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The Hamburg Tree Pruning System – A framework for pruning of individual trees

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Abstract: Trees in urban areas are pruned for several reasons. Each pruning cut causes a wound, which leads at least in the exposed wood at the wound surface to discoloration and decay. The extension of the resulting defect depends on wound diameter, tree species, time of wounding, wound treatment, and last but not least the attachment of the branch to the stem. The effects of different pruning cuts on urban trees has been investigated in Hamburg, Germany, since 1985. The study of 750 different pruning wounds on typical urban tree species lead to the Hamburg Tree Pruning System (Hamburger Schnittmethode). The system is described in this paper and answers the following questions: How should branches with and without a branch collar be removed? How should dead branches be removed? How should branches with included bark or codominant stems be removed? What are the differences between tree species in wound response? What is the maximum wound size which will be effectively compartmentalised by the tree?

Key words: Arboriculture, pruning, discoloration, decay, compartmentalisation

Introduction

Trees are pruned for several reasons: forest trees are pruned to produce high class timber, trees in urban areas are pruned e.g. for safety reasons and along highways and power-lines for clearance. While extensive studies on the pruning of conifers have been available for a long time (e.g. Mayer-Wegelin 1936, 1952), the first detailed research on tree pruning of deciduous trees was carried out by Shigo and staff (Shigo et al. 1978, 1979; Green et al. 1981; Shigo 1984, 1989). In Germany the results were first introduced at an arboricultural conference in 1984 and caused feelings of confusion and protest in the following years. Until then in Germany, the flush cut had been regarded as the correct method when removing a branch back at the stem. Since then, the main question has been whether Shigo's alternative method of cutting to the outside of the branch collar is better for the tree than flush cuts.

Because a lot of branches have e.g. no branch collar or included bark in the fork further investigations were done about the wound reactions after pruning of branches with different attachments to the stem. This paper summarises the results of altogether 750 pruning wounds and gives recommendations for the arboricultural praxis.

Material and methods

A total of 750 different pruning wounds were inflicted on 115 street and park trees (Dujesiefken and Liese 1988) by comparing different cut locations. The branches were attached differently to the stem, e.g. with or without branch collar and codominant stems with and without include bark in the fork, but no epicormic shoots. The trees differed little in vigor, age and existing damages. Most trees were 60–100 years old and were growing in urban sites. Trees included 15

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maple (*Acer* spp.), 15 beech (*Fagus sylvatica* L.), 25 oak (15 *Quercus robur* L., 10 *Q. rubra* L.), 15 lime (*Tilia* spp.), 10 poplar (*Populus* × *euramericana* [Dode] Guenier) and 15 horse-chestnut (*Aesculus hippocastanum* L.). Additionally 10 apple (*Malus* spp.) and 10 cherry (*Prunus* spp.) trees were pruned, which were nearly 20 years old.

One year after pruning, four trees which contained 44 pruning wounds were felled for dissection in radial direction to measure the area of discolouration as an indicator of compartmentalisation, the dieback of the cambium at the lower margin of the wound and the thickness of the callus (Dujesiefken et al. 1988). Additionally the attachment of the branch to the stem (e.g. with or without branch collar, with or without included bark) were recorded. Also the branch diameter (cm) and the wound size (cm^2) according to the cut location were measured. Afterwards the wound reactions especially of the different cutting approaches, wound sizes and branch attachment to the stem were compared and the collected dates statistically analysed. Four years after pruning, 64 additional trees with 351 pruning wounds were investigated in the same way (Dujesiefken 1991). After six years another 268 pruning wounds from 37 trees were analysed. Nine and ten years after pruning compartmentalisation was evaluated on 87 different pruning cuts of six lime and four horsechestnut trees (Dujesiefken et al. 1998; Stobbe et al. 1998).

In the first year of the study additionally a total of 60 branches without a branch collar of maple, horse-chestnut, birch (*Betula verrucosa* Ehrh.), hornbeam (*Carpinus betulus* L.), oak and lime (10 per species) were reduced to a stub of 10 cm and examined after one year to answer the question where reaction zones were formed (Dujesiefken 1991).

Results and discussion

How to cut branches with and without a branch collar?

