CHAPTER 16
Firearms, Ballistics and Impression Evidence

Confidential Correspondence

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IV. PHYSICAL PROPERTIES IN EVIDENCE

Chapter 16: Firearms, Ballistics and Impression Evidence

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Chapter 16.1: Forensic Firearms and Ballistics

Learning Goals and Objectives

Firearms are frequently used in the commission of criminal acts. In this chapter, you will need to understand the following concepts:

- How have firearms developed and what are their basic principles of operation;
- What are the differences and features of handguns, long guns and shotguns;
- What is meant by ballistics and what factors affect the trajectory of a projectile;
- How do gun and ammunition design affect aspects of ballistics.

Introduction

Firearms have played a key role in human history and they clearly remain a ubiquitous part of society worldwide today. Everyone who has ever been to the movies or watched television is well acquainted with our fascination with firearms. “Westerns” have made famous the 19th-century revolver-carrying outlaw confronting the rifle-wielding law officers. War movies and urban crime shows frequently depict handgun and automatic weapon use in all types of settings. We see handguns carried by our law officers, long guns by hunters, and even larger weapons by members of the armed services. There is no denying that firearms are a part of our everyday lives.

Today, firearms are by far the most common weapon used for deadly assault and are involved in an overwhelming number of robberies and other types of violent and assault crimes (Figure 16.1.2). When firearms are used in the commission of a real-life crime, forensic science plays a central role in linking a firearm and a criminal together.

Historical Perspective

In order to understand how modern firearms work, it is very useful to roughly understand how these weapons have evolved over the years and how they continue to change today. It all began with the invention of gunpowder. This first chemical explosive was discovered by Chinese alchemists sometime around the 9th century and was used initially in fireworks to scare away evil spirits. At least by the early 13th century, however, the Chinese had invented and begun using...
primitive versions of firearms, but it wasn’t until the start of the 14th century that these weapons began to be developed into more reliable implements of warfare and assault. Early weapons were very crude and were referred to simply as “hand cannons” (Figure 16.1.3), a device that grew out of the much older 10th century fire-lances – a hollow tube filled with gun powder at the end of a spear that functioned similarly to a crude flamethrower when ignited. In a modest advance over the earlier fire-lances, hand cannons worked simply by placing gun powder at the closed end of a tube, tamping projectiles, such as stones or metal shrapnel, into the tube and igniting the gunpowder through a small hole above the powder. Obviously, such weapons were relatively ineffective as firearms because of their extreme inaccuracy, difficulty and slowness of charging them, and the personal hazards that they presented to the shooter (they tended to explode rather than shoot). They were, however, more effective than bows and arrows and other early weapons. For example, hand cannons could be quickly made in relatively large numbers and shot by inexperienced soldiers with only a brief training period, as opposed to arrow-based technologies where it took months to build a good bow or cross-bow and sometimes months or even years to master shooting effectively. It didn’t take people too long to recognize the potential advantages that gunpowder-based weapons provided for assaulting enemies from “safe” distances, beyond the range of retaliatory spears and arrows. The recognition of these battlefield advantages spurred experimentation and new designs in firearm operation. It could well be argued that the history of the world has been shaped by waves of innovation in firearm technology.

Paralleling the early development of better gun mechanics was a necessity to improve the explosive properties of the gunpowder itself. Modifications in the relative amounts of gunpowder’s primary components (carbon, sulfur and potassium nitrate), along with the occasional introduction of small amounts of other chemicals, produced more reliable, faster burning and higher power explosives. These chemical advances required stronger gun chambers made of metal instead of the previously used wooden barrels in order to withstand the explosive power of the new powder. The use of more regularly shaped projectiles, especially those which prevented the propulsive gas from escaping around the shot without moving it down the barrel, began to be adopted. The combined developments in chemistry and machinery coupled to produce new weapons that could launch their projectiles farther and with much greater accuracy than ever before.
possible. Once again, each small success drove further experimentation and development toward the realization of the great potential of firearms to alter the balance of power on the field of battle.

