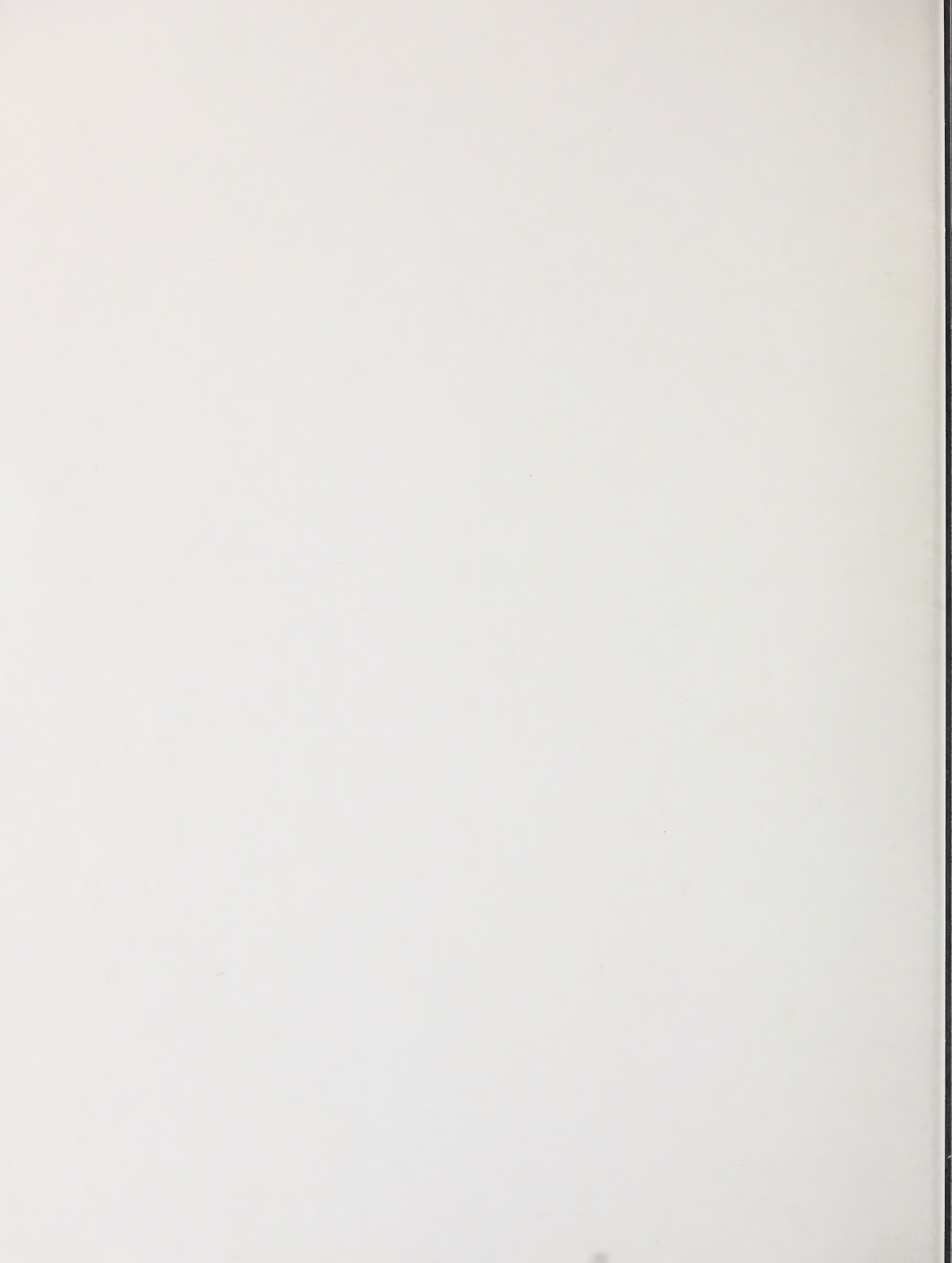
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• PRUNING •
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Pruning tools

contents

Figure 1. Pruning shears



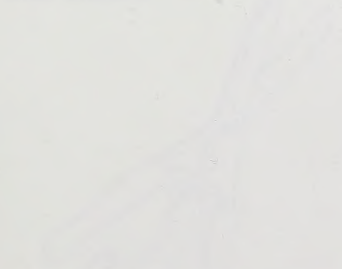
Figure 2. Long handled lopper



Figure 3. Hand saws



Figure 4. Pruning saws and chains



Time and budget are important factors in choosing pruning tools. The following items should be considered in choosing a tool for a particular job.

Pruning with long-handled shears is best for large trees. The long handles allow the user to reach high into the canopy without the need for ladders. Long-handled loppers are used for cutting larger branches. Hand saws are used for cutting smaller branches. Chainsaws are used for cutting large trees and stumps.

When choosing a tool, consider the following factors: 1. The size of the tree or branch to be cut. 2. The frequency of use. 3. The budget. 4. The availability of the tool. 5. The safety of the tool. 6. The ease of use. 7. The durability of the tool. 8. The weight of the tool. 9. The length of the handle. 10. The type of blade.

