

A Basic Firearm Tutorial

By

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Statistics for Firearm-Related Deaths

According to a 2005 study conducted by the Centers for Disease Control and Prevention (CDC), there were almost 31, 000 firearm-related deaths within the United States. Of the 31, 000 deaths, 55% of those deaths were certified as suicides, 40% certified as homicides, 3% certified as accidents, and the remaining 2% were certified as undetermined. A previous study by the CDC covering the years 1993 to 1998 also found that most firearm-related deaths were again caused by self-inflicted acts and men and individuals between the ages of 15 and 34 comprised a majority of those firearm-related deaths.

Every medical examiner or coroner's office across the country has investigated a firearm-related death. Depending on your jurisdiction, these types of deaths may comprise a large portion of your caseload or a small portion. Regardless of the number of firearm-related deaths your office investigates, every medicolegal death investigator must be knowledgeable in the safe handling of firearms, basic ballistics terminology and the parts of a particular firearm, whether it be a semi-automatic handgun, revolver, shotgun or rifle.

General Safety Practices

The safe approach to and subsequent handling of firearms is your personal responsibility. Safety is the number one priority when handling such weapons. At any death scene involving a firearm, the death investigator **MUST ALWAYS ASSUME THE FIREARM IS LOADED!** Most accidental discharges of a firearm are the result of not following safe gun handling practices and failure to use common sense.

Not all firearms use the same safety systems. Therefore, it is wise not rely solely on the mechanical safety features of the weapon. Never assume that safety is in working order.

Here are a few safety tips:

- Before handling any weapon, make sure you fully understand its operation.
- Never take another person's word that the firearm is unloaded. Always make sure the weapon is unloaded yourself.
- Never pass a firearm to another person until the cylinder or action is open and you have looked to make sure the weapon is not loaded.

- The person handling the firearm is always in control of the direction the weapon is pointing. When transferring a firearm to another person, make sure the barrel of the weapon is pointing away from any person or an object that may cause a ricochet.
- Avoid placing your fingers inside the trigger guard and avoid placing objects near the trigger so as to not accidentally discharge a potentially loaded weapon.
- Never carry or store the firearm with its hammer or striker in the “cocked” position
- Avoid handling a firearm while crossing an obstacle.
- When transporting a firearm back to the lab for analysis, remember to keep any ammunition separate from the firearm so that they are not accessible to unauthorized persons.
- Once the firearm has been “rendered safe” and is determined to not be loaded, place a trigger lock on the weapon. **DO NOT PLACE A TRIGGER GUARD OR LOCK ON A LOADED FIREARM!**
- Transport all weapons with the cylinder or action open.

Finally, if you are at all unsure about the safe handling of a firearm at a scene or in the lab, request law enforcement’s assistance in making sure the weapon is made safe and unloaded. These are just a few tips to help keep you safe when handling firearms. The aforementioned safety tips are certainly not all-inclusive. For more information, consult your local law enforcement agencies, firearm manufacturers and local gun safety class instructors and ask them if they would provide an in-service training for your office.

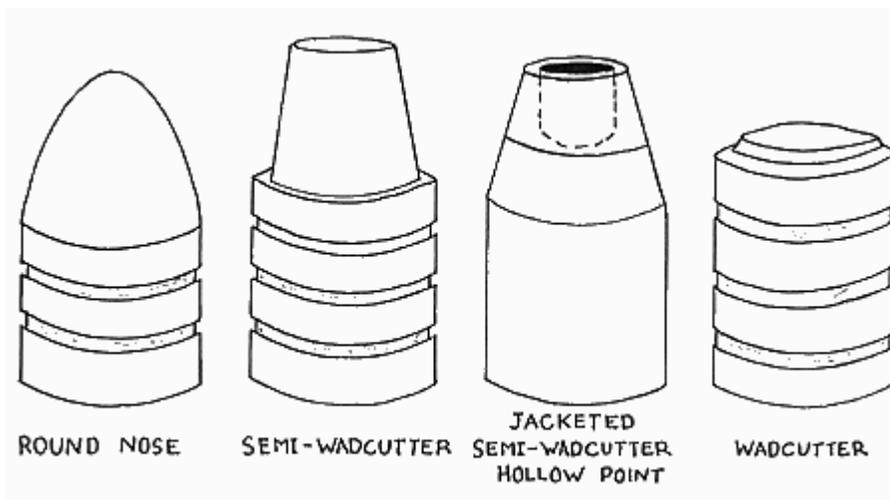
Common Ballistic Terminology

Below is a list of common ballistic terms used in the field of forensics. It would behoove all medicolegal death investigators to familiarize themselves with these terms and to be able to apply these terms as appropriate.

