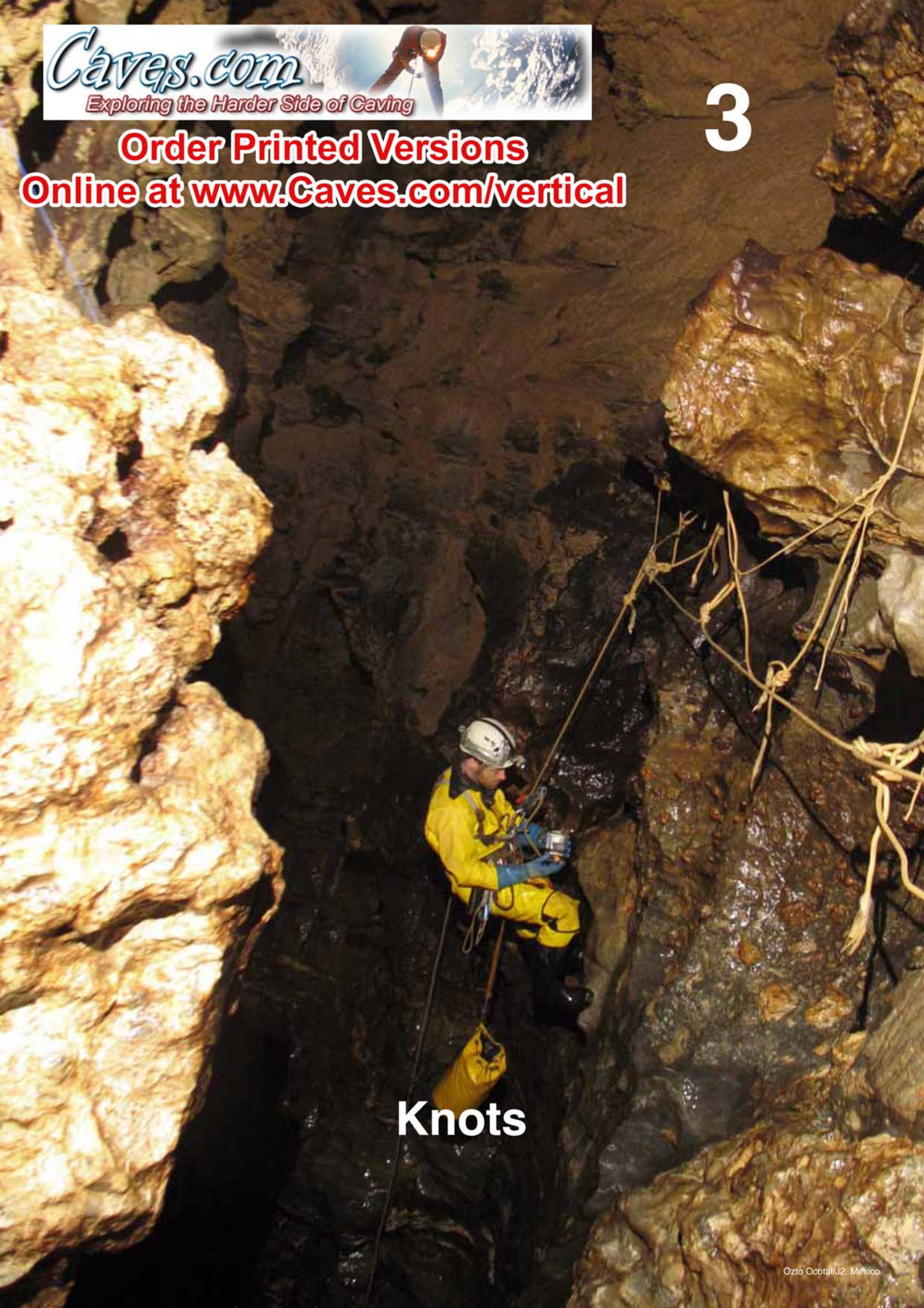
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Knots
Ozto Ocotal/J2, Mexico

A good knot has certain characteristics:

- Easy to tie
- Readily verified as correctly tied
- Secure once tied and no slip under load
- Easy to untie after it has been loaded
- Weakens the rope to a minimum

There is no need to learn a vast repertoire of knots. Rather it is preferable to learn only those few knots that work best in as many situations as possible. This aids efficiency and safety as greater familiarity increases speed and reduces the probability of tying the knot incorrectly.