PRUNING IN ALBERTA



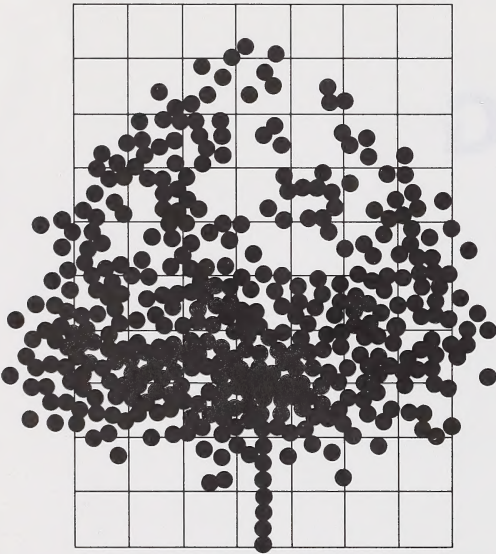
Pruning is an essential part of tree care. It helps to maintain the health and structure of the tree. Pruning can also improve the appearance of the tree. In Alberta, the best time to prune most trees is in late winter or early spring. Pruning should be done before the tree starts to grow in the spring.

Pruning should be done carefully to avoid damaging the tree. The cuts should be made at an angle, away from the trunk. The cuts should be made just outside the branch collar. The branch collar is the area where the branch meets the trunk. The branch collar will heal the wound over time.

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Why do you prune?

When you train and prune plants the aim should be to obtain the maximum decorative effect or the best crop possible. At the same time, it is important to maintain an attractive appearance with a balance between growth, flowering, and fruiting, while keeping the plant vigorous and in good health.

Pruning tools

There are tools designed specifically for pruning. The average home gardener requires a modest investment in the correct tools for pruning.

Pruning saws are specially designed with teeth set at wider angles to allow cutting into green moist wood without binding. The only tool larger than a hand saw that should be used by an amateur pruner is some type of power saw for larger branches or whole trees. This type of work is best left to a professional pruner as it is both dangerous and requires special methods.

Figure 1. Pruning saws

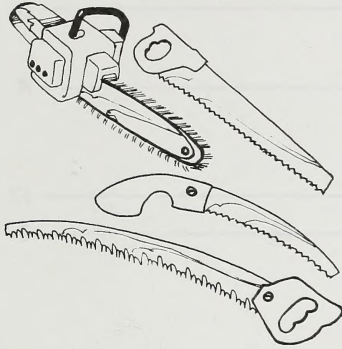


Figure 2. Long handled lopper

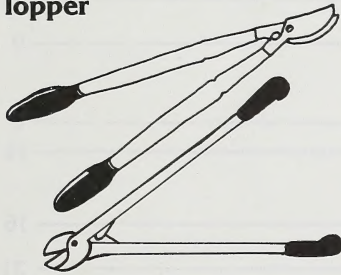


Figure 3. Hand pruner

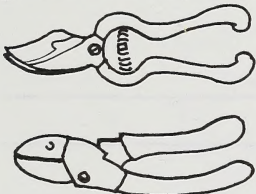
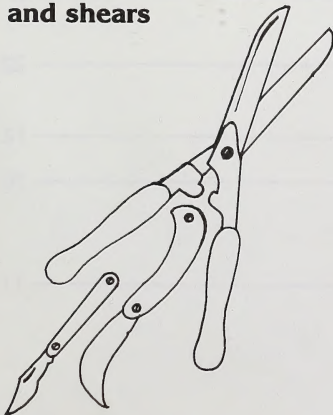


Figure 4. Pruning knives and shears



Branches or stems smaller than 5 cm (2 inches) can be cut with a long handled lopper. There are a number of types available; you should look for a tool with well attached handles, scissor-like action, and a rubber bumper just behind the pivot point. This rubber bumper helps absorb the shock of cutting through a large branch that would otherwise be transmitted up the operator's arms and felt in the shoulders.

For small branches less than 2 cm ($\frac{3}{4}$ inch) in diameter, the tool to use is a hand secateur or hand pruner. There are many sizes and qualities available but only two basic designs. The anvil type is designed with a straight-edged blade which cuts down onto a bar of softer metal. The scissor type has two convexly curved blades which cut in a scissors like fashion. Both types will work well in making pruning cuts but the scissor type is preferred as it tends to make a cleaner cut and leaves less of a stub.

These, then, are the three basic tools: the pruning saw, the long handled lopper, and the hand pruner. Based on 1984 prices, you would have to spend approximately \$50 to equip yourself for average pruning jobs with good quality tools. There are cheaper tools but they usually are of inferior materials, and would probably have a shorter useful life.

Supplementary tools could include hand or powered hedge shears and a pruning knife. Shears should be selected on the basis of a sharp cutting edge, the balance of the tool, the weight of the tool (the lighter the better, because you have to hold shears up for long periods of time), and the comfort of the tool to you as a user. Pruning knives can be anything from a small pocket knife to a kitchen paring knife or a specially designed pruning knife. When selecting a knife look to see how suitable it is for you and know the quality of the steel used in the blade. You must keep it sharp at all times because a dull knife does more damage than good.