Flush cuts led to two to three times bigger wounds than branch collar cuts. Flush cuts developed more callus tissue at the wound edges after one growing season, but the wound closure was faster at the branch collar cuts than at the flush cuts because of the smaller wounds. Ten years after pruning only small wounds were closed completely and most pruning wounds from more than 5 cm in diameter were still open (Fig. 1a and b). Additionally, flush cuts led to much more discoloration in the woody tissue and caused extended cambial dieback at the wound edges compared to branch collar cuts (Fig. 2).

These results confirm Shigo's recommendations for pruning at the edge of the branch collar (Shigo et al. 1978, 1979) and also accord with findings from Neely (1988).

Right from the beginning of the study it was obvious that many branches, especially in the upper crown, do not have a branch collar and sometimes additionally have included bark inside the fork. If a branch without

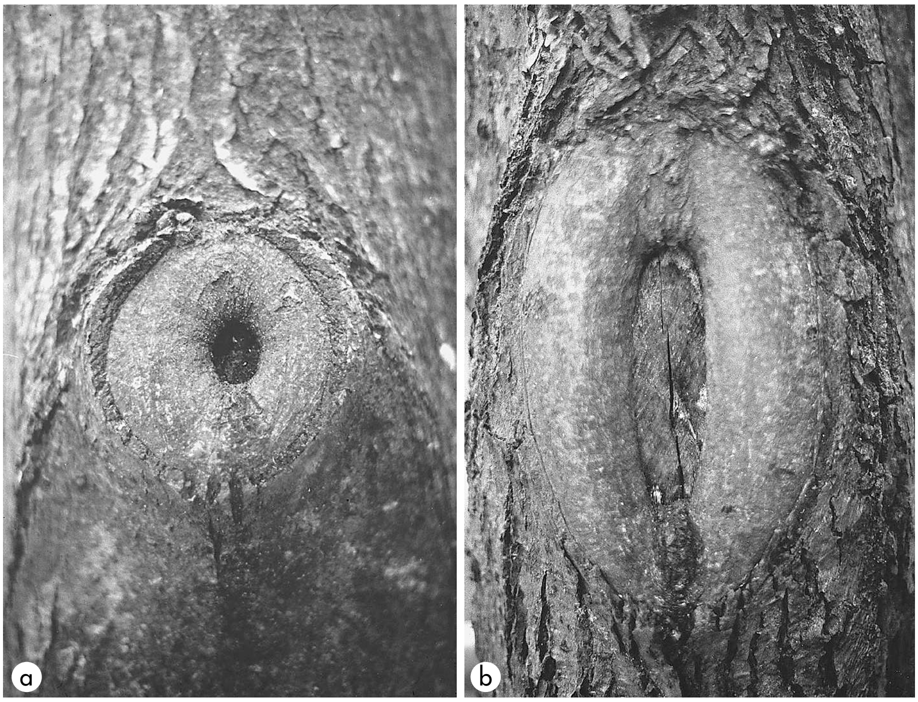


Fig. 1. a: *Tilia* spp., branch collar cut, formation of wound wood nine years after pruning.
b: *Tilia* spp., flush cut, wound wood nine years after pruning; the wound is less closed than the branch collar cut.



Fig. 2. *Aesculus hippocastaneum* L., compartmentalisation of two similar sized branches nine years after pruning, radial view; left: flush cut with big discoloration reaching far into the stem; right: small discoloration after branch collar cut, restricted solely to the area of the branch base.

Fig. 3. Slanting pruning wounds on branches without visible branch collar lead to cambial dieback on the lower margin of the wound.

Fig. 4. Funnel-shaped reaction zone at the base of a branch with a branch collar, radial view.


Fig. 5. S-shaped reaction zone formed one year after stub-cut at the base of a branch without branch collar, radial view.

Fig. 6. A branch with included bark usually has no collar and a lip-like rib instead of a branch bark ridge.

