The Reconstructive Aspects of Class Characteristics and a Limited Universe

Class characteristics consist of the intended features of an object. The class characteristics of bullets would include obvious things such as caliber, weight, method of construction, composition, design and location of any cannelures, base shape, heel shape, nose shape, and any number of more subtle features. In our normal laboratory efforts these provide a ready sorting process that can quickly pare down the choices of source for a fired bullet. Although not ordinarily thought of as a means of identification, in situations where we are presented with a limited universe, class characteristics can provide definitive answers in shooting reconstruction cases.

Figures 3.1(a) and 3.1(b) show two views of a selection of unfired 38 caliber and 9 mm bullets. From left to right, these are a cannelured Winchester aluminum-jacketed bullet, a nickel-plated Winchester jacketed hollow-point (JHP) bullet, a Russian full-metal-jacketed (FMJ) bullet with a copper-washed finish over a steel jacket, a Remington JHP bullet with a scalloped jacket, a Federal Hydra-Shok bullet, a Winchester Black Talon bullet with a black copper oxide finish, a CCI-Blount Gold Dot JHP bullet, and a Remington Golden Saber bullet with a brass jacket. Each of these bullets exhibits certain distinguishing class characteristics.

Figure 3.2 shows each bullet from Figure 3.1 after discharge and recovery from a tissue simulant. This reveals some additional manufacturing features of potential value for certain bullets, such as the central post in the Federal Hydra-Shok and the “talons” on the Winchester Black Talon (subsequently renamed the Ranger SXT).

The following case examples employ the concept of a limited universe. A limited universe represents a situation where there are a finite number of choices for an event. In these cases the analyst is typically presented with two or three types and brands of ammunition whose sources are known or have been established. It is understood that these limited choices are
the only ones for the particular event. An eliminative process for all but one contender and subsequent correspondence in class characteristics of this only remaining choice establish an identity of the source where there is a limited universe of candidates.

CASE EXAMPLES

Case 1

Consider a situation where an innocent bystander was killed by an errant shot in a multiagency police operation. Three law enforcement agencies were involved in the attempted arrest of an armed and highly dangerous subject. One or more members of each agency ultimately fired shots
during an exchange of gunfire with the subject. The fatal bullet passed through the victim and was never found. A portion of the bullet’s jacket was recovered from the wound track, however. The initial laboratory report describes this item as a fragment of a bullet jacket that lacks any rifling impressions and is therefore not suitable for identification purposes.

Agency A carries and fires 9 mm Winchester SilverTips; Agency B, Federal Hydra-Shoks; and agency C, Remington Golden Sabers. The armed subject fired a revolver loaded with plain lead bullets.

Given the limited universe for the source of this fatal injury, this case can be solved on the basis of the differing jacket compositions for these three bullets: nickel-plated gilding metal for the SilverTip, plain gilding metal for the Federal Hydra-Shok, and brass for the Remington Golden Saber.

Case 2

Let us modify Case 1 to the extent that the innocent bystander lives and has a partially expanded bullet in her body (visible on X-rays). This bullet is in an area where the treating doctors conclude that it is safer to leave it in her body rather than to remove it. Four agencies fired their handguns in this hypothetical example using the following ammunition: Winchester SilverTip, Winchester Black Talon, Federal Hydra-Shok, and Remington Golden Saber. As before, the armed suspect fired a revolver loaded with plain lead bullets. How might the question of responsibility be resolved in this situation?

A possible solution resides in a pair of X-ray films: one in the lateral view and one in the anterior/posterior (A/P) view. It would be quite surprising if such films did not already exist in the victim’s medical records. If this is the case, lateral and A/P films should be requested with a concerted effort to get the clearest possible views of the projectile. If they do not exist, then additional X-rays should be prepared. If either the barb-like talons of a Black Talon or the central post of the Hydra-Shok can be seen in one of these films, the question is answered. It would also be answered upon the appearance of the classic profile of an unexpanded, round-nose lead bullet of the type from the suspect’s revolver. Given the differences in jacket composition of the law enforcement agencies’ ammunition, scanning electron microscopy–energy dispersive spectroscopy (SEM/EDS) analysis of the “bullet wipe” around the entry hole in the outermost garment can also result in a resolution of this case.

