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# DESCRIPTION OF ARBORIST METHODS FOR FOREST CANOPY ACCESS AND MOVEMENT

ROMAN DIAL[1,2]

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ABSTRACT. Arborist methods and equipment are described for climbing trees. Equipment lists and sources are provided and techniques illustrated. Many arborist methods of non-injurious access, ascent, within-crown movement, and descent are applicable to certain tropical forest situations. Arborist methods of access are most appropriate for trees with lowest limbs below 25 m above ground level; however, methods of ascent and movement within crowns are useful for any trees, including those with lowest limbs above 25 m, that can support a climber's weight. Problems presented by limbs with heavy epiphyte loads are addressed. The advantages of arborist techniques include low cost of equipment specifically designed for climbing trees; increased safety using ropes manufactured for tree climbing; greater mobility and availability of ropes for re-use within the crown; and minimum exertion for ascent and descent using the limb as pulley.

## INTRODUCTION

Canopy biology has grown expansively over the past two decades (e.g., compare Perry 1978 with Moffett 1993), particularly in the tropics. With this growth, a diversity of tree access methods has followed, but with little documentation of technique and method (but see Perry 1981, Whitacre 1981, Mitchell 1982, Mori 1984, Nadkarni 1988b, Munn 1991, Tucker & Powell 1991, Wilson 1991, Lowman & Moffett 1993, Moffett 1993, Moffett & Lowman 1994). Here we present methods of access, ascent, descent and traverse used by professional and recreational arborists (as described, e.g., in Tree Climbers International 1987, New Tribe 1993), but previously unreported in the scientific literature.

Many of these arborist methods were used in Puerto Rican rain forest canopy over a nine month period during which over 2,000 man-hours were spent executing a canopy-level exclosure experiment, measuring the abundance and transport of aerial arthropods, and elucidating a canopy food web. Thirty trees between 20 and 30 m high were climbed and re-climbed.

The techniques were applied in two lower montane, second-growth, tabonuco forests. Tabonuco forest is named for its dominant tree species, the broad-leaved evergreen tabonuco tree (*Dacryodes excelsa*), and grows on the windward sides of the mountainous eastern Caribbean Islands (Puerto Rico to Grenada) between 100 and 600 m. In 1989, Hurricane Hugo severely damaged one of the forests we studied. This disturbance resulted in abundant undergrowth <3 m high of *Piper,* a *Urera* nettle, and *Cecropia.* The other forest was relatively undisturbed with essentially no undergrowth <3 m high. In the disturbed forest *Prestoea* palms and *Cecropia* dominated the understory. Neither forest supported many epiphytes and each was structurally simpler and shorter than mainland tropical rain forests of similar climate.

Due to the requirements of experimental manipulations within individual tree crowns, we required tree climbing methods that allowed freedom of movement within crowns, comfort, and safety. We found the best methods applied traditional arborist techniques using a blend of equipment from mountaineering (ascenders, descending devices, carabiners, etriers, slings) and arborist (ropes, harnesses, throw bags, and saws) sources.

The purpose of this paper is to describe, illustrate, and provide source information for equipment and techniques allowing access, ascent, lateral mobility, and descent that are safe for the scientist and non-injurious for the tree. Partial applications and limitations of the techniques are also discussed, particularly with respect to very tall trees and to trees with heavy epiphyte loads. Solutions from the recreational tree climbing community address some of these limitations.

Our hope is that other canopy scientists will find these techniques and equipment appropriate to their own use and that canopy science will be more productive and safer as a result. For those who have never climbed trees before, these techniques provide an ideal starting point. For those

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who have been climbing for a decade or more, we hope that this paper opens up new options and advantages that can be incorporated into well-proven systems.

## Materials and Methods

Professional tree climbing in the U.S. is at least 75 yr old, as documented in an out-of-print catalog of arborist equipment provided by Sierra Morino Mercantile (Mountain View, California; see Appendix). Individual arborists climb several new trees daily and their work requires extensive within-tree movement that is both safe and inexpensive. For a $200 investment in arborist equipment and using arborist techniques, it is quite possible to safely climb 30 m trees using only a 50 m rope and a harness. With another rope and a 4 m pole saw, it is possible to traverse from one tree to another without the need to descend to the ground. The ropes used are designed for tree climbing and the harnesses for sitting and dangling. These advantages of price and applicability should appeal to budget- and safety-conscious ecologists.

### Access

The most time-consuming stage of a tree climb is often initial access. We define access as the first contact with the canopy that will then allow occupation of the crown. Once initial access is accomplished, either by arborist methods described here or by others, the arborist techniques of ascent and within canopy movement can be applied.

As Perry (1978, 1981) has described, a crossbow may send an initial line over a limb. Our experience with crossbows has been unsatisfactory. The fishing line attached to the bolt (crossbow arrow) is difficult to flake-out (to lay down so that line feeds out smoothly) without becoming tangled. Use of a variety of fishing reels, including a model specifically designed for the crossbow, increases drag on the line and dampens bolt flight. Without much control over where the bolt goes after clearing the limb, tangles and bolt loss are common. Stock bolts are too light to pull the line down to the ground; weighted bolts frequently break the bow string.

Compound bows with saltwater fishing reels and 30 pound monofilament line are used by recreational arborists to access very tall conifers in the Pacific Northwest of the United States. These climbers shoot solid, fletchless (no feathers), fiberglass arrows with rubber target tips to 40 m (Tom Ness pers. comm.). Longbows also have served canopy biologists well in accessing tall trees (30–40 m) (Tucker & Powell 1991; Tim Laman pers. comm.).

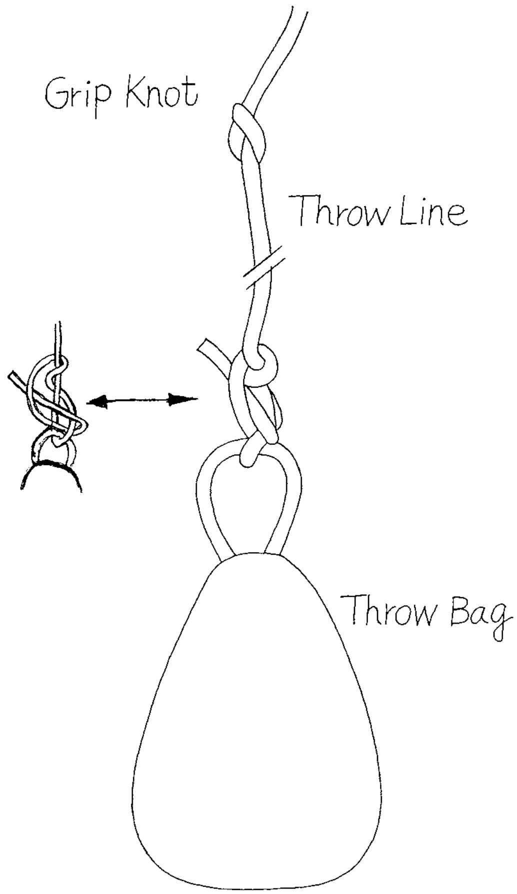
We used a crossbow to access the canopy of two of 30 trees we sampled. We also prussiked (that is, to wrap two prussik lines directly around the trunk, then alternately move them upwards to ascend) 20 m directly up the bole of one tree (prussik slings encircling the 48 cm DBH trunk). In this case, as with tree climbing spikes or Swiss tree grippers (Mori 1984), access and ascent are simultaneous. The method was slow, laborious, and uncomfortable; however, it may prove suitable for palms.

