**J.A. PFISTERER**

Biologist, licensed tree consultant and expert witness in tree biology and tree care.
Friesenbergstrasse 27, D-76530 Baden-Baden.

## Modern models in tree architecture as a helpful tool for natural pruning

Introduction

Pruning is a more or less intense traumatisation of trees. It is desirable to do so in accordance with a tree's nature and not against it. The skill to prune naturally either requires long practical experience or good models and programs. In order to predict how a certain tree will react on an arborist's work its growing strategies should be understood. For the practical use in tree work, morphological models are sufficient.

Every tree variety has its typical silhouette. The specific silhouette also occurs when a group of the same variety grows close together and it will even be restored by reiterates some years after a severe traumatisation (e.g. thunderstorm, snow load, incorrect pruning). Recent approaches have been made by F. Hallé (*Modular Growth*, 1986) and C. Edelin (*Organization Patterns*, 1991). For tree work it is necessary to overview a tree crown as a whole. The *Model of Competition* helps for this purpose (Pfisterer, 1999 b). A second tool for natural pruning is to understand the different branching patterns in trees and shrubs. Typical branching leads to a corresponding *architecture* (Hallé at al, 1970, 1978). For practical purpose in tree work one architecture model (Rauh's model) was designed too wide ranging by the authors, so it has to be separated into 3 subdivisions (Pfisterer, 1998 a).

Model of Competition

Darwin's proverbial 'Struggle for Life' not only occurs between neighboring trees within a forest stand. Remarkable competition also exists within a tree crown (Pfisterer 1999 b). The mechanism seems to be primarily a source-sink relationship (Huber 1928, Zimmermann 1983, Bauerle et al. 1999). In any branch, a distinct correlation exists between water supply and photosynthetic rate. The better a branch is irradiated, the higher its photosynthetic rate and the higher its need for – and supply with – water. A well supplied branch produces a higher amount of hormones to control its undernourished neighbors, growing in the shadow or lower in the crown. This competition leads to an imbalance between dominant and suppressed branches. Whether a branch is dominant or not can be assessed by its shoot length and growing direction. Erect branches reaching to the canopy usually dominate their flat growing, lower neighbors.

The model contributes to a better understanding of the correlations within a tree crown, formerly described as *Apical Dominance* (Troll 1959) or hierarchic and polyarchic Pattern of Organization (Edelin 1991). The amount of competitive power between leader and side branches decides whether a tree crown's organization is hierarchic or polyarchic. The crown of a fir (*Abies spec.*) is hierarchically organized. All trees with a single leader do the same. In contrast adult french pussy willows (*Salix caprea*) and sycamore maples (*Acer pseudoplatanus*) usually have flat, polyarchic crowns with several axes of corresponding dominance. Young trees of both varieties are hierarchically organized.

Shrubs generally develop into colonies of codominant axes. An axis itself may be organized more or less hierarchically. This is why large, old shrubs may grow into a tree shape (e.g. common elder, *Sambucus nigra).*

Hierarchically organized trees can do the same after the leader (and the apical dominance) has been weakened or lost.

Even one single branch from below may straighten up (*Epinasty*) and develop a secondary crown (*Reiteration*; Oldeman 1974). The purely morphological description can be used for tree work, if we assume, that the different patterns are the result of the actual quality of competition, typical of a certain tree at its present age.

During a tree's long life the crown may change its hierarchy and even its branching pattern (*Crown Metamorphosis*, Edelin 1986; Pfisterer 1998 b). Crown metamorphosis occurs in all tree architectures typical of temperate climate (except palms and bamboo). Competition and metamorphosis as its result can be used for planning tree work.

