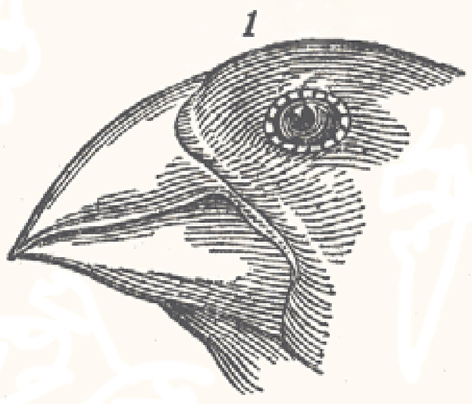
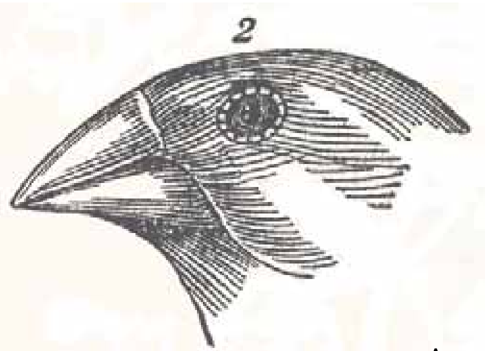
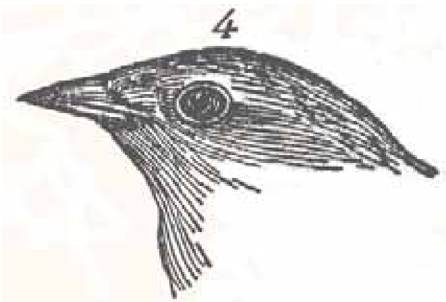


The Evolution of Climbing Equipment Standards





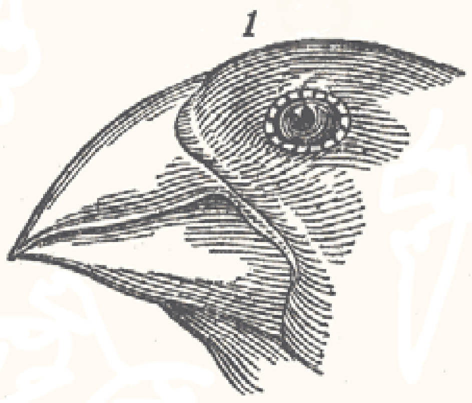
Dave Custer

American Alpine Club/Alpine Club of Canada Delegate to the
UIAA Safety Commission
CWA Engineering Standards Committee Member
MIT Lecturer

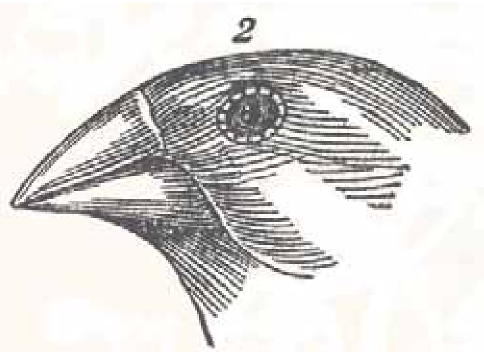
1. Geospiza magnirostris.
3. Geospiza parvula.

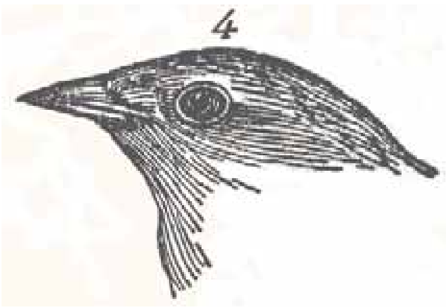
finch images from Charles Darwin's Voyage of the Beagle

2. Geospiza fortis.
4. Certhidea olivasea.

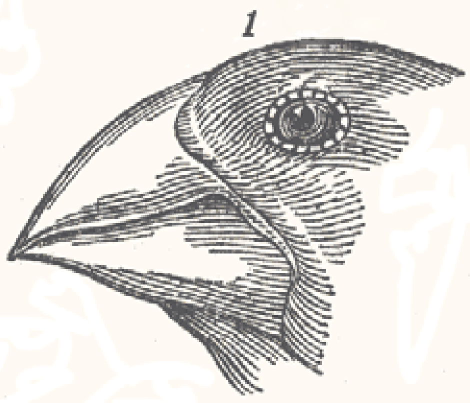


are standards for the birds?

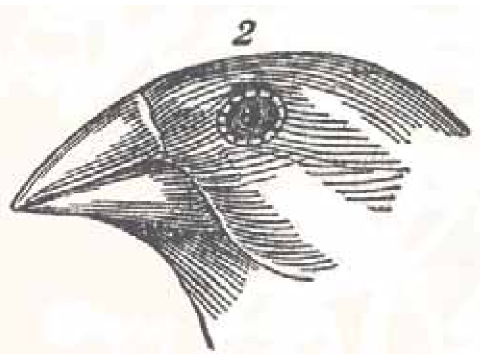




- climbers
- equipment manufacturers
- gym owners & operators
- safety folks
- regulation folks
- me

