Bullet Ballistics

Here is a good partial explanation of some bullet ballistics and how weight, speed & bullet type. A more detailed complete article can be seen at
The Library of Utah Website.

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 (50,000 to 70,000 for rifles psi vs. 30,000 to 40,000 psi for handgun chamber). Higher pressures require a bigger gun with more recoil that is slower to load and generates more heat that produces more wear on the metal. 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 measurement will be used in examples below. (Bruner et al, 2011)

The controlled expansion of gases from 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, but decreasing pressure in the barrel as the gas expands. Up to a point of diminishing pressure, the longer the barrel, the greater the acceleration of the bullet. (Volgas, Stannard and Alonso, 2005)

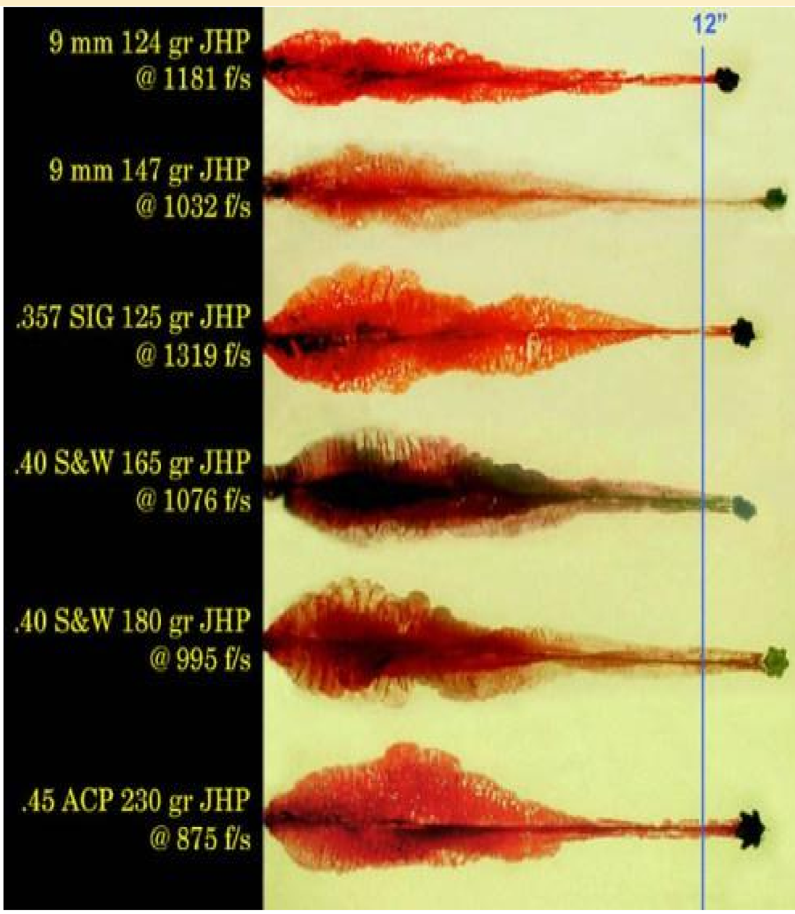
As the bullet traverses the barrel of the gun, some minor deformation occurs, called setback deformation. This results from minor (rarely major) imperfections or variations in rifling or tool marks within the barrel. The effect upon the subsequent flight path of the bullet is usually insignificant. (Jandial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

External ballistics (from gun to target)

The external ballistics of a bullet's path can be determined by several formulas, the simplest of which is: Kinetic Energy (KE) = 1/2 MV2 Velocity (V) is usually given in feet per 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:

Kinetic Energy (KE) = W(V)2 / (450,435) 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.