Firearms apparently spread either through trade routes or by invasion forces to the Middle East and Europe by the early 1300’s. The hand cannons quickly evolved in Europe into much larger bore cannons used to help break sieges and bring down fortifications. Eventually, the rather crude personal hand cannons also gave rise to a number of new designs, in particular those with greatly improved ignition mechanisms such as the matchlock and wheelock igniters. All of these designs, however, were ultimately replaced by the vastly improved flintlock weapons of the early 17th century. These flintlock weapons involved a long, hollow metal barrel, higher energy gunpowder, and vastly improved shot and firing mechanisms. The heart of the flintlock firing system made use of a spark created by moving a piece of flint over a steel plate (the “frizzen”) to ignite a small primer charge that then set fire to the main charge (Figure 16.1.4). Flintlock guns, however, suffered from many drawbacks including poor reliability (e.g., most commonly misfires, accidental firing, no firing, barrel fouling, and explosions), the inability to be fired in wet conditions, high maintenance, slow firing, and rather severe safety problems. Despite these difficulties, flintlock muskets fueled the armies of much of the world between the mid-17th and mid-19th centuries, in some places even into the 20th century. In these flintlock guns, most of the familiar components of modern guns came together for the first time – the long barrel, a highly explosive charge and an efficient firing mechanism for igniting the charge.

Flintlock muskets and earlier firearms, where the gunpowder, wadding and bullets all had to be loaded down the barrel of the gun (“muzzle-loading”), eventually gave way to breech-loading firearms in the mid-19th century. A breech-loading weapon places the ammunition directly into the firing chamber without having to put it down the barrel. The transition point between the older muzzle-loading and the modern breech-loading weapons involved the advent of something called a percussion cap (Figure 16.1.5). These caps were small metal cases that contained a tiny amount of shock sensitive explosive, such as mercury fulminate. When the percussion cap was struck with the gun’s hammer, the explosive detonated and ignited the main charge of the ammunition. This meant that the shooter did not need to fuss with the complexity of priming the weapon but could simply charge the ammunition, snap on the percussion cap, and shoot. This type of ignition system also led to the development of the first efficient multi-shot revolvers, such as the “Pepper-box” revolver shown in Figure 16.1.6.

Military uses certainly drove much of the development of firearms, where accuracy, speed of firing, weapon durability and the need for ever increasing high-energy projectiles were of paramount importance.
importance. It didn’t take too long to realize the advantage that could be provided by ammunition that combined a percussion cap igniter directly into a prepackaged unit along with the main explosive charge and bullet. The term ammunition, while originally used to describe anything used as a weapon, has come to most commonly refer collectively to projectiles, explosives (e.g., gunpowder) and fuses taken together. Thus, breech-loading weapons were revolutionized by the advent of fixed ammunition – ammunition that combined primer, an accurately measured main charge and bullet all enclosed in a single, easily handled, water-tight casing or cartridge (Figure 16.1.7). Each intact unit of firearm ammunition, consisting of the primer, bullet or shot, and explosive charge, is usually referred to as a round. A complete fixed cartridge could be loaded directly into the firing chamber exceedingly rapidly as a self-contained, all-in-one unit. Prior to fixed ammunition, the primer, main charge, and bullet all needed to be “loaded” in separate actions – a slow and sometimes unreliable practice under anything but ideal conditions, especially in the heat of battle or in adverse weather conditions such as rain. Advances arising from the industrial revolution, however, allowed for the first time the rapid manufacture of millions of “rounds” of standardized fixed ammunition to within small dimensional tolerances. This uniform ammunition could be quickly, reliably and safely placed directly into a firing chamber and did not require operators to load each component individually. The famous Springfield rifles were among the first long guns to take full advantage of this technological breakthrough (Figure 16.1.8). An important aspect of breech-loading firearms is that the gun’s barrel no longer had to be completely smooth; since the bullet and ammunition did not have to pass down the barrel, the barrel could be scored, or rifled, to vastly improve the accuracy of the weapon (see later sections describing rifling). Muzzle-loading barrels could not be grooved since ammunition would “foul” the grooves as it was loaded, leading to poor weapon functioning.

While fixed ammunition contained all of the necessary components for firing, many different designs were explored in actual practice. In the most successful designs, including a large portion of the ammunition still used today, a shock sensitive compound, such as mercury fulminate or a similar compound (see Chapter 14), is placed inside the metallic primer cap (firing cap) which is then snugly fitted into the main charge. Side, pin, rim and center placements of the firing caps were all tried, although

Figure 16.1.7. 19th Century Fixed Ammunition with bullet, main charge, and primer all in one complete unit (en.wikipedia.org/wiki/File:Snider-Martini-Enfield_Cartridges.JPG).

