Chapter 5

Knots, Hitches, Bends and Anchors [1]

Generically, the term knot is used to cover knots, hitches, and bends. Although the chapter is subdivided by knots, hitches, and bends, the term, knot, is used generically in this chapter. Knots, hitches and bends are structurally different and serve different purposes. A *hitch* needs an object or another rope to maintain its internal integrity. A *bend* fastens two ropes together. Unlike a hitch, a *knot* is a self-supporting. It does not need an object or another rope to maintain its internal integrity. Along with principles and definitions, the three types of knots are used as the organizational structure and headings in this section.

Principles and Definitions

Knot – The critical element in determining a knot is that when it is tied, it is self-contained and self-supporting. It does not need another object or rope to maintain the integrity of the knot (e.g. a hitch does). And, it does not tie two ropes together (i.e. bend).

Also, it should be noted that the term knot is often the generic term used for hitches and bends much like Xerox ® is synonymous with copying and used interchangeably with all copying. Similarly, Kleenex ® is synonymous with tissue paper and used interchangeably with it. So generic is the use of knot as part of the nomenclature, obvious bends such as the water knot, grapevine knot, or barrel knot are actually called knots. This chapter recognizes the difference between knots, hitches, and bends. It is structured along these distinctions. However, the term knot is used generically and interchangeably with hitch and bends.

Hitch – A hitch needs an object or another rope to tie it. Without the object or other rope, it will fall apart. The other object or rope assists in maintaining its structure. Without a tent peg or tree limb, a clove hitch will fall apart. Without another rope, the Prusik will fall apart. Both need an object or another rope to maintain its structure and integrity.

Bends – Bends are used to tie two ropes together. The water knot is used to tie the two ends of webbing together to create a sling. Also, the water knot and double fisherman's knot are really bends.

Families – Examination of knots reveals that their internal structure tends to repeat themselves in other knots. This suggests that knots can be grouped into families. Also, this helps when visually examining knots because the configurations are similar. A member of the overhand knot family, the figure eight is sometimes considered as a family of knots itself because it is one of the largest families of knots. Also, families can extend over different types of knots. The bowline (i.e. knot) and sheetbend (i.e. bend) have identical configurations. Two half-hitches and the clove hitch have the same configurations. Two half-hitches are tied around an object. A clove hitch is tied around an object. The fisherman knots (i.e. a bend) are two interlocking overhand knots. The water knot (i.e. a bend) is an overhand knot.

[1] This chapter was written by Robert B. Kauffman who is solely responsible for its content.

Families can be extended to include similar configurations but where the number of loops or other element are varied in the knot. The single, double, and triple fishermen knots (i.e. bends) have the same configuration except for the number of internal loops. The double sheetbend is similar to the sheetbend, except that it has a second internal loop. The barrel or triple fisherman has three internal loops.

Perhaps the most common knot group is the overhand knot (Figure 5.1). Add one more half turn and it becomes the all familiar figure eight knot and figure eight family. Add a third half-turn and the knot becomes the figure nine knot. So in a very real sense, the figure eight knot is really a variation of the overhand knot. The conclusion is that there are a few basic knots with many variations.

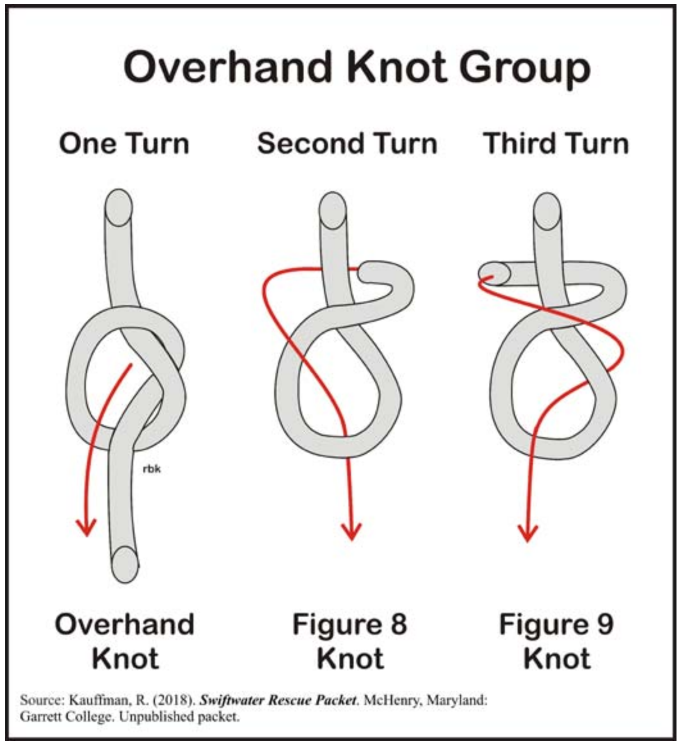


Figure 5.1 – Overhand Knot Group – Source: Author – [file:\-KN-OverhandGroup.cdr]

Parts of a Rope (Figure 5.2) – The following are some commonly used rope terms. It is useful in orientating and describing the parts of a rope as well as working with a rope. Some of the terminology seemingly overlaps with other terms, such as the difference between a bight and loop. The purpose of labeling the parts is that it helps orient the reader when describing how to tie the knots.

Bight – A bight is a bend in the rope where the line comes back on itself but doesn't cross over itself. It is a loop where the rope doesn't cross over itself. It is usually taken out of the center of the rope.

Loop – In contrast with a bight, a loop is a turn in the rope where the lines cross over each other. When tying a bowline, the first step is to make a loop. The line crosses over each other and held between the thumb and second finger. The first step in tying a trucker's hitch shown in Figure 5.2 is to create a loop (i.e. actually multiple turns). The second step is to create a bend that is pulled through the loop.

Working End – The working end is attached to the item being rigged or hauled. Think of it as the end of the rope working or currently occupied.

Standing End – The standing part of a rope includes all the rope excluding the working end.

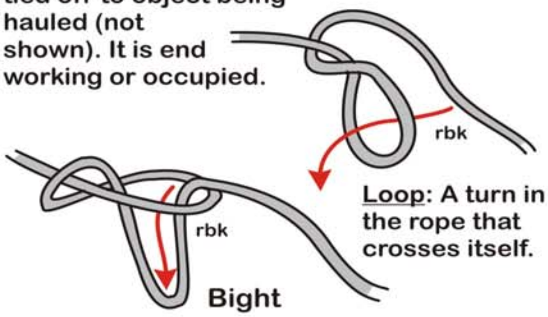
Running End – The running end is the free end of the rope. Sometimes it is called the *free end*. It is part of the standing end of the rope and it is the section of the rope used to tie a knot, hitch or something else.

Tying Considerations – Some knots are selected because of their strength (e.g. figure-8). Some are chosen because a life might depend on the knot being "bombproof" (e.g. figure-8 on a bight). Some knots are selected because they can be tied quickly and untied easily (e.g. bowline). Others have a specific purpose or functions (e.g. a Prusik uses a double fisherman and webbing is tied using a water knot).

Parts of a Rope
Figure 5.2

Working End: The end tied off to object being hauled (not shown). It is end working or occupied.

Standing End: All the rope not fasten to the object being hauled.



Loop: A turn in the rope that crosses itself.

Bight: A loop that does not cross over itself, usually taken from the center of the rope.

Running End: The end of the rope not tied off and free to use.

Relative Strength of Knots
Figure 5.3

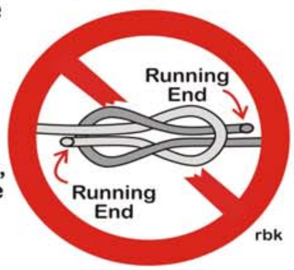
100%	No Knot
75%-80%	Figure 8
70%-80%	Bowline
65%-70%	Double Fisherman's
60%-70%	Water Knot
60%-65%	Fisherman's
60%-65%	Clove Hitch
60%-65%	Overhand Knot
60%-65%	Two Half-hitches
43%-47%	Square Knot

Patterns and Running Ends
Figure 5.5

Square Knot

"Killer" Square

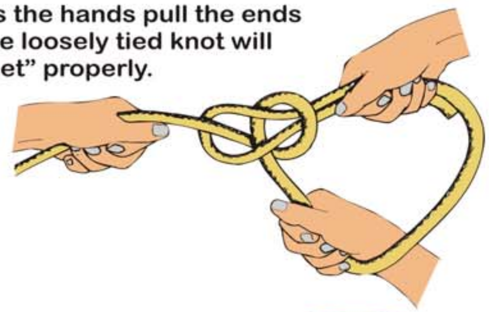
Except for the running ends, both knots look identical. The "killer" square will come undone, even under a little tension.



Source: rbk

Setting and Dressed
Figure 5.4

As the hands pull the ends the loosely tied knot will "set" properly.



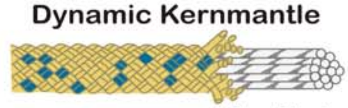
This knot is not "dressed" properly. Note the kink or unwanted twist in the webbing.

Types of Rope
Figure 5.6

Laid Rope

Solid Braid

Dynamic Kernmantle



A braided sheath is woven over the twisted-core which acts as a shock absorber.

Static Kernmantle

rbk

A protective sheath is woven tightly over the load-bearing parallel-fibers in the core.

Source: Smith, B., and Padgett, A.,(1996). ***On Rope - North American Vertical Rope Techniques***.Huntsville, AL: National Speleological Society, Inc.

Function – Many knots are designed for specific uses and functions. A sheetbend and double fisherman are designed to tie two ropes together. A sheetbend is easy to untie. A double fisherman is virtually impossible to untie once it cinches. A water knot is designed to tie two pieces of webbing together but not two ropes. A bowline is designed to tie a loop in the rope. A clove hitch is designed to tie a rope to a branch or peg.

Strength (Figure 5.3) – Tie a knot in a rope and it will immediately lose 1/4 to ½ of its strength. A figure eight retains roughly 75% – 80% of its original strength. In contrast, a square knot retains only 43% – 47% of the rope's original strength (Figure 5.3). The knot creates a stress point where the fibers on the outside of the bend are stretched more and those on the inside. The strands may even become compressed on the inside of the bend. The differential in stresses can lead to rope failure at this point. A good rule to remember is that when the object around which a rope is bent is at least four times the diameter of the rope (e.g. pulley, branch, a knot, etc), the bend in the rope as a practical matter will be unstressed.