Case 3

An armed subject was being chased by two law enforcement officers down a long dark alley. In one location, Officer A fired a single shot of Federal 9 mm + P + ammunition loaded with Hi-Shok bullets from his Glock model 17, 9 × 19 mm-caliber pistol. After an additional 200 feet of foot chase, Officer B fired a single shot of Federal 9 mm Luger ammunition loaded with Hydra-Shoks from his Glock model 19, 9 × 19 mm-caliber pistol. The subject escaped the foot chase for a short period of time before being dropped off at a local emergency room. Figure 3.3 shows a lead core that was collected from the scene in the alley, and Figure 3.4 shows a bullet removed from the subject in the emergency room.

Which officer was responsible for shooting the individual, and which officer missed? Purposefully, some information was given that should have made the reader think about, but dismiss, as an option in a limited universe. Specifically, while the models are different, both officers shot Glock 9 × 19 mm-caliber pistols, which share the same general rifling characteristics. The lands and grooves on these bullets will not separate out the individual who shot the subject.
In this specific limited universe scenario, even if only one of these bullets was recovered, the correct answer is Officer B. While no one knows all the various manufacturing characteristics associated with individual bullets, it is the responsibility of investigators of shooting incidents to know as much as possible about, and to be interested in, their subject matter. The bullet core from the alley shows some key rib marks down the long axis of the bullet that are common to Federal Hi-Shoks. Conversely, the bullet in the specimen vial has a clearly identifiable Hydra-Shok post.

CLASS CHARACTERISTICS AND FIRED CARTRIDGE CASINGS

Without being a firearm and tool mark examiner, it is possible to begin to get an idea of the minimum number of firearms involved in a shooting. By looking at the class characteristics of the breech face impression on the casings, we can separate out which are in agreement and which are different. Some of the fundamental things to look at are firing pin aperture shape, breech face mark direction and pattern, and firing pin shape. Other marks that are usually visible with the naked eye, but which may be intermittently produced, should not be used to make early categorization determinations. These include, but may not
be limited to, firing pin drag marks, ejection port dings, and ejector marks. Additionally, while the overall relationship and positioning of ejector and extractor marks are usually fairly consistent from the same gun, there is a degree of inaccuracy due to the motion of the gun and casing during the cycle of fire. In other words, a gun with an ejector set at the 8-o’clock position may leave ejector markings on a fired cartridge case at 7 o’clock, 8 o’clock, or 9 o’clock. The same concept applies to extractor mark positions.

**EXAMPLE**

Consider a very common scenario in which we have an unknown number of guns involved in a shooting event. In some cases, there may be clusters of casings that are physically separated, suggesting that separate firearms were used for different clusters or that motion took place between the two locations. Examine Figures 3.5 and 3.6, paying special attention to the firing pin impression shape and firing pin aperture flow-back shape. Both of these casings are the same brand and basic style, but the marks left by the guns used to fire them are very different. In the first figure we see a slightly rectangular firing pin aperture and an elliptical firing pin impression; in the second figure we see evidence of a hemispherical firing pin impression and a circular firing pin aperture.

For this example let us say that one cluster of casings, all possessing markings represented in Figure 3.5, was recovered from the front yard of a residence, while the other cluster of casings, like that in Figure 3.6, was collected in the street in front of that residence. Both are shown with the extractor mark set to 3 o’clock as viewed. With these two sample cartridge casings from each group, the on-scene shooting reconstructionist can be certain that a minimum of two firearms were

**FIGURE 3.5** Fired cartridge casing displaying a rectangular firing pin aperture and an elliptical firing pin impression. Only Glock pistols and early Sigma-style pistols are known to have this set of class characteristics.

**FIGURE 3.6** Second fired cartridge casing showing circular firing pin aperture back flow and a hemispherical firing pin impression. While these class characteristics are relatively common, the arced breech face markings narrow the possible firearm types involved.
involved in the incident. This type of determination can usually be done with the naked eye. A word of caution, however: The fact that a group of casings from a scene all share these general characteristics does not mean that they are from the same gun. A thorough examination at the lab with a comparison microscope would be needed to complete that aspect of the investigation.

