22

THE LEAD FALL

INTRODUCTION

The lead fall is the event that we all dread and hope never comes to pass. It presents the real possibility of getting hurt or getting killed, or of hurting or killing others on the climbing team. It is essential to understand what happens during the lead fall and how it affects us and our equipment. Armed with this knowledge, you can minimize your risk.

A lead fall is a very dynamic event. What happens during the fall cannot be predicted with certainty. Even if you try to mimic the movement that you believe will happen in a lead fall, you cannot duplicate the actual event. Petzl had to use high-speed cameras to verify that gate flutter actually happens during a lead fall. You may predict that a biner will travel in a particular direction at a given speed. The actual movement will vary depending on a number of factors: your position relative to the piece; how long a runner you place on the piece; how far you fall; whether the climb is overhanging or not; or any number of other complicating factors. Ultimately, you will have to take your best guess as to what will happen, and you may be wrong.

There are some things about lead falls that are known, however, and we will discuss them here.

THE ANATOMY OF A LEAD FALL

Let's study a simple lead fall. You are a 180-pound climber leading on an 11 mm rope with an advertised **static elongation** of 5.7% and an advertised **impact force** of 9.4 kN. You have climbed up a dead vertical climb about 50 feet, placing protection as you went. Your tie-in knot is 10 feet above your last piece. You fall.

How far have you fallen? You have fallen 10 feet to your last placement, 10 more feet past your last placement, and more than 5.7% of 50 feet of rope due to stretch, or another 2.85 feet, for a total of more than 22.85 feet, until the rope completely stretched out and started to rebound. The rope will always stretch farther in a fall than in a static elongation stretch.

How much force did you generate? One older study (Microys, 1977) calculated the impact force (shock load, impact load) at 1,137 pounds (a factor .4 fall) on your body at the moment the rope was stretched its farthest. A more recent study published in *Rock & Ice Magazine* calculated the impact force in a factor .5 fall with a 176-pound climber at about 900 pounds.

What kind of damage did you do to your body? If you didn't hit any rock, ledges, protrusions, etc., and managed to stay upright, you felt the exerted force on your body, which was dissipated quickly, and you were not injured. If you hit a ledge with your foot, you may well have sprained, broken, hyper-extended or bruised your ankle and/or foot. If you got your leg tangled up in the rope and flipped over, you may have hit your head against the rock. If you twisted in any other direction, you may have injured another part of your body.

What kind of damage did you do to your gear? You stressed several pieces of equipment. You shock loaded your rope, which stretched; it is now slowly recovering its original shape, which may take 10-15 minutes. You shock loaded your uppermost piece more than any other gear, and may have dislodged the piece if it was natural pro. You shock-loaded your harness, which doesn't stretch but does deform, and it is probably recovered, but slightly worse for wear.

