The Study of Knot Performance and Knot Failure

Exploring the Secrets of Knotted Cordage to Understand How Knots Work

The Terminology of Knot Performance

Words Useful for Discussing Knot Security, Stability, Breaking Point, and Strength

To-day we have naming of parts.
– Henry Reed, "Naming of Parts"

Knot nomenclature is not, and never has been, entirely consistent.
– Cyrus L. Day

Words finely used are in truth the very light of thought.
– Longinus

If we are to understand one another in our description of knots, it is essential that we should use a standard terminology.
– Stanley Barnes
Anglers' Knots, 11

Introduction to “The Terminology of Knot Performance”

This part defines terms and that I have found useful for discussing knot performance. Some of them are drawn from the specialized terminology that has grown up in knot-tying groups such as sailors and anglers, and others from the ordinary vocabulary of the English language. I have also explained the guidelines I used in selecting and defining these terms, especially for introducing several new terms and re-defining some traditional ones.

Throughout these studies, numbers in parentheses refer to pages and illustrations in *The Ashley Book of Knots*.

Many of the structures that create friction in knots – hitches, tucks, wraps, and so on – are so commonplace that knot users no longer notice them and most knot books never mention them. Many of them have been overlooked entirely and have never been named, identified, or defined.

I set out in this study of knot terminology with both hope and trepidation. On the one hand I have kept in mind the goal suggested by Stanley Barnes that “if we are to understand one another in our description of knots, it is essential that we should use a standard terminology.” I have set out to make clear my own use of terms and the concepts they refer to and to explain why these terms are necessary for studying knot performance. I hope that this study of terminology will contribute to the study of knots by encouraging discussion of knotting terms among knot specialists.

On the other hand, I realize that, as Cyrus Day has said, “Knot nomenclature is not, and never has been, entirely consistent” (25). I would add, “and probably never will be.”

This study is in two parts:

* Guidelines for Selecting and Defining Terms
* A Glossary of Terms for Studying Knot Performance

Guidelines for Selecting and Defining Terms

> If a thing has no proper and peculiar term, . . . then necessity compels us to borrow elsewhere what is lacking.
>
> – Cicero

The most important function of standard terms is to provide a concise way to refer to a structure, a concept, or a procedure. Specialized terminology makes it possible to avoid repeating long phrases and making extended explanations; the terms are a useful shorthand.

The introduction of new terminology serves to draw attention to aspects of knot performance that have not been pointed out and have often gone unnoticed. If a thing has no name, it has usually not been recognized and it is easy to overlook. Giving it a name makes us more aware of it. As Adam discovered early on, it is handy to have a specific name to refer to the things you are talking about.

One useful device that has apparently not been named or adequately explained is called here *tuck-under-turn*. Other new terms handy for discussing the performance of knots are *entry point, nub, inter-space, hitch-and-bight, slide-and block, connectors, core-and-wrap,* and *straight-line segment.* These are among the terms defined and discussed here.

General Principles for Selecting and Defining Terms

The terms defined here have been selected to communicate with a wide audience of both general knot tyers and specialists. Some terms in current use, such as *nip* and *standing part*, are re-defined so that their meaning is made more specific or broadened to meet the special requirements of this study. Terms such as *strand* and *bend* that are sometimes used in more than one sense have been replaced by words that refer to only one thing. Some ambiguous terms such as *sharp* have been replaced. Where there are gaps in our terminology pertaining to the parts of knots and how they work, other terms have been newly coined.

Following are the principles I followed for selecting and defining terms used on this website.

- Select and use words that readers will understand in the sense intended.
- Follow John Kirkman’s general principle for selecting and using terminology in “Using ‘Controlled’ Language: “Use each word to convey one meaning only. … Use only one word to convey each meaning.”
- Create or re-define terms to fill gaps in the vocabulary. For example, distinguishing the various parts of an individual knot is essential for analyzing the breaking point and strength of knots. Terms such as *entry point, collar, stem,* and *first curve* are needed for discussing these structures.
- Avoid proliferation of new terms.

Guidelines for Choosing the Best Term

- When available, use words that have been established in common use by both knot tyers and the general community. Do not use terms such as *stend* and *wend*, which are sometimes used for “standing end” and “working end.” Although widely used in the knotting community, they are not generally known and need special explanation. Use the full terms “standing part” and “working end.”
- When there is a gap in the vocabulary, create or re-define the word that best fills the gap. The most suitable word communicates the idea, seems to fit naturally, and is easy to remember.
- Use the most familiar word consistent with clear communication of the sense. When ordinary terms are adequate, prefer them to scientific or specialized technical terms.
- When possible, use a familiar word that *suggests the meaning*, such as *tail, entry point,* and *stem*.