People generally assume that knots weaken a rope because of the tight bends the rope makes as it winds through the knot. This is not entirely true. Consider an 11 mm rope with a loop knot connecting it to a 6 mm maillon at one end. When the rope is loaded to failure, it typically breaks at the point where the loaded rope exits the knot. It does not break at the small radius where it passes through the maillon or at the minimum radius bend in the knot.

Nylon fibre fails when the stress concentration from pressure and tension on it is sufficiently high to soften it, in much the same way as you can melt snow into a snowball by squeezing it. The rope does not necessarily get much hotter, it softens at a lower temperature when under pressure. Inside the knot there is a combination of tension, pressure and higher temperature as the rope wraps around itself and the forces become concentrated to such a degree that the rope fails at a much lower load than it would without the knot. The way to reduce the strength lost in a knot is to use one that has a maximum of 'active surface'; one that spreads the pressure over as much rope as possible. This is difficult to determine visually though generally the bulkier the knot the better it will perform.

Any knot is likely to perform better if you tie it neatly rather than with strands needlessly crossing one another creating extra pressure concentrations. The main value of neatness however, is that it makes a knot easier to verify. Once you have your knot tidy, pull it as tight as you can by hand so that it tightens up correctly when you fully load it.

Knot strength is not so important with new 11 mm ropes that can afford considerable strength loss and still remain safe but when using thin rope, you should tie the best knot that you can.

End loop knots

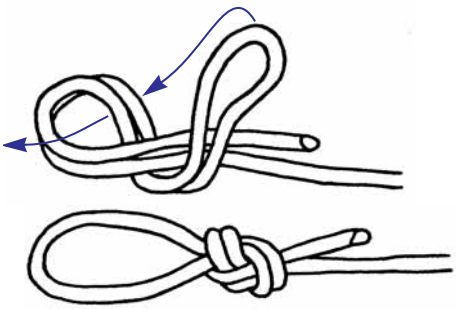


Figure-8 loop, the most versatile and popular of loop knots

If you had to learn just one knot for caving, that knot must be the Figure-8 in its various forms.

You need an end loop knot to attach one end of the rope to a belay. The most suitable knots are the **Figure-8** loop and the **Figure-9** loop for ropes of 9 mm or less because of its unequalled strength. You can use a Figure-9 for thick and/or stiff ropes but it will be difficult to tie and use a lot of rope. In either case, tie the loop then clip it to a maillon or karabiner, put the loop over a natural anchor, or tie a single knot, thread the rope end through and anchor, then thread the rope back through the knot.

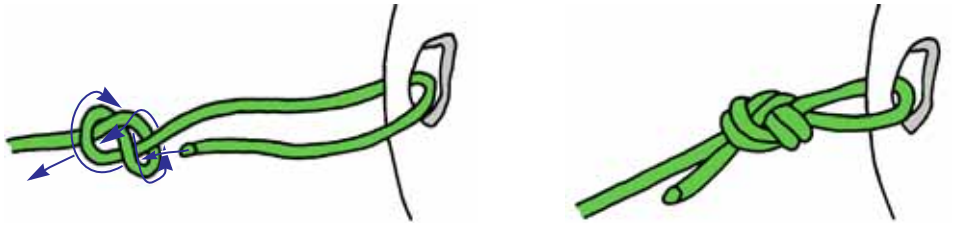
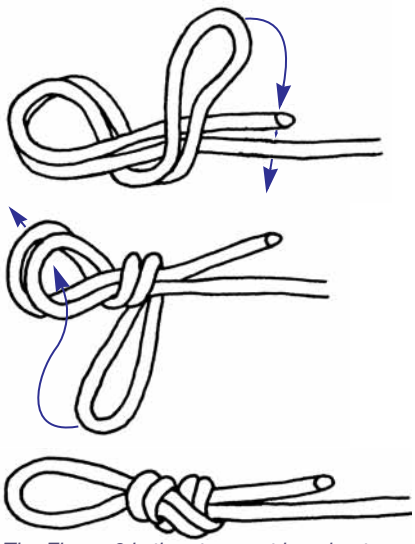
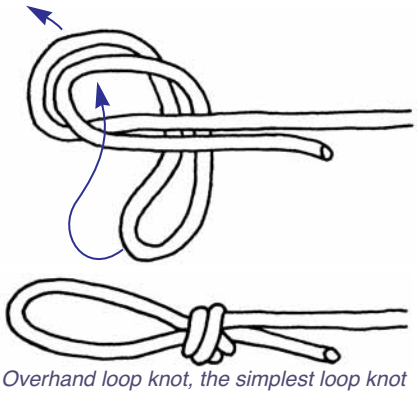


