GLACIERS AND CREVASSES • EQUIPMENT FOR GLACIER TRAVEL • FUNDAMENTALS OF GLACIER TRAVEL • CREVASSE RESCUE RESPONSE • INSIDE THE CREVASSE • RESCUE METHODS • SPECIAL RESCUE SITUATIONS • PATHS TO THE SUMMIT

CHAPTER 18

GLACIER TRAVEL AND CREVASSE RESCUE

Glaciers can offer a convenient route to alpine summits, but they hold many hazards—namely crevasses, the chasms that split a glacier as its great mass of consolidated snow flows slowly downhill. Although glacier travel is a specialized skill, it is very necessary to mountaineering; therefore, climbers must learn how to contend with crevasses.

To travel safely on a glacier, climbers first need all the basic snow travel skills outlined in Chapter 16, Snow Travel and Climbing. To that must be added the ability to detect and avoid crevasses and other glacier hazards. If climbers regard crevasses with a healthy respect, they may never fall into one. If a fall does occur, it is imperative that climbers know the techniques that provide the best chance of safe recovery and escape from a crevasse. Before stepping onto a glacier, climbers must have a clear appreciation of the dangers as well as confidence in their ability to deal with those dangers.

GLACIERS AND CREVASSES

Glaciers constantly change as snow supply and temperature influence their advance and retreat. In classic form, glaciers are like a frozen river creeping down a mountain (as shown in Figure 18-1), yet they differ from a river in many ways. Some glaciers are small, relatively stagnant pockets of frozen snow. Others are icefields of immense proportions, full of teetering forms and dramatic releases of ice. (See Chapter 27, The Cycle of Snow, for information on the formation of glaciers.)

Glacial flow patterns can be very complex, but a typical mountain glacier may flow between 150 and 1,300 feet (roughly 45 to 400 meters) per year. Most glaciers flow faster in the warmth of summer than in winter because they are lubricated by increased meltwater. Glacial flow breaks the surface of the ice into those elemental mountaineering obstacles known as crevasses.

Crevasses often form where the angle of the slope increases significantly, putting tension on the snow and ice, which then split open (fig. 18-1e). Crevasses also commonly form where a glacier makes a turn, with the outside edge usually crevassing more (fig. 18-1f); where the distance between valley walls either narrows or expands; or where two glaciers meet. Crevasses may also develop around a bedrock feature that obstructs the glacial flow, such as a rock formation protruding through the ice—a *nunatak* (fig. 18-1d). At the point where a moving glacier breaks away from the permanent snowcap or ice cap above, the large crevasse called a bergschrund is formed (fig. 18-1b). The middle of a glacier tends to have fewer crevasses than the sides, and a gently sloping glacier usually has fewer crevasses than a steep, fast-moving one.

Crevasses are most dangerous in the accumulation zone (fig. 18-1h), that portion of a glacier that receives more snow every year than it loses to melting. Here, crevasses (fig. 18-2a and b) are frequently covered with snow bridges that may be too weak to support a climber. Below the accumulation zone is the area of the glacier where annual melting matches or exceeds the yearly snowfall. Between the two zones is the *firn* line, also known as the *névé* line (fig. 18-1c), both words for “old snow.”

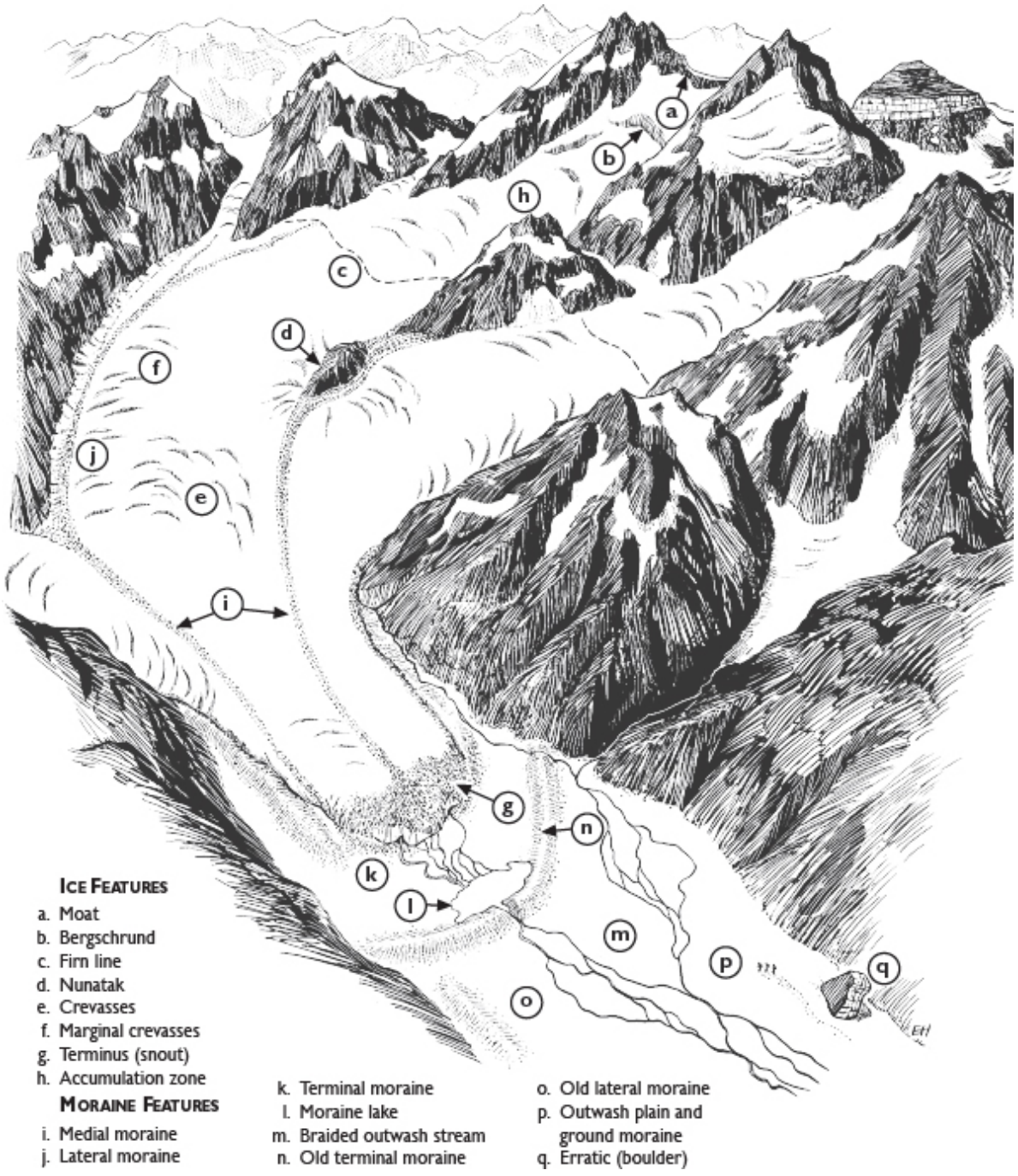

Fig. 18-1. Aerial view of a glacier showing principal features.

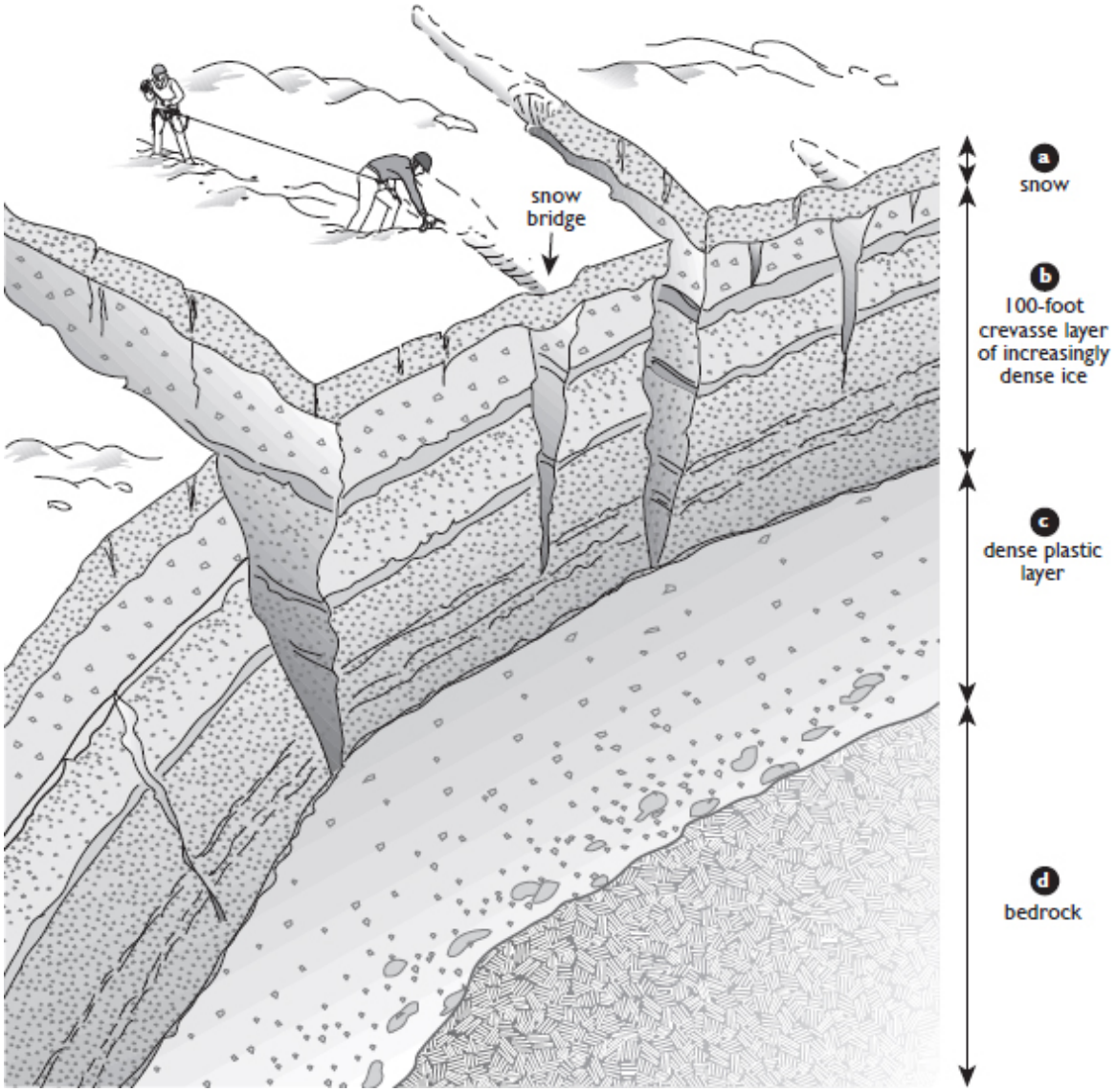

Fig. 18-2. Crevasse formation: a and b, crevasses open up in the upper snow and ice layers as glacier angle increases; c, denser lower area moves without splitting; d, bedrock.

The deeper layers of a glacier, denser and more plastic than the upper section, can move and deform without cracking (fig. 18-2c). If this deeper, older ice becomes exposed, the glacier takes on a folded, seamless appearance, often without any true open crevasses. Travel on such a glacier can be relatively simple and safe. These glaciers are usually fairly flat, with narrow, shallow crevasses that are not difficult to cross. Below it all is bedrock (fig. 18-2d).

OTHER COMMON GLACIER HAZARDS

Common hazards on glaciers beyond crevasses include: ice avalanches, moats, glacial moraines, meltwater, whiteouts, and rockfall.

Ice avalanches. Ice avalanches can pour from the steep, jumbled glacial sections known as icefalls (see Figure 16-37h in Chapter 16, Snow Travel and Climbing) when seracs (towers of ice) come crashing down (see Figure 16-37f and g). The inexorable movement of a glacier means that ice avalanches can occur anytime; their activity is only partly related to season, temperature, or snowfall. Serac collapse does seem to happen frequently during the day when the temperature rises above freezing and at night when it drops below freezing. Travel through these areas should be prudently swift if it cannot be avoided.

Moats. Big gaps that appear when winter snows melt back from a rock face, called moats (fig. 18-1a), can present major barriers to glacier travelers who need to regain the rock in order to stay on route. Belayed mountaineers may be able to cross a snow bridge over a moat or climb into the moat and back up onto the rock on the other side.

Glacial moraines. Mounds of rocky debris carried and then deposited by the glacier, called glacial moraines (fig. 18-1i, j, k, n, and o), make rugged venues indeed for mountain travel, impeding efficient movement by a climbing party. Moraines are typically steep-sided, narrow ridges with partly buried boulders ready to dislodge at the slightest touch. The moraine surface is often as hard as cement. As climbers approach the fringe where the glacier begins, there may be a soupy mix of ice and moraine gravel, or rocks skating around like ball bearings on hard ice.

Meltwater. The runoff flowing from a glacier (fig. 18-1m) can be a chilling challenge to cross. During warm weather, consider waiting to cross until the cooler hours of the next morning, when flow should be at its lowest. (See "Rivers and Streams" in Chapter 6, Wilderness Travel, for more advice on crossing rivers.)

Whiteouts. In a whiteout on a glacier, sky and snow merge into a seamless blend of white—with no apparent up or down, east or west—taxing routefinding skills to the utmost. Climbers can defend against a whiteout by taking such precautions as placing route-marking wands, noting compass bearings and altimeter readings, or recording GPS waypoints during the ascent—even when it looks as though clear weather will prevail. If snow or clouds close in and leave the climbing party in a whiteout, these simple precautions will pay off on the descent.

Rockfall. Glaciers are subject to rockfall from bordering walls and ridges. For glacier climbs, whatever the season, the general rule is "early on and early off." The nighttime cold freezes rock in place and prevents most rockfall, whereas direct sun melts the bonds. The greatest hazard comes in the late morning, when sun melts the ice, and in the evening, when meltwater expands as it refreezes, breaking rocks loose.

EQUIPMENT FOR GLACIER TRAVEL

Take a look at climbing gear with glaciers and crevasses in mind. Here are some considerations in getting ready for glacier travel.

ROPES

Ropes with "dry" treatment, although more expensive, absorb much less water from melting snow and pick up less grit from a glacier. This makes them lighter and easier to work with following an overnight freeze. The type of rope needed depends on the glacier.

Shorter 30- to 50-meter (121- to 164-foot) half and twin ropes are generally adequate for most glacier travel. The lighter, thinner rope is more than adequate for general glacier use, because crevasse falls put a relatively gradual impact on the rope due to rope friction on the snow and over the lip of the crevasse. An added advantage is the lighter pack weight.

Steep technical climbing, however, which has the possibility of severe leader falls, requires a 50- to 60-meter (164- to 196-foot) single climbing rope or two half or twin ropes used in the double-rope or twin-rope technique (see Chapter 14, Leading on Rock).

HARNESSES

For glacier travel, be sure the waist belt and leg loops of the harness can adjust to fit over several layers of cold-weather clothing. Glacier travelers also wear a chest harness, which can be made from a piece of webbing. (See "Harnesses" in Chapter 9, Basic Safety System.)

ICE AXE AND CRAMPONS

An ice axe and crampons are as important for safe glacier travel as they are for travel on any firm, sloped surface of snow or ice. The ice axe aids with

balance and provides a means for self-belay and self-arrest. If a rope mate drops into a crevasse, other climbers on the rope use their ice axes to go into self-arrest, controlling and stopping the fall. Choose an ice axe with a uniform taper from the spike to the shaft, because a blunt spike, curved shaft, and grip enhancements make it hard to sink the axe into the snow when probing for crevasses.

When walking roped on a glacier, climbers may consider tethering their ice axe to the harness. The benefit is that in the event climbers lose their grip on the ice axe, it will not get lost. The downside is that in case of a fall, climbers may get injured by the ice axe. (See "Ice-Axe Leash" in Chapter 16, Snow Travel and Climbing.)

