moving, the speed at which that person was traveling – whether walking or running – can be estimated by the depth of the toe and heel portions of a print. For example, the footprint impressions of a running person typically have deeper indentations at the toe and than the heel and overall the entire impression if deeper when running compared to those made by someone walking.

**Tire Tracks**

Vehicles of all types have been part of criminal activity. Because of the relatively heavy weight of vehicles and the deeply engraved characteristic patterns found on the tire treads, tire impressions are often found marking crime scenes in the soil, sand, mud, snow, asphalt and other surfaces. Tread patterns have also been effectively lifted from victims hit by the vehicle.

In many ways, tire tracks are similar to footwear impressions in that both class and individual characteristics may be identified when comparing recovered tracks with known origin references (Figure 16.3.15). Because of the variation in the patterns, it is often possible to determine the manufacturer, model and sometimes even the year of manufacture of a particular tire from its tread design. Three-dimensional imprints may also show the marks from the side-walls of the tire, including imprints of make, model, number, and manufacturer. Measuring the distance along a single track between a repeating identifiable mark, such as a damage mark or worn spot on the tire, can provide the circumference of the tire.

Information which can be used to match a tire track with one specific tire can come from wear and damage patterns. Since tires are made from relatively soft materials and interact at high speeds with hard objects and surfaces, wear is expected for tire treads (Figure 16.3.16). Damage occurring from irregular road surfaces or from impact with small objects further individualizes a particular tread. Comparing any imperfections found in the tire impression with those on the suspect tire can provide valuable information that may support or refute a connection to the crime scene of that particular tire and, therefore, of one specific vehicle. It is important to note, however, that tires continually wear and that the patterns may not match exactly if the vehicle has been driven significantly since the time the impression was made.

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**Figure 16.3.16.** Typical wear patterns on car tires (www.2carpros.com/articles/how-car-tires-work).

**Figure 16.3.17.** Tool mark impressions on a door jam formed when the door was forced open (http://forensicphotoshop.blogspot.com/2009/05/tool-marks-and-shoe-prints.html).
Tire impressions can also give information about the vehicle itself. Measuring the distance between two tracks can give information regarding the width (wheelbase) and distance between the axles of the vehicle. Track widths are not always the same between front and rear axles, a further identifying feature when observed. The turning radius of a vehicle may also be estimated in certain cases.

**Tool Marks**

Tools are commonly employed in criminal acts – from break-ins and vandalism to assaults and robberies. Identifying characteristic markings can, as with other types of impression evidence, identify a type or even the one specific tool employed in these actions.

Tool mark creation arises in a variety of ways ranging from screwdrivers and crowbars used to open doors and windows to weapons used in violent crimes that were placed on an imprinted surface. Of particular importance is the presence of any striations that might be present in the markings. For example, shown in Figure 16.3.18 is a comparison microscope image comparing the striations found on a cut lock with those found on a suspect bolt cutter. Matching these unique imperfections provides strong evidence connecting the two items. Similarly, the details of the cut marks on other soft materials, such as plastics, can also reveal a wealth of data to draw upon (Figure 16.3.19).

![Figure 16.3.18. Striation matching (right) from a lock (left) with a pair of bolt cutters (center). The striations show that striations from the lock on the left and those found on the cutters on the right of the image](www.nj.gov/njsp/divorg/invest/criminalistics.html).

![Figure 16.3.19. Marks made on plastic coated wires cut by a tool can help identify the tool used](www.fei-natural-resources.com/forensics/image-gallery.aspx).

![Figure 16.3.20. A police badge was used in an assault to convince the victim that the attacker was a police officer. The badge was a copy and held in a plastic case. After leaving the crime scene, the attacker discarded the police badge but retained the clear plastic cover in his wallet. When later arrested, the attacker still had in his wallet the pastic case that contained a perfect impression of the discarded badge](www.nj.gov/njsp/divorg/invest/criminalistics.html).
There are clearly too many other types of impressions than are possible to detail here. In essence, any time a harder object comes into contact forcibly with a softer one, the opportunity for transferring an impression is possible. For example, Figure 16.3.20 shows the impression of a police badge in plastic. An offender used the badge, placed in a plastic holder of his wallet, to gain access and attack a victim. The criminal discarded the badge but retained the plastic case in his wallet—a plastic case that later showed the detailed impression of the badge and providing strong evidence of the suspect's connection to the crime.

