FT Walton Beach Bonsai Society

How Trees Adapt & Respond: The Growth Cycle Vie Hormones

A Review of the online literature

By
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Purpose:

To introduce new members of our Bonsai club to trees and the principles of how trees adapt to changes to their external environment and make appropriate responses to those events. This information has been narrowed down to the main items of interest to the Bonsai community.

This article mainly deals with woody trees that grow from their apex, (tips). However some of the techniques and information must be modified for the branch development on Pines.

Introduction: The evolution of knowledge involving the growth mechanisms that regulate the growth of trees.

The tree is a system and one needs to understand how the tree system operates and how it responds to events in its environment. It is responsive to and dependent upon its external environment, hence it is a subsystem of the earth's environment which includes man and his actions. The principles of the "growth control regulators" in the horticultural literature need to be incorporated into our Bonsai training and writing as a supplement to our current educational approach.

The early Bonsai Masters grew the art of Bonsai through thousands of years of observations, trials and errors. Since they had no knowledge of what went on inside the tree, they concentrated their focus on observing the exterior of the tree. This approach required them to learn hundreds of different scenarios by rote. Each scenario was learn as a separate event, prune a limb, prune a root, pinch a bud etc. Then there was a different out come for different trees and a different scenario for each different season of the year, hence more to learn and remember. This approach requires years of study before the student of Bonsai becomes comfortable with any specific scenario they might encounter. Each new Master passed his knowledge down just as he had learned it from his Master. This approach to teaching or learning Bonsai has come down to us almost intact. Thus we approach Bonsai with very few guiding principles and models by which to understand and predict the outcome of any particular action we may wish to perform on a tree. Our younger members may therefore flounder for years before they feel really comfortable making decisions for themselves. Many may drop out in frustration.

Our counter parts in the fields of horticulture, forestry, botany, biology etc. have made slow but definite progress in beginning to understand the principles of how a tree grows, responds to events in nature, and die. They have accomplished this by changing their focus from the external of the tree to the internal of the tree. In the 1930s, (Ref. 20), the hormone Auxin was identified as a growth hormone and since it appeared to be the only one, all growth was accredited to it. It took another 10 years, the 1940s, until the hormone Cytokinin was identified, (Ref. 21), since then four more growth hormones have been added to the list. If you are interested in learning more about hormones, a chart appears in the supplemental readings at the end of this article that describes the different hormones, (Ref: 32)

It was not until the 1970s, (Ref. 14), that the research literature began to have numerous articles about hormone controlled growth principles. They now acknowledge that it is the internal mixtures hormones that occur within the tree that control its growth and its' response to external events.

It is through the understanding and application of the trees' internal processes as an addition to the existing Bonsai teaching approach that we may move the teaching of Bonsai forward into the 21st century. The addition of such models and principals in our teaching and literature may empower our new members to progress in the art much faster and with greater ease and confidence. Such ease, confidence and speed of learning may well reinforce the early efforts of these novices thus keeping their enthusiasm strong enough to for them to continue to grow and become long term contributors to the art of Bonsai.

Quotes:

"Because the tree as a whole is too complex to comprehend at a functional level, we must use simplified models to understand the tree reactions to change*."*- Dr. Kim D. Coder, Professor Silvics/Ecology – May 15, 1997 (Ref. 3)

"When you know basic plant physiology, you can answer most of your own questions about pruning and growth." "Understanding the physiology of woody plants is in fact a very powerful tool for the artist's toolbox. When you understand how trees grow and respond, you are no longer limited to cookbook formulas for pruning, potting, learning by rote etc. – Brent Walston, proprietor of Evergreen Gardens and prolific Bonsai writer – 02/01/2008 (Ref. 18)

At times you will find information repeated, repetition is still one the strongest tools used in education and training. The following information should be approached as a reference. You should not attempt to cover or understand it all in one sitting; some sections may require that you read them several times depending on your current knowledge of the subject.

Tree 101: Understanding the jargon.

In any course of study, it is necessary to understand the language used in that field; called the jargon. It is also necessary to understand the definition of various operational terms. You will hear these items discussed in your club and encounter them in the literature you read. Below, you will go through some 1) definitions and 2) descriptions of how various functions operate within the tree and later 3) examples of how to use the information presented here in your Bonsai work. Early in the article you may begin to wonder how any of this relates to learning how to care for and develop a Bonsai; that will become obvious when you get into the examples. There is a lot of information to digest; hopefully you will view the article as reference that may be reviewed as many times as needed.

Section 1: Tree 101- definitions:

In this section you will cover some basic definitions that will be used throughout this article and other Bonsai writings. No need to try and memorize the definitions as the items will also be defined in the material that follows. This material assumes that as a new Bonsai club member you know next to nothing about the growth of trees. No insult intended.

Trunks, Limb, Branches and Stems: ***Limbs are attached to the trees' trunk; branches are attached to the limbs and stems are attached to branches.***

Energy: **A term associated with growth.**

Node: **A node is where buds appear or leaves grow.**

Internode*: An internode is the bare section of a stem between the leaf sprouts or buds on a stem. Their length varies greatly with the amount of nutrients and water they are supplied from the roots*

Buds: ***The bud at the very end of a limb is called a terminal or apical bud (Fig. 1). The others buds on the limb are referred to as lateral buds (Fig. 1),***

adventurous buds and may be scattered throughout the limb' often not visible. The stem in between lateral buds is called an internode.

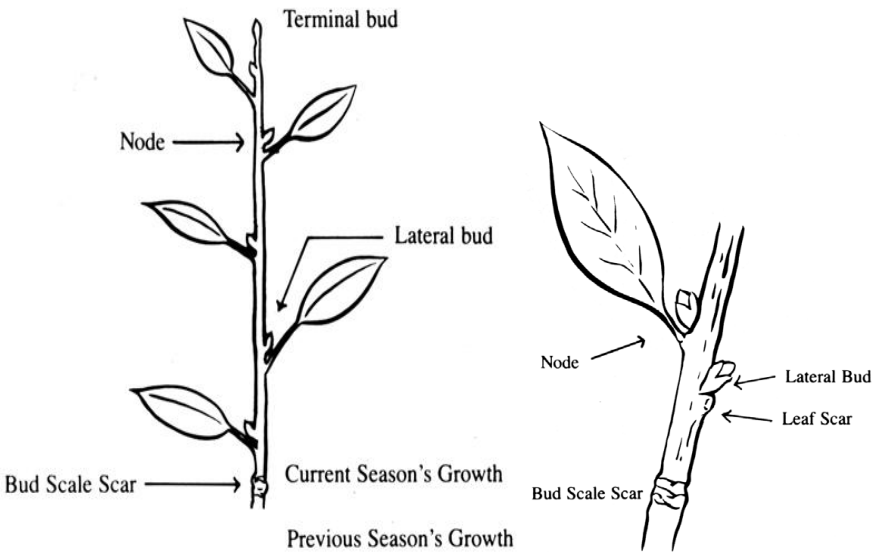


Fig. 1, (Ref. 35) **Courtesy of Gary L. Wade, Ph.D. Professor and Extension Horticulturist**
Department of Horticulture
The University of Georgia

Bud Break: When a bud opens it is said to break.

Back-Budding: **back-budding occurs when new buds appear on "old" wood. Many trees will back-bud as the result of the tips of a branch being pruned or after a trunk chop.**

Apical dominance: Refers to the fact that the apical bud generates a hormone that keeps the buds on the limb behind it from breaking. This makes the apical bud the dominant growth point on the limb.

Latent Buds: Buds that are on the bear stem between leaf stems; often invisible.

Meristem: On the very tip of a bud or a root there is a section called a meristem. The cambium is also a meristem. The meristem is made up of millions of **undifferentiated living cells. They are equivalent to stem cells in humans.**

Cambium: A small amount of green material just under the bark that is made up of millions of undifferentiated cells and wraps around the entire tree.

Pathways: ***The pathways inside the cambium ring are called the Xylem*** **(Pronounced zī-lem)*. The pathways outside of the cambium are called the phloem (Pronounced* flō-em)*. These two pathways conduct fluids up and down the tree.***

Flush*: To flush means a strong burst of growth.*

***R*amification:** ***R*amification is a technique whereby numerous small twig-like branches are developed so that they are in proportion with the scale of the Bonsai tree.**

Pads: A large area of ramified branches may take on the look of a pad of growth. Pads are used a lot in the development of pine Bonsai.

Transpiration: The process by which water is drawn from the roots by relative humidity, up the tree and out of the leaves into the atmosphere.