Figure 16.1.8. The Springfield Trapdoor Rifle from 1873 was one of the first mass-produced breech-loading rifles and was adopted by the US Army (http://operatorchan.org/k/arch/es/61024-100.html).
Advances in the rapid delivery of fresh ammunition and the extraction of spent cases allowed the development of efficient “repeater”, semi-automatic and automatic (“machine gun”) weapons, including those that hold many cartridges of ammunition without the need for manual reloading. Today, there is an enormous variation in commercial and military weapons, from small-bore handguns to massive artillery weaponry. The fastest military automatic machine guns today can shoot up to a staggering one million rounds per minute (“Metal storm” weapon) while high-precision sniper rifles can hit moving targets several miles away with startling accuracy. Guns for civilian use are readily available in all shapes and sizes, from tiny derringers to very large hunting rifles, shotguns and some semi-automatic weapons.

To better understand the weapons encountered in forensic work, the next section describes the major types of modern firearms and their modes of operation.

Firearm Basics

A firearm is usually defined as an assembly consisting of a barrel and a mechanical action that allows a projectile(s) to be propelled forward through the action of an extremely fast combustion reaction. As expected, given such a general definition, there is an enormous range and variety of firearms, spanning from miniature pistols to massive military weapon systems. But all of these weapons have several basic features in common: an explosive material is detonated within an enclosed chamber which provides only one direction for the escape of the enormous pressure built up from the reaction. The release of this high-pressure gas is channeled to push an object, the projectile, down a tube toward a target with great energy. The combustion chamber where the explosion occurs is designed with an intentional “weakness” – one open side with all of the remaining sides sealed – like a box without a top. The projectile tightly fits within the walls of the chamber such that when the explosion occurs, the energy of the escaping gas acts upon the end of the projectile to force it down the barrel. All firearm designs must accommodate this basic mode of action in some fashion.

The propulsive force given to a projectile most often comes from the rapid combustion of gunpowder. In this reaction, one mole of solid gunpowder may produce up to six moles of hot, expanding gas (depending upon the type of powder used). This means that a relatively small volume of solid gunpowder can produce a very large volume of gas. For example, if a one gram sample of carbon were entirely converted to gaseous CO$_2$ at the combustion temperature of gunpowder (~3300°F), the CO$_2$ would occupy a volume of about 85 liters (ca. 3 ft$^3$) – an increase in volume well over 190,000 times! Since this volume of gas is confined initially to a very small space in the gun chamber, an enormous pressure develops behind the bullet. For example, the pressure in the chamber of a common .223 rifle is on the order of thousand pounds per square inch.

Note: A mole is a unit of measure that contains a certain number of things. One mole of carbon, sulfur or CO$_2$ all contain the same number of items: 6.023 x 10$^{23}$. The mole allows us to compare quantities of very small items such as atoms and molecules where the numbers are very large, even in the smallest samples (See Chapter 12 for more on the mole).
of 4,300 atmospheres (that’s a pressure 4,300 times the pressure that is found on the surface of the Earth, or about 62,000 psi). The typical buildup of high-pressure gas upon firing a firearm is illustrated in Figure 16.1.9. This huge pressure is quickly relieved as the bullet is forced down the barrel with great energy and velocity.

Over time, gun designers have discovered a variety of innovative ways to modify all of the required features of firearms in order to maximize particular desired end results, such as accuracy, projectile mass, weapon size, bullet velocity, terminal ballistics, and other features. In forensic science, however, three basic firearm designs are most commonly encountered in criminal actions: the handgun, rifle (long guns), and shotgun.

**Handguns**: Handguns are smaller firearms that are designed specifically for operation using one hand and represent a broad class of weapons that includes derringers, pistols, revolvers, and others. Sometimes, the word pistol is used interchangeably with handgun, but technically a pistol is just one specific type of handgun (one with the barrel and chamber in one solid piece). Handguns are the easiest firearms to carry as they are lighter in weight and can be more quickly and easily brought into action. They are, however, far less accurate over longer distances due to their relatively short barrels and, therefore, are most often considered primarily as defensive weapons. In one recent study, it was found that only 11% of handgun shots fired from assailants and 25% of the bullets fired by police hit their intended targets. In a defensive situation, it is far easier to keep a handgun’s muzzle pointed at an attacker than a long-barreled rifle during a struggle. The components of typical handguns are shown in Figure 16.1.10.