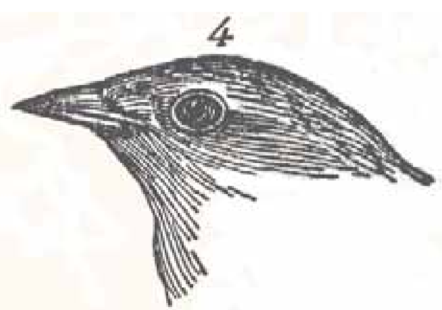


a history of climbing equipment standards

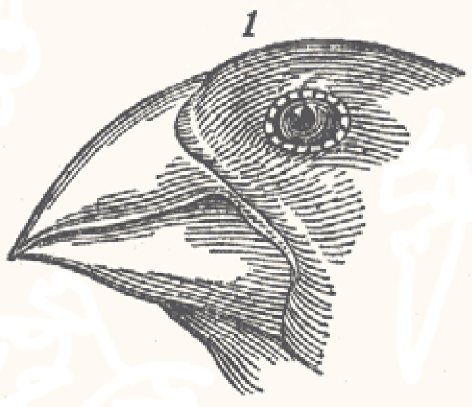


the physics behind climbing standards

examples of radiative adaptation in climbing

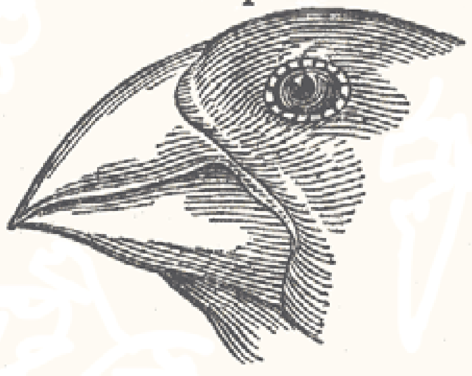


a peek at where gym climbing standards might go



causes of equipment &/or standards evolution

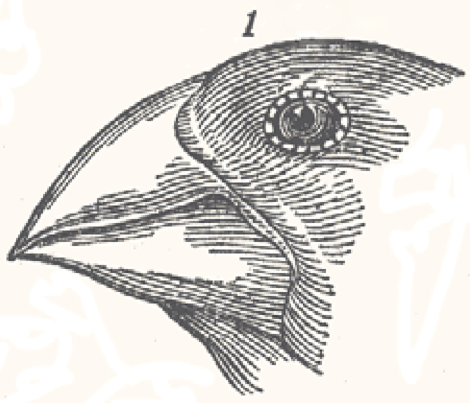
- accidents
- marketing
- demographics
- climbing developments
- developments in related sports
- research
- assorted climbing organizations
- government regulation



deep history

- not many climbers
- not much standardization
- no money to be made
- it was a stupid sport anyhow

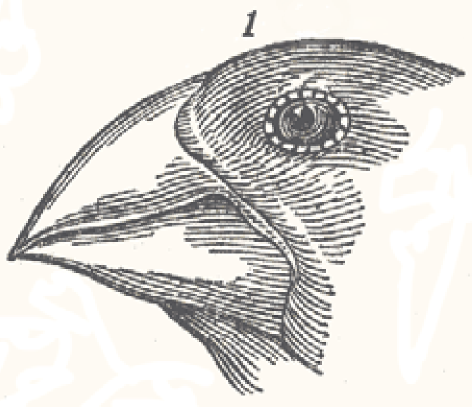
very similar to the aid climbing scene today.



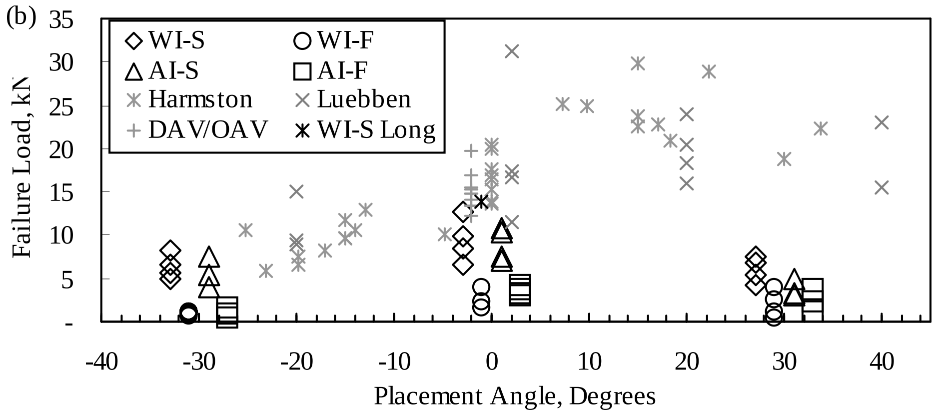
more climbers, accidents, & $$$, lead to more attention to standards

- mid 60s, rope testing
- early 70s, UIAA safety commission
- 70s and 80s, research & standards
- 90s CEN, ASTM, etc.

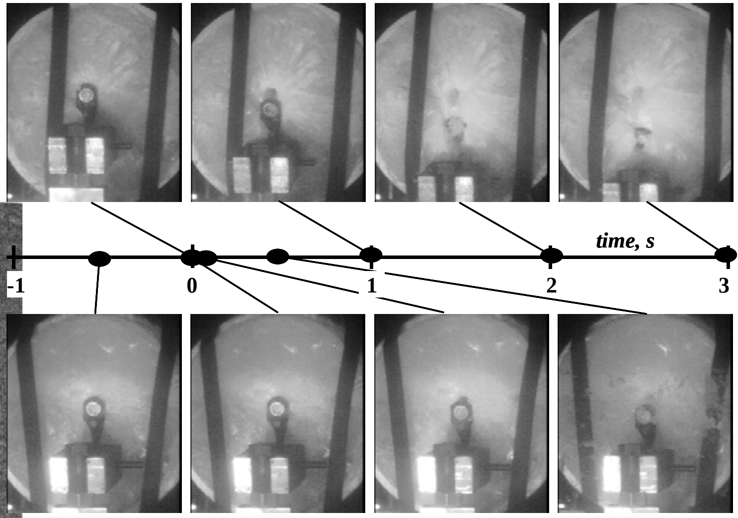
research and standards effectively reduce "equipment failure" to zero.



research

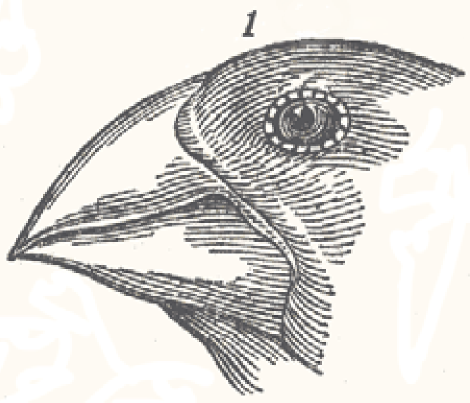


with research, inadequate equipment becomes extinct quickly.



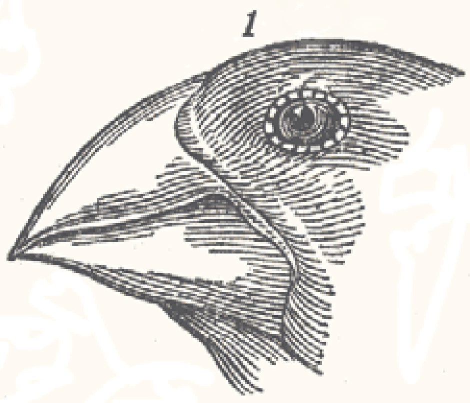
busted gear images from DAV Sicherheitskreis Taetigkeitsbericht 1980-1983

best practices become apparent.



standards organizations

UIAA
CEN PPE directive (CE)
ASTM/ANSI/ISO
CWA
(REI)