Differentiation: ***The process by which a certain mixture of hormones causes undifferentiated cells to form specific material that the tree needs. These could be stems, buds, flowers, seeds etc.***

Movement: ***The curves in a trunk or limb are referred to as movement.***

Taper: ***When a trunk decreases in diameter as in goes up the tree, it is referred to as taper. Both taper and movement are highly prized in Bonsai.***

Up-pot: ***To transfer a tree from a smaller pot to a larger pot, usually without pruning its roots.***

Tree in training: ***You will <u>almost never</u> find a tree ready to go right into a shallow Bonsai pot. It is normally be necessary to grow your tree in the ground and/or in an over-size pot or container for a number of years while you work on developing it. Such a tree is said to be in training. An over-size pot is said to be a training pot.***

Food*: Fertilizer is not food. Fertilizer is comprised of the nutrients and minerals that the leaves of the tree will convert into sugars and carbohydrates that the tree will use as food. When you see the term food in the literature or head it mentioned in your club meetings, it is the sugars and carbohydrates that are being referred to; not fertilizer. Warning the term is often misused.*

Escape: **Escape means to let the roots grow out of the drain holes of a pot and go into the ground.**

High energy limb: **A limb that demonstrates strong growth.**

Reverse taper: ***A portion of the trunk has a larger diameter than the section below it. That condition is considered a negative feature.***

Root Rot: **a condition that occurs usually when trees are over-watered. The roots stay too wet resulting in a decaying root system. The roots are typically brown or black in this condition, and should be removed to protect the health of the tree. Symptoms are usually yellowing foliage and poor growth. Unfortunately, when symptoms are visible, severe damage may already have occurred.**

Items of interest on the Tree:

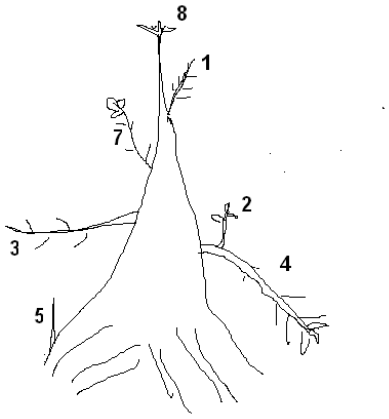


Fig. 2

1. ***A High energy Limb is usually a limb growing very vertical. High energy is another term for very strong growth.***
2. ***Water Sprout is a vertical growing stem from the top of the old section of a branch***
3. ***Low energy limb is usually a limb growing less vertical and weak growth.***
4. ***Lower energy limb is usually a limb bent very low.***
5. ***Sucker from the root is a sprout growing straight up from the roots or lower trunk***
6. ***N/A***

7. ***Limb of moderate energy***
8. ***Apical branch at the apex of the tree, usually the highest energy branch on the tree***

Section 2: The Basic Tree Model (Ref: 3)

In this section you will be introduced to the basic components of the tree. Be sure and concentrate on the discussion of path ways.

Objectives: You should know the function of the three components of the tree. You should be able to identify which pathways feed the tops and which feed the roots and function of the cambium.

Ref. (37)

The Tree is composed of three interactive and interactive components which comprise the tree's three growth zones: They are dependent upon and reactive to each other.

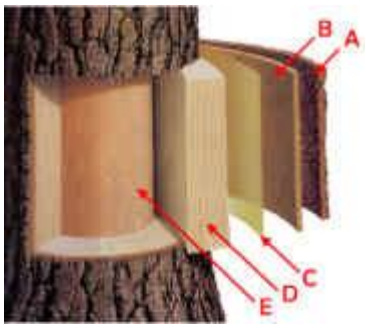
- **Leaves (See Crown above)**
- **Connecting tissue (the cell pathways inside the trunk) (See Trunk above)**
- **Absorbing roots**

These three components interact with each other in such manor that any change in one will cause a change in the other two.

I believe that everyone is generally familiar with leaves and roots. The leaves manufacture food for the tree and roots support the tree as well collect the minerals, nutrients and water that the leaves use in the process of manufacturing food. Because of the importance of pathways, I will spend some time on that subject to be sure that the reader

understands their function. Currently the importance of pathways, their development and maintenance is seldom discussed in our Bonsai literature. Let's look at the inside of the tree. This called the **Anatomy of a Tree**

Fig - A



A

The outer bark is the tree's protection from the outside world. Continually renewed by the phloem from within, it helps keep out moisture in the rain, and prevents the tree from losing moisture when the air is dry. It insulates against cold and heat and wards off insects.

B

The inner bark, or "phloem", is pipeline through which food and hormones are passed to the rest of the tree. It lives for only a short time, then dies and turns to cork to become part of the protective outer bark.

C

The cambium cell layer is the growing part of the trunk. It annually produces new bark and new wood in response to hormones that pass down through the phloem with food from the leaves. These hormones, called "auxins", stimulate growth in cells. Auxins are produced by leaf buds at the ends of branches as soon as they start growing in spring.

D

Sapwood or the xylem is the trees' pipeline for water and minerals moving up to the leaves. Sapwood is new wood. As newer rings of sapwood are laid down, old inner

cells lose their vitality and turn to heartwood.

Heartwood is the central, supporting pillar of the tree. Although dead, it will not decay or lose strength while the outer layers are intact. A composite of hollow, needle like cellulose fibers bound together by a chemical glue called lignin, it is in many ways as strong as steel. A piece 12" long and 1" by 2" in cross section set vertically can support a weight of twenty tons!

E

Ref: 24 Both the write-up and the figure are the Courtesy of the Arbor Day Foundation.

The two pathways are a series of vascular cells in the trunk of the tree that transport water, nutrients, minerals and hormones to the leaves and food and hormones down to the roots. Generally speaking they serve the same purpose as human blood veins and arteries. As the interior pathway cells, (*Xylem),* die they become the dead wood that supports the tree. Almost 95% of tree is comprised of dead tissue leaving only about 5% tissue that living portion of the tree. As the exterior pathway cells, (Phloem), die they become the bark of the tree.

The pathway structure inside the trunk is similar to a divided highway. See Fig. - A. Such a highway has three parts. It has a lane going in one direction, a divider and a lane going in the opposite direction. The cambium is the divider between the two pathways. There is one pathway, inside the cambium, going up the tree, called the xylem, (Pronounced zī-lem), from the roots to the leaves. There is another pathway, outside the cambium, coming down the tree, called the phloem, (Pronounced flō-em), from the leaves to the roots. These two pathways are comprised of vascular cells. Dividing them is the cambium. The cambium is that green stuff just under the bark in between the two pathways. The cambium is comprised of undifferentiated living cells that surround the truck and the branches, (REF: 7 & 20). These cells are capable of becoming anything that the tree may need. Since the cambium wraps around the tree, for our discussion,

it may be considered a circle. The pathway inside of the circle formed by the cambium is called the xylem. The job of the xylem is conduct water, nutrients and minerals from the roots to the leaves, (called the root to shoot connection). The pathway outside of the cambium called the phloem conducts food from the leaves, called the shoot to root connection. It is the job of the cambium to growth new pathway cells for both the xylem and the phloem each year thereby growing the diameter of the trunk, limbs and branches. The cambium will also form a callus and eventually becomes new bark to cover a wound in case of injury to the tree's trunk or branches. It is with the aid of the mixture of the different hormones within the tree that inside part of the cambium can differentiates new cells into what becomes new pathway material.

Ref: 24 Courtesy of the Arbor Day Foundation.

Above are the xylem pathway rings which can be seen on a trunk or a limb that has been cut into, (Ref: 24). As these pathways of the xylem grow old, they are forced by the pressure of the newly created cells toward the center of the tree where they are compacted overtime to form the dense dark heartwood of the tree. The same action takes place on the outside of the cambium but these new cells become the new phloem rings. As they become worn out over time they die and form the bark of the tree.

It is important you understand the action of the pathways because they comprise one of the two major "growth control regulators" that will be discussed in detail.

By understanding how each of the three main components of the tree, leaves, pathways and roots interact with each other, the out come of any Bonsai activities can be planned and predicted ahead of the event. No single one of the trees' three components acts in isolation; any change in one component evokes a change in the other two. Thus the trees' hormones are constantly rebalancing themselves to respond to the changes to it's' environment.

Those who practice the art of Bonsai have in the past viewed the results of their actions such as top pruning, root pruning etc., after the event. It is more desirable to be able to predict these results before such activities are performed. To do so requires a basic knowledge of the main "growth control regulators" within the tree.

That's why you are reading this article; you want to get ahead of the curve by managing, planning and anticipating the results of your actions.

Section 3: The Tree as a System: (Ref: 18)

In this section you should gain an overview of the internal elements of the tree and how they strive to keep the tree balanced as a system.

Objective: Understand the mechanism the enables the tree to reacts to external events. Understand how the tree interfaces to the earth and its' environment.

Unlike humans, the tree is immobile and also lacks the dexterity of humans. Therefore it must meet every challenge in the environment with only its internal chemistry to rely on. Down through the centuries the tree' genetics have developed programmed responses to each event that may impact the tree. It does this primarily through the use of hormones.

The tree is a composite of hormones, enzymes, peptide, and proteins etc. As a system, it strives to maintain a balance of this chemistry. Any

change in the external environment will upset the balance and cause an internal change in the mixture of the tree's chemistry. Its' chemistry will then react and strive to respond to the external event; this will often cause an external event to occur on the outside of the tree; a bud will break, a limb will increase in diameter, a root will grow etc..

The Tree as a Sub- System:

The tree may also be viewed as a sub-system in that it interfaces to the upper environment and the lower environment of the earth. The leaves are the primary interface to the upper environment. The upper environment, (sun, heat, humidity & wind), provides sun light, carbon dioxide, (CO2), heat, oxygen and some moisture. The trees' leaves bring in CO2 through the stomata, (small holes in the leaves). The leaves with the aid of the CO2, sun light, nutrients and water produces food (carbohydrates/sugar) and in the process releases oxygen and water through the stomata into the upper environment. Movement of water, minerals and nutrients from the roots to the leaves is performed by a mechanism called transpiration.

The roots are the trees' primary interface to the lower environment, (ground). They provide an anchor for the tree. The roots also take in oxygen, water, nutrients and minerals from the soil. The roots' collect these items and sends them along with various hormones on their way up the xylem pathways to the leaves. The roots, in turn, receives hormones and the food manufactured by the leaves vie the phloem pathways. The roots store the food as a reserve for future use by the tree. The roots also use some of the food to grow new extensions of the root system. This expansion of the root system is necessary in order to bring in the new nutrients and water that is required by the trees' new growth. The growth of the roots is controlled by the hormone Auxin, which is sent down the phloem along with food from the leaves.

Section 4: The Two Major "Growth Regulator Fields" (Ref. 3)

In this section you are introduced to the two major growth regulating components and the two of the growth hormones that control the trees' growth.

Objectives: Be able to identify the two major "Growth Regulators and how they function. Be able to identify the two major growth hormones

and how they are generated. Be able to identify which parts of the tree are affected by a dominant ratio of any specific hormone. Be able to identify how the temperature through the year affects the strength of the "Growth Control Field".