Figure-8 threaded back on itself to tie through an eyehole



The Figure-9 is the strongest loop knot and a must for thin ropes

When the anchor is a large natural or a thread, Figure-8 and Figure-9 knots are slow to tie. The Bowline on the other hand is quick and easy to tie around large objects. Despite its popularity the Bowline is a potentially dangerous knot, it is easy to mis-tie, can be jiggled undone by continued movement of the rope and undoes easily when loaded wrongly. For these reasons alone, the Bowline is not recommended for any life support application. Anyone who still wishes to use a Bowline must 'lock' it with an extra Overhand knot or half a Double Fisherman's knot around the standing rope.



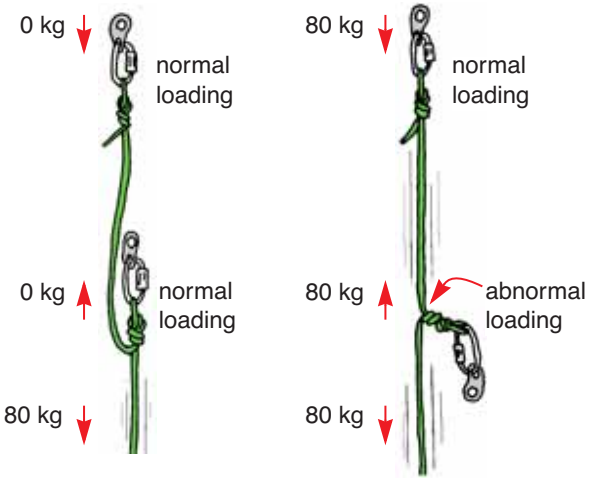
Overhand loop knot, the simplest loop knot

The simple **Overhand** loop has its uses. It is not so strong as the Figure-8 and Figure-9 loops, but is small and uses a minimum of rope. In very stiff rope it may be the only knot you can reasonably tie.

Tie all end of rope knots with ten or more centimetres of 'tail' hanging out of them so that as the knot tightens under load it does not come undone.

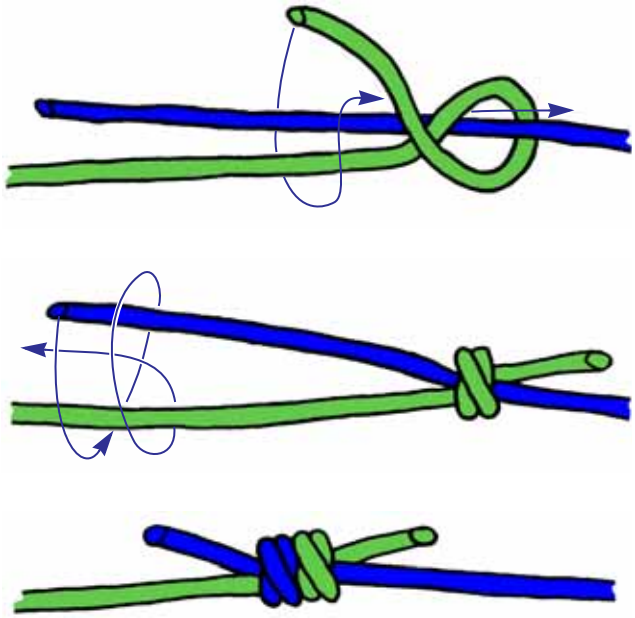
Mid-rope knots

You will often need to tie a rope off somewhere along its length. Here the loading of the knot becomes more complicated. Take a rebelay for example. The knot acts as an end loop in normal use but if the belay fails the knot would be pulled apart (abnormal loading). The mid-rope loop must be good under these two distinct types of loading.