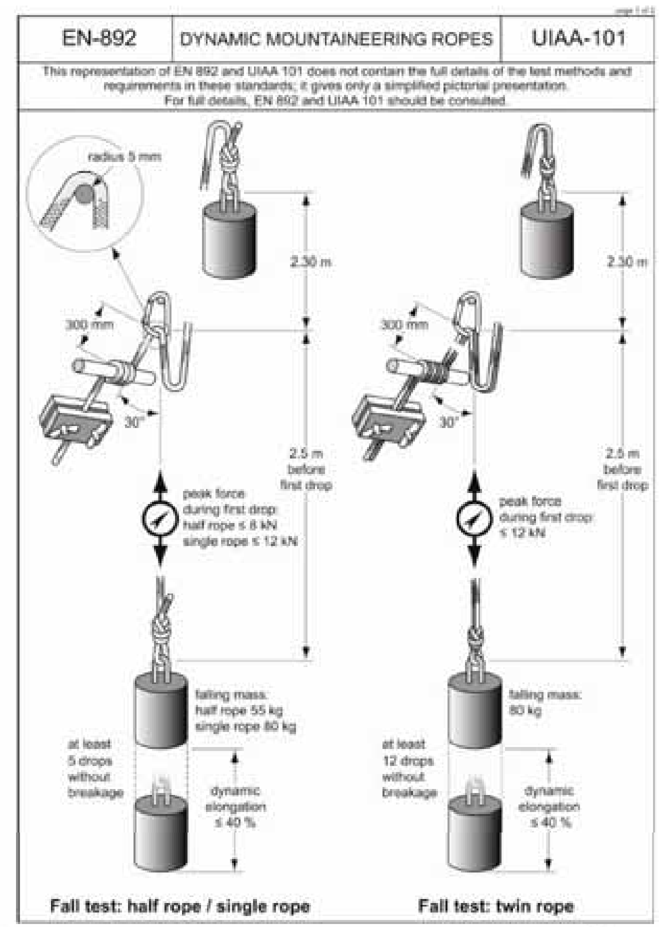


equipment standards

(individual components of the safety system)

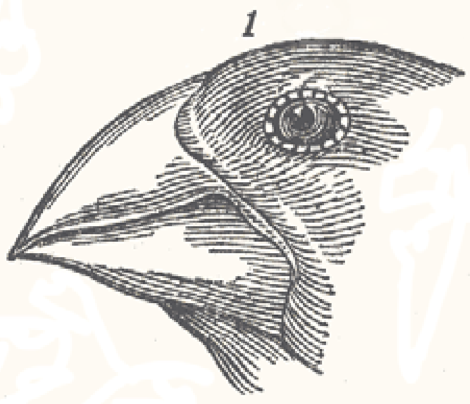
Nr	Title of the UIAA standard	Full text	Pictorial	Reference to
101	Dynamic Ropes	125 kb	288 kb	EN-892
102	Accessory Cord	122 kb	123 kb	EN-564
103	Tape	122 kb	140 kb	EN-565
104	Slings	123 kb	118 kb	EN-566
105	Harnesses	123 kb	182 kb	EN-12277
106	Helmets	123 kb	154 kb	EN-12492
107	Low Stretch Ropes	125 kb	n.a.	EN-1891
108	Sharp Edge Resistant Dynamic Ropes important note	549 kb	101 kb	UIAA-101
121	Connectors (Karabiners)	187 kb	329 kb	EN-12275
122	Pitons	128 kb	177 kb	EN-569
123	Rock Anchors	in revision	194 kb	EN-959
124	Chocks	122 kb	255 kb	EN-12270
125	Frictional Anchors such as Friends and Sliders	122 kb	201 kb	EN-12276
126	Rope Clamps, Ascenders	135 kb	152 kb	EN-567
127	Pulleys	123 kb	154 kb	EN-12278
128	Energy Absorbing Systems for Use on Vie Ferrate	149 kb	344 kb	EN-958
151	Ice Anchors	183 kb	132 kb	EN-568
152	Ice Tools (Axes and Hammers)	145 kb	259 kb	EN-13089
153	Crampons	122 kb	182 kb	EN-893
154	Snow Anchors (Dead Man)	213 kb	143 kb	-

New Standards for Abseiling Devices (UIAA-129) and Belaying Devices (UIAA-130) are currently in preparation.



17

Annex 2: Sample Graphic
UIAA Safety Committee Minutes, June 2003 Meeting, Canmore Canada



systems theory

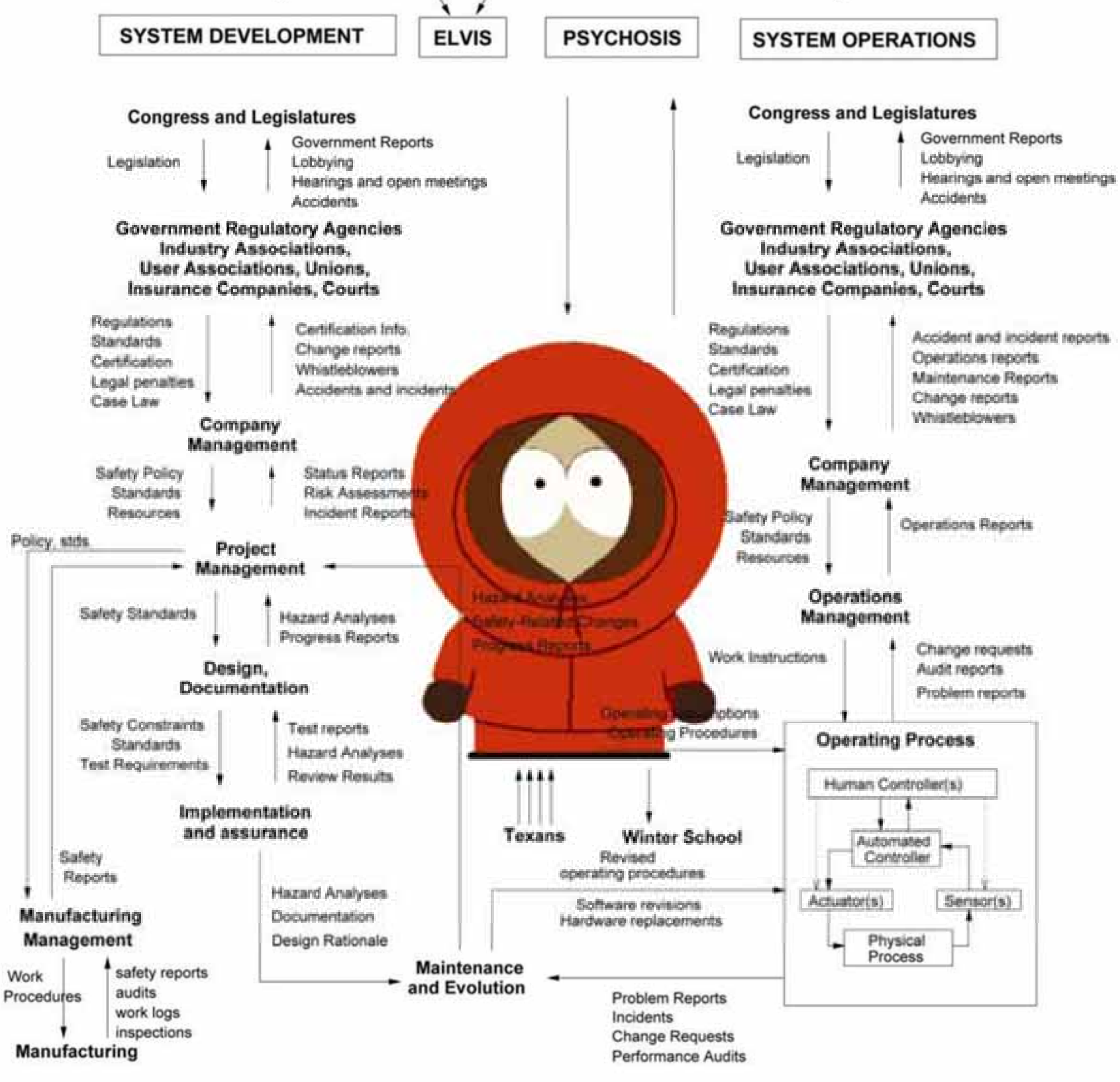
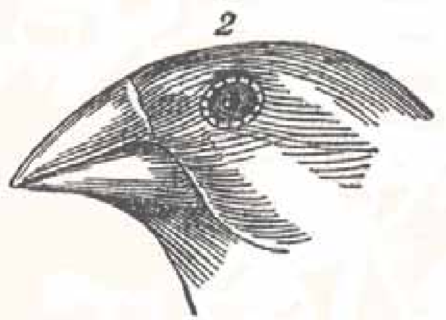