The "Growth Regulator fields" are responsible for regulating the growth of all the separate parts of the tree as well as the tree as a whole.

The two fields are called:

1) **The "Growth Control Field". Usually, it just referred to as the "control field".**
2) **The "Growth Control Pathways"**

The "Control Field":

Below you are introduced to the balancing action of two of the growth hormones; Auxin and Cytokinin. Upon completion should be able to predict the out- come of pruning the top branches and the results of pruning roots on these hormones. You should also be able to predict the results of changing the balance the between the two hormones.

1) The "control field" is said to serve the tree at the cellular level. That is to say that each leaf, branch and root tends to have its own individual pathway leading down to its individual roots, (Ref. 3). This autonomy becomes more pronounced as the tree grows older. Hence, it may be said that each limb, stem, etc. is autonomous. It does not share its' food or water with any other limbs. It is not usually affected if another branch is pruned or dies. A branch's individual health is dependent upon the health and the strength of its own leaves, pathway and the on the health and growth of its own roots. You will learn how to help care for and develop these pathways and how they perform the work of the "control field".

The "control field" is comprised of three hormones.

1) **Auxin, (Pronounced: o̓x-sən)**
2) **Cytokinin, (Pronounced: sī-tə-kī-nən)**
3) **Abscisic Acid, (Pronounced: ab-si-zik)**

These three hormones are constantly present through out the tree. What is crucial to the "control field" is the ratio of the mixture of the three hormones. Different mixtures of the three hormones produce different results. A bud may break, roots may grow, a branch may die etc. If an individual practicing the art of Bonsai understands the outcome of the different mixtures, he or she can predict the out come of various actions such as pruning, bending a limb, allowing a limb to grow, pinching a bud, etc.. The "control field" varies in strength during deferent times of the year as you can see below.

Annual "control field" Model, Spring through Winter: (Ref. 3)

This information covers the variance of the strength of the "control field" throughout the year. This variance is due to the fact that efficiency of the leaves and roots varies with the temperature throughout the year.

1. **Winter: Very low "control field" strength. This is a dormant period; most of the tree activity is suspended.**
2. **Very early spring: Low "control field" strength. Roots start to grow.**
3. **Spring thru early Summer: High "control field" strength. Strong shoot growth and root growth, also new pathway connections are fashioned, and springwood in the tree is produced as the xylem grows.**
4. **Mid - late summer: Moderate "control field" strength. Due to the effects of heat on the roots and leaves, thus the tree may become semi-dormant.**
5. **Early Fall: intermediate high "control field" strength. Leaves, Stems and roots renew their 2nd growth cycle. This produces one last short flush of growth before late fall and winter.**
6. **Mid to Late Fall: Very low "control field" strength. Only slight growth activity; primarily root growth. The trunk and branches may thicken.**

The Hormones of the "control field":

The major affects of the hormone Auxin are discussed. Auxin performs functions other than the ones describe here. This discussion is limited to the aspects of Auxin that are helpful for the person practicing the art of Bonsai to understand.

Auxin as part of the "Growth Control Field":

Auxin is a hormone produced by any growth activity in the top of the tree. The strongest level of Auxin is produced by the apical buds. Auxins' strength varies in direct ratio to the growth of the buds/limbs/branches and the vertical orientation of these limbs/branches. You will learn more on this later. (Ref: 12, 24)

Auxin like the other hormones serves many different functions. This article will only discuss the ones that are of most importance to the understanding of the person studying Bonsai.

1) **Auxins hormones are involved in plant-cell elongation**
2) **Auxin creates apical dominance by suppressing bud break behind the apical bud**
3) **Auxin stimulates root growth.**
4) **Auxin hides from sun light; it concentrates on the shady side of the tree. (Ref: 15)**

Apical dominance means that the Auxin produced by the buds at the apex, (end of the branches) tries to suppress the growth of any bud break behind it; these other buds are called latent or adventurous buds.

The presents of Auxin causes cells to elongate. It does not cause them to divide but they do grow in length.

Auxin travels down the phloem of the tree to the roots. When the ratio of Auxin becomes higher than that of Cytokinin, it signals the roots to grow.

The flow of Auxin is driven by two systems. One is gravity the other is the proton pumps within the cells, (Ref: 28). The flow of Auxin is strongest when the two systems are working together at their maximum efficiencies. This occurs when a limb is growing absolutely vertical. The less vertical a limb grows the more the effects of gravity are reduced, thereby reducing the flow of Auxin. In the case of limbs bent below 45 degrees the flow of the proton pumps is also some what reduced due to the resistance of pumping up hill to get the Auxin to the main trunk.

Limbs that grow very vertical are referred to as high energy limbs (See #8, 1, 7, 2 and 5 Fig. 3). Note: Though all of these are considered high energy limbs, #7 has lower energy than #1 and both are lower than #8, 2 or 5 because # 7 and 1 are not as vertical. The lower a limb is bent away

from vertical, the weaker it becomes; it is said to be a low energy limb below 45 degrees (See #3 and 4 Fig. 3). Number 5 is called a sucker and #2 is called a water sprout. Both will be discussed later. Understanding the energy level of the various limbs will prove to be very important to your Bonsai work. Fig 3A Shows "water sprouts and "suckers" in red. The branches in Fig. 3A are mainly high energy branches but the less vertical they are the lower their energy. The very tip or the apex of the tree is the highest energy limb on the tree.

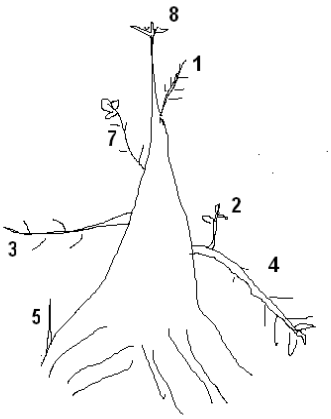


Fig. 3

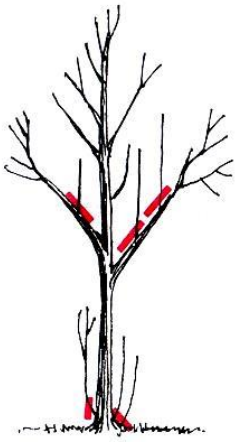


Fig 3A: Courtesy of the Arbor Day Foundation .

Cytokinin as part of the "Growth Control Field":

The major affects of the hormone Cytokinin are discussed. Cytokinin performs functions other than the ones describe here. This discussion is limited to the aspects of Cytokinin that are helpful for the person practicing the art of Bonsai to understand.

One of the main jobs of Cytokinin when mixed with Auxin is to promote cell differentiation which causes undifferentiated cells to become specific material; such as a leaf, a stem or a new cell, what ever the tree needs at that point in time. When Auxin and Cytokinin are present in the right mixture they promote cell division; which is how the tree grows and/or replaces dead or injured cells.

When the ratio level of Cytokinin is higher than that of Auxin, it signals the tops of the tree to grow. Cytokinin is produced by root growth. Remember root growth is signaled by high Auxin ratios. The Cytokinin produced by the root growth travels up the xylem to the tips of the branches; where it signals for the tops begin or keep growing. This changing balance between Auxin and Cytokinin forms the growth cycle of the tree.

These two hormones act like the old play ground see/saw. At any moment in time Cytokinin may be higher, later Auxin may the higher. During each of these transitions either tops are growing or roots are growing. They operate in an opposing cycle; roots don't grow while tops are growing and tops don't grow while roots are growing. The literature refers to this as an "episodic out of phase cycle".

Let's take a moment out to be clear on the distinction between hormones and food.

1) Hormones are like traffic lights, they provide signals.
2) Food provides the energy to perform the act called for by the hormone signals. Without food the act called for by the hormones will not happen. If food is available, the amount of food available will determine how much growth will occur. It is a large amount of food available that creates long internode in the stem growth. A low amount of food creates short internodes. Short internodes are very desirable in Bonsai trees. The techniques used to develop and control the internode growth is outside scope of this article.

Section 5: The "Growth Control Pathways"

In this section the physical mechanism that prioritizes the distribution of the food from the roots throughout the tree is discussed. The fact that priority is all ways given to the strongest components of the tree follows nature's rule of survival of the fittest. Understanding this priority is extremely important to the practitioner of Bonsai.

Objective: You be able to describe how the pathways supply the most resources to the leaves and limbs that supply the most food. You should be able to describe how limbs may be strengthen, weaken or caused to die overtime.

The "growth control pathways" determine where in the tree the tree's resources are used and or stored, (Ref.3).

It is the job of the "pathway control" to supply the largest amount of resources to the limbs which are most beneficial to the trees' health and survival prospects. In conjunction with the roots, the pathways decide which limbs live or die; as well as which limbs grow strong or weaken. It does this by allocating where the water, minerals, nutrients and other resources go. The stronger a particular pathway the more water and nutrients go to the limb connected to that xylem pathway. This system rewards each limb in proportion to the amount of food produced by the leaves on that limb. The more food the leaves of a limb produces, the larger the xylem pathway connecting the roots to that limb must increase to transport extra water and nutrients to support further growth for that limb and material for its' leaves. The pathways of the limbs that produce less and less food shrink overtime. At some point the flow may become so small that the roots shut down that pathway and that limb weakens and dies. The reasons behind a limb producing less food are many. It may have been damaged, or its' roots are diseased; often it has gotten shaded out by another limb or tree. In the latter case it's no sun, no food. If you were to cut the trunk into and look at the pathways (called annual rings), you find that some have a large diameter and some a smaller. The size of the pathways is how the largest resources are distributed to the limbs/branches/leaves that are the most important to the trees survival and growth. The size of the pathways are constantly being adjusted by the amount of food its' limb produces vie its leaves. (Ref: Phone conversation with Dr. William Chaney, Purdue University 5/19/2009)

If you are still with me, you have been through a large amount of information. I admire your persistence. Finally comes the fun part, we see how all this information is used

First let me introduce some of the key questions that you may want to ask yourself before you undertake any action. The answers will give you

some insight to the trees reaction to the abuse you intend to inflict upon it. After a brief introduction we will then see how one goes about using this knowledge to achieve desired results.