Let us add one more layer to this hypothetical investigation and say that as the investigation of the scene is wrapping up, detectives take into custody three suspects in a vehicle several miles away who confess to being involved in the shooting. The detectives relay that three pistols were collected: a 9 mm Luger-caliber H&K USP, a 9 mm Luger-caliber Beretta 92FS, and a 9 mm Luger-caliber Glock 17. Once again, a thorough examination using a comparison microscope will be needed to determine if these are the specific firearms used in the event, but some preliminary conclusions can be made.

Hopefully, if the reader is a seasoned shooting scene reconstructionist, the breech faces of the listed guns will be in memory. The uninitiated can refer to Figures 3.7 through 3.9. Immediately, the Glock breech face should stand out from the other two. Given this limited universe of possibilities, the casings represented by Figure 3.5 are in agreement with the

**FIGURE 3.7** H&K USP pistol. (a) Breech face of pistol. (b) Sample cartridge casing fired in pistol.

Note the firing pin drag mark emerging from the central firing pin impression. A recoil-operated pistol with a falling barrel design can, but not always will, leave such a mark. However, a recoil-operated pistol, such as a Beretta 92FS, that does not have a falling barrel will not leave such a mark.

**FIGURE 3.8** Breech face of a Beretta 92FS pistol.
class characteristics of the Glock pistol. It may be more difficult to discern the other set of casings from the Beretta and HK pistols because they both possess circular firing pin apertures and hemispherical firing pins.

To see an example of how complex such investigations can be, however, refer to Figure 3.7(a). Once again the cartridge casing is oriented with the extractor at 3 o’clock as viewed but, more important, note the small drag mark coming up and out of the firing pin impression. This firing pin drag indicates that the firearm used to discharge this cartridge casing is recoil-operated with a falling-barrel design. It is critical to understand that this mark may not always be present on casings from falling-barrel guns but should not be present if the firearm used does not have a falling-barrel design. In the limited universe scenario given previously, only the HK USP is a recoil-operated pistol with the class characteristics of a circular firing pin aperture and a hemispherical firing pin.

CLASS CHARACTERISTICS AND FIRED BULLETS

Another example of the use of the limited universe at scenes is general rifling characteristics imparted to bullets when they are driven down barrels with differing numbers of lands and grooves. Two notes of caution relating to this type of examination: (1) Be aware of and careful not to cause cross-contamination of different bullets when a trace evidence examination or DNA is needed later in the investigation; (2) be careful in the evaluation of patterns when the potential for deformation of the bullet or fragment is high. This latter point is especially critical when rifle bullets striking hard materials are at issue. If significant fragmentation has occurred, a laboratory examination may not even be particularly fruitful, let alone a field examination. For those cases where a relatively pristine set of bullets can be compared, the most simple way to proceed is to place the items base to base. In this manner, a rough idea of the following class characteristics can be compared: caliber, direction of twist, number of lands and grooves, and widths of lands and grooves.

EXAMPLE

Keeping in mind that this examination will only yield the minimum number of guns involved in the incident, let us take the case of a shooting event with no suspects, no firearms recovered,
and no leads. Six bullets of the same caliber and FMJ style are recovered from a decedent. They are in pristine condition, and since they are all from the same body, no DNA examination is needed. Placing the bullets base to base allows us to see if the impressed rifling characteristics cross smoothly from one to the other.

First examine Figure 3.10. Both bullets have the same overall number of lands and grooves, six, but the direction of the bullet on the left is left twist while that of the bullet on the right is right twist. These two could not have been fired through one barrel. The resulting V shape at the junction of the bases is the easy way to spot differing directions of twist.

Next, look at Figure 3.11. Here the direction of twist is in agreement, so the pattern flows smoothly from one side to the other; however, notice that whereas one edge of a land impression is aligned at the closest point as viewed, the alignment quickly falls apart as one travels down the side. On the left is a 6-right bullet; on the right is a 12-right bullet. The bullet on the right was fired through yet a third barrel. Now examine Figure 3.12. Finally we have an example where caliber, direction of twist, number of lands and grooves, and widths of lands and grooves agree. These two bullets could have been fired through the same barrel.