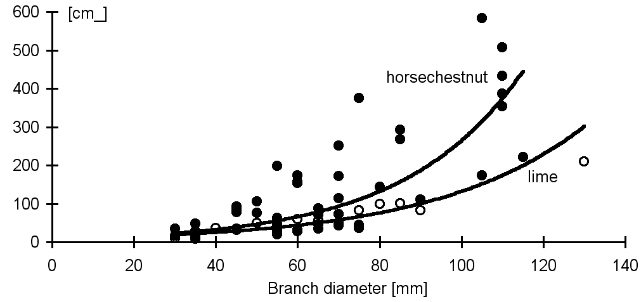


Fig. 7. *Tilia* spp. and *Aesculus hippocastaneum* L., the area of discoloration inside the trunk depends on the branch diameter.

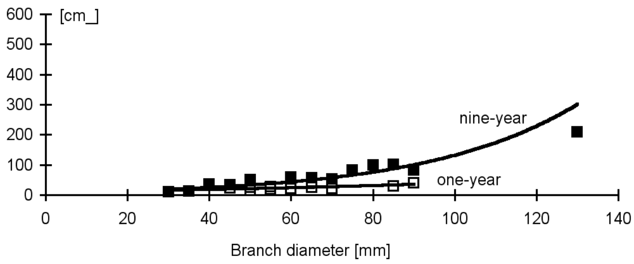


Fig. 8. *Tilia* spp., extension of discoloration in accordance to branch-diameter one and nine years after pruning.

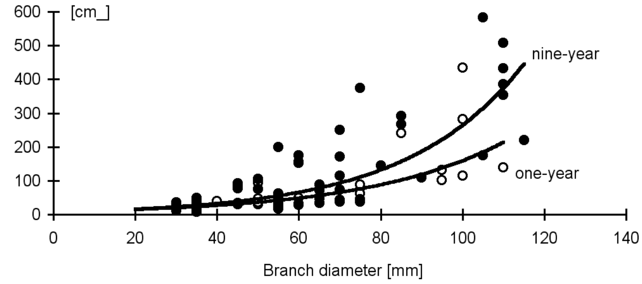


Fig. 9. *Aesculus hippocastaneum* L., extension of discoloration in accordance to branch-diameter one and nine years after pruning.

a collar was pruned with a slanted angle to the stem, the cambium at the lower margin died back several centimetres. Therefore the wound size increased, and at the lower margin of the wound a little dead stub developed (Fig. 3). The wound wood grew only partially over the cut surface, so that the wound closure was slowed down.

It was also evident for all trees in this study, that branches with branch collars normally formed a funnel-shaped reaction zone in the area of the swelling (Fig. 4). The wound wood developed on the outer margin of the branch collar where the reaction zone contacts the cambium which is in line with findings by Dujesiefken et al. 1991 and Eisner et al. 2002 on.

In branches without a branch collar the shape of the reaction zone was different (Fig. 5). Instead of a funnel-shaped a S-shaped reaction zone was developed. On the upper side of the branch the reaction zone was formed near the branch bark ridge, like in branch stubs with a branch collar, but on the lower side the reaction was closer to the stem.

The points where the reaction zones contacts the cambium on the upper and on the lower side of the branch bases in Figure 4 and 5 show the location for the pruning cuts: branches with collar should be removed outside the swelling at the base of the branch (mostly in a slanted angle to the stem), and branches without collar should be removed also outside the branch bark ridge, but with a more parallel cut to the stem to avoid the formation of a dead stub at the lower margin of the wound. This cut is not a flush cut, because the branch bark ridge remains at the stem, and the cut is more outside the stem. The wound is a lot smaller than the flush cut and oval shaped. The cambium at the wound edges is supplied with assimilates, therefore the tree can wall off the wound directly from the wound edges. With this cut the smallest possible wound and the best closure are possible. This cut is also part of the European Tree Pruning Guide (1999).

How to cut dead branches?

Dead branches usually have a swelling of living tissue at the base – like a collar – formed by the stem rather than by the branch which is invaded by various wood destroying fungi (Butin & Kowalski 1983a, b, 1986). Close to the stem, wood decay in the dead branch is particularly intensive and creates a breaking point. Just as branch collars should not be cut when pruning live branches, neither swollen areas of living tissue at the bases of dead branches should be removed.

Insufficient compartmentalisation in the stem is usually only observed in thick dead branches and in less vigorous trees. In these cases neither a visible branch collar nor a swelling at the base can be found (Aufsess 1975). Such branches respectively cut wounds from thick dead branches always require surveillance, especially at trees in urban areas for safety reasons.