- Use the least technical term appropriate to the sense to be communicated. Use terminology that is familiar and as simple as possible, while remaining intelligible to specialists and true to the subject. Use *core* and *wrap* rather than borrowing the botanical terms *spadix* and *spathe*. If you can find no substitute for a technical term, such as *isomorph* used in linguistic studies, use the technical term.
- When searching for an appropriate word, use a thesaurus to find the simplest, most obvious, and most familiar terms, not the most learned.
- Use terms that are least likely to be ambiguous. Use the word *curve*, for example, rather than *coil* or *bend*, both of which have other meanings in knot study.
- Use terms that would be most generally understood without definition or explanation and as far as possible avoid terms that some readers would find puzzling. Eschew erudite, pedantic, polysyllabic, and recherché nomenclature. Above all, eschew obfuscation.

Guidelines for Writing Definitions

- Define terms using ordinary language.
- Describe concepts rather than trying to define them abstractly. Give examples.
- Illustrate parts of knots with photographs, using labels and callouts. Avoid using hand-drawn illustrations, which can be misleading or inaccurate.
- Define words primarily to communicate with ordinary knot users, not with technical specialists. The aim is not to define terms so that an engineer or physicist would be satisfied with their accuracy and precision but to define and use them so that the average person who uses knots will know what you are talking about. While scientific terminology would probably make the discussion more technically accurate, it would not lead to greater understanding by general knot users.
- Define and use terms as precisely and unambiguously as popular usage permits. Remember that only a few terms in knot study can be defined as strictly as concepts in Euclid and that the forms of knots are more varied and amorphous than the five platonic solids.
- Define terms in such a way that a reader will be able to identify the thing it refers to and to recognize it when they see it.
- When defining the parts of knots, state their form, their function in specific knots, and the way they affect knot performance.
- Define terms concisely.
- Avoid using abbreviations.
- Re-define terms in current use when it is necessary to sharpen or broaden a concept. For example, use the term *nip* in a restricted sense.
- When a word in current use needs to be re-defined, sharpened, or discarded, explain why.

A Glossary of Terms for Studying Knot Performance

This alphabetical glossary defines the terms used in this site. The aim of the glossary is to facilitate discussion of knot performance. The concepts are discussed more fully in the individual parts of this site.

Most of these terms are not to be thought of as precise or rigorously-defined scientific terminology, but as handy ways to designate specific parts of a knot, well-known operations, and the like.

Abnormal Load

A *normal load* pulls in a direction the knot was designed to withstand. An *abnormal load* comes from a direction the knot was not designed to withstand. This distinction is often overlooked. These terms refer to the way we customarily use the knot. Note that a load is normal or abnormal for a particular knot in a particular application.

See also *normal and abnormal load*.

Abnormal Load on an Unstable Knot

An abnormal load can affect an unstable knot several different ways. The first effect of deformation, accidental two-stage failure, is usually undesirable and can be disastrous. Deliberate deformation can be beneficial: as a method for tying knots, a step in loosening a knot, a way to lock a knot, a way to create a desired alternative form, a method for quick release, or a way to adjust a knot. In addition, deliberate deformation can be an effective way to study the properties of knots.

See also *normal and abnormal load.*

Anchor

The anchor is the structure in the nub of a knot that merges with the lower end of the stem. It moors the stem and gives the standing part a point to pull against. This pull sets up stresses in the first curve. The position and configuration of the anchor and the anchor point help to determine the severity of the first curve and the strength of the knot. In a Bowline, the anchor is the upper arm of the hitch. In a Double Fisherman's Knot, the anchors are the wraps at the ends of the nub.

Anchor Point

The anchor point is the location at the lower end of the first curve where the stem merges with the top of the anchor. The location of this juncture vitally affects the severity of the first curve and thus the strength of the knot. The anchor and the anchor point are of central importance in the study of knot strength, but so far as I am aware, they have not previously been identified.

In most instances, the exact location of the anchor point cannot be precisely pinpointed; it is more of a site or a general area than a point. But despite this imprecision, it is a useful term.

Angle of Entry

Angle of entry pertains to the angle of the standing part with respect to the nub of the knot. See *standing part* and *severity*.

Axis of Tension

The *axis of tension* in a knot lies along the main direction of pull or the line of longitudinal force. In a bend, tied in free-standing ropes, for example, the main axis of tension typically runs from one loaded standing part to the other. In knots of the Bowline type, at the point where the standing part enters the nub and passes over the collar, the load pulls the stem more or less out of the line of the axis of tension, causing the rope to curve as it enters the knot. This is a critical concept in understanding knot breaking point and strength. An extreme form of this pull is in a loaded Overhand Bend, as described in the part on knot strength.

Backup or Security Knots

Climbers can prevent untimely failure of their life-support knots by backing them up with another knot or an additional hitch or tuck that keeps them from slipping apart or deforming. The most common backup knots are a Half Hitch, an Overhand Knot, and a Half Grapevine, any one of which can be tied around an adjacent segment. A knob or stopper knot in the end of a rope keeps it from backing out. These knots typically add little friction to a knot but can increase its stability. Some climbers refer to a backup as a *finishing knot* or a *check knot*.