TABLE 18-1. SIZING PRUSIK SLINGS

CLIMBER'S HEIGHT	FOOT SLING LENGTH	WAIST SLING LENGTH
5 feet (1.5 meters)	11 feet (3.4 meters)	5 feet (1.5 meters)
5 feet 6 inches (1.7 meters)	11 feet 6 inches (3.5 meters)	5 feet 6 inches (1.7 meters)
6 feet (1.8 meters)	12 feet (3.6 meters)	6 feet (1.8 meters)
6 feet 6 inches (2 meters)	13 feet (3.9 meters)	6 feet 6 inches (2 meters)

Crampons provide secure footing and enable efficient travel on refrozen snow, which is typically very hard in the early morning. A word of warning about using crampons for descending steep glacial terrain: A number of accidents and falls have resulted from crampon points getting caught on climbers' clothing or gear hanging low from gear loops. It is important to develop good habits of foot placement and gear management (see the "Crampon Safety Rules" sidebar in Chapter 16, Snow Travel and Climbing). Wearing crampons in soft snow—often encountered on descent later in the day

during warmer months—can also be dangerous, so weigh the benefits and risks of keeping crampons on as you travel.

ASCENDERS

Climbers traveling on glaciers also carry prusik slings and/or ascenders, depending on the route.

Prusik System

For personal safety, one of the most important pieces of gear a glacier traveler can carry is a set of prusik slings for ascending the rope after a crevasse fall. The slings are two loops of 5- to 7-millimeter Perlon accessory cord attached to the climbing rope with friction hitches. When a climber puts weight on a prusik sling, the hitch grips the rope firmly; when the climber's weight is removed, the hitch can be loosened and moved up or down the rope.

Though there are many ways to configure a prusik setup for glacier travel, the Texas prusik system is the focus here. Figure 18-3 shows details on how to make Texas prusik slings for the feet (fig. 18-3a) and waist (fig. 18-3b) using 6-millimeter accessory cord. As with all prusik systems, it is critical to size the slings correctly for each individual's height (see Table 18-1). Figure 18-4 shows a way to approximately gauge the correct sizing. When a climber is standing in the sling (as shown in Figure 18-20c), the top of the foot sling (fig. 18-4a) should be at about waist level and the top of the waist sling (fig. 18-4b) should be at about eye level.

Before taking the slings out onto a glacier, check their sizing at home. Dangle in the slings from a rope thrown over a garage rafter or a tree limb to find out if or whether they need to be adjusted.

The two slings are commonly attached to the rope with prusik hitches. Some climbers prefer the bachmann friction hitch because it incorporates a carabiner, which makes a good handle to use while loosening and sliding the slings because it can be gripped easily with a gloved hand. If webbing must be used rather than accessory cord, the klemheist is the best friction hitch to use. (See "Knots, Bends, and Hitches" in Chapter 9, Basic Safety System.)

Mechanical Ascenders

Some glacier travelers carry mechanical ascenders, which attach to the rope more easily than friction knots do. On icy ropes, the ascenders work better

and can be operated more readily with gloved hands. A disadvantage is that ascenders traditionally have been heavy and expensive, though a number of cheaper, lightweight devices are now available. Some models have smooth, rather than toothed, cams. These ascenders grip the rope by pure camming action, so they may be safer to use in situations where high fall forces may occur, such as in a crevasse fall. (See “Mechanical Ascenders” in Chapter 15, Aid and Big Wall Climbing.)

OTHER STANDARD GLACIER GEAR

Often each climbing party carries a shovel, which is useful in flattening campsites and in rescue situations. Each party member should also carry the following gear:

Rescue pulley. Many models of pulley have been designed for use in climbing. Pulleys for use in rescue hauling systems should be compatible with a friction hitch (that is, the pulley should not get jammed when used with a prusik or bachmann hitch). If no pulley is available, a carabiner can be used in the rescue hauling system, but it adds considerable friction.

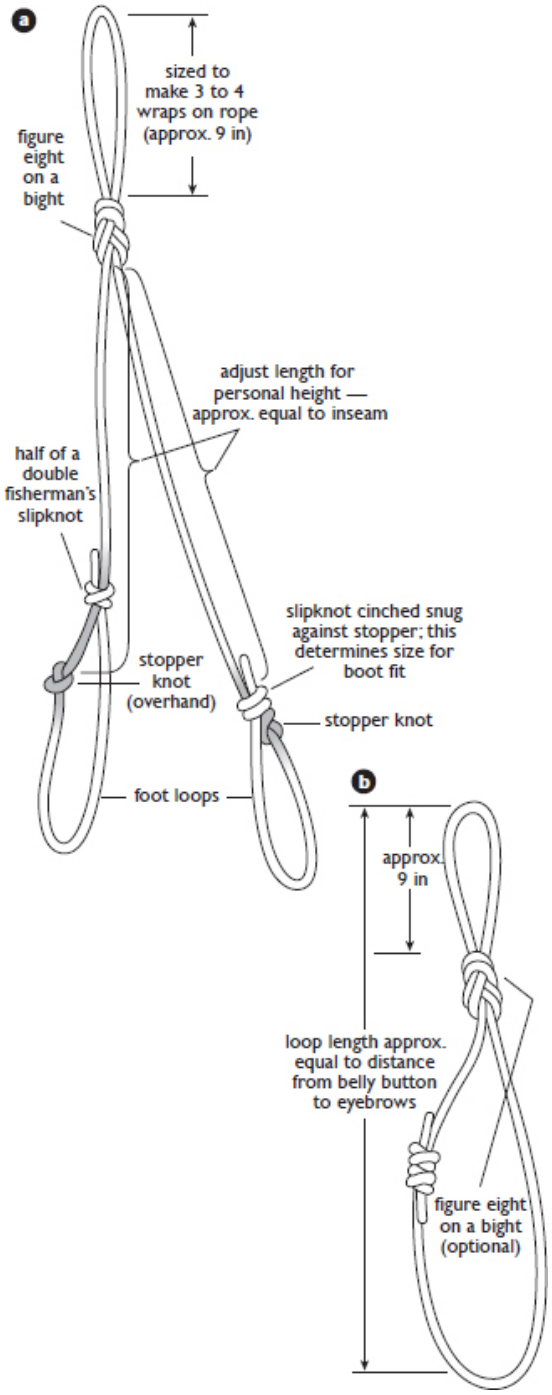

Fig. 18-3. How to make Texas prusik slings using accessory cord: a, the foot slings; b, the waist sling.

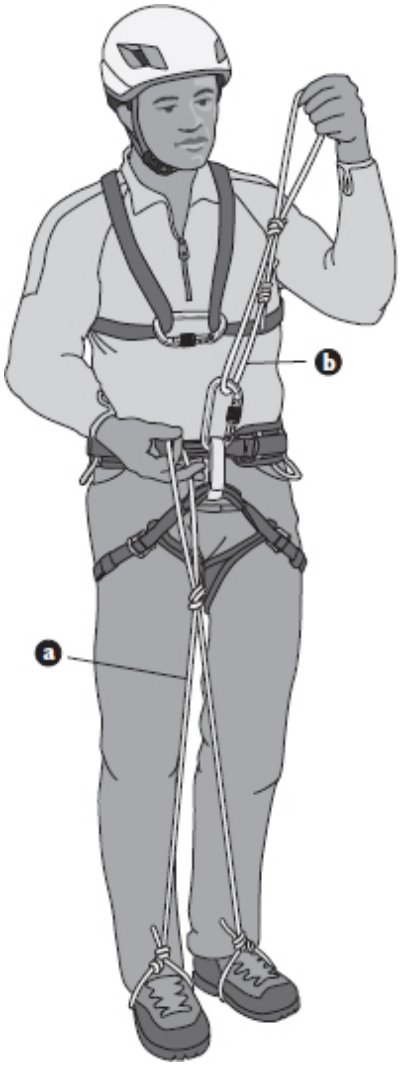

Fig. 18-4. Texas prusik dimensions: a, foot sling should extend from boots to belly button; b, waist sling should extend from belly button to eyebrows.

Anchor. If conditions warrant, carry a snow or ice anchor such as a snow picket or an ice screw. (See "Snow Anchors" in Chapter 16, Snow Travel and Climbing, and "Ice Screws" in Chapter 19, Alpine Ice Climbing.)

Runners. Bring at least one double-length and two single-length runners for attaching to anchors. Tied runners, rather than sewn runners, work better for crevasse rescue, because their length can be more easily adjusted.

Belay device. See "Using Belay Devices" in Chapter 10, Belaying.

Carabiners. Carry at least two locking carabiners and three regular carabiners.

CLOTHING

To be ready for a fall into a crevasse, climbers need to dress for the frigid interior of the glacier even when it is a hot day on top. Priorities collide here, because climbers are preparing for the cold but at the same time trying to minimize sweating.

Select outer garments that can easily be ventilated, such as pants with side zippers and a jacket with armpit zippers. Zip these closed if you end up in a crevasse. Consider strapping an insulated jacket, if you are not wearing it, to the outside of the pack, where it can easily be reached. Stash a warm hat and gloves in the jacket pockets.

For the base layer, wear a long-sleeved light-colored top that reflects the sun's heat but still provides warmth if you end up inside a crevasse. A lightweight wind jacket can take the edge off breezy conditions and serve as a valuable midlayer without taking up much space or weight in the pack. Another useful item is a lightweight neck gaiter that can be pulled up over the face or converted to a head covering for sun and wind protection. Wear liner gloves, at a minimum, to protect hands in the event of self-arrest.

SKIS AND SNOWSHOES

Skis or snowshoes are essential for winter or arctic mountaineering because they distribute climbers' weight over a larger area, thus keeping them from sinking too deeply into the snow. Skis or snowshoes also reduce the chance of a climber breaking through snow bridges over hidden crevasses, which is helpful on some glacier climbs. Snowshoes are usually more practical than skis for roped glacier travel unless all members of the rope team are highly skilled skiers (for further information on ski mountaineering, see Resources).

WANDS

Wands can be used to mark the location of crevasses, identify turning points, and show the climbing route in case a whiteout occurs on the return and the climbing team is not using a GPS device. Space between wands should be a distance equal to the total length of the climbing party when roped and moving in single file. For example, a party of nine (three rope teams on 50- or 60-meter ropes) will use 10 to 12 wands for each mile (1.6 kilometers) of glacier walking; smaller teams or climbers on shorter ropes will need more.

Wands can also be used to indicate potential danger. Two wands forming an X indicate a known danger, such as a weak snow bridge over a crevasse. Wands can also be used when setting up camp on a glacier to mark the

boundaries of the safe areas for unroped walking and the location of buried supplies (caches).

Climbers usually make their own wands using 30- to 48-inch (76- to 122-centimeter) green-stained bamboo garden stakes topped with a colored duct tape flag. Write the party's initials on the flags (and consider numbering them) to be certain the team is retracing the correct route. On ascent, insert the wands so they indicate the direction of travel, deeply enough to compensate for melting snow or high winds. Make sure to remove your wands on descent, but do not remove other parties' wands.

FUNDAMENTALS OF GLACIER TRAVEL

Climbers should be moving well before the sun rises and begins weakening snow bridges and loosening avalanche slopes. On glacier climbs, parties grow to appreciate alpine starts: the brilliance of stars at higher altitudes, perhaps the glow of moonlight on snow, the distinctive sounds of crampons on ice, the tinkling of carabiners in the still night. Sometimes the climbing party is alone on the glacier; other times, distant trains of lights show that other parties are also on the route. The magic of watching a sunrise from high on a mountain above a sea of clouds remains with a climber long after memories of the trip's exertion have faded.

Climbers should head out on the glacier with prevention in mind, practicing effective risk management strategies to avoid a crevasse rescue scenario. See the "Crevasse Risk Management" sidebar.

USING THE ROPE

When and where to rope up for glacier travel is a major decision that requires considerable experience and expertise. However, the general rule of safe glacier travel is to rope up. This holds whether or not climbers are familiar with the glacier and whether or not they believe they can see and avoid all of its crevasses. Roping up is especially important in areas above the firn line, where snow accumulates and conceals some crevasses.

It is tempting to walk unroped onto a glacier that looks like a benign snowfield, especially if climbers have gone up similar routes time after time without mishap. Avoid the temptation. Taking the extra time to deal with the rope, like wearing a seat belt in a car, greatly increases a climber's chances of surviving the most likely accident on a glacier: falling into a crevasse.

Some climbers travel unroped on certain glaciers in the area below the firn line if crevasses are stable and easily seen, but this kind of unroped travel is best left to climbers with a great deal of glacier travel experience.

CREVASSE RISK MANAGEMENT

Defending against a crevasse fall

- First line of defense: reliable footwork, good routefinding, vigilance
- Second line of defense: good rope management and glacier travel skills
- Third line of defense: adequate power to stop a fall

Rescuing after a crevasse fall

- Preclimb assignment of a crevasse rescue incident commander and backup commander
- Formulation of a simple, effective rescue plan tailored to the circumstances
- Timely, accurate assessment of a fall and its consequences
- Quick appraisal of available rescue personnel and gear resources
- Competent deployment of the rescue plan

On bare ice, which is often encountered in the late season, it is dangerous to rope up, because crevasse falls are almost impossible to arrest on hard ice. Under these circumstances, consider the conditions and determine if using a running belay would be prudent (see "Running Belays" in Chapter 16, Snow Travel and Climbing).

Rope Teams

Rope team size is a complex decision that must take into account the need for speed and efficiency, the experience of the team members, and the conditions. Generally, smaller teams are better coordinated, more efficient, and faster than larger teams. On the other hand, larger teams are better able to arrest a fall and have more haulers available for crevasse rescue. Like many climbing decisions, there are unavoidable trade-offs that are best made on the basis of skill and experience.

Rope teams of three or four climbers each are ideal for travel on glaciers where no technical climbing will be encountered. With a rope team of three or

four, more people are available to arrest a rope mate's fall or aid a climber who has fallen into a crevasse. A minimum party size of two rope teams is recommended so a team involved in an accident will have backup help.

Glacier travelers usually put three people on a 37-meter (121-foot) rope and three or four people on a 50- or 60-meter (164- or 196-foot) rope. These configurations space the climbers far enough apart so that as the rope team crosses a typical crevasse, only one person at a time is at risk. Where there are truly humongous crevasses—in the Himalaya or the Alaska Range, for example—climbers may need to space themselves farther apart. Keep in mind that under more typical glacier travel conditions, closer spacing allows for better communication and more rapid response to falls.

On technical glacier terrain—with slopes steeper than 40 degrees or with severe crevassing—belaying may be necessary, making it more efficient to travel in two-person rope teams. In this situation, having a second rope team as rescue backup becomes even more important. While the person who is on the same rope as the fallen climber holds the rope fast, the second team can set up a snow anchor and initiate the rescue (see "Crevasse Rescue Response," later in this chapter).

Tying In

It is best to tie the rope directly in to the tie-in loops on the harness—rather than tying a butterfly knot or a figure eight on a bight in the rope and clipping the loop in to two locking carabiners at the harness—because the direct tie-in does not require a carabiner (a potential weak link) to connect climber and rope. Of course, a clip-in connection makes it easy to disconnect and reconnect to the rope, but this is not normally done repeatedly over the course of a day on a glacier. Following are some general glacier tie-in procedures, depending on the size of the rope team.

Two-person rope. The most convenient procedure is to have only a portion of the rope stretched between the climbers, because a full rope length can have too much slack as the climbers weave through a maze of crevasses. Using only part of the rope also leaves some rope free for rescue use. Shortening the rope with coils is the preferred method for tying in to a shortened rope, although the remaining rope may also be stored in the climber's pack. This is illustrated and explained in "Special Rescue Situations" later in this chapter.

Three-person rope. Two of the climbers tie in at the very ends of the rope, usually with a rewoven figure eight through the tie-in loops of their harnesses (fig. 18-5). The middle climber ties in to the center of the rope, most commonly with a butterfly knot (fig. 18-6). It has the advantage of being easier to untie after having been weighted, but as noted above, it adds two carabiners to the tie-in. Use two dedicated locking carabiners opposite and opposed to clip it to the harness belay loop, separate from the carabiner for the waist prusik sling. If the waist prusik sling is on the same carabiner, it could be difficult to remove the sling should it need to be moved to the other strand of rope because the butterfly knot would be loaded with the fallen climber's weight.