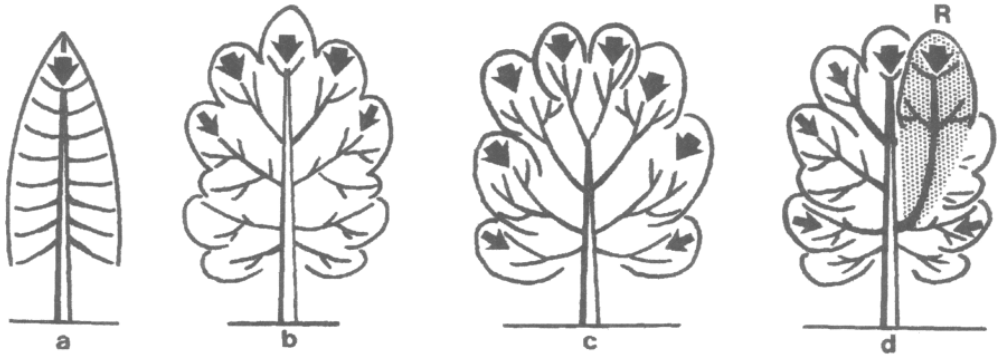


**Figure 1**: Various degrees in competition.
**a** Tree crown with absolute hierarchy.
**b** Small colony of codominant leaders.
**c** Polyarchically organized canopy.
**d** A suppressed branch has produced a reiterat (R). After having reached the canopy the reiterat develops a dominance similar to the leader.

In addition to the concept of competition there is another model which is important for natural pruning: the catalogue of Tree Architecture, revised for tree work.

Models of Tree Architecture

In 1970 Francis Hallé and Roelof A.A. Oldeman published their 23 models of tree architecture (Hallé and Oldeman, 1970, Hallé, Oldeman, Tomlinson, 1978). For temperate climate, the catalogue can be reduced to ten. The models describe the different branching patterns and growing strategies in woody plants. Trees of a similar architecture can be pruned similarly. The authors named their models after famous botanists; for better understanding typical trees are added in brackets.

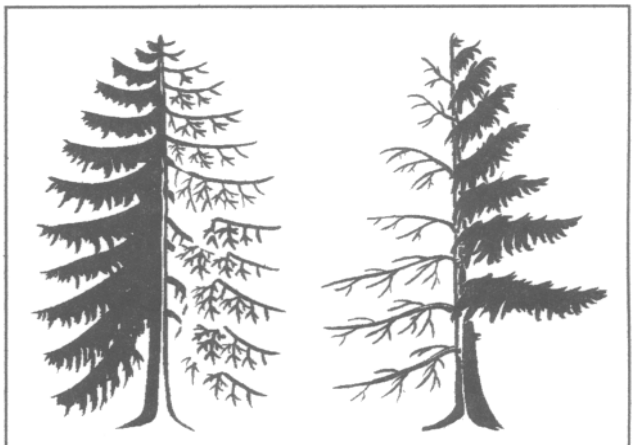

Figure 2: Massart's Model (left) and Attim's Model (right)

Massart's Model (*Abies* Type), Attim's Model (*Cupressus* Type)

Trees with an orthotropic trunk with tiers of plagiotropic branches. Massart's Model: regular tiers (e.g. *Abies, Picea, Sequoia, Metaseqoia, Cedrus, Taxodium, Taxus, Ginkgo, Ilex aquifolium*). Hierarchy may be complete or it may decline when the tree grows old (*Cedrus, Ginkgo, Ilex*). Attim's Model: in temperate climate there is one family only: *Cupressaceae*. Branching is less regular. Pruning of both models is similar. Crown thinning and raising is recommended. Crown reduction is difficult. Heading leads to a multiple crown.

Rauh's Model

The architecture is determined by a monopodial trunk which grows rhythmically and thus develops tiers of branches, the branches themselves being morphogenetically identical with the trunk. One of the most popular architectures in temperate climate. For the purpose of pruning the concept of this model was too wide ranging, including trees with a regular growth such as pine, poplar and maple, trees with a more irregular growth such as live oak, walnut and most of the fruit trees and thirdly shrubs of both branching patterns regular: e.g. cornelian cherry, irregular: e.g. hazelnut, juneberry. For practical use it was necessary to divide this model into three sections (section I: trees of regular growth, section II: trees of irregular growth, section III: shrubs, Pfisterer 1998 a). To separate the shrubs was not necessary, their reactions after being pruned are similar. Shrubs of this architecture show an extreme basitony and mesotony. This is why pruning inside an axis is not recommended.