- **Action:** The part of a firearm that loads, fires, and ejects a cartridge. Includes lever action, pump action, bolt action, and semi-automatic. The first three are found in weapons that fire a single shot. Firearms that can shoot multiple rounds ("repeaters") include all these types of actions, but only the semi-automatic does not require manual operation between rounds. A truly "automatic" action is found on a machine gun.
- **Barrel:** The metal tube through which the bullet is fired.
- **Black Powder:** The old form of gunpowder invented over a thousand years ago and consisting of nitrate, charcoal, and sulfur.
- **Bore:** The inside of the barrel. "Smoothbore" weapons (typically shotguns) have no rifling. Most handguns and rifles have "rifling".
- **Breech:** The end of the barrel attached to the action.

- **Bullets:** The projectile. They are shaped or composed differently for a variety of purposes.
 - "round-nose" - The end of the bullet is blunted.
 - "hollow-point" - There is a hole in the bullet that creates expansion when a target is struck, creating more damage.
 - "jacketed" - The soft lead is surrounded by another metal, usually copper, that allows the bullet to penetrate a target more easily.
 - "wadcutter" - The front of the bullet is flattened.
 - "semi-wadcutter" - Intermediate between round-nose and wadcutter.
 - "semi-wadcutter" - Features of both semi-wadcutter and hollowpoint.
 - "Hardball" – The lead core is encased in a solid metal jacket, usually copper, sometimes another metal such as silver. Also referred to as "Full metal jacket."
 - "Softball" – Lead nosed bullet, not encased in a metal jacket.
- **Butt or buttstock:** The portion of the gun which is held or shouldered.
- **Caliber:** The diameter of the bore measured from land to land, usually expressed in hundredths of an inch (.22 cal) or in millimeters (9mm).
- **Cartridge:** Also called a "round". Made up of a case, primer, powder, and bullet.
- **Centerfire:** The cartridge contains the primer in the center of the base, where it can be struck by the firing pin of the action.
- **Chamber:** The portion of the "action" that holds the cartridge ready for firing.
- **Choke:** A constriction of a shotgun bore at the muzzle that determines the pattern of the fired shot.
- **Double-action:** Pulling the trigger both cocks the hammer and fires the gun.
- **Double barrel:** Two barrels side by side or one on top of the other, usually on a shotgun.
- **Gauge:** Refers to the diameter of the barrel on a shotgun in terms of the number of lead balls the size of the bore it would take to weigh one pound (10 gauge, 12 gauge, etc.) ".410-gauge" really refers to caliber, but is worded as such to refer to a shotgun.
- **Hammer:** A metal rod or plate that strikes the cartridge primer to detonate the powder.
- **Ignition:** The way in which powder is ignited. Old muzzle-loading weapons used flintlock or percussion caps. Modern guns use "primers" that are "rimfire" or "centerfire"
- **Lands and grooves:** Lands are the raised metal inside the barrel left after the spiral grooves are cut to produce the rifling.
- **Magazine:** This is a device for storing cartridges in a repeating firearm for loading into the chamber. Also referred to as a "clip"
- **Magnum:** An improved version of a standard cartridge which uses the same caliber and bullet, but has more powder, giving the fired bullet more energy. Magnum shotgun loads, however, refer to an increased amount of shot pellets in the shell.
- **Muzzle:** The end of the barrel out of which the bullet comes.
- **Pistol:** Synonym for a handgun that does not have a revolving cylinder.

- **Powder:** Modern gun cartridges use "smokeless" powder that is relatively stable, of uniform quality, and leaves little residue when ignited. For centuries, "black powder" was used and was quite volatile (ignited at low temperature or shock), was composed of irregularly sized grains, and left a heavy residue after ignition, requiring frequent cleaning of bore.
- **Primer:** A volatile substance that ignites when struck to detonate the powder in a cartridge. "Rimfire" cartridges have primer inside the base, while "centerfire" cartridges have primer in a hole in the middle of the base of the cartridge case.
- **Revolver:** Handgun that has a cylinder with holes to contain the cartridges. The cylinder revolves to bring the cartridge into position to be fired. This is "single-action" when the hammer must be cocked before the trigger can fire the weapon. It is "double-action" when pulling the trigger both cocks and fires the gun. Sometimes referred to as a "wheel gun" since the cylinder turns like a wheel.
- **Rifling:** The spiral grooves cut inside a gun barrel that give the bullet a spinning motion. The metal between the grooves is called a "land".
- **Rimfire:** The cartridge has the primer distributed around the periphery of the base.
- **Safety:** A mechanism on an action to prevent firing of the gun.
- **Shotgun:** A gun with a smoothbore that shoots cartridges that contain "shot" or small metal pellets (of lead or steel) as the projectiles.
- **Sights:** The device(s) on top of a barrel that allow the gun to be aimed.
- **Silencer:** A device that fits over the muzzle of the barrel to muffle the sound of a gunshot. Most work by baffling the escape of gases.
- **Single-action:** The hammer must be manually cocked before the trigger can be pulled to fire the gun.
- **Smokeless powder:** Refers to modern gunpowder, which is really not "powder" but flakes of nitrocellulose and other substances. Not really "smokeless" but much less so than black powder.
- **Stock:** A wood, metal, or plastic frame that holds the barrel and action and allows the gun to be held firmly.



