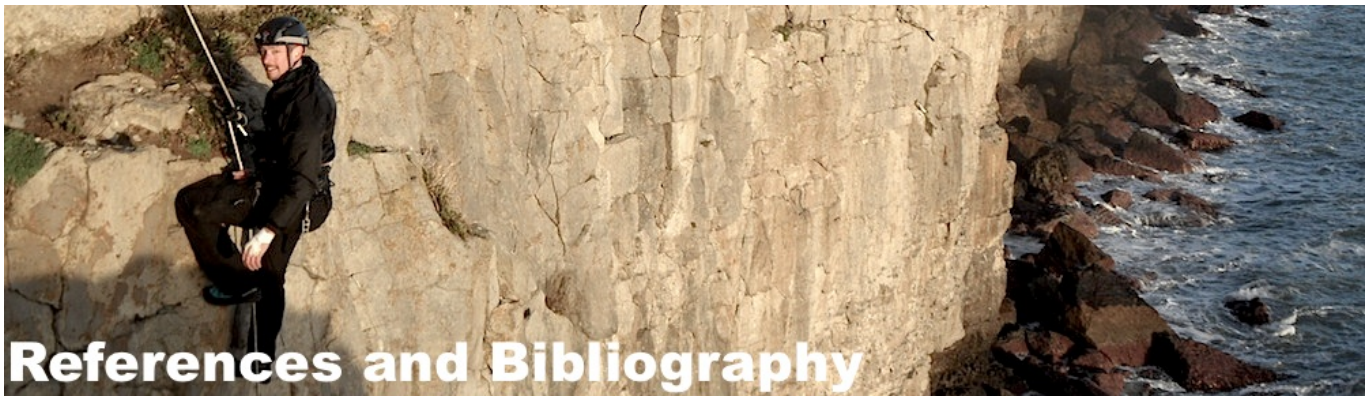

This site presents the images from the ebook *High: Advanced Multipitch Climbing*, by David Coley and Andy Kirkpatrick. In order to keep the cost of the book to a minimum most of these were not included in the book. Although they work best when used in conjunction with the book, most are self-explanatory.

Please use the following links to buy the book: Amazon USA (kindle) / Amazon UK (kindle) / itunes / kobo

Back to Other Chapters

This appendix lists all the references in the book together with a few other that make interesting reading. For geeks like David, fighting your way through them will hopefully make for a pleasant afternoon sitting in the rain in some café somewhere in the world.

Chapter 1

How hard can bears climb? (So put anything you leave at the base somewhere safe and bear and rodent proof – squirrels are often the problem.) See:
http://www.supertopo.com/inc/photo_zoom.php?dpid=Oj4_NzYgIiQgIg

Chapter 3 Multipitch Physics

For a model of rope dynamics see Richard Goldstone's essay http://www.rockclimbing.com/cgi-bin/forum/gforum.cgi?do=post_attachment;postatt_id=746%29).

For a discussion by the UIAA of how ropes age and other facts see
http://theuiaa.org/upload_area/files/1/Conference_on_nylon_and_ropes.pdf and
http://theuiaa.org/upload_area/files/1/About_Ageing_of_Climbing_Ropes.pdf.

See: http://www.petzl.com/files/all/product-experience/SPORT/R32-PE-CORDES-EN.pdf
For some real-world drop tests on ropes with different belay devices

Dynamic vs. static belaying and the change this makes to impact forces on the top runner.
http://www.rockandice.com/lates-news/what-they-dont-teach-you-in-belay-school

See: http://www.theuiaa.org/upload_area/files/1/Karabiners_Be_Aware!.pdf and
http://theuiaa.org/upload_area/files/1/Attaching_to_rope_by_karabiner.pdf for a description of several ways carabiners can fail).

For a detailed discussion of the forces experienced by a belayer, see:
http://www.xmission.com/~tmoyer/testing/Simulation_of_Climbing_and_Rescue_Belays.pdf.

A detailed analysis of the result of incorporating large angles into three-point powerpoints and of

the length of the arms in a powerpoint has been made by Marc Beverly and others (http://www.caves.org/section/vertical/nh/51/Multi-point%20pre-equal%20anchors.pdf).