If we tally up the total number of varied general rifling characteristics, we see that the minimum number of barrels for this incident, commonly phrased as the minimum number of firearms, is four. One barrel rifled 5 right, one barrel rifled 12 right, one barrel rifled 6 right, and one barrel rifled 6 left. With some care, it is certainly possible to then evaluate the rifling characteristics of firearms in the field as well.
One final note: Can you spot the single visible difference in manufacturing characteristics between one of the bullets and the remaining five? It is important to also realize that it does not matter if some of the bullets are total metal jacketed, hollow point, or plain lead. If the samples being observed are pristine enough to compare and the issue of deformation has been ruled out, this tool can be very powerful at the scene.

**Propellant Morphology**

A distance determination based on a powder pattern around a bullet hole in clothing was previously cited as a simple example of a shooting reconstruction. Figure 3.13 illustrates the conical expulsion of partially burned and unburned powder particles from the muzzle of a handgun at discharge. It is this predictable and reproducible phenomenon that has served criminalists and firearm examiners as the basis of such distance determinations for decades. These powder particles also possess (and frequently retain) physical attributes that can be exploited to solve certain shooting reconstruction questions.

Although it is beyond the scope of this book to describe the various manufacturing methods and the chemistry of classic and modern small arms propellants, the common physical forms are easily illustrated in Figures 3.14(a) through (i). These figures show seven distinct forms of contemporary smokeless gunpowder followed by four granulations of black powder and Pyrodex RS (a black powder substitute) on 1/8-in. grids. Because no firearm–ammunition combination is 100% efficient in burning all of the powder in a cartridge, a few too many particles of unburned and partially burned propellant may be left behind in the fired cartridge case, in the chamber in which the cartridge was fired, in the bore of the firearm, and, of course, deposited on objects or surfaces in close proximity to the muzzle. The cylinder gaps of revolvers also represent a source of such deposits that have special reconstructive value, as will be pointed out later in this chapter.

**FIGURE 3.13** Gunshot residue production from a semiautomatic pistol.

The bullet is just a few inches beyond the muzzle. Numerous particles of partially burned gunpowder have emerged from the muzzle in a conical distribution. A cloud of soot or “smoke” is also visible in the muzzle area. A faint plume of sooty material can also be seen escaping upward from the chamber area. The slide of this semiautomatic pistol has just started to move rearward and the fired cartridge is still in the chamber.
FIGURE 3.14  Common physical forms of contemporary smokeless gunpowder, black powder, and Pyrodex RS on 1/8-in. grids: (a) extruded tubular powder; (b) Trail Boss; (c) Hercules unique unperforated disk-flake powder; (d) spherical ball powder-Remington 38SPL JHP; (e) Accurate #7 (manufactured by IMI) flattened ball powder; (f) Winchester 231 cracked ball powder; (g) Lamels 6.5 x 55 mm Swedish Mauser powder; (h) four granulations of black powder—4F, 3F, 2F, and “Ctg.”; and (i) Pyrodex RS (1990s, current form).
CASE EXAMPLES

Case 1

The following hypothetical case is an example of the application of propellant morphology to shooting reconstruction.

A subject known to have been in an altercation with three armed individuals in the parking lot of a bar was shot and killed by a single perforating gunshot wound to the chest. Three suspects were quickly apprehended and found to have the following guns: a 7.65 mm Walther PPK, a Lorcin .32 automatic, and an Iver Johnson .32 S&W revolver. All three admitted to firing a shot but each claimed to have discharged a “warning shot” into the air. The fatal bullet was never recovered.

Two fired .32 automatic pistol cartridges were found near the body. Initial laboratory examination establishes that a Geco-brand cartridge was fired in the Walther PPK and that a Winchester-brand cartridge was fired in the Lorcin. The Iver Johnson .32 S&W revolver was found to have one expended Remington-brand cartridge under the hammer. All of these findings substantiate the admissions of the three suspects insofar as their having discharged their pistols. Live rounds of the corresponding brands were also found in each pistol.
The medical examiner’s autopsy report describes some powder stippling around the entry wound. The charging bureau at the prosecutor’s office wants to know who to charge with murder and who to charge with lesser offenses related to firearms violations.

**Analytical Approach**

At this point we will expose the reader to a theme that will be repeated many times in this text. *What do we know about the problem?* It is the beginning step in the scientific method. All three firearms in this example are essentially of the same caliber. Given the uncertainty associated with estimating the caliber of the responsible firearm from bullet hole size in the victim’s shirt, and given the same problem with the diameter of entry wounds in skin, such measurements cannot lead to a valid resolution of this incident.