On another occasion we established a 70 m tyrolean traverse (a rope line affixed to two trees that was then traversed using harness and ascenders) through the forest to access seven trees adjacent to the traverse line. In this case each tree was accessed by throwing the arborist's throw bag (see below) or a climb line into the trees adjacent to the traverse. The tyrolean method was efficient, although somewhat dangerous and uncomfortable.

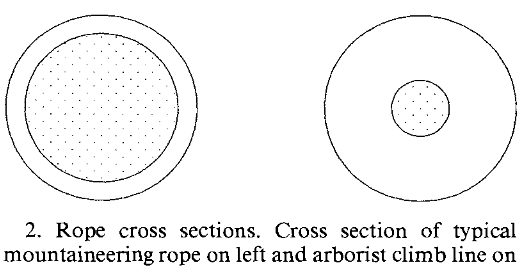
The safest and most efficient method of access was the arborist's weighted throw bag (Figure 1). We used the throw bag in 27 of 30 trees, if not for initial access, then for secondary limb access. The throw bag (also called throw weight) is a lead shot filled bag weighing about 0.5 kg. It is attached to one end of a 50 m × 4 or 5 mm diameter polypropylene throw line. The throw line is first flaked-out on the ground so that the end with the throw bag is on top of the coil. Then the climber takes a neat hand coil of the throw line together with the throw bag and throws underhand over the highest limb reachable (10–25 m).

If the tree of interest has no branches at this height or lower, a neighboring tree may be the key (see below); or devices such as spikes, crossbow (Perry 1978), longbow (Tucker & Powell 1991), or slingshot (Nadkarni 1988b) can be employed. It may require upwards of 1 hr to get the line over a 20 m limb; however, once accomplished, access is nearly guaranteed, unlike a successful monofilament shot which may break as a successive line is pulled up. We were unable to obtain a slingshot during our Puerto Rican work; however, those familiar with both throw bags and slingshots have found that the slingshot is more efficient for rigging lines between 15 and 25 m and that throw bags are faster for the lower trees (T. Laman pers. comm.).

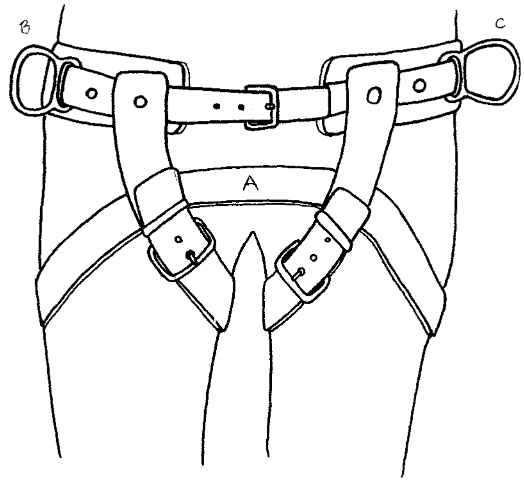
There are three clear limitations to the throw bag technique of access. The first is limb height above ground. As mentioned, most arborists can throw only to limbs approximately 20 m up. Some, with the recent technique and equipment developments of New Tribe (Grants Pass, Ore-



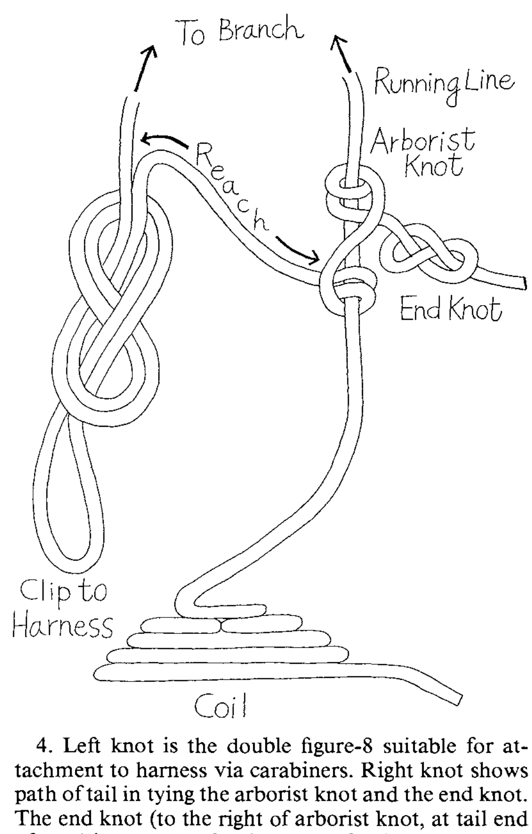

FIGURES 1–4. Important arborist equipment. 1. A throw bag with attachment knot and grip knot (overhand knot). The grip knot is 0.5 to 1.0 m from the throw bag. Dimensions of the throw bag are approximately 10 × 6 cm. A bowline works as a suitable attachment knot.



2. Rope cross sections. Cross section of typical mountaineering rope on left and arborist climb line on right. The shaded regions show the core of each rope; the sheath area is unshaded. The sheath protects against abrasion and the core gives the rope dynamic strength for holding falls. In general, there is little opportunity for falls while climbing trees using the techniques described here; instead, high abrasion resistance is required.




3. One version of a utility harness used by arborists to work in trees. Point A is the rope attachment point. Some harnesses have a permanent metal ring attached to this strap. Point B is a fixed ring suitable for the hitch knot (FIGURE 9) of a flip line which then clips with a snap link to C for use as shown in FIGURE 7.




4. Left knot is the double figure-8 suitable for attachment to harness via carabiners. Right knot shows path of tail in tying the arborist knot and the end knot. The end knot (to the right of arborist knot, at tail end of rope) is necessary for the proper friction functioning of the arborist knot. All knots are shown in a loose configuration. Reach and running lines are described in the text.

gon; see Appendix), are able to throw to 25 m (T. Ness pers. comm.). To overcome this limitation, arborists climb a nearby tree (called a transfer tree, see section on moving from tree to tree below) and throw from there. For the tallest, stands of diptocarps of Southeast Asia, this method may not be ideal for initial access (T. Laman pers. comm.); however, it still affords upward motion within many crowns where the branches are less than 20 m apart. For the largest trees, an initial access using a compound or longbow (Tucker & Powell 1991) can place the tree climber in position to move further upward using the throw bag for subsequent movements.