Fig. 18-5. Rigged and ready end climber. Note prusik slings attached to rope—the other ends of the foot prusik sling can be clipped to the harness or stuffed in a pocket.

Four-person rope. Divide the rope into thirds. Two climbers tie in at the ends, as just described above; the other two tie in at the one-third points, as described above.

Chest Harness

The purpose of the chest harness is to keep the climber upright in case of a crevasse fall. A chest harness can easily be created from a length of tied webbing (see "Chest Harness" in Chapter 9, Basic Safety System). Put the chest harness on over your base layer, or any layers you will not be removing, before heading out onto the glacier. Adjust the size of the harness to fit snugly yet comfortably.

In most cases on nontechnical glacier climbs with lighter packs, the chest harness is not clipped in to the rope during travel. In expedition travel or when climbers are carrying heavy packs, clipping the chest harness will help them stay upright in case of a fall; not clipping the chest harness may make it very difficult to regain an upright stance inside a crevasse. Traveling with the chest harness clipped to the rope hampers the ability to perform self-arrest in case of a teammate's fall, though, because the tension on the rope comes high on a climber's body. A good compromise is to unzip outer layers enough to clip the climbing rope in to the chest-harness carabiner when crossing a snow bridge or otherwise facing immediate danger of a crevasse fall; otherwise, travel with the chest harness unclipped.

Fig. 18-6. Rigged and ready middle climber: butterfly knot and three locking carabiners (two for the butterfly knot, the other for the waist prusik sling).

Prusik Slings

Attach prusik slings to the climbing rope immediately after roping up to begin glacier travel, so that the slings are ready for use in an emergency (see Figure 18-5). The middle person on the rope will not know which end of the rope might have to be climbed after a fall; therefore, the middle climber should attach one prusik to the section of rope that goes to the climber in front and the other prusik to the section that goes to the climber behind (see Figure 18-6). After any fall, only one of the prusik slings will have to be moved to the side of the rope that must be climbed. Regardless of how the prusik slings are attached, stuff both foot loops into pockets, so they are ready to be pulled out and slipped onto the feet when needed, or clip them to the harness.

Rigging for glacier travel with a cordelette in place of the Texas foot prusik may be preferable. A single foot loop system allows the other foot freedom to balance against the crevasse wall, which can aid ascent if the unhindered crampon can make adequate purchase on the wall. This may be especially useful at the crevasse lip.

If using mechanical ascenders, do not attach them to the rope until after a crevasse fall; if an ascender receives a shock load, it can damage the rope.

Some climbers girth-hitch a sling to their pack haul loop and clip it to a shoulder strap with a carabiner, so that if they fall into a crevasse, the pack is easier to secure and take off. This also makes it easier to anchor a pack on steep sections of the glacier.

Rope Management

Following a couple of rules will help keep a roped party safe on a glacier.

No slack. The first rule of rope management on a glacier is to keep the rope extended—not taut, but without undue slack. A rope that is fully extended between climbers is insurance against a long plunge into a hidden crevasse. Increasing slack in the climbing rope puts additional force on the next climber in case of a fall (because the first climber is falling deeper into the crevasse), making it more and more difficult to arrest promptly. The falling climber therefore drops farther, increasing the chance of hitting something or becoming wedged if the crevasse narrows. For the climbers holding the fall, a slack rope can also pose the danger of causing them to be dragged into the hole too.

The rope leader should set a pace the others can follow for a long time. Consider the type of terrain the team is moving through and adjust the pace accordingly. The second, third, or fourth climbers must try to closely match

the pace of the leader so the rope stays extended. Followers should be alert going downhill, when it becomes easy to walk too fast and create slack.

At sharp turns, the rope tends to go slack when the climber in front of you heads in the new direction and then tightens when you near the turn yourself. Throughout the turn, adjust your pace to keep the slack out of the rope. At sharp turns, it is usually necessary to make new tracks, outside the leader's footsteps, in order to keep the rope fully extended—though at other times, following climbers would normally stay in the leader's path for safety and ease of travel.

To keep the right amount of tension in the rope, travel with a small loop of the climbing rope, 6 to 12 inches (15 to 30 centimeters) long, held in the downhill hand. Gripping this makes it easier to feel the progress of rope mates and adjust your pace as needed. Keeping the rope on the downhill side of a glacier keeps the rope out from under your feet and helps avoid entangling the rope in crampons.

Do not forget safety when the party reaches a rest stop or campsite. Always belay climbers into and out of a gathering place. The rope must stay extended and slack-free until the area has been thoroughly probed for crevasses. Once a safe area for the team has been established, the climber in front belays the next climber into the safe area by pulling the rope through his or her prusik, with ice axe in hand. In case of a fall, the belayer releases the rope and drops into the arrest position; the prusik hitch will hold the rope. When leaving the safe area to resume climbing, belay the climbers out using the prusik as well.

Right angle to crevasses. The second important rule of rope management on a glacier is to run the rope at right angles to a crevasse whenever possible. A rope team that travels more or less parallel to a crevasse is risking a lengthy pendulum fall for a climber who falls in (fig. 18-7). Although it is not always possible to keep the rope at right angles to a crevasse, keeping this goal in mind helps climbers choose the best possible route (fig. 18-8).

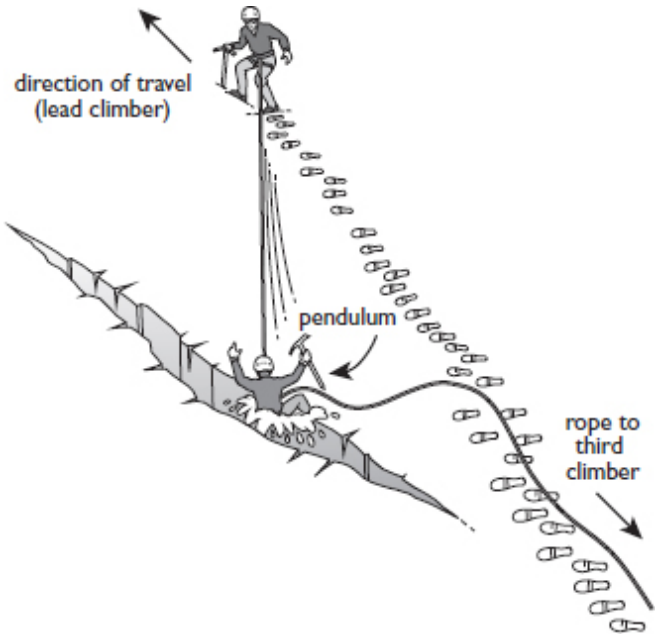

Fig. 18-7. Where the rope runs more or less parallel to a crevasse, a fall would be made worse by a pendulum.

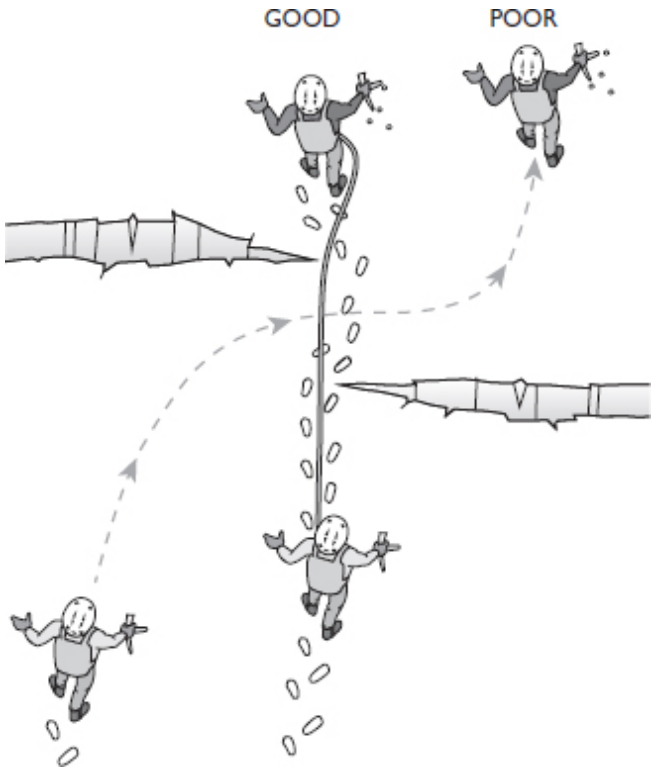

Fig. 18-8. Be aware of your rope partner's position in order to keep the rope as perpendicular to crevasses as possible.

DETECTING CREVASSES

Figuring out where the crevasses are and picking a route through them is fundamental to safe glacier travel. On many glaciers, routefinding is part planning, part experience, and part luck. See the "Tips for Detecting Crevasses" sidebar below.

Sometimes climbers can get a head start on planning by studying photographs of the glacier before the trip, because some crevasse patterns remain fairly constant from year to year. Online mapping resources provide overhead views of the glacier that can be helpful in identifying these patterns. Seek out recent reports from parties who have visited the area, though in summer, reports older than a week are generally not too helpful, due to melting. On the approach hike, try to get a good up-valley or cross-valley look at the glacier before reaching it. Climbers may see an obvious route that would be impossible to discover once they are on the glacier. Take photos and make notes to help remember major crevasses, landmarks, and route options.

Though looking at guidebook photographs and getting distant views of a glacier are useful, prepare to be surprised when you actually get there. What appeared to be small cracks may be gaping chasms. Also, just because a crevasse cannot be seen does not mean it is not there; it may be covered by a thin layer of snow or may not be visible from your angle of view. Stay alert and be prepared to backtrack and take an alternate route.

TIPS FOR DETECTING CREVASSES

- **Keep an eye out for sagging trenches in the snow** that mark where gravity has pulled down on snow over a crevasse's opening. This is a prime characteristic of a hidden crevasse. The sags are visible by their slight difference in sheen, texture, or color. The low-angle light of early morning and late afternoon tends to accentuate this feature. (The sags may be impossible to detect in the flat light of a fog or in the glare of the midafternoon sun, and it takes additional information to distinguish them from certain wind-created forms.)
- **Be wary after storms.** New snow can fill a sagging trench and make it blend into the surrounding surface. (At other times, however, the new snow can actually make the sagging trench more apparent by creating a hollow of new snow that contrasts with surrounding areas of old snow.)

- **Be especially alert in areas where crevasses are known to form**—for example, where a glacier makes an outside turn or where slope angle increases.
- **Regularly sweep your eyes to the sides of the route to check for open cracks to the left or right.** Cracks could hint at crevasses that extend beneath your path.
- **Remember that where there is one crevasse, there are often many.**

After setting up base camp, have an advance party scout out the first portion of the route in daylight; this can sometimes save many hours of predawn routefinding, resulting in a more efficient and safer climb.

Snow Probing

Snow probing is the technique to use if a suspicious-looking area has been found and the party wants to search it for crevasses. If a probe locates a crevasse, continue probing in all directions around this area to find the crevasse's true lip. Probe with the ice axe, thrusting the shaft into the snow a couple of feet ahead. Keep the axe perpendicular to the slope and thrust it in with a smooth motion. If resistance to the thrust is uniform, the snow is consistent to at least the depth of the axe. If resistance lessens abruptly, you have probably found a hole. If the route must continue in the direction of this hole, use further axe thrusts to establish the extent of the hole. The leader should open up the hole so it is obvious to followers.

The value of probing depends on climbers' skill and experience at interpreting the changes they feel in the snow layers. An inexperienced prober may think the shaft has broken through into a hole when all it has done is hit a softer layer of snow. The ice axe is a limited probe because it is relatively short. The lead climber can also use a ski pole (with the basket removed), which is lighter, longer, and thinner than an axe, for easier, deeper probes.

CROSSING A CREVASSE FIELD

Climbers have a number of ways to safely cross a field of crevasses. The techniques described below are typical, but they will have to be adapted as needed in the field. Routefinding on a glacier involves finding a path around or over all the visible crevasses, guarding all the time against hidden

crevasses. The crossing is seldom without its detours as climbers carefully pick their way over the glacier.

Make an End Run

Crossing directly over a crevasse is rarely a preferred choice. Where a crevasse narrows in width, often near its end, the safest and most dependable technique is to go around it, in an end run. A 0.25-mile (400-meter) detour may gain the rope team only 20 or 30 feet (7 to 10 meters) of forward progress, but it is often better than a direct confrontation with the crevasse. In late summer, when the winter snow has melted down to the ice, it may be possible to see the true end of the crevasse, but if seasonal snows still blanket the glacier, the visible end of the crack may not be its true end. Make a wide swing around the corner, probing carefully (fig. 18-9). Look closely at adjacent crevasses to judge whether one of them could be an extension of your crevasse; you might actually be crossing a snow bridge.

Use a Snow Bridge

If an end run is impractical, the next choice is to cross a crevasse on a snow bridge. Deep winter snow hardened by wind can create a crevasse bridge that lasts into the summer climbing season. Other, sturdier bridges are actually thin isthmuses between two crevasses, with foundations that extend deep into the body of the glacier.

Study a snow bridge carefully—try for a side view—before putting any faith in it. If in doubt, the leader can approach it to probe and get a close-up look while the second climber stays braced against the taut rope, prepared in case the leader possibly breaks through and ready to drop into self-arrest if needed (fig. 18-10). After the leader gets across, the rest of the party follows exactly in the leader's steps, also receiving a degree of protection from a taut rope held by a braced climber.

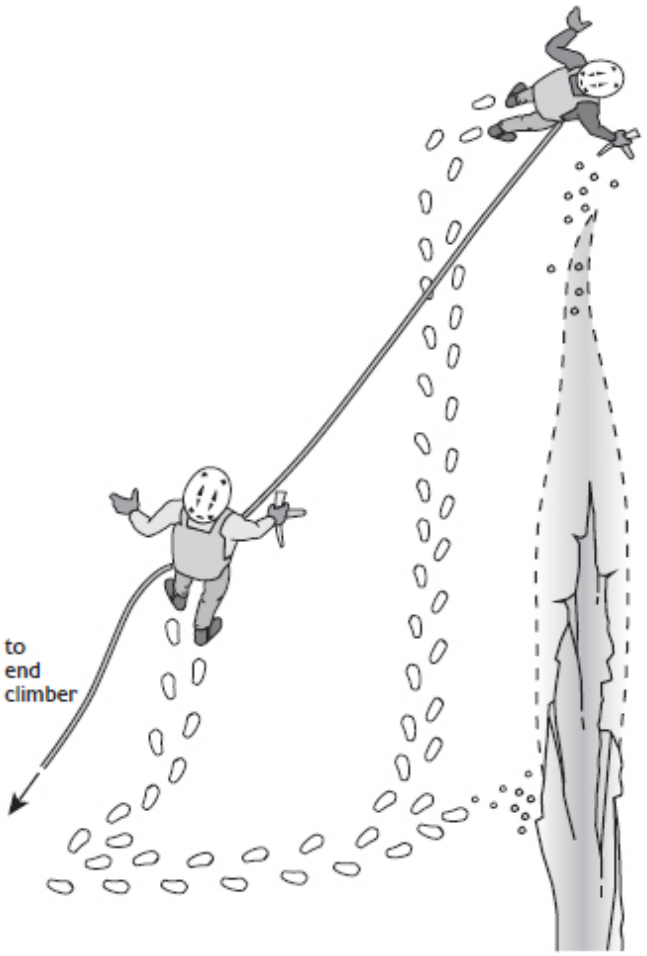

Fig. 18-9. End run around a crevasse, keeping the rope fully extended by not following in the leader's footsteps.

A snow bridge's strength varies tremendously with temperature. A bridge that might support a truck in the cold of winter or early morning may collapse under its own weight during an afternoon thaw. Use caution every time you cross a snow bridge. Do not assume that a bridge that held in the morning during the ascent will still be safe during the descent in the afternoon. In cases of dubious snow bridges, setting up a belay may save the party from having to execute a time-consuming crevasse rescue.