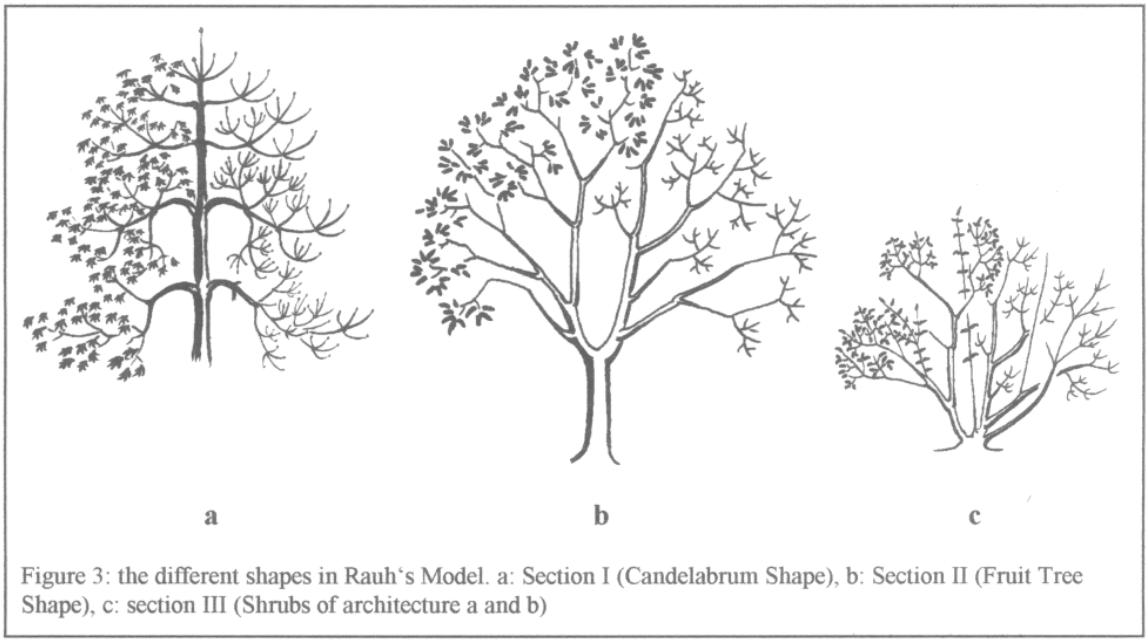


Figure 3: the different shapes in Rauh's Model. a: Section I (Candelabrum Shape), b: Section II (Fruit Tree Shape), c: section III (Shrubs of architecture a and b)

Rauh's Model, Section I: Candelabrum Shape (*Acer-Pinus* Type)

Candelabrum-like crowns (e.g. *Pinus, Acer, Populus, except P. tremula, Quercus rubra*). Lateral branches preferredly develop at a shoot's top leading to dense crown surfaces and bald inner parts. Crown thinning and raising are easy to do. Crown reduction is only possible if the crown is sufficiently branched in its inner parts. To keep a large growing tree small (e.g. for shade tree purposes or in a cemetery), the crown can be colonized at an early stage (removal of the leader).

Rauh's Model, Section II: Fruit Tree Shape (*Malus* Type)

Instead of terminal clusters (Rauh I) lateral buds occur in a spiral arrangement along the axis. This makes the architecture more flexible. Aged crowns are more or less polyarchic. Most temperate fruit trees develop according to this architecture, examples are *Quercus, except Q. rubra* (Rauh I) and *Q. palustris* (Massart); *Juglans, Crataegus, Sorbus* etc.).

Rauh's Model, Section III: Shrubs ( *Spinosa* Type)

Shrublike plants of Rauh's model from either section I or section II. A more distinct differentiation is not necessary because pruning is nearly the same. Their extreme mesotony is the problem. If a stem is shortened, the rest of it will be covered with reiterates next year. So shrubs of this model can be thinned only by completely removing some older axes. Most of the *Rosaceae* e.g. *Amelanchier, Choenomeles, Malus x floribunda, Potentilla fruticosa, Prunus spinosa, Rosa*. Candelabrum shape e.g. *Cornus mas, Cotinus coggygia, Daphne cneorum, Hippophae rhamnoides.*

Troll's Model (*Fagus* Type)

The second architecture which is very popular among temperate trees and even more flexible than Rauh's model. In contrast to Rauh II Troll's model describes tree forms typically decurrent. All axes develop pla-

giotropically, the architecture being built by their continual superposition. Young trees may develop a leader, aged crowns usually are polyarchic. Pruning is similar to Rauh's model, section II (*Malus* Type). *Carpinus, Celtis, Fagus, Tilia, Ulmus,* and one coniferous genus, *Tsuga*.