Section 6: Questions to ask yourself

In this section 6 questions are put forth as a guide to your activities. Asking yourself these question, may help you in arriving at a full understanding of what the end result of your planned activities may be.

1. **What are you trying to achieve?**
2. **What season is it?**
3. **What action are you going to take?**
4. **How will that action upset the trees' hormone balance?**
5. **What will be the trees reaction to this unbalance of its hormones?**
6. **Will that reaction give you the results you looking?**

Fun is doing stuff to a tree.

Section 7: Dilemmas

In this section a small number of various scenarios are offered as just some of the examples of how you might use the information you have gone through to help answer the ever present question of "What happens if I do XYZ to my tree". The examples are presented as "Dilemmas".

Object: When you have finished the exercises below you should be able to apply the principals of "growth hormones" to most of the Bonsai situations you may encounter. Go through exercises until you are comfortable that you can put the information to practical use.

The practitioners of Bonsai never seem to be happy unless their doing something to some poor unsuspecting tree. So, lets' go through some

the more common activities that you will find yourself asking questions about. But before we go there, lets review some things we learned.

1. **Top growth produces Auxin**
2. **Root growth produces Cytokinin**
3. **High ratios of Auxin signals root growth**
4. **High ratios of Cytokinin produces top growth**

Now!!

Dilemma (1)

Q: I have a limb that is too long. What happens if I cut it back?

Answer: Remember the Auxin in the "control field"? One of its jobs is to suppress any bud break behind the apical bud. Whether you cut just the tip off of the limb or a section of the limb, you remove the apical bud and drastically reduce the Auxin mixture in the "control field" of that limb. Now there is little or no Auxin to suppress the latent buds on the limb from breaking. Breaking means that the buds open. Since you have reduced the Auxin, the Cytokinins ratio is now dominant. The higher Cytokinin ratio gives the latent buds a grow signal. The result of your cut will most likely be that a number of buds will break to form new branches on your shorter limb. Warning, pines are different. You must never cut a pine limb back so far that no needles are left on the limb. That limb will die! This means that you may have to reduce your pine limb back a little at a time over several seasons. However, the same growth principles are still at work on pines. Cutting off the tip of a branch to induce new buds to break on the shortened limb, is a technique called "Back Budding" and you will use it very often in your Bonsai work.

Dilemma (2)

Q: I have a rather tall tree that I think it would make a great bonsai. What happens if I cut the trunk off to make it shorter?

Answer: The larger part of your question was answered in Dilemma (1). The difference is the exaggerated results. In Dilemma (1) you reduced the Auxin in a single limb. In this situation you are going to almost

eliminate the Auxin in the entire tree. This leaves the Cytokinin levels extremely high. Therefore the growth signals to the tops are very strong. With an extremely low level of Auxin left in the trunk, almost every latent bud on the trunk will try to break.

Given that the tree has been well fed in the past, it has enough food stored for the whole pre-cut tree. All of his food now has no where to go except to the growth of the new breaking buds. This will support an explosion of new growth. All of this new growth sends a large amount of Auxin down to the roots. This signals strong root growth which in turn results in a large amount of Cytokinin be sent back up to the top of the tree to signal more top growth. All of this new leaf growth now begins to generate a large amount of food to fuel even more growth. This exaggerated cycle of growth continues until the summer heat* slows it down or the food supply runs out. The tree will experience another flush of growth in the fall. It is not unusual for the tree to put up a six foot or taller leader in just one growing season. This technique is called a "Trunk Chop". You will use this technique to shorten trees and/or to create taper and movement in your trees' trunk. This is another technique you will use quite often. Creating taper will be covered later.
*** "You will find *Bonsai containers and heat, in the supplemental readings below for the effects of temperature on tree growth.***

Dilemma (3)

My number one lower limb is too vertical. What happens if I wire in down much lower?

Answer: At this point you need to learn a little more about Auxin and review a little pathways Info.

1. **The more vertical the orientation of a limb the stronger the Auxin flow.**
2. **These are called high energy limbs.**
3. **The subsequent growth cycle cause by strong Auxin flow causes a larger, stronger pathway to develop.**

Now back to your dilemma. The lower you wire the limb down, the weaker you may make the limb. This is because it difficult for Auxin to be pumped up hill and this also has a diminish effect of gravity. It is

possible that the reduced Auxin flow may reduce the growth of that limb which may weaken its' pathway. Thus there are a number of precautions.

1. **You need to be sure that a higher limb does not shade out the limb you're wiring down. Remember, no sun, no food produced, the lower limb would continue to weaken further and perhaps die.**
2. **You need to be sure and rotate your tree so that your low limbs are not all ways on the shady side. These two items are especially important for pines.**
3. **You will want to encourage lots of new growth on this lowered limb. The more fine branching you create the more food the limb will produce. The more food that is produced the stronger the pathway remains. Producing fine branching is called "ramification". Ramification also allows you create pads of foliage on your limb, which increases the number of leaves/needles and apical buds to generate food for that limb. See photo below. This increases or maintains the health/size of that pathway and ensures that excess food is available for increasing the diameter of the trunk and branches. The techniques of creating ramifications and pads are beyond the scope of this article. Below is example of how through ramification a dense pad of foliage is created across the branch using ramification. Observe the lower limbs.**

   With care the wired limb should be just fine. Watch out for the wire cutting into the bark as the limb grows.

Photograph courtesy of Michael Hagedorn

Dilemma (4)

I have just brought a nice plant from the nursery. It is about 8 inches tall. If I put in a bonsai pot how long before it will be a beautiful Bonsai like I see in the books?

Answer: I take it from your question that you do not want to keep this tree the size as it is now. I assume you want to grow into something that gives the appearance of an old tree of great character with a large trunk. If that is the case then the answer is never. This is one of the most general misconceptions of people just staring out in Bonsai. Putting a tree in a shallow bonsai pot is almost the final act that you will perform on a tree after it's' development and training period. Lets review some or our growth regulation theory.

1. **Auxin signals root growth.**
2. **Root growth produces Cytokinin**
3. **Cytokinin in turn signals for more top growth.**

For roots to produce Cytokinin they must grow. By putting the tree in small bonsai pot you have severely restricted its' root growth. The strength of the growth cycles between the tops and the roots will get smaller and smaller over time. There will reach a point where the tree is so root bound that there is practically no growth. The Auxin and Cytokinin signals are diminished and roots are taking in only small amounts of nutrients and water. Much smaller internodes and leaves are produced therefore much less food is produced. Putting the tree in bonsai pot is the primary way to slow its' growth so that it stays virtually as it is. At that stage it is considered a finished bonsai. It is not uncommon for a tree to need to be developed, (called training), for 15 to 25 years before it is put into a Bonsai pot. See developing a Bonsai below. Yes, there are all ways exceptions.

Dilemma (5)

I am told that I must prune the roots periodically. Why? I thought I need the roots to get maximum top growth.

Answer:
You are correct; if you prune the roots the tree will stop growing for a period of time while the roots reestablish themselves. Almost anything you do to the tree will stops its' growth while it rebalances itself. That's the price you pay for altering the tree. The reason you repot is to refresh the soil in your pot which will breaks down over time may become compact and clog up your drainage. As to why you must prune, because in time the roots out grow the pot. After a time the tree becomes so root bound that tree may weaken and eventually die. See dilemma (4). By cutting back the roots you can use the same pot and yet the roots now have room to grow. That means the new roots can now take in more water and nutrients from the new soil you replaced in the pot. They can also now produce stronger Cytokinin signals which encourage top growth. The tree is re-energized through these stronger growth cycles and the pathways are strengthened or at lest maintained. The will be a short period of no top growth while the roots re-establish themselves but if repotting is done at the proper time this should be a relatively short period. Warning: When you cut off the roots you remove a certain amount of stored food; this is usually not a real concern unless the tree is already weak. One does not work on weak trees. However, you also reduced the roots ability to take in water. If through transpiration the

tops are losing more water that the roots can replace the tree may be stressed and damaged. As general rule take off the same ratio of tops as you do roots unless the amount of roots you remove is fairly small.

Dilemma (6)

A year ago someone at the club wired a limb down for me. I later took the wire off to keep it from cutting into the bark but now the limb is rising up again. What did I do wrong?

Answer: Nothing. I am going to assume that the tree or perhaps the branch is fairly young. At lest young enough that the pathways inside the limb are not old enough to have harden off to the point that they are very difficult to bend. Now let's review a little about Auxin.

1. **Auxin does not like sun light.**
2. **Auxin concentrates in areas away from the sun.**

If the limb was bent fairly low, it means that top of the limbs' surface, which is now more or less horizontal, is exposed to sun light. Auxin in order to avoid the sun light is concentrated in the under part of the limb away from the sun. As was stated before, Auxin elongates cells. The high concentration of Auxin in the under part of the limb elongates the cells on the under side while cells on the upper side of the limb remain stationary. This forces the branch to curve up. Even if the branch is too ridged to be curved upward you will notice that the younger tips of the branch will turn up. *It is not unusual to need to rewire a young vigorous branch a number of times.*

Dilemma (7)

I have a new tree that I need to style. There is a lower branch is just in the right place to be used as a permanent, number 1, branch. However, it has been growing under a higher branch that has shaded it out. As a result the branch is smaller in diameter than the other branches I'll be saving. It looks out of place. Is there a solution?