Anatomy of Firearms

Modern firearms are manufactured in a variety of shapes and sizes to fit multiple purposes. There was a time when the forensic pathologist was faced with a less complex situation, with fewer types, models, and mechanisms available for use. Unfortunately, the proliferation of firearms in this country includes not only sheer numbers but also a staggering array of models. Included in this array are semi-automatic and even automatic weapons built primarily for military usage. However, virtually any type of gun can be found on the streets in use by youth gangs, persons involved in drug trafficking, paramilitary "survivalists" and even what we would consider "ordinary" citizens.

Handguns

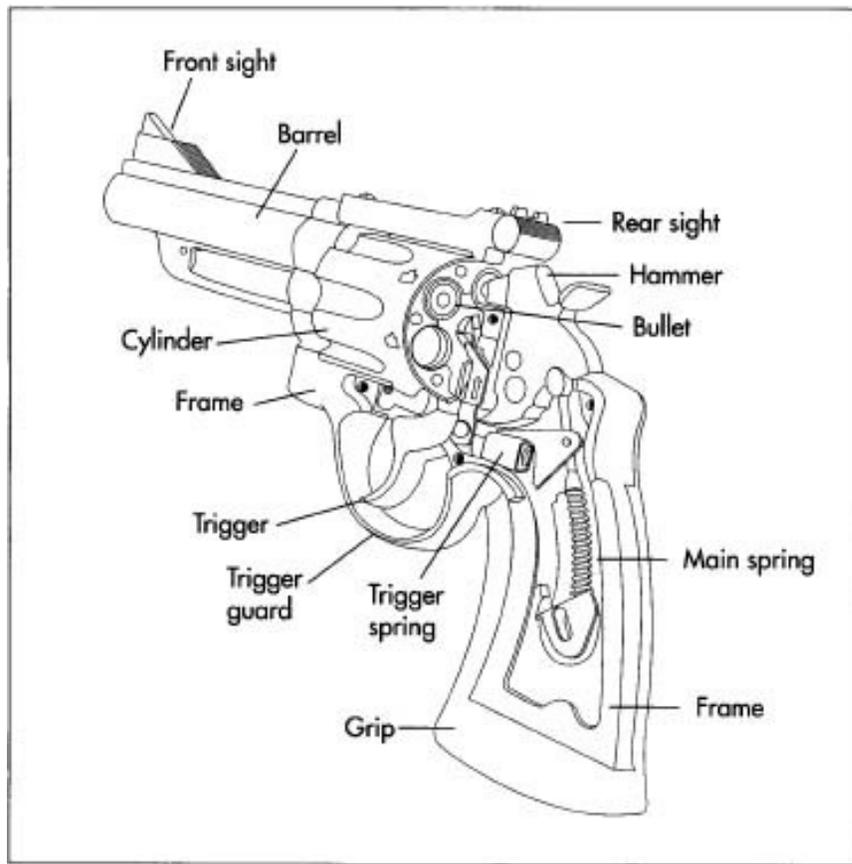
From the very start, a handgun was conceived as a compact weapon for self defense. Even though today there are handguns made specifically for target competition or hunting, most are still designed with defense in mind. Thus, handguns are compact for concealment and ease of carrying. This becomes a part of the legal definition of a handgun, as they are considered "concealable" and therefore deemed dangerous and are controlled by law in most states. Of course, a handgun should be capable of firing a projectile accurately at a target. The energy delivered must be sufficient to quell any attack, yet be light enough so that the recoil generated does not wrest the gun from the shooter's hand; this is difficult in practice and there is no perfect choice, so many types of handguns are manufactured for different situations. Finally, since no one can be guaranteed a perfect shot or a single attacker, a handgun must fire multiple shots. The two most common defensive handguns are the double action revolver and the semiautomatic pistol.

Revolver

The revolver has several advantages and unique features. Importantly, they are less expensive, simpler in design, and more reliable than semiautomatics. A revolver is easy to master, even for novices. Revolvers, for whatever reason, seem to be more accurate than semiautomatics. On the bad side, revolvers are limited to six shots, are relatively slow to reload, the gap between barrel and cylinder makes them less efficient, and the trigger pull is greater. The anatomy of a representative double action revolver is shown below:



Barrel length is smaller for concealment and longer for accuracy or energy. The ejector rod under the barrel is used to eject fired cartridges before reloading. Sights on a revolver are usually a blade in the front and a notch on the rear. The frame is the largest part, and all other pieces attach to it. Frames are usually made of blued or plated steel, stainless steel, or lightweight alloys. A revolver may weigh less than 1 lb to more than 4 lbs. The cylinder contains five or six holes for the cartridges and can be swung out for easy reloading. This must be a conscious act, so that no empty cartridge cases will be found at a crime scene unless the assailant stopped to reload.