**Bite Marks**

Bite marks have been used to help identify the attackers in violent crimes, especially sexual assaults. Bite marks have been successfully used to identify individual people from the marks left in foodstuffs (e.g., apples, cheese, chocolate), pencils, leather, chewing gum, and human flesh, among others.

Figure 16.3.22. Bite marks on a victim can be matched to a casting of a suspect’s teeth (www.nlm.nih.gov/visibleproofs/galleries/technologies/vitropsy.html).

Figure 16.3.23. Characteristic sizes and features of a human bitemark (from www.forensicmed.co.uk/wounds/bitemarks/).
(Figure 16.3.21). The process gathering and analyzing bite mark evidence usually involves photographing the gouges or wounds (in the case of human flesh) with appropriate scale markers and having a cast taken of a suspect’s teeth, usually by a forensic odontologist (dentist). The casting from the suspect’s teeth and the bite marks found on a victim or on other objects at the crime scene are then compared to find or refute a connection between the two tooth-mark patterns (Figures 16.3.22 and 16.3.23).

Bite marks can also arise from non-human attacks. Bite marks from domestic animals are most common with between 1 and 2 million reported annually in the US, mostly from dogs. Dogs and other animals have characteristic tooth patterns that can help identify the species, size and mannerism of a particular animal. For example, rodents tend to leave small, parallel marks and typically attack the face, head, fingers and toes first. Dogs tend to bite around the head and neck and usually result when defending their territories.

Today, however, the use of forensic bite mark analysis is under intense scrutiny with much work and discussion on both sides of the issue. Whether the current practice of individualizing an attacker by this type of analysis will hold up to scientific scrutiny or whether it will determined that it does not provide enough uniqueness to identify a particular assailant is yet to be definitively determined. The basic premise that is under debated is whether there is sufficient variability between the dentition of individual people to make a unique identification possible and whether this information can be extracted from bite mark wounds on victims so that a meaningful comparison and unambiguous match can be made. Time will tell how the debate will be decided.

**Theodore “Ted” Bundy**

Probably the best-known use of bite-mark impression evidence in criminal justice comes from the case of Ted Bundy. Bundy was a serial killer who assaulted and murdered at least thirty young women between 1974 and 1978.

Bundy was arrested in Utah in 1975 on a number of other (not related to the murders?) charges before escaping from his prison and continuing his spree of assault and murder. Then, in January of 1978, Bundy entered the Chi Omega sorority house at Florida State University and murdered two women and assaulted two others. One of the victims, Lisa Levy, was found with a deep bite mark wound from the attacker. Bundy was arrested about a month later, after he had committed other assaults and at least one more homicide.

At his trial, Bundy handled much of his own defense (in spite of five court-appointed defenders). The crucial evidence that led to his conviction came from an analysis of bite mark wound on Levy. Castings of Bundy’s teeth were made by odontologists and pictures of his dentition were overlain upon scaled pictures of the victim’s bite mark. Odontologists Richard Souviron and Lowell Levine testified that the bite marks on the victim uniquely matched those taken from Bundy’s dental castings.

After a brief deliberation, the jury found Bundy guilty of two murders, three counts of attempted
first-degree murder, and two counts of burglary. Six months later, Bundy was also tried and convicted of the murder of 12-year old Kimberly Leach in Orlando, Florida. The judge ordered Bundy executed on the murder convictions.

After exhausting all possible appeals, Bundy finally agreed to talk with investigators where he confessed to (but without ever taking the responsibility for) over thirty murders, including some that investigators were not even aware of. Bundy was ultimately executed for his crimes on Jan. 24, 1989.
Chapter 16 References and Bibliography

GLOSSARY OF TERMS

**Action:** The mechanical apparatus of a firearm that loads, fires and ejects the cartridge.

**Air gun:** Weapons that move a projectile solely by the release of stored gas pressure rather than through combustion.

**Alternative light sources (als):** Light sources that employ light of different wavelengths (colors) to visualize the components of an impression.

**Ballistics:** The study of how projectiles move through space.

**Barrel:** The metal pipe that guides the initial flight of the bullet.

**Breech:** The end of the gun barrel nearest to the action.

**Breech block (or face):** The back of the firing chamber.

**Breech-loading Firearm:** A weapon in which the ammunition and bullet are placed directly into the firing chamber without having it put down the barrel.

**Broach cutter:** A tool used to simultaneously cut all of the rifling grooves by forcing the cutter head down a smooth, drilled-out gun barrel while rotating the cutter with a characteristic twist rate.