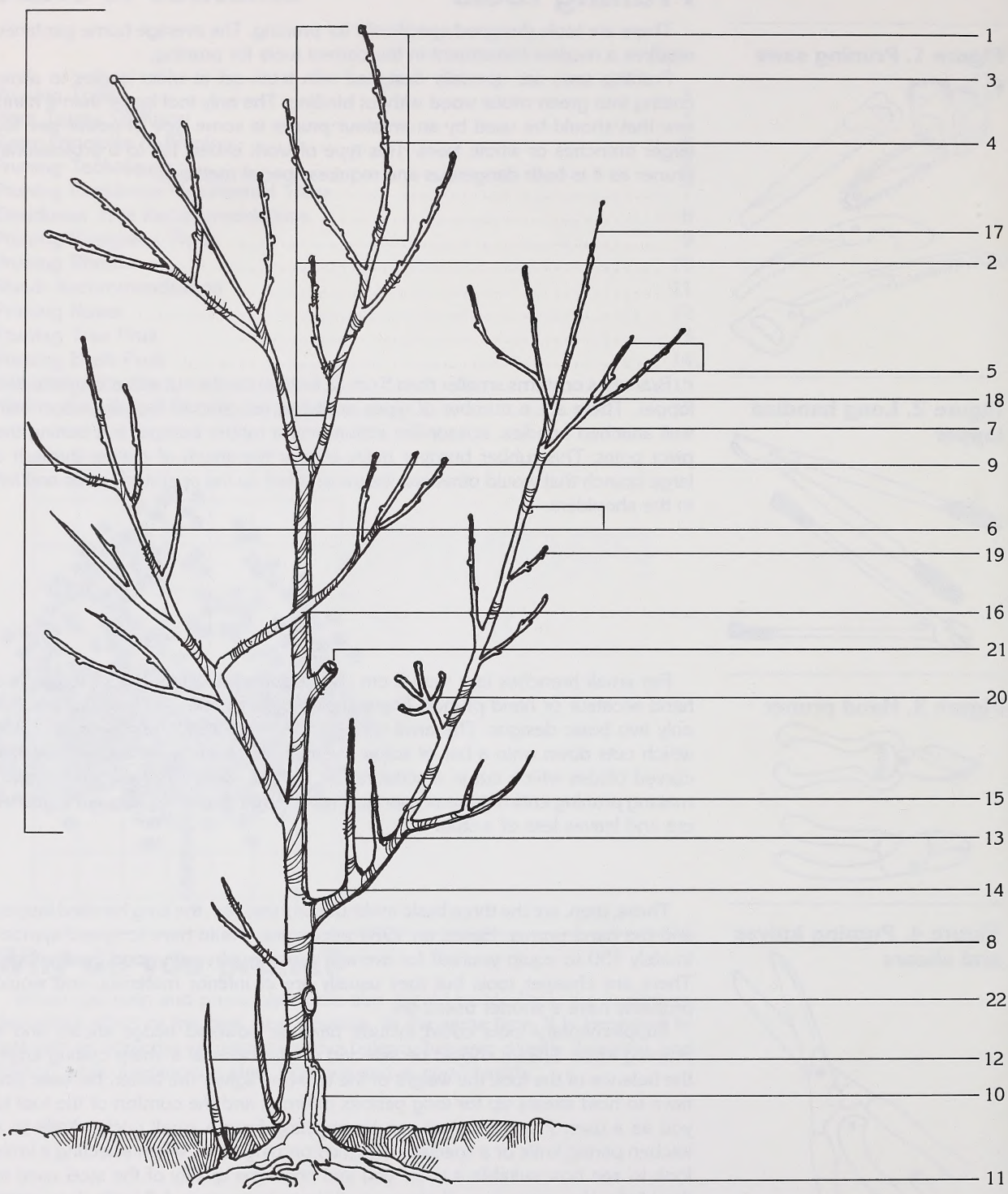


Figure 5. The numbered parts are described on the opposite page.

Plant terms to know

There is a body of knowledge built around most living things with a set of terms that describe that knowledge. Pruning is both an art and a science and certain terms need to be learned if pruning is to be done properly.

The illustration of the tree in Figure 5 uses the terms you should become familiar with. The parts of the tree are marked by numbers and these are described below.