Answer: Yes, but it will require patience on your part and a little luck. Perhaps you should have bypassed this tree when you looked it over. Either you did not notice the flaw or the tree has such strong potential that you wanted to work with it regardless. With a little cooperation from

nature, you may still make it work. Lets' review of the some of the information you've been over.

1. **By now you recognize that the internal growth process is a cycle.**

Top growth produces Auxin – Auxin produces root growth – root growth produces Cytokinins – Cytokinins produces top – and the cycle repeats itself. During the process the pathways are enlarged and strengthened in order to meet a heaver flow demand for nutrients, minerals, water and food.

2. **Food is needed to create growth.**
3. **To make food the limb needs sun.**
4. **For the sun to make more food, the limb needs more leaves.**
5. **More leaf growth equals more food and more Auxin.**
6. **Auxin will encourage root growth which will produce more Cytokinins and water which will strengthen the pathways. The leaves should be able to increase an excess of food thus allowing the branch to thicken.**
7. **Auxin hides from sun light.**

So, the key is to generate strong growth on the weak limb.
If the limb is shaded from the sun, it is not producing enough food for the limb to grow. Remember secondary growth, (diameter), is the trees' last priority for the allocation of food. The pathway on this limb and its' roots may be getting weaker each season. 1) The first thing will be to cut off or bend the limb that is shading the weak limb out of the way. At this point the weak limb needs all the sun it can get. 2) For *deciduous trees* let the weak grow wild until the diameter is close to the size you need. The limb may need to approach 5 to 8 feet in length. 3) When you are convinced that the limb is the right size, is currently healthy and the tree is well fed cut the limb back to about two or three buds near the trunk. Each time the limb grows to 5 to 7 new buds, cut it back to two of the new buds. This technique develops taper and movement in your limb. Continue this growing and cutting back until the limb is the correct length for you tree. A method of speeding up the development of the limb If this tree is in a early developmental stage is cut back most of your other limbs so that they don't compete too strongly with the weak limb. In the case of pines, remember your "back budding" lesson in Dilemma (1). Again you want to let the limb grow wild until it reaches the correct size. But now you must work this long limb back a little at a time

by “back budding”. You want to try and force latent buds to break in order to get more branching for more needles closer to the trunk. If the limb is bent low, there is probably very little Auxin on the top of the branch, due to the increased sun light. Now there is a good chance that some latent buds will break. You increased this probability when you removed the affects of the Auxin produced by cutting the apical tip. If you get some buds to break on the bear part of the limb, you need to create many fine branches in order to produce more food to strengthen the limb then cut the apical tip again. Repeat until the limb is the correct length. Do not attempt to back bud more than once a year. During this process keep the tree well fed and watered.

The chance of any buds breaking is always problematic. If you do get breakage, the process of thickening the limb is long term. This depends of course on just how much smaller it is than the others you are saving as permanent limbs.

Now: A walk on the wild side.

You may wish try a couple of advanced and rather unorthodox ideas.

1, To increase the probabilities of getting buds to break; you may want to try a “Bud Notching” approach. Growers of orchards that produce fruit, citreous, nuts and grapes need to development as many branches on their trees as possible. Using their understanding of the suppressing powers of Auxin they have developed a technique called “Bud Notching”. They cut a small notch just in front of a latent bud in order to interrupt the Auxin flow to that bud.

 Ref: 36

Their rate of success in getting buds to break has been as high as 70%. A few Bonsai practitioners in the FT Walton Beach club have used a variance of that notching technique, called "scoring" with good success. Remember notching carries no guarantees, but you will increase the probabilities of buds breaking.

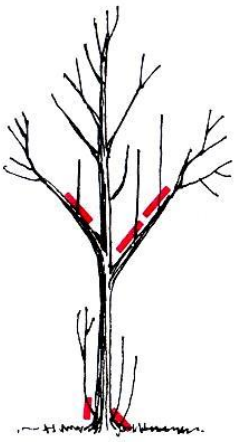
To use the "scoring" variation you need a real sharp blade. I use an X-Acto knife. You want to start at one end of the bare part of your limb. Make a small cut; straight down across a small portion of the limb, not a notch". The cut should be offset from the top center of the limb at an upward angle slightly to one side. This should be a straight cut not a notch. Go up the limb about a quarter of an inch, more or less, and make the same type of cut on the opposite side. Alternate cuts from one side to the other until you completed the bare portion of the limb. If you are dealing with a tree where the latent buds are visible then make your cut a little in front of the bud other wise just make your cuts at random.

How to make the cut? First lets' review a little about pathways. Remember the pathway closest to you is the phloem. It is on the outside of the cambium just under the bark. You know that the phloem carries the Auxin and food down the tree. It is phloem you want cut in order to stop the Auxin affecting that bud. Put the knife on the limb, support the under side of the limb with a stick or a finger. On top of the flat side of the knife use your thumb or finger to gently press down on the flat top of the knife until you hear a soft snap or feel it. You will have just cut through the phloem and cambium. The resistance you hit was the harder xylem wood. Do not press so hard that you cut through to xylem. You

have now interrupted the Auxin flow and eliminated it suppressing powers in small portion of the limb hopefully ahead of some latent bud.

Be sure your limb gets good sun and fertilize your tree often. Now you wait. Neither "Bud notching" nor "Scoring" guarantees that a bud will break but it certainly increases the probabilities.

The following may be considered somewhat of a controversial technique. You will use the same cut as you did above. However this time instead of making your cuts off center, you cut straight across the top of the branch. The technique you employed before will produce branching a little on either side of the limb. With this technique you are trying get a bud break on the very top of the limb. A bud growing right from the top of a limb is called a "Water Sprout". Water sprouts are considered bad news and almost any literature you read will tell you to get rid of them immediately. Water sprouts grow on limbs. If they grow on the lower part of the trunk or from a root, they are called suckers. Lets' review some of our past information. Fig: Ref 24 Figure courtesy of the Arbor Day Foundation.



1. Limbs that grow straight up vertically are high energy limbs.
2. Because of there high Auxin flow they quickly produce strong pathways and roots; therefore grow quickly.
3. Because they are strong growers they consume a lot of resources.

4. They rapidly increase the diameter of the limb that supports them.
5. The high energy limbs shown on the branches in red are called "water sprouts"
The lower on the trunk and roots are called "suckers"

The intension here is to try and make all these so called negatives work for us in a positive manner. As you have already learned any strong growing limb must create a strong pathway to keep it nourished. Increasing the strength of the pathway increases the food and diameter of the trunk and/or limb to which

the water sprout is attached. This is exactly what this limb needs. Warning: Water sprouts because of their vertical orientation grow very quickly as do the limb to which they are attached. You must watch the sprout very carefully; as the limb to which it is attached approaches the size you need remove the sprout immediately. The limb will become oversize if the "water sprout" is left on too long. Depending on how large an increase you need in the limb, the sprout may well do its job in less than one growing season. You should also keep a close eye of the portion of the limb beyond the water sprout. If the end of that limb seems to weaken (rare), remove the water sprout immediately and try the process again next season when the end of the limb has recovered its' strength with good feeding and sun light.

Dilemma (8)

The people in my club constantly talk about taper. None of the plants that I've seen in the nurseries have any taper. Where do I get a plant with taper?

> **Answer: The answer to this would fill several articles. Unless you buy a plant from a Bonsai nursery you most likely will not find any plants with taper. Most Bonsai practitioners normally buy a plant from a local nursery or grow one from seed and then developed the taper over several years. It is a matter of growing the lower trunk of you tree to the size you want and then chop off the top of the tree at the desired height, adding a little height for die back. The desired height for this first section of trunk should be I/3 of the total planned height of your finished tree plus a little more for die back. The right you must plan. Also this will be the site of your first lower branch; if you are luckily enough to have one of the new sprouts break there. For correct branch placement see "The Rules of Bonsai" in the supplement reading section. Remember that one first thing you do when you get a new tree is to decide how tall you going to make the finished tree and the placement of its' front. Remember in Dilemma (2) this technique of cutting off the top of the tree was identified as a "trunk chop". Once the chop has been done, you let a new leader grow until the trunk of the new section is the size you want and then chop it again. The new section of trunk should of course be smaller than the first section; thus creating taper. Chop again. When the trunk of the third section reaches the size you want, you cut the leader off to the height you had planned for tree, plus a little for die back. The two new sections you have created should be progressively smaller in diameter as they go from bottom to top. This is how you create taper.**

Because the new leading sprout will break from the one side of the old section of trunk, it will be growing off-set from the old section thereby creating what is called movement /curve in your trunk. Normally two 'trunk chops' will do the job. That gives you three sections but the number of chops is arbitrary. It depends on what you are trying to achieve. This is a very general answer. You need to reference an article devoted to "trunk chop". Generally speaking you have already learned about how about the hormone action and the growth cycles of a "trunk chop" in Dilemma (1). The chop is normally done at first of the spring growing season in order to get the full benefit of its' strong growth period. Normally, you grow a tree to be trunk chopped in the ground or in a five gallon pot and let it escape. Escape in this case means to let the roots grow out of the drain holes in the pot and go into the ground. This is almost as good as planting the tree directly in the ground with the added advantage of being able to control the surface roots in the container. You must continue to water and fertilize from the top of the container even though the lower roots are in the ground. For a step by step illustration of a trunk chop see, see trunk in the supplemental readings after this article. Not all trees respond to a "Trunk Chop" with the same results. Before performing a "Trunk Chop" seek out the advice of a more experienced club member

Dilemma (9): Every one in my club is talking about pinching candles on their pines. I not sure I understand the importance of this.

Answer: This is going take a lot of answering. There are a number of reasons to pinch candles, so I'll break it down into different parts.