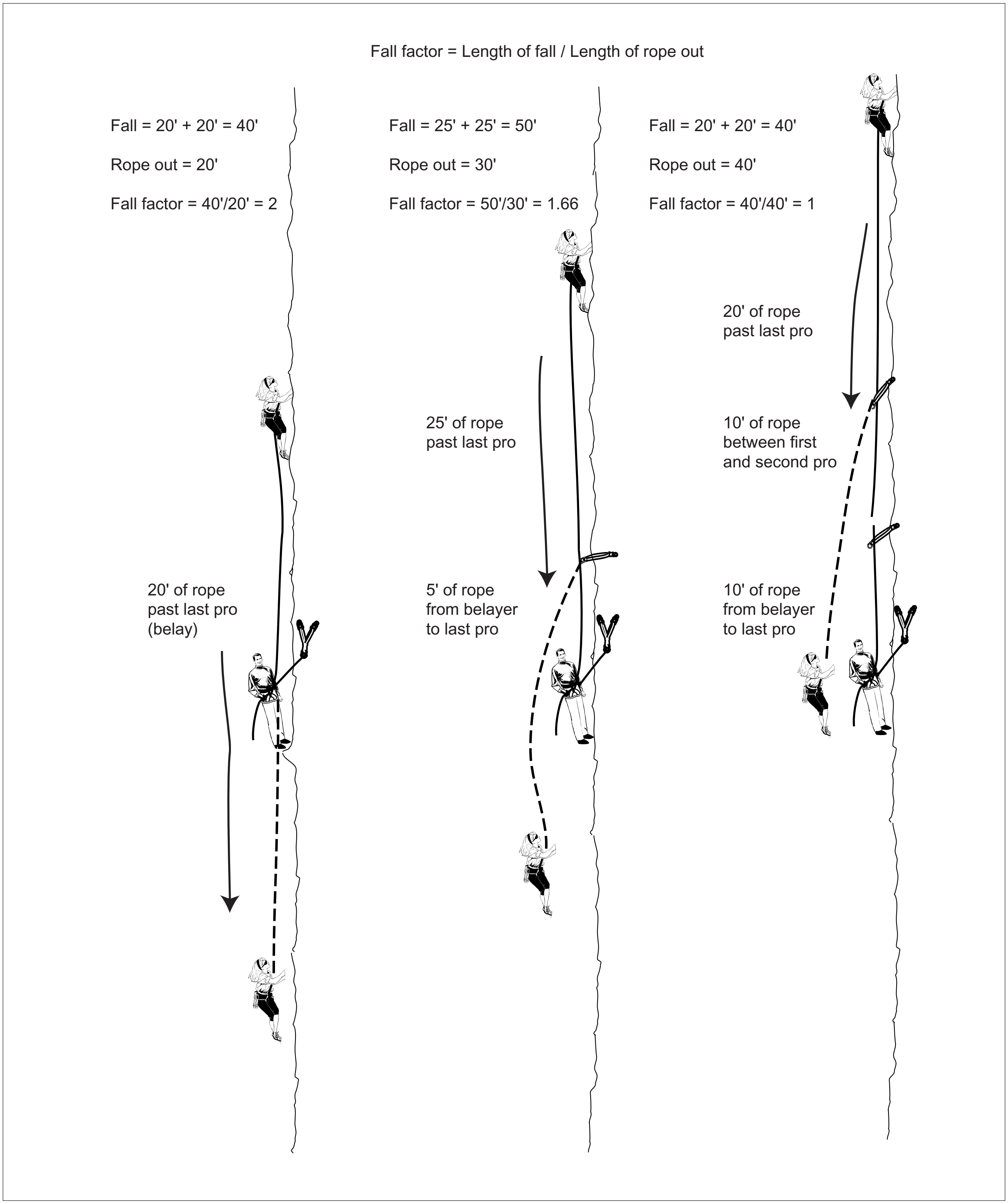

Fig 22-01a

The first picture is a fall factor 2, the most severe fall possible. No pro has been placed and the climber fell directly on the belayer.

The second picture is a very bad fall that approximates the severity of a UIAA test fall used to certify new ropes.

The third picture is classified as a "severe" lead fall, or a fall factor 1. Manufacturers recommend that a rope be retired from lead status after a single severe lead fall. The harness and any quickdraw or runner in use at the top pro placement should also be retired from lead status.