1. **Terminal Growth** is the uppermost, usually central, growth on a stem. If this terminal growth is removed (by accident or by pruning) then the dominance this growth has over the remaining stem is broken, and another bud or buds will develop to take its place. This results in unchecked, wild growth in the remaining part of the stem or branch.
2. The **leader** is the central, vertical dominant stem of a tree or shrub. If the leader is cut or broken by accident, then the whole tree will display an unchecked growth until another stem or stems take over as a new leader.
3. **Terminal buds** are those buds that grow at the end of a stem and produce the terminal growth.
4. **Lateral buds** are those buds that grow from the sides of a stem and from which **lateral branches** develop.
5. **Scaffold branches** are the main branches of the tree.
6. **Secondary branches** are branches that grow from the main scaffold branches.
7. The **trunk** or main branch is the original shoot from which all branches arise. Sometimes it is referred to as the central leader.
8. The **crown** is the top growth of the plant including all scaffold, secondaries and lateral growth arising from the trunk.
9. The **bud-union** or graft is the place where a portion of a branch (scion) of one variety has been joined to the root (stock) of another, to form one plant. Many fruit trees are grafted.
10. **Roots** are the underground parts of the plant that serve to anchor the tree, and take up moisture and nutrients required for the plant's survival.
11. **Suckers** are shoots arising from the root system below or just at ground level. This term usually refers to unwanted growth from below the graft.
12. **Watersprouts** are vigorous vertical shoots that usually arise on the top surface of main or secondary branches. These sprouts are usually caused by severe damage or heavy pruning of the top growth of a tree.
13. A **strong crotch** is one that is U-shaped and where the branch is attached to the trunk with a wide angle.
14. A **weak crotch** is one that is V-shaped and where the branch is attached to the trunk with a narrow angle. These types of crotches are prone to wind damage.
15. A branch that grows toward the centre part of a tree or shrub sooner or later **crosses** another growing outwards. Damage to bark can result from the two branches rubbing together; this usually calls for the removal of the inward growing branch.
16. **New wood** is a term used for growth put on during the current season.
17. Wood older than one season is referred to as **old wood**.
18. **Spurs** are structures that bear the flowers and fruit. Apple spurs are short, stubby and thick whereas European plum spurs may be very long and thin.
19. As a spur grows it may develop side spurs and become a **branched spur**.
20. When pruning never leave a **stub** as this could be a site for infection and may never heal over.
21. **Properly pruned** branches leave no stub and quickly heal over.
- 22.

Basic principles of pruning

Each type of tree or shrub requires a slightly different pruning method and the time of year pruning can be done successfully varies with the species. The basic principles of pruning are few and easy to learn. But the student as well as the master pruner must keep in mind the slight differences between plant materials **before** making a pruning cut.

1. Visualize the shape of the plant at maturity. To do this, you must first be familiar with the natural growth habit of the plant in question.
2. Remove dead, damaged and diseased wood.
3. Select the main scaffold branches (if a tree) or the main stems you want to keep (if a bush) and remove all of the others. This is an application of the "work from large to small rule" which is basic to pruning: cut from the largest branch or stem to the smallest.
4. Do corrective pruning by removing weak crotches, crossed branches, suckers and watersprouts.
5. Thin out the crown to well spaced, strong branches or stems, secondaries and laterals. This promotes a healthier plant by admitting more air and sunlight into the centre of the crown.
6. Treat all wounds bigger than 2 cm ($\frac{3}{4}$ inch) with tree emulsion or shellac. (Use only products specifically formulated for trees as other products may have ingredients harmful to the tree).
7. Remember that too much of anything is not always best; this is particularly true of pruning. You can always prune again next year.

Pruning techniques

There are basically four ways to prune: pinching, thinning, heading back and shearing.

Pinching is the removal of stem tips. This method controls terminal growth and allows laterals to grow faster.

Thinning is the practice of removing whole branches to open out the crown. This practice is especially useful in fruit trees as it allows more fruit to be set on the inside of the tree.

Heading back is commonly practised on flowering shrubs to encourage thicker growth and more flower buds setting as a result. Removing the terminal growth and some of the laterals helps to create a more compact, strongly branched tree or shrub.

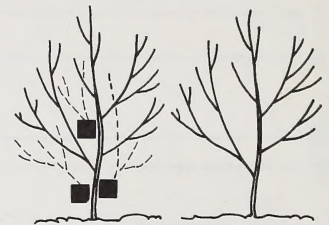
Shearing is practised on hedges and to shape specimen trees. It involves cutting back evenly all exposed areas of a shrub or tree to gain the desired effect. Topiary is the practice of shearing trees to direct their growth in an artistic way.

All four pruning techniques are used when pruning woody plant material.

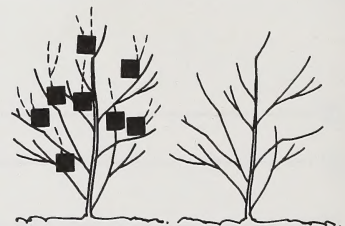
Figure 6



Pinching



Thinning



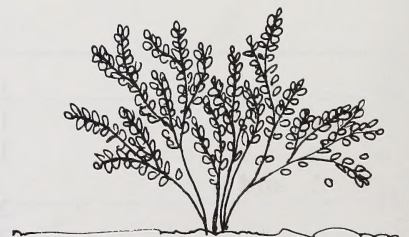
Heading back



Shearing

Topiary

Repeated heading back
with no thinning



Continued thinning
with no heading back

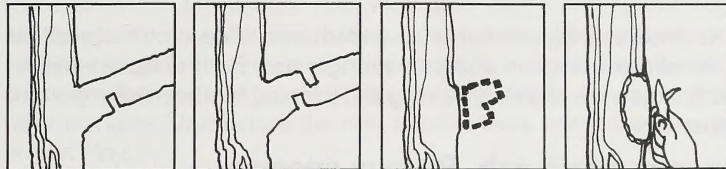
Pruning deciduous ornamental trees

Prune trees from an early stage in their growth as it is at this time that a good basic form can be created. Early light pruning is inexpensive and results in a stronger healthier tree. The time of year to prune is related to the species being pruned and its intended use in the landscape.