Handguns come in a variety of designs that include single-shot and multi-shot variants. Single-shot handguns are usually used for target shooting and hunting. **Revolvers** feed the ammunition to the barrel of the gun by rotating a cylinder that contains a number of separate firing chambers loaded with filled cartridges. Once fired, the barrel is rotated to align another loaded chamber with the barrel. In this way, it is possible to rapidly fire typically between five and eight shots.

Both semi-automatic and fully automatic handguns have been developed. In a semi-automatic weapon, the energy released from one firing is used to mechanically eject the spent case and reload the next fresh round into the firing chamber. One round is fired for each pull of the trigger. In a
fully automatic weapon, the filled rounds are reloaded as in the semi-automatic weapon but the weapon continues to fire when the trigger is held down – multiple shots are fired from one trigger pull. Pistols are reloaded through the use of a magazine – a device that is spring loaded with ammunition that forces a new cartridge into the firing chamber immediately after one round has been fired, as shown in Figures 16.1.10 and 16.1.11.

Revolvers tend to be simpler than the automatic weapons, easier to maintain, and are usually capable of firing larger bullets while automatic weapons typically can shoot more rounds at a time and be reloaded faster.

Long guns: Long guns are named for their relatively long barrels and include a number of types, such as the well-known rifle (Figure 16.1.12). The longer barrels of these weapons allow them to have far better accuracy over long distances than handguns. Thus, long guns are best known for their accuracy while handguns are best appreciated for their convenience.

One of the major advances in improving the accuracy of firearms came from the discovery that forming spiral groves, called rifling, on the inside of the gun’s barrel causes the projectile to spin about its long-axis in a motion leading to something called spin or gyroscopic stabilization (Figure 16.1.13). Spinning an elongated projectile greatly improves its aerodynamic properties, allowing it to go much farther and with much better precision and accuracy. The improved stability and accuracy of a spinning bullet is similar to the stabilizing effect seen in the spinning of a football, soccer ball or bullet, greatly improves the aerodynamic performance of the object.

Figure 16.1.12. Parts of a rifle (www.hunter-ed.com/mi/course/ch3_parts_bolt_action_rifle.htm).

Figure 16.1.13. The inside of a gun barrel showing the grooved rifling that causes the bullet to spin when it leaves the barrel (www.rhinovault.com/Ballistics.htm).

Figure 16.1.14. Spinning a projectile, such as a football, soccer ball or bullet, greatly improves the aerodynamic performance of the object (www.shutterstock.com/pic-46730656/stock-photo-spinning-football.html).

Introduction to Forensic Science

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The rifling inside of a gun’s barrel may be described in several ways to give useful characteristic information about an individual weapon. First, the number of grooves inscribed in the barrel, producing characteristic “lands” and “grooves” (Figure 16.1.13), may be counted. The grooves are the places where some of the barrel metal has been removed to create a depression, leaving the “higher”, untouched lands projecting farther into the center of the barrel. For example, the rifled barrel shown in Figure 16.1.15 has six grooves and six lands. Other guns may have between two and eight, or even more, grooves.

Second, the handedness of the twist can be either to the right (dextrorotatory) or to the left (levorotatory), causing the bullets to spin in one particular direction. American rifles traditionally spin the bullets to the right while British rifles often are designed to cause left-handed spins. Finally, the length of the barrel necessary for a groove to make one full rotation of the twist (360°), called the twist rate, can be measured. For example, it might take ten inches of barrel to complete one full rotation (1:10 twist) or 25 inches (1:25 twist), or any of many other possibilities. For example, a Remington .22 rifle has a 1:14 twist rate while a Winchester .243 has a 1:10 twist. The shorter the twist rate distance, the faster the bullet will spin. It is important to note that these rifling features are imprinted in relief on any bullet fired from the gun, helping greatly in the identification of the gun type that fired a particular bullet (see below).