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

Drag (D) = f(v/a)k&pd2v2 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 & is a constant for yaw (deviation from linear flight). p 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:

"When evil becomes commonplace it becomes invisible"

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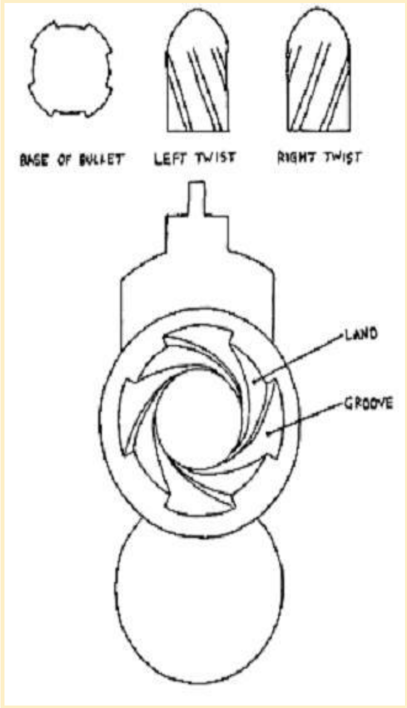
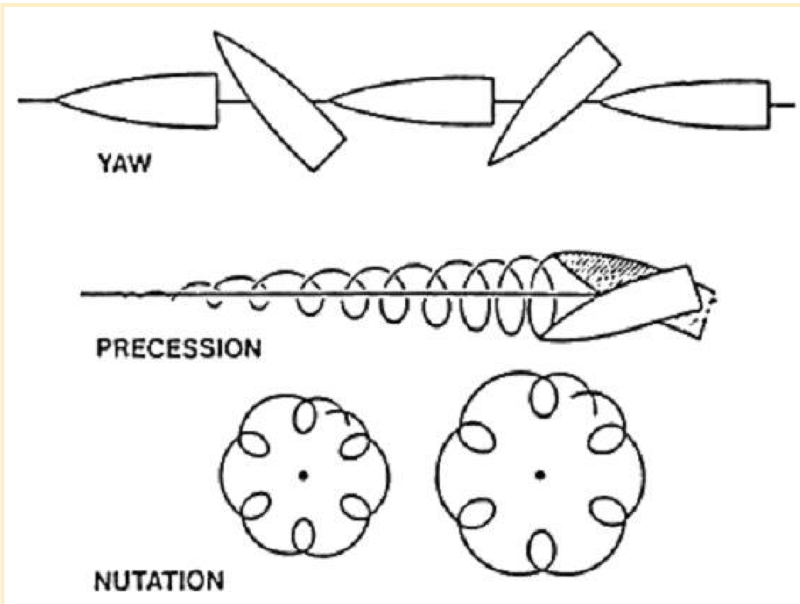
r = D / M Drag is difficult to measure, so the Ballistic Coefficient (BC) is often used: BC = SD / I

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).

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 in its flight path through the air. 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:



Yaw refers to the rotation of the nose of the bullet away from the line of flight. Precession refers to rotation of the bullet around the center of mass. Nutation refers to small circular movement at the bullet tip. Yaw and precession decrease as the distance of the bullet from the barrel increases.

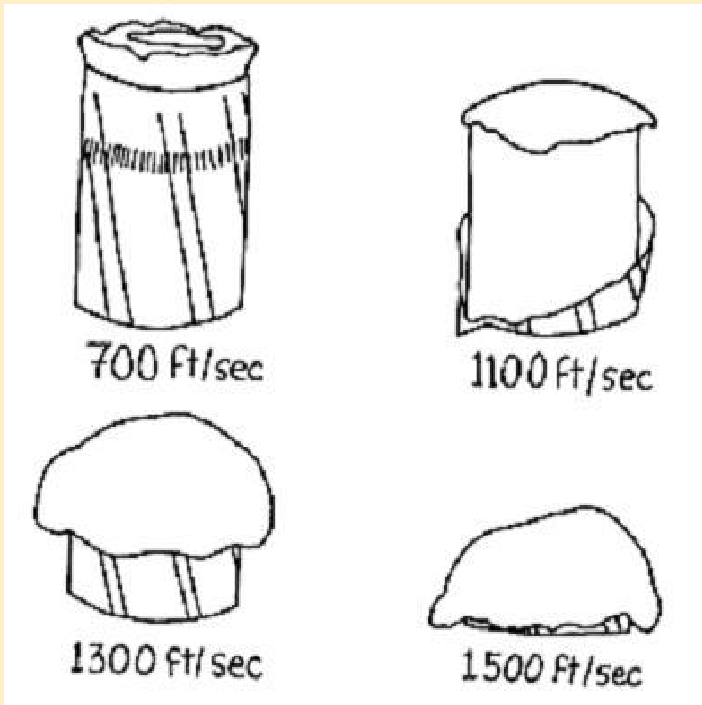
What do all these formulae mean in terms of designing cartridges and bullets? Well, given that a cartridge can be only so large to fit in a chamber, and given that the steel of the chamber can handle only so much pressure from increasing the amount of gunpowder, the kinetic energy for any given weapon is increased more easily by increasing bullet mass. Though the square of the velocity would increase KE much more, it is practically very difficult to increase velocity, which is dependent upon the amount of gunpowder burned. There is only so much gunpowder that can burn efficiently in a cartridge. Thus, cartridges designed for hunting big game animals use very large bullets.