Ease to Tie/Untie – A knot should be relatively easy to tie. When tying a line around a post or object, the bowline is easier and quicker to tie than a figure-8 follow-through.

Often overlooked is the ability to easily untie a knot (see Figure 5.12c). A bowline is easy to untie even after heavy loading. Just bend the "horse collar" section of the knot over the working end of the rope and the knot will fall apart. In contrast, once under load, a double fisherman can be virtually impossible to untie. It derives this attribute from its lineage to the overhand knot.

Setting and Dressed (Figure 5.4) – In tying a knot, the knot is tied loosely. *Setting* is the process of tightening the knot so that it becomes dressed. A knot is *dressed* when it is configured properly. All the parts of the knot are in their proper location and the knot looks as it is pictured in the textbook. This is important because, a properly dressed knot makes for easier inspection and an improperly dressed knot can lose up to 50% of its strength.

Inspection (Figure 5.5)– It is important to determine that a knot is tied properly and is safe. A properly dressed knot makes it easier to determine if the knot is configured correctly. A figure-8 knot has a unique and distinct configuration. It looks like the figure eight. In a figure-8 follow-through the second rope runs parallel to the first rope within the knot. This creates a distinctive pattern. Also, it relates to the knot being properly dressed. Next, there may be a key element of the knot that needs to be checked. In the square knot, the two running ends are on the same side of the knot (Figure 5.5). In the "killer square" the running ends are on opposite sides of the knot. Except for this feature, both knots look identical. Unfortunately, the killer square knot will literally fall apart under tension.

Amount of Rope Used – Some knots consume more rope than others. A figure eight on a bight consumes 36% more rope than a bowline. Yet both knots create loops in the end of a rope. A simple experiment was conducted with 8mm cord. With a 2.5" loop, a bowline consumed 11.5 inches of cord. In contrast, a figure eight on a bight consumed 18 inches of cord or 36% more cord than a bowline. This is not insignificant, and at some point, it can affect the amount of rope available to reach the object on the working end of the rope.

With its three loops, a triple fisherman's knot consumes more rope than a double fisherman or a single fisherman. Leaving a 1" tail, half of a single fisherman consumed 4.25 inches of the 8mm cord. Half of the double fisherman consumed 5.75 inches or 26% more cord for the additional loop. With three turns, half of the barrel or triple fisherman consumed 8.25 inches or 30% more cord than the double fisherman. Since not much additional strength is gained by using a triple fisherman over the double fisherman, the double fisherman saves rope.

Types of a Rope (Figure 5.6) – Several of the common rope types are presented in Figure 5.6. These are laid, braided and kernmantle. In a laid rope, the strands are usually twisted to be in opposition to each other. This encourages the rope from becoming unraveled. A major disadvantage of the laid rope is that abrasion cuts the outside strands weaken the rope when that strand moves inward and become supporting strands.

Kenmantle rope is comprised of the *kern* and the *mantle*. The mantle is a woven outer sheathing that protects the kern. Kenmantle ropes are either *dynamic* or *static*. The kern in a dynamic rope consists of twisted strands of fibers. Dynamic ropes are used in climbing and are designed to stretch under load. Specifically, they are designed to absorb the fall of a climber. The kern in a static rope consists of parallel unidirectional strands of fibers. The design minimizes stretch. They are used in rescue situations and not in lead climbing or in situations designed to absorb falls.

Ropes are constructed out of nylon, spectra, and polypropylene as well as natural and other materials. Nylon is one of the more common materials. It is strong, flexible, and does not float in water. Spectra is much stronger than nylon which is reflected in its cost. Also, it floats. Polypropylene has less strength than nylon. It is inexpensive and it floats in water. In whitewater situations, spectra is often the rope of choice because it is strong and floats.

Knots

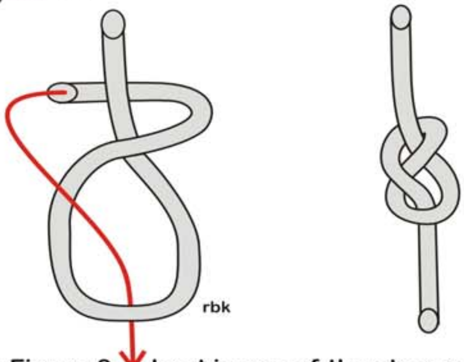
When tied, a knot is self-contained and self-supporting. It doesn't need an object or another rope to maintain its integrity (i.e. hitch). Traditionally, the term knot is used to include both hitches and bends. To make matters more confusing, many hitches and bends actually incorporate the term knot in their name. The double fisherman's knot and water knot are actually bends. Two families of knots are emphasized in this section. They are the figure eight and bowline.

Figure Eight Family (Figure 5.7) – The figure eight knot is foundational in that it is the basis for a whole family of knots. Although it is a member of the overhand knot family, the figure eight knot is considered as its own family of knots (see Figure 1). By itself, the figure eight has little utility and is used as a stopper knot that is tied at the end of a rope to stop someone who is repelling from dropping off the line at the bottom of the rope. The figure eight on a bight, figure eight follow through, or in-line figure eight have utility and considerable usage along with other derivations of the figure eight not noted here.

Figure -8 – Figure-eight on a Bight (Figure 5.8) – The figure eight on a bight provides a loop in the end of the rope. The running end of the rope is made into a bight and the bight is tied as if were a simple figure eight. If the person is creating a loop and then clipping it (i.e. carabiner) into something else, this knot is quick to tie and efficient to use. In contrast, if tying a loop around a person or some other fixed object, the figure eight on a bight is tied as a "follow-through" knot which is time consuming in contrast to tying a figure-eight on a bight (see Figure 5.9).

Figure eight

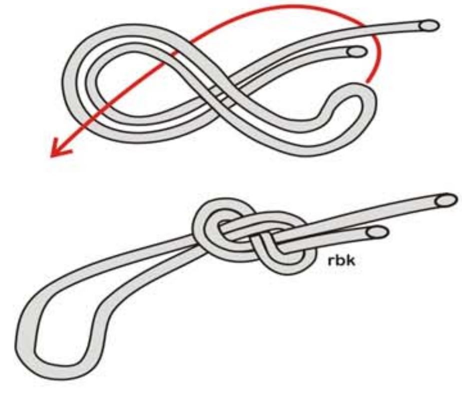
Figure 5.7



The Figure 8 knot is one of the strongest knots. It can be used as a stopper knot, to tie two ropes together, or to tie a loop in the end of a rope.

Figure eight on a bight

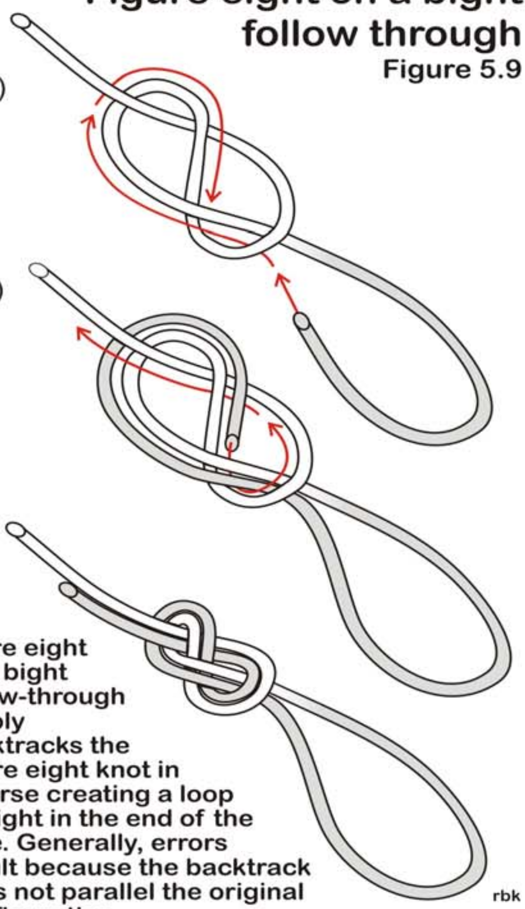
Figure 5.8



Fold the rope back on itself. Tie a Figure 8 knot with the two strands as you would the Figure 8 pictured above.

Figure eight on a bight follow through

Figure 5.9

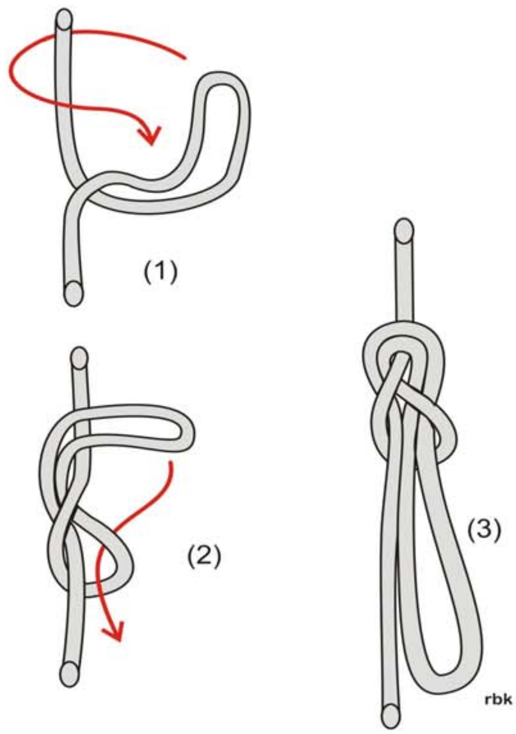


The figure eight on a bight follow-through simply backtracks the figure eight knot in reverse creating a loop or bight in the end of the rope. Generally, errors result because the backtrack does not parallel the original configuration.

Source: Smith, B., and Padgett, A.,(1996). ***On Rope - North American Vertical Rope Techniques***.Huntsville, AL: National Speleological Society, Inc.

In-line figure eight

Figure 5.10



Make an overhand loop on the rope (1). Go around the back of the rope, and through the loop (2). Seat Knot (3).