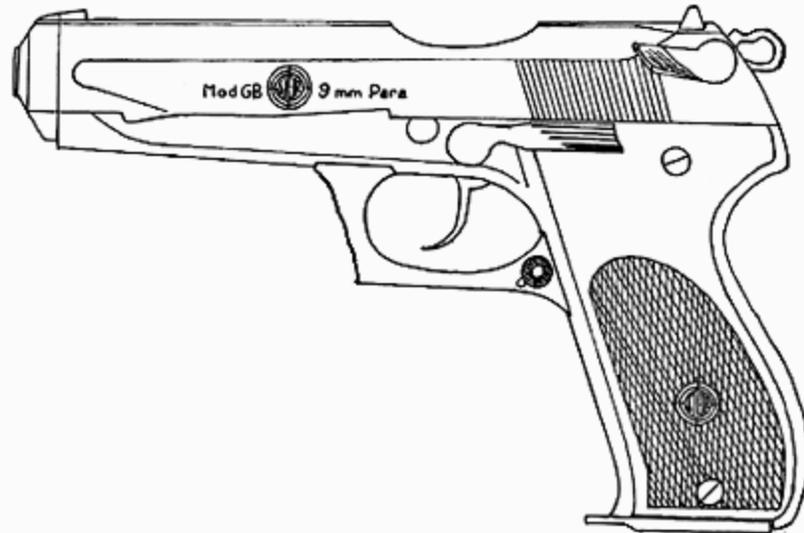


www.self-defender.net/weapons/handguns.htm

There is a gap between cylinder and barrel (known as the "cylinder gap," allowing the cylinder to turn freely. This also allows gases to escape laterally, which at close range may deposit gunshot residue on surrounding structures and allow the forensic pathologist to reconstruct the scene. The lockwork translates the trigger pull to rotation of the cylinder, cocking and fall of the hammer. If this is done in one motion of pulling the trigger, it is termed "double-action." Single-action revolvers (old Colts of "cowboys") require manual cocking of the hammer before the trigger is pulled. Different types of grips are employed; larger grips allow more accuracy, smaller grips provide easier concealment.

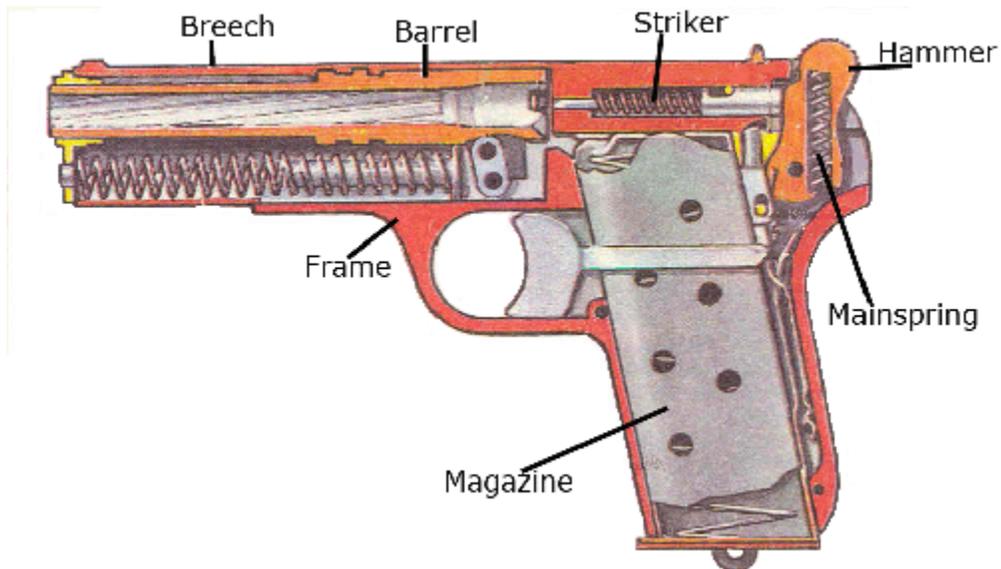
Semiautomatic Pistol

This is a more recent development than the revolver, originating late in the 19th century, mostly through the efforts of John Browning. In fact, almost every semiautomatic handgun available today is a copy of his two most famous designs: the Colt model 1911A government 45 and the Browning Hi Power 9 mm. The anatomy of a semiautomatic pistol is given below:



The advantage of semiautomatics is the use of recoil generated by the fired cartridge to eject the empty cartridge case, load the next cartridge, and cock the hammer. This is more conducive to firing multiple shots, so many are designed to carry 15 to 19 rounds. Disadvantages include a more complicated mechanism requiring more practice, and cartridge cases which are shorter to work well for auto-loading. The larger revolver cartridges are more powerful than semiautomatic cartridges for this last reason.