"Loopholes for Government are nooses for the people"

To reduce air resistance, the ideal bullet would be a long, heavy needle, but such a projectile would go right through the target without dispersing much of its energy. Light spheres would be retarded the greatest within tissues and release more energy, but might not even get to the target. A good aerodynamic compromise bullet shape is a parabolic curve with low frontal area and wind-splitting shape. The best bullet composition is lead (Pb) which is of high density and is cheap to obtain. Its disadvantages are a tendency to soften at velocities >1000 fps, causing it to smear the barrel and decrease accuracy, and >2000 fps lead tends to melt completely. Alloying the lead (Pb) with a small amount of antimony (Sb) helps, but the real answer is to interface the lead bullet with the hard steel barrel through another metal soft enough to seal the bullet in the barrel but of high melting point. Copper (Cu) works best as this "jacket" material for lead.

Terminal ballistics (hitting the target)

Yaw has a lot to do with the injury pattern of a bullet on the target, termed "terminal ballistics." A short, high velocity bullet begins to yaw more severely and turn, and even rotate, upon entering tissue. This causes more tissue to be displaced, increases drag, and imparts more of the KE to the target. A longer, heavier bullet might have more KE at a longer range when it hits the target, but it may penetrate so well that it exits the target with much of its KE remaining. Even a bullet with a low KE can impart significant tissue damage if it can be designed to give up all of the KE into the target, and the target is at short range (as with handguns). Despite yaw, an intact bullet that comes to rest in tissue generally has its long axis aligned along the path of the bullet track, though its final position may be either nose forward or base forward. (Jandial et al, 2008)



Bullets produce tissue damage in three ways (Adams, 1982):

1. Laceration and crushing - Tissue damage through laceration and crushing occurs along the path or "track" through the body that a projectile, or its fragments, may produce.

2. Cavitation - A "permanent" cavity is caused by the path (track) of the bullet itself with crushing of tissue, whereas a "temporary" cavity is formed by radial stretching around the bullet track from continued acceleration of the medium (air or tissue) in the wake of the bullet, causing the wound cavity to be stretched outward. For projectiles traveling at low velocity the permanent and temporary cavities are nearly the same, but at high velocity and with bullet yaw the temporary cavity becomes larger (Maiden, 2009).

3. Shock waves - Shock waves compress the medium and travel ahead of the bullet, as well as to the sides, but these waves last only a few microseconds and do not cause profound destruction at low velocity. At high velocity, generated shock waves can reach up to 200 atmospheres of pressure. (DiMaio and Zumwalt, 1977) However, bone fracture from cavitation is an extremely rare event. (Fackler, 1996) The ballistic pressure wave from distant bullet impact can induce a concussive-like effect in humans, causing acute neurological symptoms. (Courtney and Courtney, 2007)

The mathematics of wound ballistics, in reference to yaw of unstable projectiles, has been described. The model works well for non-deformable bullets. (Peters et al, 1996)(Peters and Sebourn, 1996)

Experimental methods to demonstrate tissue damage have utilized materials with characteristics similar to human soft tissues and skin. Pigskin has been employed to provide an external layer to blocks of compounds such as ordnance gelatin or ballistic soap. Firing of bullets into these materials at various ranges is followed by direct visual inspection (cutting the block) or radiographic analysis (CT imaging) to determine the sizes and appearances of the cavity produced (Rutty, et al, 2007).