Neophytes, following the motto, “If you can’t tie a knot, tie a lot,” often tie half hitches or half knots over the basic knot. Depending on how they are applied, these added structures can actually increase the stability of a knot or merely appear to.

See *retainer*.

Bend

A bend is a knot used to join two ropes together, such as a Square Knot and a Becket Bend.

Bowline-Type Knots

The term “knots of the Bowline type” includes most knots. In knots of this Bowline type, the first curve is at the entry point and is forced by the collar. In other knots, the core-and-wrap knots, the first curve is further inside the nub of the knot.

Breaking Point of Knots

Both the terminology and concepts pertaining to the breaking point of knots is poorly developed. For that reason, some of the following terms have been re-defined and others are newly coined.

Collar

The *collar* is the segment of rope that the stem passes over or through at the entry point. In a Bowline, for example, the collar is the arc of the bight. The configuration of the collar is crucially important to knot performance because it affects the amount of curve in the stem.

In knots of the Bowline type, the stem curves as it passes over the collar. In some knots such as a Figure Eight Loop and a Flemish Bend, an inner collar lies next to the collar and parallel to it. The stem thus crosses over a double collar.

In knots of the core-and-wrap type, the collar does not deflect the stem from a straight line. In these knots, the stem curves deeper inside the nub.

In most knots, the collar is located so that it forces the standing part into a curve that is more or less out of line with the axis of tension or main longitudinal force of the knot.

Connector

A *connector* is a segment of rope in a knot that functions mainly to join one structure of the knot to another. The clearest examples are the three segments in the center of a Sheepshank that connect the hitches and the bights.

Cordage

I use the term cordage to refer to anything used for tying a knot, from rope to grapevine to barb wire to the sleeves of a sweater. In these studies, the cordage is usually rope.

Core

In knots of the core-and-wrap type, the *core* is the more or less long segment of rope that runs from the standing part to the interior of the knot. This is the structure that Barnes calls the “standing part extension” or the “continued part” (47, 83). In a Blood Knot, the cores run to the center of the knot. In a Double Fisherman’s Knot, they run from one end of the knot to the other. In these knots, the core and the upper part of the stem are coextensive.

The terms *core* and *core-and-wrap* refer to the structure of a particular kind of knot, not to a type of rope. These terms are not to be confused with the core-and-sheath construction of some climbing rope or with Ashley’s use of the word core to mean the heart of four-strand shroud-laid rope, wire rope, and sinnet. (Glossary, heart 600; shroud-laid 603).

Core-and-Wrap Construction

The term *core-and-wrap* pertains mainly to the small group of knots of the Blood Knot type, which includes the Double Fisherman’s Knot. The structure and mechanics of these knots are quite different from knots of the Bowline type. In the *core-and-wrap* construction, several wraps enclose a central core, which is the same segment as the upper part of the stem. The first curve in a core-and-wrap knot, the place where the segment that enters the knot is forced out of a straight line, is not at the entry point as in knots of the Bowline type, but well within the nub of the knot.

The Blood knot and the Double Fisherman's Knot, as well as other knots tied with core-and-wrap construction use the *slide-and-block* device, a configuration of rope in which the wraps of each half of the knot slide along the core of the other half until the two halves meet in the middle of the knot. At that point, each half of the nub prevents the other from moving further. The wraps prevent the opposing halves of knots of this type from moving out of alignment. The crux of a slide-and-block knot works on the principle of blockage, not, as in most knots, on the principle of squeezing segments together to create friction.

The term “barrel knot” is sometimes used to designate this kind of knot. While the term *core-and-wrap* is more cumbersome, it designates this type of knot without specifically referring to any particular knot, and it explicitly refers to the construction of the knot, not merely its outward resemblance to a familiar object. The same is true for the term *slide-and-block*.

Although several other knots use the surrounding helix of the core-and-wrap construction, they are not bends and do not use the slide-and-block device. Knots that use the core-and-wrap construction but not the slide-and-block principle include Two Half Hitches, many other hitches, the climber’s Half Grapevine, the Stevedore Knot, and the Hangman’s Noose.

Ashley (#295 #345 #1413) and Day (110) illustrate the Blood Knot and mention its virtues for anglers. But the core-and-wrap construction has apparently not been explained since Stanley Barnes described the structure and performance of a Blood Knot more than half a century ago. For this reason, few of the terms pertaining to these knots are in common use. This is despite the fact that a variety of the Blood Knot is popular among anglers, the Double Fisherman’s Knot and Half Grapevine have come into common use for life support, and the Hangman’s Noose is a perennial favorite among boys.

I surmise that the word “blood knot” derives from the use of this knot in the tails of the scourges used for punishment, especially in sailing vessels. This knot made the tails heavier and bulkier than the un-knotted leather cords, so would have been particularly effective, I suppose, in drawing blood.