The barrel is normally hidden by the slide. Choices of barrel length are limited. The slide is a key part to the operation of a semiautomatic:



www.self-defender.net/weapons/handguns.htm

The slide is able to move back along the axis of the barrel under tension from a spring. Since the cartridge base rests on the slide, the slide does just that under the force of recoil generated by the firing of the cartridge. As the slide and empty cartridge case are accelerating backwards, the case is struck by a stationary piece of metal that bumps it to the side. This is conveniently located next to a hole in the slide (the ejection port), so that the empty cartridge case continues its acceleration in a direction perpendicular to the pistol and into the air, landing from 2 to 20 feet from the fired gun. The rearward-moving slide also cocks the hammer. After the case is clear, the slide hits a stop and the spring tension starts it forward. The magazine spring is pushing on a column of rounds tight up against the bottom of the slide. As the slide comes back by the column of cartridges, it grabs the top one and pushes it forward and up a short ramp into the chamber where the slide locks it in place.

The handle, or butt, is more important here because it contains the magazine holding the cartridges. Safety mechanisms prevent accidental firing. Some lock the hammer, while other designs lock the trigger.

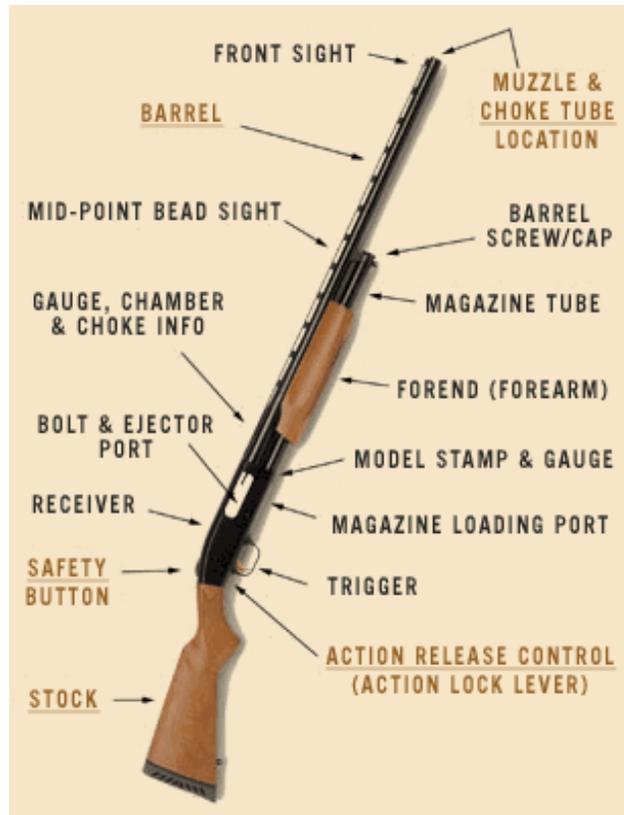
Even on open ground ejected cases may be difficult to find, as they typically roll into a hiding place such as grass or small depressions in the ground. Thus, ejected cases will virtually always be left behind at the scene, but must be searched for diligently.

Rifles

Rifles differ from handguns in the length of the barrel and the presence of a butt stock. They are harder to carry, are poorly concealable, and more loosely regulated than handguns. However, they are much more accurate and shoot more powerful cartridges than handguns. Rifles may be manufactured as single shot, but most commonly are bolt action, used for large caliber hunting rifles. Military rifles are semiautomatic or automatic, having a detachable magazine holding 5 to 50 rounds. Pump action and lever action rifles, usually of lower caliber, have magazines below the barrel.

Shotguns

Shotguns have a similar external appearance to rifles, but differ in the lack of rifling inside the barrel, which is the basis for their legal definition. A shotgun shell may contain one large projectile (called a slug), a few pellets of large shot, or many tiny pellets. Shotguns are available in single shot (break action), double barrel, pump action, and semiautomatic.



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Other Types of Firearms

The single action revolver has remained popular for its historic appeal, reliable design, and uncanny balance. For some reason a single action Colt 45 is easier to shoot from the hip than a modern revolver, and is used almost exclusively in trick shooting.

Semiautomatic versions of submachine guns (such as the Uzi) are classed as pistols for legal reasons. These often have the ability to hold 20 to 30 rounds, but are otherwise identical to conventional handguns in similar caliber. The expense of such weapons precludes their use by most criminals, but they may be used by persons involved in organized crime, drug-dealing, and gangs.