How to cut branches with included bark or codominant stems?

Included bark occurred nearly in every tree species, but very often in *Fagus*, *Prunus* and *Tilia*, and it developed frequently in V-shaped forks and between codominant stems (Fig. 6). Included bark means inner and outer bark that forms between the branch and the trunk. The vascular cambium turns inward within the branch bark crotch. The branch bark ridge turns also inward and forms a lip-like rib or ridge. Branches with included bark in the crotch are poorly attached to the stem and normally have no visible collar. Such branches should be removed from the tree in an early stage, e.g. in the nursery or by formative pruning on the young tree. They should be shortened or cabled when encountered, especially when there is a split in the fork.

When branches with included bark should be removed, they must be pruned outside the lip-like rib and the cut must be straight to avoid cambial dieback at the lower margin of the wound. The observation of older cuts showed that in spite of proper pruning on top of the wound no wound wood was developed, because here the cambium is badly served with assimilates according to the included bark.

Codominant stems also occurred in all tree species in this study, but most often in e.g. *Acer, Fraxinus* and *Tilia*. The development of such stems should be avoided by removing one stem in an early stage in the nursery or during formative pruning on the young tree. If the diameter of codominant stems gets too big the stem should be reduced, not removed. This reduction slows the growth rate on the cut stem, which helps to develop into a branch rather than a codominant stem. Additionally the pruning wound and the resulting discoloration and decay is far away from the fork of the codominant stem. When removing such stems the cut must be made close to the remaining stem outside the branch bark ridge. This result accord with other recommendations (Shigo 1989; European Tree Pruning Guide 1999; Gilman 2002).

Differences between tree species in wound response

The different branch attachments being introduce above occurred in nearly every tree species, so that this framework is regarded as applicable independently of tree species and site, cause and aim of the treatment. But even the correct cutting location can lead to far reaching discoloration and decay inside the trunk. The essential parameters are the diameter of the branch and the ability of a tree to compartmentalise wounds. Several investigations about the compartmentalisation of similar wounds at different trees show that there are severe differences among tree species (e. g. Lenz & Oswald 1971; Shortle 1979; Bauch et al. 1980). In general there exist two groups of different compartmentalising trees (Dujesiefken 1991). Weak compartmentalising genera are e.g. *Aesculus, Betula, Malus, Populus, Prunus,* and *Salix*. In comparison effective compartmentalising genera are e.g. *Carpinus, Fagus, Quercus,* and *Tilia*.

Fig. 10. *Aesculus hippocastaneum* L., two big pruning wounds with far reaching discoloration inside the trunk.