Figure 6.1: General Form of a Model of Socio-Technical Control

from A New Approach To System Safety Engineering, Nancy G. Leveson, http://sunnyday.mit.edu/book2.html

systems theory makes pin the blame on the victim more difficult



physics basis for standards

$$\frac{W}{g}\frac{d^2x}{dt^2} = W - P \quad (18)$$

where g is the acceleration due to gravity. The rope is again assumed to be elastic. Hence equation (2) is used in equation (18) to yield

$$\frac{d^2x}{dt^2} + \frac{kgx}{WL} - g = 0 \quad (19)$$

whose solution is

$$x = \left(a_0 - \frac{WL}{k}\right)\cos\left(t\sqrt{\frac{kg}{WL}}\right) + \frac{a_1}{\sqrt{\frac{kg}{WL}}}\sin\left(t\sqrt{\frac{kg}{WL}}\right) + \frac{WL}{k} \quad (20)$$

in which a_0 and a_1 are constants of integration. When $t = 0$, then $x = 0$ and therefore $a_0 = 0$. Likewise when $t = 0$, $\frac{dx}{dt} = \sqrt{2gH}$ and $a_1 = \sqrt{2gH}$. Equation (20) reduces to

$$x = \sqrt{\frac{2WHL}{k}}\sin\left(t\sqrt{\frac{kg}{WL}}\right) - \frac{WL}{k}\cos\left(t\sqrt{\frac{kg}{WL}}\right) + \frac{WL}{k} \quad (21)$$

The tension follows from inserting equation (21) into equation (2)

$$P = \sqrt{\frac{2WHk}{L}}\sin\left(t\sqrt{\frac{kg}{WL}}\right) - W\cos\left(t\sqrt{\frac{kg}{WL}}\right) + W \quad (22)$$

Another form of the equation is

$$P = W + W\sqrt{1 + \frac{2kH}{WL}}\sin\left[t\sqrt{\frac{kg}{WL}} - \arcsin\frac{1}{\sqrt{1 + \frac{2kH}{WL}}}\right] \quad (23)$$

Equations (22) and (23) show how the tension in the rope varies with time as a result of an impact load due to a free fall of a weight onto the rope. The practical significance of these equations may readily be understood by considering an actual fall. Let a man weighing 150 pounds fall 20 feet on a 10-foot length of rope. The H/L ratio is 2. Using equation (23), it is possible to compute what the tension in the rope will be at any instant after the rope has begun to stretch. If these values of tension and time are plotted, the

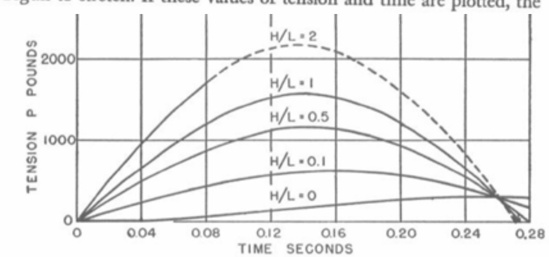


FIG. 6. Relation between tension and time in 7/16-inch nylon rope for a fall

image from American Alpine Club Journal, 1950

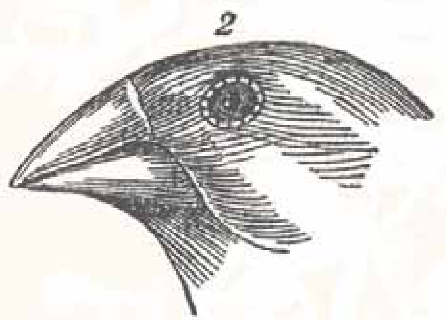
climbers can tolerate ~10 G deceleration (18 G permitted on US Navy pilots during parachute deployment)

the Earth's gravitational field is 1 G (9.8 m/s^2)