"Do you want to know why you're not taking my AR-15?
Because I have an AR-15"

"The very reason you want to take my AR-15 - is the very reason I have an AR-15"

The following images illustrate bullet deformation and damage:

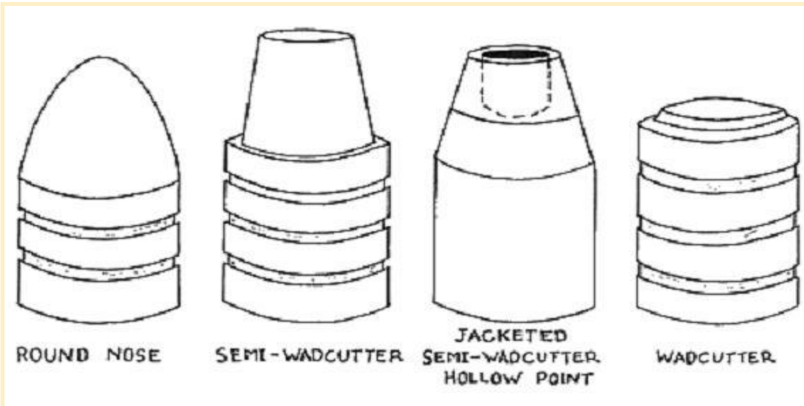
- Bullet track in clay model, gross

- Deformed bullet recovered from shooting victim, gross

Bullet velocity and mass will affect the nature of wounding. Velocity is classified as low (1000 fps), medium (1000 to 2000 fps), and high (2000 fps). (Wilson, 1977) An M-16 rifle (.223 cal) is designed to produce larger wounds with high velocity, lower mass bullets that tumble, cavitate, and release energy quickly upon striking the target. A hunting rifle (.308 cal or greater) would have a larger mass bullet to penetrate a greater depth to kill a large game animal at a longer distance.

Bullet design is important in wounding potential. The Hague Convention of 1899 (and subsequently the Geneva Convention) forbade the use of expanding, deformable bullets in wartime. Therefore, military bullets have full metal jackets around the lead core. Of course, the treaty had less to do with compliance than the fact that modern military assault rifles fire projectiles at high velocity (>2000 fps) and the bullets need to be jacketed with copper, because the lead begins to melt from heat generated at speeds >2000 fps.

Bullet shapes are diagrammed below:



"Frangible" bullets are designed to disintegrate upon striking a hard surface. Such bullets are typically made of a metal other than lead, such as copper powder compacted into a bullet shape, as diagrammed below:

The distance of the target from the muzzle plays a large role in wounding capacity, for most bullets fired from handguns have lost significant kinetic energy (KE) at 100 yards, while high-velocity military .308 rounds still have considerable KE even at 500 yards. Military and hunting rifles are designed to deliver bullets with more KE at a greater distance than are handguns and shotguns.

The type of tissue affects wounding potential, as well as the depth of penetration. (Bartlett, 2003) Specific gravity (density) and elasticity are the major tissue factors. The higher the specific gravity, the greater the damage. The greater the elasticity, the less the damage. Thus, lung tissue of low density and high elasticity is damaged less than muscle with higher density but some elasticity. Liver, spleen, and brain have no elasticity and are easily injured, as is adipose tissue. Fluid-filled organs (bladder, heart, great vessels, bowel) can burst because of pressure waves generated. A bullet striking bone may cause fragmentation of bone and/or bullet, with numerous secondary missiles formed, each producing additional wounding.