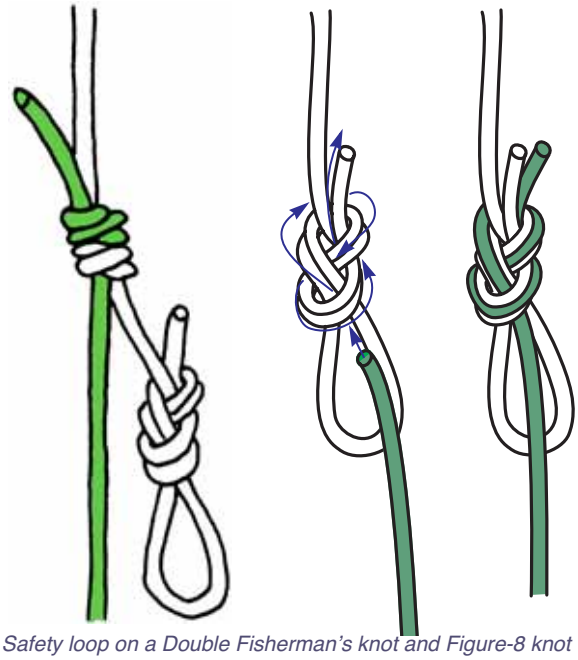


When the rope is rigged tight between anchors the Alpine Butterfly knot is popular because it looks right and uses very little rope. While the Alpine Butterfly performs well under abnormal loading, it is almost never loaded in this manner. Under normal loading it performs badly. Both the Alpine and standard Butterfly are only other knots to learn and neither is very strong. The simple expedient of using a Clove hitch also looks good but unfortunately its performance is highly variable depending on whether it slips or not. Figure-9 and Figure-8 knots still come out on top (see Table 3:1, Recommended rigging knots).

Rope joining knots



The Double Fisherman's knot is the best all round rope joining knot



Safety loop on a Double Fisherman's knot and Figure-8 knot

Two special considerations for rope joining knots are that they be short so that you can pass them easily and that they are relatively easy to untie after loading. Difficult to untie is a major problem with any rope joining knot.

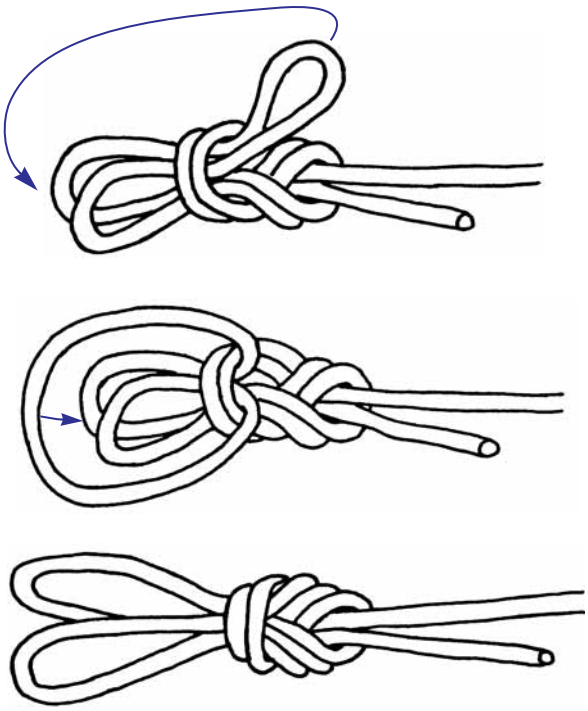
The **Double Fisherman's** knot is one of the best ways to tie ropes end to end. It is easy to tie, you can untie it and it works well on ropes of unequal diameters.

The other knot that you can use for joining ropes of equal diameters is the Figure-8, that some say is easier to untie than the Double Fisherman's. You could also use a Figure-9 in the same manner. It is more awkward to tie but has the advantage that it may be easier to untie after loading.