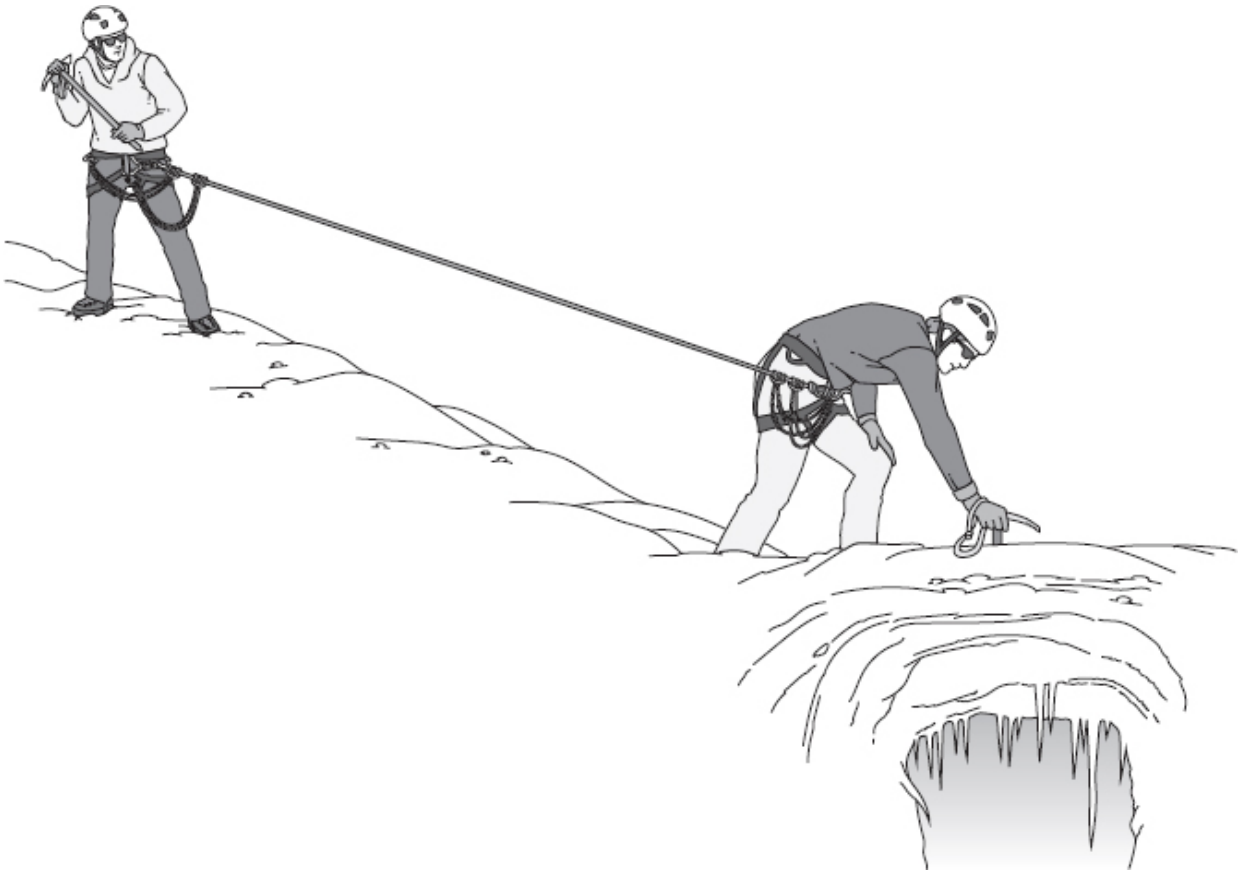

Fig. 18-10. Crossing a snow bridge with caution.

Jump

Jumping is one of the least common tactics for crossing a crevasse (fig. 18-11). Most jumps across crevasses are short, simple leaps. Before planning a desperate lunge, be sure you have ruled out all the alternatives and see that you are well belayed.

While well supported by a taut rope or by a belay, probe to find the true edge of the crevasse. If a running start is needed for the jump, tramp down the snow for better footing. Put on a jacket and gloves (you should already be wearing a helmet); check prusiks and harness; and spool out the amount of rope slack needed from the belayer. Then jump with your ice axe in the self-arrest position, ready to help you claw over the lip if you fall shy of a clean landing on the other side.

Once the leader is safely on the other side, the rope is now linked to the landing side, so the other climbers have a less-dangerous jump ahead: the belay rope can help pull up any jumper who falls just short of the target.

Use caution and common sense if the leap is from the high lip of a crevasse over to a lower side. (Bergschrunds, for example, often have an overhanging high wall on the uphill side.) Injuries are possible in a long, hard leap. If such a leap must be made, keep feet slightly apart for balance, knees bent to absorb shock, and ice axe held ready for a quick self-arrest. Beware of getting crampons caught on clothing.

Go into the Crevasse

On rare occasions, it may be practical to get to the other side of a shallow crevasse by climbing down into the crevasse, crossing it at the bottom or at a narrow point, and climbing up on the other side. This tactic should be attempted only by a strong, highly trained, well-equipped party that is ready to provide a good belay. One further caution: often what appears to be a solid bottom is not; if the crevasse bottom collapses and leaves a climber hanging, the party must be able to provide assistance.

Fig. 18-11. Jumping a crevasse (tie-in knot and belayer not shown).

Use the Echelon Formation

Certain crevasse patterns preclude the rule of keeping the rope at right angles to crevasses. If the route demands travel that is parallel to crevasses, it

sometimes helps to use the echelon formation: climbers somewhat to the side of and behind the leader, as in a series of stair steps (fig. 18-12). This formation is safest on stable, heavily crevassed glaciers on which the location of crevasses is known and the risk of hidden holes is small. The formation offers an alternative to following in the leader's footsteps through a maze of crevasses where single-file travel is impractical. Avoid moving in echelon formation where hidden crevasses are likely.

CREVASSE RESCUE RESPONSE

The depths of a great crevasse are awe-inspiring. On a fine day, the walls are a sheen of soft blue ice in the filtered light from high above, and the cavern is cool, still, and quiet. It is a place every climber should visit occasionally—for crevasse rescue practice. But if you end up in a crevasse at another time, you may be relying on your climbing teammates to get you out safely (see the "Crevasse Rescue Safety Precautions" sidebar).

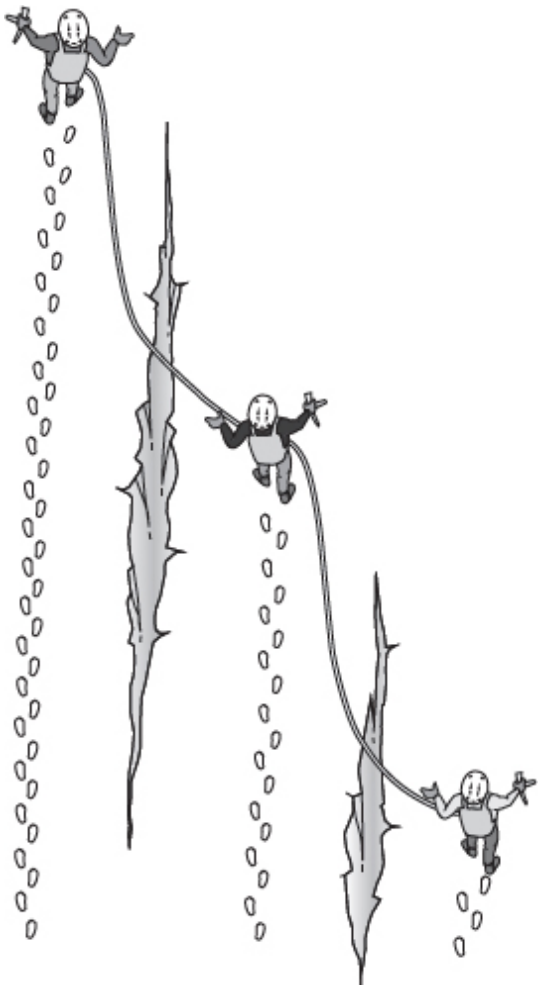

Fig. 18-12. Echelon formation, with a rope team in a stair-step-like position.

It is typically the first person on the rope—often one of the more experienced members of the team—who falls in when a rope team crosses a hidden crevasse. Here is the scenario: You are the middle person on a three-person rope team traveling up a moderately angled glacier. The leader walking 50 feet (15 meters) in front of you suddenly disappears beneath the snow. What do you do? (A middle-climber fall is discussed in "Special Rescue Situations," later in this chapter.)

Stop the fall immediately! Drop into self-arrest (facing away from the direction of pull) and hold the fall. The other rope partner (the end climber) will do the same thing. (Chapter 16, Snow Travel and Climbing, has details on ice-axe self-arrest.)

Once the fall is stopped (fig. 18-13), the critical steps in crevasse rescue begin. Learning these procedures well requires training in the field, augmented with annual practice. The principal steps in a successful crevasse

rescue, beginning the instant the fall is stopped, are listed briefly here and discussed in detail in the sections that follow. (The more involved seven steps in accident response are discussed in Chapters 24, First Aid, and 25, Alpine Rescue.)

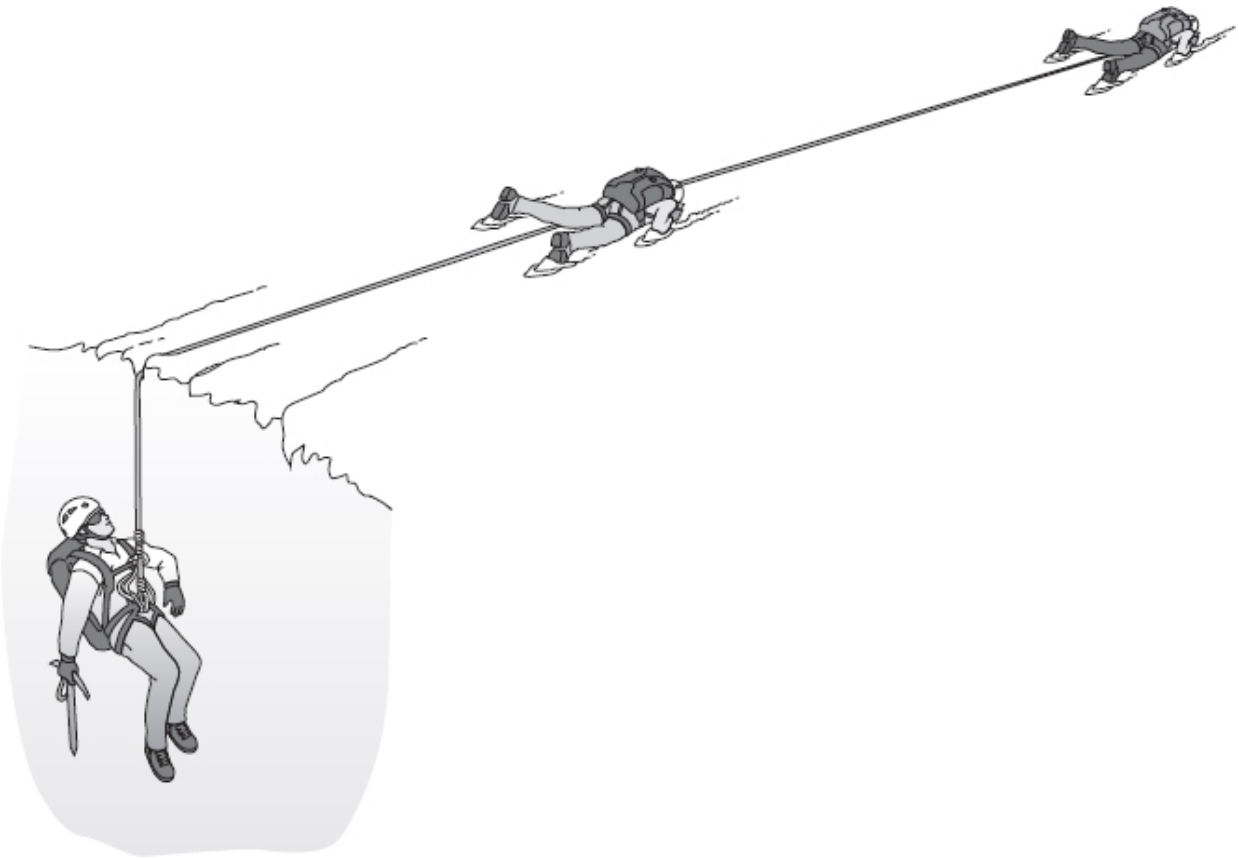

Fig. 18-13. Stop and hold a fall into a crevasse.

Step 1. Set up a secure anchor system.

Step 2. Communicate with the fallen climber.

Step 3. Devise a rescue plan. There are two basic choices: **Option 1.** Self-rescue—the fallen climber ascends the rope with prusik slings. **Option 2.** Team rescue—team members use a hauling system to pull the climber out.

Step 4. Carry out the plan: **Option 1.** For a self-rescue, assist the fallen climber as needed. **Option 2.** For a team rescue, set up the chosen hauling system, then haul the climber out.

STEP 1. SET UP A SECURE ANCHOR SYSTEM

The goal in the first step of crevasse rescue is to anchor the climber in the crevasse and allow the rescuers safe access to communicate with the fallen climber. There are many ways to build a bomber crevasse rescue anchor. Glacier travelers should learn several ways to build anchors that can be adapted to changing conditions, variations in gear, and number of climbers. Following is one approach to building a secure anchor system.

Build the Initial Anchor

If another trained rope team is available, they can begin setting up a rescue anchor—this is a distinct advantage of traveling with more than one rope team. Otherwise, the end climber on the rope generally has responsibility for setting up the initial anchor. To free up the end climber, the middle climber on the three-person team stays in self-arrest to support the weight of the fallen climber, usually an easy task because rope friction across the snow does much of the work.

The end climber slowly gets out of self-arrest, making sure the middle climber can hold the weight alone, and then sets to work establishing an anchor (fig. 18-14). In snow, a picket is often a good choice for the initial anchor because it can be placed quickly in a vertical position, with either a top-clip or midclip attachment, depending on the consolidation of the snow. An ice axe may also be used (see "Snow Anchors" in Chapter 16, Snow Travel and Climbing). If there is ice present, an ice-screw anchor will be needed (see "Ice Screws" and "Setting Up Ice Anchors" in Chapter 19, Alpine Ice Climbing). Place the anchor 5 to 10 feet (1.5 to 3 meters) downrope from the middle climber, toward the lip of the crevasse.

CREVASSE RESCUE SAFETY PRECAUTIONS

While working to rescue a fallen climber, observe these primary safety considerations:

- All anchor systems must be absolutely reliable, with backup anchors to guard against failure.
- All rescuers must be connected to anchors at all times.
- The rescue must proceed as quickly as possible using efficient, thorough execution of every essential step.