The speed at which a projectile must travel to penetrate skin is 163 fps and to break bone is 213 fps, both of which are quite low, so other factors are more important in producing damage. (Belkin, 1978) Designing a bullet for efficient transfer of energy to a particular target is not straightforward, for targets differ. To penetrate the thick hide and tough bone of an elephant, the bullet must be pointed, of small diameter, and durable enough to resist disintegration. However, such a bullet would penetrate most human tissues like a spear, doing little more damage than a knife wound. A bullet designed to damage human tissues would need some sort of "brakes" so that all the KE was transmitted to the target.

It is easier to design features that aid deceleration of a larger, slower moving bullet in tissues than a small, high velocity bullet. Such measures include shape modifications like round (round nose), flattened (wadcutter), or cupped (hollow point) bullet nose. Round nose bullets provide the least braking, are usually jacketed, and are useful mostly in low velocity handguns. The wadcutter design provides the most braking from shape alone, is not jacketed, and is used in low velocity handguns (often for target practice). A semi-wad cutter design is intermediate between the round nose and wad cutter and is useful at medium velocity. Hollow point bullet design facilitates turning the bullet "inside out" and flattening the front, referred to as "expansion." Expansion reliably occurs only at velocities exceeding 1200 fps, so is suited only to the highest velocity handguns. A frangible bullet composed of a powder is designed to disintegrate upon impact, delivering all KE, but without significant penetration; the size of the fragments should decrease as impact velocity increases.

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 hollow point 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)

"Life comes at you fast - Reality comes Even faster"

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.

Many different cartridges are available using different loads and bullet designs. Some of these are outlined in the table below to compare and contrast the ballistics.

Reprinted from ***The Library of Utah Website.***

This is my personal take on ammo selection and considerations:

Ammo and bullets is a very complex subject with lots of variables. I will try to talk about some of these factors and considerations to consider when picking out ammo.

Ammo is basically about two main things, speed and weight (third factor is ammo expansion) - some say speed is more important, others say weight is more important. Normally bigger is better, bigger hole, bigger weight. Many different things go into bullet dynamics and performance.

When a bullet hits a target, several things happen. It makes a primary and secondary cavity. The primary cavity is the track of the bullet, the primary of a .22 or .45 will only differ by the .45 making a bigger hole, the bigger the hole the more and faster the blood loss. The secondary cavity is made by speed, the faster the bullet the faster it pushes mass out of its path, smashing that flying tissue up against other tissue and organs, so that action creates the secondary cavity. The bigger the secondary cavity means possible more blood loss, more secondary damage and more shock to nearby organs and tissue. A way to picture this is if I shoot in the hand with a .22, it will make a hole the size of a .22 bullet, that is the primary cavity. If I shoot you in the hand with a .223 traveling at over 3000 feet per second, your hand will somewhat explode, expand rapidly and meat will fly off, the flying stuff is the secondary cavity. Another way to imagine this is diving into a pool of water, a diver hits straight and makes a little splash, but a cannonball creates a large splash and bigger hole, this is like a ball bullet (straight dive/little splash) or an expanding hollow point (cannonball/big splash).

So, the bigger the primary and the bigger the secondary normally does more damage and will incapacity the target quicker and more effectively. A .45 is slower but makes a bigger hole, a 9mm is faster but makes a smaller hole. The heavier the weight of the bullet, the more the bullet will NOT be affected by other things like wind, rain, clothes, doors, sheet rock, bone, skin and tissue. Energy transfer is when the energy of speed and weight (sometimes called kinetic energy) of a bullet is transferred from the bullet to the body, bone or target. (Energy = Mass times Speed)

Smaller lighter slower bullets can ricochet off bones, buttons, glass and other things easier than a bigger heavier bullet that tends to push forward with the heavier weight. A .22 will not shatter a bone like a much larger and heavier .45 will. I have seen 9mm and 40 calibers bounce off or deflect off many windshields of cars, yet a .45 will punch a hole in a windshield and rarely bounce off. Of course the angle of shot and windshield will affect this, but a heavier bullet is less impacted by objects it hits than lighter bullets.