**Bullet:** The projectile fired from a weapon.

**Button Rifling:** A process in which a small, shaped form is forced down the smooth gun barrel at very high pressures, compressing rather than cutting the metal into the grooves to form a rifled barrel.

**Caliber:** The diameter of the gun barrel in 1/100th of an inch.

**Cartridge:** Ammunition made up of casing, primer, powder, wadding and bullet.

**Casting:** A physical replica of an impression, formed by a moldable material, that sets into an actual-sized, permanent reproduction of the original impression.

**Chamber:** The enclosure in a gun’s design that contains the cartridge when ready to fire.

**Dental stone:** A gypsum product that when mixed with water and pored into a mold sets to form a hard, strong and stable solid that doesn’t require reinforcement.

**Drag:** The force that opposes the forward motion of the bullet created by air resistance.

**External (intermediate) ballistics:** The study of the flight of the bullet from the time it leaves the end of the gun barrel until it reaches the target.

**Fixed ammunition –** Ammunition that combines primer, an accurately measured main charge and the bullet all enclosed in a single, easily handled, water-tight casing.

**Flintlock weapon:** Firearms that use a spark created by moving a piece of flint over a steel plate (“frizzen”) to ignite a small primer charge that then sets fire to the main charge.

**Firearm:** 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.

**Firearms identification:** The process of determining “if a bullet, cartridge case or other ammunition component was fired by a particular firearm.”

**Fully automatic weapon:** A firearm where the filled rounds are reloaded automatically (see semi-automatic weapon) and the weapon continues to fire multiple shots when the trigger is held down.

**Gauge:** A measure of the diameter of the barrel of a shotgun.

**Gravity:** The force that constantly pulls objects downward with a constant force, defined as $F = mg$ (where $m$ is mass and $g$ is the gravitational constant).

**Grooves:** The places where some of a gun’s barrel metal has been removed (rifling) or shaped to create a depression.

**Gunpowder:** An explosive chemical mixture of carbon, potassium nitrate and sulfur that undergoes a rapid oxidation reaction and is used to propel projectiles in firearms.

**Gunshot residues:** Deposits of unreacted explosive materials and solid combustion byproducts that are discharged from openings in the gun into the nearby environment upon firing.

**Hammer:** The part of the action that drives the firing pin into the primer on firing.
**Handgun**: Smaller firearms that are designed for operation using one hand.

**Impression evidence**: Items of evidence that carry the lasting and observable marks from contact with another object.

**Internal (initial) ballistics**: The consideration of the part of a bullet’s path that occurs within the gun itself.

**Kinetic energy**: The energy of motion that is given by the expression of $KE = \frac{1}{2} mv^2$ (where $m$ is the mass and $v$ is the velocity of the moving object).

**Lands**: The portions of the inside surface of a rifled gun barrel that project farthest into the center of the barrel adjacent to grooves.

**Latent impression**: Impression evidence that is not immediately observable but which can be made visible using a variety of techniques.

**Long gun**: A category of firearms with relatively long barrels that includes rifles.

**Magazine**: A device for holding and delivering cartridges.

**Magnum**: A cartridge containing more than the standard amount of powder which delivers more power to the bullet.

**Mandrel**: A rod-shaped, grooved template with raised ribs corresponding to the desired rifling grooves; a slightly oversized, smooth gun barrel is compressed or hammered into shape around the mandrel leaving the formation of grooves and lands inside the barrel when the mandrel is removed.

**Muzzle**: The very end of the gun barrel where the bullet exits the weapon.

**Muzzle-loading firearm**: A weapon in which the bullets and ammunition are loaded directly down the barrel of the gun.

**National Integrated Ballistics Information Network (NIBIN)**: A database used to compare stored firearm pattern information with unknown (crime scene recovered) patterns.

**Negative image**: An image formed when some material covering a surface is *material is removed* by contact.

**Oblique lighting**: Light that comes in at a low (or oblique) angle relative to the surface.

**Percussion cap**: A small metal case containing a tiny amount of shock sensitive explosive, such as mercury fulminate that when struck sets off the main charge of the ammunition.

**Plastic**: A moldable material.

**Plastic impressions**: Impression evidence that have been formed when an object is imprinted into a soft, moldable material.

**Polygonal rifling**: An alternative to the traditional lands and grooves rifling where “hills” and “valleys” form a more rounded, polygonal pattern.

**Positive image**: An image created when an object leaves something behind on the surface which can be visualized.

**Powder**: The solid explosive used to propel the bullet.

**Primer**: The shock sensitive compound that ignites the main charge of a cartridge upon being struck.

**Revolver**: A firearm in which ammunition is moved into place for firing by means of rotating a cylinder that contains a number of separate firing chambers loaded with filled cartridges.