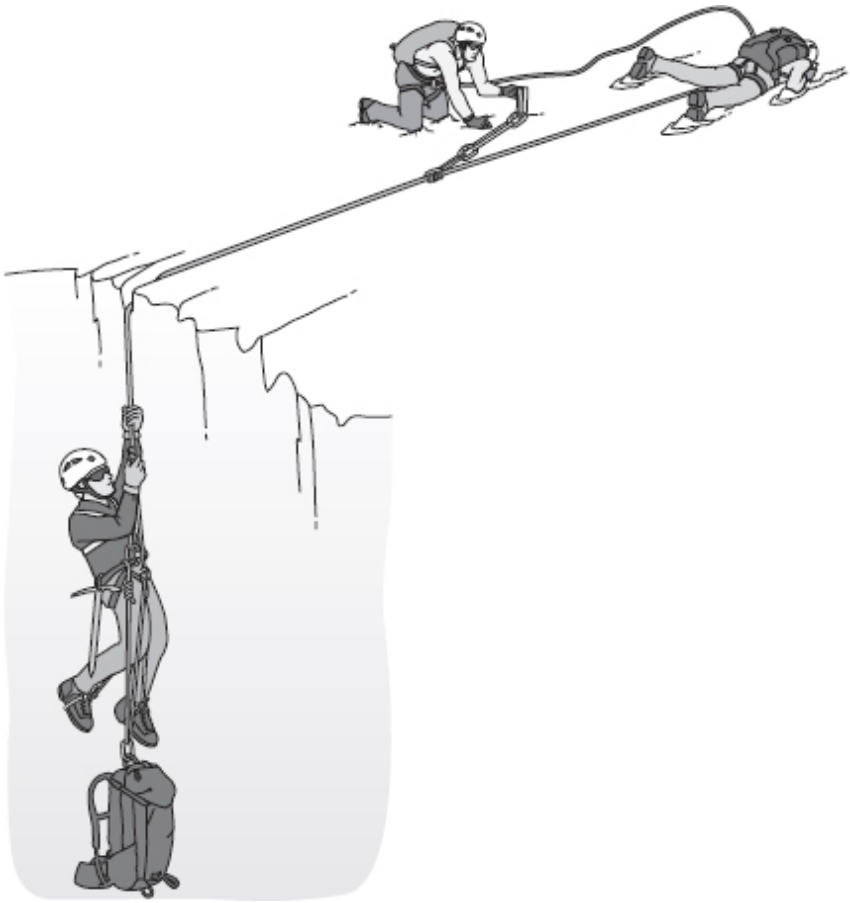

Fig. 18-14. End climber sets up the initial anchor, while middle climber holds fallen climber.

Attach the Rope to the Anchor

The person who has set up the anchor now attaches a short sling to the climbing rope with a prusik hitch; a bachmann or klemheist friction hitch may also be used (see "Knots, Bends, and Hitches" in Chapter 9, Basic Safety System). This person then attaches a runner to the sling with a carabiner and then clips the other end of the runner to the anchor with a locking carabiner (as shown in Figure 18-14).

The next move is to slide the friction hitch down the rope, toward the crevasse, until the sling assembly is tight, ready to take a load. Now anyone who is still in self-arrest can ease the load onto the anchor (but still remains in self-arrest, to back up the initial anchor). Confirm that the anchor is solid and that the hitch is gripping the climbing rope tightly. (Keep in mind that if a prusik hitch is used, one rescuer will have to tend the hitch later, whenever the fallen climber is being pulled up. The bachmann friction hitch, on the other hand, usually requires less tending.)

As soon as the load is transferred to the initial anchor, back up the friction hitch. Tie a figure eight on a bight in the climbing rope 12 inches or so (about 30 centimeters) up-rope from the friction hitch. At the same time, use a locking carabiner to clip a rescue pulley to the carabiner already on the sling, running the climbing rope through the pulley. Clip the figure-eight loop in to this new carabiner (fig. 18-15). With the pulley in place, the beginnings of a 3:1 (Z) pulley hauling system are now created (see "Step 3. Devise a Rescue Plan" below), saving time later if such a system needs to be set up to haul the climber from the crevasse.

Build the Second Anchor

Never trust a single anchor that is certain to be fully weighted. Back it up with a second anchor. While the end climber is building the second anchor, the middle climber remains in the self-arrest position as a temporary backup to the initial anchor.

The second anchor makes the system as fail-safe as possible. This anchor needs to be bomber, so take the time to do it right. As with the initial anchor, use a picket or a deadman for snow or an ice screw for ice. In snow, a good combination is a picket for the first anchor and a deadman (such as a buried picket) for the second anchor (fig. 18-16).

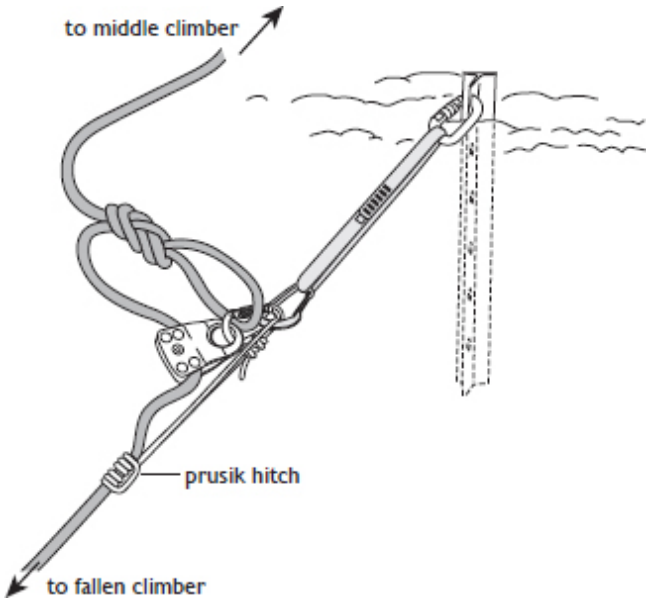

Fig. 18-15. Pulley and figure eight on a bight installed in the initial anchor.

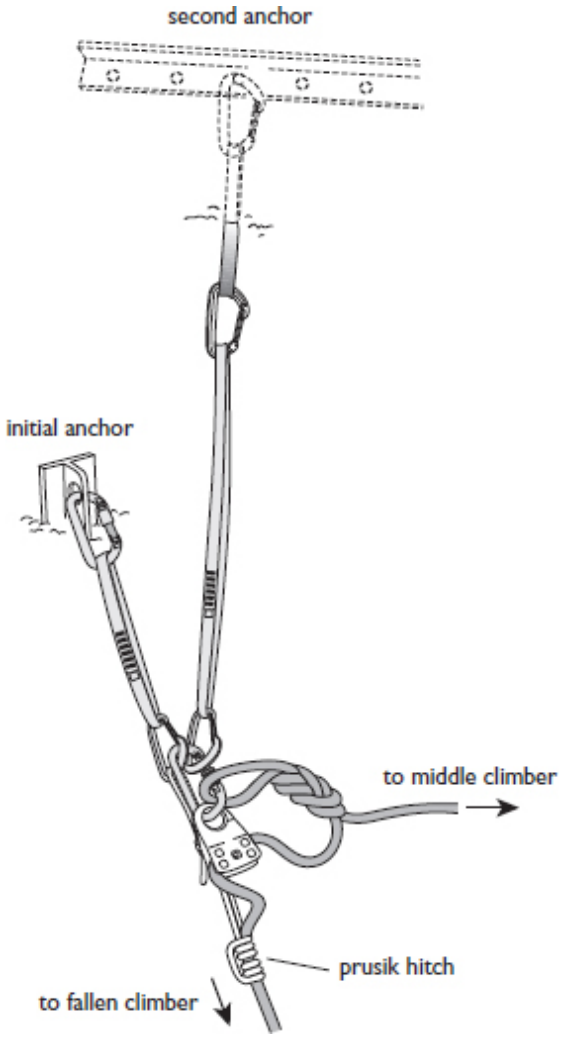

Fig. 18-16. Install a second anchor to make a tight and well-aligned connection.

Link the second anchor to the sling that is tied to the climbing rope with a prusik hitch in the same way that the initial anchor was linked to the sling. Attach a runner to the sling with a carabiner (also clipping through the pulley carabiner at the same time), and then clip the other end of the runner to the second anchor with a carabiner. Try to make a taut connection from anchor to sling, and remember the principles of equalization: keep the angle between the two anchor slings small (see "Equalizing the Anchor" in Chapter 10, Belaying).

With a secure anchor system in place, the team members are free to proceed to the next steps in the crevasse rescue response. It is important for climbers to remain attached to the main anchor at all times during the rescue, using a personal anchor clipped directly in to the main anchor, using a waist prusik or

other sling friction-hitched to the climbing rope, or by staying tied in to the climbing rope and requesting a belay.

STEP 2. COMMUNICATE WITH THE FALLEN CLIMBER

To develop a complete understanding of the fallen climber's situation so the party can devise a rescue plan, someone now needs to assess the fallen climber's situation.

A rescuer can be belayed from the anchor by a teammate or, better yet, a rescuer can move to the lip of the crevasse with a self-belay. Use a prusik hitch to connect a sling to a rope that is attached to the anchor (this can be the climbing rope or a separate rope that is anchored), then clip the sling to the harness with a locking carabiner. By sliding this prusik hitch along the rope, a rescuer can move toward the crevasse edge on an anchored self-belay (fig. 18-17).

Probe with the ice axe when approaching the crevasse lip to discover where the snow surface may be undercut. Approach the lip to the side of where the fall occurred so you do not knock snow and ice down onto the fallen climber.

Try to talk with the fallen climber. If there is no answer, the fallen climber may simply be out of earshot, or noisy wind on the glacier may be masking the response. If further attempts still bring no response, the rescuer needs to rappel or be lowered on belay into the crevasse to further assess the situation and perform urgent first aid if needed. If the climber is seriously injured or unconscious, the rescue method must take into account that the climber cannot actively participate in the rescue. Some crevasse rescue systems are better for dealing with this situation than others. (See the information on an unconscious fallen climber in "Special Rescue Situations" later in this chapter.)

If there is voice contact with the fallen climber, ask questions to find out the full situation. Is the climber wedged in? Injured? In need of more clothing? Is the climber now standing in prusik slings? Most importantly, assure the climber that things are progressing topside but that the rescuers need more information to determine the best way to carry out the rescue.

The fallen climber should be able to tell the rescuer whether self-rescue—by climbing up the side of the crevasse or by prusiking out—is a possibility or whether a hoist from above will be needed. There may even be the option of lowering the climber farther down, to a ramp or ledge from where self-rescue or hauling might be easier. The rescuer appointed to make assessments

at the lip of the crevasse has a great deal of responsibility, so this person should be skilled in rescue techniques and first aid and be prepared to provide important input on the rescue plan.

Fig. 18-17. Anchor system complete; self-belayed rescuer communicating with fallen climber. Note anchored ice axe protecting rope from entrenchment at lip of crevasse.

Minimize Entrenching of the Rope

Regardless of the rescue method, it is essential to pad the lip of the crevasse to minimize further entrenching of the rope. The entrenched rope adds a lot of friction to the raising system, which exerts tremendous force on the anchors if enough mechanical advantage or pulling power is used. An entrenched rope will also hinder the rescuers' efforts to hoist the climber up over the lip and

will confound a fallen climber's own attempts to prusik over it. Properly prepping the lip may take some careful excavation.

For padding, slide the shaft of an ice axe, a ski, a foam pad, or even a pack under the rescue rope as close to the edge of the crevasse as can safely be reached. Be careful when working with sharp objects (ice-axe picks, ski edges) around the entrenched rope since a tensioned line is more easily cut. Anchor the padding items so they cannot fall into the crevasse (see Figure 18-17).

STEP 3. DEVISE A RESCUE PLAN

Now it is time to choose a method for getting the fallen climber safely out of the crevasse. Will the climber attempt self-rescue? Or will the team members topside set up a hauling system to pull the climber out? After choosing between self-rescue or team rescue, the party must choose among the various methods of either self-rescue or team rescue. Factors that affect these decisions include the condition of the climber, the number of rescuers, the equipment available (ice climbing tools, additional ropes, pulleys, and so forth), weather conditions, topography of the crevasse area, and any other variables that will affect the safety of victim and rescuers.

Option 1. Self-Rescue

Self-rescue is often the easiest and fastest form of crevasse rescue, regardless of party size. It has the added advantage of keeping the fallen climber active and warm. Of course, it requires that the fallen climber be basically uninjured and able to maneuver in the crevasse. For small parties that lack the muscle power to hoist the fallen climber or that are pinned down holding the rope, self-rescue may be the only practical option. This is especially true for a two-person party traveling alone. A good self-rescue method for ascending the rope is the Texas prusik (see "Rescue Methods" later in this chapter).

Option 2. Team Rescue

Climbers have several choices among team-rescue methods, each with its own particular advantages. Described and illustrated in "Rescue Methods" later in this chapter, they are summarized here as part of the decision-making process.

Direct haul. For a large party with an unentrenched rope, direct pull using brute force works very well. It is fast and uncomplicated, uses minimal equipment, and requires little or no help from the fallen climber. It works best when perhaps a half dozen strong rescuers can haul on the rope and when the pullers are on flat ground or downhill from the fallen climber.

2:1 (single) pulley method. When the rope is badly entrenched or when there are sufficient haulers, the 2:1 pulley method may be best. An entrenched rope will not matter because this method requires a separate length of rope—either the unused end of the accident rope or another rope entirely. The length of available rope must be at least twice as long as the distance from the initial anchor to the fallen climber. The mechanical advantage of the pulley makes hoisting this way a lot easier than by using brute force alone, though it still usually takes a minimum of three or four people to do the pulling. The fallen climber must be able to contribute to the rescue, with at least one good hand for clipping in to the rescue pulley and for maintaining balance.

3:1 (Z) pulley method. When a fallen climber is unable to help in the rescue or when few haulers are available, the 3:1 pulley may be the best method. The pull force is on the accident rope, which may be partially entrenched in the snow, but the high mechanical advantage of the system gives haulers the power to overcome some entrenchment.

Other rescue methods. Though the crevasse rescue systems mentioned above are among the most common, there are other team-rescue methods worth considering. Piggybacking two systems together, such as a single-pulley setup hauling on a 3:1 pulley system, creates a higher mechanical advantage and, thus, even more hauling power. Other notable options include the Double Mariner 5:1 haul, the 6:1 drop loop method, and the Spanish Burton 5:1 system—all worth exploring further.

Alternatives

A climber who falls into a crevasse does not necessarily have to come back out at the same spot. Check the possibility of lowering or swinging the fallen climber to a ledge. It might be a good spot for the victim to rest, as well as perhaps a gateway to a different part of the crevasse where rescue will be easier. Consider whether the bottom of the crevasse looks solid. This could offer another resting spot and a possible path to a climbing route or a snow ramp back to the surface.

STEP 4. CARRY OUT THE PLAN

Now the fallen climber must be safely removed from the crevasse. If self-rescue is the chosen plan, the climbers topside assist as needed. If it will be a team rescue, the climbers topside set up the selected hauling system and pull the fallen climber out. See "Rescue Methods" later in this chapter.

A party with enough people or a second rope team should assign one climber as the communicator at the lip of the crevasse throughout the rescue. Be careful near unstable crevasse edges so as not to dislodge debris onto the climber below. Good communication is especially important as the fallen climber approaches the lip to ensure that the climber is not getting pulled into the crevasse wall.

In cases where the fallen climber has trouble climbing out over the crevasse lip due to an entrenched rope, consider lowering gear (ideally, linked to a different anchor) such as slings tied together, carabiner chains, et cetera, to provide additional support points or an alternate exit.

INSIDE THE CREVASSE

While the climbers on top are preparing for rescue, the fallen climber has work to do down in the crevasse, beginning with the moment of recovery from the fall. The fallen climber should do the following.

Get Pack and Ice Axe Out of the Way

If possible, send your pack and ice axe up on a rope lowered by the rescuers. If this is not possible, clip the axe to your harness, letting it hang so it does not interfere with your movement (see Figures 18-14 and 18-17). If at the beginning of the climb you did not rig a runner to the pack's haul loop (see "Using the Rope" earlier in this chapter), do this now: Girth-hitch a short sling through the pack's haul loop, then clip the sling with a carabiner in to the climbing rope between your harness and prusik attachments. The pack will then hang below you; as you prusik up the rope, the hanging pack will slide freely along the bottom of the loop of climbing rope and weight the rope, making it easier for you to climb (fig. 18-18).

Attain an Upright Position

If you did not land upright or already shift your body, work yourself into an upright position. Normally you do this by clipping the climbing rope through the carabiner at your chest harness. (This may be difficult or impossible to do until you have hung your pack, as described above.)

Get into Prusik Slings

Remove the prusik slings' foot loops from your pocket and slip one of the two adjustable loops over each boot (see "Using the Rope" earlier in this chapter). If you are wearing crampons, it will not be easy. Cinch the slipknot to tighten the slings around your boots. Getting into your prusik slings that are attached to the climbing rope permits you to alternate between standing in the foot sling and sitting from the waist sling as you dangle (fig. 18-19). You will be a lot more comfortable and will be ready to climb up the rope using the slings.