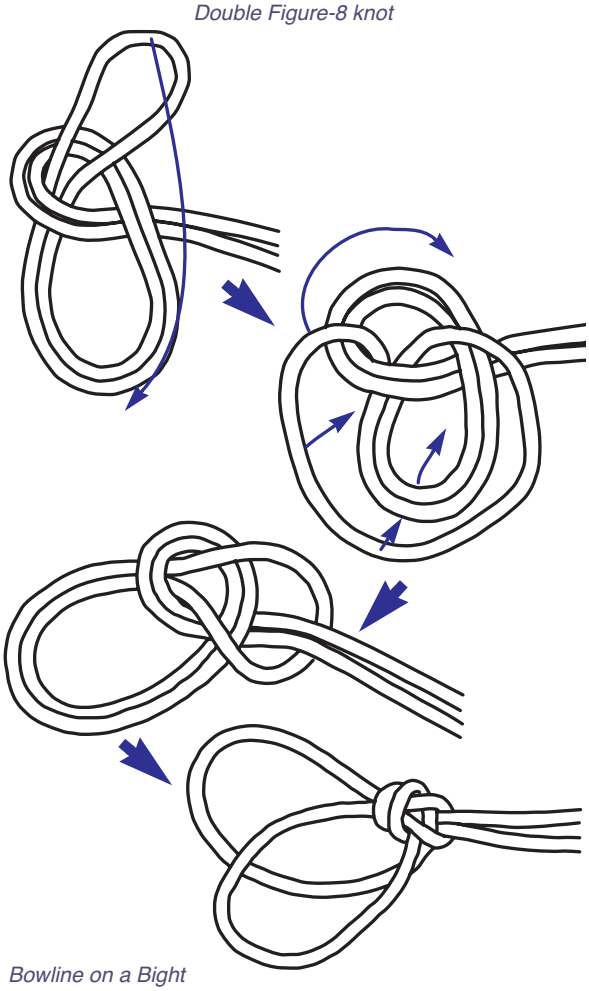
Whenever you join two ropes on a pitch you need a safety loop to clip your cowstail to when crossing the knot to avoid hanging on only one ascender. Tie a **Figure-8 loop** in the upper rope, then thread the lower rope back through it to make a rope join with a built-in safety loop. The resulting knot is bulky, but no longer than any other Figure-8 knot.

If you prefer a **Double Fisherman's**, hang a tail about a metre long out of the bottom of the knot so that you can put a **Figure-8 loop** in it. Be aware though, that the safety loop is never loaded unless someone falls on it, so will probably jiggle loose as the rope moves around.

Other knots



Double Figure-8 knot

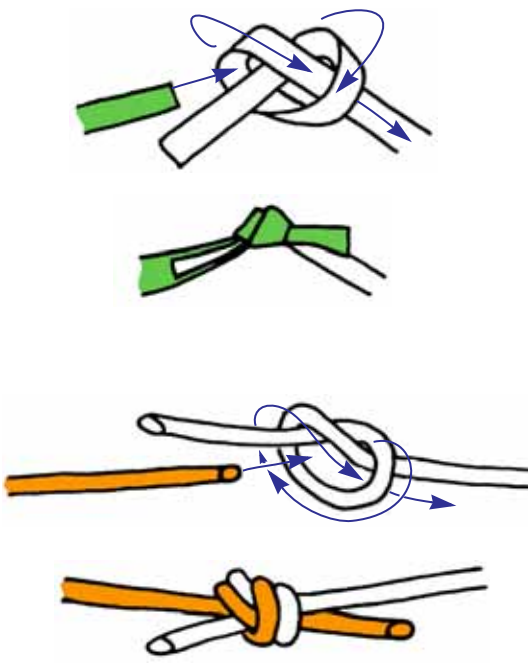


Bowline on a Bight

You can use the knots described so far to rig everything but there are a few other knots that are handy to know.

The **Double Figure-8** is good for Y belays and you can tie it as a mid or end loop knot. The two loops formed are easily adjustable and you can attach them to separate anchors, tie them to a ring hanger or use both on the same natural anchor to reduce the wear that would occur within a single loop. Use 'Double' loop knots with discretion. Should either loop be cut close to the knot—on a sharp natural belay for instance—there is the theoretical possibility that the cut end could slip back through the knot just like a short tail on any knot could do, and both loops fail. If only one loop is loaded it is perhaps possible for the other to slip back through the knot and the entire knot to undo. This is unlikely while the knot is loaded but could occur if the knot is loose when loaded and the loop is very short. Possible solutions are to clip something into each loop or if the anchor for one loop is 'weak', you can thread the 'strong' loop through it.