Lots of useful stuff on various topics (in German):
http://www.jdav.de/chameleon//outbox//public/47/dav_ausbilderhandbuch_2005_sicherung.pdf

Lots of useful equations are to found in here:
http://ocw.mit.edu/courses/special-programs/sp-255-physics-of-rock-climbing-spring-2006/index.htm

A discussion about the UIAA and CE standards:
http://www.rockandice.com/gear-guide-tips/making-sense-of-the-uiaa-ce-and-3-sigma-ratings?A=WebApp&CCID=14153&Page=9&Items=10

The following is a list of useful references to in-depth material on rope and fall dynamics provided by rgold in a post (http://www.supertopo.com/climbers-forum/1073010/Fall-Force-calculator) on SuperTopo:

Attaway, S. W., Rope Systems Analysis, International Technical Rescue Symposium, Albuquerque, NM (1996), http://lamountaineers.org/xRopes.pdf

Attaway, The Mechanics of Friction in Rope Rescue, International Technical Rescue Symposium, Fort Collins, CO (1999), http://www.jrre.org/att_frict.pdf

Attaway and Weber, C., Predicting rope impact forces using a non-linear force deflection. International Technical Rescue Symposium, Denver, CO (2002), http://web.mit.edu/sp255/www/reference_vault/second_order_rope_fit.pdf

Attaway and Beverly, J.M., Measurement of dynamic rope system stiffnes in a sequential failure of lead climbing falls. http://www.amga.com/resources/various/Sequential_Failure_Paper.pdf

Bedogni, V., Computer mathematical models in belaying techniques. Nylon and Ropes for Mountaineering and Caving, Torino, Italy, (2002)

Bramley, A., Philips, A., and Vogwell, J., Forces Generated in a Climbing Rope During a Fall, The Engineering of Sport 6

Custer, D., An estimation of the load rate imparted to a climbing anchor during fall arrest. Engineering of Sport, 6th International Conference, Vol I pp 45--50 (2006).

Powerpoint version, http://web.mit.edu/sp255/www/reference_vault/the_yowie_factor.pdf

Leonard, R.M., Wexler, A., Belaying the leader, Sierra Club Bulletin 31 (7) (1946)

Manin, L., Richard, M., Brabant, J.-D., and Bissuel, M., Modeling the climber fall arrest dynamics, ASME International Design Engineering Technical Conferences and Information in Engineering Conference, IDETC-IEC 2005, pp 1077--1084, Long Beach, CA (2005)

Manin, L., Richard, M., Brabant, J.-D., and Bissuel, M., Rock climbing belay device analysis, experiments and modeling, The Engineering of Sport 6, Vol 1 pp 69--74, Springer (2006)

Pavier, M., Experimental and theoretical simulations of climbing falls, Sports Engineering 1 (2) pp 79--91 (1998)

Pavier, Derivation of a rope behavior model for the analysis of forces developed during a rock climbing leader fall, The Engineering of Sport 1. (1996)

Chapter 4 Equipment

Details of UIAA rope standards:
http://theuiaa.org/upload_area/cert_files/UIAA_101_ropes_October_2013.pdf
and
http://www.hamradio.si/~s51kq/photo_album/Climbing_and_Mountaineering/pdf_climbing/UIAA/PictUIAA101-EN892DynamicRopes.pdf

In this article: http://bealplanet.com/sport/anglais/facteurdechute.php
Beal confirm that there is a relationship between the impact force a rope places on the system in the UIAA test (i.e. for a very harsh fall) and more common falls. This suggests that low impact rated ropes do indeed offer advantages in common situations.

This article discusses the reason for various rope failures and concludes double/twin ropes might a good idea in the mountains, but possibly not for the reason you might think:
http://personal.strath.ac.uk/andrew.mclaren/Turin2002/CD%20congresso/Rope%20Failures.pdf

When sports climbing, it's common to use different snap gates for clipping the bolts and for clipping the rope. In the past climbers also tended to have bent gates for clipping the rope, both due to the ease of clipping, and as a fool proof way of keeping the 'bolt clipping' end away from the rope. This is because small nicks in the running surface of a carabiner caused by falling on square edged bolts can tear right through the rope's sheath: see http://dmmclimbing.com/knowledge/carabiners-and-potential-rope-damage/ for a graphic illustration of this.

For more information on shock absorbing extenders see:
http://www.rockclimbing.com/Articles/Gear_and_Reviews/Review_The_Yates_Screamer_243.html and http://www.yatesgear.com/climbing/screamer/use.htm and
http://www.blackdiamondequipment.com/en-us/journal/climb/all/qc-lab-to-screamer-or-not-to-screamer).

For some reasons why screamers might not be as good as some people think:
http://www.rockclimbing.com/cgi-bin/forum/gforum.cgi?post=2636388;sb=post_latest_reply;so=ASC;forum_view=forum_view_collapsed;

For some comments on dyneema slings see: http://www.geir.com/mythbuster.html.