Air guns which use pneumatic pressure to fire a projectile are generally known as "BB guns" and have been around for over 200 years. Three mechanisms are employed:

1. Air is pumped into a pressure chamber reservoir and released by trigger pull
2. A spring compression system is used to drive a piston to compress air (most "toys" are of this variety)
3. A pressurized, carbon dioxide filled cartridge is attached. (Harris et al, 1983)

Even though cheap "Saturday night specials" are readily available, youths and youth gang members may attempt to build their own firearms. These are sometimes called "zip guns." Typically, they are crude, and adapted to fire available ammunition. In one study, such guns caused unusual muzzle imprints, intensive soot deposits at the entrance wounds and on the hands, intensive CO-effects, burns, and in one case a skin laceration of the hand holding the weapon. The bullets showed a reduced penetration depth, and characteristic firing marks were missing. (Karger et al, 1995)

Lastly, there has arisen a new group of handguns for hunting big game and long range target competition that are nothing but single shot rifles with shortened barrels and no butt stock. These shoot rifle or hybrid rifle cartridges and deliver rifle energies.

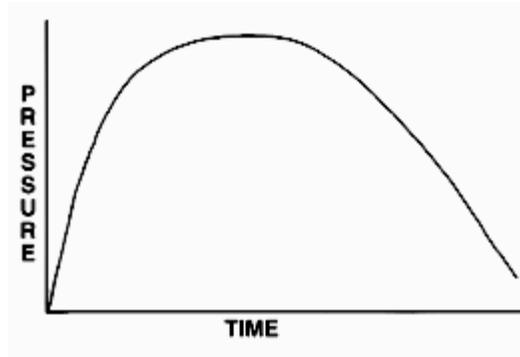
Basic Ballistics

The term ballistics refers to the science of the travel of a projectile in flight. The flight path of a bullet includes: travel down the barrel, path through the air, and path through a target. The wounding potential of projectiles is a complex matter. (Fackler, 1996)

Internal or initial ballistics (within the gun)

Bullets fired from a rifle will have more energy than similar bullets fired from a handgun. More powder can also be used in rifle cartridges because the bullet chambers can be designed to withstand greater pressures (70,000 psi vs. 40,000 psi for handgun chamber). It is difficult in practice to measure the forces within a gun barrel, but the one easily measured parameter is the velocity with which the bullet exits the barrel (muzzle velocity) and this is what will be used in examples below.

The controlled expansion of burning gunpowder generates pressure (force/area). The area here is the base of the bullet (equivalent to diameter of barrel) and is a constant. Therefore, the energy transmitted to the bullet (with a given mass) will depend upon mass times force times the time interval over which the force is applied. The last of these factors is a function of barrel length. Bullet travel through a gun barrel is characterized by increasing acceleration as the expanding gases push on it. Up to a point, the longer the barrel, the greater the acceleration.



As the bullet traverses the barrel of the gun, some minor deformation occurs, called setback deformation. This results from minor (rarely major) imperfections or variations in rifling or tool marks. The effect upon the subsequent flight path of the bullet is usually insignificant. (Jandial et al, 2008).

External ballistics (from gun to target)

The external ballistics of a bullet's path can be determined by several formulae, the simplest of which is:

$$\text{Kinetic Energy (KE)} = 1/2 MV^2$$

Velocity (V) is usually given in feet/second (fps) and mass (M) is given in pounds, derived from the weight (W) of the bullet in grains, divided by 7000 grains per pound times the acceleration of gravity (32 ft/sec) so that:

$$\text{Kinetic Energy (KE)} = W(V)^2 / (450,435) \text{ ft/lb}$$

This is the bullet's energy as it leaves the muzzle, but the ballistic coefficient (BC) will determine the amount of KE delivered to the target as air resistance is encountered.

$$\text{Ballistic coefficient (BC)} = SD / I$$

SD is the sectional density of the bullet, and I is a form factor for the bullet shape. Sectional density is calculated from the bullet mass (M) divided by the square of its diameter. The form factor value I decreases with increasing pointedness of the bullet (a sphere would have the highest I value).