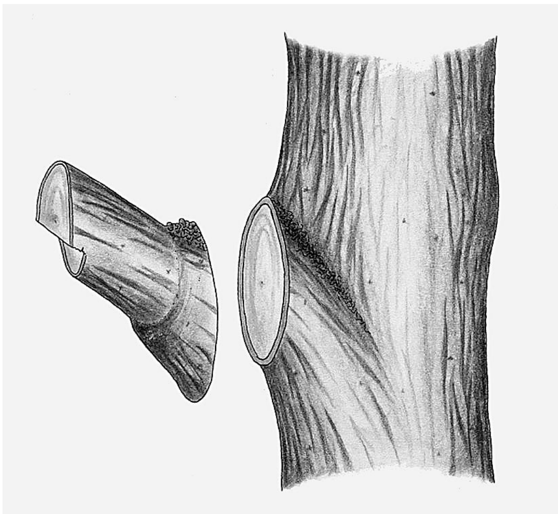
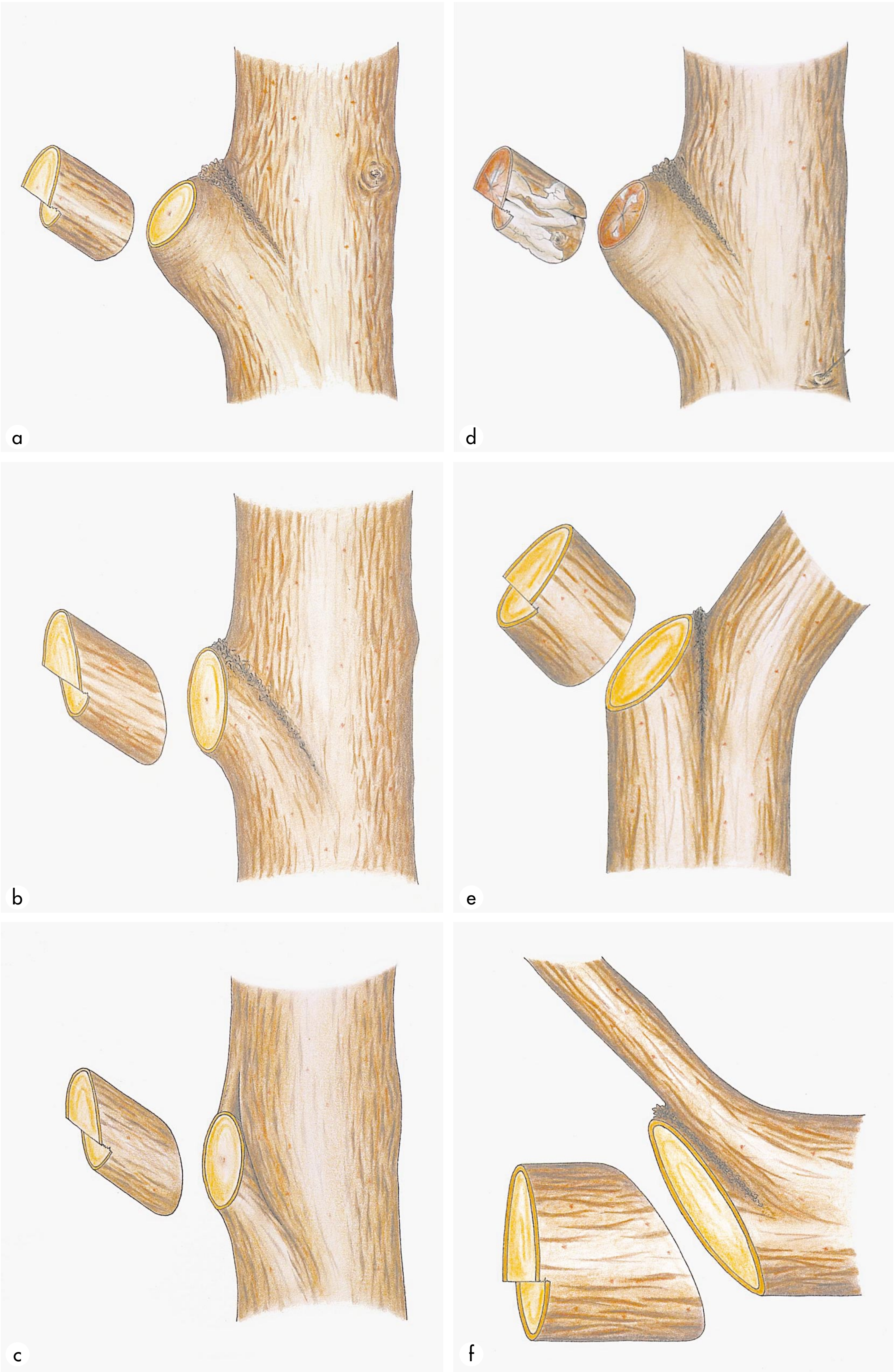


Fig. 11. Wrong pruning: the flush cut leads to big wounds and vast discoloration and must be omitted; Illustration: Gunnar Kleist.

Additionally, the mechanisms of the compartmentalisation of deciduous trees depends on the physiological activity of the parenchyma cells as well as on the availability of stored material. For that reason also seasonal periods have an influence on the wound reactions of trees. This does not only effects the expansion of the discoloration in the wood, but also the dieback of the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cambium and the callus formation at the margin of the wound (Dujesiefken & Liese 1990; Dujesiefken 1991; Liese & Dujesiefken 1996).