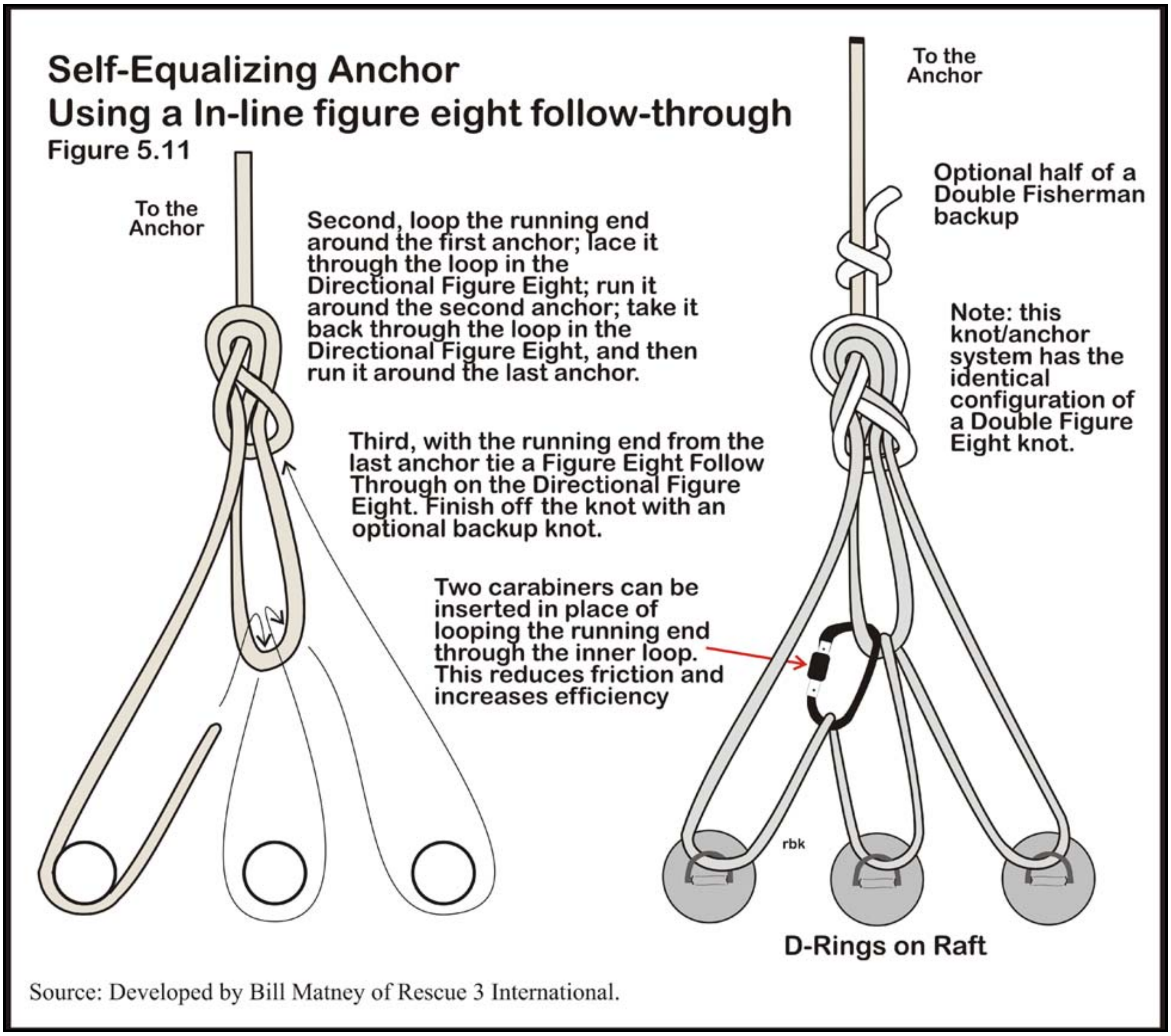


Figure-eight Follow-through (Figure 5.9) – For climbers, this is the knot used to tie into the harness. It is "bullet proof" in that it won't come undone and it provides maximum protection. It is designed to create a loop in the rope connected to the harness or around the person or other object that is secure and provides maximum protection. It is a staple of climbers. The disadvantage of this knot is that it does take time to tie. Under normal circumstances this is not a problem. In an emergency situation and when time is of the essence, this can become more problematic.

In-line Figure Eight (Figure 5.10) – The in-line figure eight is a figure eight tied onto the middle of the main line. It is a specialized knot. It is not difficult to tie and it is relatively easy to untie. It is superior to tying a overhand knot on a bight which is virtually impossible to untie once loaded. It forms the base knot in creating a self-equalizing anchor (see next item).

Directional Figure Eight Follow-through (Figure 5.11) – The running end of the in-line figure eight is worked back through the loop and then retraced the knot as diagramed. The setup is a self-equalizing anchor system where the pull on each anchor is the same. The system can easily incorporate multiple anchor points with the addition of another loop. If there is an abundance of carabiners, they can be used to clip the loops around the anchors to the loop at the bottom of the figure eight.

The system has been used in river rescue and to a lesser extent in climbing. The system can be hooked to multiple D-rings on a raft to extricate it from a pinning. Or it can be used to anchor a haul line to multiple trees used as anchors where no one tree would serve as a suitable anchor. Actually, it should be used more in climbing since it is truly self-equalizing, particularly when used with carabiners.

Bowline (Figure 5.12) – The bowline is used to tie a loop in the end of a rope. The advantage of using the bowline is that it can be tied quickly and easily. Also, it consumes less rope to tie than a figure eight follow-through. The knot maintains its integrity under tension. However, it can loosen when placed in continuous tension and compression situations. In the climbing community the bowline has fallen into disfavor for this reason. When a climber falls, they tend to bounce which can loosen the knot. If there is any doubt that the bowline could be placed in a tension and compression situation, back it up.

Untying the Bowline (Figure 5.13) – Even after being placed under extreme tension, the bowline is easily untied. Bend the working end or "neck" forward. This frees the horse collar which can be flipped over the bent working end (i.e. "neck of the horse"). The knot will easily fall apart.

Yosemite Tie-off (Figure 5.14) – If there is a need for a secure bowline, back it off. The Yosemite tie-off is one of several acceptable methods. When tied correctly, the Yosemite tie-off creates a double sheetbend configuration which has an extra loop in the knot.

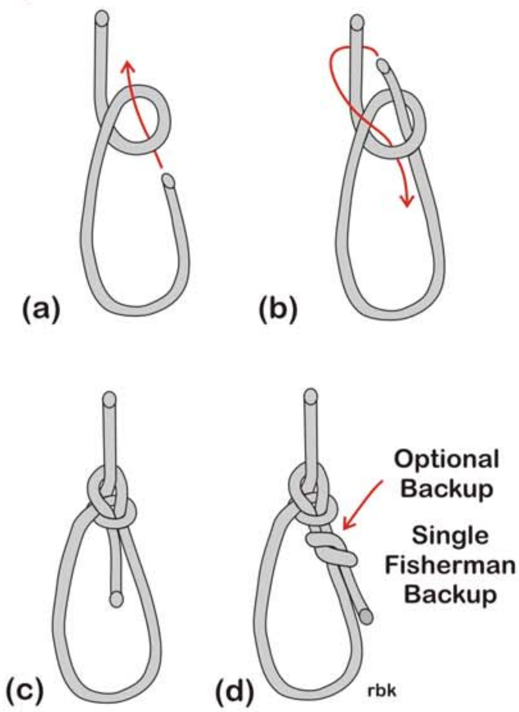
Other knots can be used to back off the bowline. Half a double fisherman's knot can be used (not shown). Half a single fisherman can be used in a pinch, but it may need to be tightened periodically since it tends to be a loose knot (see Figure 5.12d).

Hitches

A hitch requires an object or another rope to maintain its integrity and structure. Without the object or other rope the hitch will simply fall apart. Several hitches are covered in this section, two half-hitches, clove hitch, Prusik, trucker's hitch, double fisherman's, tensionless anchors, and munter hitch.

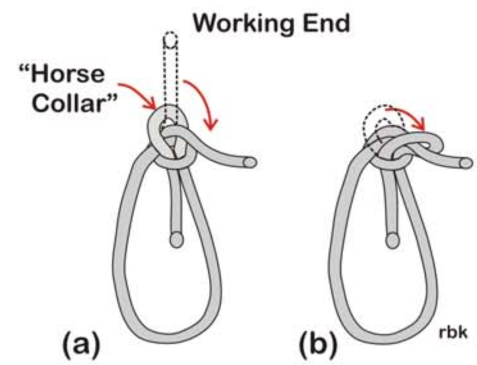
Two Half-hitches (Figure 5.15) – Two half-hitches are commonly used to tie a loop around an object or another line. It is useful in tying off the running end in a trucker's knot where it cinches down on the loop (see Figure 5.18). Technically, when tied correctly, the knot has the same configuration as a clove hitch (Figure 5.16a). A common variation is where the loop is looped back against itself (Figure 5.16b). Most people are unaware of the variations and simply tie one or more hitches. This author is unaware of any difference in strength or holding power between either tying approach. Tying a third or more half-hitch is a common practice and tends to enhance its holding power (Figure 5.16c&d). In addition, tying multiple half-hitches is useful for reducing excess rope.

Bowline
Figure 5.12



Source: Smith, B., and Padgett, A.,(1996). ***On Rope - North American Vertical Rope Techniques***.Huntsville, AL: National Speleological Society, Inc.