The idea behind stopping a target is hitting the brain stem, stopping the brain, or stopping the ability for the target to move or either get away or stop it from charging you. Hitting a head shot is tough and a much smaller target. Most people are taught to shoot center mass or more specifically, center mass of the target available. By shooting center mass you are more likely to hit your target. Shooting center mass increases your chances to hit vital organs and tissue, creating more blood loss. Blood loss is important since the brain and body requires blood to act. So the faster you can create massive blood loss, the faster your target stops moving. Bigger holes and deeper holes create faster bleeding.

Remember a pistol is traditionally a "Defensive Weapon" when you let a target get too close and you cannot engage it with a more powerful "Offensive Weapon" like a Rifle. Pistol rounds have come a long way with more speed, heavier weights and better bullet design and materials over the years. But few pistol rounds gives you the weight, size and speed of a rifle round.

Therefore, a general rule of thumb, bigger diameter, bigger weight and faster speed is best for most damage and incapacitation. Incapacitation being more blood loss, more tissue and organ damage and more crushed or broken bones.

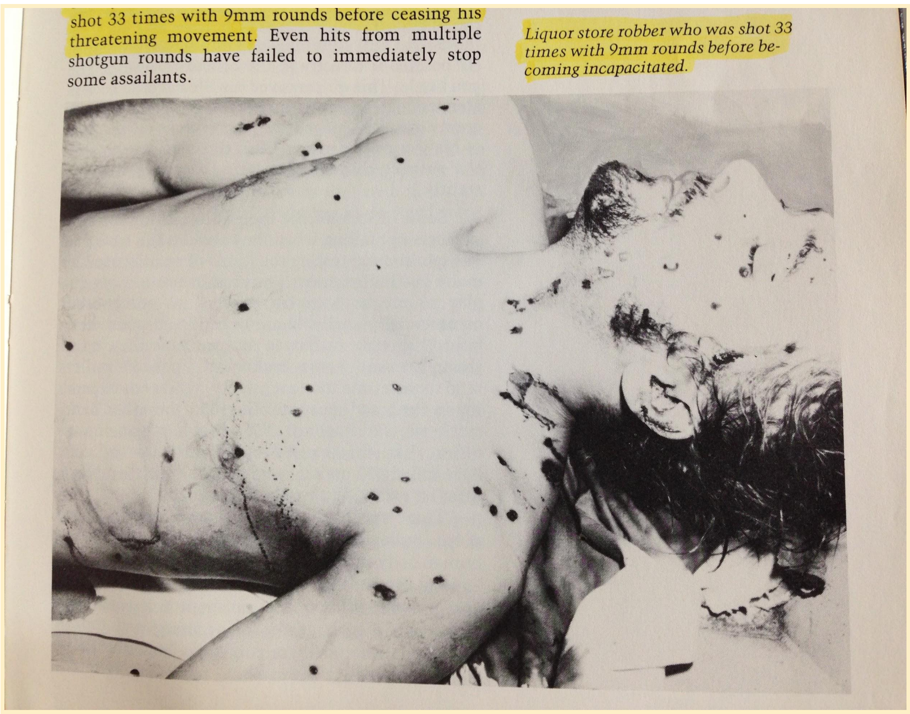
Bullet design is another factor to consider. What you choose depends on what you want or expect to use the ammo for. Hollow points can lose some weight but are designed to expand upon impact, that way you get a bigger hole from bullet expansion and a bigger primary cavity. Faster speed gives you a bigger secondary cavity. However, when a bullet expands, it slows down much faster and does not make a long or deep primary cavity (less penetration) like a round nose solid tip bullet, that will tend to push right through the target. Then you have frangible bullets that shatter and tear apart, so you get many small primary cavities but not much speed or penetration, with the theory being more holes, more bleeding, more blood loss. The more the bullet penetrates, the longer the primary and secondary cavity will be, so the more blood loss and tissue damage. Most bullets are lead with metal jacket, but you can also get steel core ammo, which can also be called armor piercing. Steel has very good penetration especially if it is going fast. The best way to tell if a bullet is Steel core is to put a magnet on it, if the bullet sticks to the magnet it has steel in it. Lots of fake green tip ammo being sold that does not have a steel core, so the magnet test is good to know.