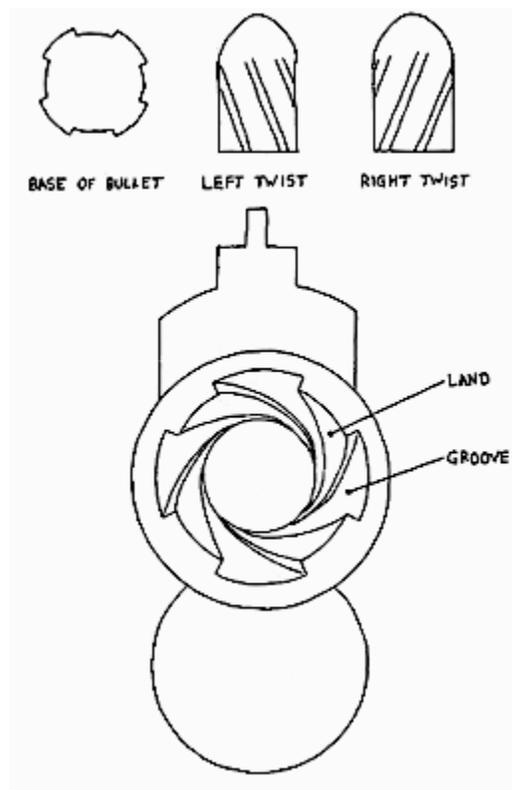
Forward motion of the bullet is also affected by drag (D), which is calculated as:

$$\text{Drag (D)} = f(v/a)k \&pd^2v^2$$

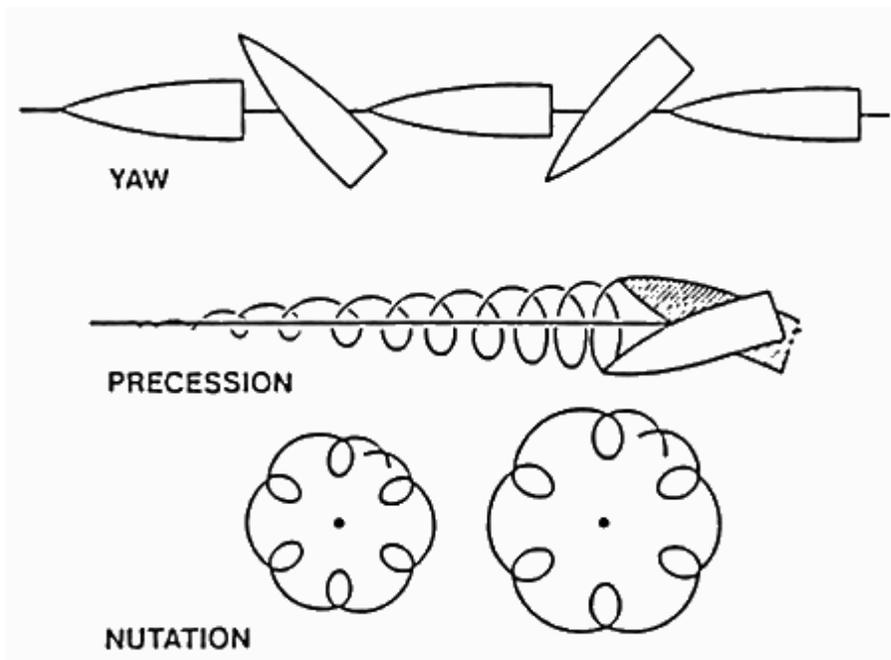
$f(v/a)$ is a coefficient related to the ratio of the velocity of the bullet to the velocity of sound in the medium through which it travels. k is a constant for the shape of the bullet and γ is a constant for yaw (deviation from linear flight). ρ is the density of the medium (tissue density is >800 times that of air), d is the diameter (caliber) of the bullet, and v the velocity. Thus, greater velocity, greater caliber, or denser tissue gives more drag. The degree to which a bullet is slowed by drag is called retardation (r) given by the formula:

$$r = D / M$$

Since drag (D) is a function of velocity, it can be seen that for a bullet of a given mass (M), the greater the velocity, the greater the retardation. Drag is also influenced by bullet spin. The faster the spin, the less likely a bullet will "yaw" or turn sideways and tumble. Thus, increasing the twist of the rifling from 1 in 7 will impart greater spin than the typical 1 in 12 spiral (one turn in 12 inches of barrel).



Bullets do not typically follow a straight line to the target. Rotational forces are in effect that keep the bullet off a straight axis of flight. These rotational effects are diagrammed below:



Handgun Ballistics

These weapons are easily concealed but hard to aim accurately, especially in crime scenes. Most handgun shootings occur at less than 7 yards, but even so, most bullets miss their intended target (only 11% of assailants' bullets and 25% of bullets fired by police officers hit the intended target in a study by Lesce, 1984). Usually, low caliber weapons are employed in crimes because they are cheaper and lighter to carry and easier to control when shooting. Tissue destruction can be increased at any caliber by use of hollowpoint expanding bullets. Some law enforcement agencies have adopted such bullets because they are thought to have more "stopping power" at short range. Most handgun bullets, though, deliver less than 1000 ft/lb of KE. (Ragsdale, 1984)