Crossover

A *crossover* is a place where one segment of rope passes over another so that their surfaces come into contact. In many knots, one segment wraps around another one to some extent. In a Bowline, there are six crossovers, and in an Overhand Knot, here are three, the minimum number possible in a knot.

While a “crossover” determined by this method is similar to the topological “crossing” in mathematical knot theory, the term crossover is less rigorously defined.

See *nip*.

Crux

The crux is specific configuration which is the most important structural device in the knot. The crux is the device that most clearly accounts for the effectiveness of a particular knot. It is the distinguishing structural device of the knot. The crux is to be clearly distinguished from the nip. In some knots, but not all, it is the device that most clearly holds this knot together. In a Bowline Bend (Ashley #1455), which is made by interlocking two Bowlines, the crux is the interlocking of the loops. In a Double Fisherman's Knot, the crux does not produce friction; it is instead a device in which opposing structures of the knot block each other in opposing pulls.

Curve

A *curve* in a knot is a segment that deviates from a straight line. I refer to the *curve* of a knot rather than *fold*, *bend*, or *coil*. I use *fold* only as a verb to mean the process of folding and *bend* to refer to a knot that joins two pieces of rope. I use the word *coil* for a series of connected spirals or rings of rope, not for part of a knot.

See also *first curve*.

Deform, Deformation

When an abnormal load falls on an unstable knot, the knot *deforms*. (In fact, any loaded knot deforms to an extent.) That is, its structural devices lose their shape. In some cases a load that is merely too heavy can deform a knot. Deformation can degrade a knot and cause it to lose its gripping power so that it is no longer secure and cannot hold the knot together well enough to bear a load. Or it can cause a knot to take on a useful new shape with entirely different performance characteristics.

Other words in current use are *capsize* (Ashley’s usual term), *tumble*, *upset*, *distort*, *convert*, and *rearrange*. While a word like *conversion* or *rearrangement* might be more fitting for beneficial changes that some unstable knots can undergo, the general word *deformation* is commonly used by topologists in the field of knot theory to refer to all such changes of arrangement.

The term *allomorph* might be useful for designating a usable knot that has been rearranged or deformed. I use it sparingly because it has a metallic technical taste to it.

Entry Point

The *entry point* is the place where the standing part begins to merge with the stem and enters the nub of the knot. This is the place identified by Day, Ashley, and Barnes as the usual breaking point for knots of the Bowline type. In knots of the Bowline type, the entry point is in the same location as the first curve, while in core-and-wrap knots, the first curve is deeper inside the knot. Bends (knots that join two ropes) have two standing parts and two entry points.

Failure

Knot *failure* to refers to unexpected or undesired coming undone, as when a Granny slips apart or a Square Knot deforms and releases inadvertently. The term is not used for a deliberate change of form or quick release. See also “one-stage” and “two-stage” failure.

Fibers

Fibers are the individual threads of a rope. See also *rope as twisted fibers*.

Finishing a Knot

Finishing a knot takes place in two steps, 1) arranging the segments and 2) tightening them.

1) Arranging

Arranging refers to working the segments of a knot in place so that parallel segments lie parallel and there are no adventitious crossovers. Some simple knots, such as an Overhand Knot, arrange themselves, while you have to be careful to arrange some knots such as a Theodore Knot systematically. In his directions for tying a simple stopper knot, Ashley describes the process of arranging elegantly: “Draw up both ends at the same time, pulling slowly with both hands, and working the knot wherever it is necessary” (#551). Ashley uses the term *adjustment* (#1594), which also seems appropriate, and the word *dressing* is sometimes used. The important thing is that you must arrange the segments before you tighten the knot.

2) Tightening

Tightening, sometimes called snugging, locking, or setting, comes after arranging. Do this by applying tension to appropriate segments.

First Curve

In all knots, the *first curve* is at the place where the stem is forced out of a straight line into a dogleg or arc. The first curve is a short sector; it extends only one or two centimeters as it crosses the collar and does not extend deeper into the nub.

In a Bowline and most other knots, the first curve is at the point where the standing part enters the nub, merges with the stem, and begins to cross over the collar.

The Blood Knot, Double Fisherman’s Knot, and other core-and-wrap knots are *straight-line knots*. In these knots, the standing part merges with the stem and enters the nub without curving. The stem remains straight in line with the main axis of tension of the knot until it makes its first curve well inside the knot.

Throughout this website, the phrase “first curve” refers to the first curve in the most heavily-loaded segment in a knot. The general principles are that the first curve of all knots is in the stem, the most heavily-loaded curve is the first curve, and the breaking point is in the first curve.

See also *curve*.

Follow Through

The phrase *follow through* by itself refers properly to a method or technique of tying a knot. In the follow-through method, the working end is woven back through a pre-tied base knot, retracing the course it takes. A Figure Eight Bend tied by this method has also come to be called a *Figure Eight Follow Through*. The most common knot designated as “follow through” is the Figure Eight Follow Through Loop, which is distinguished from the Figure Eight Loop tied on a bight only by the method of tying; the finished knots themselves, whether they were tied by one method or the other, are identical in form. The Water Knot, which climbers use to join the ends of webbing, is tied by this follow-through method, and an Overhand Loop can be tied in this way.