Cordelettes
See http://user.xmission.com/~tmoyer/testing/ for some comments.

Rap tat
Visit www.youtube.com/watch?v=t01OkBLTO64 to see a water (tape) knot failing when tied in dyneema; and see http://dmmclimbing.com/knowledge/knotting-dyneema-vid/
for a table of the strengths on knots in dyneema slings.

On joining slings with a girth hitch
http://blackdiamondequipment.com/en/experience-story?cid=qc-lab-connecting-two-slings-together

Tails
It is important that the cow's tail or daisy is never attached to the rope loop - you might untie the rope whilst hanging from the daisy. This might well prove fatal. In addition this will cross-load the knot, and even a figure of eight tie-in knot can be pulled apart if cross-loaded. (See http://vimeo.com/40767916)

Drop test results (see http://www.caves.org/section/vertical/nh/53/RiggingForRescue-LanyardsPartII-2006.pdf) suggest that in FF1 to 1.5 falls, i.e. mimicking someone climbing above the belay and slipping, a Purcell Prusik subjects the climber and the belay to much lower forces.

It is important to understand that daisies and slings are not in general designed to anchor you to the rock. They work fine if you just need to hang off things, but are not for falling on. Unlike the rope, they have no dynamic properties, so a fall on one would be aggressive for the daisy, the anchors and you (see: http://theuiaa.org/upload_area/files/1/Beware_of_Quickdraws_for_Self-Belay.pdf or http://www.geir.com/mythbuster.html). Beal have done some tests comparing rope-based and tape-based daisies. Rope-based ones produce lower forces (see: http://bealplanet.com/sport/anglais/longes-dynaclip.php).

It is important not to shorten a traditional daisy by back clipping it with the main locking carabiner at the end, i.e. having more than one pocket clipped to the locker. There is a good video on Black Diamond's website showing what can happen if you do this and it looks like a magic trick: http://www.blackdiamondequipment.com/en-us/journal/climb/qclab/qc-lab-daisy-chain-dangers-en-glbl-en-us.

Grigri on Trad
For some tests by Geir Hundal on using a Grigri on trad see http://www.geir.com/mythbuster.html.

For similar results see Beal's site (look at the bar charts):
http://bealplanet.com/sport/anglais/facteurdechute.php

Or Petzl's
http://www.petzl.com/files/all/product-experience/SPORT/R32-PE-CORDES-EN.pdf

Helmets
See Petzl's website for some stories about helmets saving lives
http://www.petzl.com/us/outdoor/verticality/helmets-0/helmet-stories-edge)

Or this on standards
http://www.petzl.com/EPI/v2/epi-en/normes/norCasGb.swf

Rope Contamination
See http://www.caves.org/section/vertical/nh/52/nh52.html for an example of failure due to contamination.

Metal Bits
Dropped carabiners and belay plates are probably safe to use unless they have grooves that could damage a rope or sling, or grooves more than 1mm deep which could reduce their strength (see http://www.onrope1.com/Myth1.htm and http://www.geir.com/mythbuster.html), however others disagree (see http://billheaner.blogspot.com/2007/11/aluminum-carabiners.html). To see just what a sharp or worn edge on the surface of a carabiner can do to a rope, see this video from DMM http://dmmclimbing.com/knowledge/carabiners-and-potential-rope-damage/ and http://www.blackdiamondequipment.com/en-us/blog/index/view/slug/qc-lab-dangers-of-rope-worn-carabiners

A hooked-up carabiner can fail at of 10% of its rated strength (http://blackdiamondequipment.com/en/qc-lab-weakness-of-nosehooked-carabiners.html).

About placing bolts, and for British sea-cliff climbers, pull tests on abseil stakes:

http://www.bolt-products.com/Glue-inBoltDesign.htm

Chapter 5 Leading and Seconding

For some more pictures of unsafe protection, see http://www.supertopo.com/climbing/thread.php?topic_id=1691689&tn=0&mr=0&utm_source=SuperTopo+purchasers+and+forum+up+to+3.22.11&utm_campaign=b63be099a7-SuperTopo_Climbing_News_May_26_20114_5_2011&utm_medium=email.)

To see a comparison of the strength of girth and basket hitches on wires see the data and video at: http://dmmclimbing.com/knowledge/improvisation-larks-foot-or-basket-hitch-vid/) . A basket o girth hitch will reduce the strength of the sling, but this is unlikely to be a problem, and is better than a carabiner over an edge (See https://www.blackdiamondequipment.com/en-us/journal/climb/all/qc-lab-extending-a-cam-sling-sling-on-sling-en-gb.)