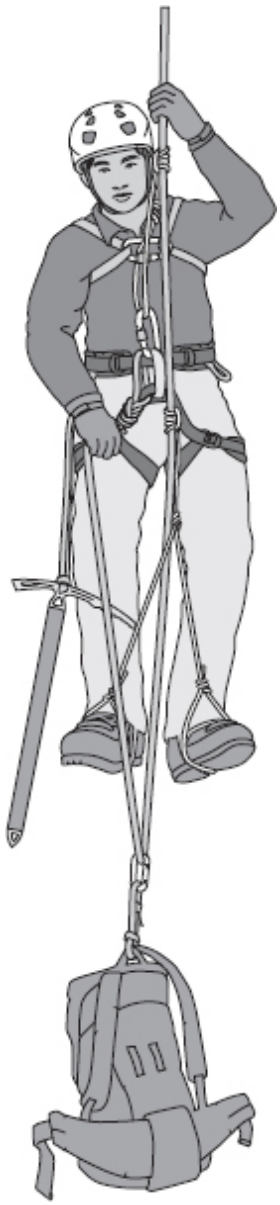

Fig. 18-18. Self-rescue using the Texas prusik system with the pack out of the way.

As soon as you have clipped in to your chest harness, moved your pack and ice axe out of the way, and caught your breath, it is usually advisable to begin prusiking partway to the top if you are just dangling free in the crevasse (see "Rescue Methods" below for a description of the Texas prusik). If possible, let the other climbers know what you are doing. Move carefully and deliberately so that you do not put sharp or sudden tugs on the rope that could interfere with their work holding your weight and setting up an anchor. Normally, though, the snow provides enough friction to help hold the rope,

especially if it is entrenched at the lip of the crevasse, so your prusiking will not hamper your rescuers.

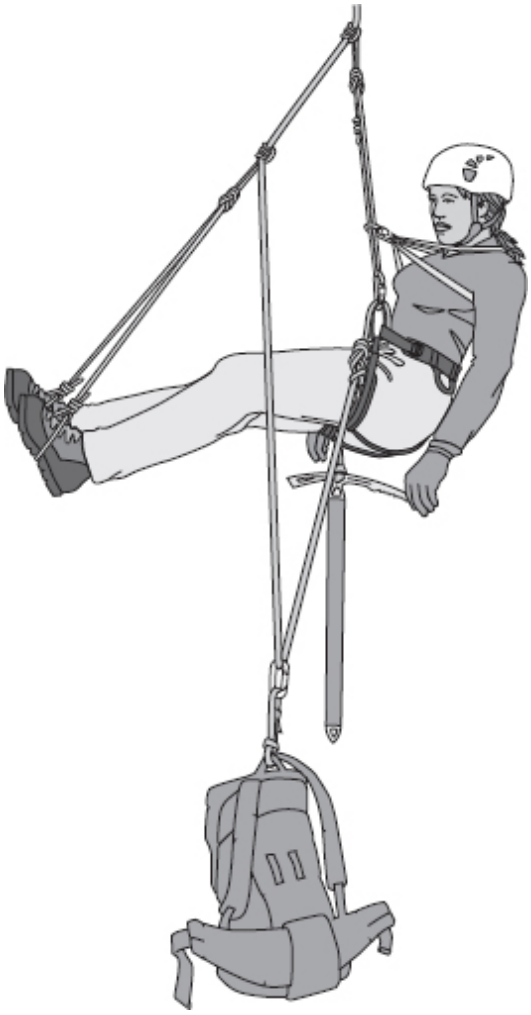

Fig. 18-19. Resting while using the Texas prusik system.

This preliminary prusiking gets you closer to the glacier surface, where it is easier to communicate with rescuers. You and the other climbers can then decide together on the best rescue plan. If the final plan is to use a hauling system, your initial prusiking will have helped by making the haul shorter. Even if the final plan is self-rescue by prusiking, you will probably need their help in getting over the crevasse lip.

If the fall did not leave you dangling free but, instead, dropped you onto a ledge, where most of your weight is off the rope, a different approach to prusiking is required. In this case, go ahead and get into the prusik slings, but wait to begin prusiking until you have talked it over with your rescuers. If you

were to start prusiking without an OK from topside, your full weight coming suddenly onto the rope could unbalance and endanger the whole team.

Keep Warm

Zip up your jacket, put on the hat and gloves you stuffed in its pockets earlier, and try to put on additional layers of outerwear if possible.

RESCUE METHODS

This section describes the principal prusiking method for self-rescue and the hauling methods for team rescue.

OPTION 1. SELF-RESCUE

The Texas prusik is a simple system that permits more progress per cycle and more comfortable rests than other methods such as the stair-step prusik. A climber with an injured leg can still ascend the rope with the Texas prusik by using just one of the foot loops. Unlike the stair-step prusik, the Texas prusik is easy to learn and execute. It will keep the climber upright without having to be connected to a chest harness. In fact, it may be easier to move the upper prusik when the climber is unclipped from the chest harness.

The Texas Prusik

This method of ascending the rope, developed by spelunkers (cavers), uses one prusik sling for the feet and a separate sling for the waist (which is clipped with a locking carabiner to your harness). The foot sling has two loops, one for each foot, tied so that they will adjust and cinch down on the boots. These are the steps for using the Texas prusik after recovering from a fall into a crevasse:

1. Stand up in the foot loops. You are now ready to move upward.
2. Unclip from the chest harness.
3. Loosen the friction hitch attached to the waist sling and slide it up the rope until it is taut.
4. Sit down in the harness, putting all your weight on the waist sling, which releases your weight from the foot sling.

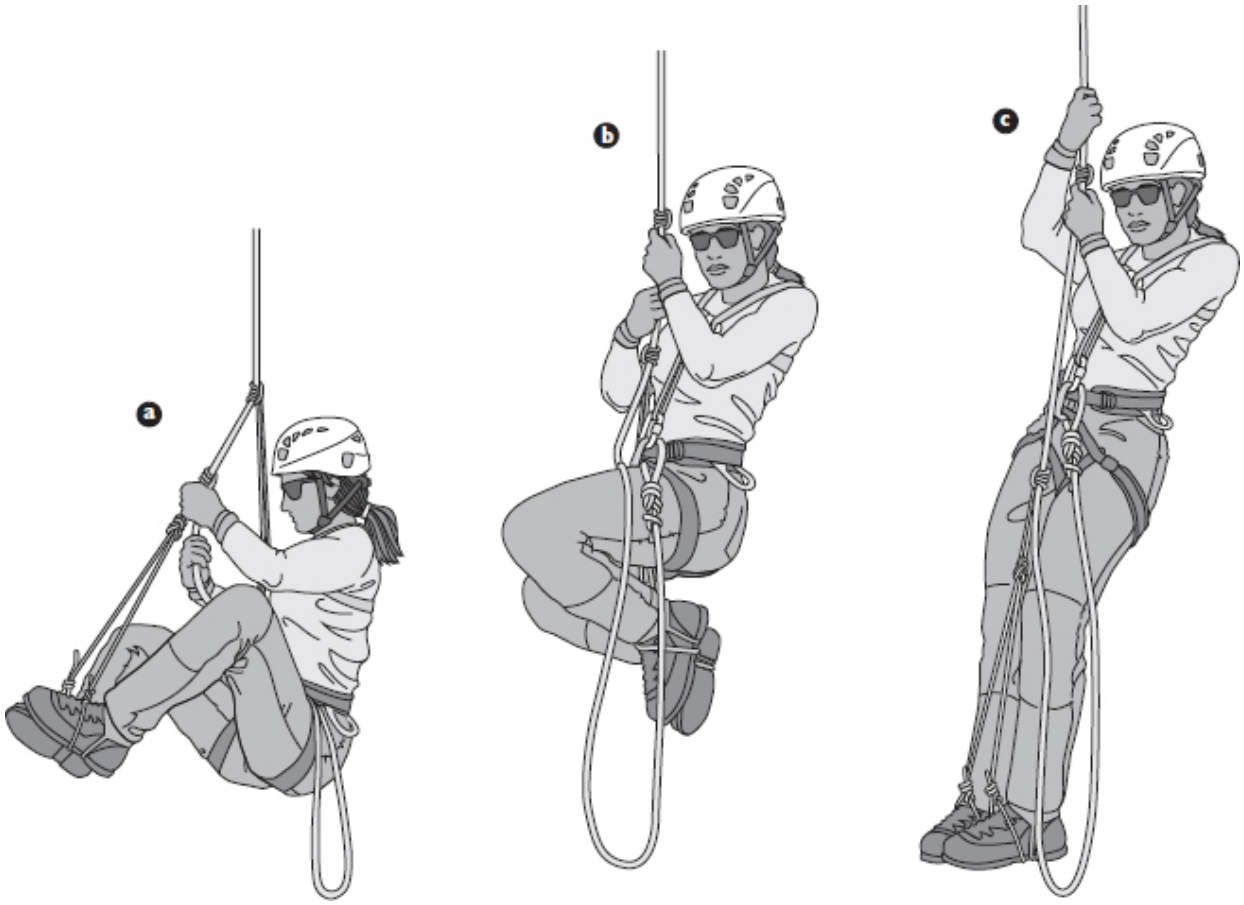

Fig. 18-20. Ascending a rope using the Texas prusik system (pack and ice axe omitted for clarity): a, sitting or resting and moving foot prusik sling up; b, sitting on heels, ready to stand; c, standing and moving waist sling up.

5. Loosen the friction hitch attached to the foot sling and slide it up the rope—18 to 24 inches (50 to 75 centimeters), if the sling is properly adjusted. Raise your feet with it (fig. 18-20a).
6. Stand up again in the foot loops (fig. 18-20b and c).
7. Keep repeating steps 3 through 6.

OPTION 2. TEAM RESCUE

All rescues are team rescues to some degree, because even in a self-rescue, the fallen climber usually needs some help getting over the crevasse lip. A full team rescue usually involves hauling the fallen climber to safety. The principal hauling methods—direct haul, 2:1 (single) pulley, 3:1 (Z) pulley, and piggyback systems—are described in the sections that follow. In any rescue system calling for pulleys, carabiners can be substituted if necessary.

However, carabiners create far more friction and make the rope harder to pull, and the load on the anchor system is correspondingly increased.

Direct Haul

A half dozen or so strong haulers line up along the accident rope and grasp it. They position themselves up-rope beyond the point where the initial anchor is attached to the climbing rope with a prusik hitch or bachmann friction hitch. The hitch is then in the right place to hold the rope if the haulers slip or need a rest. Before hauling begins, unclip the backup figure-eight loop (shown in Figures 18-15, 18-16, and 18-17) from the anchor system. Then the haulers go to work, pulling hand over hand on the rope or moving step by step away from the crevasse.

One rescuer tends the hitch, making sure the rope moves smoothly through it, and also keeps an eye on the anchor system. If there are enough people, another person can be stationed at the lip of the crevasse to stay in communication with the fallen climber.

The haulers should pull the rope at a slow, steady pace, especially when the fallen climber reaches the crevasse lip. If the rope has cut into the lip, the fallen climber could be injured by being pulled into the crevasse wall. At this point, rescuers may ask the fallen climber to scramble over the lip (with the help of an ice axe) while they hoist.

2:1 (Single) Pulley System

The 2:1 pulley system theoretically doubles the amount of weight that each hauler could raise without a pulley, though friction lowers this ratio somewhat. Because this method uses a length of rope that is separate from the rope going to the fallen climber, this is the method of choice if the accident rope is entrenched into the edge of the crevasse. However, it also requires the assistance of the fallen climber, so it cannot be performed when the fallen climber is unconscious. To carry out a rescue using the 2:1 pulley system, follow these steps:

1. Use a rescue rope (the unused end of the accident rope or a separate rope altogether) that is at least twice as long as the distance from the initial anchor down to the fallen climber. Attach the rope to either the existing anchor system or a new rescue anchor.
2. At the point where the rescue rope will go over the lip of the crevasse, prepare the lip with padding, such as an ice axe or pack, to prevent the

rescue rope from entrenching itself in the snow.

3. Double the rescue rope into a big loop. Affix a pulley to the loop and attach a locking carabiner to the pulley. Leave the carabiner unlocked.
4. Lower the pulley and carabiner dangling from the loop down to the fallen climber (fig. 18-21a). Have the climber clip and lock the carabiner in to the belay loop on the harness. Confirm that this has been done. Check that all the climber's equipment is secure and ready for hauling to begin. Have the climber clip the rescue rope—the portion that is between the pulley and the pulling rescuers above (not the portion that is between the pulley and the anchors above)—in to the chest harness, to help the climber stay upright.
5. Assign a rescuer to attend to the slack that will develop in the original accident rope as the fallen climber is raised. It is critically important that this person pull slack through the friction hitch so that the rope is always ready to accept the fallen climber's weight, in case the pullers slip or need a rest. If the fallen climber's pack is clipped to the accident rope, there will be considerable weight on the rope, and it may require two people to take in the slack. Keep the existing backup figure eight on a bight tied to the initial anchor in the system while the slack is taken in; do not remove the knot.
6. With everything ready, the haulers start pulling on the unanchored end of the rescue rope (fig. 18-21b). To ease their task somewhat, the fallen climber can pull up on the anchored side of the rescue rope while the hauling proceeds; this unweights the unanchored end of the rescue rope somewhat.

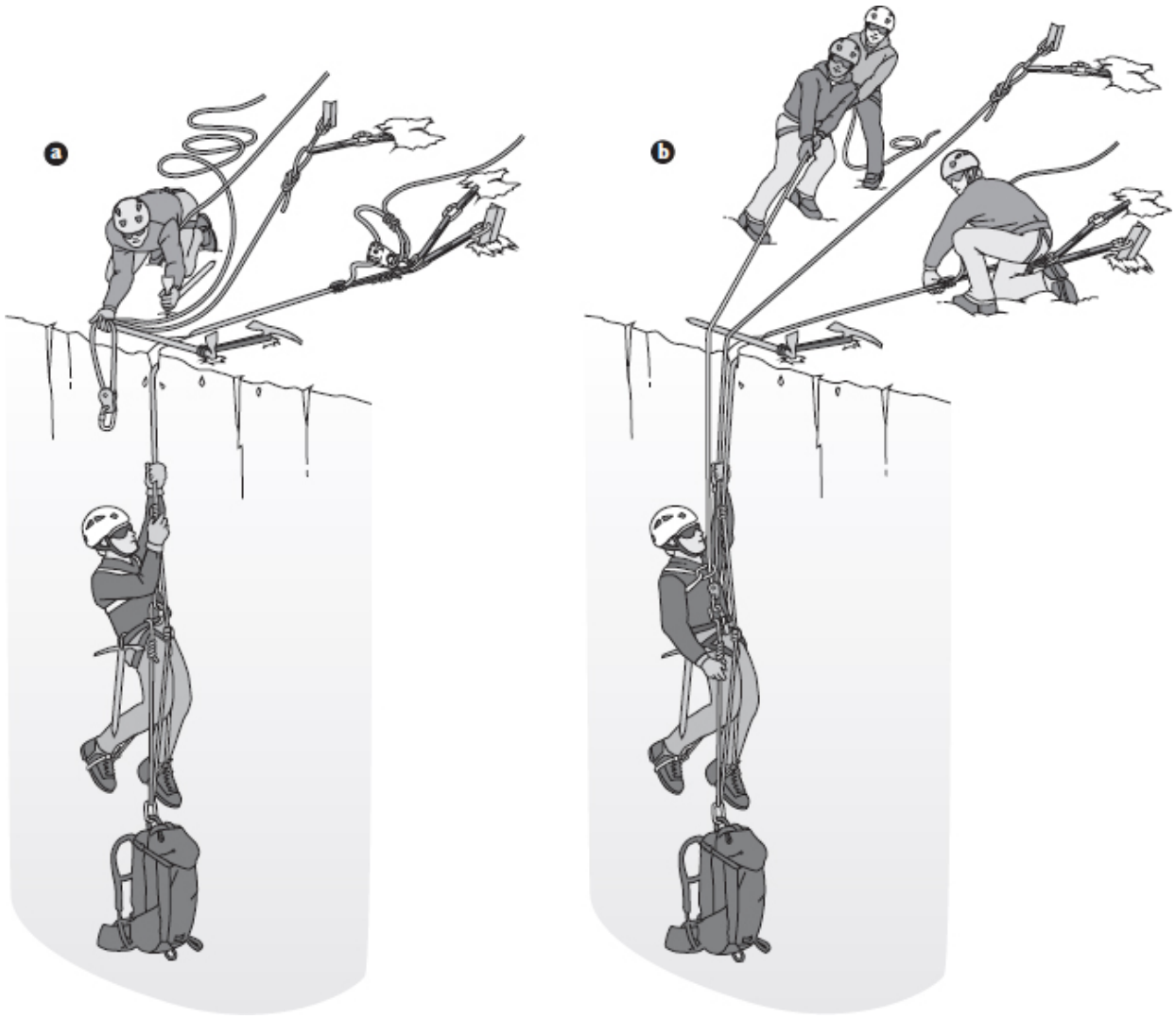

Fig. 18-21. Setting up and raising a climber with the 2:1 (single) pulley system on a new rope (rescuers' personal anchors omitted for clarity): a, lowering the pulley to the fallen climber; b, raising the fallen climber.

