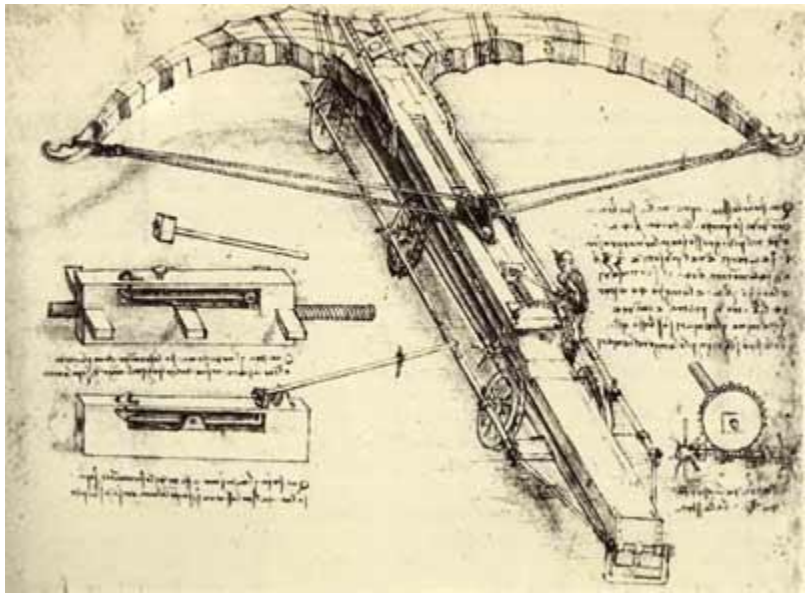
How Crossbows Work

By Tracy V. Wilson

Wilson, Tracy V.. "How Crossbows Work" 29 September 2006. HowStuffWorks.com. <http://science.howstuffworks.com/crossbow.htm> 05 May 2015.



A diagram of a crossbow by Leonardo DaVinci. ~ Image courtesy Sandia National Laboratories

Introduction to How Crossbows Work

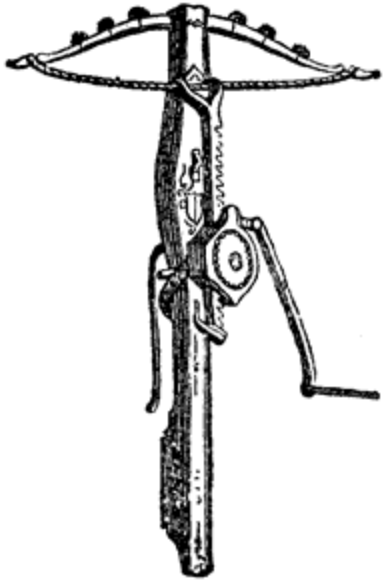
The crossbow, a weapon popular with Wookiees, vampire slayers and some modern hunters, looks like a cross between a bow and a rifle. Like a bow, it uses a fast-moving string to launch projectiles, but it also has a trigger and a stock, like a rifle. Based on these similarities, some people may think that the inventor of the crossbow took pieces from a rifle and attached them to a bow. But crossbows have been around much longer than guns have.

Archeologists have found crossbows in 2,500-year-old Chinese graves, and some historians believe that they existed in China as early as 2000 B.C. Crossbows also appeared in the Mediterranean region by the fourth century A.D. Roman military writer Flavius Vegetius Renatus mentions them in a text written in 385 AD, and they were prevalent in Europe throughout the Middle Ages.

In both Chinese and Mediterranean societies, early crossbows had the same basic parts. They were essentially bows mounted horizontally to wooden **tillers**, or **stocks**. When shot, an arrow, or **bolt**, traveled down a groove or through a notch in the tiller. Both styles also incorporated devices to make drawing the string easier. One common device was a **stirrup** at the front of the crossbow. A person could brace the crossbow with his foot while drawing the string with both hands or with a hook attached to his belt.

Both types of crossbows employed a **trigger** to release the cocked string. Roman crossbows used a rotating nut held in place by a lever, and Chinese crossbows used a system of hooks and levers. Since the two types of crossbows have such different firing mechanisms, historians believe that the two cultures developed them independently of each other.

It may seem hard to believe that two different cultures could invent roughly the same mechanical device. But the crossbow is really a logical improvement of the bow, which has existed since prehistory. Early bows were simply pieces of wood with their ends connected by a bowstring. Improvements to the basic bow, such as more effective bow shapes and better materials, made them more powerful and efficient. But firing even the best bow quickly and accurately still requires strength, agility, speed and a fair amount of skill. Becoming an expert archer with a longbow can take years.