Other considerations are when and under what conditions are you planning on shooting, in winter when people are wearing lots of clothes and large thick jacket, hollow point ammo does not penetrate as well as compared to a guy wearing just a t-shirt in summer. Of course, if a bullet is going faster it will go deeper than a hollow point going slow.

That is just some of the many considerations when choosing ammo and as you can see lots of factors, but the short answer is: Bigger, heavy and faster is best.

" If you think you can or think you can't, you are probably right"

Here is a big reason why I choose a .45 caliber over a 9mm caliber -
Robbery suspect was shot 33 times with a 9mm before being stopped:



shot 33 times with 9mm rounds before ceasing his threatening movement. Even hits from multiple shotgun rounds have failed to immediately stop some assailants.

Liquor store robber who was shot 33 times with 9mm rounds before becoming incapacitated.

Stopping Power - Hatcher Values

General Julian Hatcher, a noted forensic pathologist, in the early 1900's developed a good formula to determine the theoretical stopping power of a firearm cartridge. His formula has withstood the test of time and validation from other studies and data related to stopping power.

You want a handgun cartridge that has a Hatcher value of over 50 for the most effective stopping power. Values over 55 have diminishing returns in that you don't gain any significant increase in stopping power for the extra recoil and control you must cope with. Handgun cartridges that don't make a value of at least 50, should not be considered for self-defense. If the rating of your handgun cartridge is under 30, it only has about a 30% chance of producing a one shot stop. Hatcher Ratings of 30 to 49 raise a one shot stop to approximately a 50% chance. Ratings of 50 or higher produce a one shot stop about 90% of the time.

Hatcher Rating - Handgun Cartridge Type

136.8 - *.44 Magnum lead wadcutter 240 grain

92.3 - .44 Magnum full metal jacket 240 grain

80 - *.41 Magnum lead wadcutter 230 grain

76.5 - *.44 Special lead wadcutter 240 grain

62.1 - 10 millimeter jacketed hollow point 180 grain

60.7 - .45 ACP jacketed hollow point 230 grain

59.4 - .40 S&W jacketed hollow point 180 grain

54 - .41 Magnum full metal jacket 230 grain

53.4 - .40 S&W full metal jacket flat nose 180 grain

51.6 - .44 Special full metal jacket 240 grain

50.3 - 10 millimeter full metal jacket 180 grain

-------------- Rounds Above this line have 90 Percent of One Shot Stop -------------------

49.1 - .45 ACP full metal jacket 230 grain

48.5 - **.357 Magnum lead wadcutter 158 grain

48.5 - **.357 Magnum lead wadcutter 158 grain

48.5 - **.357 Magnum lead wadcutter 158 grain

45.2 - .357 SIG jacketed hollow point 147 grain

39.9 - 9 mm jacketed hollow point 147 grain

39.7 - *.38 Special lead wadcutter 158 grain

36.6 - .357 SIG full metal jacket 147 grain

32.7 - **.357 Magnum full metal jacket 158 grain

32.3 - 9 mm full metal jacket 147 grain

26.7 - .38 Special full metal jacket 158 grain

18.3 - .380 Auto jacketed hollow point 95 grain

11.1 - .32 Auto jacketed hollow point 71 grain

3.7 - .25 Auto jacketed hollow point 50 grain

4.2 - .22 Long Rifle jacketed hollow point 40 grain

* Jacketed hollow points will have the same rating as wadcutter bullets if the bullet hollow tip is greater than 1/2 of the caliber of the bullet.

* .357 Magnum ratings are taken from a firearm with a 3 inch barrel. Longer barrels will raise the rating of the round.