Oxman (1993) reports on an arborist ascent of a 100 m redwood tree in California. The ascent required mixed access techniques: spikes and flip line to access the initial transfer tree to 70 m (the 100 m target tree was too big in diameter for the spike and flip line technique apparently), followed by tying in with arborist rope and knot (discussed below) and a pendulum swing to the next transfer tree 5 m away, which was climbed for some distance before transferring into the final 100 m tree. Thus, two transfer trees, spikes, flip line, and arborist rope methods were used to climb a 100 m tree.

The second limitation concerns undergrowth and understory. If there is too much undergrowth, a small area may be cleared to provide for throwing. In the *Cecropia* and *Piper* brush of Puerto Rico, we cut a 3 m radius circle with a machete. The throw line sometimes tangled with lianas and required a change in angle of throw. When stuck, a quick tug was sufficient in all cases (except one) to retrieve it. A second bag might be a valuable addition to the kit in case the first gets permanently wedged. We used non-palm understory trees to access taller neighbors, and never found the understory problematic, although it could be in other forest types. Puerto Rico's tabonuco forests are fairly clean of epiphytes and lianas; thus, problems with the throw bag were minimal.

The third limitation is that palm trees are not accessible using this technique, since the throw line would probably lodge in the palm fronds. Moreover, the methods of ascent and movement described below would prove unsuitable for palm crowns and their fronds.

Once the throw line is passed over the limb and the throw bag retrieved, the arborist ties the 50 m × 12.5 mm diameter climb line to the throw line. Several brands of braided polyester ropes are specifically designed and manufactured for tree climbing at two-thirds to half the price of mountain climbing ropes. Twelve-strand Arborplex of Samson (Seattle, Washington) and 16-strand Safety Blue of New England Ropes (New Bedford, Massachusetts) are the most popular. Unlike nylon mountain climbing ropes, which act as dynamic springs manufactured to withstand leader falls, polyester arborist ropes are static lines with thick sheaths manufactured to withstand friction and UV degradation. Static mountain climbing ropes devote less than 20% of their material diameter to withstanding friction, whereas climb lines devote nearly 70% of their diameter to rope protection from wear. Thus, while mountaineering ropes typically devote 35% of their cross-sectional area to abrasion resistance, over 90% of the cross-sectional area of an arborist's climb line is devoted to abrasion resistance (FIGURE 2). Moreover, the handling characteristics of kernmantle ropes do not allow for use of the arborist knot. We advocate that only those ropes designed for tree climbing should be used for climbing trees.

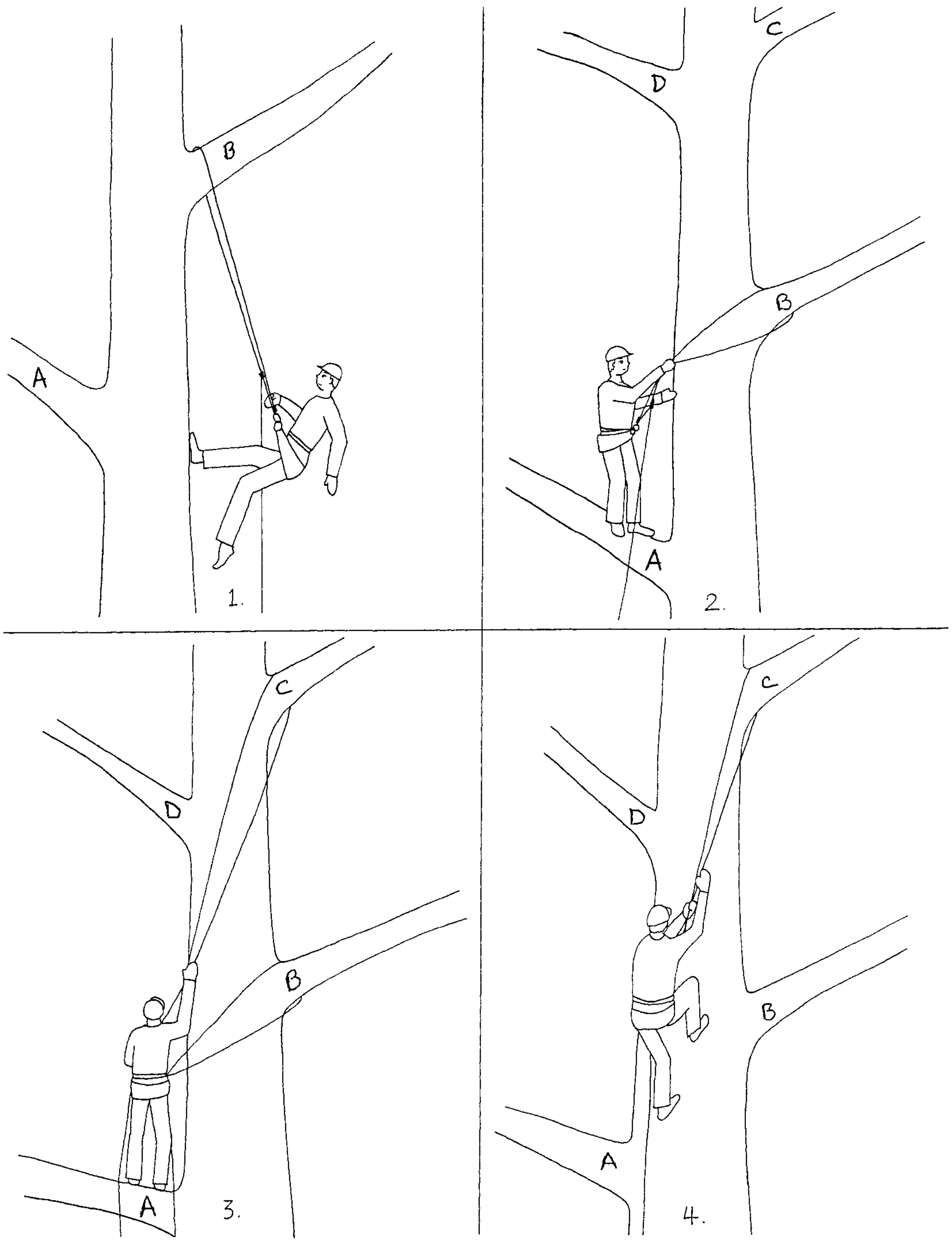
We do not coil our climbing ropes. Instead we feed them into rope bags, such as nylon sleeping bag stuff sacks. This method is faster than coiling and completely eliminates tangles when withdrawing the rope. To withdraw the rope, simply grasp the final end inserted into the bag (usually marked by the double figure-8 knot) and pull out the line as needed. Ropes are more easily packed and protected this way. One further advantage is apparent when dropping ropes for descents. By leaving the rope in the bag and then dropping the bag, tangles in branches are prevented.

Once tied to the climb line, the throw line is pulled until the climb line passes over the access limb and down to the ground. The climb line and throw line are then untied. The access limb is tested by grabbing the climb lines (both sides) and dangling, bouncing, swinging, and jerking.

### Ascent

At this point, two different arborist techniques can be applied for ascent. Both will allow for re-use of the rope within the tree climbed; that is, neither technique requires fixing the rope to ground level anchors (for example, a nearby tree trunk). The advantage of having the rope available for re-use in the tree is that the climber can move up as high as desired or possible.