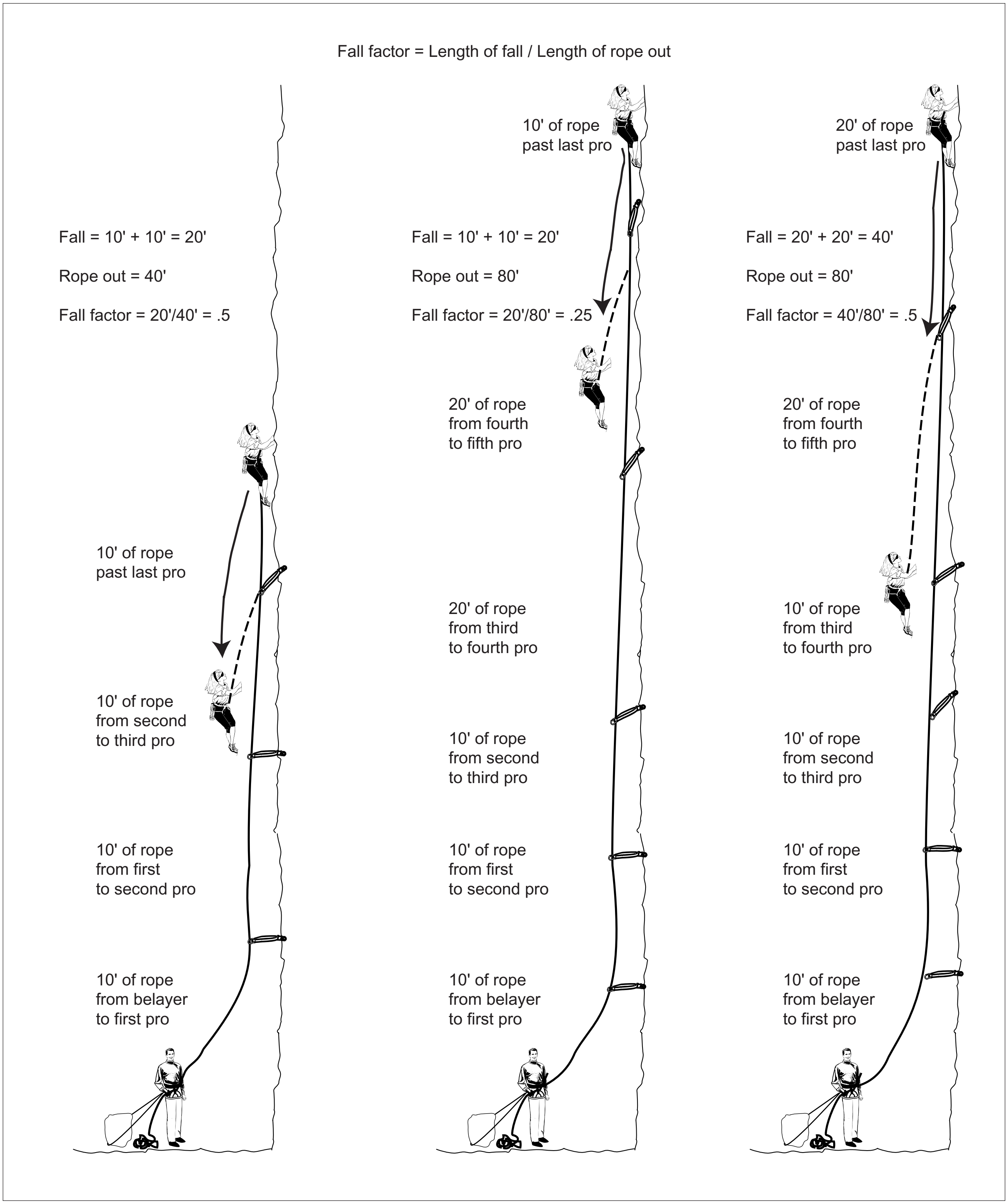

Fig 22-01b

The first two pictures feature the same length fall, but show that the greater the amount of "rope out," the less severe the fall. This suggests that it is better to place pro closer together at the bottom of the climb; pro in the upper sections can be spaced more widely.

Pictures two and three feature the same length of rope out, but the longer fall produces a more severe fall factor. This confirms what common sense tells us: the farther you fall, the worse the impact on the equipment.

What kind of damage did you do to your belayer? If your belayer was anchored in, you jerked him/her around a little, but not badly. You shock-loaded the belayer's harness, but not as badly as yours. The belayer's anchor held nicely.

How do we know this?

THE FALL FACTOR

Lead falls are measured by the "**Fall Factor**." This is a ratio that compares the length of the fall to the length of the rope "out" (the length of rope between the belay device and the climber's tie-in knot). Mathematically, the fall factor is as follows:

Length of fall / Length of rope out = Fall Factor

Although the climbing world (manufacturers, writers, retailers) uses the "fall factor" as a guide to help understand the damage done to a rope and other gear, it is more of a laboratory figure than a practical one. The calculation eliminates many factors which can affect the shock-loading of a rope during a fall: rope stretch, friction in the belay device, friction in the top protection point carabiner, friction from sliding against the rock, and other factors. However, it is useful for understanding the severity and impact of a fall, and useful for measuring the effectiveness of all the related gear. The fall factor describes the worst case of a fall with the given parameters; if friction helped to hold the fall, it would be less severe, or impart less force to the climber's body than a pure fall.