A knot can be tied by the follow-through method only when a working end is available. This method cannot be used for knots tied in the bight or in the middle of the rope.

For tying some knots in some practical situations, the only way of tying is by the follow-through method. While some knots can be tied by either method, the Figure Eight Bend and the Water Knot can be tied only by the follow-through method.

For tying a knot by the follow-through method, it is essential to follow the exact procedure. This is so because it is easy to mistake the correct route of the working end through the knot. The result can be only an inferior variety or the knot or a complete disaster.

Friction

Friction is the mechanical force that makes knots work. The principle working in a knot is that when two segments of rope come into contact, even when one merely touches another, they create friction. Squeezing the segments against each other creates pressure which increases the friction. The greater the pressure, the greater the amount of friction, and the better the knot holds. For this reason, it is useful to think of *degrees* of friction, from negligible to extreme.

Hitch

A *hitch* is a knot that is attached to an object such as a railing or post. I also use the term to designate a particular structural device in a knot. In this use, a hitch is a segment of rope that crosses over or tucks under itself inside a knot, such as the structure in a Bowline that squeezes the bight, and the four structures in a Flemish Bend that wrap around two parallel segments at each end of the knot. Ashley uses the word *hitch* in this sense in his description of a Magnus Hitch (#1230). Several writers use the word *loop,* and at least one uses *crossing turn*.

Hitch-and-Bight Device

The crux of a Bowline is the powerful *hitch-and-bight* device. The hitch encircles the bight and squeezes it in a fast grip.

Inter-Space

Inter-space is the term I use for the space or potential space between round turns and the spar they wrap around. This is the space that the working end is threaded through in a single Half Hitch. It is also the space where the tuck is made in the tuck-under-turn device in a Fisherman’s Bend (#1840, #1841, #1885). I don’t particularly like the term, but I have not found a better one. It has nothing to do with Star Wars. As a structural device, it apparently helps to create a very secure and stable knot. Ashley comments that the Magnus or Rolling Hitch is tied with “the Half Hitch within the encompassing circuit of the knot.” (223 #1230).

See “tuck-under-turn.”

Knot

I haven’t tried to write a dictionary-type definition of the word *knot*—rather, I have tried many times without ever coming out with anything useful. My attempts at writing a formal definition are little more than a rhetorical exercise, no doubt interesting but of little use. I fid it best to define the word by example: knots are configurations of cordage such as those in *The Ashley Book of Knots* and numerous other knot books. Everyone knows what I’m referring to, and with a formal definition, they would know no more.

The question of what a knot is becomes important, to be sure, when we talk about deformation and allomorphic varieties of knots. But once again, I have found no clear way to define the changelings. And besides, once again, it is easy to see what I refer to by yanking sideways on the tail of a loosely-tied Bowline.

Load

The *load* is the pull exerted on a knot, for example, by a weight suspended from the loop of a Bowline. A load can be normal or abnormal.

Nip

While the term *nip* is defined in various ways, as used here it refers to the place in a knot where a load creates the greatest pressure and friction. In a Bowline, the nip is at the crossing of the hitch. As Ashley used the term, the nip is the place within the knot where pressure provides friction. As used by Warner, it means “the place where a particular crossing first makes the knot secure” (*Behaviour* 194).

The nip is not to be thought of as the *only* place where pressure is created—far from it: pressure is created at every point in a knot where segments of rope come into contact. Nor is it to be thought of as the weakest point or the breaking point. The term is useful for designating the structures that hold a knot together. See Ashley 284 (#1594).

As I use the term, the nip is to be found where a heavy load falls on a well-anchored segment that wraps at least part-way around another segment. While the heaviest load may fall on another structure, the greatest pressure is created in the nip. For that reason, the nip is a crucial element in the knot. Except for bends, a Sheepshank is the only common knot I know that has two nips in plain sight.

Compare and contrast *crux* and *breaking point.*

Normal and Abnormal Load

A normal load pulls in a direction the knot was designed to withstand. The terms *normal* and *abnormal* refer to the way we customarily use knots in ordinary applications. One correspondent has used the phrase “expected usage,” which apparently refers to the same thing. A normal load falls on a Bowline, for example, when the standing part is attached to a fixed point above and a weight is suspended from the loop below, with no sideways pulls. A normal load tightens the structures of most knots. This is the way we employ the knot when we use our wits and have good luck.

An abnormal load comes from a direction the knot was not designed to withstand. An abnormal load tends to pull segments out of line and to deform an unstable knot. A sideways yank on the tail of a Bowline, for example, is an abnormal load.