The mention of powder stippling by the medical examiner offers considerable hope because the intervening clothing stands to have filtered out some of the powder particles. If the fatal wound was sustained in bare skin, the medical examiner’s retention of some representative powder particles from the stippled area is critical to the solution of this case. In this hypothetical example, subsequent examination of the victim’s shirt reveals numerous particles of spherical ball powder around the bullet hole—see Figure 3.14(d).

Examination of the Geco-brand ammunition, the fired Geco cartridge, and the bore of the Walther pistol all reveal lamel-form powder residues—see Figure 3.14(g). The Iver Johnson revolver and its Remington ammunition show unperforated disk-flake powder—see Figure 3.14(c). Examination of the fired Winchester cartridge from the Lorcin pistol reveals ball powder residues, as does a tight-fitting cleaning patch pushed through the bore of this pistol prior to any test firing. The disassembly of several of the live Winchester cartridges from the Lorcin’s magazine also reveals the propellant to be spherical ball powder. By simple inspection of the class characteristics of the propellants and propellant residues, the Geco and Remington shooters are excluded and the shooter of the Winchester ammunition is included.

![Figure 3.15](image)

**FIGURE 3.15** View of the inside of a fired cartridge casing. The scale bar represents 1/100th of an inch.
Case 2

The reader should consider for a moment an alternate to the previous hypothetical example. In the homicide in this case, two firearms and one fired cartridge casing were recovered at the scene from each gun. There was a single, fatal, through-and-through gunshot wound to the decedent; however, no projectiles were recovered. One fired cartridge casing is a Winchester brand, and the other is a Federal brand. The morphology of the powder particles on the decedent’s clothing determines them to be ball powder. Figure 3.15 at the bottom of the previous page shows what is observed inside the mouth of the Federal brand cartridge casing.

Which of the two cartridge casings in this limited universe scenario is associated with the fatal gunshot wound? If the Winchester cartridge casing has remnants of ball-type powder, the correct answer is that it is associated with the fatal gunshot wound. No matter what is found in the Winchester cartridge casing, however, the particles in Figure 3.15 are clearly not ball. They are either disc flake, or flattened/cracked ball. This effectively excludes the Federal casing as being related to the fatal shot. If (1) these two cartridge casings are the only realistic possibilities for the source of the fatal bullet, (2) no residues are found in the Winchester cartridge casing, and (3) the Federal cartridge casing is excluded, the conclusion is that the Winchester is the only option by default.

REVOLVERS AND THE LIMITED UNIVERSE

Revolvers offer another source and dimension insofar as gunshot residue (GSR) and powder deposits are concerned. Such residues not only emerge from that muzzle but also emerge in an oval or fan-shaped pattern from the right and left sides of the cylinder gap. As Figure 3.16 shows, these hot and highly energetic gases can blast or burn a characteristic pattern into almost any surface immediately adjacent to the cylinder gap. Figures 3.17(a) and (b) illustrate the reconstructive value of muzzle and cylinder-gap deposits. Cylinder-gap deposits are of special value in possible suicide cases, in alleged struggles over a
revolver, in purported accidental discharges in holsters, or when the revolver in question was placed on or against some surface where, it is claimed, it discharged. This subject will be revisited in a later chapter.

THE WORTH OF WEIGHT

To some readers this topic may seem inappropriate to the subject of reconstruction. Others may conclude that it is so elementary as to be insulting. But sometimes it is the simplest of things that can solve a case. Something as basic as the weight of a projectile, a bullet core, or a fragment of a projectile can answer a reconstructive question. A number of otherwise very competent examiners have occasionally overlooked the obvious and simple solution to some of the following questions:

- Is a bullet fragment part of a particular fragmented bullet or some other bullet? Answer: If the weights of the two items exceed the weight of the intact bullet, the fragment is from some other projectile.
- Of what value is the weight of a severely deformed 22 rimfire bullet? Answer: A long-rifle bullet can be differentiated from a 22 short or 22 long bullet.
- Are cast bullets from the same mold all of the same alloy? Answer: Differences in alloy composition will produce significant differences in bullet weights for bullets cast in the same mold.
What is the weight of an unfired bullet based on the weight of either a separated core or a separated bullet jacket?  
Answer: For each manufacturer, there is a relationship between the total weight of a bullet, its lead or lead alloy core, and its jacket. (See the table of core and jacket weights in the Appendix.)