The maximum fall factor, or worst lead fall possible, is a factor 2 fall, and "no fall" is a fall factor of "0." The higher the fall factor, the harder and worse the fall is, and the more it stresses both the climber and the equipment. Keep in mind in the following discussion that a fall mainly stresses the rope that is actively involved in the belay chain, i.e., the rope that runs from the belay device to the climber's harness. The rope piled on the ground that is not yet part of the belay chain is not stressed.

Fall Factor 2

Imagine you have climbed 20' up the fourth pitch of a dead vertical climb, without any protection. You fall 20' back to the belay and an additional 20' farther below your belay anchor. The fall factor is 40/20=2 (fig 22-01a). This is only possible on a multi-pitch climb or a climb where the leader can fall below the belay stance.

Keep in mind that at the point where your fall has taken up all the slack in the rope, at the end of your 40' fall, you have developed quite a head of steam in a downward direction. Left unchecked, you will "impact" the ground at a much greater force than just body weight. The purpose of the rope is to absorb this impact force and limit the impact on your body to a maximum allowable force of 12 kN (2700 pounds of force).

Fall factor 1

Imagine you have climbed 20' up the fourth pitch of a dead vertical climb and have placed one bomber piece 10' off the deck. If you come off, you will fall the 10' above the piece and the 10' below the piece, for a total fall of 20'. The fall factor is 20/20=1 (fig 22-01a). This also is possible only on a multi-pitch climb or a climb where the leader can fall below the belay stance; if it occurred on a single-pitch climb, the leader would hit the ground and there would be no force imparted to the rope or other gear.

In this fall, also, your body has developed an impact force that must be dissipated. However, with a shorter fall on the same amount of rope, the rope doesn't have to work as hard to limit the force on your body to 12 kN.

A factor 1 fall is considered "severe" by rope manufacturers. They recommend retiring a rope from lead status after a factor 1 fall or greater. Also, harness manufacturers recommend retiring your harness if you experience a severe lead fall, due to concerns about hidden damage to the stitching or other parts.

Fall factor less than 1

The vast majority of falls are much less than a factor 1 fall. Look at the examples (fig 22-01b). In general, you can assume that the greater the fall, given the same amount of rope out, the more severe the damage is to the rope. While this should be self-evident without needing to mathematically prove it, the less-obvious corollary is also true—the lesser the amount of rope out, given the same distance fall, the more severe the damage is to the rope.

In practical terms, the higher you go with properly placed protection, the less severe the fall factor and lead fall. The impact force developed in a lead fall of less than factor 1 is significantly less.

Fall factor 0

Before looking at this fall, think about a rope in a slingshot belay system. The rope can be slack, it can be under tension, or it can be at that equilibrium point where there is no slack or tension. It is this state that allows a factor 0 fall.

Now imagine the fall. You are on a climbing stance, not weighting the rope. There is no tension pulling you up, and no slack rope to be pulled tight should you fall. And you do fall. The length of the fall (rope stretch is never included in fall factors) is zero. The length of rope out does not matter (at least for the fall factor calculation). The fall factor is 0/(some length of rope)=0. The impact force is a lot less than that of a factor 1 lead fall. But there is a definite impact force when the rope finally stops the climber. The impact force is about twice the climber's body weight. This means that a 150-pound climber generates a force of at least 300 pounds on the top anchor. The force is actually greater than 300 pounds, as we will see later.

What is the actual force felt by the climber during a lead fall? According to Helmut Microys, who wrote an article in 1977 entitled "Climbing Ropes" for issue 21 of the *American Alpine Journal*, fall factors for a 180-pound climber (very close to the typical climber weight used in UIAA calculations) are calculated as listed in this table:

Fall Factor	0.4	0.8	1.0	1.4	1.6	2.0
Impact Force in pounds	1137	1521	1676	1947	2067	2288
Impact Force in kN	5	6.8	7.5	8.7	9.2	10.2

Another more recent computer study (*Rock & Magazine*, July/August 1995) shows this table:

Fall factor	.5	.5	.5	1.5	1.5	1.5
Weight of climber in pounds	132	176	220	132	176	220
Impact force in pounds	764	899	1012	1214	1394	1574
Impact force in kN	3.4	4	4.5	5.4	6.2	7

These results are printed here just as an example. The difference in the final impact force is probably due to improvements in rope design. We cannot guarantee that the figures quoted above were correctly calculated. As mentioned in the equipment chapter, ropes are required to limit the force on a climber's body to 12 kN or less (2698 pounds of force). The actual force felt in a factor 2 fall for most climbers is less than that; in the above example, it is 10.2 kN (2288 pounds of force). This has several implications which we will discuss throughout this and other lead climbing chapters.