Part 1: The reason to pinch. In many deciduous trees such as Maples, Elms, Bald Cypress, Oaks etc. The length of a branch or even the creation of a branch can be accomplished by pruning. Some times all the branches on such deciduous tree may be pruned off in hopes that the new ones that sprout will be in a more desirable position. This cannot be done with Pines. To get all the branches on a Pine in the proper place and the proper length, the branching is best developed from the time that the tree is a seedling. Even if you have limb in a desirable position the length and density of the limb must be controlled. The Pine will try to keep growing from the tip; this must be stopped. Plus you want to encourage lots small branches not just a few longer ones back down the branch. Creating many small branches on a limb as you recall is called "Ramification". To start the pinching process you allow

the candle to grow five of six inches in the spring. Remember this type of growth creates a strong Auxin signal and the health and vigor of the pathway is maintained or increased. For the next step in process you pinch these candles off at the base. Later new buds will develop at the base where you pinched off the candle. Generally there will be 4 new buds. You keep two of these buds; one on each side of the branch. You eliminate the buds that are oriented front and back, unless you want the limb to grow longer. If you want the limb to grow longer then the forward facing bud should also be left on. If you have left only the two side buds you now have created two new lateral branches on the original branch; each growing in opposite lateral directions. You do this to each of the new branches each growing season until you have created a wide pad of small branches across the limb. This normally involves the lower and middle limbs. See Pic: below. Notice how the branches take the form of a triangle. A large number of small twig-like cover the limb and look like pads of greenery. These will become denser over time.

Photograph courtesy of Michael Hagedorn

Therefore the control of the growth and both the direction and the density of branches on a Pine, is accomplished by candle pinching <u>not</u> pruning. The one exception is "back budding" which you covered in Dilemma (1). You really need to read an article devoted entirely to the pinching of pine candles

because there are timing consideration that are beyond the scope of this article.

Part 2: Here you will be introduced to equalizing the energy level across the entire Pine tree by timing the candle pinch on different parts of the tree. Currently there are two models employed, one is a vertical model and the other a horizontal model. In the wild, Pines usually grow with their middle and lower limbs bent low. The literature that describes energizing the tree uses the following vertical model. Remember high energy levels equal strong growth levels. See Drawing below.

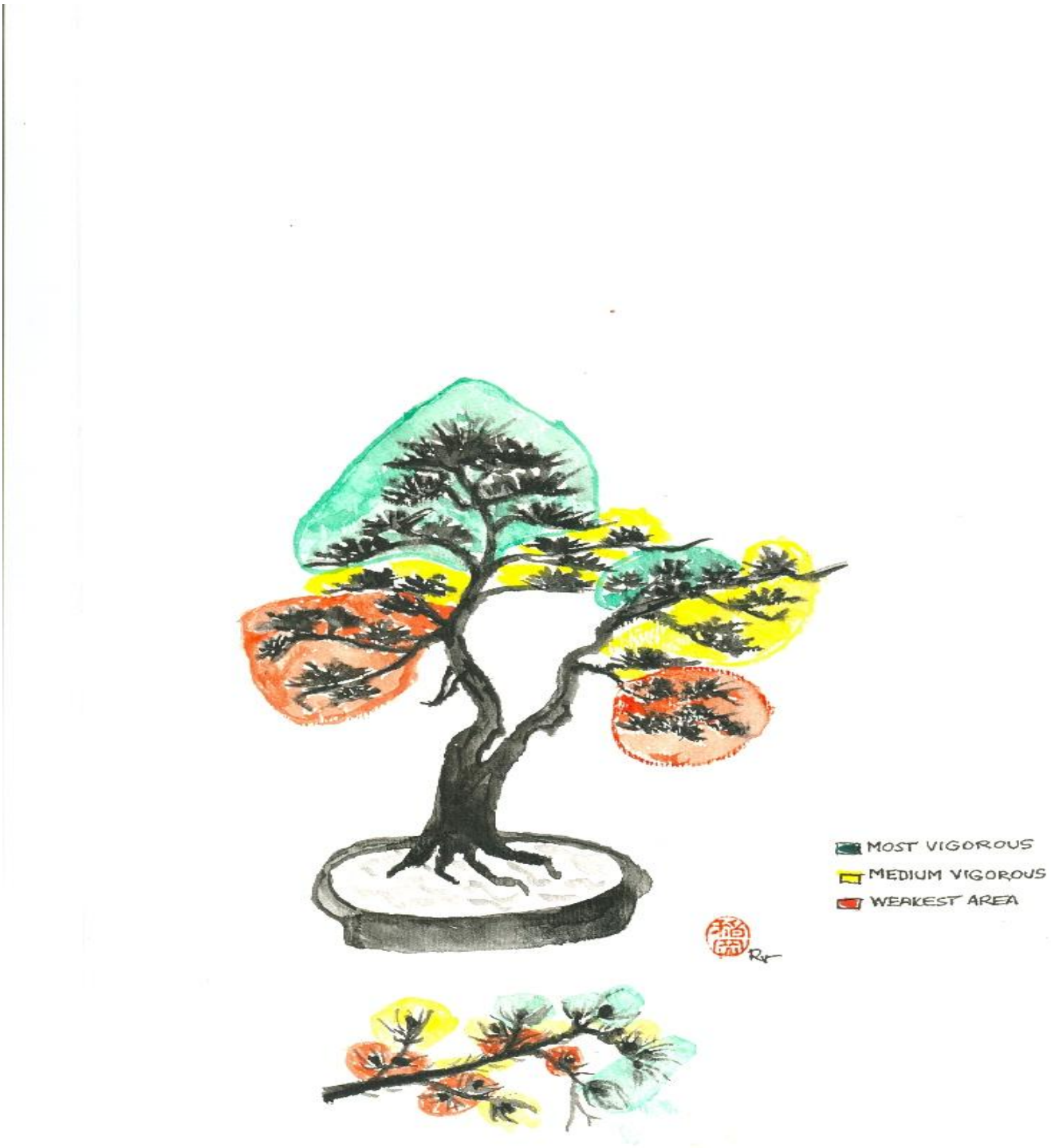


Figure *courtesy* of Rosemarie Voelker Ft Walton Beach Bonsai Club 8/2009
Used with her permission

It divides the tree into three vertical sections. It refers to the top third of the tree, (Blue section), as the high energy section. It refers to the middle

third, (Yellow), as a medium level and the lower third, (Red), as a low energy section. This is a fairly useful model to follow because of the way we grow limbs on our bonsai trees. We normally bend the limbs of pine lower and lower as we go down the tree, thus lowering their energy. Remember the lower a branch is bent the lower its' energy.

Figure *courtesy* of Rosemarie Voelker Ft Walton Beach Bonsai Club 8/2009
Used with her permission

The literature also describes energizing the tree using a horizontal model on the individual limbs. Instead of going up and down the tree vertically, this model looks at each branch horizontally from the apical tip back to the trunk. Notice that the two branches closest to the trunk have no high energy portion. This is because branches close to the truck are considered low energy branches. You should take both models into consideration when deciding which candles to pinch and when.

Both models approach the tree or the branch in sections. The vertical model describes the tree as being strong at the top and declines in strength as you come down the tree in thirds. The horizontal model describes the branch as being strong at the tip and declines in strength as you approach the trunk.

Both of these models no doubt were developed from observing how pines as well as other trees grow.

However useful the vertical and the horizontal models may be, we will ignore them for the moment and consider the information that you have learned above which will give you a good review of what is going on inside the tree as well as adding another tool to your bag of knowledge.

First of all it is not the section of the tree that defines the strength of a limb or branch. As you learned earlier, it is the orientation of the limb to the trunk or the branch to the limb. The more vertical the orientation of a limb or branch the higher its' energy level will be; no matter the section of the tree to which it is attached. This of course is due to the stronger Auxin flow on vertical limbs. With this rule you can evaluate each limb accurately; no matter where its' location on the tree. Now it is generally true that the limbs in top section grow more vertical than limbs in the mid or lower section. This fact makes the vertical model useful. But as usual, there will all ways be exceptions. Two glaring examples are the "water spout" and the sucker. Water sprouts are likely to grow on any limb that is bent over 60 degrees from vertical. The lower the limb, the more likely a "water spout" may occur, especially if you have cut the apical tip in order to try and "back bud". Since it is vertical, it will grow all out of proportion as will the limb to which it is attached. The sucker grows from a root at the bottom of the tree or low on the trunk and usually oriented straight up. Because of its' vertical orientation it suck up a large amount of the trees resources and should be eliminated as soon as spotted unless you want to use it thicken the lower section of the trunk. In that case leave it until you are satisfied with the trunk size. However, you should only use this approach if the sucker is very low on the truck. If you let it grow higher up the trunk, you may create reverse taper or a large bulge. So you need to evaluate each limb and branch accurately, to avoid letting some general rule lead you astray. You will probably find yourself using all three approaches

Summary:

This has been only a few examples of how you can use your knowledge of "Growth Control Regulators" to predict the outcome of any action you intend to perform on a tree. In all cases, you must keep in mind the current health and condition of the tree and the time of year.

The material provided in this article is general in nature. Each tree like each human is different. Through the literature and the members of you local club you will learn the esoteric difference of various trees and their specific needs and the dos and don'ts. But the material you have just gone through should provide you with a solid base from which to launch your Bonsai career.

The material in this article is not meant to replace the current literature or training approaches but to act as an addition and supplement to the existing information and teaching methods.

The end of the article.

Supplemental readings are below the references.