Untying the Bowline
Figure 5.13

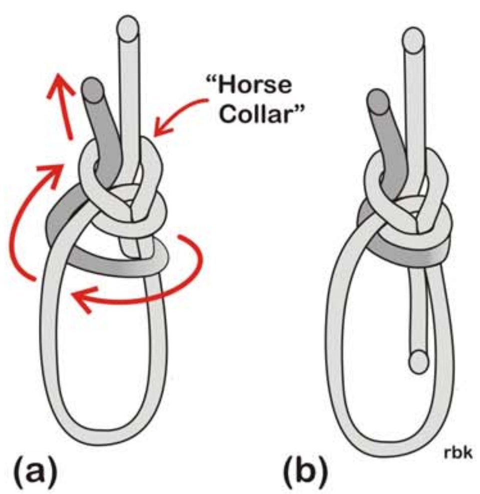


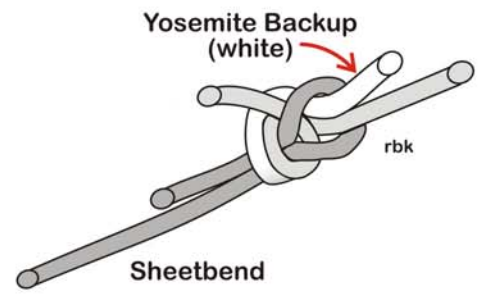
Bend the working end of the rope over the knot (a). This frees the horse collar to be flipped over the working end (b). The knot will become loose and easy to untie.

Source: rbk

<u>A Knot Tying Story</u>: The rabbit comes out of his hole (a); goes around the tree and seeing the fox goes back down into his hole (b). The rabbit grabs his tail and the fox grabs the tree (don't ask me why, but you need to do so to make the knot work). They both pull (c) .... Then they both go bowling (pun intended).

Yosemite tie off on the bowline
Figure 5.14





The bowline tends to be a loose knot and under a tension/release situations, it can potentially become undone. (a) Take the running end, bring it around, through the loop, and up through the "horse collar" as shown. It is parallel to the working end. (b) Set and dress the knot. It is now backed up. It works on a sheetbend also (above right).

Source: Smith, B., and Padgett, A.,(1996). ***On Rope - North American Vertical Rope Techniques***.Huntsville, AL: National Speleological Society, Inc.

Clove Hitch (Figure 5.16) – The clove hitch is used to tie a line to a post or tent peg. The knot has the same configuration as two half-hitches. The difference is that the clove hitch fastens the rope around a fixed object (e.g. peg, posts), and two half-hitches fasten the line around another line. The clove hitch is a loose knot and in tension and compression situations, it tends to become loose and undone. This author usually backs up the clove hitch with two half-hitches to maintain its internal integrity (see Figure 5.16c).

Prusik (Figure 5.17) – The Prusik is a multi-purpose hitch. It is used in climbing as an ascender. In mechanical advantage systems, it is used in the hauling system and in self-adjusting brake. In many circles, it is preferred over mechanical devices because it slips at around 900 lbs of tension. This protects the system from fatiguing elsewhere. The Prusik is a hitch because without the main line to maintain its integrity, the knot will fall apart.

The Prusik is designed to cinch down on the rope and kinking the rope at a slight angle helps to increase its hold. In theory, the Prusick works best when the diameter of the Prusik is significantly smaller than the main line. In rescue work, this author has used Prusiks with diameters that are close to the main line with little adverse effect. In swiftwater rescue, most mechanical advantage systems use Prusiks in both the hauling system and self-equalizing brake.

The first step in making a Prusik is to make a sling. Tie the two ends of the rope together using a double fisherman's knot. Next, loop the loop around the main line and through itself as pictured in Figure 5.17.

Third is the issue of where the double fisherman knot is located. There are three options. First, the double fisherman can be positioned over the Prusick as pictured in Figure 5.17. In theory, this minimizes the loss of tensile strength due to a knot in the system and in theory, the tensile strength of the Prusik approaches that of the rope without a knot. In practice, it may not make that much difference. The Prusik has two supporting lines. If the rope has a tensile strength of 900 lbs, it has an effective tensile strength of 1,800 lbs. It should be noted that some people find it easier to tie the Prusik by positioning the double fisherman over the knot. In addition, some people find it easier to tie the Prusik by latching onto the knot and passing it through the loops. There is a method to this approach and it works well.

The second option is to have the double fisherman located on the side of the sling. As a practical matter, this approach is satisfactory also. Remember, if the Prusik fails (i.e. slips on the rope) at 900 lbs, two 1,800 lb tensile strength cords are not going to fail at the knot even if the knot reduces the strength of the Prusik cord by 50%.

The third option is to locate the double fisherman where the carabiner fastens into the Prusik. This should be avoided since it places undue stress on the system. Often, when tying the knot, the double fisherman is grasped and looped through and around the main line. It is convenient. This approach will tend to line up the knot where the carabiner clips into the sling. For this reason, this approach to tie the Prusik should be avoided.

Prusiks can easily cinch down on the main line making them difficult to move and readjust unless the knot is loosened. For a Prusik to be effective, it needs to be loosened easily and readjusted along the main line. This is a three-step process of loosening the knot, moving it and re-cinching it. It is important to loosen the knot first or it will be difficult to move a cinched Prusik. To loosen or untie the Prusik, pull the "horse collar" over itself. Conceptually, this process is similar to loosening the bowline (see Figure 5.13).

Trucker's (Rigger's) Hitch (Figure 5.18) – The trucker's hitch is used to fasten boats, construction materials, and other items to roof racks on a car, or to fasten lines to tent pegs that are easily adjustable. Close inspection of the rig reveals that the hitch is the same configuration as a Z-rig and offers a theoretical 3:1 mechanical advantage (see Figure 6.8). This mechanical advantage makes the trucker's hitch an attractive rig for when the line needs to be taught or when the tension on the line needs to be adjusted. The adjustable lines to the tent pegs are an example of this re-adjustment. The other good feature of the trucker's hitch is that it is easy to untie and when untied, the hitch simply falls apart. A key to having it fall apart easily is to put several twists (i.e. 3-4 twists) in the initial loop.

In situations where the tension needs to be monitored or adjusted, or where there needs to be micro adjustments made in hauling line, the trucker's hitch works well in these situations. For example, the author uses it to set up and adjust lines in river rescue including the strainer drill (see Figure 2.10).

Two half-hitches are used to finish off and lock the trucker's hitch into place (see Figure 5.15). If there is any doubt regarding the two half-hitches, use three half-hitches. The half-hitches need to fit snugly against the loop or it will slide down the line until it becomes snug. If it is anticipated that the system will be readjusted, tie the half-hitches using a bight in the rope. Pulling on the one side of the bight unties the half-hitches. In addition, extra line can be daisy chained (not shown).

Tensionless Anchor (Figure 5.19) – Traditionally, the tensionless anchor has been used to anchor ropes around trees. This author has used the tensionless anchor to fasten boats, construction items and other items to be hauled to the roof racks on his car. It has replaced the trucker's hitch in this use. It works by the rope creating friction around the anchor. It is a hitch because it uses the tree or roof rack to maintain its integrity and structure. In contrast, the anchors depicted in the anchor section use slings to create the anchor. At some point there is considerable overlap between a hitch which requires an object for it to wrap around and an anchor. In the end, it may be a fine distinction.

Often the tensionless anchor is drawn with the rope neatly coiled around the anchor. This need not be the case. Only the first two coils should be neatly looped around the anchor and free of crossovers. This aids when finishing off the knot. Feel free to coil the unused portion of the rope around the anchor with numerous crossovers.

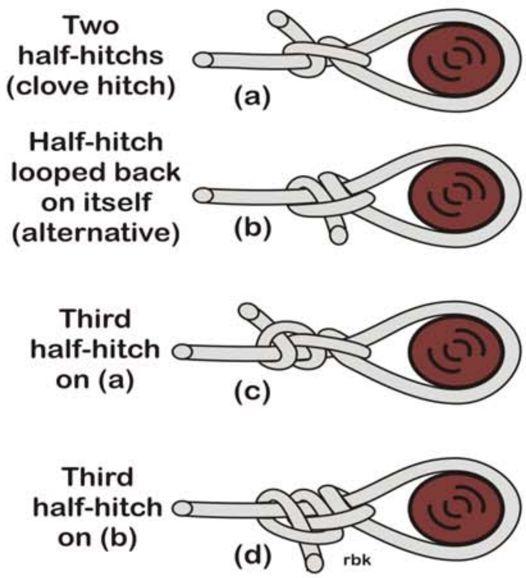
The literature shows several ways to finish off the tensionless anchor. The first is to let the free end hang loose (not pictured). This is not recommended. If the tensionless anchor is only under tension, the system will tend to maintain its integrity and not loosen. Regardless, this author doesn't like loose ends and prefers a tie off method. If the system is under repeated tension and slack, the anchor will loosen and the system will begin to fall apart.

The second method of finishing off the tensionless anchor is tie a figure eight on a bight and fasten the knot to the main line with a carabiner (not shown). This approach is slightly better than using no tie off. It does provide fail safe protection where if the system loosens and begins to unwind, it will eventually lock down on itself.

The third approach brings the loose free end around the main line on the first coil and cinching it off as shown in Figure 5.19. This is why it is important to neatly coil the first two coils. After the first two coils, the rope can be wrapped in any fashion that is convenient and crossing over itself does not affect the integrity of the anchor.

Two half-hitches

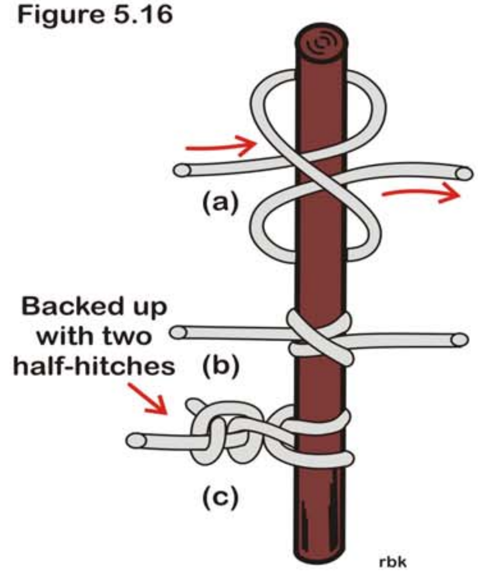
Figure 5.15



The technically correct version is pictured in (a). It looks like a clove hitch. A common alternative is to loop back on itself (b). There is no evidence of a loss in effectiveness. If there are any questions add a third half-hitch (c&d).