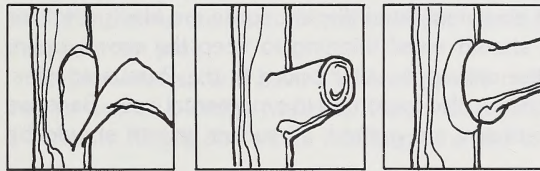
Trees grown mainly for their foliage should be pruned in late March to mid-April. However, birch and maple trees should not be pruned this early. These two species have a tremendous sap flow until their first leaves have fully opened. Birch and maple should be pruned from mid-June to early July. Generally, ornamental trees are planted where their mature size can be accommodated. If this has been done, only minimal, corrective type pruning needs to be applied to the tree as it grows.

Sometimes large limbs are damaged or grow in a direction necessitating their removal. A four-step cutting procedure should be followed to remove large heavy limbs. The following illustration shows this procedure.

Figure 7. A. Correct way to remove a branch in four steps



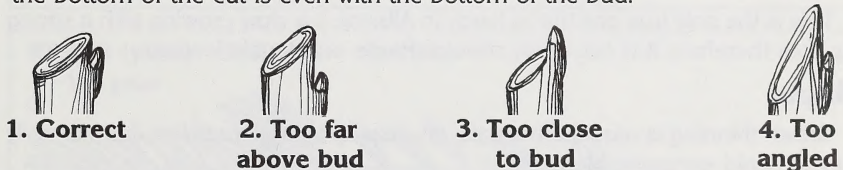
B. Wrong way to remove a branch



Finish all large cuts by paring the cut edge smooth and covering the exposed surface with tree dressing.

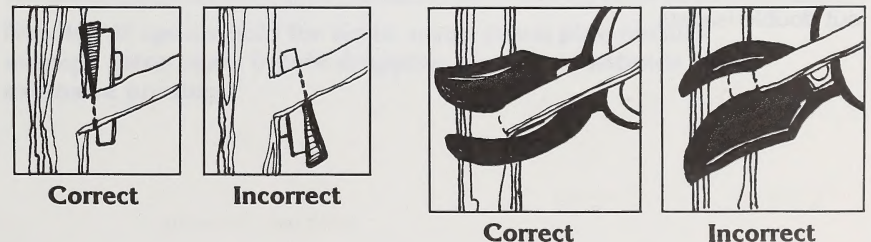
The angle of the pruning cut is also important. Always cut back to a bud that faces the outside of the tree. This way you reduce the possibility of crossing branches and too thick a crown. Determine the correct angle by placing the pruning tool so that the top of the cut is slightly above the top of the bud and the bottom of the cut is even with the bottom of the bud.

Figure 8 - How to cut larger branches



Remember to cut cleanly and leave no stub. The correct positioning of the pruning tool is important when doing this.

Figure 9. - Removing smaller branches. Cut cleanly and leave no stub. The correct positioning of the pruning tool is important when doing this.



A form of pruning that is not recommended and that results in very unsightly and weakened growth is **pollarding**. This kind of pruning becomes necessary when trees are planted in areas where there is not room for them to fully develop. It is also practised in areas where trees might interfere with power lines and pose a hazard. As this type of pruning has to be done every couple of years it is usually very expensive. The best way to reduce pruning maintenance costs is to plant trees that do not grow as high as the power lines.

Deciduous tree recommendations

Poplars, willows

These large, fast growing trees should be planted in areas that allow adequate space for growth. Give willows grown for their colorful bark a heavy pruning as new wood has the most color. Griffin poplar should not be pruned except, as for the other poplars, for corrective purposes.

Ash, elm

Both ash and elm are widely planted as boulevard trees. Wider crotched scaffold branches on the elm will result in a slightly stronger tree. Both of these varieties are slow growing large trees and early training and thinning are the most important pruning requirements.

Crabapple, mountain ash, Prunus species

All these are grown for their abundant floral display; some are also grown for their colorful foliage. Pruning should entail thinning to keep the crown open: before bloom in the case of the crabapple, after boom in the Prunus species. Directing strong scaffold branches is also important in ornamental trees. Because crabapples and Shubert chokecherry are grafted, all sucker growth should be removed annually.

Birch

Birch require very little pruning. Do not allow weeping birch to form a low fork (1 to 2m from the ground) as this will become a split crotch. The tree will naturally divide again at about 3 to 4m which should be allowed. Remember to prune only in late June or early July to avoid excessive bleeding.

Bur oak

This is the only true oak that is hardy in Alberta. It is slow growing with a strong tap root therefore, it is not easily moved. Prune out double leaders.

Maple

Crown thinning is required annually on maples but wait until late June or early July to avoid excessive bleeding.

Larch

This is the only deciduous-coniferous tree growing naturally in Alberta. Prune out double leaders.