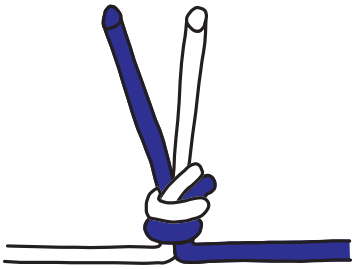
The **Bowline on a Bight** is a worthwhile alternative to the Double Figure-8. It is not as strong as the Double Figure-8, so like any Bowline, only use it on 10 mm or thicker ropes. It uses less rope, is easier to adjust and easier to tie—once you figure it out.



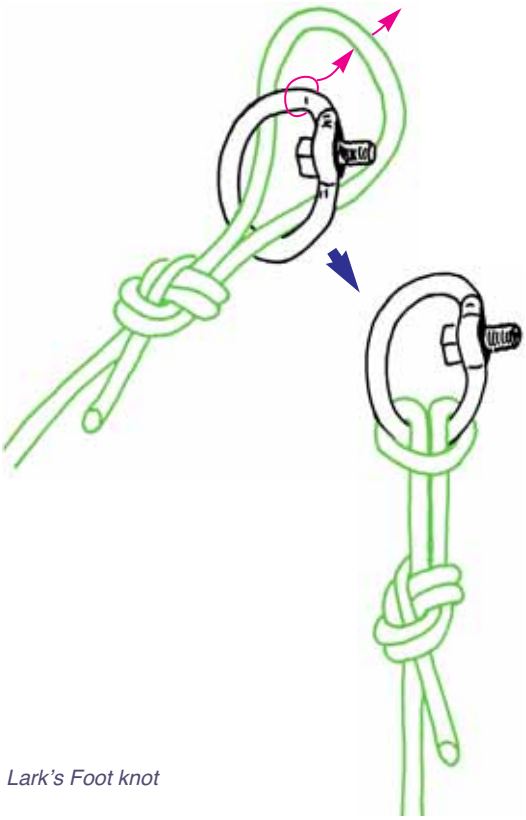
Tape knot (Round knot when tied in rope)

A **Tape** knot is **the** knot for tape. It is not very strong but other knots may not hold in tape. A **Round** knot is a tape knot tied in rope. It too is not very strong but makes a small neat knot that is most useful for the 'Cord technique'.

The **Overhand** knot is suitable for making an eye in the end of a tape, and as a stopper knot. It can also be useful for a rope-joining knot if you are pulling the rope down after you—a through trip for instance. An Overhand knot under abnormal load runs over edges very well as there is no knot-edge to catch on things. It is not especially strong, but this is not a problem if you're only descending on it and it's doubled. Use extra-long tails hanging out of the knot—30 cm or so, and as for any knot, pull the knot tight before you use it. Don't use a Figure-8 in the same way as the Figure-8 can invert and unroll its way off the end of the rope at low load.

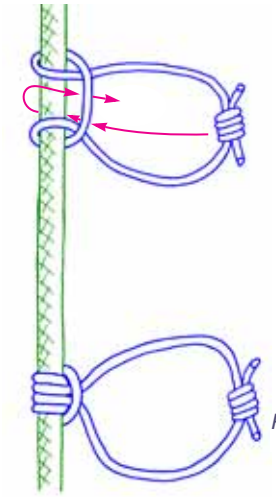


Overhand knot as rope-joining rock



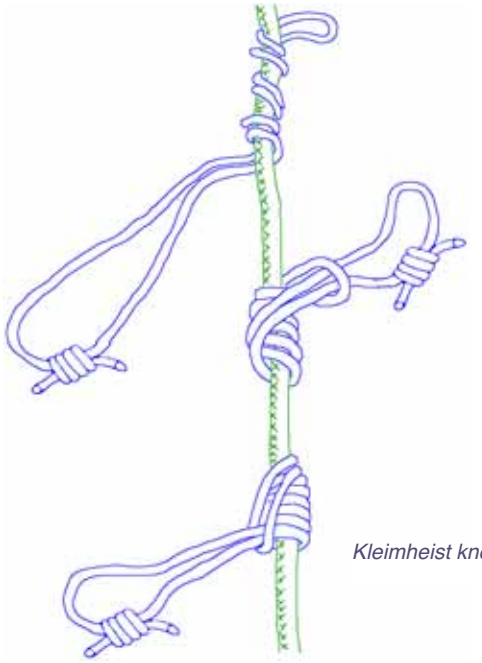
Lark's Foot knot

The **Lark's Foot** knot (Girth hitch) is the best way to tie the middle of a rope to a ring hanger. Always tie it in a loop knot as illustrated and never use it alone as it may slip. Do not use a Lark's Foot for attaching tapes to trees or natural anchors as it can be arranged in such a way as to increase the load on the rope.