How can the total weight of live cartridges be useful?  
Answer: Consistency (or inconsistencies) in loading can quickly be detected. Significant differences (such as two different bullet weights, a missing powder charge, or a double powder charge) in otherwise visually indistinguishable ammunition can be detected by weighing the intact cartridges.

Of what value is the weight of intact cartridge cases versus fragments of burst or separated cartridge cases?  
Answer: Weight can serve as a means of ascertaining whether the entire burst cartridge is represented by the fragments presently in the examiner’s possession.

How can the weight of deformed shot pellets, buckshot, and/or spherical projectiles be useful?

The last question deserves special attention. The predischarge size (shot size number or diameter) of shotgun pellets from badly deformed, but otherwise intact, pellets can be determined from their weight. Table 3.1 lists the nominal weights in grams and milligrams for American shot sizes. It also gives the approximate diameter of these shot sizes in English and metric units.

It might also be useful at this point to recall that the diameter of American shot sizes in inches can be derived from this equation:

\[
diameter \text{ (in.)} = \frac{17 - \text{shot size #}}{100}
\]

For example, #6 shot gives 0.11 inches for its diameter from this equation.

The diameter of deformed spherical lead projectiles such as those fired from muzzle-loading rifles and cap-and-ball revolvers can also be determined from their weight, as will be demonstrated. This is especially useful to the battlefield archeologist. Prior to the mid-1800s nearly all firearms fired spherical lead projectiles. Some firearms continued to employ such projectiles during and immediately after the American Civil War. The majority of these

**TABLE 3.1**  Shot and Buckshot Sizes and Average Weights per Pellet

<table>
<thead>
<tr>
<th>Shot Size</th>
<th>T</th>
<th>BBB</th>
<th>BB</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>7½</th>
<th>8</th>
<th>8½</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (in.)</td>
<td>.20</td>
<td>.19</td>
<td>.18</td>
<td>.16</td>
<td>.15</td>
<td>.14</td>
<td>.13</td>
<td>.12</td>
<td>.11</td>
<td>.10</td>
<td>.095</td>
<td>.09</td>
<td>.085</td>
<td>.08</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>5.08</td>
<td>4.83</td>
<td>4.57</td>
<td>4.06</td>
<td>3.81</td>
<td>3.56</td>
<td>3.30</td>
<td>3.05</td>
<td>2.79</td>
<td>2.54</td>
<td>2.41</td>
<td>2.29</td>
<td>2.16</td>
<td>2.03</td>
</tr>
<tr>
<td>Weight: Pb (mg)</td>
<td>771</td>
<td>663</td>
<td>561</td>
<td>394</td>
<td>325</td>
<td>265</td>
<td>211</td>
<td>167</td>
<td>128</td>
<td>96</td>
<td>82</td>
<td>71</td>
<td>59</td>
<td>49</td>
</tr>
<tr>
<td>Weight: Fe (mg)</td>
<td>541</td>
<td>465</td>
<td>394</td>
<td>276</td>
<td>228</td>
<td>186</td>
<td>148</td>
<td>117</td>
<td>90</td>
<td>68</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Buckshot Size</th>
<th>000</th>
<th>00</th>
<th>0</th>
<th>No. 1</th>
<th>No. 2</th>
<th>No. 3</th>
<th>No. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (in.)</td>
<td>.36</td>
<td>.33</td>
<td>.32</td>
<td>.30</td>
<td>.27</td>
<td>.25</td>
<td>.24</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>9.14</td>
<td>8.38</td>
<td>8.13</td>
<td>7.62</td>
<td>6.86</td>
<td>6.35</td>
<td>6.10</td>
</tr>
<tr>
<td>Weight: Pb (g)</td>
<td>4.49</td>
<td>3.46</td>
<td>3.16</td>
<td>2.60</td>
<td>1.90</td>
<td>1.51</td>
<td>1.33</td>
</tr>
</tbody>
</table>

*Note: The weights of shot are in milligrams and those of buckshot are in grams.*

SHOOTING INCIDENT RECONSTRUCTION
were percussion (cap-and-ball) revolvers. They quickly faded from the scene with the introduction of cartridge-firing arms. However, renewed interest in historic firearms has led to the manufacture of numerous, fully functional replicas. On rare occasions such guns have been involved in accidental shootings and even employed in the commission of crimes.