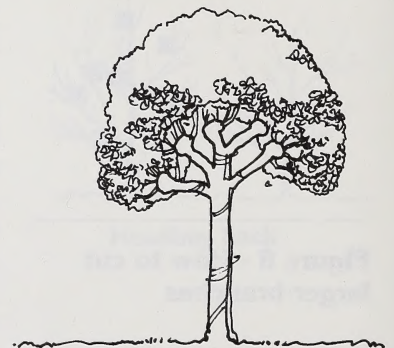
Figure 10. Natural growth compared to growth of a pollarded tree



Natural Growth



Pollarded



Resulting unnatural weakened regrowth

Pruning evergreen trees

The main evergreen trees in Alberta are spruce and pine. Evergreens grown as specimen trees should not require anything except corrective pruning, i.e., cutting out dead, damaged, or diseased branches. If the leader of an evergreen tree is either cut or accidentally broken, immediately tie up one of the top lateral branches to form a new leader. If this is not done there will be two or more terminal growths competing for dominance. The resulting double or triple leader will have a very weak crotch that is susceptible to wind damage.

Figure 11. Leader damage



Top is broken



A lateral branch is tied up to act as a new leader.



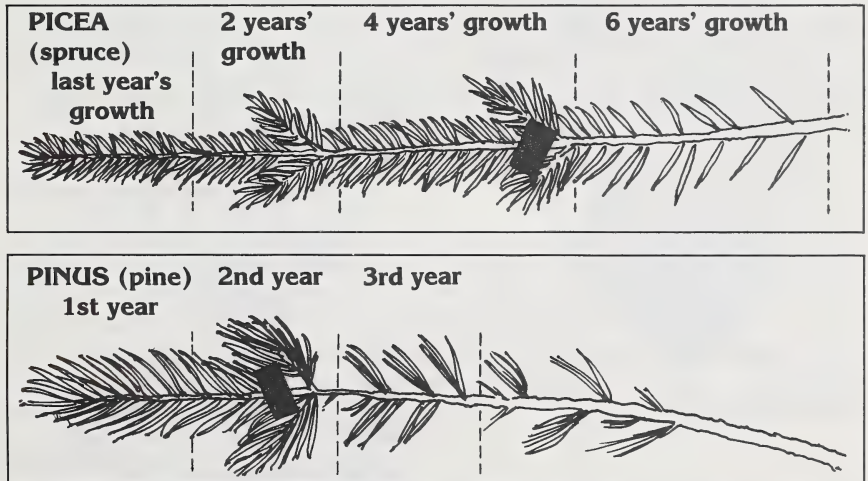
New leader is established, ties are removed

Pruning pine and spruce should be limited to partially removing the new growth (candles) at the terminal of each branch or twig. Pinching back up to one half of this growth on pines and cutting spruce back with hedge shears will tend to contain the growth in the current year and if carried out each year, will result in a denser, bushier looking tree. This pruning should be done after the candles have elongated but before the new needles have opened out, usually about the end of May.

If you cut back into old wood that has no needles on it then that branch will probably die. As the illustration shows, you can cut back further into spruce trees than you can pine.

As pine and spruce have a natural needle cast they are not the best type of tree to use as a hedge material. They will tend to get very thin if maintained at a constant height and width, resulting in a very unsightly hedge.

Figure 12. New growth on spruce and pine



Needles of spruce hold for six to seven years; pine needles average three years before dropping. Spruce withstands more extensive pruning.

Pruning shrubs

Shrubs are grown for the beauty of their foliage, stem color or bloom, or for their screening effect as a hedge. Sometimes these purposes are combined, as in a hedge of lilac or red osier dogwood. There are many different kinds of shrubs and many different ways to prune them but some general rules of thumb can be applied (with exceptions) to shrubs.

1. Shrubs that bloom before June 20 should be pruned immediately after the bloom period.
2. Shrubs that bloom after June 20 and are grown for foliage or stem color should be pruned in the dormant season or just before growth appears in the spring.

There is a commonly held, but quite incorrect idea, that all shrubs should be pruned, and pruned hard, each spring. This may take the form of shearing the shrub into a neat ball or severely cutting back branches to keep the shrub within bounds. Both techniques result in a misshapen ugly specimen with few or no flowers.

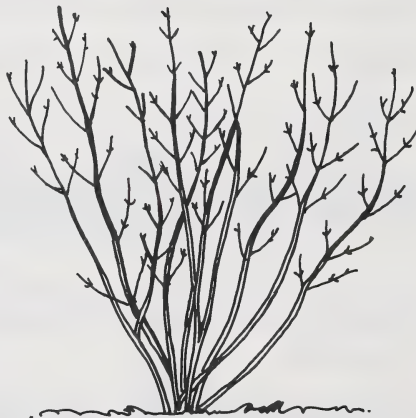
It is probably preferable to leave the shrub alone if in doubt as to when to prune. Most shrubs have a naturally graceful growth habit and only require pruning every other year. Some shrubs only require a low maintenance pruning schedule; one that removes three to four of the old stems and allows three to four new ones to grow each year. Shrubs should have corrective pruning done each year.

An understanding of the basic principles behind pruning and knowledge of the growth habit and the method of flowering of the plant concerned are important, particularly the age of the wood on which the flowers are borne.

Figure 13.



Unpruned shrub



Shrub pruned to remove about one-third of the old wood and most of the crossing branches. Most flowering buds on new wood remain.



Sheared shrub still has too many old and crossing branches, while many important flowering buds have been cut off. Not recommended.