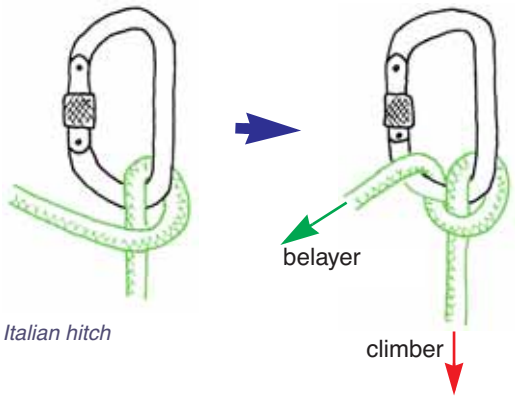


Prusik knot

The **Prusik** and **Kleimheist** knots are two of a family of knots designed to slide along a rope when the body of the knot is held but grip when loaded through its sling. For many years it was the only means available for *prusiking* up a rope. Today they have been almost completely replaced by mechanical ascenders. However, They are still useful in emergency situations for replacing a damaged or lost ascender or for temporarily tying off a rope. Try to use cord that is 2 mm or more thinner than the rope they are to be tied to, with a minimum of 6 mm cord for life support uses. A reasonably supple cord is best although you can use tape with less success. The knot illustrated is a Four Layer Prusik knot. An extra wraps on either knot can be used to give more grip if needed (see also No ascenders on page 135).

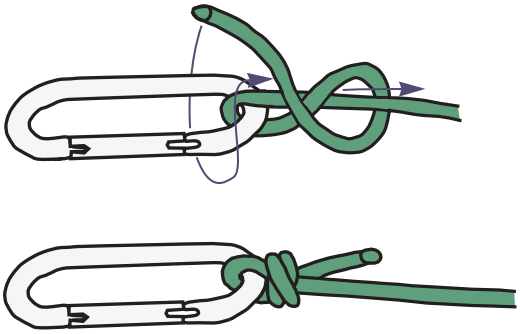


Kleimheist knot



Italian hitch

The **Italian hitch** (Münter hitch) is not so much a knot as a friction hitch. It is exceptionally useful for creating extra friction while abseiling and for emergency abseils. As a belay friction device, an Italian hitch is very effective and requires no more than a locking karabiner and a rope.



The Barrel noose is the best for tying the karabiner to your cowstail

The **Barrel**[1] **noose** is **the** knot to tie your karabiner to your cowstail. It has comparable strength to the popular Figure-8 loop, but more importantly, in drop tests it has a lower impact force than a Figure-8, and a much lower impact force than an Overhand Loop knot (Long, Lyon & Lyon, 2001). Add to this that is it smaller than either Figure-8 or Overhand and holds your cowstail around the right way ready for use—there is no reason not to use it.

Stopper knots

Every rope should have a stopper knot tied in the end before anyone descends it so that the first caver down does not slide off the end if the rope is too short. When you are packing ropes for a cave tie a stopper knot in both ends of every rope and check them as the rope is put down the pitch. The type of knot is not important—a Figure-8 loop is often used. The main thing is that it must not untie itself and has enough tail so that you cannot push it off the end of the rope if you hit it hard.

One way of being sure that there is a stopper knot in the end of the rope is to tie all ropes with an end loop in each end, then cover them with heat-shrink plastic so that they cannot be undone (Expé. 1987). However the knot is then prone to jamming as the rope is hauled up pitches.

When there is excess rope at the bottom of the pitch a stopper knot becomes superfluous. Instead, the first caver to descend should roll up the rope so that it hangs off the ground. This will keep people from stepping on it, stop it from being damaged by falling rocks and supply a little bottom weight when you are prusiking the pitch.