An alternative type of rifling, called polygonal rifling, has recently become common. In this type of weapon, the traditional lands and grooves are replaced by “hills” and “valleys” in a more rounded, polygonal (multi-sided shape), most often a hexagonal (six-sided) or octagonal (eight-sided) pattern (Figure 16.1.16). The advantage of polygonal barrels is that they are very fast and inexpensive to manufacture relative to traditionally grooved barrels. The process simply uses a tool (mandrel) with the polygonal shape that is inserted into the bore of the barrel. The barrel is then pressed (“cold forged”) around the polygonal mandrel to form the shaped bore. These barrels are relatively smooth and have far fewer striations than traditionally grooved barrels since no material is “gouged” out but is instead simply pressed around a mold. Bullets fired from these polygonal barrels do have characteristic stria markings, although they are...
generally less pronounced that found for other types of rifling. Like handguns, long guns come in a variety of shapes and sizes. In many places, there is a minimum legal barrel length, 16” in the US in Canada, for example. The firing mechanism can also be single-shot, semi-automatic or fully automatic in design.

**Shotguns**: Shotguns are often considered to be a type of long gun but are distinguished from other long guns by several design features and by the type of projectiles which are fire from them (Figure 16.1.17). Shotguns use ammunition that contains either many small pellets, called shot, packed into a single cartridge (Figure 16.1.18), or a single, solid projectile, called a slug. Because rifling would prematurely scatter the small pellets, shotgun barrels are smooth and usually not rifled. The gauge of a shotgun generally refers to the size of the shot used (Figure 16.1.18). The diameter of the shotgun’s barrel is equal to the size of the balls that are needed to weight one pound. For example, a 12-gauge shotgun’s barrel is roughly the same diameter as a single ball weighing 1/12 of a pound while a 20 gauge shotgun’s barrel is the same as that of a shot weighing 1/20 of a pound. Once the shot leaves the barrel of the gun, the individual pellets scatter (Figure 16.1.19). The size of the scatter pattern increases as the distance from the gun increases (Figure 16.1.20).

**Shotguns** are particularly useful
when precise aim is not important but projectile coverage of an area is desired instead, such as against a rapidly moving or airborne target. Shotguns are also used widely by police and military agencies in urban environments because the potential spread of the projectiles may increase the likelihood of hitting an intermediate range target without accurate aiming.

**Air Guns:** A commonly encountered family of “firearm-like” weapons that do not meet the usual definition for a firearm are air guns. These weapons are probably best considered within this group, however, because of their overall similarity of operation to firearms. Air gun weapons move a projectile solely by the release of stored gas pressure rather than through combustion. This group includes the common BB guns, air-rifles, air pistols and some types of shotguns that expel projectiles by compressed gas, such as compressed air, CO₂ or nitrogen. These devices date their origin to at least the mid-1500’s and have remained popular in certain settings since then.

**Figure 16.1.21.** Some of the many types of ammunition available. To give a scale for comparison in the picture, the tall, blue-tipped bullet on the right (No. 58) stands approximately one foot (30 cm) tall. (sub-silencersuppressors.com/?page_id=2608).

Air guns have several advantages and drawbacks over conventional firearms. They are typically lightweight, relatively easy to manufacture, and can fire very rapidly and quietly in almost any physical environment, including in very wet conditions. Additionally, they can be readily improvised whenever a pneumatic source can be built (a source of pressurized gas) and don’t require the careful storage necessary for powder-based ammunition. Air gun ammunition is most often shaped pellets or round balls that are extremely inexpensive – top-of-the-line “Olympic” air gun ammunition costs about 2¢ each compared with 50¢ each for some of the least expensive firearm ammunition. Compared to firearms, however, they tend to provide far less power and are less accurate over longer distances. Modern air guns are usually intentionally built for lower pressure operation for safety reasons, although air guns are available that can rival certain features of firearms. High pressure air guns can expel projectiles at velocities over 1100 ft/s and are popular with both target shooters and small game hunters.