A crossbow with crannequin ~ *Public domain image*

Crossbow Advantages

Crossbows don't require the same physical strength or training that ordinary bows do:

- When using a traditional bow, an archer must draw, aim and shoot in fairly quick succession. The longer it takes the archer to aim, the more fatigued his arm will become, and the less accurate his shot will be. Being able to aim and shoot quickly requires lots of practice. But if the archer uses a crossbow, he can draw the string -- or **cock** the crossbow -- and leave it that way as long as he needs to.

- An archer who isn't very tall can't use a very long bow. If he isn't very strong, he also can't draw the string on a powerful bow. In other words, a person's size and upper body strength limit the size and strength of the bow he can use. With a crossbow, though, an archer can use his strongest muscle groups -- the ones found in his thighs and buttocks -- to draw the string. A crossbowman can even use

tools like levers or cranks to supplement his strength. This means that a crossbowman can use a more powerful weapon than a traditional archer with the same amount of strength.

Early crossbows did have a few disadvantages, though. An archer could load, aim and shoot a bow in around six seconds, but a crossbowman required nearly a minute to do the same task. Crossbows also had far more moving parts than plain longbows. But crossbows gave armies the option of arming recruits with ranged weapons regardless of their level of skill at archery.

In general, military crossbows could be very fast or very powerful, but not both. For example, in the 14th century, European crossbow makers began making weapons from steel and incorporating **crannequins** in their design. A crannequin was a toothed wheel attached to a crank. When a soldier turned the crank, the wheel moved a toothed rod, which pulled the bowstring and cocked the crossbow. With a crannequin, a soldier could cock crossbows that he would not have the strength to cock on his own. However, the soldier had to remove the crannequin before each shot, and re-cocking and reloading a crossbow with a crannequin could take several minutes.

At the other end of the spectrum, some Chinese crossbows were built for speed. Designers added cocking levers and magazines full of bolts to the basic crossbow. Bolts would automatically fall from the magazine when the string was cocked. Often, the crossbow then automatically released the bolt. With this type of crossbow, a soldier could fire several shots per second, although the bolts did not travel as fast or do as much damage as a bolt shot from a steel crossbow with a crannequin.

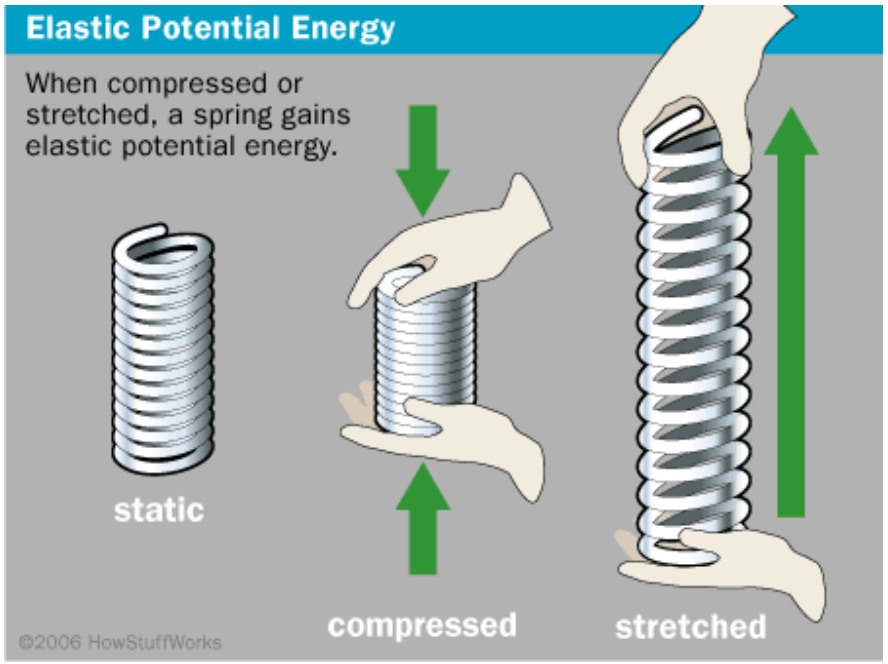
But regardless of whether it's built for strength or speed, a crossbow's basic function is basically the same as a bow's. We'll look at the factors that affect a bow's power and speed in the next section.