Shrub recommendations

Early flowering shrubs (bloom prior to June 20)

These shrubs bloom from buds set on last year's growth and your aim should be to promote more flower buds for the next year. To accomplish this you must encourage strong new growth that will set buds during the current growing season. Prune immediately after bloom has finished. Prune by thinning out weak stems and by heading back selected stems to promote strong lateral shoot development. Unpruned shrubs of this type usually become twiggy and ungainly with few flowers each season. Early flowering examples are: some mock orange varieties (*Philadelphus*), lilacs (*Syringa*), some spirea varieties (*Spirea*), and flowering plums (*Prunus*).

Late flowering shrubs (bloom after June 20)

These shrubs bloom mainly on wood grown during the current year, but some do bloom from buds set the previous year. If the bloom period starts near the end of June (in the case of some potentillas) the first early flowers could be from buds set on one-year-old wood. The remainder of the summer bloom would be on current growth. By pruning you want to create a large number of strong, current year twigs and thereby a large number of flower buds. Potentillas require only minimal pruning as they retain their shape naturally; only some annual thinning may be required. Spireas, on the other hand, usually require severe cutting back of all stems to only two to four buds from the base to encourage new growth for late summer bloom. Lilacs and honeysuckles require regular pruning, in the case of lilacs to keep them from becoming thick and overgrown,

Foliage and stem color shrubs

The desired effect you want to achieve is that of either a large mass of colored (or variegated) foliage, or the production of many new woody stems for best winter color. Both entail pruning hard each spring to force a great deal of new twiggy growth. To be successful, you must also feed and water these shrubs well to keep them healthy and vigorous.

Some people prefer to cut almost to the ground each year; others will allow a basal framework to develop and cut back to that frame each spring. Both methods will accomplish the same objective.

Evergreen shrubs

Most evergreens require minimal, if any, pruning. They should, if space allows, be allowed to develop naturally. The occasional removal of a wayward shoot that detracts from the overall symmetry is usually all that is required. Juniper responds well to having vigorous shoots trimmed back to a side branch. Cedars respond well to shearing to help keep wayward shoots in check and maintain the overall shape of the plant. Mugo pine can be kept dense by pinching new candles in half each spring.

Hedges

Hedges require early pruning to encourage dense basal growth and further pruning to keep the basal growth well leafed out. The top of a hedge should be narrower than the base so that it will not cast shade on the lower branches. If the hedge base is shaded it becomes leggy and open and will not serve the purpose of the hedge.

Figure 14. Hedge cutting



Pruning roses

Although they could take a full book themselves, this will be a short note on roses. Most people have a rose or two in the home garden; whether these are newly purchased tea roses or are hardy shrub roses will make no difference to these instructions.

In the wild, roses produce strong new shoots from near the base of the plant each season. In the following years the secondary, or lateral growth from these shoots becomes progressively weaker. Food taken in by the roots is directed to new growth and eventually the original shoots are starved out – a natural but slow method of pruning. The purpose of pruning roses then is to short-circuit nature by cutting away the old shoots and to encourage the production of vigorous disease-free new growth and a large number of flowers for the rose gardener.

Rules of thumb for pruning roses

1. Cut with sharp tools above a new bud at the correct angle.
2. Cut back into healthy wood. If the pith is brown or discolored cut the shoot back until healthy white pith is reached or to a strong vigorous bud.
3. Cut to an outward pointing bud to encourage an open centre habit.
4. Only allow one shoot to grow from a pruning cut.
5. Completely cut out any diseased, dead or damaged growth along with any weak, spindly growth.
6. Keep all branches well spaced to allow free air-flow through the plant and to allow light to reach all leaves. This lessens the likelihood of such diseases as black spot and rose mildew which thrive under stagnant air conditions.
7. Remove prunings from the area to reduce the possibility of spreading disease. Place prunings in the garbage or, if allowed, burn them.

More detailed pruning methods should be obtained by reading other manuals that cover all aspects of rose growing.



Figure 15. Roses produce flower buds only on wood produced in the current season. Old wood can be severely pruned as shown.

Pruning fruit trees

There are three principal methods of training fruit trees:

1. **Central leader system:** The central leader is allowed to grow unchecked. The resulting tree is usually too large to pick fruit from without using a ladder, thereby adding a double danger: falling off the ladder and damaging either yourself, the tree, or both.
2. **Modified leader system:** The young tree is allowed to grow naturally but the main scaffold branches are selected at well spaced intervals. Once five to seven scaffolds are selected, the leader is cut out (modified) and the resulting tree is shorter in overall height and usually wider in spread. This is the preferred method for training fruit trees in Alberta.
3. **Open centre system:** This is a more severe modification of the central leader (usually cut between 0.75 to 1 metre from base) resulting in a low headed tree that has a number of scaffold branches close to the base of the tree; this is inherently a weaker structure. This method is not recommended for prairie conditions.

Each species of fruit tree is pruned in a slightly different manner because of the placement of fruit buds (either spurs, shoots or both) and general differences in growth habit.

Apples

Fruit is borne at the ends of spurs that form on branches two years old or older. Some fruit is also borne on new one-year-old wood. As pruning is done to encourage fruit spur development, thinning out entire branches (rather than heading back) is the most desirable practice. Spurs may live for eight to ten years.