Insofar as modern arms are concerned, spherical lead projectiles are almost exclusively associated with shotgun ammunition in the form of buckshot and the smaller shot sizes primarily used for bird and small game hunting. Also, some pistol and revolver cartridges are available that are loaded with small shot. The compositions presently available are lead (both dead soft and hardened), steel, bismuth, and tungsten-impregnated polymer spheres. Table 3.2 describes some of the physical properties of interest for these metals. Copper has been included because of its use in bulleted ammunition and contemporary frangible projectiles. Antimony is added in relatively small amounts (typically 0.5–5%) to harden lead.

### Derivation of Sphere Diameter from Weight

In the case of lead spheres, the formulas that follow, derived from the equation for the volume of a sphere and the density of lead, are quite useful in calculating the original diameter of a lead ball. The weight of a sphere composed of any of these metals is directly related to its diameter. This relationship is forensically useful because projectiles, particularly soft ones such as lead, will often deform upon impact. If no metal has been lost during terminal ballistic deceleration, the weight of a deformed spherical projectile can be used to derive its original diameter or caliber. Table 3.1 revealed how this would be useful for deformed shot from shotguns. Any loss of material can usually be determined by a careful inspection of the deformed lead ball under the stereomicroscope. The diameter of a lead ball is closely related (but usually not identical) to the caliber of the muzzle-loading firearm from which it was discharged. This concept will be revisited later in this section.

The mathematical derivation for the relationship between the weight of a spherical projectile and its diameter is as follows: The formula for the volume \( V \) of a sphere is \( \frac{4}{3}\pi r^3 \), where \( r \) is the radius of the sphere. This formula can be rewritten on the basis of diameter \( (d = 2r) \) and simplified to give

\[
V = 0.5236d^3
\]
From the simple relationship between weight, density, and volume (that is, \( W = D(V) \)), a general expression relating the weight \((W)\) of a spherical projectile to its diameter \((d)\) is

\[
W = 0.5236d^3(D)
\]  

(3.2)

**Lead Spheres**

The density of pure lead in _grains per cubic inch_ is 2873.5. These units have been selected because American calibers are usually given in inches and projectile weights in grains. The metric equivalent for the density of lead in _grams per mm\(^3\) is 0.011345. This value is useful for projectiles weighed in grams with their diameters measured in millimeters. For lead spheres, Eq. (3.2) can be further reduced by inserting these density values to give

\[
W \text{ (in grains)} = 1504.6d^3 \text{ (in inches)}
\]

or

\[
d = 0.08727W^{1/3}
\]  

(3.3)

The metric equivalent for \(d\) in millimeters and \(W\) in grams is \( W = 0.005940d^3\), or

\[
d = 5.522W^{1/3}
\]  

(3.4)

Table 3.3 provides a partial list of commercially produced lead balls for flintlock and percussion rifles, pistols, and revolvers. It illustrates the value of these equations and provides
some insight into the varied sizes and sources of such projectiles as well as a check of the calculated weights (in grains) versus the actual weights.

The lead spheres listed in Table 3.3 are contemporary, swaged balls from various commercial sources. “Bullet” molds, both contemporary and historical, for casting round balls are readily available. Some of them cast balls in sizes that fall between the values in the table. Projectiles made in this manner (as opposed to the modern swaging process) are likely to show a casting seam and a sprue mark. Additionally, cast balls may be alloyed with other metals such as tin and antimony, both of which will lower their density. Lyman’s No. 2 bullet metal, for example (a popular lead alloy composed of 90 parts lead, 5 parts tin, and 5 parts antimony), has a density that is 95.7% that of pure lead and a hardness of 15 on the Brinell scale. This compares to a Brinell hardness number (BHN) of 4 for pure lead.

The diameters of spherical lead balls and their relationship to the caliber of the muzzle-loading firearms used to fire them can be somewhat confusing. Muzzle-loading single-shot pistols and rifles were most often loaded with a patched ball, that is, a swatch of cloth, usually circular and on the order of 0.015 in. thick. Pillow ticking and fine woven linen were common choices for patching material. Very thin deer skin or other animal skins were also known to have been used during the era of muzzle-loading firearms.