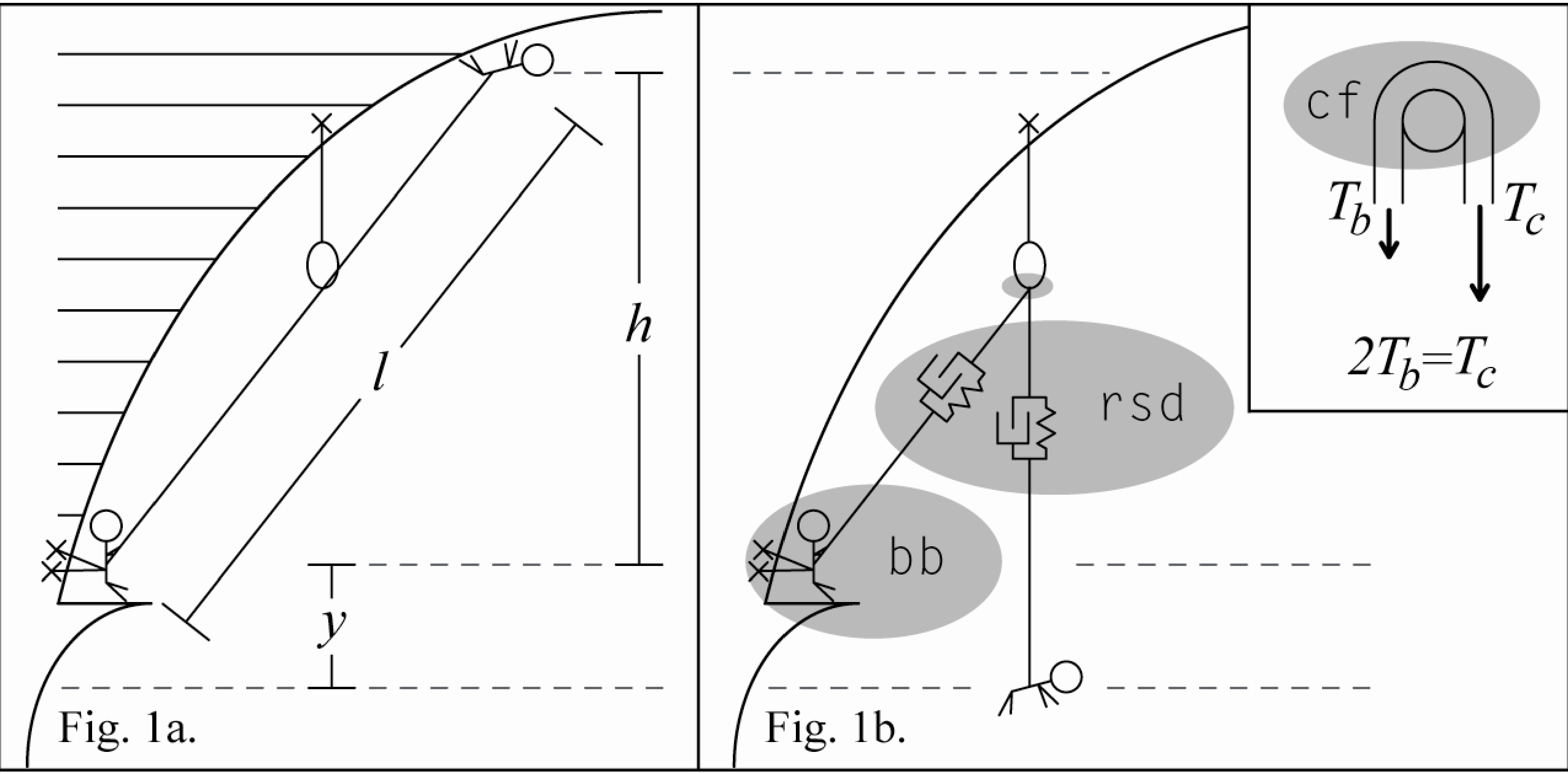
safe fall arrest distance lies between 1/10 of fall distance (physics) and 1/5 fall distance (UIAA/CE dynamic rope standard)

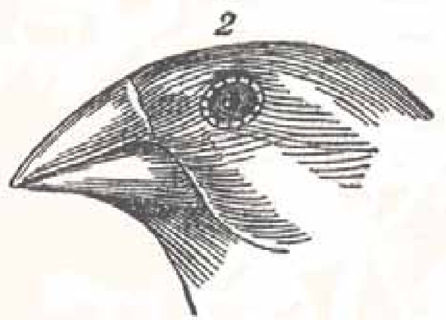
$$mgh + mgy = \tfrac{1}{2}ky^2$$

$$T = mg\left(1 + \sqrt{1 + 2\frac{MF}{mg}}\right)$$

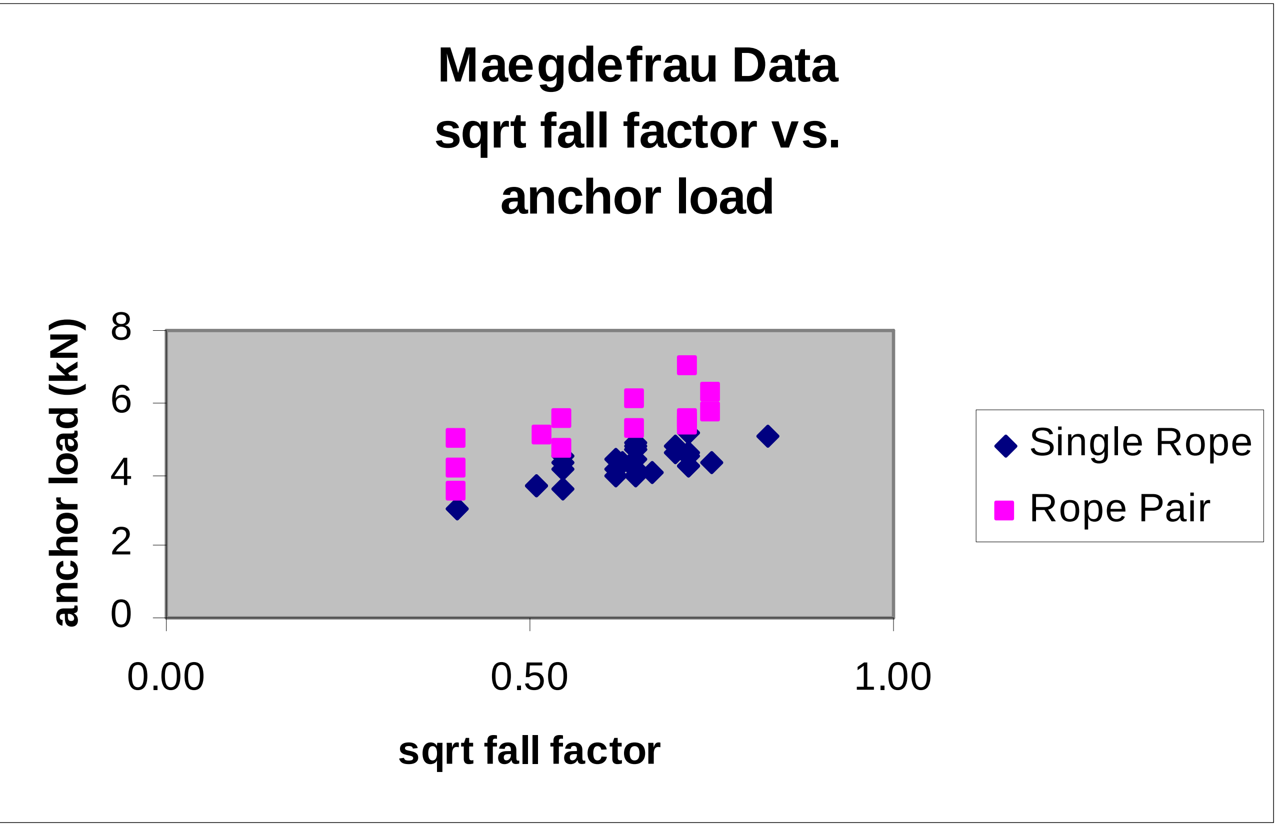


where the energy goes during fall arrest





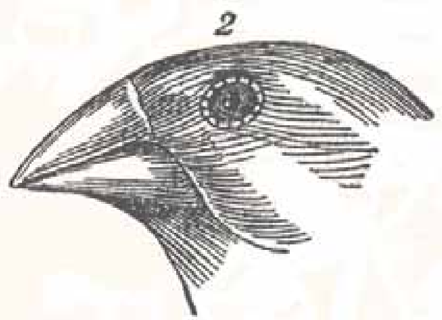
theory, experiment, and standards match well



data from Helmut Maegdefrau's PhD thesis

95% of falls put less than 7 kN on the top anchor (minimum permitted open gate carabiner strength).