**Rifling**: Spiral grooves inside of the gun’s barrel which cause the projectile to spin about its long-axis.

**Round**: An intact unit ammunition (primer, bullet or “slug” and main charge).

**Semi-automatic weapon**: A firearm in which the energy released from one firing mechanically ejects the spent case and reloads the next fresh round into the firing chamber; one round is fired for each pull of the trigger.

**Serial number restoration**: The process of making visible serial numbers stamped into a gun that have been filed or ground away.
**Shotgun**: A type of long gun without rifling that uses ammunition containing either many small pellets (shot) packed into a single cartridge or a single, solid projectile (slug).

**Shrapnel**: Fragments of metal from a bomb, shell or mine.

**Sight**: The device on top of a gun that improves aim and accuracy.

**Silencer**: A device, placed over the muzzle, that reduces the noise emitted by firing a weapon.

**Spin (or gyroscopic) stabilization**: The rotational movement of an elongated projectile around its long axis which greatly improves its aerodynamic properties allowing it to go much farther and with increased precision and accuracy.

**Stock**: Frame that hold the barrel and action together to allow aiming and firing.

**Stria (striations)**: Tiny, random imperfection marks transferred between two objects that pass with direct contact.

**Terminal Ballistics**: The study of what happens when a projectile hits its target.

**Three-dimensional impression**: Impressions that occur when an object comes into contact with a soft or moldable substance to leave behind an exact three-dimensional imprint of the original object.

**Twist rate**: The length of a gun barrel in which the rifling makes one full rotation (360°).

**Two-dimensional impression**: Impressions that occur when an object comes into direct contact with a hard surface or material that is not indented or molded by contact with the object but onto which patterns can be transferred by the deposition or removal of materials.

**Visible impressions**: Impression evidence that is readily observable without any visualization aids.
QUESTIONS FOR FURTHER PRACTICE AND MASTERY

16.1. Land and groove marks on a recovered bullet arise from
(a) the rifling in the gun’s barrel.
(b) the striations in the gun barrel’s walls.
(c) the impression from the firing pin.
(d) the impression of the breechblock of the gun.
(e) all of the above.
16.2. What is meant by terminal ballistics.
16.3. Explain the difference between muzzle loading firearms and breech loading firearms.
16.4. What is the function of a percussion cap?
16.5. What is fixed ammunition and what are its advantages?
16.6. What is rifling and what effect does it have on a bullet?
16.7. What is the difference between a pistol and a revolver?
16.8. What is the difference between a semi-automatic and a fully automatic weapon?
16.9. What are the lands and grooves in a rifle barrel?
16.10. What is polygonal rifling?
16.11. What is meant by twist rate? What effect does increasing the twist rate have on a projectile?
16.12. What are some of the features of a shotgun that distinguish it from a rifle?
16.13. How is the caliber of a gun determined? Why are bullets referred to by caliber?
16.14. What is meant by the term ballistics?
16.15. What are the three “phases” of ballistics for a projectile? Explain each phase.
16.16. What are the typical methods for rifling a gun barrel?
16.17. What information can a forensic scientist determine from examining a fired bullet?
16.18. What are stria and how do they occur?
16.19. What identifying information can be obtained from a bullet casing that may connect it to a particular weapon?
16.20. What is gunshot residue (GSR)?
16.21. A forensic technician studies the GSR pattern at a crime scene. The technician measures the pattern of the GSR on objects leading up to the victim. After conducting a comparison test with the murder weapon, what conclusions can be drawn about the position of the killer relative to the victim?
16.22. What two chemicals are typically used when trying to restore an illegible gun serial number?
16.23. What is the fundamental principle being used with regard to metal crystal structure in serial number restoration through chemical treatment?
16.24. What is the difference between a positive impression and negative impression?
16.25. What are the three basic types of impressions? Explain the differences and give examples.
16.26. What methods are used to process impressions?
16.27. How do alternative light sources aid in photographing impressions?
16.28. What is the preferred medium used for making a forensic casting? What are its advantages over the old plaster of Paris medium?
16.29. What information about a suspect might be determined from (a) the size of a shoe print (b) the distance between shoe prints (c) the depth of the heel and toe imprints?
16.30. What identifying markers are looked for when analyzing tire impressions at a crime scene?
16.31. What are tool marks?
16.32. What is the debate in the legal community about bite mark impressions as admissible evidence?