THE EFFECT OF A LEAD FALL ON THE BELAY CHAIN

The worst effect of the impact force of a lead fall is on the rope and the top piece of protection, but it also affects the climber's other protection, the climber's harness, and the belayer's harness and anchor. To review, the belay chain consists of the belayer anchor, the rope, the belayer and the belayer's harness, the belay device, all protection placed by the leader, the leader's tie-in knot, the leader's harness and the leader. The rope and top protection are by far the most affected components of the chain.

Effect On the Rope

A lead fall damages that portion of the **rope** that extends from the belay device to the climber's tie-in knot. The damage may be only slight in a given fall, such as a factor .20 fall, but at least some fibers are damaged, reducing the elasticity of the rope. Repeated falls will damage more and more fibers, which eventually reduces the ability of the rope to absorb the energy of the fall. When enough fibers have been damaged, the rope loses its ability to absorb the force of the fall, and a future fall may break the rope. This repeated loading will also cause the rope to shrink.

Climbing literature abounds with the statement that "There are no reported instances of a rope breaking during a lead fall, or in any other normal climbing activity." There are, however, instances of ropes cutting, or breaking over sharp edges. What is known about the loss of shock-absorbing ability has been gathered by testing ropes repeatedly. These tests have led manufacturers to recommend that a rope be retired from lead use following certain guidelines. Manufacturers in general recommend safety precautions that don't test the limits of the product's capabilities; even though you can probably use a rope after a severe lead fall, retiring it from lead use will guarantee that it will not fail on you. It is not worth it to take the chance.

Here is an example of some test results from BlueWater, one of the largest climbing equipment manufacturers in the U. S. (This is not an endorsement of BlueWater or BlueWater products, just a sample test result.) BlueWater conducted a test of one of their 10.5 mm ropes on a UIAA test tower to simulate sport-climbing conditions. In the test, they dropped a "standard" climber weight of 176.4 pounds (80 kg) a distance of 5'3" (1.6 m) with 8'2.4" (2.5 m) of rope out, for a fall factor of .64. The rope lost 32% of its strength after 25 short falls, 40% after 50 falls, 52% after 100 falls, and 63% after 125 falls. One core strand broke after 75 falls and three core strands broke after 100 falls. None of these figures can be counted on to predict what will actually happen when you fall on your rope, but they can and do give an indication of the declining strength of a rope after repeated falls.

Manufacturers recommend that you retire a rope from lead climbing after any severe lead fall. Keep in mind, however, that the damaged portion of the rope may be small. If only the first ten feet were damaged, you can cut this off and have a shorter lead rope. (This can present another problem if you or someone else count on the rope being a full rope length and discover too late that it is not.)

Manufacturers usually recommend the following:

In **heavy use**, such as frequent guiding or sport climbing, retire the rope from lead use every 3-6 months.

In **medium use**, such as weekend warriors who take climbing holidays, retire the rope from lead use after 1-2 years.

In **light use**, retire the rope from lead use after 2-4 years.

In addition, you can extend the life of your rope by using a fatter rope such as 11 mm for working cruxes. You should occasionally swap ends if you are doing heavy sport climbing or working a route to allow full recovery to the "un-stretched" position.

Rope manufacturers are required to make ropes that limit a climber's impact force to a maximum of 12 kN (224.8*12=2698 pounds of force). This shock-absorption also limits the damage done to other components of the belay chain, but does not prevent all damage.