The first technique, the traditional arborist technique, utilizes the access branch as a pulley. The benefit is reduced exertion during ascent. (An analogy would be carrying a 75 kg load across a room: while it is possible to carry it in one load, and while two or three loads might require more total kinetic energy, it is easier to move it in 3 trips of 25 kg each.) The disadvantage is that a tree with thin bark might suffer rope abrasion damage on the top of the limb (T. Ness, T. La-




FIGURES 5–9. The traditional arborist method of ascent.

FIGURE 5. In this overall view, Limb A is the lowest limb and serves as a stance. A throw bag and throw line were used to place a climb line over limb B. In Panel 1 the arborist uses an arborist knot to ascend. His first destination is limb A where he can stop, as in Panel 2, and prepare to access limb C. Limb C is accessed by tying a knot (monkey's fist) on the end of the rope opposite to harness attachment. This end is free because the arborist method does not require the rope to be anchored to the ground. Because the climb line is only attached to the arborist, the opposite end is available for accessing the next limb, C, as shown in Panel 3. Once the climb line is passed over limb C, the arborist can tie in, attach arborist knot or ascenders, and then detach from the

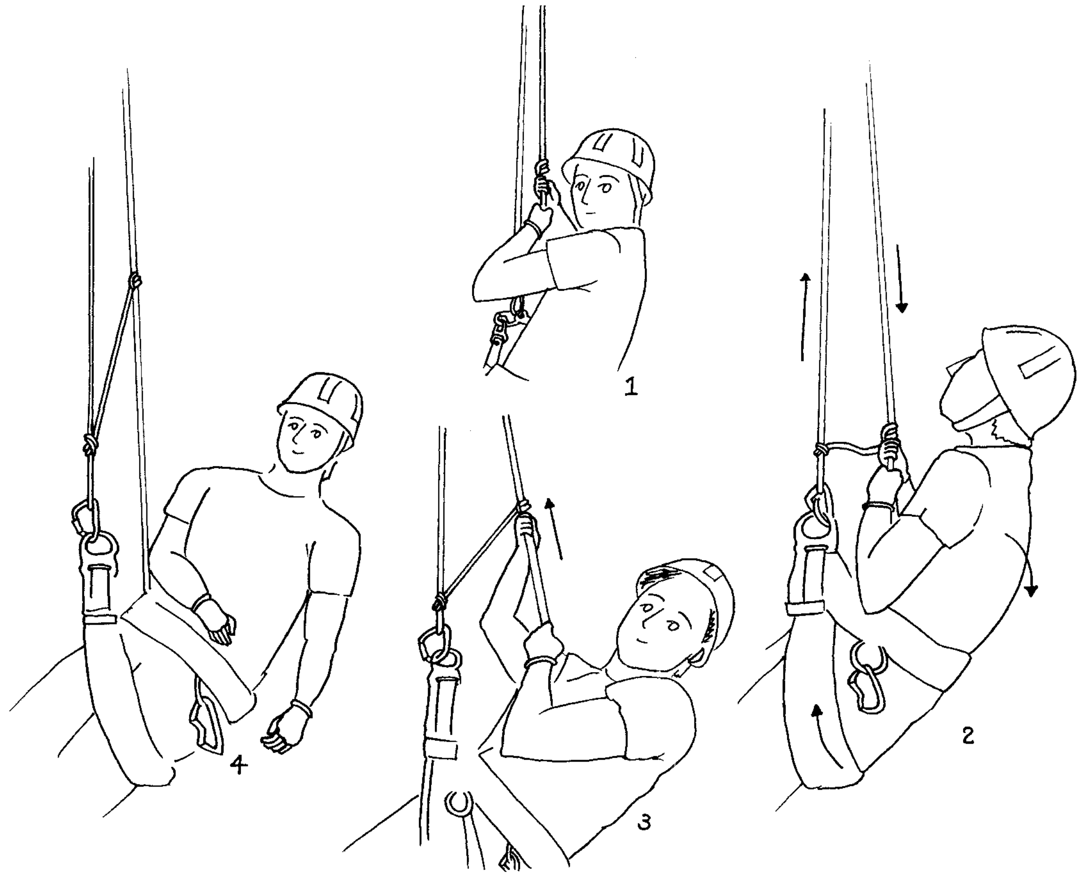



FIGURE 6. The arborist knot is used by grasping the running line below the knot (Panel 1). Then the arborist pulls down on the running line (Panel 2), simultaneously pulling the arborist up. Holding tight with the lower arm below the knot, the arborist uses his upper hand to grasp the knot, now no longer under tension, and slides the knot up to full reach (Panel 3). The arborist sits back in the harness, puts tension on the tail, and engages the knot about the running line; this leaves the hands free for work (Panel 4) or rest. The process is repeated as necessary. A single mechanical ascender could replace the knot; the sequence and method of ascent would remain identical.

man pers. comm.). While we never had a problem with this, each of our trees was only climbed on two successive days once a month for nine months. Also, if the epiphyte load is heavy, the rope will cut into the epiphytes and possibly seize, and debris may rain down as the rope moves through the organic matter (T. Laman pers. comm.).

The second ascent technique, the recreational arborist technique, requires more effort, but no more than conventional mountaineering techniques. This method is particularly well suited for limbs with heavy epiphyte burdens (T. Ness pers. comm.).

### Traditional Arborist Ascent

If the limb passes the safety test, the arborist ties into the utility-harness (FIGURE 3) approximately 2–2.5 m from either end of the rope. The

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climb line used for ascent to limb B (Panel 4). This detachment from limb B should only occur after securing with a second safety rope such as a daisy rope, flip line, or sling. The backup equipment should be attached only after limb C has been accessed, its climb line attached to the climber, and its strength thoroughly tested. In this way, a rope shorter than the tree can be used to ascend the entire tree. Alternatively, two ropes can be carried and their use alternated. If the epiphyte load is too great, a loop in the end of the rope and a carabiner can be used to snug the rope up against the limb creating a top anchor for the rope (see text).