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Supplemental Readings:

Index:

1. **Food**
2. **Plant Hormones**
3. ***Bonsai containers and heat***
4. ***Rules of Bonsai***
5. ***Trunk Chop***

Food:

Photosynthesis is the process of converting sun light energy into chemical energy and storing it in the form of sugars and

carbohydrates, (food). This process occurs in plants and some algae. Plants need only sun light, carbon dioxide ($CO_{2)}$, and water (H_2O) to make food, (Ref 26). The literature as well as we club members often speak of the tree's food as if it were one lump that move from top to roots or roots to tops. The fact is that the food processed by the leaves is stored in a multiple number of places. The leaves retain some food. There is a little packet food stored behind each apical bud that will be used to open that bud when the opportunity occurs, (Ref: 27). There is certain amount of food stored in the stems and limbs. A significant amount of food is used for respiration that is used in keeping the tree alive. Last but not least a quantity of food is use to increase the diameter of the trunk and branches. Any excess food stored in the roots. A quantity of the food is used up during top growth and root growth. A large amount of the food is used up in respiration. Repatriation is the process of keeping the tree alive. Just as in humans, thousands of cells are dying every minute. Those cells need to be replaced; existing cells need to be nourished. New growth needs the energy from the food. Various processes going on within the tree need energy to do their work. Last but not lest any excess food is stored in the roots for future requirements. In other words as the food moves down the tree from the leaves, every component grabs its share. Food allocation is not an arbitrary process. The tree allocates the food according to the most important needs of the tree. Below is a food allocation model.

***Food – Priority Allocation Model,* (Ref 2)**

Photosynthesis converts the suns energy into carbohydrates & sugar (food). - The tree has a priority order for the allocation of these carbohydrates. (Oliver and Larson (1996):

1. Maintenance of living tissue (respiration)
2. Production of fine roots,
3. Flower and seed production,
4. Primary growth (elongation of branches and roots).
5. Secondary growth/diameter growth. Growth of the xylem, the water/nutrients-conducting cells, which becomes wood & the phloem, the food conducting cells, which become bark.

Let's look at the items above. Number 1 is a must; the tree must maintain its internal components or die. Number 2, the tree must grow and or replace its fine roots because they are the primary roots that take in water and nutrients. Number 3, the genetics of the tree dictates that it protects the survival of the species by procreating. Number 4, the tops of the tree must grow to compete for sun light. The roots must grow to gain new territory in order find new resources in the form of water, nutrients and minerals. This is because the roots quickly depletes the resources in its' current area. *Number 5, the last order of priority is the secondary growth, which is the diameter of the truck and branches. The practitioners of bonsai place great deal of value in large diameter trunks. Therefore you must assure that your tree is well fed in that trunk growth is last in line for food allocation.*

As the availability of food to the tree declines, carbohydrate allocations are gradually pulled up the physiological processes ladder. Respiration is all ways the first to be allocated any of the available resources. This why you can find natural Bonsais in the wild that can be over a hundred years old and yet be only 10 or 15 inches tall. They are getting just enough food to live but not enough for any of other four physiological processes. In the case of high altitudes, short growing sessions can also be a contributing factor.

Plant Hormones (Ref: 32)

Different hormones affect different plant processes. Understanding how hormones work allows horticulturists to manipulate plants for specific purposes.

<u>Auxins</u> produced in the terminal buds suppress the growth of side buds and stimulate root growth. They also affect cell elongation (tropism), apical dominance, and fruit drop or retention.

<u>Gibberellins</u> affect:
- **The rate of cell division**
- **Flowering**
- **Increase in size of leaves and fruits**
- **Seed and bud dormancy**

• Induction of growth at lower temperatures (used to green up lawns 2 to 3 weeks earlier)

<u>Cytokinins</u> promote cell division, and influence cell differentiation and aging of leaves. Essential for top growth

<u>Abscisic acid</u> is considered the "stress" hormone. It inhibits the effects of other hormones to reduce growth during times of plant stress.

***Bonsai containers and heat:* (Ref: 33)**

Generally tree growth follows the following guidelines.

Soil and exterior temperatures:

- Root growth may start at 50F or higher some trees as low as 40F
- Maximum root growth occurs between 70-80F
- Growth is reduced as much as 90% at 95F.
- Conifers may be killed in a few hours at 117F
- The process of photosynthesis breaks down at temperatures above 90 degrees, no food is produced.

In nature the tree normally experiences a fair amount of temperature variation. Feeder roots of trees tend to inhabit the upper 3 feet or so of the soil, hence they are affected by the increase in temperature from direct sun and ambient air temperatures. These effects rarely go below about 1 foot of soil.

In the world of the shallow containers used in Bonsai the situation is a bit different. The temperature variations can be much more exaggerated. Bonsais can be quickly damaged in the intense summer heat. This is especially true of those in dark containers which absorb and store the sun's radiation more efficiently.

In his book, "Plant Production in Containers" Dr. Carl Whitcomb cites some research showing that very high temperatures can be experienced by roots in containers. One researcher in So. California found that soil temperatures in black plastic containers can reached a maximum of 115F and remained at or above 100F for 5 hours, (Harris, R.W. 1967 "Factors). The point being is that Bonsais may need protection from the summer sun in some climates. Plants

that are in dark pots that are only 2'' to 3'' deep are especially vulnerable. The lower southern states are especially vulnerable.

The Rules of Bonsai: Ref: 34 **John Naka's book Bonsai Techniques Vol 1, 1973**

Rules for trunks and nebari:

Nebari is the Japanese word for the surface roots that make Bonsai trees so appealing.

The art of Bonsai is a two part discipline. There is the horticultural side of growing the tree and keeping it alive. Then there is the artistic side of making the tree look like a grand old master piece and displaying it to its' fullest potential. There are very few rules or models on the horticultural side in our bonsai literature. However, the artistic side has a rich and excellent menu of rules to live by.

John Naka, often cited as the father of American Bonsai, compiled the following rules.

1. The height of the tree should be six times the diameter of the lower trunk. The term caliper is often used in place of diameter.

2. Trunk should lean slightly toward the viewer.

3. Trunk should flare at base to visually anchor the plant.

4. Nebari, (Roots), should radiate from the flare like a wagon wheel.

5. No eye-poking roots, (directly at viewer).

6. Apex of the tree should lean toward viewer.

7. Trunk should taper as it ascends. No reverse taper.

8. Grafts should match under-stock and scion so that they are unobtrusive, or be placed low enough to disappear into the nebari.

9. Curves in trunk should not result in 'pigeon breast' (round curve toward viewer).

10. Apex should finish vertical to the base. 'Flow' should be maintained.

11. Trunk line should not move 'back on itself'. This is one of my rules and difficult to explain. It relates to the flow of the tree. A trunk line that moves back on itself creates a 'C' curve.

12. In both formal and informal upright, the apex should be over the base.

13. In informal uprights, too many 'S' curves will be tiresome.

14. As a tree ascends the curves should be closer together (related to branch placement).

15. A tree should have only one apex.

16. Twin tree trunks should divide at the base, not higher up.

The rules of Branches:

1. No crossing branches crossing or branches that cross the trunk.

2. No eye-poking branches (pointed directly at viewer).

3. First branch should be placed approximately one third the height of the tree.

4. Succeeding branches, each should be placed at one third the remaining distance to the top of the tree.

5. Branches go on the outside of the curves (No belly branches).

6. Branch caliper should be in proportion to the trunk. Branches that are thicker than one third the trunk caliper will be too thick.

7. First branch should be left (or right), second branch right (or left), third branch should be back branch.

8. Branches should visually alternate, no parallel branches.

9. Branches should diminish in size and caliper as they ascend.

10. There should be space between the branches to 'Let the birds fly through'.

11. First and second branches (Left and Right branches) should be placed forward of the mid line to 'invite' the viewer.

12. First, second, and third branches are approximate 120 degrees apart, with the back branch not directly behind the tree, (called a hug).

13. Only one branch per trunk position, no 'wheel and spoke' or whorled branches, or bar branches (branches directly opposite each other).

14. Branches should create an outline of a scalene triangle with the apex representing God, the middle corner man and the lower corner earth.

15. Secondary branches should alternate left and right and follow the rules of main branch placement, except there should be no secondary branches moving up or down. This creates the foliage pad.

16. To create the illusion of an old tree, wire the branches down. Young trees have ascending branches. The branches near and in the apex can be horizontal or ascend since this is the young part of the tree.

17. Branches for cascades generally follow the rules for uprights, except that the trunk moves down.

18. In twin trees, there should not be branches between the trees which would cross the trunks. The outside branches of both trees creates the triangle of foliage.

19. A jin should not be hidden in foliage.

The rule of Pots:

1. The tree should be placed behind the mid line of the pot, and to the left or right of the center line.

2. The depth of the pot should be the caliper of the trunk, except for cascades.

3. Colored glazed pots should be used for flowering and fruiting trees and the colors should complement the flower color.

4. The width of the pot should two thirds the height of the tree. For very short trees, the width should be two thirds the spread of the tree.

5. Style of the pot should match the tree. Uprights without much movement should be in rectangular pots, informal uprights with a lot of trunk movement should be in oval or round pots. Massive trees should be in deep rectangular pots.

Culture:

1. The soil should be uniform not layered. (New rule, you will still find controversy).

2. Fertilize full strength. (New rule, there will be controversy).

3. Water from above, not by submerging the bonsai, this will prevent the buildup of salts.

4. Increase humidity by using a tray of pebbles and water or by keeping the area under the bench wet, not by misting. (This is my rule, there will be controversy. Misting increases the salt buildup on the leaves, and does practically nothing to raise humidity.)

5. Remove most of the 'fines' from any soil mix, using only coarse particles. Fines are very small partials of the soil you are using.

6. Water when the plants need to be watered, not by a fixed schedule.

7. Keep temperate climate plants outside. Only tropical and subtropical plants (for the most part) are suitable for indoor bonsai. Temperate climate plants must be given an appropriate period of cold dormancy if they are to be kept indoors.

A must for your library:

1. **John Naka's book Bonsai Techniques Vol 1, 1973, Bonsai Institute of California, is by far the best treatise on the 'rules' of bonsai that I have found. Anyone can create convincing bonsai by following these conventions. Once they are mastered, you can begin to create without thinking about 'rules'.(Ref: 34)**

2. **John Naka's book Bonsai Techniques Vol 2**

Trunk Chop

Harry Harrington of BONSAI4ME graciously gave me his permission to reprint the following article.