Effect On the Top Piece of Pro

The forces resulting from a lead fall can be imparted to all the gear that protects the climber, but the majority is taken by the last piece of pro the climber set. This piece, the draw connected to it, and the biners connecting the draw take a serious jolt. Let's look at this force for a minute. Remember, the force on this top piece is not just the force that the climber feels. Since the rope configuration looks like a slingshot, think back to the anchor physics chapter. There is a multiplication of forces that occurs on the top piece. The force of the climber falling has to be balanced on the other side of the biner by a large enough force to stop the climber. After taking into account the coefficient of friction of the rope-bearing biner above the climber, which is about .67, the force needed to hold the climber equates to about 67% of the maximum force the climber feels. This means the belayer must exert about 67% of the climber's impact force in some way to stop the fall. Therefore, the total force on the top piece of protection is the force the climber feels plus the force needed to stop the climber's fall. If the force on the climber is 10.2 kN as described above in the fall factor 2 fall, the force needed to stop the climber is 67% of 10.2 kN, which is about 6.8 kN. The total force imparted to the placement is 17 kN, or 3821.6 pounds of force. This means the bolt or pro placement, and the draw, and each biner, must hold that much force.

Let's calculate the maximum force that you can realistically expect to have to deal with. Rope manufacturers are required to make ropes that limit the impact force on the climber to 12kN (about 2700 pounds of force). Multiply this number by .67 to come up with 8 kN (about 1800 pounds of force. Add these together to come up with 20kN or about 4500 pounds of force. This is the maximum that the worst lead fall should have to hold. However, this is a factor 2 fall, which can only happen when there is no pro placed, and the leader can free fall below the belayer. In this instance, the impact is not taken by a single upper piece, but by the belay anchor, which is composed of several pieces, and which distributes the force among them. As a practical matter, if you take a fall greater than fall factor 1, you are dropping below the belay; even if your pro pops because of the excessive forces, you will be stopped eventually by the belay itself. In Microys study, he determined that the climber's impact force was about 7.5 kN (1676 pounds). The resultant force on the top piece would have been about 12.5 kN (2800) pounds of force. This is very close to the magical number 12 kN, or the maximum impact force ropes are designed to provide. It is very realistic to look at pro, draws, and biners that are rated at about 12 kN, or 2700 pounds of force. It gives you one number to remember when you evaluate equipment. We have already discussed the advantage of protecting early and more often on the first part of the climb. This is the way to protect against the harder lead falls.

After a fall, it is wise to inspect the top piece and gear to make sure it has not been damaged. Even the biner clipped through a bolt is worth a look, to make sure it didn't rotate to some weird position. In the case of natural pro, check to make sure the piece has not shifted from its intended position. When using girth-hitched or slip-hitched runners, make sure they still are properly set.

Effect On the Rest of the Belay Chain

A lead fall can place a severe impact on the climber's harness. The force of the fall can damage the stitching holding it together or damage the webbing itself. Remember that most manufacturers recommend retiring a harness after a severe lead fall, and also recommend retiring a harness after normal usage following the same guidelines listed above for lead ropes.

The belayer can be affected, also. Some of the shock is passed on to the belayer's body. If the belayer is tied tightly to an anchor and is loading the anchor when the fall comes, the shock is passed mainly to the anchor itself, with some shock-absorption in the deformation of the harness. This results in a "harder" fall for the climber, but the belayer is not in as much danger of losing control of the belay. If the belayer is not tied in at all, there is a great danger of being pulled into the rock or off of the stance, with unpredictable results.

HOW TO MINIMIZE THE SHOCK LOAD OF A LEAD FALL

The belayer anchor tends to be a static point in absorbing shock. Do not attempt to absorb shock in the anchor system by leaving it loose. The anchor should be solidly built with no give.

The belayer can absorb some shock by taking a loose stance at the belayer anchor. The belayer's body weight will be pulled upward, blunting some of the force. The amount of shock absorbed will be dependent on how far up in the air the belayer's body is lifted. The deformation of the belayer's harness around the body will also absorb some shock. If there is enough advance notice, or the belayer is very quick to react, he/she can absorb shock by dropping to the ground, as long as the brake hand never loses control. This will provide a longer uplift and absorb more shock.

The slippage of the rope through the belay device will help absorb shock. The amount of slippage will vary according to the belay device. A device that locks off more quickly (such as a Petzl Gri-Gri) will absorb less shock than a device that lets the rope "run," such as a figure-eight rappel device set up incorrectly in a rappel configuration or using the large hole. These latter configurations are very dangerous in a lead situation because they may not lock off at all.