**Figure 16.1.22.** Typical rifle ammunition components (www.hunter-ed.com/nt/courses/cds5_rifle_handgun_cartridges.htm).
Ammunition

The ammunition for firearms comes in as many variations as the weapons themselves. They vary depending upon which outcome the designers are attempting to optimize – speed, accuracy, distance, or other characteristics (Figure 16.1.21). Ammunition is most often defined by the size of the gun barrel that it is designed for, usually given as a caliber or mm measurement. **Caliber** is the size of a gun barrel, measured between opposite grooves, and expressed as a fraction of an inch. For example, a barrel with a diameter of 0.22 inches is referred to as .22 caliber. The diameter can also be expressed in mm (1/1000 of a meter) such as 9 mm. Even though caliber actually refers to the size of the gun’s bore, cartridges are referred to by the caliber weapon in which they are intended to be used. As described previously, shotguns are usually defined by gauge rather than caliber or mm used for other firearms.

Ammunition is also defined by the amount and type of powder used, the dimensions and shape of the projectile, composition of the bullet (what metals make up the alloy used in the bullet), and other features. An example of typical rifle ammunition is shown in Figure 16.1.22.

Ballistics

Ballistics is the study of how projectiles move through space. The field is particularly concerned with how the flight of a projectile can be influenced by features such as projectile shape, the force used to drive the projectile forward, aerodynamic considerations, and others. Gun and ammunition designers work to understand the factors that affect the flight of projectiles and optimize features that lead to the desired characteristics of the flight. The ballistics of a projectile is usually considered in three “phases”: internal (initial), external (intermediate) or terminal ballistics.

**Internal Ballistics:** Internal, or initial, ballistics deals with the part of a bullet’s path that occurs within the gun itself. The explosion of gunpowder in the chamber causes a large force to be applied on the base of the bullet which propels it forward. Pressure is a measure of the force applied to a given surface area – in this case the area of the end of the bullet. Rifles usually generate far more pressure than handguns, 70,000 psi for a rifle compared with 40,000 psi for a typical handgun, leading to a much higher force applied to the bullet. Higher pressures require stronger chambers and generate more recoil and combustion byproducts. The force of the expanding gas continues to accelerate the bullet down the length of the barrel – the longer the barrel, generally the higher the acceleration.

**Figure 16.1.23.** Effect of air resistance, or drag, in opposing the forward motion of a bullet through the air (www.hnsa.org/doc/firecontrol/partc.htm).

**Figure 16.1.24.** Two bullets of the same mass, one fired and one dropped vertically, will reach the ground at the same instant (www.lightandmatter.com/html_books/lm/ch06/ch06.html).

**Figure 16.1.25.** The downward effect of gravity on the trajectory of a bullet (www.lightandmatter.com/html_books/lm/ch06/ch06.html).
**External Ballistics**: External, or intermediate, ballistics focuses upon the flight of the bullet from the time it leaves the barrel of the gun until it reaches the target. A number of features define the specific flight properties of a bullet and include the energy propelling it forward, the bullet’s shape, its mass, and environmental conditions (e.g., wind, rain, etc.).

The ideal situation in gun design would be to have as much of the energy as possible from the contained explosion reaction converted into moving the projectile down the barrel. This process actually represents a conversion of the chemical energy of the gunpowder into the kinetic energy for the projectile.

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**Some Helpful Firearms Definitions**

- **Action**: Mechanical apparatus of a firearm that loads, fires, and ejects the cartridge.
- **Barrel**: Metal pipe that guides initial flight of the bullet.
- **Breech**: End of the gun barrel nearest to the action.
- **Breech block (or face)**: Back of the firing chamber.
- **Bullet**: Projectile fired from a weapon.
- **Caliber**: Diameter of the gun barrel in 1/100th of a inch.
- **Cartridge**: Ammunition made up of casing, primer, powder, wadding and bullet.
- **Chamber**: Enclosure that contains the cartridge when ready to fire.
- **Gauge**: Measure of the diameter of the barrel of a shotgun.
- **Hammer**: The part of the action that drives the firing pin into the primer upon firing.
- **Lands and grooves**: The spiral groves and raised positions inside a gun barrel resulting from rifling.
- **Magazine**: Device for holding and delivering cartridges.
- **Magnum**: Type of cartridge containing more than the standard amount of powder resulting in more power to the bullet.
- **Muzzle**: The very end of the gun barrel where the bullet exits the weapon.
- **Powder**: Solid explosive used to propel the bullet.
- **Primer**: Shock sensitive compound that ignites the main charge of a cartridge upon being struck.
- **Rifling**: The spiral grooves or polygonal interior shape inside a gun barrel.
- **Sight**: Device on top of a gun that improves aim and accuracy.
- **Silencer**: Device, placed over the muzzle, that reduces the noise emitted when the weapon is fired.
- **Stock**: Frame holding the barrel and action together which allows aiming and firing.