Comparing knots

The results presented in Table 3:1, Table 3:2 and Table 3:3 give a general picture only. The performance of knots is variable as shown by the ranges of values and the generally higher figures given by Long, Lyon & Lyon, 2001 and depends on many factors including rope diameter (most samples 10 mm), wet or dry (most samples dry), knot packing and tightness, and to a lesser extent temperature.

What appears to be a clear advantage in favour of bulky knots such as the Figure-9 and Double Figure-8 knots is more obvious on 8 mm and 9 mm rope than 11 mm rope.

Ozto Ocotal/J2, Mexico

1. It doesn't really have a name... Also called a Double Overhand noose. I've also seen what may be described as a 'Triple Fisherman's Knot' called Barrel Knot.

Table 3:1 Recommended rigging knots

Knot	Form	Static strength % of original	Falls# FF1 80 kg rated/10	Use
Figure-9 loop		70[M] 68-84[L]	10	General, thin rope
Figure-9 loop (abnormal)		55[M]	8	Rebelay failure, Y-belay
Figure-8 loop		55[M] 66-77[T]	8	General
Figure-8 loop (abnormal)		40[M]	5	Rebelay failure, Y-belay
Double Figure-8 loop		61-77[L]	10	Rebelay, Y-belay
Double Fisherman's		55[M] ~70[L]	10	Rope join
Figure-8 join		50[M]	-	Rope join
Overhand loop		50[M] 58-68[L]	5	Tape knot Stopper knot
Tape/Round		45[M]	-	Tape join Cord Technique
Barrel noose		67-77[L]	-	Cowstail, semi-permanent attachment to a karabiner

M From Marbach and Rocourt, 1980 and Courbis, 1984
[L] From Long, Lyon & Lyon, 2001
[#] Ratings for old rope. Mid-rope knots have a more pronounced effect on new rope

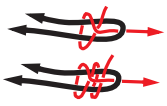
Table 3:2 Other rigging knots

Knot	Form	Static strength % of original	Falls[#] FF1 80 kg rated/10	Use
Overhand loop (abnormal)		45[M]	7!	Rebelay failure, 'Shock absorbing' knot, rappel pull-down
Lasso Bowline		-	5	Natural belay
Bowline on a bight		50	7	Rebelay, Y-belay
Alpine Butterfly		61-72[L]	5	Mid-rope tie-off Y-belay
Alpine Butterfly (abnormal)		-	3	Rebelay failure Y-belay
Clove hitch		##[L]	2	Mid-rope tie-off, cowstail

M From Marbach and Rocourt, 1980 and Courbis, 1984
[L] From Long, Lyon & Lyon, 2001
[#] Ratings for old rope. Mid-rope knots have a more pronounced effect on new rope
!Then again it may be 0 on a thin rope because of the highly variable performance of the knot
Long, Lyon & Lyon, 2001 claim slippage at "widely varying forces" on static rope, and comparable with an overhand on dynamic rope

Other rigging knots are knots that work, and often used, but there are better knots around for the same purpose.

Table 3:3 Not recommended for rigging knots

Knot	Form	Static strength % of original	Falls# FF1 80 kg rated/10	Use	Comments
Bowline		50[M] 55-74[L]	8	General	Weak, insecure until loaded, insecure if you load the loop
Bowline on a bight (abnormal)		40	5	Mid-rope tie-off Y-belay	Weak
Butterfly		45	5	Mid-rope tie-off Y-belay	Weak, insecure, distorts easily
Butterfly (abnormal)		47	5	Rebelay failure Y-belay	Weak, insecure, distorts easily
Figure-9 stopper		-	3**	Direct tie to bolt hanger	Rope may damage on hanger edge
Single fisherman's		40	-	Rope join	Creeps, may untie, weak
Reef		10	0	Not for rigging Pack closure	Very easy to untie. 10% value is the untie load. Unlikely to stay tied long enough to break.
Sheet bend & Double Sheet bend		—	—	Join dissimilar diameter ropes— Dyneema to rope.	Unties easily, weak.

M From Marbach and Rocourt, 1980 and Courbis, 1984
[L] From Long, Lyon & Lyon, 2001
[#] Ratings for old rope. Mid-rope knots have a more pronounced effect on new rope
** Only when used as shown

Not recommended for rigging knots are those that can be dangerous to use in rigging. Either because they are weak or because they loosen easily when in use.

Voronia, Abkhazia