See also *abnormal load.*

Nub

The nub is the knotted part or the body of a knot. The nub of a Bowline, for example, includes all of the structures except the standing part, the tail, and the loop.

The word *nub* comes in handy for talking about the place where the standing part enters the knot.

One-Stage and Two-Stage Failure

In one-stage failure, an insecure knot under load simply slips apart and comes untied all at once. A Granny knot often comes undone in this way, and other knots are vulnerable in the same way if they are tied in slippery cordage or not tightened up properly.

Two-stage failure works in a very different way. In the first stage, an abnormal load pulls an unstable knot out of shape. Deformation alters the structures that create pressure at key locations and destroys the knot’s ability to hold together. After the knot has become insecure in this way, continued application of the load will cause it to slip apart and come undone.

See *stability, deformation,* and *abnormal load*.

Practical Knots.

By practical knots I mean knots that are used for doing a job, not ones that are mainly decorative.

Retainer

A *retainer* is a device that serves mainly to hold the tail of a knot in place, such as the hitches in a Pipe Hitch or the carabiner in a Tensionless Hitch. Retainers add a negligible amount of friction but keep other devices from coming undone. The term is familiar from orthodontia, where the retainer serves a similar purpose and works in a similar way. Many backup knots are retainers; they add a great deal of stability to a knot, and in that way contribute to its security, but they may add very little friction. The distinction between a retainer and a backup knot is that we ordinarily think of the retainer as an integral part of the knot, while a backup knot is an add-on.

Rope As Twisted Fibers

To try to discover general principles that apply to all knots tied in any cordage and to simplify the discussion, I have set aside many complexities. As a correspondent noted, the structure of a rope is not as simple as “a string of entwined fibers.” While this description “might accurately describe a simple cable bundle, such as the core of a static kernmantle rope, . . . a laid rope is composed of three twisted strands, each composed of twisted fibers.” For this reason, as this correspondent pointed out, “the sharing of tension among strands at a curved ‘stem’ is a significantly more complicated matter.” A full understanding of the performance of a knot tied in any particular material would have to take these complexities into account, but this goal is beyond the scope of this study.

Security

The term *knot security* refers to how well a knot keeps from slipping apart and giving way. A *secure* knot creates enough friction to hold the knot together and to resist slipping apart and coming untied when it is subjected to a normal load and used in the normal way. Knot security is clearly defined by Ashley: “The security of a knot is determined by the stress it will endure before it breaks. To determine *security* a material is required that will slip before it breaks” (16). A Figure Eight Loop is extremely secure. A Granny Knot used as a bend is notoriously insecure. An *insecure* knot tends to slip apart and come undone, even under a normal load.

Knot *security* is to be clearly distinguished from knot *strength*. These are distinct properties of knots. As Ashley put it, “A secure knot often breaks; a strong knot often slips” (16). Writers frequently point out this distinction, but the terms are easy to confuse.

Knot security is also to be distinguished from knot *stability*.

Segment

The term *segment* refers to a particular section of rope in a knot, such as the loop of a Bowline or the bights in a Sheepshank. Because one segment merges with another without a definite break, it is usually not possible to determine precisely where one segment ends and another begins. But the idea is important. I use the term *segment* because the word *strand* has two meanings. Ashley, for example, defines the word *strand* as “two or more yarns twisted together” (604), and chapters 5–10 of his book describe double and multi-strand knots, where the term is used in that way. But he also uses the word to mean a single piece of rope, as in chapters 3–4 on knob knots.

Severe, Severity

Severity refers to the degree that a curved segment of rope deviates from a straight line. The angle of deviation in a severe curve is wide. Some studies of knots use the terms "magnitude of curve," or "maximal" curvature or bend or refer to "tight," "gradual," "high," "highest," or "greatest" curves. It is often difficult to tell exactly what these terms mean and they are not used in this study. The words *severe* and *gentle* are used here.

Severity of the First Curve

In the study of the breaking point and strength of knots, the severity of the first curve is of paramount importance, while the severity of other curves is of no importance. The first curve can be slightly bowed out where it crosses the collar, or it can sharply curve at that place. The severity of the first curve in knots of the Bowline type is determined by the relative positions of three points or locations: 1) the point where the standing part begins to merge with the stem, 2) the place where the first curve crosses over the collar, and 3) the anchor point. If these locations are way out of line, as they are in an Overhand Bend, the stem is forced into a wide angle and a severe curve. If they are in more of a straight line, as in a Bowline, the stem curves more gently

This has been for me the most useful concept of severity. This also appears to be the usual sense of the word *sharp* and *sharpness* implied by most knot writers, but it is often hard to say because they sometimes use the words *sharpness* and *radius* interchangeably and they do not explicitly tell what they have in mind when they use the terms.

Severity and the Strength of a Bowline-Type Knot

The severity of the first curve determines the strength of a knot of the Bowline type. The more severe the first curve, the weaker the knot. A knot in which the stem curves sharply when it enters the nub, such as in an Overhand Bend, will be very weak. A knot in which the stem curves gently when it enters the nub, such as in a Bowline and a Flemish Bend will be comparatively stronger.