Chapter 6 The Belay

Direct Belaying

Using two carabiners in a direct belay is unlikely to make the rope feed more easily (see: http://www.blackdiamondequipment.com/en-us/journal/climb//qc-lab-autoblock-misuse.

Belaying Off the Rope Loop or Belay Loop?

When using an indirect belay, some people attach the belay plate to their belay loop, others use the loop of rope that that they are tied in with. (A discussion about this can be found on ukclimbing.com http://www.ukclimbing.com/articles/page.php?id=1129.)

The Sliding-X

Tests with a small (100 kg) static load on an anchor with a small angle between two arms of equal length possibly indicate that sliding system do not equalized better than non-sliding ones. (See Self equalizing anchors: a myth? R. Owen and S. Naguran: http://www.whitewater-rescue.com/support/pagepics/selfequalanchor.pdf) The main trouble with such experiments is that, unlike in the real world, the angle of the force does not vary so the system never really gets the chance to slide.)

Belaying with a Munter

For an in-depth discussion of direct belays and Munter's see bersicht Standplatzbau (von Chris Semmel – DAV-Sicherheitsforschung Zeichnungen Georg Sojer Stand: Juli 2009).

Chapter 10 Descent

The Hunt for the Perfect Rap Knot

Several sets of pull test results have been published, including this one from Black Diamond (http://www.blackdiamondequipment.com/en-glbl/journal/mountain/all/qc-lab-what-is-the-best-rappel-knot-en-gb-en-eur), and this from Tom Moyer (http://user.xmission.com/~tmoyer/testing/EDK.html).

For a long discussion of some rap knot pull tests including the difficulty of pulling various knots over edges, see: http://www.caves.org/section/vertical/nh/52/PreferredKnots.pdf and http://www.bwrs.org.au/sites/default/inline-files/1%20main%20paper.pdf

There seems to be no consensus in the climbing literature on how to join the ropes if the diameters are very different. Tom Moyer's results indicate that a correctly tied overhand is fine when one rope is 11mm and the other 8mm, which is encouraging. Tests by Edelrid2 on a 10.5 tied to an 8mm rope, also suggest the overhand knot when tied correctly seems fine (reported at http://www.gudelius.de/spst.htm).

Results in http://www.jdav.de/chameleon//outbox//public/47/dav_ausbilderhandbuch_2005_sicherung.pdf also seem to imply the EDK works with very different rope diameters, but it is not clear to me (DC) how the ropes were tied (an EDK with difference diameter ropes can be tied with the thin rope on top or underneath the fat rope, and it is not clear if both ways are equally safe).

For pull tests on a big fat fish and a flat fish sandwich see: http://www.gudelius.de/spst.htm

On third hands
It would seem that the third hand's carabiner can very occasionally release a leg buckle (see http://ascenttraining.blogspot.co.uk/2011/03/safety-alert-on-abseiling-with-prussik.html).
Care is also needed when attaching the third hand to harnesses that use a plastic clip buckle on the leg loop. These have been reported as unclipping themselves, and in this case the whole leg loop opens up (see http://www.ukclimbing.com/forums/t.php?t=505204&v=1#x6871432).

Knotting Dyneema
DMM have tested the strength of various knots used to join dyneema webbing, see: http://dmmclimbing.com/knowledge/knotting-dyneema-vid.)

Nylon against nylon
If a climber is lowered on a rope passing over a nylon cord or sling she is unlikely go far before the cord or sling melts completely through — possibly only 3m (10ft) (see this article from the UIAA:
http://theuiaa.org/upload_area/files/1/Use_of_slings_when_lowering_off_and_abseiling.pdf).

Put a knot in the end of the rope!
As this story shows, it is easy to rap off the end of the ropes because there is a good chance you are thinking about something else:
http://publications.americanalpineclub.org/articles/13199903700/print

Chapter 11 Cheating

Lowering off a single bolt
See: http://www.petzl.com/files/all/en/activities/sport/Solutions-Sport-climbing_Catalog-2011.pdf
For a way of backing yourself up if doing this.

Chapter 12 Going Solo

Rope damage
Repeated falls onto a rope rigged for solo top roping is likely to damage the rope at any point it is in contact with the rock, usually near the anchor. This is because although you might fall off at varying points, the rubbing will always be on the same part of the anchor rope. It is surprisingly easy to completely destroy the rope: see (http://www.petzl.com/en/outdoor/product-experience/self-belay-solo-climbing/introduction). It is therefore a good idea to climb all the way to the anchors occasionally to check the condition of the rope.