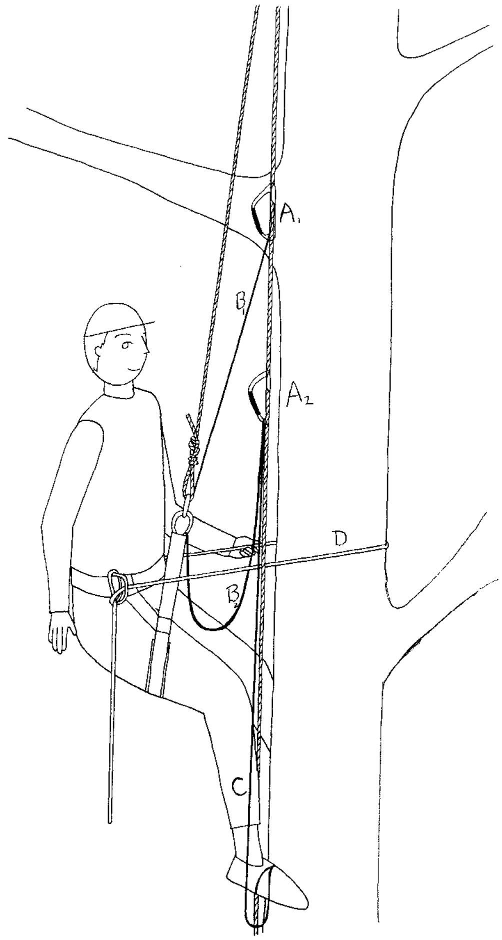


FIGURE 7. The mechanics of double ascender ($A_1$ and $A_2$) attachment to a harness are similar to those of mountaineering. Two slings ($B_1$ and $B_2$) are attached to the harness. One sling goes to each ascender. It is very important to get the sling lengths exactly right (i.e., properly adjust the reach), with one sling ($B_1$) allowing complete arm extension upwards (but NO further). The second, lower ascender sling ($B_2$) is slightly longer than an arm reach. The short sling-ascender combination ($A_1$ and $B_1$) goes above the long sling-ascender combination ($A_2$ and $B_2$). The lower ascender has one (or two) foot sling(s), C. We prefer mountaineering etriers over fixed length loops as they prove useful in other contexts (surmounting giant limbs, for example). D shows the flip line in place around the bole.

2–2.5 m tail of the rope is used to tie the arborist knot (FIGURE 4, right). To tie into a harness while maintaining a useable tail, we prefer the double figure-8 (FIGURE 4, left). This figure-8 knot forms a 10–15 cm loop which attaches to the harness via two parallel locking carabiners, their gates opposite and opposed as in many mountaineering systems.

The mechanics of the traditional arborist method of ascent differ from mountaineering/caving methods. The rope runs from the harness of the arborist upwards into the tree and over a limb, then back down and into the arborist's hands. We refer to this latter half of the rope as the running line. We use the running line to pull into the tree, benefitting from the pulley effect that the limb and line offer (FIGURE 5, Panel 1). Perry (1978) fixed the running end of a mountain climbing rope to a nearby anchor, e.g., a tree bole, and ascended the fixed line using ascenders. If the epiphyte load is great, the recreational arborist technique discussed below is preferred over either the traditional arborist technique, or the Perry (1978) method.

If desired, the traditional arborist method can be used for re-ascending trees with heavy epiphyte burdens by securing a true, mechanical pulley (as used by rescue workers) with a sling around the branch. Ascent is very smooth and easy. This might be desirable where several trees are re-sampled frequently as it reduces body fatigue.

### Arborist Knot

With sufficient strength and boldness, an arborist can hoist into the tree with hands alone. But because of the mechanical advantage offered by the line passing over a smooth limb, the weight lifted is only half body weight (ignoring friction, of course). Instead of bare hands, arborists employ the arborist knot (also known as a taut-line hitch; FIGURE 4, right and FIGURE 6) or mechanical ascenders.

Like mechanical ascenders the arborist knot engages the rope under tension; when slackened, it slides over the rope. Unlike the prussik knot (familiar from mountaineering and caving, e.g., Larson & Larson 1982), which has a bilateral symmetry, the arborist knot is tied as a single strand using an inverted symmetry. Unlike a single prussik knot, a single arborist knot can be used for ascending, descending, and traversing.

The arborist knot serves as an ascender but requires no special purchase. It can also supplement the climbing kit for those using ascenders when a second or third ascender is desirable but unavailable, as when switching from one ascent rope to another. Like all ascenders, reach (distance from the knot/ascender to the harness) is of utmost importance. The proper reach requires the knot/ascender to be an arm's length above the head. If too long, the knot/ascender ends up