Clove hitch

Figure 5.16

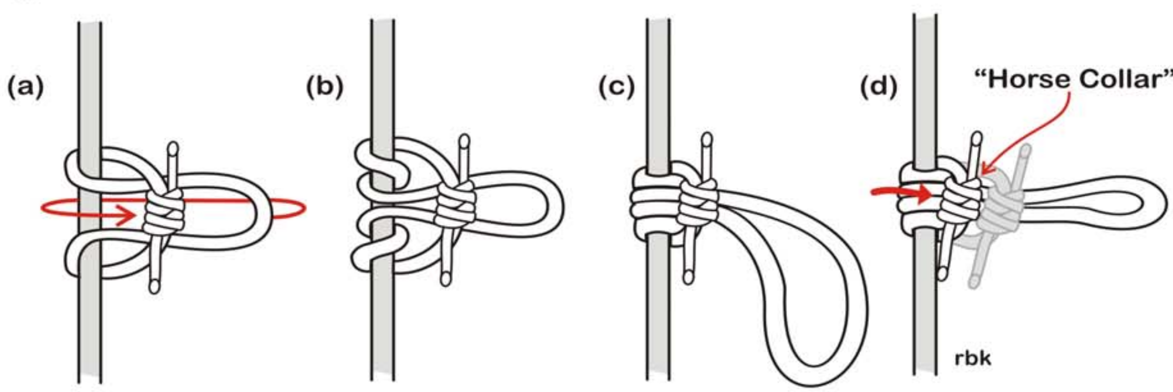


Careful inspection reveals that the clove hitch and two half-hitches are identical knot configuratons.

Usually, the author ties the clove hitch off with two half-hitches since the clove hitch tends to loosen and easily falls apart (c).

Prusik

Figure 5.17



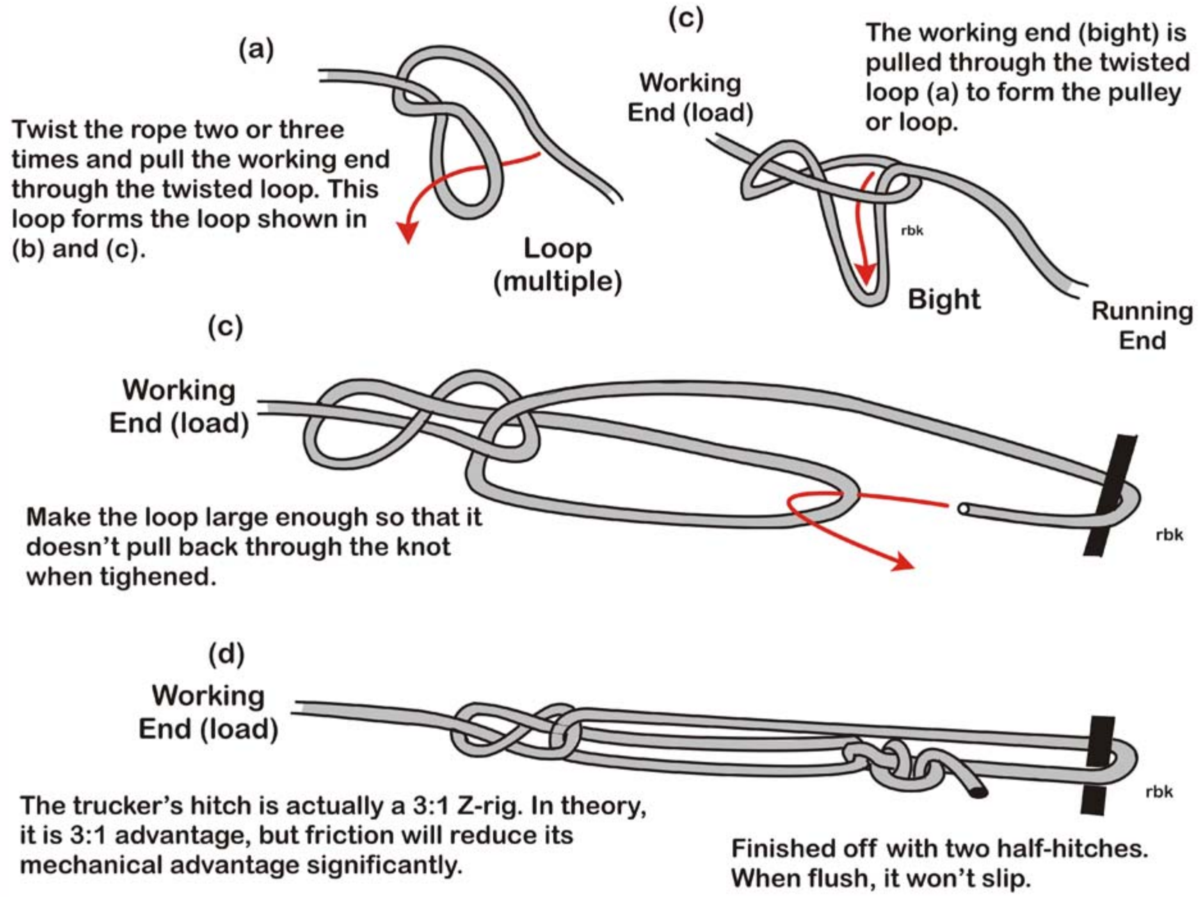
1) Tie two ends of the cord using a double fisherman's knot (not shown).

2) Hold the double fisherman's knot in the one hand and loop two to three times around the main rope (a) & (b). A third loop is often added for extra bight (not shown). Make sure the loops are parallel with each other (c).

3) To untie a tight prusik, flip the double fisherman's knot (i.e. horse collar) back over the loop (a) and push the loop through the horse collar (d). This will loosen the knot allowing it to be easily readjusted.

Source: Smith, B., and Padgett, A.,(1996). ***On Rope - North American Vertical Rope Techniques***.Huntsville, AL: National Speleological Society, Inc.

Trucker's (Rigger's) Hitch
Figure 5.18



Source: Kauffman, R. (2015). ***Swiftwater Rescue Packet***. McHenry, Maryland: Garrett College. Unpublished packet.

Tensionless Anchor

Figure 5.19

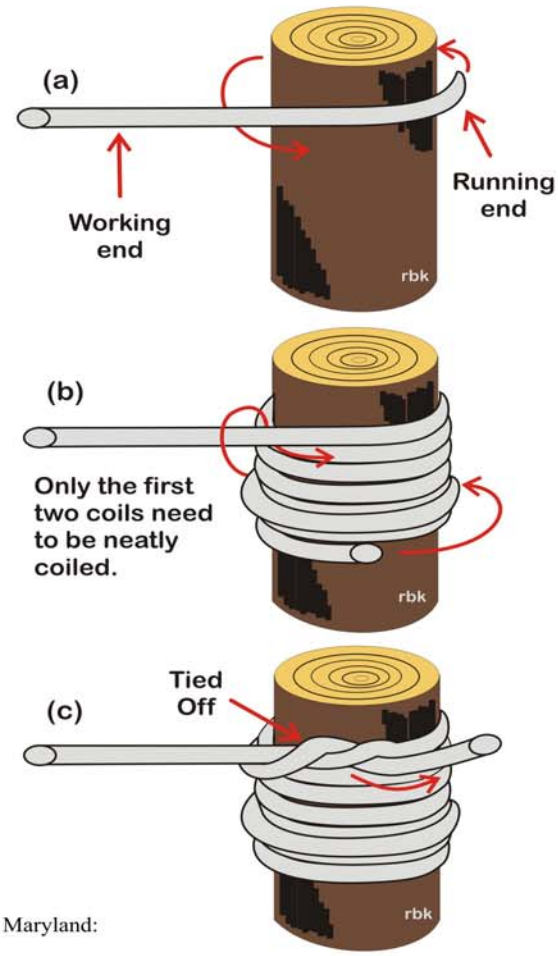
A tensionless anchor utilizes the friction created by the rope wrapped around a tree, car roof rack, or other object to prevent slippage of the standing end of the rope.

Many texts depict a tensionless anchor with the running end not tied off or just hanging (b). The problem is that the system will tend to losen and begin to unwind particularly, if the system is placed under cycles of tension and slack.

A good way to tie off the anchor is shown in (c). The free end is simply looped around the working end and pulled taught. It locks the rope and maintains the integrity of the system. This author has used this system to fasten boats to a car roof rack for years. It is quick and easy to tie and untie also.

Some people will tie the free end to the working end using two half-hitches (not shown). It works, but in the estimation of this author, it is not as efficient as the method shown in (c).

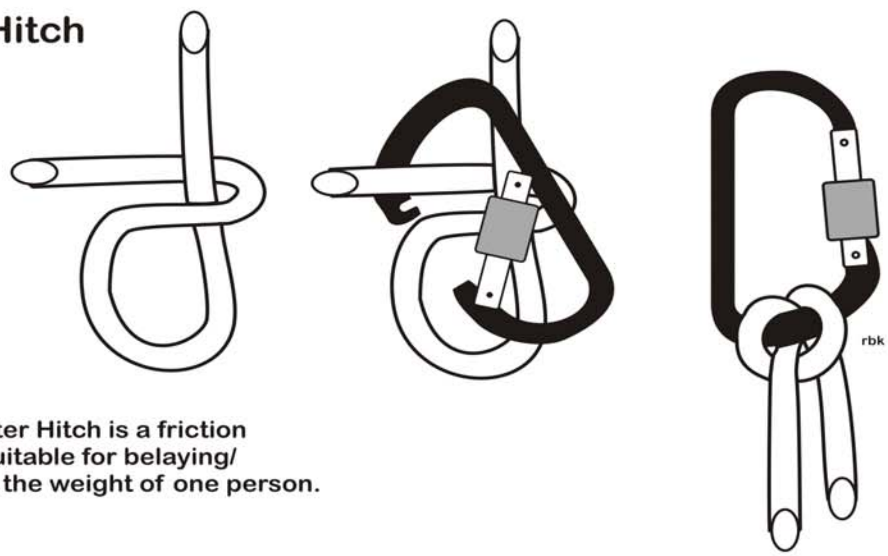
Only the first two loops need to be neatly coiled. This is for the tying off. The remaining coils can be wrapped crossing over each other without ill effect.



Source: Kauffman, R. (2015). ***Swiftwater Rescue Packet***. McHenry, Maryland: Garrett College. Unpublished packet.