Petzl have tested what happens when a mini-traxion is subjected to a fall factor one fall: the rope was severely damaged (http://www.petzl.com/files/all/product-experience/SPORT/PE-minitraxion-P07-EN.pdf); this is why a minitraxion should never be used to belay a second up as it is less easy to ensure slack does not accumulate.

Soloing on a Reverso
When roped soloing device that sits somewhere between the categories of "possible general method" and "for emergency use only / you're going to die method" is the Reverso. Personally

because of a lack of test drop data, and because the manufacturers don't recommend it, I (DC) would only use it in an emergency. However Andrew Young and others have made extensive use of it (see http://www.mountainz.co.nz/content/article/article.php?article=220406_ropesolo.php&direct=general). See some more comments on the soloing webpage/pdf.

Two Minitraxions

Some climbers use a pair of mini-traxions attached in series to add redundancy and the use of two devices was the recommendation from Petzl (http://www.petzl.com/en/outdoor/product-experience/self-belay-solo-climbing/introduction). The first is clipped to the belay loop with an oval locking carabiner as usual; the second is attached via an extender to a maillon through the tie in points. An elastic cord around the neck is then used to keep the upper mini-traxion in place (See http://www.petzl.com/en/outdoor/self-belay-solo-climbing/solution2-two-ascenders for various possibilities).

Petzl have since had a change of mind based probably of the observation that using a similar device for the backup means that if the climber messed up with the first trax, for example attached it upside down, they will mess up in exactly the same way with the second trax. They now recommend using a different device for the backup, for example a Basic ascender as shown in http://www.petzl.com/us/outdoor/product-experience/self-belay-solo-climbing/introduction-us

Chapter 13 Self Rescue

Strength of Prusik knots

A discussion of the strength of various Prusik knots and mechanical ascending devices can be found at http://www.trescue.com/uploadfiles/RopeTest48.pdf

Harness hanging syndrome

According to Tyson and Loomis, harness hanging syndrome (where blood trapped by the harness reduces flow to the brain) can onset rapidly (see http://www.caves.org/section/vertical/nh/45/nh45.html for a discussion of the subject). So there is the need to get to the victim as quickly as possible and to encourage him to move, even slightly.

Difficult prusik situations

What to do if you need to prusik up the rope but you don't have a Reverso or any slings on you, or if you need to escape the system without using a sling or length of cord: http://www.mountainproject.com/v/prussiking-without-any-slings-or-cords/108353040

Chapter 14 Tactics

An example of why there are good reasons to keep it simple, and not to try new ways of doing things on the fly, without first practising in a safe place: http://climbing.ilooove.it/story/climbing-my-way-back-up

Knots Appendix

On the strength of knots: http://efclimbers.net/wp-content/uploads/2013/02/Knot-and-cord-strength.pdf
And http://www.paci.com.au/downloads_public/knots/03_Cordage_Institute_Tests.pdf

Interesting pull tests results by Tom Moyer on various things (including a Munter and a belay plate): http://user.xmission.com/~tmoyer/testing/pull_tests_11_98.html

More fun tests from Tom Moyer: http://user.xmission.com/~tmoyer/testing/pull_tests_7-00.html

On why cord fails: http://knotcyphers.pbworks.com/w/page/8216878/Knot%20Strength%20-%20or%20Weakness

On the strength of a half-double fisherman's: http://www.caves.org/section/vertical/nh/46/doitie.html

Localization of breakage points in knotted strings (major geek warning): http://iopscience.iop.org/1367-2630/3/1/310/fulltext/

In some sandstone areas knots are used for protection, instead of cams/wires. Here are some tests on cord used in this way: http://www.joergbrutscher.homepage.t-online.de/knotene.htm

A little on why some knots might be stronger than others: http://personal.strath.ac.uk/andrew.mclaren/Alasdair_Brown_2008.pdf

Cordelette pull tests by Tom Moyer and others: http://www.caves.org/section/vertical/nh/49/cthsc/cthsc.html

Tests on prusik knots of various types: http://www.rockclimbing.com/Articles/General/A_scientific_study_of_common_friction_knots._273.html

One way to tie into the middle of a rope (bowline on a bight step through): https://www.youtube.com/watch?v=PzIP4IUnqvI&feature=player_embedded

More than anyone needs to know about bowlines (serious geek warning): http://www.paci.com.au/downloads_public/knots/Bowlines_Analysis.pdf

Back to Other Chapters