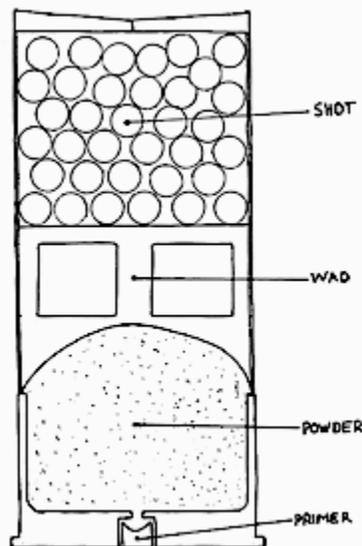
However, there is a myth, kept alive by portrayals of shooting victims on television and in films being hurled backwards, that victims are actually "knocked down" or displaced by being struck with the force of a bullet. In fact, real gunshot victims relate that they had no immediate reaction. (Fackler, 1998) The maximum momentum transferred from different small arms projectiles, including large caliber rifles and shotguns, to an 80 kg body is only 0.01 to 0.18 m/s, negligible compared to the 1 to 2 m/s velocity of a pedestrian. (Karger and Knewbuehl, 1996) Incapacitation of gunshot victims is primarily a function of the area of the body wounded. Immediate incapacitation may occur with gunshot wounds to the brain and upper cervical cord. Rapid incapacitation may occur with massive bleeding from major blood vessels or the heart. (Karger, 1995)

The two major variables in handgun ballistics are diameter of the bullet and volume of gunpowder in the cartridge case. Cartridges of older design were limited by the pressures they could withstand, but advances in metallurgy have allowed doubling and tripling of the maximum pressures so that more KE can be generated.

Shotgun Ballistics

Wounding is a function of the type of shot, or pellets, used in the shotgun shell. Weight, in general, is a constant for a shell so that 1 oz of shot would equal either 9 pellets of double O buckshot or 410 pellets of #8 birdshot. A 00 or "double ought" pellet is essentially equivalent to a low velocity .38 handgun projectile. The spread of the pellets as they leave the muzzle is determined by the "choke" or constriction of the barrel at the muzzle (from 0.003 to 0.04 inches). More choke means less spread. Full choke gives a 15 inch spread at 20 yards, while no choke gives a 30 inch spread at the same distance. (DeMuth et al, 1976) A "sawed-off" shotgun has a very short barrel so that, not only can it be concealed more easily, but also it can spray the pellets out over a wide area, because there is no choke.

A shotgun shell is diagrammed below:



At close range, the pellets essentially act as one mass, and a typical shell would give the mass of pellets a muzzle velocity of 1300 fps and KE of 2100 ft/lb. At close range (less than 4 feet) an entrance wound would be about 1 inch diameter, and the wound cavity would contain wadding. At intermediate range (4 to 12 feet) the entrance wound is up to 2 inches diameter, but the borders may show individual pellet markings. Wadding may be found near the surface of the wound. Beyond 12 feet, choke, barrel length, and pellet size determine the wounding.

If the energy is divided between the pellets, it can be seen that fewer, larger pellets will carry more KE, but the spread may carry them away from the target. Pellets, being spherical, are poor projectiles, and most small pellets will not penetrate skin after 80 yards. Thus, close range wounds are severe, but at even relatively short distances, wounding may be minimal. Range is the most important factor, and can be estimated in over half of cases, as can the shot size used. (Wilson, 1978) A rifled slug fired from a shotgun may have a range of 800 yards. (Mattoo et al, 1974)

Shotgun slugs can produce significant injury. Because of the slug's size and mass, survival at close range is rare. (Gestring ML et al, 1996)

The Polyshok Impact Reactive Projectile (IRP) is a form of shotgun ammunition with a lead bead core encased within a single, plastic projectile. The lead core is designed to disintegrate on impact so that lead fragments are distributed over a small area. This reduces the likelihood of exit or collateral damage on missed shots. This projectile produces a single entrance wound, and both plastic and lead components can be found within the wound, regardless of the range of fire. The single entrance wound with limited area of tissue damage suggests a shotgun slug, while the small lead fragments within the wound suggest small size shot pellets, but together these findings are characteristic for the IRP (Nelson and Winston, 2007).

Photos of Some Common Firearm-Related Wounds



Contact Entrance GSW

Photo courtesy of library.med.utah.edu/WebPath/FORHTML/FORIDX.html



Intermediate Entrance GSW

Photo courtesy of library.med.utah.edu/WebPath/FORHTML/FORIDX.html



Intermediate SGW

*Photo courtesy of Dennis Klein, MD
Iowa Office of the State Medical Examiner*

I hope I have provided you, the reader, with information that will help in your firearm-related death investigations. Some of the information in this article was supplied from various sources, as the list of below references will describe. A multitude of information is out on the web and in textbooks and magazines on firearms and ammunition.

References

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