20 kN forces on anchors require inappropriate use or a very, very bad karma (20 kN is the minimum closed gate carabiner strength).

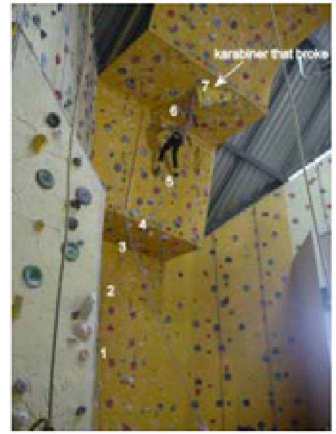


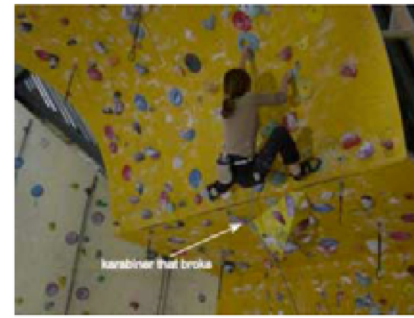
equipment still fails

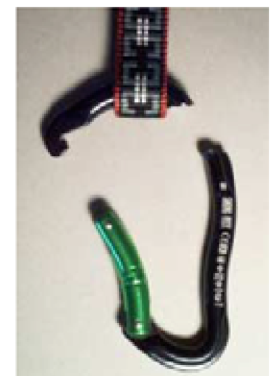
misuse
fatigue
overuse
abuse
modification
chemical abuse

SafCom 2004 meeting item 33: Unusual accidents concerning metal parts

<u>Broken biner, indoor climbing wall, the Netherlands</u>
48 kilo climber, just above 7th runner (see picture below-right for fall position),
circa 12 meters of rope, Grigri-belay device, belayer took in slack rope during fall
Singing Rock K538 light bent gate (made by Aludesign), gate-open 7 kN
Karabiner hang upside-down in sling (gate opening up; like this =>)
Considerable deformation, gate and nose no visible damage
Conclusion: diagonal loading in combination with gate-open

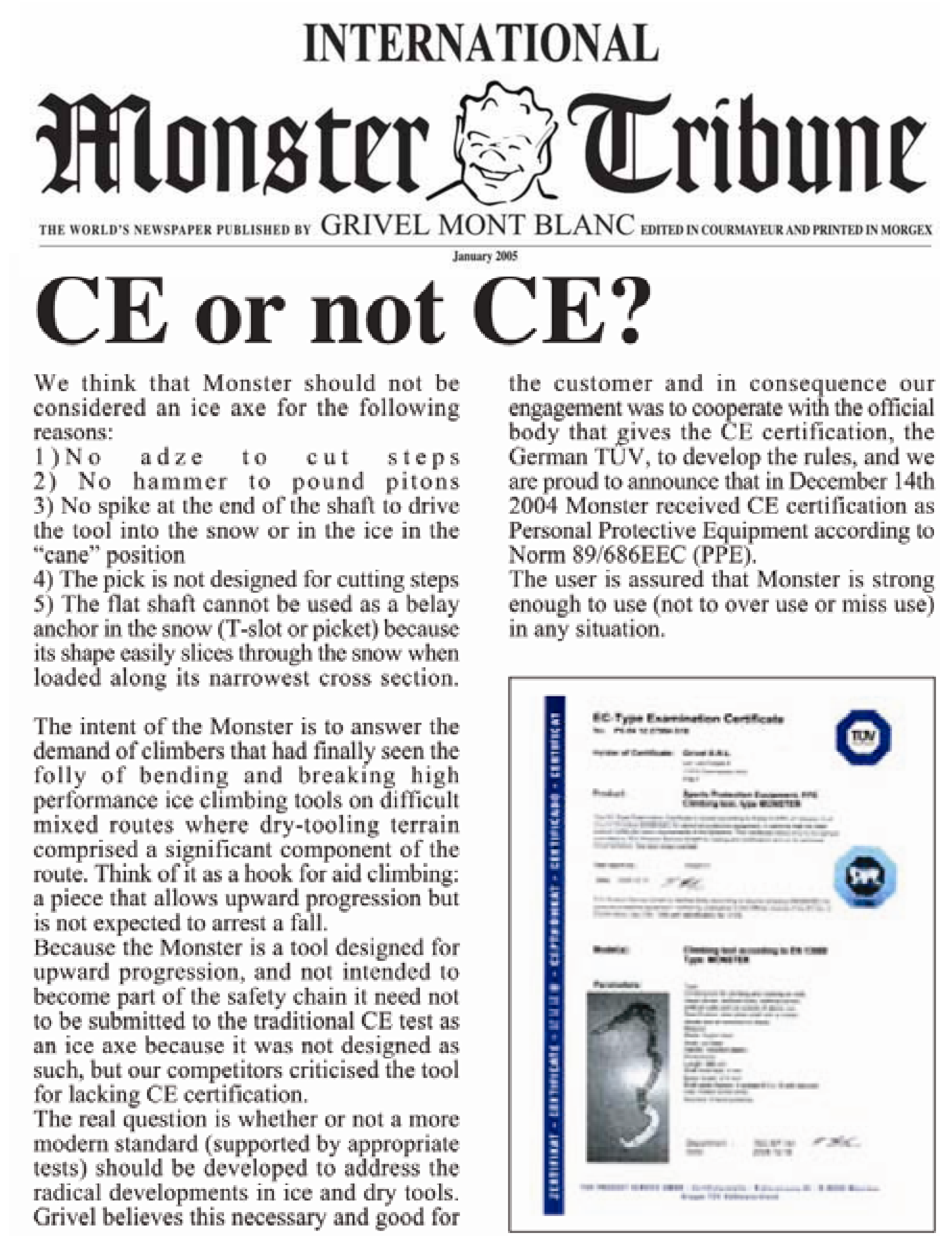






Carabiner failure images from 2005 UIAA SafeCom meeting minutes

ice ax standards



INTERNATIONAL
Monster Tribune
THE WORLD'S NEWSPAPER PUBLISHED BY GRIVEL MONT BLANC EDITED IN COURMAYEUR AND PRINTED IN MORGEX
January 2005

CE or not CE?