Severity and Strength of Core-and-Wrap Knots

The strength of core-and-wrap knots such as a Blood Knot and a Double Fisherman's Knot is determined by the severity of the first curve and by the relative amount of the full load that falls on it. The amount of load on the first curve is reduced by the wraps that squeeze the stem.

The severity of curves in other parts of any knot does not affect their strength.

Slide-and-Block Device

See *core-and-wrap construction* for a discussion of this term.

Squeeze

A Bowline works primarily on the principle of squeeze, as the hitch squeezes together the legs of the bight and keeps them from slipping out.

Stability

What Knot Stability Is

Knot *stability* refers to the degree that a knot can keep its form or arrangement when it is subjected to an abnormal load. Some knots are so stable that they firmly resist distortion or alteration and do not easily change form even when subjected to an abnormal load. Stability can range from the considerable stability of a Double Fisherman’s Knot to the extreme fragility of a Slippery Hitch (Ashley #82). Most other knots come somewhere in between.

Other words for this change of form and arrangement are *capsize, tumble, upset, or distort*. I generally use the term *rearrange* for beneficial or neutral change of form and reserve *deform* for undesirable change that reduces the knot’s ability to hold together.

Although knot stability is an essential concept for understanding how knots behave, the concept of knot stability has not come into general use, even among knot specialists.

The Effects of Instability

An abnormal load falling on an unstable knot can change the form and arrangement of the individual structures. This rearrangement can deform a knot and cause it to lose its gripping power so that it is no longer secure and will fail to hold itself together well enough to bear a load. Or it can cause a useful or beneficial change to a different form.

Distinguishing Stability from Security

Knot stability and knot strength are distinct aspects of knot behavior, although the distinction is often overlooked. Stability is often thought of as merely an aspect of security.

These two properties, insecurity and instability, affect knot performance in very different ways, their causes are very different, and their remedies are very different. Although they are both important aspects of knot performance and are closely related, they are clearly distinct characteristics. They are, of course both relative qualities, not absolute.

Be sure to distinguish security from stability.

See also *one-stage and two-stage failure* and *security*.

Standing Part

The standing part is the straight segment of rope that merges with the stem as it enters the nub of a knot. It is of indeterminate length. A full load falls on the standing part. The angle of the standing part to the nub at the entry point greatly affects the severity of the curve in the stem and thus the breaking point and strength of the knot. In knots of the Bowline type, the standing part enters the nub at an angle so that the stem curves at the entry point, weakening the knot. In core-and-wrap knots, the standing part enters the nub in a straight line so that the stem does not curve at the entry point. The concept of the standing part in this sense is essential for discussing both the breaking point and the strength of a knot. Cyrus Day uses the term in this sense (16). Clifford Ashley uses the term *lead* to indicate this segment. But he also uses it in several other senses.

Stem

The stem is the segment of rope that connects the standing part to the nub. The stem of a Bowline merges with the standing part at the top of the nub, crosses over the collar, and merges with the anchor below. The first curve is in the stem. In knots of the Bowline type, which includes most knots, the rope begins to curve as it enters the knot and starts to cross over the collar. In knots of this type, the stem and the first curve are conterminous; they have the same boundaries. In knots of the core-and-wrap type, such as a Double Fisherman’s Knot, the stem passes further into the nub before it begins to curve.

Straight-Line Knots

Core-and-wrap knots are also *straight-line knots*. In these knots, the standing part does not form an angle with the nub but enters straight into the knot without curving. For this reason, the core remains straight in line with the main axis of tension in the knot until it makes its first curve well inside the nub.

As Stanley Barnes pointed out in 1947, knots of the core-and-wrap type usually break at the center of the knot. In knots of this unusual construction, the line from the standing part to well within the nub is virtually straight, and the core does not curve until it reaches the center of the knot or beyond. For this reason, when straight-line knots such as a Blood Knot and a Double Fisherman’s Knot are subjected to an excessive load, they tend to break somewhere inside the knot instead of at the entry point.

Core-and-wrap knots are known to be stronger than other knots. This is apparently because the wraps reduce the load on the core so that the load that falls on the first curve is quite diminished.

Strength

Knot *strength* refers to the ability of a loaded knot to resist breaking, or to the degree that a knot weakens the rope it is tied in. *Strong* and *weak* are relative terms. Bench tests show that an Overhand Knot weakens a rope by about half, a Double Fisherman’s Knot by about a fifth. Knot strength is to be clearly distinguished from knot security.

Stretch, Stress, and Strain

Stress, used here as it is in physics, refers to an applied force that tends to strain a segment of rope. The stresses that cause a knot to break are set up by loading a curved segment. The most important kinds of stress in a knot are tensile, that is, stress created by pulling.