CHEWBACCA'S CROSSBOW

Chewbacca's favored weapon isn't simply a crossbow. It's a **bow caster**, a handheld weapon capable of firing energy bolts or solid projectiles. You can learn more about Chewbacca's bow caster at the Star Wars databank.

The Physics of Crossbows

Crossbows started to disappear from military use when reliable firearms became widely available. However, they remained popular for hunting in Europe in the 15th and 16th centuries. Hunters and target shooters still use them today, although modern crossbows often appear far more sophisticated than their early counterparts. They're usually made from exceptionally strong, lightweight metals, and they can incorporate scopes, adjustable stocks and other gadgets. But no matter how sophisticated a crossbow is, at its heart it's basically a bow. Similarly, a bow is basically a spring.



You've probably seen firsthand how a spring responds to force. If you press down on a spring, it expands to its original shape when you let go. The same thing happens if you pull its ends in opposite directions. This is because of the spring's **elastic potential energy** -- the energy it stores because of a change in its shape. When you pull one end of a spring, it stores elastic potential energy until you let go. Its potential energy then becomes **kinetic energy**, the energy of movement, allowing the spring to resume its normal shape and sometimes to bounce around. You can read more about kinetic and potential energy in How Force, Power, Torque and Energy Work.

This is exactly what happens when you draw a bow. Unlike with many toy bows, you aren't pulling on a stretchy string. Instead, as you pull the string toward your ear, you pull the tips of the bow's **limbs** toward you and closer together -- your strength changes the bow's shape. When you let go, the bow springs back to its original shape and the bowstring moves back to its original position. The movement and energy propel the arrow from the bow at high speed.

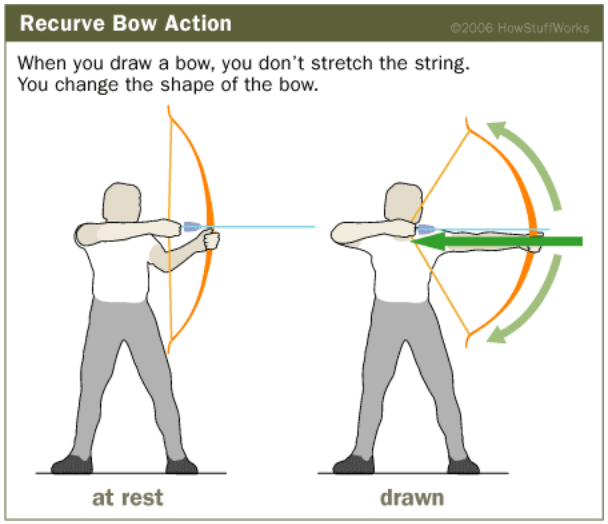
Two factors determine the amount of energy a bow can hold. Its **draw weight** is the amount of force required to draw the bow. A bow's draw weight increases the farther back you pull the string. Its **draw length** is the distance between the bowstring's position at rest and its position when drawn. The total amount of energy that a bow can hold is approximately equal to its draw weight times its draw length, divided by two. In other words, a bow's overall strength depends on how hard it is for you to pull the string and how far back you are able to pull it. Bow manufacturers express this strength in terms of:

- The bow's **energy**, measured in foot-pounds or joules
- The arrow's **velocity**, measured in feet or meters per second

A recurve crossbow with a draw weight of 150 pounds and a telescopic sight. ~ Image courtesy Liam Skoda

- Several factors can affect a bow's draw weight and length, changing the velocity at which an arrow will travel:
  - Its **size**: Simple longbows are much more powerful than simple short bows.
  - Its **shape**: The first bows were simple curves of wood. **Recurve** bows, used today in Olympic archery events, curve away from the user at the end of each limb. These curves shorten the **bracing height**, the distance between the string and the bow at rest. This means that the string travels farther before coming to a stop and releasing the arrow, which can give the arrow a little extra momentum. The shape of the bow also causes it to apply additional spring force to the string.
  - Its **composition**: A bow's **density** and **tensile strength** determine how much energy it can hold and how well it can return to its original shape when shot. English longbows were often made from **yew** wood because it was strong and elastic. Many modern bows are **composite** bows, which use different materials in different parts of the bow, making some parts more flexible and others more rigid.

All of the physics concepts that apply to bows apply to crossbows as well. Larger crossbows that a person aims from the shoulder are more powerful than smaller, handheld crossbows. Most modern crossbows have fiberglass limbs, which are strong but flexible, and older crossbows used steel limbs. Nearly all use recurve or compound bow designs, although some have two separate bow limbs rather than one continuous bow.