We think that Monster should not be considered an ice axe for the following reasons:
1) No adze to cut steps
2) No hammer to pound pitons
3) No spike at the end of the shaft to drive the tool into the snow or in the ice in the "cane" position
4) The pick is not designed for cutting steps
5) The flat shaft cannot be used as a belay anchor in the snow (T-slot or picket) because its shape easily slices through the snow when loaded along its narrowest cross section.

The intent of the Monster is to answer the demand of climbers that had finally seen the folly of bending and breaking high performance ice climbing tools on difficult mixed routes where dry-tooling terrain comprised a significant component of the route. Think of it as a hook for aid climbing: a piece that allows upward progression but is not expected to arrest a fall.
Because the Monster is a tool designed for upward progression, and not intended to become part of the safety chain it need not to be submitted to the traditional CE test as an ice axe because it was not designed as such, but our competitors criticised the tool for lacking CE certification.
The real question is whether or not a more modern standard (supported by appropriate tests) should be developed to address the radical developments in ice and dry tools. Grivel believes this necessary and good for the customer and in consequence our engagement was to cooperate with the official body that gives the CE certification, the German TÜV, to develop the rules, and we are proud to announce that in December 14th 2004 Monster received CE certification as Personal Protective Equipment according to Norm 89/686EEC (PPE).
The user is assured that Monster is strong enough to use (not to over use or miss use) in any situation.

EC-Type Examination Certificate

image from Grivel web site.

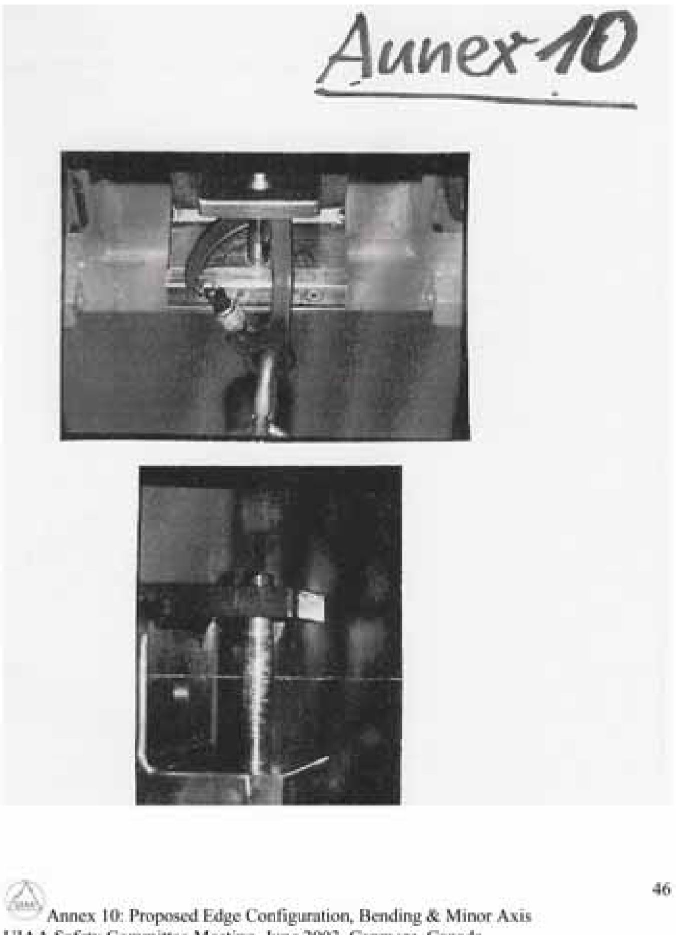
current ice ax standards are based on the demands of mountaineering

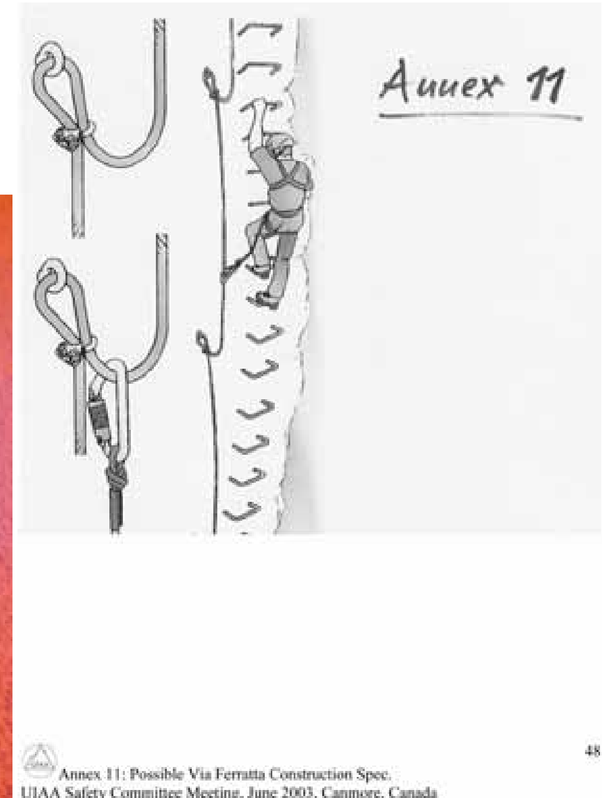
B and T blades?
shaft strength?

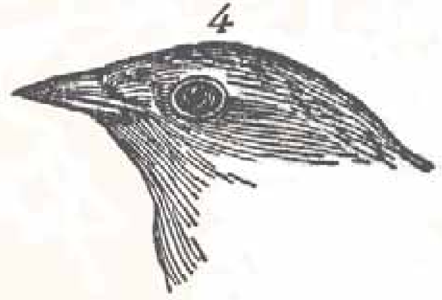
the remedy will be slow, probably by intended use.