WWW.BONSAI4ME.COM

BONSAI BASICS ADVANCED TECHNIQUES SPECIES GUIDES
ARTICLES BONSAI GALLERIES HOME

Developing Informal Upright Trunks for Deciduous Bonsai

http://www.bonsai4me.com/AdvTech/ATdevelopingtrunksforbonsai.htm

In the article Field Growing it was established that for a thick trunked bonsai, the tree must first be allowed to grow freely in the ground or a pot to help thicken the trunk.

Having thickened the trunk by allowing free growth for a number of years, it is unlikely that the trunk have much taper and will often lack any movement.

There are a number of ways of introducing taper and movement to a field grown trunk; this article describes one method that is known to be widely used in Japanese growing fields to 'build' *myogi* or informal upright trunks for bonsai. This process can equally be applied to a collected or nursery tree that is currently too tall for use as a bonsai and needs to be reduced in height.

By studying the following images, it is hoped that the reader will understand and use some of the techniques described to introduce taper and movement in the trunks and new branches for their trees.

This method is intended for deciduous trees only but some of its principles can be applied to coniferous species.

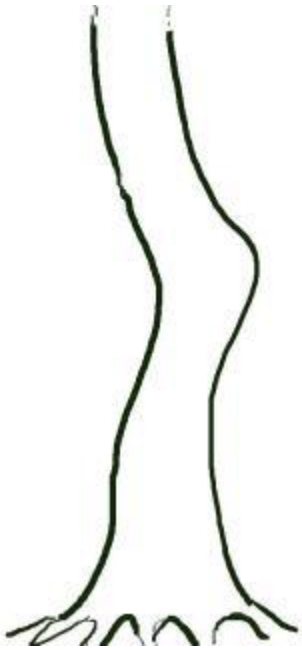

Image 1 shows the lower portion of the trunk of a tree growing in the ground. Its girth is adequate for use as a bonsai but there is little movement or taper.

Ideally, the finished bonsai will be *approximately* 6 times the height of the trunk diameter. The diameter of this trunk is 3" so the ideal height of the tree when it is finished will be 18". If a taller bonsai is required, this tree will need growing on for further years before this process begins. Once the trunk has been chopped, it will barely thicken until the new section above it has all but reached the same girth and at which point, taper is all but lost. Refer to this article for an example

So the projected final height of this tree will be 18". The first branch should be at *approximately* a 1/3 of the overall height. This means that the first branch should be 6" from the base of the tree.

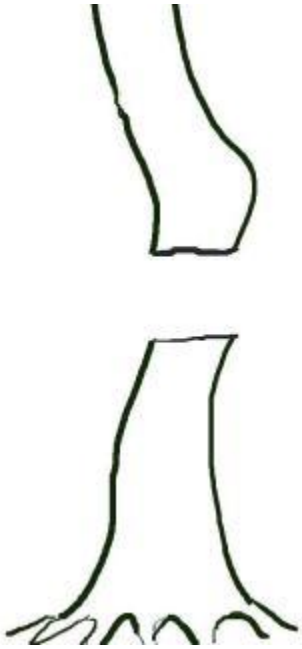

Image 2. Late Winter/early Spring. The trunk is chopped with a straight cut at a height of around 12", approximately 2/3 the height of the finished tree. If additional movement is required on a very straight lower trunk, the chop can be made at 6" or 1/3 of the height of the tree.

A straight cut reduces moisture loss and potential dieback; until a new shoot has appeared and been chosen as the new leader, there is no point in making a diagonal cut as is sometimes advised. As with all cuts, the chop should be sealed with cut paste.

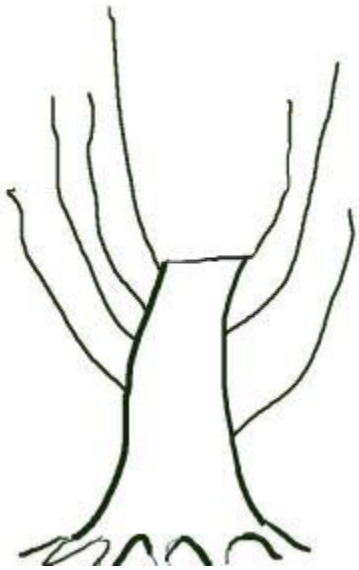

Image 3. Autumn. The tree drops its leaves and reveals the effects of a growing season left to grow freely. The heavy chopping has resulted in strong budding from all over the trunk.

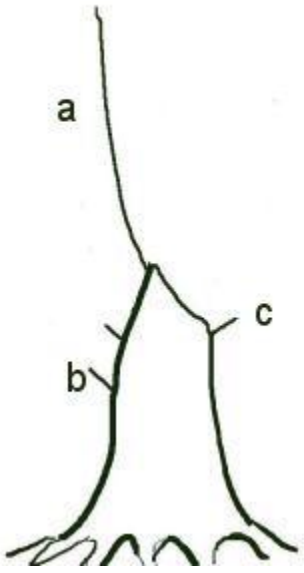

Image 4. Autumn or Spring. (I prefer to carry this work out on deciduous trees immediately after leaf drop but it can equally be carried out in Spring before bud break).

The shoot (a) is chosen to be the new section of the trunk. It is left un-pruned to accelerate its thickening which in turn will help to heal the scar caused by the trunkchop. The trunkchop can be tidied up into a diagonal cut now or left until mid Spring at which point it will heal faster.

Shoot b will be the first branch. Along with the other shoots that are retained, it is pruned back to 1 or 2 nodes or leaf joints. Pruning the future branching back this hard begins the process of building taper and natural movement to the branching. It also promotes further back budding from the trunk the following Spring.

Shoot c will be the second branch and will be positioned on the outside of the trunk's bend to the left. It s growth will also help promote healing of the scar at the base of the trunk chop. For trunk that has been chopped to a third of its projected final height, c will be the first branch and b can be removed.

At all stages of development, when selecting which shoots to retain. Look for those that have short internodes. Branches will only occur from nodes, the closer the nodes (leaf joints) are now; the easier branch placement will be in the future.

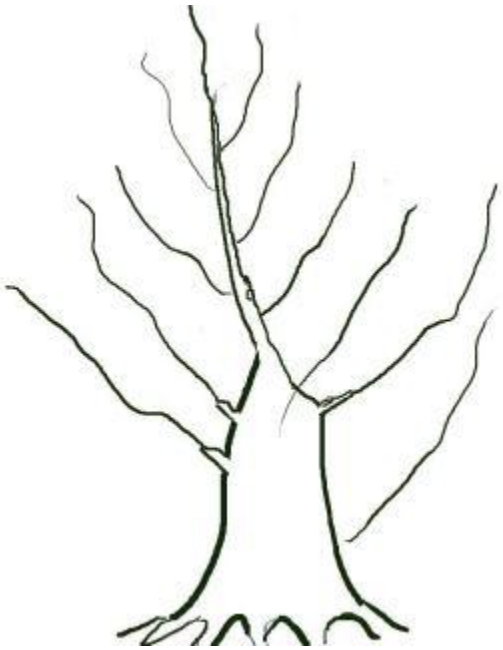

Image 5. Autumn. After one or more growing seasons of free growth, the tree has produced many new shoots. The new trunk leader, left

unpruned previously has now started to thicken and introduce taper to the trunk line. It has also produced new shoots of its own that can be used to change the direction of the trunk.

Image 6. Autumn or Spring. The first and second branches (b and c) are pruned back hard, leaving just 1 or 2 nodes or leaf joints from the new growth.

The new trunk built from shoot (a) is chopped back to a secondary/sub branch. This changes the direction of the trunk-line back towards the right and introduces a second pronounced change in taper.

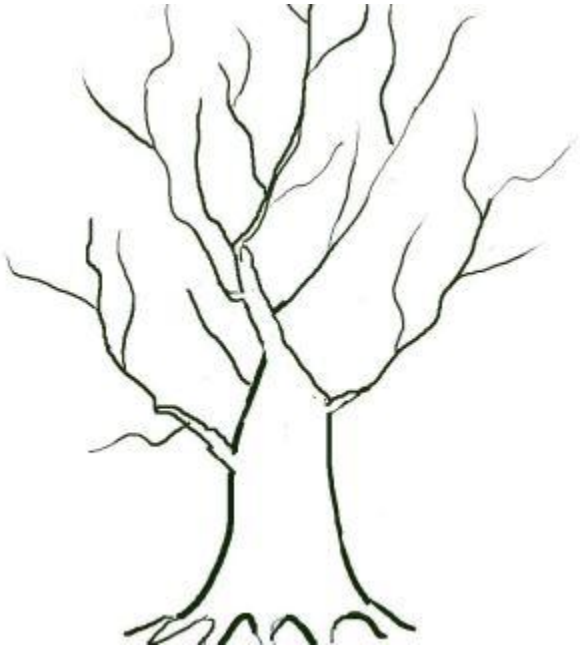

Image 7. Autumn. Another one or more seasons of growth have finished. The third section of the trunk has now become established and has its own sub branches.

The first branches (b and c) also have 3 sections of taper and secondary branches that are noticeably thinner.

The tree can be developed further in the ground for a number of years to exaggerate taper and movement or can be lifted and placed into a bonsai pot to start the development of the fine outer twigs on the very outside of the tree.

It is important to understand that the longer the period between each of the following stages, the greater the taper created. Trees that are trunk chopped to a new leader on an annual basis will have less but more 'natural' taper. (Sometimes known as a 'faraway view', a heavily tapered bonsai being said to have a 'near view')

Do not try to 'speed up' the process of creating taper by cutting back within a season; any growth that follows pruning within the same growing season or vegetative period, will be of the same thickness.

End