Munter Hitch

Figure 5.20



The Munter Hitch is a friction device suitable for belaying/ lowering the weight of one person.

Source: Kauffman, R. (2015). ***Swiftwater Rescue Packet***. McHenry, Maryland: Garrett College. Unpublished packet.

The author has used this version of the tensionless anchor for years to fasten boats and other items to the roof racks on his car. It replaced the use of the trucker's hitch for tying down boats on roof racks. It is easy to tie and untie. It works equally well on metal roof racks. Also, the system tends to maintain its integrity when experiencing repeated tension and compression situations. However, if there are known situations with extreme repeated tension and compression situations, the author will normally revert to the trucker's hitch which will maintain its integrity regardless.

Munter Hitch (Figure 5.20) – The munter hitch is a friction device that can be used in place of a rappelling device. The author uses it in place of a clove hitch on a carabiner tied off with two half-hitches (not shown). Either way works. The advantage of using either a tied off munter hitch or clove hitch is that it prevents the carabiner from rotating.

Bends

Bends tie two ropes together. Three bends are covered, the sheetbend, water knot and double fisherman's knot. A figure eight follow through is not included. However, it can easily be inferred (see Figure 5.9 and Figure 5.11). Simply retrace the figure-eight knot.

Sheetbend (Figure 5.21) – The sheetbend is used to tie two ropes together. Careful inspection of the knot reveals that it has the same configuration as a bowline (see also Figure 5.12). Hence, the sheetbend has most of the same attributes as a bowline. It tends to be a loose knot. Under tension and slack, it will tend to become loose and come apart. Like the bowline, it is easy to untie. Simply, break the "horse collar" and the knot falls apart. For additional strength, consider a double sheetbend with two internal loops.

Water Knot (Figure 5.22) – The water knot is used to tie two pieces of webbing together to form a sling. This is the primary purpose of the knot and no other knot excels like the water knot in this capacity. It is a strong knot, and does not need to be backed up. Normally, it is not used to tie two ropes together. A sheetbend or figure-eight follow through would be preferred.

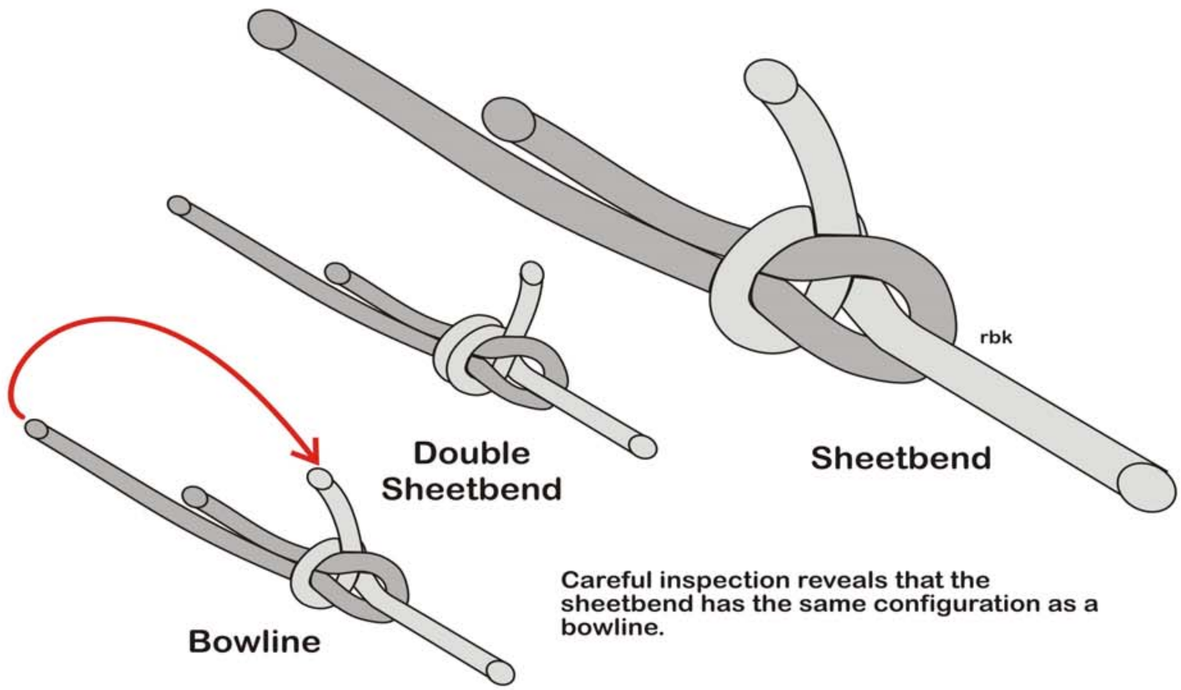
Literally, the knot is tied as a follow-through overhand knot. Tie an overhand knot loosely in the webbing. With the other end, follow through the knot in reverse. Seat and dress the knot. Avoid kinks. The follow through webbing should parallel the original knot. No backup is needed. The knot maintains its tightness under stress and compression.

Double Fisherman (Figure 5.23) – Normally, the double fisherman is used to fasten two ends of a rope together to form a loop or sling. Sometimes, it is called the grapevine knot. It is an integral component in creating a sling and tying the Prusik. Half of the knot is often used as a backup knot for other knots. The knot cinches on itself making it extremely difficult if not virtually impossible to untie after being loaded. For this reason, it is used in situations where it won't be untied. When tying together two separate lines that will eventually be untied, other knots such as the sheetbend or figure-8 follow-through would be preferred.

Sheetbend

Figure 5.21

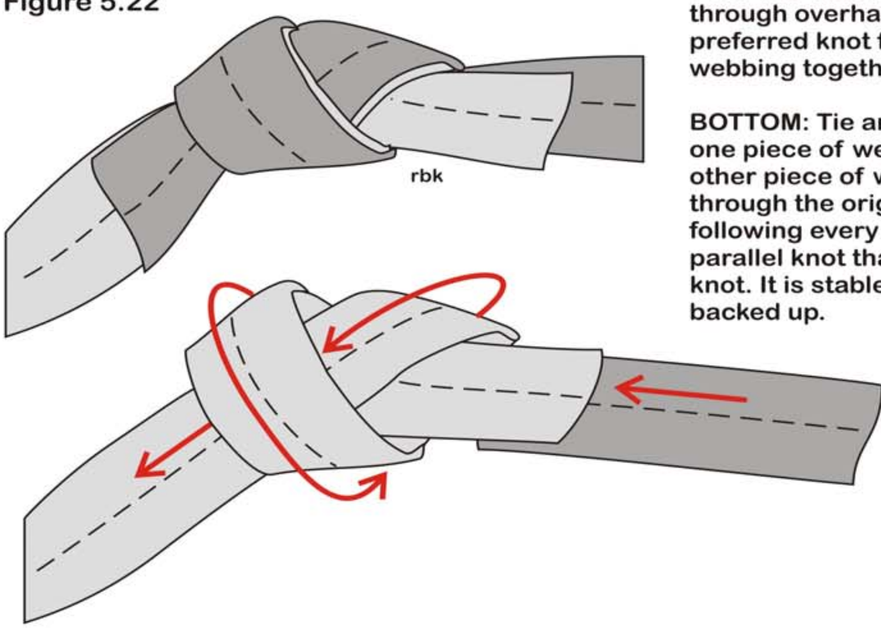
Use the sheetbend for tying two ropes together even if they are of different diameters. A double sheetbend is better.



Careful inspection reveals that the sheetbend has the same configuration as a bowline.

Water Knot (Bend)

Figure 5.22



TOP: The water knot is a follow-through overhand knot. It is the preferred knot for tying two pieces of webbing together.

BOTTOM: Tie an overhand knot in the one piece of webbing (right). With the other piece of webbing, trace it back through the original overhand knot following every bend. It creates a parallel knot that mirrors the original knot. It is stable and need not be backed up.

Source: Smith, B., and Padgett, A.,(1996). ***On Rope - North American Vertical Rope Techniques***. Huntsville, AL: National Speleological Society, Inc.

The configuration of the single, double, and triple fisherman are essentially the same except for the number of wraps around the rope. The configuration of the single fisherman is that of an overhand knot with the other end of the rope passing through the center of the other overhand knot. A single fisherman's knot has one loop. A double fisherman's knot has two loops and the barrel or triple fisherman's knot has three loops. A single fisherman's knot tends to be a loose knot and in backup situations, half a double fisherman is generally preferred. In terms of strength, there is not much difference between a double fisherman's knot and the triple fisherman. However, the triple fisherman's knot consumes more rope. In most situations, the double fisherman is more than adequate in terms of strength and in maintaining its integrity.