Drag in the protection system will absorb shock, but should not be induced to help protect against a fall. Carabiners made of large diameter stock used as the rope-bearing biners will provide more friction (absorb more shock) than carabiners made of small diameter stock, although this is not the primary reason for choosing a particular carabiner.

The rope is the primary shock absorber. A larger diameter rope will absorb more shock. The leader's harness deformation will absorb some shock. Do not attempt to minimize shock by tying a loose knot in the leader's tie-in knot. The knot should be properly dressed and solidly tightened.

Remember, never attempt to minimize shock loading at the expense of losing control of the belay.

It is appropriate here to discuss static rope or sling briefly. Dynamic rope is designed to absorb the shock of a fall. Static rope is not. Dynamic rope is required to reduce the shock on your body to a non-dangerous level. Static rope makes no such reduction. A fall on a static rope of less than four feet can kill a person. Never use a static rope to lead on.

HOW TO FALL

There is no one answer to the question "How should I fall?" The answer depends on the unique environment that you can encounter in a given fall. For example, if the climb is totally overhung, you will not get hurt by any ledges. If the climb is on blocky, irregular rock, and you hit a ledge on the way down, you can easily get hurt. In general, harder climbs with nothing underneath the climber are safer to fall from than easier climbs with rock to fall on. The majority of injuries in falls occur because of the climber hitting rock or the ground on the way down, and it is this collision with the rock that you need to be aware of and protect against.

Falls are usually of two types: the expected and the unexpected. If you expect or know you are going to fall, or you are working a difficult move and are not sure you can "send" it, you may be able to do a little preparation. This happens often when someone is "working" a sport route. The leader expects to fall, and orients himself/herself in a direction such that it will be a harmless fall into the air.

An unexpected fall can be much worse. If you do not have time to plan or react, it is easy to hit rock on the way down, and it is easier to lose control of your body's orientation to the rock. When you start to spin, twist or tumble, your chance of injury goes up dramatically, partially because of the increased exposure to head injury.

The best defense against a bad fall is to be aware at all times of the direction in which you are going to fall (this is the line of action). Develop the ability to constantly re-analyze what will happen to you should you fall as you ascend, just as you constantly re-analyze your automobile's position when changing lanes, slowing down, or speeding up in traffic.

Try to use the following guidelines when you actually fall. Remember that the fall may be over before you realize it and have a chance to react.

Do not freeze up or flop around. Freezing up leaves your body stiff and more prone to tumbling if you hit rock, or if an extremity hits rock. Going totally limp may allow your limbs to take the full brunt of a contact if you hit rock on the way down. By keeping your limbs somewhat tense but flexible, you can absorb shock and help to direct your body in a safer direction.

Avoid tumbling. Keep your body oriented upright to the rock and assume a loose but controlled position, like a cat—arms out front and to the side, protecting the body and head. If you strike rock, your body should give but not break or flop.

Avoid grabbing the rope. If this is a natural pro climb, you can dislodge your last piece. If you grab the rope, you can burn your hands or smash them between the rope and rock when your body swings into the rock.

If you are **falling from an overhang**, you are the least likely to fall onto something. The main danger is getting entangled in the rope and twisting, having the rope snap a body part in the wrong direction, or rope burn.

If you are **falling onto a vertical face or sliding down a smooth friction slab** with no rock projections, your main danger is tumbling. If you spin or tumble, you can slam body parts into the rock, which is very close on a vertical climb. On smooth friction slabs such as Glacier Point Apron in Yosemite, where the climbing is on smooth 45-degree rock, some climbers advocate turning around and running downhill until the rope catches to avoid the feet hitting the rock and forcing a head-over-heels tumble. This is a specialized technique, and if you do not have good reaction time, you may be just as likely to get injured this way as facing the rock.

If you are **falling onto chickenheads, ledges, other rock projections, or the ground**, you are more likely to get injured. If you fall and hit something on the way down, it is best to hit with your feet, which you can do best when you stay upright. If you tumble or spin, you have more of a chance to hit your head. Falling from a more vertical face climb is usually less dangerous. If you are attempting a lieback move, your body is already tipped to the horizontal, and the pressure you are exerting to keep yourself in the lieback turns into a force that pushes you more horizontal when you fall. Keep this in mind in any climbing stance in which you deviate from a vertical stance. Before you make the move, think about what you might do when you fall.