3:1 (Z) Pulley System

The 3:1 pulley system magnifies the muscle power of small climbing parties by offering a three-to-one theoretical mechanical advantage through the use of two pulleys. It can be set up and operated with no help from the fallen climber, making it valuable for rescuing an unconscious person. The 3:1 pulley system normally uses the accident rope. It requires more equipment and is more complicated than the other hauling methods described above.

First, confirm the solidity of the initial anchor system, because the 3:1 pulley system puts considerable stress on it. Take the loose end of the climbing rope attached to the fallen climber—the end that extends unweighted

beyond the anchor—and lay out a long loop on the snow. This loop and the rest of the rope going from the anchor to the fallen climber should form a giant flat S in the snow, somewhat like a Z or a backward Z with the sharp edges worn off.

At the first bend in the Z (by the initial anchor system), the first pulley for hauling is already in place; this is the pulley attached to the initial anchor system with a locking carabiner when the system was first set up. Also clipped in to the locking carabiner are the prusik sling (also called the *ratchet prusik*) and the backup figure-eight loop (see Figures 18-15, 18-16, and 18-17).

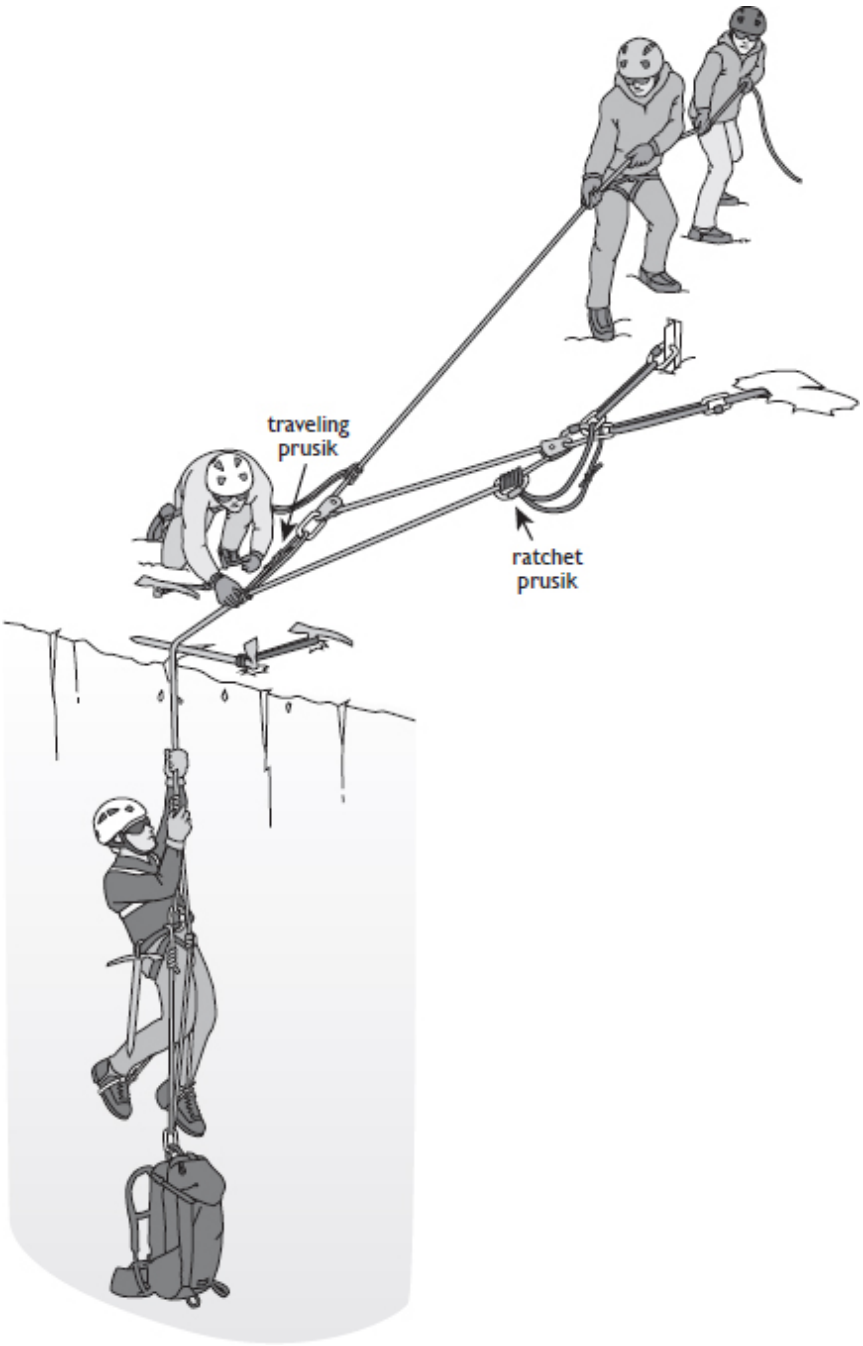

Fig. 18-22. Raising a climber with the 3:1 (Z) pulley system.

At the second bend in the Z (the slack bend, closer to the crevasse lip), install a second pulley on the rope. Use a friction hitch to attach a short sling to the taut section of rope going from the anchor's first pulley to the fallen climber, and clip this sling with a carabiner in to the second pulley (this is called the *traveling sling* or *traveling prusik*). Drag the friction hitch (traveling prusik) and traveling pulley as far down the taut rope as possible

toward the crevasse (fig. 18-22). It may have to be seen to be believed, but this is now a 3:1 pulley system, ready for use. Here's how to haul using the 3:1 pulley system:

1. Unclip the backup figure-eight loop from the initial anchor system and untie the knot as soon as the haulers and fallen climber are ready for pulling.
2. If the ratchet or keeper sling used a prusik hitch to attach the accident rope to the initial anchor system, assign a rescuer to tend the hitch so that the rope slips freely through it as the rope is pulled in. If a bachmann friction hitch was used instead, the attachment should tend itself, and the front hauler can simply keep an eye on it to see that all is well.
3. Start pulling at a steady rate, either hand over hand or by holding tight and walking backward.
4. The hauling will soon bring the second (traveling) pulley in close to the first (stationary or ratchet) pulley at the initial anchor. Stop hauling when the pulleys are about 2 feet (0.5 meter) apart. If they are pulled too close, the figure Z is collapsed and the mechanical advantage is lost.
5. Once hauling has stopped, relax the pull on the rope enough to transfer the fallen climber's weight back onto the ratchet or keeper sling at the initial anchor.
6. Reset the traveling pulley by loosening the traveling sling that is linked to the traveling pulley and sliding it back down the taut accident rope toward the crevasse lip once again.
7. Keep repeating steps 3 through 6.

Beware of the pulling power of the 3:1 (Z) pulley system. If care is not used, the climber can be injured by being pulled forcefully up into the lip. As the fallen climber nears the lip of the crevasse, use a friction hitch (for example, a prusik hitch) to attach a webbing chain to the taut accident rope and lower the webbing chain to the fallen climber (fig. 18-23a), who can use it like an aider (*etrier*) to step up and pull up over the lip of the crevasse (fig. 18-23b). See "Aiders (*Etriers*)" in Chapter 15, Aid and Big Wall Climbing.

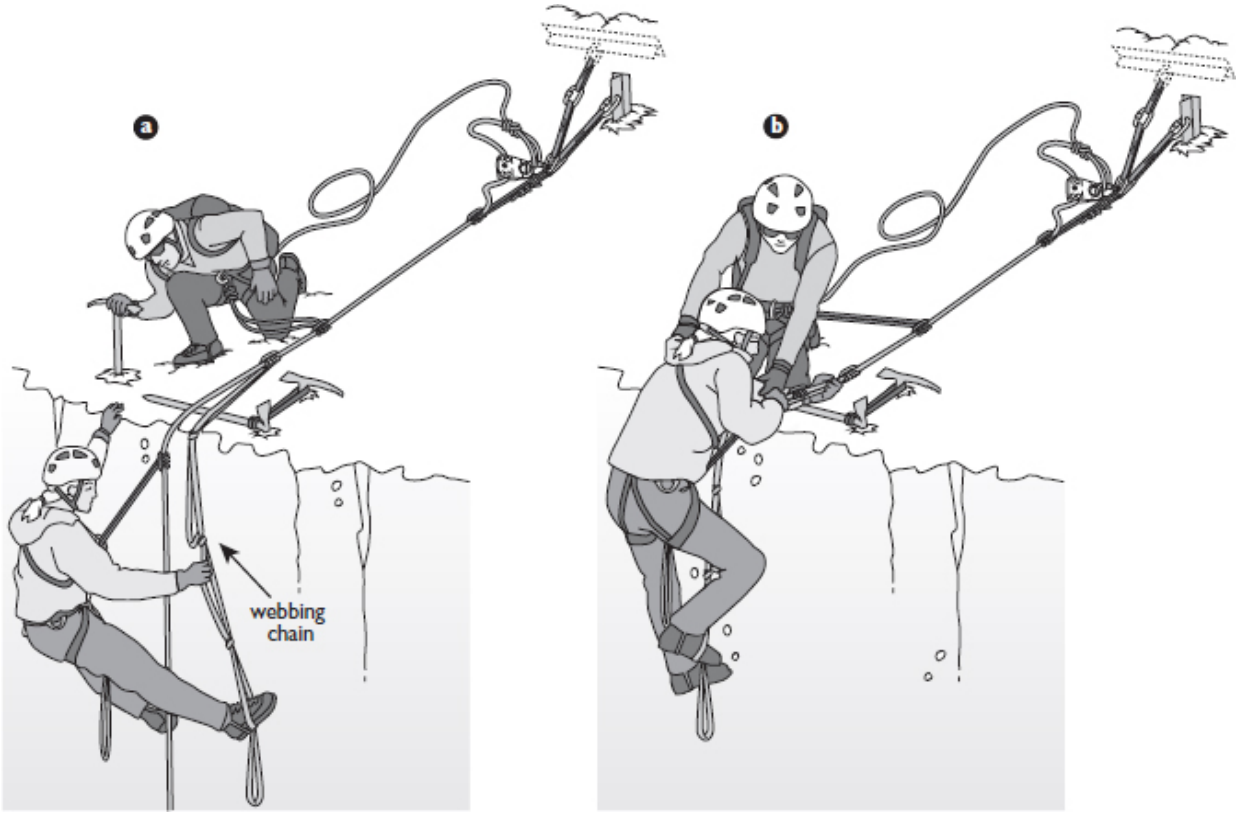

Fig. 18-23. Helping fallen climber over the lip of a crevasse (foot prusiks omitted for clarity): a, rescuer lowers webbing chain attached to taut accident line so climber can put right foot into it; b, as climber steps up in webbing, rescuer helps the fallen climber scramble over the lip.

Piggyback Pulleys

To get even more mechanical advantage out of a rescue hauling setup, combine or "piggyback" two systems. For example, establish a separate 2:1 pulley setup to haul on the rope coming from a 3:1 pulley system. This gives a six-to-one theoretical mechanical advantage. One note of caution: beware of using piggyback systems to overcome the resistance of pulling the victim over the crevasse lip; serious injuries have resulted.

A 5:1 pulley system can be constructed in different ways. One method is to clip a carabiner and a triple runner or cordelette 15 to 25 feet (5 to 8 meters) long to the traveling prusik. Another method is to add a second traveling prusik and pulley (or carabiner) to a 3:1 pulley system (see Figure 25-6c in Chapter 25, Alpine Rescue). For a 4:1 advantage, set up a 2:1 single-pulley system to haul on another 2:1 pulley system.

SPECIAL RESCUE SITUATIONS

A crevasse rescue can be complicated by any number of unusual twists. This section describes some special situations that could be encountered and ideas on how to deal with them. The situations can become complicated, and the rescuers' response will have to be adapted to the conditions of the moment. Anything that works safely is fine. (See Chapter 25, Alpine Rescue, for more details on accident response and additional rescue techniques.)

WHEN THE MIDDLE PERSON FALLS IN

It is awkward at best when the middle person on a three-person rope team falls into a crevasse, especially if no other climbers are around to set up the rescue anchor. With no second team, the only two people who can help are separated by a crevasse, each in self-arrest. Here is a general procedure for getting out of this fix.

The climbers begin by deciding which side of the crevasse will be the rescue side—that is, which side the fallen climber should come out on. Usually, one of the two rescuers in self-arrest is holding more weight than the other. The one holding the least weight usually has the best chance to get up and establish an anchor—this climber's side will be the rescue side—while the rescuer on the other side stays in self-arrest to hold the fall.

After the climber on the rescue side sets up the rescue anchor (see "Step 1. Set Up a Secure Anchor System" above), the climber in self-arrest on the other side of the crevasse can slowly release tension on the climbing rope and ease the fallen climber's weight onto the anchor.

If the climber who was in self-arrest is needed to help in the rescue operation, the climber on the rescue side now tries to belay the climber on the self-arrest side over to the rescue side. The rope on the rescue side can be used for belaying, if it is long enough, or a second rope—carrying a second rope is a good precaution for a rope team traveling alone—can provide the belay. If no belay or safe route across the crevasse is available, however, the climber on the self-arrest side could be stuck there. This climber would then set up an anchor and stay put.

The most advantageous rescue plan now is for the fallen climber to self-rescue by ascending the rope on prusik slings, coming out on the rescue side, where the anchor has been placed. If a self-rescue by prusiking is not possible, then a 3:1 pulley or a piggyback system could be tried. This all

takes plenty of time, competence, equipment, and resourcefulness. Learn to use the bachmann friction hitch (see "Friction Hitches" in Chapter 9, Basic Safety System) for times when you might have to haul alone, because the hitch requires less tending than a standard prusik hitch in a hauling system.

In the case of a four-person rope team, the situation is a little simpler in the event that one of the two middle members falls into a crevasse. Conduct the rescue in a routine manner from the side that has two climbers topside.

WHEN A TWO-PERSON TEAM IS ALONE

For a party of two people with no other rope team nearby, glacier travel is risky and discouraged. Both climbers absolutely need to know their rescue techniques, period. The climber who stops a fall must set up an anchor alone while in self-arrest and then create a hauling system appropriate for a single person (such as a 6:1 drop loop system) if one is needed. Therefore, each climber must carry at least two pieces of snow or ice protection for an anchor appropriate to the conditions, plus the equipment (pulleys, carabiners, slings) to set up a hauling system. And all of this must be readily at hand on harnesses or pack straps.

Rope teams of two should shorten their rope by taking in coils (see below), which automatically makes available an extra length of rope for rescue use. Packing along a second rope is also a good precaution. The climbers should not have the rope clipped in to their chest harnesses, because this makes rescue very difficult. And with only two people, it is even more important than usual to travel with a personal prusik system ready for use.