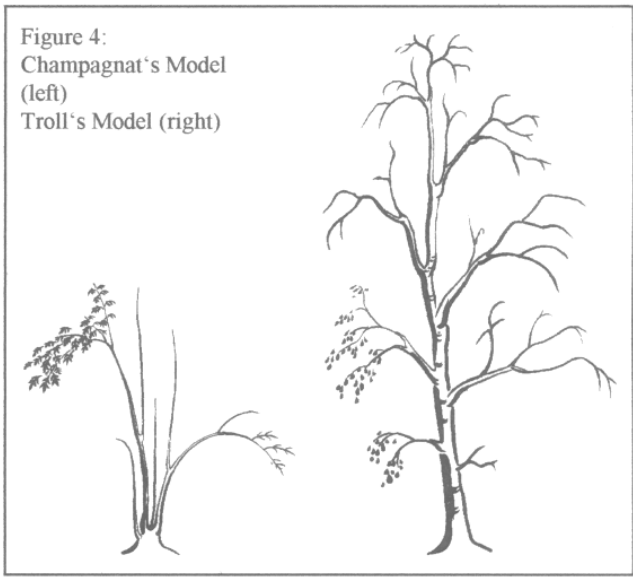

Figure 4:
Champagnat's Model (left)
Troll's Model (right)

Champagnat's Model (*Sambucus* Type)

Shrubs of an architecture resembling Troll's model. Shoot elongation is done with reiterates (mesotony). Reiterates occur from the base (basitony) or an axillar bud develops into a new leading branch (mesotony). Aged main axes can be pruned back to a secondary leader without provoking reiterates. Shrubs of this model can be pruned in a more sophisticated manner than shrubs following Rauh III (e.g. *Buddleja, Forsythia, Philadelphus, Sambucus, Spiraea, Tamarix*).

Scarrone's Model (*Aesculus* Type)

Development of the trunk resembles Rauh's Model. Branches grow orthotropically, ramification is sympodial because of terminal flower buds. Branches elongate from axillar buds. In temperate climate two typical representatives: adult trees of *Aesculus* and *Liriodendron*. During their life span both species undergo a metamorphosis. Young *Aesculus* develop after Rauh I, similar to *Acer*; young *Liriodendron* develop after Massart, similar to *Ilex*. Pruning of young trees follows the rules described for Rauh's or Massart's model. In aged trees crown thinning is possible as well as reducing branches that are too long. The polyarchy of aged canopies must be respected. Crown reducing should be carried out on all or at least most of the codominant leaders.

Koriba's Model (*Ailanthus* Type)

*Ailanthus* and *Catalpa* are typical representatives of this model. In contrast to Aesculus (Scarrone's Model) the stem also develops sympodially. This is why *Ailanthus* becomes decurrent at an early stage. Crown thinning and raising is easy. Crown reduction must respect the canopy's polyarchy.

Fagerlind's Model (*Cornus* Type)

Usually shrubs. Typical representatives are flowering dogwoods, e.g. *Cornus controversa, C. florida, C. kousa, C. macrophylla*; *Arbutus*, *Enkianthus.* A monopodial stem bears tiers of sympodial branches. Flowers develop from terminal buds. Hierarchy is not very strong, Reiterates may occur from the bottom or from inner parts of branches. Trees of this architecture model develop flat canopies when aged, shrubs expose flat layers of branches on different levels. Crown thinning and removing of suckers (*reiterates*) only are recommended. In old shrubs senescent main axes can be removed completely, if young shoots have developed.