Plums

Fruit is borne on lateral spurs which may be one centimetre (Japanese types) to one metre long (European types). The bearing life of the spurs is from six to eight years. Pruning should be limited to creating a strong main frame on the tree with little or no heading back.

Apricot

Fruit is borne on one-year-old shoots and on short spurs which carry most of the crop. The spurs only live two to three years, therefore, pruning should be heavy enough to continue new growth and to develop new spurs to keep the tree bearing. The modified leader system is recommended.

Pears

Fruit is set on spurs that have a long life. Pruning is almost identical to that for apple trees. More scaffolds can be left on a modified leader frame.

Figure 16. Central leader system



Figure 17. Modified leader system



Figure 18. Open centre system



Pruning bush fruit

Again, knowing fruiting and growth habits is all important when pruning bush fruits.

Raspberries

There are four types of raspberries grown in Alberta: red and yellow, black and purple. Pruning procedures for red and yellow raspberries differ from those for black and purple raspberries.

Red and yellow raspberries grow canes in their first season with no fruit. In the second season the canes grow lateral shoots which bear fruit. At the end of the second season the fruit bearing canes die. Pruning entails cutting these dead canes in late summer or early spring and thinning weak new canes to promote only strong canes in each clump.

Black and purple raspberries grow new canes with laterals in their first season. In the second season more laterals are produced and all laterals will flower and bear fruit. The canes die after bearing fruit. Pruning should entail cutting one year old canes down to about 0.5 to 0.75 metres, which will encourage more lateral development in the second season, which in turn will result in a heavier crop. The pruning out of two year old spent canes and thinning out the weak new canes should be practised each season.

Currants

Red, white and black currants are grown in Alberta. Red and white currants bear fruit on spurs of two and three-year-old canes. Older canes bear inferior fruit, so pruning is aimed at keeping old wood thinned out and new wood growing in. The well pruned red or white currant bush will have three stems each of three, two and one-year-old wood. Black currants, on the other hand, bear their fruit on last season's growth. It is, therefore, necessary to keep new growth coming in and old growth almost totally cut back. Ideally black currants should have 9 canes with three to four two-year-old canes and five to six canes from the previous year's growth.

Gooseberries

Gooseberries belong to the same genus as currants (*Ribes*) but are pruned to have nine canes with three each of one, two and three-year-old canes. Fruit is borne along the sides of one-year-old shoots and on spurs on two and three-year-old wood.

Bush cherries (nanking, korean and mongolian)

Bush cherries are treated the same as gooseberries with nine stems; three each of one, two and three-year-old wood. Pruning should be aimed at keeping the bushes open to allow fruit to set within the centre of the bush.

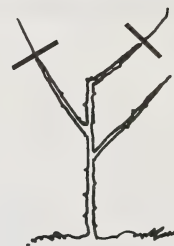
Saskatoons

Fruit is borne on one-year-old and older wood with the youngest branches bearing the largest, sweetest fruit. Prune to control height (2 to 2.5m); thin the centre to keep open and cut off low branches.

Figure 14. Pruning currant and gooseberry



One year branch



Two year branch



Three year branch

Conclusion

As shown, pruning is a simple system of manipulating mother nature to work for you by creating more bountiful harvests or by creating beauty and form where there had been before only unchecked randomness. Hopefully, this manual will assist you in understanding the science and art of pruning.

Further sources of pruning information

1. Sunset Pruning Handbook by the Editors of Sunset Books. Lane Publishing Co. This book features an alphabetical listing of plants and describes not only the plant but how to properly prune it.
2. Pruning Trees, Shrubs and Vines by Garden Way Publishing. Bulletin No. A-54. A very good small booklet for beginners.
3. The Simon & Schuster Step-By-Step Encyclopedia of Practical Gardening: Pruning. Published in co-operation with the Royal Horticultural Society. Editor-in-chief Christopher Brickell. This book is for the more advanced pruner who is familiar with botanical nomenclature.

Most books on basic gardening have sections on pruning and would be too numerous to mention.

Conclusion

Final head

The first part of the paper discusses the importance of the final head in the context of the overall structure of the document. It highlights the role of the final head in providing a clear and concise summary of the main findings and conclusions of the study.

Further sources of funding information

The following section provides a detailed overview of the various funding sources that supported the research. It includes information on the names of the funding agencies, the amounts of funding received, and the specific terms and conditions of each grant.

Additional funding was provided by the National Science Foundation, the Department of Education, and several private foundations. The total amount of funding received for this project was \$1,200,000 over a three-year period.

Conclusions

The research conducted over the past few years has yielded significant insights into the role of the final head in the context of the overall structure of the document. The findings suggest that the final head plays a crucial role in providing a clear and concise summary of the main findings and conclusions of the study.

References

The following references were consulted during the course of this research. They provide a comprehensive overview of the current state of knowledge in this field and serve as a valuable resource for anyone interested in this topic.

Appendix A: Final head and overall structure

This appendix provides a detailed overview of the final head and overall structure of the document. It includes a diagram illustrating the relationship between the final head and the overall structure of the document.

Appendix B: Funding sources

This appendix provides a detailed overview of the various funding sources that supported the research. It includes information on the names of the funding agencies, the amounts of funding received, and the specific terms and conditions of each grant.

Figure 1: Final head and overall structure



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