If you end up as the sole rescuer in a two-person rope team, holding your partner's fall with your self-arrest, begin your rescue efforts by augmenting the security of your arrest position by digging in your feet and pressing the ice axe more firmly into the snow. Imagine that you are establishing a belay stance while lying down.

Try to free one hand by rotating the upper half of your body—but keep leaning on the axe and bracing yourself with at least one stiff leg. If the rope is clipped in to your chest harness, unclip it now. At this point, you will see the value of keeping the appropriate anchors easily accessible.

When you get one hand free, place a picket, ice screw, or second ice tool—anything secure enough to hold the fallen climber and allow you to get up and create a main anchor. Once the initial protection is in place, clip the loose end of your foot prusiks to this protection with a carabiner. Slowly transfer the

weight of the fallen climber to the initial protection. Now follow the steps described in "Crevasse Rescue Response" earlier in this chapter, though you will probably experience more difficulty than would a larger rope team or group of teams: set up a secure main anchor, communicate with your fallen partner, settle on a rescue plan, and carry it out. Ideally, your partner will be able to handle self-rescue, prusiking out. If not, try a 3:1 pulley or piggyback hauling system. Of course, if you are unable to make an initial placement of protection in the first place, the climber in the crevasse has no choice but to try self-rescue while you remain in self-arrest.

Traveling on a glacier alone as a party of two requires a high degree of competency with crevasse rescue systems. Study and practice plenty before attempting it.

Shortening the Rope with Coils

Shortening the rope by coiling it over the shoulder—"climbing in coils"—is the preferred method of travel for two-person glacier teams. The technique results in closer spacing between rope partners for more efficient, comfortable travel, and it provides some free rope for a hauling system or other rescue use.

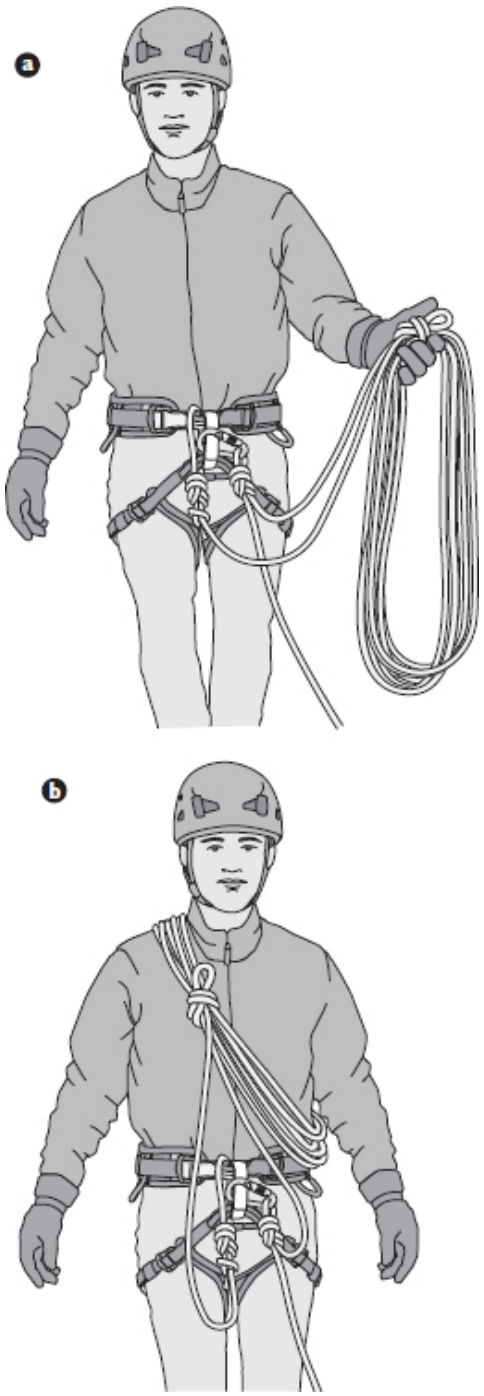

Fig. 18-24. Shortening the rope with a coil: a, tying in and creating the coil; b, draping the coil out of the way (prusik slings omitted for clarity).

The coil also provides a means of quick transition between the closer spacing of roped glacier travel and the full rope-length requirements of belayed climbing. This transition is important on an alpine climb where a

glacier approach is followed by belayed rock or ice climbing. To create the coil, take these steps:

1. Tie in to the rope at your harness, as you would normally.
2. Take a series of coils of rope into your hand (usually five, but no more than nine) until you have the desired spacing between you and your rope partner. Secure the coils together by tying an overhand knot around them, using a loop of the rope (fig. 18-24a).
3. Get the coils out of the way for travel, stowing them securely anywhere, such as in the top of your pack or over one shoulder and under the opposite arm, where they are easily accessible (fig. 18-24b).
4. Attach the shortened length of climbing rope to your harness with a figure eight on a bight clipped to the belay loop with a locking carabiner so that any force coming onto the rope will be taken by this knot.

A variation of the coil is often used in Europe; climbers put six butterfly knots on a bight in the rope, three at each end near each of the two climbers. Research by Ecole Nationale de Ski et d'Alpinisme (ENSA) Chamonix recommends an initial 10-foot (3-meter) space between the climber and the first knot, a second knot 6 feet (2 meters) beyond the first knot, and a third knot 6 feet (2 meters) beyond the second knot (fig. 18-25). This method works on the principle that in the event of a fall into a crevasse, the rope will entrench and the knots will catch in the crevasse lip. This takes most of the weight off the arresting climber, which makes it considerably easier to set up the initial rescue anchor.

To use this rope to extract the fallen climber from the crevasse, the other climber must untie the knots in the rope before hauling. This may be possible because most of the load should be taken by the knot wedged in the lip of the crevasse. If the rescuer cannot do this, then rescue may be performed using a 2:1 pulley system with the loose end of the rope or using another rope if there are sufficient people to haul and the fallen climber is uninjured. For a single hauler, the best approach is a 6:1 drop loop on the accident rope. Since more complex systems are beyond the scope of this book, take time to research this method online or through information listed in Resources.

When self-rescuing, one disadvantage of tying knots in the rope is that the fallen climber must pass them when ascending out of the crevasse. This is a bit awkward and slow but doable: the fallen climber ties their prusik onto the rope above the loaded knot, transfers weight to the prusik to unweight the

loaded knot, unties the butterfly knot in the rope below, and continues prusiking, repeating this process for each knot that needs to be passed.

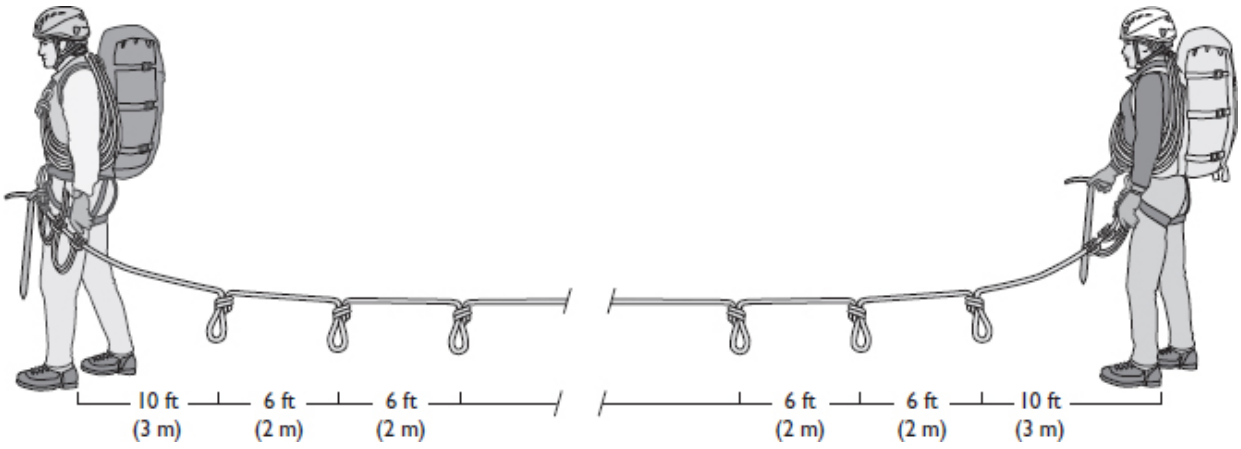

Fig. 18-25. Two-person glacier travel team with knots in rope, which aid in arresting a fall into a crevasse by catching in crevasse lip.

WHEN THE FALLEN CLIMBER IS UNCONSCIOUS

To help an unconscious climber, a rescuer must descend immediately by rappelling or being lowered on belay. This rescuer must descend with enough clothing and equipment to avoid hypothermia, ascend independently if needed, and provide proper first aid. Major crevasse falls are likely to cause injuries. The rescuer can administer urgent first aid and also get the fallen climber right-side up if necessary. Time is critical because there may also be an increased risk of suspension trauma, asphyxiation, and/or hypothermia—and possibly cardiac arrest when moving a hypothermic crevasse rescue victim. The rescuers must then consider which of the hauling methods they will use, keeping in mind that the fallen climber is unable to participate in the rescue. Helping an unconscious climber over the lip of the crevasse will require a rescuer to work right at the edge of or from inside the crevasse. Monitor the condition of the unconscious person, taking care to cause no further injury.

WHEN THERE IS MORE THAN ONE VICTIM

If more than one person has fallen into a crevasse, assess each person's condition and the best method for getting each one out, and then decide the order of rescue. Practicality usually determines the order of rescue, unless there is ample backup for rescuers and equipment. Be sure that each fallen

climber is given warm clothing, if needed, and keep everyone informed of rescue plans as they develop.

WHEN THE WORKING SPACE IS CRAMPED

The climber who drops into self-arrest position to stop a rope mate's fall could be lying so close to the lip of the crevasse that there is very little room to place an anchor or pulley system. A solution to this situation is to set up the main anchor where there is enough room—on the up-rope side of the climber in self-arrest (instead of the usual place, between the rescuer and the crevasse). Leave 24 inches or so (60 centimeters) of slack between the main anchor and this rescuer, so that this person is not trapped in the system by tension on the rope.

Then set up a temporary anchor, between the rescuer in self-arrest and the crevasse, that will take the weight of the fallen climber long enough to enable the rescuer to get up from self-arrest position and untie from the rope. Once hauling begins, untie the prusik sling attached to the temporary anchor.

WHEN THE WORKING SPACE IS BETWEEN TWO CREVASSES

Rescuers trying to work in a very narrow area between two crevasses can consider moving the operation. The rescue might proceed better if it is run from the opposite side of the crevasse that holds the fallen climber.

Another option is to change the direction of pull on a 3:1 pulley system. Hook a third pulley to the anchor and run the hauling end of the rope through it (fig. 18-26). Now the rescuers can pull in a direction more parallel to the crevasses.

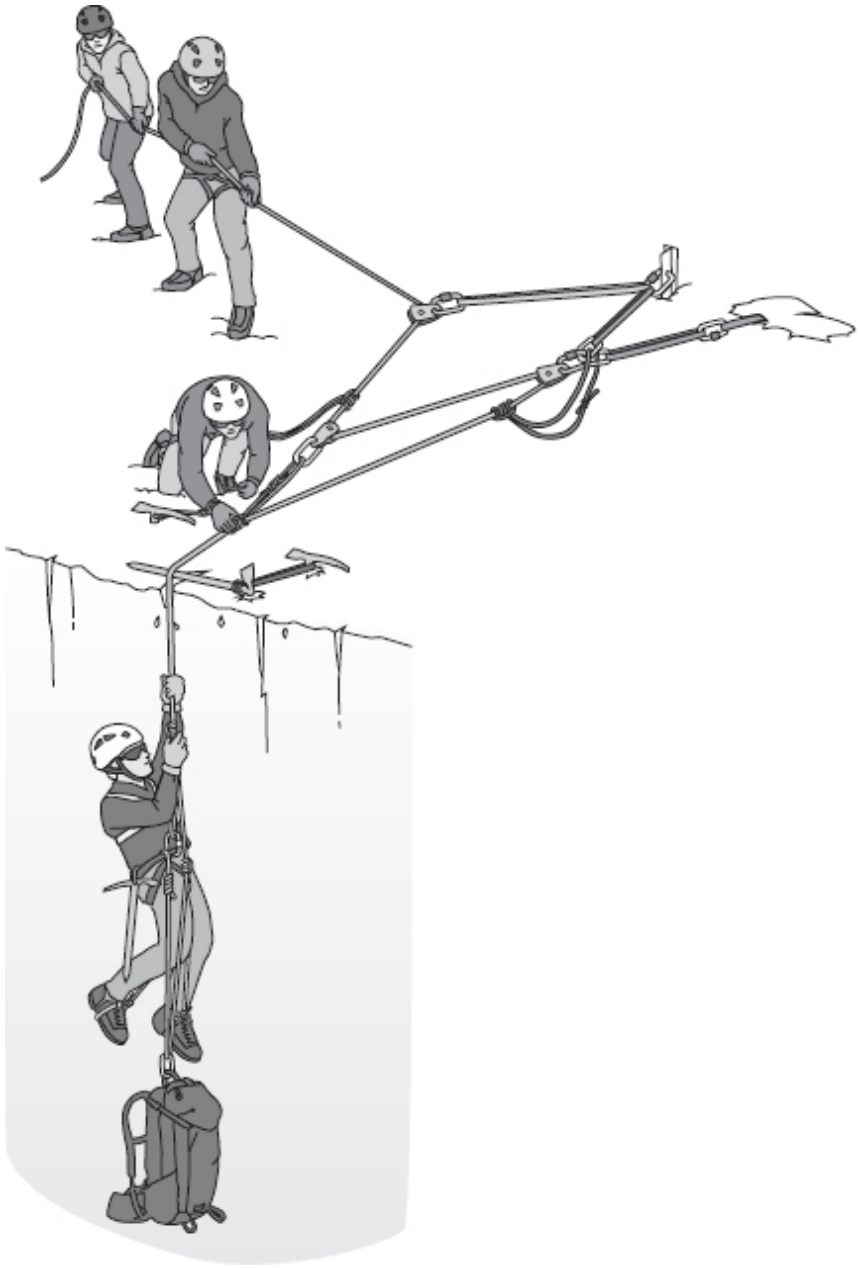

Fig. 18-26. Adding another pulley to the 3:1 (Z) pulley system for a change of direction in a tight space, such as between two crevasses.

WHEN THE ROPES ARE ENTRENCHED

The upward progress of a person climbing out or being pulled out of a crevasse can be stopped cold by a rope that has dug itself into the lip. This situation calls for some improvisation. For instance, a rescuer can attach prusik slings or aiders (*etriers*) above the entrenched portion of the rope and

drop them down for the climber to step into. See "Aiders (*Etriers*)" in Chapter 15, Aid and Big Wall Climbing.

Another option is to switch to a new rescue rope. A rescuer can lower a new rope to the fallen climber (as shown in Figure 18-21). Or the fallen climber can, in effect, provide a new rope by tossing the loose end of the climbing rope up to the rescuers. This is done by prusiking up to the lip, tying in higher up on the climbing rope, untying from the loose end of the climbing rope, and throwing the loose end up to the rescuers.

A new rescue rope, carefully padded at the lip of the crevasse so it does not also get entrenched, opens up several rescue possibilities. The fallen climber can switch prusik slings from the original climbing rope to the new free rope. Or the rescuers can haul the fallen climber up and out on the new rope. Or the fallen climber can merely transfer all weight to the new rope to give rescuers a much better chance of freeing the entrenched line.

PATHS TO THE SUMMIT

Glaciers can appear to be obvious, rather convenient routes to alpine summits, but in reality they are massive, dynamic systems that hold many hazards—especially with climate change reshaping the glacial landscape. Climbers who seek the freedom of the glaciated peaks must learn how to safely negotiate crevasses and other dangers. Clearly, the best strategy for travel on a glacier is to minimize risk by defending against a crevasse fall. Even when precautions are taken, however, falls and other accidents can occur. Anyone planning to travel on a glacier must master the techniques for dealing with the hazards and effecting a successful rescue if necessary. With these skills, climbers can safely take advantage of these glacial paths up to alpine summits.