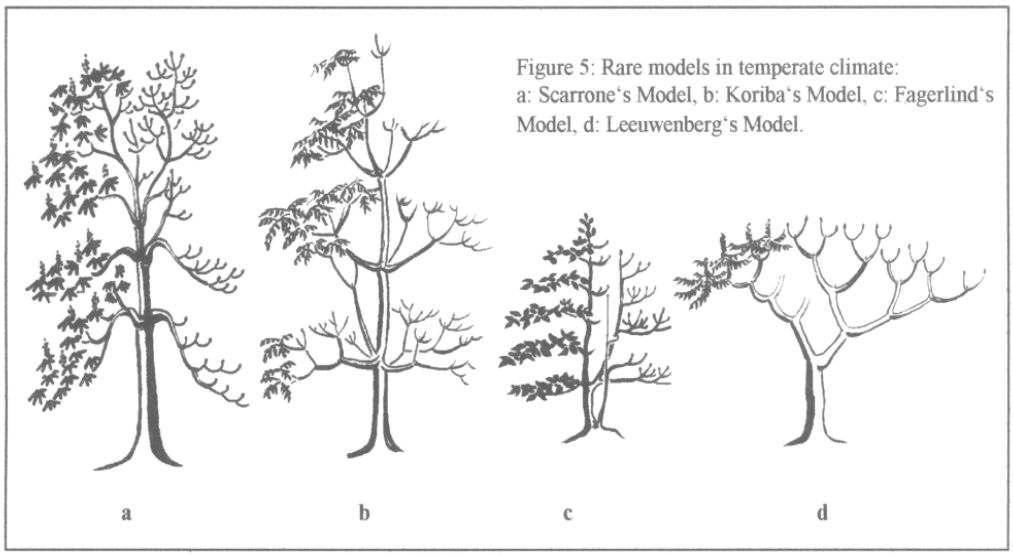


Figure 5: Rare models in temperate climate:
a: Scarrone's Model, b: Koriba's Model, c: Fagerlind's Model, d: Leeuwenberg's Model.

Leeuwenberg's Model (*Syringia* Type)

The model with the most polyarchic architecture in our parks. Adult plants bear terminal flower buds on every branch. Branch elongation occurs sympodially by lateral buds; terminal buds usually develop a flower. Side branches show similar dominance. No leader exists, old plants have flat canopies. Plants typical of the architecture are *Rhus, Syringia, Pieris, Rhododendron*. Crown thinning and lifting is easy to do. Crown reduction is only possible on small twigs. Buds for rejuvenation should be visible. Pruning back to sleeping buds will damage the natural structure for years.

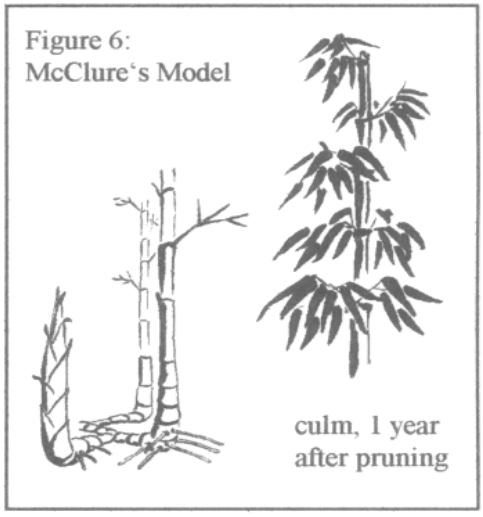


Figure 6:
McClure's Model

Mc Clure's Model (*Bamboo* Type)

Two distinct systems of axes: plagiotropic rhizome systems underground, above ground grass like stems of two different axes. Main axe bald and orthotropic, side branches in layers and bearing leaves. Orthotropic axes do not reiterate and stop growing after an extension which is genetically determined. Axillary buds exist at the bases of side branches. A main axe pruned back cannot extend a second time. If side branches are shortened, axillary buds reiterate dense layers of foliated branches.

Discussion

Modern morphological tree models can contribute to a better understanding of a tree's development either undisturbed or disturbed. The individual architecture of a certain tree is the result of three genetically determined regulating mechanisms, BRANCHING PATTERN, COMPETITION between the axes within a tree's crown and the ability to REITERATE. Ramification, typical of a certain variety leads to a corresponding branching pattern of stem and crown. The quality of competition leads to a certain organization pattern within a crown. A dominant leader will develop a new crown organized in an absolute hierarchy.

Weaker leaders develop crowns with a less strict hierarchy. Leaders of similar or weak dominance lead to polyarchic crowns or shrub-like forms. The ability to reiterate decides how a tree will react to a traumatisation. Reiteration from sleeping buds leads to new shoots (i.e. suckers) polyarchicly organized. Reiteration by epinastic movement of an existing branch leads to a new shape of crown which is nevertheless organized in a fashion similar to the crown before it was traumatized.

Observation of the different mechanisms regulating a tree's individual shape assists in the planning of any tree work in strict accordance with the particular tree's nature (Pfisterer 1996, 1997, 1998 b, 1999 c). A tree can naturally be pruned for different purposes (Pfisterer 1999 a), rejuvenated (Pfisterer 1998 d) and even Bamboo plants can be pruned according to their nature (Pfisterer 1999 e).

Summary

Modern models in tree morphology refer to our actual knowledge of plant physiology and recent research with branching patterns and growing strategies of woody plants. The article refers to the practical use of recent tree models typical of woody plants in temperate climate: the *Model of Competition* and the *Models of Tree Architecture*. The models serve as a basis for a program in natural pruning.

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