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**Figure 16.1.26.** The “wobble” and “rotation” of a typical bullet as it moves along its trajectory.

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**Figure 16.1.27.** Various bullet shapes that greatly affect the intermediate ballistic properties of the bullet. (http://library.med.utah.edu/WebPath/TUTORIAL-GUNS/GUNBLST.html).
energy of the projectile. Kinetic energy, the energy of motion, is given by the expression of KE = \( \frac{1}{2} mv^2 \) (where \( m \) is the mass and \( v \) is the velocity of the object moving), and describes the force moving the projectile in a straight line. The more energy applied to the bullet (the more powder used in the ammunition), the faster a bullet of fixed mass will move. Another way to look at this is that as the bullet becomes larger, more explosive force will be needed to move it to a given velocity.

Opposing the forward motion of a bullet is **drag** or air resistance (Figure 16.1.23). As a bullet moves through the air, it must force the air out of its path, causing friction that opposes the forward motion of the bullet. The amount of drag depends largely upon the size and shape of the bullet.

Gravity also plays a very important role in determining a bullet’s trajectory (the path a bullet takes). Gravity constantly pulls objects downward with a constant force (\( F = mg \), where \( m \) is mass and \( g \) is the gravitational constant). In fact, a bullet simply dropped vertically at the same instant as one fired horizontally from a rifle (at the same height off the ground) will hit the ground at exactly the same moment as the fired bullet (Figure 16.1.24). A bullet that is fired at twice the speed of sound will drop about 3 inches in 100 yards and about 30 inches by the time it has travelled 300 yards (Figure 16.1.25). The faster a bullet travels, however, the less it will drop over a fixed distance because it takes less time to reach the target when moving faster.

Bullets do not typically follow completely straight line pathways to a target but instead wobble” and rotate, such as shown in Figure 16.1.26. The more wobble and rotation in a bullet as it travels, generally the less accurately it can reach it’s target. The design of a bullet has much to do with both how the bullet travels through the air and what is intended when it strikes a target (terminal ballistics). For example, a thin, needle-like bullet has reduced air resistance and may travel very rapidly and accurately but imparts very little of its kinetic energy to any object that it hits, slicing through the target with less
damage. A round bullet, in contrast, has far a greater air resistance, causing it travel more slowly and less accurately, but it would deliver most or all of its energy into the target, causing far more damage (assuming it actually makes it to the target). Many bullet designs are, therefore, available that deal with these conflicting features to optimize a desired outcome (Figure 16.1.27).

**Terminal Ballistics:** Terminal ballistics describes what happens when a bullet hits its target. Biological aspects of a bullet hitting a living object, including tissue damage, have already been presented in detail in Chapter 8. Bullets may tumble, flatten (Figure 16.1.28), fragment and melt when they encounter a target (Figure 16.1.29). The pattern of injury or damage depends upon the shape, speed and motion of the bullet when it strikes. Significant damage may also result from the impact of shock waves arising from the compression and rarefaction of air along the path of the bullet (Figure 16.1.30). The more energy that the projectile can impart to its target, the more damage that will be done.

### Right to Bear Arms

In the US, the 2nd Amendment to the US Constitution deals with the right of people to own firearms. The Amendment says that “*A well regulated militia being necessary to the security of a free State, the right of the People to keep and bear arms shall not be infringed.*”

A vigorous debate continues today, however, about what the “right to bear arms” phrase in this amendment really means. Some argue that it refers to private individuals while others contend that it includes only the military use of arms. The Supreme Court has historically interpreted this phrase as referring to an *individual’s right* to own and carry weapons, within reasonable limits. In both 2008 and 2010, the Supreme Court ruled in two 2nd Amendment cases that the wording protects an individual’s right to “possess a firearm, unconnected to service in a militia and to use that arm for traditionally lawful purposes, such as self-defense within the home.” They did, however, also support limitations on what type of weapons fall into this category of “lawful use.”