via ferrata

via ferrata standards



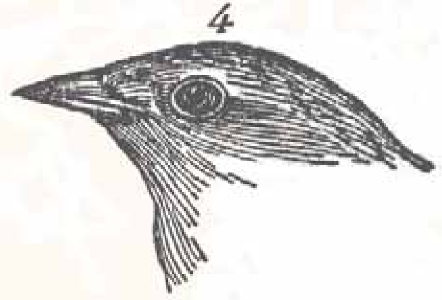




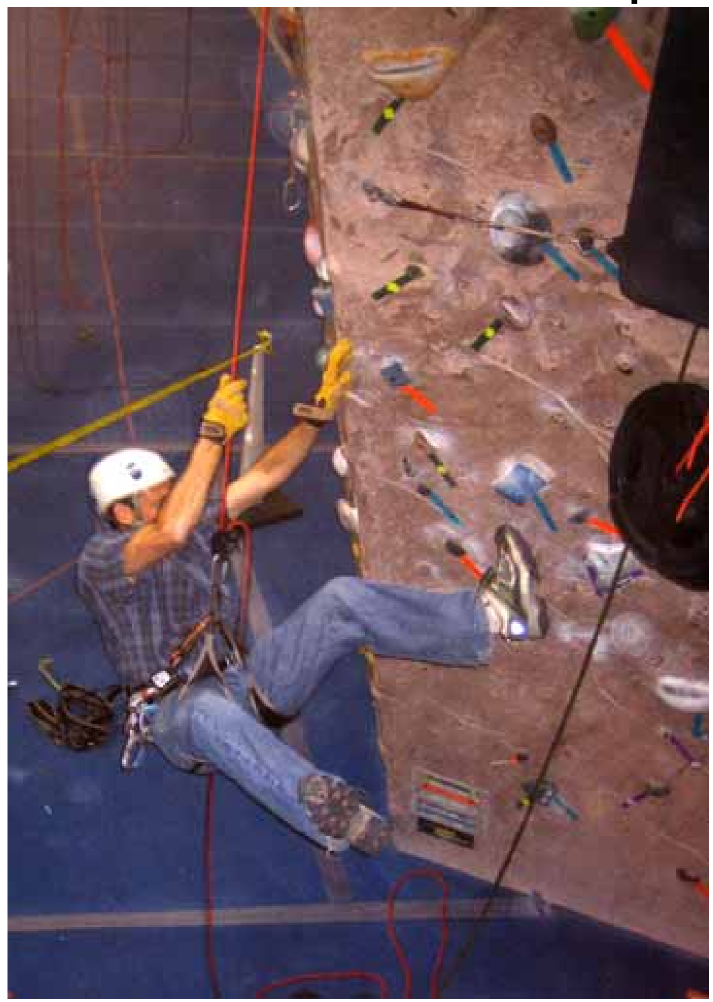
lessons from standards history

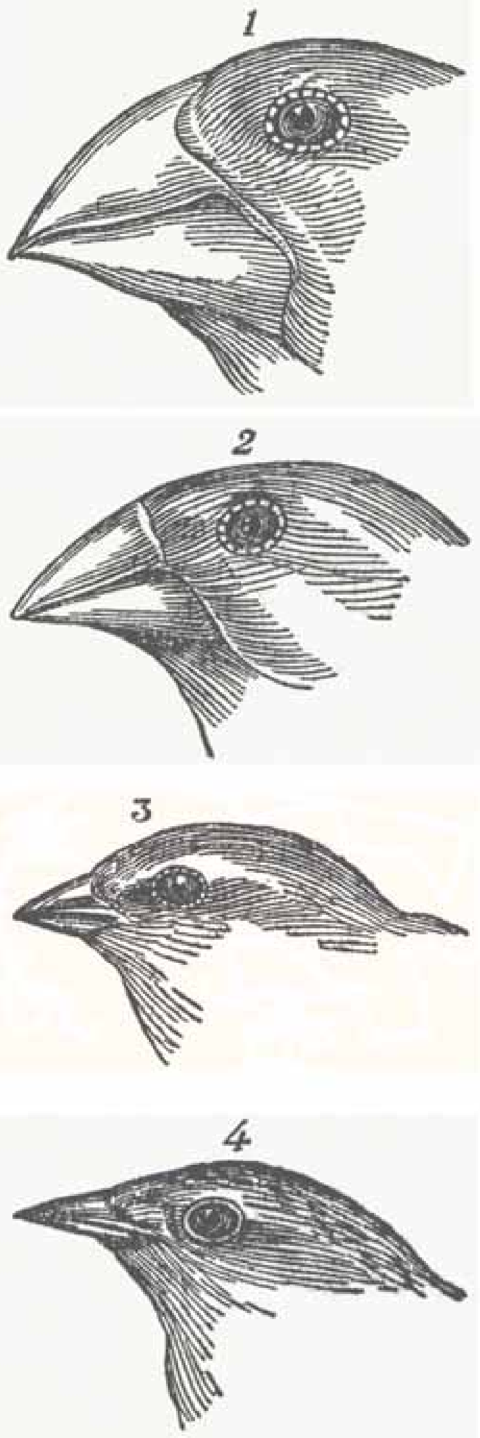
Standards evolve.
Standards are based on research & “physics”.
Standards prevent equipment failure accidents.
The evolution is slower than the evolution of the sport.

Expect:
Standards development to follow new climbing developments.
Increased standardization of safety systems.
Increased standardization of best practices for safety systems.

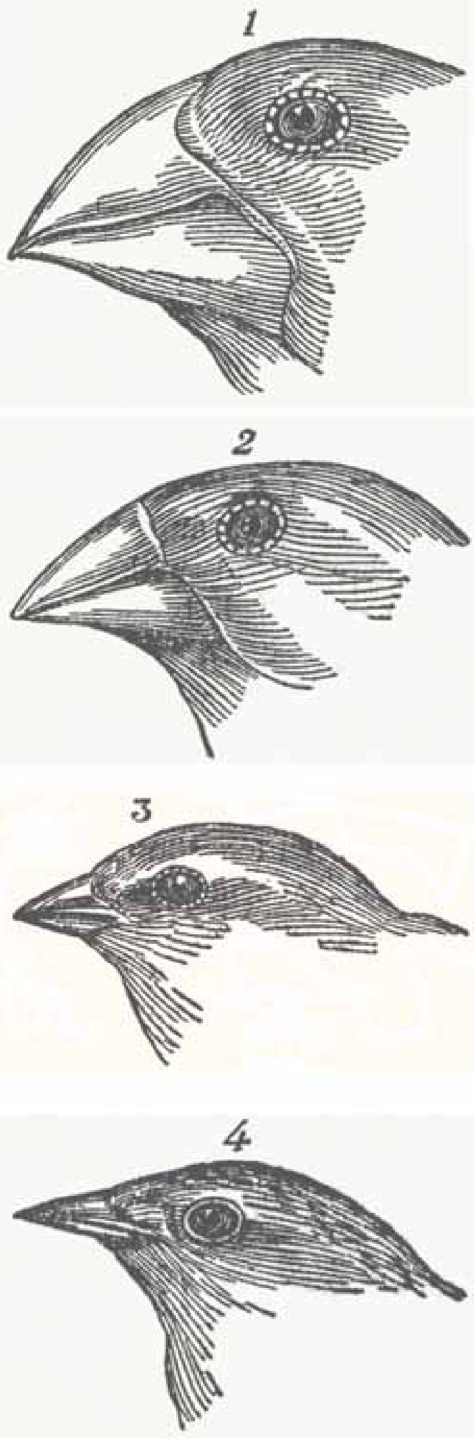


wild prediction: belaying will become a sport




1
2
3
4


questions?



best practice examples