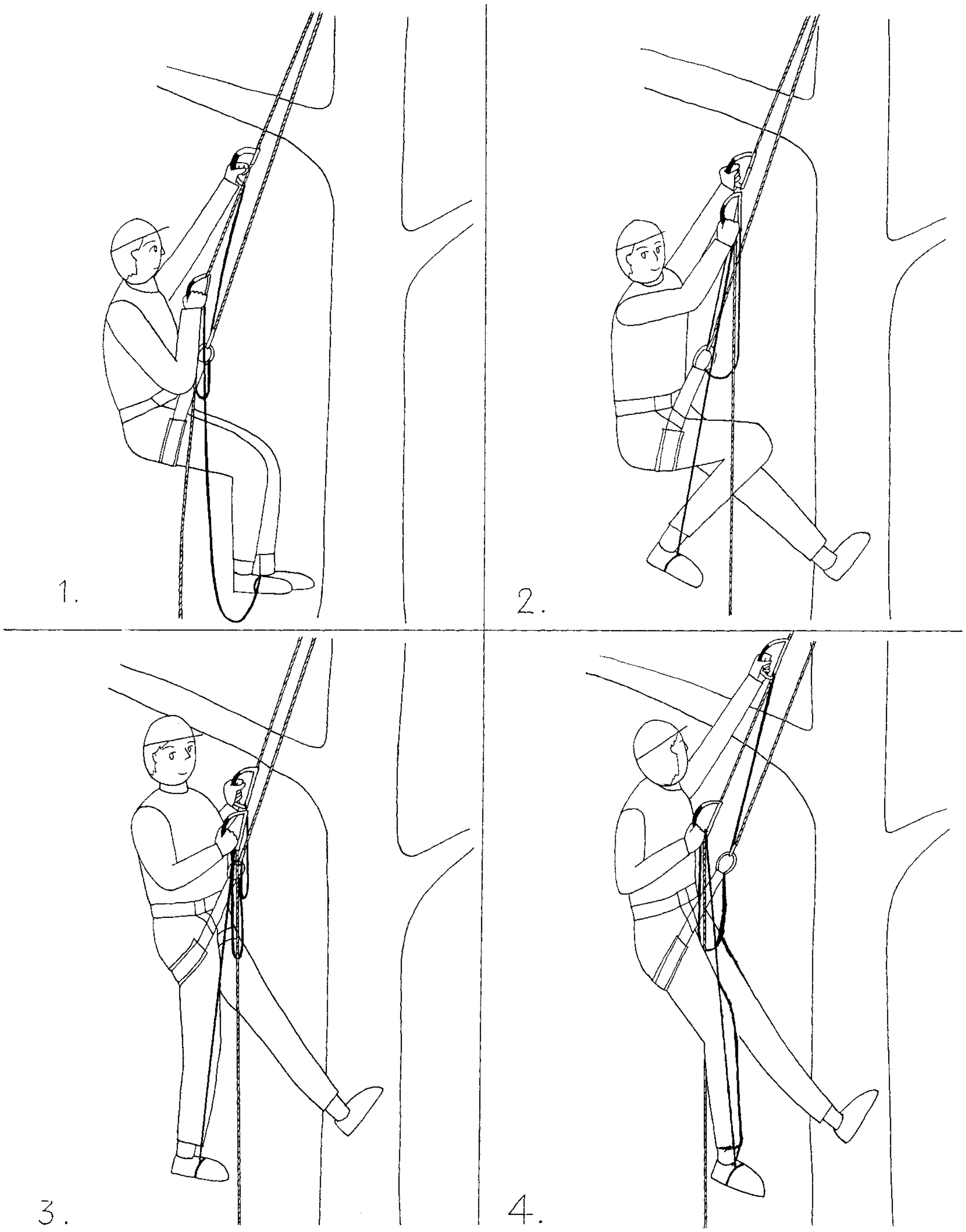


FIGURE 8. To ascend a tree, the climber slides the upper ascender as high as possible on the running line, and then sits (Panel 1). This upper ascender is now supporting the arborist's weight via the sling from ascender to harness. The lower ascender is unweighted and slid upward until abutting the upper one (Panel 2). This raises the foot slings. The arborist stands up in the higher foot slings, using both ascenders as handholds (Panel 3). In standing position, the tension is on the lower ascender, freeing the upper ascender to be slid higher. The upper ascender is slid higher and the entire procedure repeated until the limb is reached.

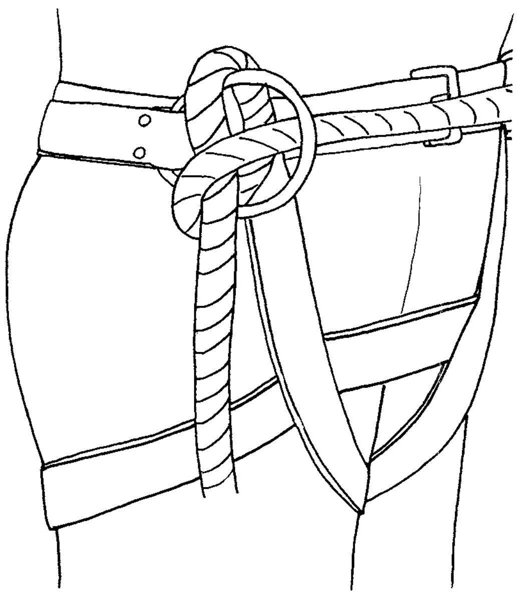

FIGURE 9. The flip line hitch tightens under tension but is adjustable with one hand. The other end of the flip line attaches with a snap link on the opposite side of the harness.

out of reach; if too short, the ascent is cramped, frustrating, and inefficient.

FIGURE 6 details how ascent is accomplished using the arborist technique. While only half the body weight is hoisted, arms may tire and hands blister (polyester-nylon blended gloves with palms criss-crossed with a rubberized substance help) over the course of a 20–30 m climb. As an ascent aid, arborists also use the foot lock, whereby the feet and knees are brought up and the rope is pinned between the feet. This allows the arborist to stand up on the rope while simultaneously pulling with the hands and sliding the arborist knot higher.

A significant disadvantage of using the arborist knot occurs if the rope runs over multiple branches: when the first branch is reached the arborist knot must be untied. This requires that the climber anchor onto the intervening branch and dangle (or mount it if possible). Now, the rope can be grabbed again above the branch (using a saw if needed to reach the rope) and then pulled over to the same side as the climber. Using one ascender and the knot, or two ascenders, can simplify the situation: if climbing with one ascender, the knot can be tied on the rope, the ascender removed and reclipped above the limb, the knot untied and the ascent continued. With two ascenders the knot can be tied to serve as back-up, and the lead ascender passed over the limb and followed by the other.

### Traditional Arborist Technique using Mechanical Ascenders

Many arborists substitute one or two mechanical ascenders, such as Clogs, Kong-Bonattis, CMI's, or Jumars, for the arborist knot (FIGURE 7). The combination of two ascenders (one with foot sling) and limb-as-pulley smooths the ascent remarkably and is easier than using the arborist knot. Even underfit novices have successfully ascended using the method that combines traditional single rope equipment (ascenders and foot slings) with arborist rope technique.

The sequence of ascender movements assumed by the arborist, i.e., alternately standing-sitting while the ascenders are alternately slid upwards, is identical to many mountaineering/caving techniques: the upper ascender is attached with a sling to the harness, the lower ascender to the harness and to a foot sling or slings. The procedure is shown in FIGURE 8. This method and the attachment of the ascenders to the running line allow for the climber to move up as if fixed rope ascending but actually self-lifting via the limb-as-pulley.

### Recreational Arborist Method

When the epiphyte load is such that the limb-as-pulley causes the sliding rope to cut into the organic mat and possibly seize, an alternative method can be used. T. Ness, a recreational arborist, recommends the use of ascenders and fixed rope for climbing trees. Ness anchors the rope to the access limb and not to a ground level tree trunk as is commonly the case in single rope technique (Perry 1978).

The technique is to tie the initial throw line (or secondary access line if using monofilament with a projectile throwing device) to the climb line and hoist the climb line over the access limb. With both ends of the climb line at ground level, the arborist now ties a double figure-8 (FIGURE 4) or bowline knot at one end (see any mountaineering or caving text, e.g., Larson & Larson 1982, for instruction to tie the bowline), and then clips a locking carabiner into the loop formed (Ness recommends a 7.5 cm screw link as safer and stronger). This carabiner is then clipped to the running line, locked, and then the running line is pulled downwards. This pulls the carabiner upward, snugging the rope like a noose around the access limb.

The rope is now fixed to the initial access limb. It has been fixed from ground level and will be available for re-use within the tree. The rope is ascended using standard caving or climbing ascent techniques (e.g., Larson & Larson 1982).

To re-use a rope within the tree, the arborist ascends the rope to a suitable limb where the rope is unweighted. Then the carabiner is unlocked, unclipped, and the noose around the tree limb is released. Like the traditional arborist technique, a climber can be dangling beneath the initial access limb with full weight on the rope supported by that limb, then pull up the opposite and free end of the rope and use it over the next access branch. By transferring weight onto the second branch and its ascent rope, the first ascent rope is unweighted and the carabiner-noose assembly can be unclipped when within reach.

### Use of the Flip Line and Utility Harness

Limbs serve as convenient stances from which to work, e.g., setting traps, marking individuals, collecting samples, etc. To enhance stability, especially with variable to high winds in many canopies, a second rope over a second limb establishes an adjustable triangulation anchor. Also, slings looped in a girth hitch around limbs and attached to the harness serve as back-up anchors.

We found that use of the arborist utility harnesses offered the most safety, stability, and comfort while climbing and working in the canopy. Rock climbing harnesses, designed for holding leader falls while mountain climbing, can become uncomfortable while dangling for long periods. Arborist utility harnesses have wide, padded leg loops and waist straps; they are very comfortable for hanging from trees. They also make tree work safer by providing for stable anchors when used in conjunction with the flip line.

The main drawback to the professional arborist's utility harness is the weight and cost. These harnesses with heavy straps, large buckles, and leather padding are both heavy and bulky. An equally comfortable arborist harness at less than one-third the weight (approximately 1 kg) and half the price is available from recreational arborist equipment manufacturer, New Tribe (Grants Pass, Oregon; see Appendix). The recreational arborist harness offers the light weight of climbing harnesses and the functionality of the utility harness.