Regardless of which bow design they use or what they're made from, most have the same basic loading, firing and safety procedures. We'll look at those next.

COMPOUND BOWS

The more work you have to do to draw a bow, the more energy it can transfer to an arrow. Compound bows use **pulleys** to help people do more work on the bow with less physical effort. In addition, when fully drawn, a compound bow's pulleys often hold part or even most of the draw weight. This is known as **let-off**, and it allows a person to hold and aim a drawn bow without as much strain or fatigue.

Cocking a crossbow ~ Image courtesy Amazon

Safe Crossbow Shooting

Most modern crossbows have the same basic loading and cocking procedure:

1. Place the crossbow's stirrup on the ground.

2. Slip your foot through the stirrup and brace it firmly. Make sure that your foot is all the way in the stirrup and will not slip out while you cock the bow.

3. Grab the string with both hands. Pull it upward using the same amount of force on both sides. If you pull harder on one side than on the other, the string will be off-center, and your shot will not be accurate. Some crossbow manufacturers sell cocking aids that use cranks or elastic straps to make cocking easier.

4. Pull the string all the way to the cocking mechanism. When the bow is cocked, you will hear a loud click. Make sure the string is completely cocked before letting go.

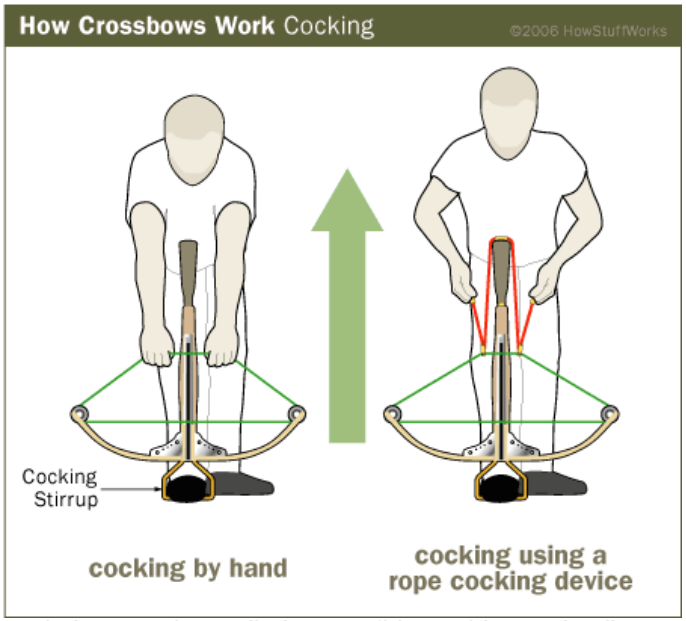
5. Place a bolt in the groove, making sure that the end of the bolt touches the string. One of the feathers, or **fletchings**, should be in the groove.

Crossbows have an automatic **safety** that engages as soon as you cock the bow. Some have a separate manual safety that you can engage yourself. Either way, the safety will keep you from firing the bow accidentally. Firing a crossbow safely requires several precautions:

- Remember that a crossbow is a weapon, not a toy. Many crossbows are used for hunting large animals and can severely injure or kill a person. Do not point one at anything you do not plan to shoot.

- Make sure nothing is in the path of the bow's string or limbs. The limbs will move forward and out and the string will move forward very quickly. The limbs and string can seriously injure any part of your body that is in their way. If a moving limb hits an obstacle like a tree trunk, it can damage the crossbow.

- Do not release the safety until you are ready to fire.



In addition, you should never **dry fire** your crossbow or use it with bolts that are lighter than those it's built to use. A crossbow is made to move very quickly while pushing a bolt, and if that bolt isn't there, the extra energy could break the crossbows' limbs. Dry firing voids nearly all crossbow manufacturers' warranties.

Finally, laws governing crossbow use vary widely, and they specify who can use a crossbow and when. Some laws permit only hunters with disabilities to use crossbows, while others permit anyone to use a crossbow during any hunting season. Before using a crossbow, particularly for hunting purposes, research the laws in your area.

CHOOSING BOLTS

The size and strength of a crossbow corresponds to the size and weight of the bolts it fires. Using a light bolt with a very strong crossbow can cause the bolt to fly erratically and can damage the bow.

Similarly, archers must choose the right arrows when using traditional bows. Arrows bend as they move, and arrows that are too long or too flexible can hit the front of the bow rather than flying past it.