With these firearms the ball is slightly undersized and held in place against the powder charge by the snug-fitting patch. With a properly selected patch and powder charge, the ball never directly contacted the bore of the gun during loading or discharge. At best, only faint vestiges of the rifling might print through the patch and onto the ball. The weave of the patch fabric may be embossed in the side or at the base of the fired ball. The patch itself survives the discharge process and represents important physical evidence. At very close range (a few inches) it will follow the projectile into a wound track. At more distant ranges, it will be found within a few yards of the location of the gun’s discharge.

Percussion revolvers, with their front-loading cylinders, use a very different approach. A lead ball of a slightly larger diameter than that of the cylinder’s chambers is mechanically forced down into the opening of each chamber with the revolver’s ramming arm. (It should be noted that the front of the ball typically receives a distinct and often identifiable imprint from the face of the ramming arm during the loading process and that this mark may survive impact with “soft” targets such as muscle or other tissues.) The rammer imprint should not be confused with imprints that might be left on a ball by a ball starter or ramrod used with muzzle-loading rifles and single-shot pistols. The seated ball retains its position in the chamber of percussion revolvers prior to discharge because of the forced fit it undergoes.

The bore into which this ball will be driven during discharge is slightly smaller than the chamber from which it is expelled. Such a projectile makes direct contact with the bore of a percussion revolver (unlike the patched ball method) and shows land and groove marking around its contacting circumference. The projectile has a diameter (before any impact deformation) equal to that of the bore of the gun.

Whether fired from a percussion revolver or from a muzzle-loading pistol or revolver, the exterior ballistic performance of spherical lead projectiles is poor compared to that of conical projectiles of the same caliber. In this context “poor” refers to a sphere’s high drag and correspondingly poor ballistic coefficient. It does not suggest that spherical projectiles are inherently inaccurate.
Steel and Bismuth Spheres

The previous equations can be recalculated utilizing the densities of steel and bismuth. For mild steel/iron of 7.87 g/cc (1994 gr/in.³), the relationships are \( W_{gr} = 1044d^3 \), where \( d \) (diameter) is in inches and \( W \) (weight) is in grains:

\[
d = 0.09857W^{1/3}
\]

For bismuth with a density of 9.75 g/cc (2469 gr/in³), the relationships are \( W_{gr} = 1293d^3 \), where \( d \) (diameter) is in inches and \( W \) is in grains:

\[
d = 0.09180W^{1/3}
\]

The more useful of these equations is the latter one, relating the diameter of out-of-round or deformed spheres of lead, steel, or bismuth to the cube root of their weights. These have been restated along with the expressions for lead in Table 3.4.

### SUMMARY AND CONCLUDING COMMENTS

The various design and compositional features of projectiles can lead to the absolute exclusion of certain sources of shots and the identification of the specific source of a shot, even though such projectiles or projectile fragments are not identifiable by traditional comparison microscopy. This is possible through the concept of a limited universe.

The propellants used in small-arms ammunition are seldom completely consumed during the discharge process and often leave recognizable particles in the bore of the firearm, in the fired cartridge case, and on any object or victim in proximity to a firearm’s discharge. Their varied physical forms and their exterior ballistic properties provide a means of reconstructing certain shooting incidents.

Everything from the casing to the bullet to the unfired cartridge itself may have potential value in shooting incident reconstruction. The investigator should be at least passably knowledgeable about the many types of available ammunition and their components.

The simple matter of the weight of a bullet fragment, a separated bullet jacket, or a deformed spherical projectile can resolve important questions in certain shooting incidents. Weight determination is a quick, nonconsumptive measurement that has often been overlooked or not fully appreciated.
3. THE RECONSTRUCTIVE ASPECTS OF CLASS CHARACTERISTICS AND A LIMITED UNIVERSE

CHAPTER KNOWLEDGE

- What class characteristics of fired bullets can you think of?
- What class characteristics of fired cartridge casings can you think of?
- What class characteristics might be of value with regard to unfired cartridges?
- How many bullet types can you name from memory?
- When was the last time you looked at the wide variety of available ammunition types with the sole purpose of understanding the subtle differences from one to the next?

References and Further Reading