The tie-in anchor point on an arborist harness slides 30 cm side to side, allowing freedom to twist, turn, and bend without changing the anchor torque. Two large D-rings on the harness sides (FIGURE 3) allow attachment of a flip line as an anchor (FIGURE 7). The flip line is tied to one D-ring with a simple self-tightening, adjustable hitch (FIGURE 9). The line passes around the bole and clips to the other D-ring. We found the 4 m model most suitable. A flip line serves the same purpose as a rock climber's daisy chain or cow's tail attached to an anchor, but is more convenient and functional. Care must be taken when placing the flip line around a branch not to irritate noxious creatures (T. Laman pers. comm.).

For hanging and observing over long periods of time, a more comfortable seat may be desirable. Bosuns chairs (Munn 1991) and mountaineer's portaledges (Nadkarni 1988a) have been borrowed from other applications and successfully used, whereas hunter's tree seats and insulated hammocks (New Tribe 1993) have been designed for tree use.

### Moving Higher and Moving About

Both methods of arborist ascent described above, the traditional, sliding-rope and the recreational, top-fixed rope methods, make the rope immediately available for use elsewhere in the tree. Because it is not fixed to the ground, the rope can be hauled up and used to move to adjacent limbs, higher limbs, or even adjacent trees. Many arborists take two or three 50 m ropes into the tree. Still, it is possible to continue to the tree top (or as near as the arborist dares) using only a single line by swinging leads (that is alternately using one end, then the other) as one moves upward. When making a transfer, arborists remain tied to the first ascent end while they take the opposite end and use it or a second rope to set up the next ascent. The flip line or a sling also provides for a second tie-in point and safety redundancy.

If the access limb is above or adjacent to another limb, stopping and standing at the lower limb is very convenient. The arborist uses this lower limb as a platform to reach the next access limb (FIGURE 5, Panel 2). If no limb exists below or adjacent to the initial access limb, there may be some difficulty pulling into the crotch. The situation is remarkably like being below an overhang during a rock climb. Etriers, extra carabiners, extra slings, and a fifi hook—all equipment borrowed from rock climbing's direct aid techniques—allow the equivalent of direct aid for working up the overhang. If the limb is insurmountable, the arborist can throw for another, higher limb from this dangling position.

Whether dangling immediately under the initial access limb, or standing comfortably on an adjacent limb, the principles of moving higher by using a new access limb are the same. Widely spaced branches may require re-use of the throw bag to reach the next limb. Otherwise, a neatly weighted climb line end will suffice.

A suitable method weights the end with a double figure-8 knot tied 2–2.5 m from the end and neatly wrapped by the tail. The weighted end and a few coils of rope are then thrown over the next, higher and new access limb (FIGURE 5, Panel 3).

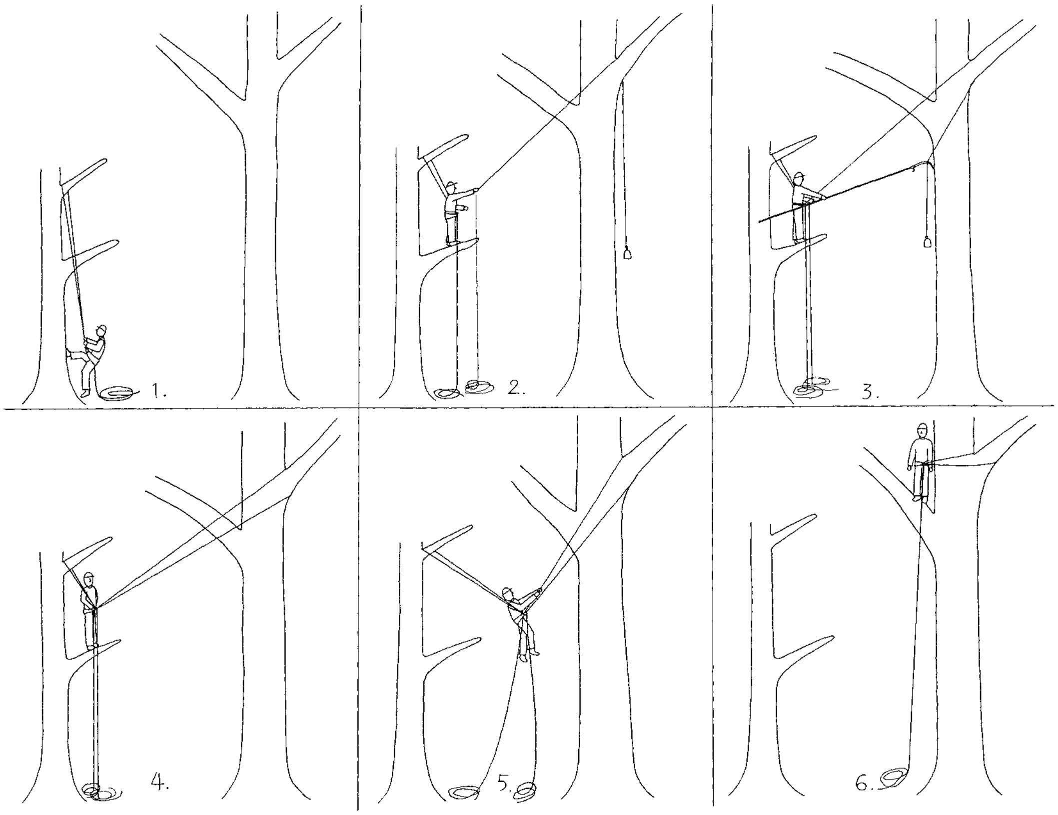


FIGURE 10. For arboreal transfer, a small adjacent tree is climbed using arborist rope techniques (Panel 1). Next, the higher target tree is accessed using a throw bag (Panel 2) and pole saw for reach (Panel 3). The arborist is attached to both ropes (Panel 4). The arborist lowers from one rope and ascends the second (Panel 5). When the transfer is complete, the first rope from the transfer tree is untied from the harness and retrieved (Panel 6).

Line flipping assists the weight in pulling the line down within reach. At this point an arborist's hand saw or extendable pole saw is useful to reach and snag the rope.

While still tied into the first rope end and branch, the climber must test a new limb for safety and then clip the newly accessed climb line to the harness using a figure-8 knot. A new arborist knot is tied about the running line using the new tail. Only now, when tied into both the initial and second limb, should the old access line be detached from the ascenders and unclipped from the harness (made safer by attaching to the bole with sling or flip line). In short, a switch from initial limb to new limb has been accomplished (FIGURE 5, Panel 4) with suitable backups in place (flip line or slings).

Many arborists carry a short 7 m piece of 12.5 mm climb line called a daisy rope for use as a miniature version of the climb line. Together with the flip line, these two pieces of gear can safeguard hand over hand climbing of closely spaced branches while trailing the long climb line. The technique is to clip in with the flip line, toss the daisy rope higher and treat it as a climb line (tie-in and ascend, or clip in both ends to harness, and hoist with one side using limb-as-pulley), then unclip the flip line and move up.