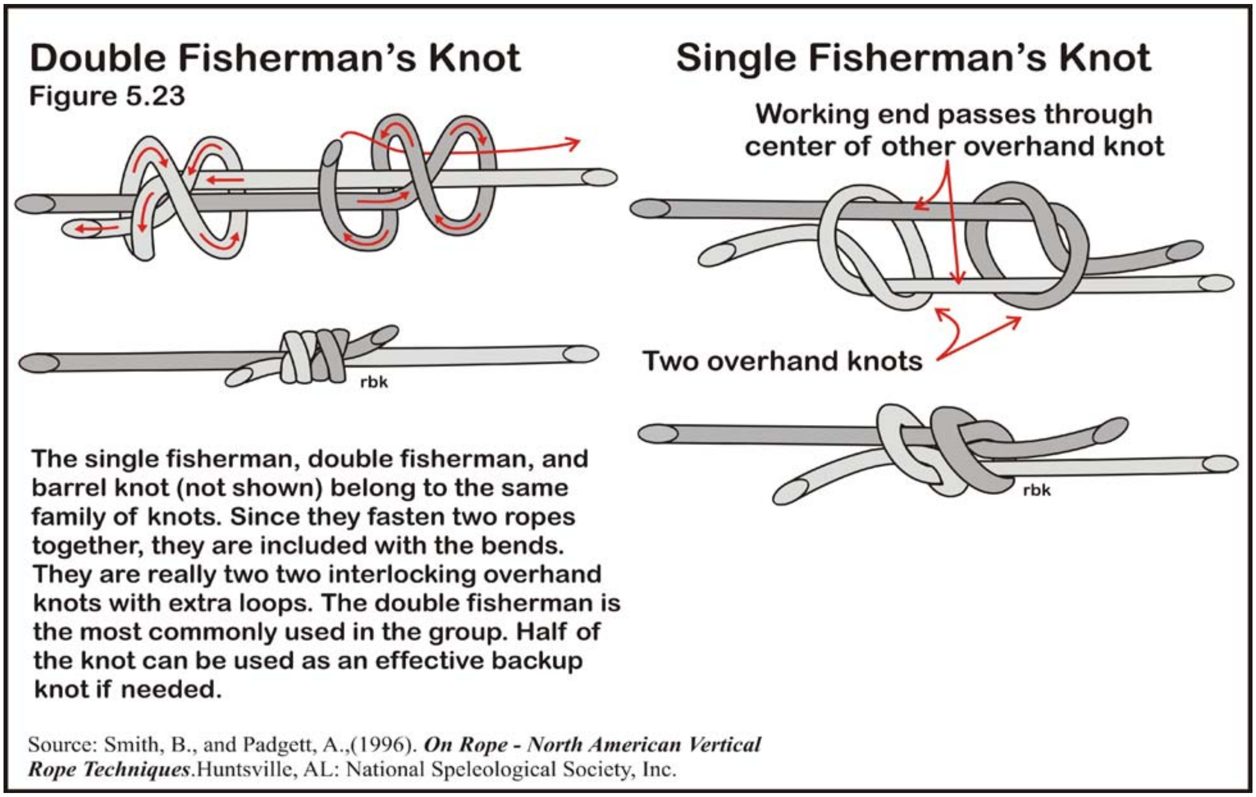


Figure 5.23

The single fisherman, double fisherman, and barrel knot (not shown) belong to the same family of knots. Since they fasten two ropes together, they are included with the bends. They are really two two interlocking overhand knots with extra loops. The double fisherman is the most commonly used in the group. Half of the knot can be used as an effective backup knot if needed.

Source: Smith, B., and Padgett, A.,(1996). ***On Rope - North American Vertical Rope Techniques***.Huntsville, AL: National Speleological Society, Inc.

Cams Straps

Currently, cam straps have not become a staple in the swiftwater rescue community (Figure 5.24). However, they are a staple in the rafting and boating communities. They are used to fasten everything to the raft in both paddle craft and oar rigs. For this reason they may be available to use in rescue situations where there are limited resources available. The traditional cam strap is a 1" polypropylene strap with a tensile strength of roughly 1,500 lbs. They come in a variety of lengths ranging from one foot to 20 feet in length.

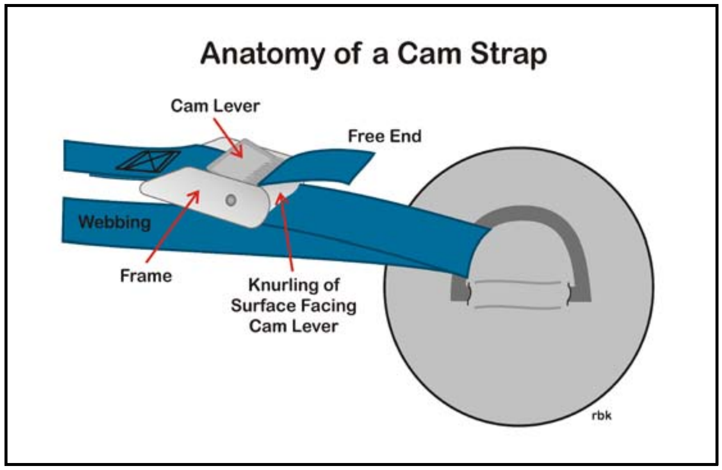


Figure 5.24: Anatomy of a Cam Strap – The NRS ® straps or generic cam straps are a stable on the river used to fasten everything to the raft. Source: Author – [file:\.EQUIP_NRSstrap.cdr]

Cam straps are easy to use and relatively foolproof. Thread the strap into the cam. Pull it taught. The cam is designed to lock down on the strap. To release, simply press the button on the back of the cam.

There are several methods used to store cam straps. Coiling the straps is one of those methods (Figure 5.25). The advantage of coiling the straps is that they store easily and compactly with other gear. There are no loose ends. They are easy to uncoil. They can be easily tossed to someone who needs a strap. The big disadvantage is that it takes time to coil the straps.

Coiling the straps is not initially intuitive. Two tips to the method include the following. First, thread the webbing behind the cam lever and where the other end of the webbing is attached to the frame (Step 1, see Figure 5.24 for parts). Second, allow sufficient length of the free end so that it can be cinched down later. This may require some trial and error. Next, the strap should hang down (Step 2). Coil the webbing back on itself upward. Coil it toward the cam opening in the frame. When coiled, wrap the free end around the coil and through the cam (Step 3). Cinch it down until it is snug. Store it in the gear bag (Step 4). It is ready for use.

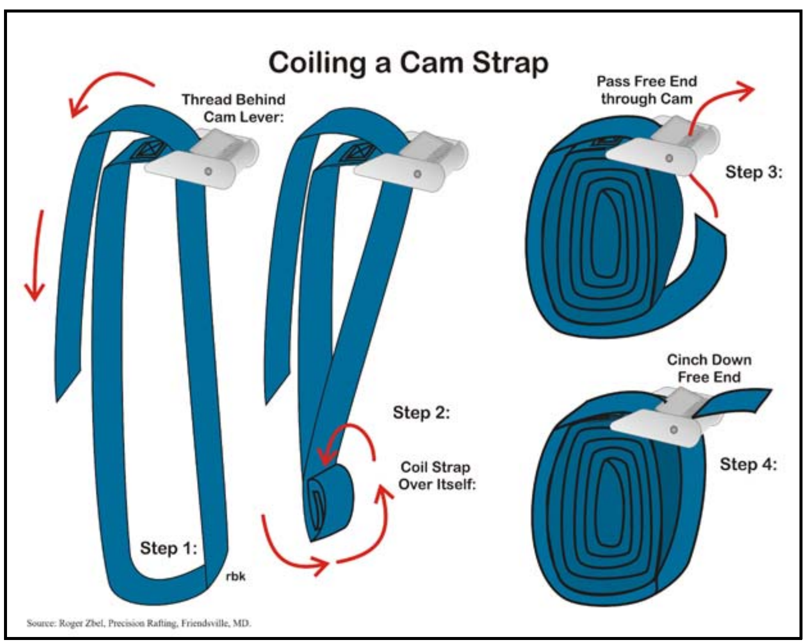


Figure 5.25: Coiling a Cam Strap – Source: Author

Anchors

In general, an anchor is a rock, tree or other object to which a line can be firmly attached. A belayer can be considered an anchor. The tensionless anchor discussed in the hitch section is also used as an anchor (see Figure 5.19). The figure-8 follow through makes an excellent self-equalizing anchor (Figure 5.10 and Figure 5.11). Usually, webbing is used to wrap around the anchor. Three anchors are discussed in this section. They are the simple or single loop, the 3-bight, and the girth hitch.

Simple or Single Loop (Figure 5.26) – One of two situations occurs. The end result is the same. The webbing is looped around an object or anchor and the water knot is tied connecting the two ends of the webbing together to make a loop. The downside of this approach is having to tie a water knot when tying the sling around the object. It takes time. Second, a pre-tied sling can be slipped or looped around an anchor which is much quicker. Often, when going around a rock, the extra length of webbing is needed to get around the rock.

The big disadvantage of the single loop is that it can slip down the anchor. This is particularly true on tree trunks and other vertical objects. It is less of a problem going around a rock anchor. The big advantage of the single loop is that it has twice the length of webbing than in the 3-bight approach which can be useful in going around a large rock.

The second version of the simple anchor is much more practical. It can be used on rocks but not trees. Most rescuers will take the sling and loop it around the anchor. This is particularly applicable to wrapping the webbing around a rock or similar anchor. If this doesn't work, the rescuer will often move to the 3-bight approach. It doesn't require retying the sling. It reorients the sling.

3 Bight (Figure 5.26) – A water knot is pre-tied in the webbing making a sling. The sling is looped around the anchor and the two ends connected with a carabiner. An advantage of this system is that it is quick and easy to construct. Another advantage of this anchor is that it reduces the load on each of the webbing strands by a fourth of the total load. It is divided by four supporting lines. As with the simple anchor, a disadvantage of this setup is that it can slip down vertical anchors such as tree trunks. As noted, a disadvantage is that it

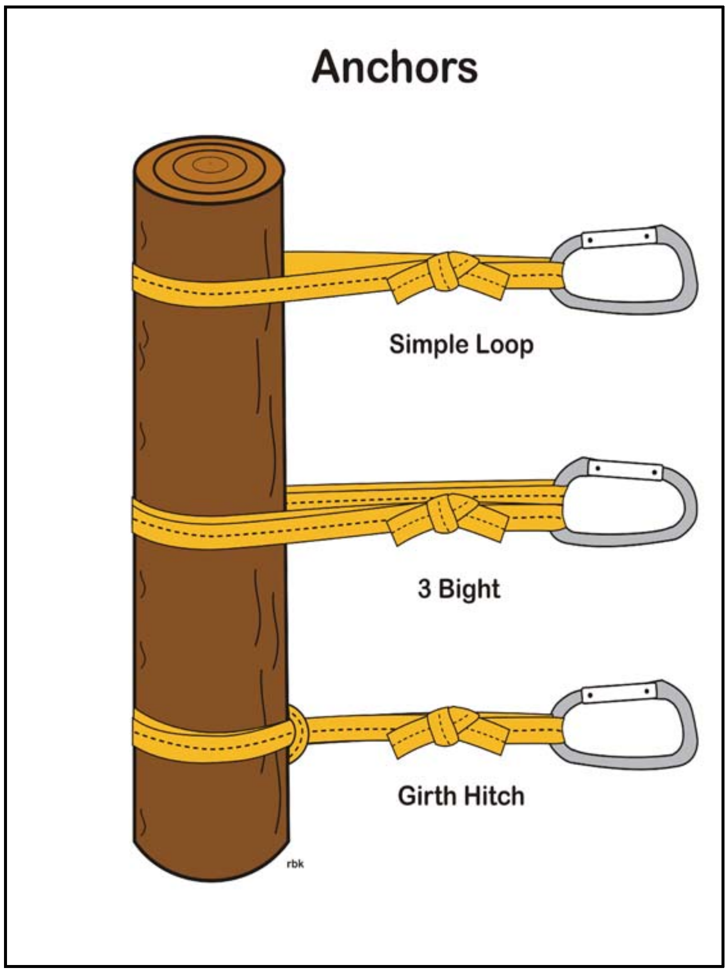


Figure 5.26: Anchors – Three types of anchors are presented. Source: author – [file:\ROPE-Anchors.cdr]

takes twice the amount of webbing to go around the same anchor as the simple anchor.