The maximum wound size which will be effectively compartmentalised

The size of a wound depends on the diameter of the removed branch as well as on the cutting location (Dujesiefken et al. 1988; Stobbe et al. 1998). Horsechestnut and lime have shown an exponential increase of discoloration with increasing branch diameter (Fig. 7). Horsechestnut is a weak compartmentaliser, and pruned branches with a similar diameter lead to more extent discoloration than at lime. The discoloration of nine-years-old pruning wounds of both tree species were bigger than for one year old wounds (Fig. 8 and 9). There was little difference in the area of discolouration when comparing small one and nine years old wounds. The differences in discoloured tissue increased with advancing branch diameter.

The essential cause is probably the age of the wounded tissue. Small pruning wounds only damage younger tissue, i.e. the increment of the last few years, which contents active parenchyma cells with the highest amount of energy reserve. Big cuts also injure older tissue in the centre of the pruning cut, that can not react as effectively. The discoloration in the middle of the wound reached farther into the stem than at the wound periphery, and the compartmentalisation of the older tissue near the pith seemed to be weaker than the reaction of the younger tissue.

The reaction zone formed immediately after wounding may be penetrated by microorganisms after several years, resulting in further new discoloration surrounding the initially discoloured wood (Dujesiefken et al. 1998; Stobbe et al. 1999a; Fig. 10). Penetrated reaction zones have also been described for ash, beech and horsechestnut (Pearce 1991) and other deciduous trees (Schwarze et al. 2000) in context with different heartrot fungi.

In this study all pruning wounds with a diameter less than 5 cm were effectively compartmentalised. Strong compartmentalising trees also react similar at cuts with a diameter until 10 cm. In all species greater wounds can lead to extent discolouration and decay in the stem (Dujesiefken 1991).

The Hamburg Tree Pruning System

To determine the best cut for optimal wound reaction, tree species and branching pattern must be taken into consideration. As a result of this research, the Hamburg Tree Pruning System was developed and first introduced as “Hamburger Schnittmethode” at an arboricultural conference in Heidelberg, Germany, in May 1989 (Dujesiefken 1991). Since 1992 the system has been integrated into the German rules and regulations for tree care methods (ZTV-Baumpflege). The new recommendation for branches without branch collar are also part of the European Tree Pruning Guide (1999). According to the branch attachment the cut has to be outside the trunk or stem tissue so that the branch bark ridge is not damaged and remains on the trunk. Flush cuts have to be avoided. This framework for tree maintenance is presented in the figures 11 and 12 a–f.

Regardless of the time of year and the tree species, it can generally be said that radical tree pruning, e.g. a drastic removal of crown parts or whole crowns, should not be a common practice. If possible, branches greater than 5 cm in diameter of weak compartmentalising trees, and than 10 cm of strong compartmentalising trees, should only be reduced partially rather than removed completely. The same applies for multiple stems. In some cases an installation of a crown securing system can render a hazard tree safe without any cuttings (Stobbe et al. 1999b; Lesnino et al. 2000). For arboricultural practise also information about tree crown architecture are necessary, especially for the formation of young trees and the crown restoration of mature trees (Drénou 1999; Pfisterer 1999; Roloff 2001; Gilman 2002). Anyway, tree pruning is best carried out at an early stage and in accordance to the framework given.

Fig. 12a–f. The Hamburg Tree Pruning System. **a:** The branch collar must remain at the stem, because it belongs to the stem tissue. The cut must be outside the branch bark ridge slanting downwards in accordance of the shape of the branch collar; **b:** Branches without a branch collar must be pruned outside the branch bark ridge and the cut must be straight to avoid cambial dieback; **c:** Branches with included bark must be pruned outside the lip-like rib or ridge and the cut must be straight. In spite of proper pruning it is possible that there is no cambial growth on top of the wound. Because of the included bark the cambium in this direction is poorly supplied with assimilates; **d:** Pruning of dead branches: the distinctive swelling at the base of the branch must remain at the stem. **e:** Codominant stems with more than 5 or 10 cm in diameter should only be partially reduced rather than removed completely. If removal is unavoidable the cut must be made outside the branch bark ridge and often the cambium at the lower side of the wound dies back several centimetres, because it can not be supplied with assimilates; **f:** For pruning to a lateral branch (reducing cut, in this case to the side) the cut must be made outside the branch bark ridge. Illustration: Gunnar Kleist.

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