### Moving from Tree to Tree

The arborist continues moving up the tree from limb to limb, or moves laterally onto other branches or trees (FIGURE 10). Significant lateral movement requires a pole saw. (T. Ness has described using a large three pronged fishing hook tied to a throw line as suitable for retrieving lines out of reach. The idea is to throw the hook and snag the distant line, to pull it in.) Pole saws extend the arborist's reach for grabbing new climb lines or throw lines up to 5 m away. They can be purchased as either telescoping poles or in 2 m sections that can be assembled to any length desired.

An often effective means to climb a high tree is to first climb a low, adjacent, transfer tree

(FIGURE 10, Panel 1). The limb on the higher, target tree is then accessed using a throw bag and pole saw for reaching the line (FIGURE 10, Panels 2, 3), or by employing a longbow, crossbow, or slingshot. Next, the arborist ties into both ropes using the traditional arborist technique and attaches arborist knots (or ascenders) on each running line (FIGURE 10, Panel 4). By using all knots simultaneously, the arborist lowers from the transfer tree on the old arborist knot, while ascending the target tree on the new one (FIGURE 10, Panels 5, 6). Mechanical ascenders can substitute for the knots, but are not as convenient for lowering (a mechanical descending device could be used here for lowering as well).

### Descent

The safest, most controlled descents use a mountaineering/caving rappel device, backed up with the arborist knot, on a rope set up as a limb-as-pulley. Just as in ascending, the devices are applied to the running line, taking advantage of the limb-as-pulley. Again, ease, control, and safety are the benefits.

If the tree climber is dangling with two ascenders on the rope, the procedure is as follows. Sit in the harness to apply tension to the upper ascender. Attach the rappel device to the running line below both ascenders and to the harness. Tie an arborist knot about the running line directly above the rappel device. Grasp the upper ascender and pull down, simultaneously pulling the slack through the rappel device. The effect is a transfer of tension from upper ascender to rappel device. Remove upper and lower ascenders from the running line. The lower hand below the rappel device feeds the rope through the rappel device. The upper hand clasps the arborist knot to prevent its engaging, and the arborist descends. Like all other techniques described here, practise this on the ground first.

Such a descent is very controlled as the arborist is self-lowering via the limb-as-pulley. It is also very safe. Releasing the loose grip on the arborist knot will allow tension to come onto the knot, forcing it to grip the climb line and stop the descent. Starting again simply requires pulling up and loosening the knot with one hand. It is also possible to descend using only the arborist knot without any other rappel device. The technique is to hold the knot in one hand while feeding the running line through with the other.

If the epiphyte load is too great to use this technique, a traditional mountaineering rappel set up with the rope draped over the branch will suffice. If the climber intends to revisit the crown, a pulley can be installed on a sling over the epiphyte-laden limb and the arborist technique used.

In general, for trees to be re-climbed (we used 4 ropes to revisit 24 trees), we left inexpensive synthetic cord as an access line. After descending, we pulled these access lines into place with the climb line. This protects the climb lines and allows their use elsewhere.

## CONCLUSIONS

We have between us four decades of experience climbing rock, ice, and snow in Asia and North America. One of us (CT) has used single rope ascender technique during mountaineering ascents of Mt. Everest, El Capitan, and Mt. McKinley. We have also climbed with arborists who use nothing but traditional arborist techniques and equipment. Based on our experience, a blending of the two worked best for the tabonuco forest of Puerto Rico. We recognise that forests differ throughout the world and that techniques developed in one region may have limited application to the rest.

However, because of the lack of information available on arborist techniques available, we have described in some detail methods used by professional and recreational arborists to climb and work safely, efficiently, and extensively in trees. We offer these techniques to those who have never climbed as an appropriate beginning. For scientists expert in other techniques, we hope that these methods will encourage a greater diversity of field studies within canopies, including manipulations and canopy modification experiments. We trust that the next generation of canopy biologists will build on a variety of techniques, extracting those combinations that increase both safety and productivity.

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## Appendix

### Equipment, Prices in 1994 $US, and Sources

- Minimum Gear:

1. 50 m × 12.5 mm (half-inch) braided polyester climb line; $85–100
2. harness; $90–150
3. throw weight; $10
4. throw-line: 50 m of 4 or 5 mm (1/8″ or 3/16″) polypropylene line; $10

- Preferred Additions:

1. a partner
2. 2–3 more polyester ropes; $85–100 each
3. rope bags for each rope; $5–10
4. 2 ascenders with attachment slings; $40–45 each
5. daisy rope—7 m × 12.5 mm polyester climb line; $15
6. 4–6 webbing slings 25 mm (1″) × 1 m tied as 0.75 m diameter loops; $1.50 each
7. 2–3 webbing slings 25 mm × 1 m tied as 0.3 m diameter loops; $1 each
8. 15 carabiners (5 locking + 10 non-locking); $5–10 each non-locking; $8–25 each locking
9. figure-8 rappel device $10
10. 2–3 etriers or foot slings; $20–25
11. 4 m flipline; cable core $55, no core $35
12. 3–4 m pole saw with extensions; $20–90
13. 0.75–1 m hand saw; $30
14. fifi-hook; $5
15. 2 fanny packs for carrying monitoring equipment, food, water; $10–60 each
16. helmet; $10–100
17. portaledge (Nadkarni 1988a); $400–500 or hunter's tree seat (available at archery supply stores and from hunting supply catalogs); $150–300
18. slingshot ($10–20; Nadkarni 1988b), crossbow ($150–200; Perry 1978), compound bow or longbow ($200; Tucker and Powell 1991), monofilament line, reel ($20–40)

- Sources for Arborist Supplies:

1. Sierra Moreno Mercantile
   1958 Latham St.
   Mountain View, California 94040
   (800)262-0800
   or
   P.O. Box 292
   Big Pool, Maryland 21711
   (301)842-2544
   Supplier of professional arborist supplies: ropes, utility harnesses, flip lines, saws, throw bags, throw lines.
2. New Tribe
   5517 Riverbanks Road
   Grants Pass, Oregon 97527
   (503)476-9492
   Supplier of recreational arborist supplies: ropes, hammocks, harnesses, throw bags, throw lines, ascenders.

● Sources for Mountaineering Supplies:

1. A5 Adventures (Ascenders, fifi hooks, portaledges)
   1701 North West Street
   Flagstaff, Arizona 86004
   (602)779-5084
2. Black Diamond (Carabiners, slings, rappel devices)
   2084 East 3900 South
   Salt Lake City, Utah 84124
   (801)278-5552

● Source for Arborist Instruction and Information:

Tree Climbers International
P.O. Box 5588
Atlanta, Georgia 30307
(404)659-TREE

TCI publishes a semiannual newsletter and an excellent 30 page booklet on basic tree climbing techniques and offers tree climbing instruction using arborist methods.