Girth Hitch (Figure 5.26) – In practice, the girth hitch is a practical anchor. It cinches down on the anchor. It can be tied quickly and easily. It is intuitive and simple to use.

A pre-tied sling is looped around the anchor and then the two loose ends are passed though the loop. An advantage of the girth hitch is that it cinches down on the anchor, making the anchor more effective. A disadvantage of the girth hitch is that because it cinches down on the anchor, it creates a stress point at the hitch. Although this is technically true, it rarely presents an actual problem or system failure.

Carabiners

Carabiners are a staple of swiftwater rescue. They are used to connect ropes to other ropes or webbing. They are used in rescue vests to connect the tether to a line in several of the rescues. Carabiners come in all types of shapes and forms. Choose a type of carabiner that you will carry with you. Locking carabiners are recommended. However, if you choose to bring non-locking carabiners with you, they are better than not having any carabiners at all.

The parts of a carabiner are presented in an anatomy of a carabiner (Figure 5.27). A locking gate is shown. The purpose of the gate is to maintain the structural integrity of the carabiner under load. It is important for the gate to remain closed under load. A locking gate screws up the gate to cover the nose. This prevents the gate from opening. Providing a visual check, a red anodized section of the gate is often provided on the gate. When it is no longer visible the gate is closed.

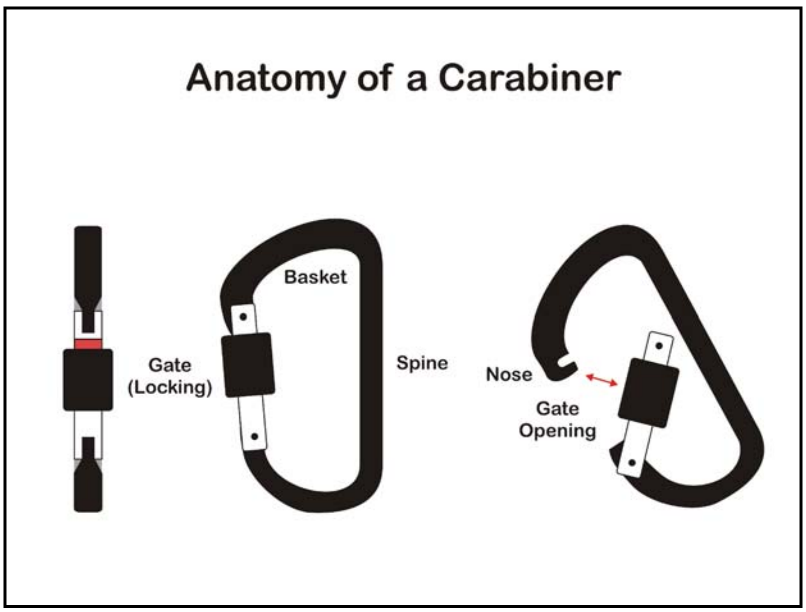


Figure 5.27: Anatomy of a Carabiner – Source: Author

A second approach is the self-locking gate where the locking mechanism is spring loaded to keep the gate closed unless actively opened. In theory, the spring loaded gate should be susceptible to sand and other river grime found in the river environment. This author has used two self-locking carabiners for years in a hostile river environment without ill effect. In fact, they have worked perfectly and in many respects better than the screw versions that can tend to become a little gritty to operate. However, there are different versions of self-locking gates and other versions may work less satisfactorily than the version used by this author.

When locking the gate, do not screw the gate tightly onto the nose. This can result in the gate becoming truly locked and difficult to unlock after being placed on load. To help prevent this, it is recommended to close the gate and then back off a quarter of a turn. If the gate becomes stuck, reload the carabiner and back off the locking mechanism.

On a “D” shaped carabiner, the basket is larger of the two ends. The gate opens into the basket. The spine is self-explanatory and carries the load placed on both ends of the carabiner. Also, of consideration is the gate opening. It limits what can be inserted into the carabiner.

It is important not to side load a carabiner. This is where a force is applied on the gate or spine of the carabiner. In swiftwater rescues this is not difficult to do. For example, in the V-lower the tether is hooked to a line. The tether is at a right angle to the carabiners connecting the lines. If not done correctly, it is easy to side load one of the carabiners (see Figure 3.11).

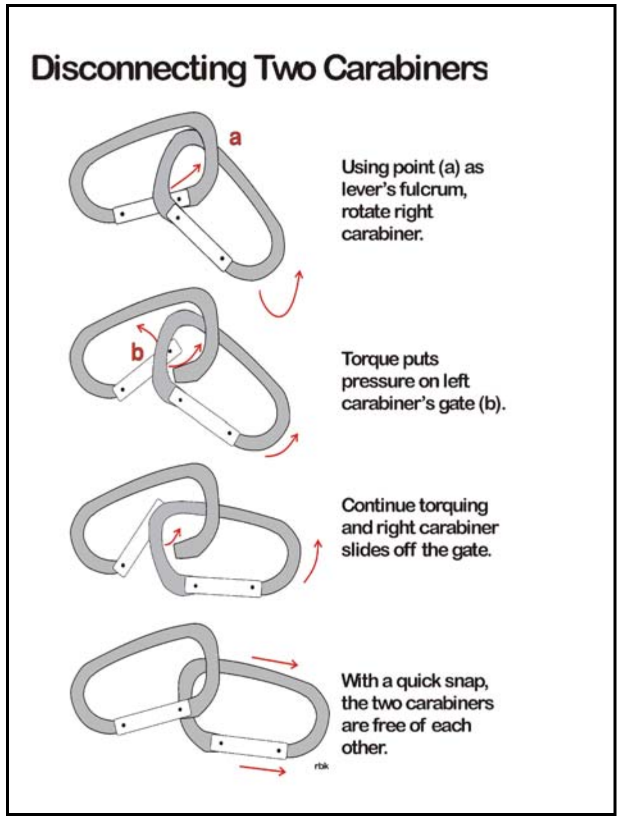


Figure 5.28: Disconnecting Two Carabiners –In swiftwater situations, two carabiners can easily become disconnected. Source: Author.

Many paddlers like to clip two carabiners into the shoulder strap of their life jacket. It looks sexy, but it can be potentially dangerous. The carabiners become a potential items to ensnare a victim. Consider carrying the carabiners in a pouch or fastened them with velcro or a similar device that will disconnect easily if snared.

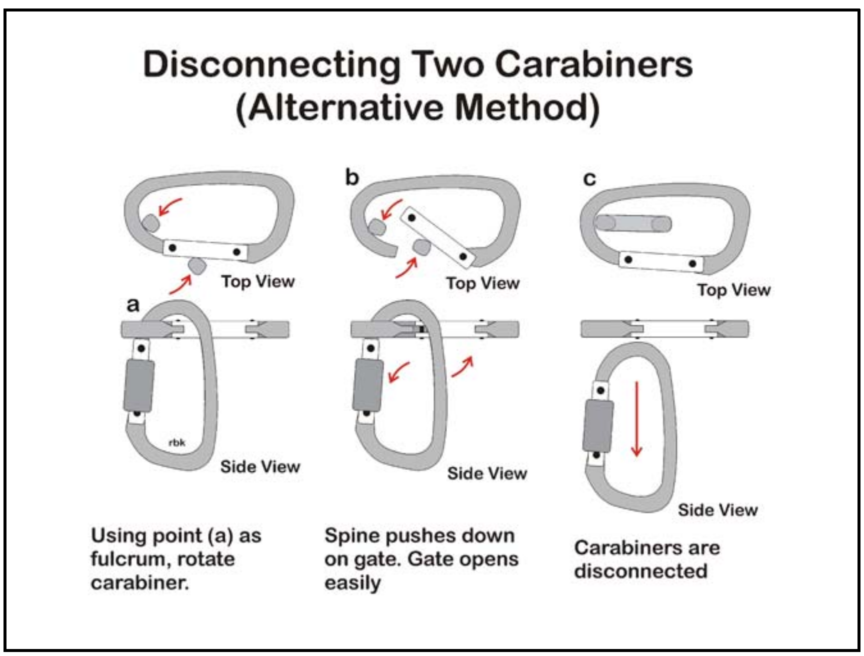


Figure 5.29: Disconnecting Two Carabiners (Alternative Approach) –In swiftwater situations, two carabiners can easily become disconnected. Source: Author.

In swiftwater applications, locking carabiners are recommended (Figure 5.28 and Figure 5.29). Two carabiners fastened together or a carabiner fastened to a “D” ring in a boat can easily become unfastened by the agitation of moving water. Figure 5.28 and Figure 5.29 show two ways that unlocked carabiners can easily become disconnected from each other.

Summary

The term knot is used generically to cover knots, hitches, and bends. Although the differentiation was used here, it may not make that much difference in practice. The three types of knots indicate three basic knot tying situations. The rope needs another rope or object for it to maintain its internal integrity (i.e. hitch). It fasten two ropes together (i.e. bend). Or it is a self-supporting knot in the rope that creates a loop or serves some other function. Although not a staple in the rescue community cam straps were introduced. In addition, anchors and carabiners were discussed.

Consider knowing how to tie one knot in each of these three situations. The corollary is that sometimes less is more. Consider being able to tie these three knots blindfolded, backwards, or forwards. The point is that knowing how to tie a few knots well is better than trying to tie multiple knots with overlapping functions poorly or with uncertainty.

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