Strain, also used as it is in physics, refers to a deformation produced by a stress. It is the effect of stress.

Stretch is used in the ordinary sense to refer to the lengthening of fibers when they are stressed by a load. In studying knot strength, stretch is the most important kind of strain. (These definitions are derived from *The American Heritage Dictionary*. See also Giancoli, *Physics*, 240–242.)

Structural Analysis

Structural analysis is the term I use for the set of concepts and procedures for studying knots. It begins by examining a knot’s gross anatomy (as a medical student might call it), then leads to an understanding of the ways the structures interact to affect its performance.

Structures and Structural Devices

Structures are the identifiable configurations of rope in a knot such as tucks, wraps, hitches, and bights. The point where one structure begins to merge with another structure may be difficult to identify.

Structural devices, made up of structures that intertwine, are configurations of rope considered from the point of view of their configuration, their dynamics, and their function. A structural device can be as simple as a tuck, a wrap, or even Ashley’s example of “loose turns that are twisted tight.” (43 #235). Or it can be as complex as the intertwined hitch and bight of a Bowline or the hitches and parallel segments of a Flemish Bend. Each knot uses one or more structural devices in a unique arrangement that creates friction and makes the knot more or less secure, stable, and strong.

Thinking of the configurations of rope in a knot as structures draws attention to the way a knot is made up of identifiable and repeatable combinations of curves and crossovers. Thinking of these configurations as structural devices draws attention to the way that these structures work, how they interact with each other, how they contribute to the knot’s performance.

Tail

The *tail* is the unloaded short segment of rope that sticks out of a knot. While *end* refers to a part of the un-knotted rope and *working end* to a part of a rope used in the process of tying, *tail* refers to a part of the completed knot.

Tuck

To make a *tuck* in a rope, you simply pass the working end around and under another segment. The first operation in tying a Double Bowknot in your shoes it to tuck one end under the other and pull tight. Ashley uses the word *tuck* as both a noun and a verb (#571) and *tucking* as a verbal. This term is so handy that I am surprised that it is not used more commonly.

Tuck-Under-Turn

Tuck-under-turn is my term for a structure used to increase the security of simple half hitches. The end is tucked through the inter-space between the turns and the object they wrap around. This device distinguishes a Fisherman’s Bend (#1840, #1841, #1885, 289) from a Round Turn and Two Half Hitches (#1839). See also Ashley, 289.

Ashley defines a Fisherman’s Bend as “a round turn with a hitch through the turns” (#1840) and comments that one of the anchor bends (#1843) is “interestingly related to the Fisherman’s Bend.” The anchor bend he refers to is the Fisherman’s Bend; a tuck is added under the turn. Warner shows several variations of this device in use (*Fresh* 142–143). The tuck-under-turn makes these knots especially secure. Again, this is a cumbersome but useful term.

Twin Knots

A twin is a knot derived from another knot by deformation. In the terminology of some of the sciences, it is an allomorph. In knot theory, these twins are sometimes called “equivalent.” When deformed, the twin retains the same pattern of over-and-under crossings, which, as topologists have pointed out, are the fundamental properties of individual knots. Just as topologists cannot distinguish a coffee cup from a donut, so they do not distinguish a Half Knot from a Half Hitch. But then, of course, as Ashley pointed out, neither do most other people. The most familiar example of twinning is perhaps the way that a Square Knot tied around a post or rail deforms to a running Girth Hitch (Cow Hitch, Larkshead, etc.). In a similar way, a Granny deforms to Two Half Hitches. Also familiar is the way that a Half Knot converts to a left-handed Half Hitch or to a right-hand Half Hitch. (I suppose these three could be called triplets, but I think I’ll refrain.) Each of the twins has different performance characteristics and can be put to a different use. I use the terms *twins* and *twinning* in preference to more accurate scientific term such as *isomorph* and *metamorphosis*, which may seem a bit heavy for what happens when you yank the tail of a Half Hitch.

Two-Stage Failure

See “One-stage and two-stage failure.”

Wide, Width.

The term *wide* pertains to the angle that a curve deviates from the axis of the knot. A wide angle deviates by more than a few degrees.

Wrap

As a verb, *wrap* refers to the way the first curve extends around the collar. In an Overhand Bend, for example, the first curve wraps a good way around the collar.

As a noun, *wrap* refers to a segment of rope that passes around another segment. An example of a wrap is the helix of a core-and-wrap knot that circles around the stem, as in a Double Fisherman’s Knot. Warner uses the word *wrap* in this sense. (*A Fresh Approach* 30)

I use the word *turn* here as Ashley does (#366, #1119) to refer to a segment of rope that passes around another object such as a post or spar, as in Round Turn and Two Half Hitches.

Wraps can be very powerful devices. In knots of the core-and-wrap type, a pigtail or corkscrew encircles a central segment of rope like the tendrils of a grapevine. In combination, the elements that make up the core-and-wrap device create a knot that is very secure, stable, and strong.