Chapter 2
Introduction to Forensic Sciences

Hate evil, love good; maintain justice in the courts.
Amos 5:15

Abstract While most of the book deals with forensic pathology, this chapter provides readers with an overview of other forensic science disciplines. After a brief description of the chain of custody, test admissibility, evidence and testimony, the chapter provides brief descriptions of a variety of forensic science careers, including forensic anthropology, toxicology, forensic entomology, firearms examination, and DNA testing.

Keywords Forensic science · Evidence · Testimony

Overview

According to one definition, the word "forensic" means the application of scientific knowledge to legal problems. The term "forensic science" refers to a group of scientific disciplines which are concerned with the application of their particular scientific area of expertise to law enforcement, criminal, civil, legal, and judicial matters. It is beyond the scope of this book to provide detailed descriptions of the various forensic science disciplines so the reader is therefore referred to the many excellent textbooks and reviews of the forensic sciences for more detailed descriptions. This chapter provides only a very broad overview of the disciplines, with an emphasis on how forensic pathologists might interact with each. Where possible, a specific organization within each discipline, that is the recognized certifying agency for that profession is provided. Readers should beware that there are other organizations and/or "boards" that present themselves as legitimate. Such entities may or may not be reputable.

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Chain of Custody

Before providing a short description of the forensic disciplines, it is necessary to discuss three concepts that are important in all forensic sciences. The first involves maintaining the proper "chain of custody" when dealing with evidence. Evidence of whatever type must be carefully and properly documented and evaluated. Because of the nature of certain types of evidence it cannot all be collected and preserved indefinitely. An example is a human corpse that is evaluated at autopsy. In such instances, proper documentation is essential in order to re-evaluate the evidence (the body) at a later date. In the case of an autopsy, such documentation is performed via diagrams, photographs, and an autopsy report. There are many other types of evidence that also require collection and preservation; for example, trace evidence such as hairs or fibers discovered at a crime scene. Some forms of evidence are actually consumed or destroyed during evaluation (for example, blood samples being tested for drugs). Maintaining a proper "chain of custody" involves producing and maintaining written documentation which accompanies the evidence and provides an uninterrupted timeline showing the secure location of the evidence from the time that it was discovered until the present time. Any transfer of evidence from one person or secure location to another must be documented. Maintaining this chain of custody helps to ensure that the evidence has not been contaminated or compromised in any way. If the proper "chain of custody" is not maintained, the breaking of the chain may well provide a potential reason for such evidence to be inadmissible in court.

Admissibility of Tests, Evidence and Testimony

The second issue of concern that crosses all fields of forensic science involves the existence of legal standards for the admissibility of forensic tests and expert testimony. One legal standard for the admissibility of a forensic test is *Frye v United States*, which states that the forensic technique in question must have "general acceptance" by the scientific community. Rule 702 of the Federal Rules of Evidence regulates the admissibility of expert testimony in regard to a test or discipline. *Daubert v Merrell Dow Pharmaceutical, Inc* states that the decision about the admissibility of scientific evidence resides with the judge hearing the case.

Expert Witness

The third issue that relates to all forensic science disciplines is the concept of the expert witness. In contrast to a "fact witness," who is usually only able to relate the facts of the issue at hand as he/she observed them, an "expert witness," because of his/her specific expertise within a particular discipline, is also able to offer opinions regarding issues that relate to the specific discipline. In order to be recognized as an expert witness, the witness must be officially qualified, or recognized as an expert, by the court. Usually this involves a legal process referred to as *voir dire*, wherein the credentials, training, experience, etc. are presented to the court via questions/answers between an attorney and the witness. So long as this presentation is acceptable to both sides and the judge, a witness may be qualified to testify as an expert in a particular field.

Forensic Science Disciplines

Forensic Pathology

Forensic pathology represents a subspecialty within the medical specialty of pathology (see discussion of pathology in Chapter 1), dealing specifically with the investigation of sudden, unexpected, and/or violent deaths. The autopsy is central to the practice of forensic pathology. An overview of forensic pathology is provided in Chapter 3.

Forensic Anthropology

Forensic anthropology is a subspecialty within the scientific field of physical anthropology (the study of human beings in relation to their physical character), in which forensic anthropologists examine skeletal remains (bones). Forensic anthropologists attempt to answer questions about bones, including questions regarding species of origin (human versus nonhuman), gender, age, race, stature, nutritional status, existence of disease processes, and the presence and character of skeletal trauma. A forensic pathologist may consult with a forensic anthropologist when attempting to address any of the questions above. A frequent instance of consultation occurs when the forensic pathologist is presented with a badly decomposed or skeletonized corpse that is unidentified (refer to Chapter 9) (Fig. 2.1 and Disc Image 2.1). Board certification in forensic anthropology is conferred by the American Board of Forensic Anthropology.

Forensic Odontology

Forensic odontology is a subspecialty within dentistry in which a dentist has specialized expertise in using dental examination to assist in the identification of human remains, and in the evaluation of bite-marks, wherein a bite-mark on a victim may be "matched" to a suspect (Fig. 2.2 and Disc Image 2.2). The majority of a forensic odontologist's involvement in forensic casework involves assisting forensic pathologists in the identification of bodies. Assistance is usually provided in cases where the body is not visibly identifiable, and identification by fingerprint comparison or other means is not possible. The most common types of cases are persons who are badly burned and those who are badly decomposed (Fig. 2.3). Chapter 9 provides

Fig. 2.1 Unidentified skull at autopsy. Consultation with a forensic anthropologist can aid in determination of gender, race, and approximate age and stature

Fig. 2.2 A bite-mark on the skin surface at autopsy

more details about dental identification. Board certification in forensic odontology is conferred by the American Board of Forensic Odontology.

Forensic Entomology

Forensic entomology is a subspecialty within the biological science discipline of entomology (the study of insects) that primarily deals with insect succession patterns in decomposing human bodies. Evaluation of insects (including larval stages,

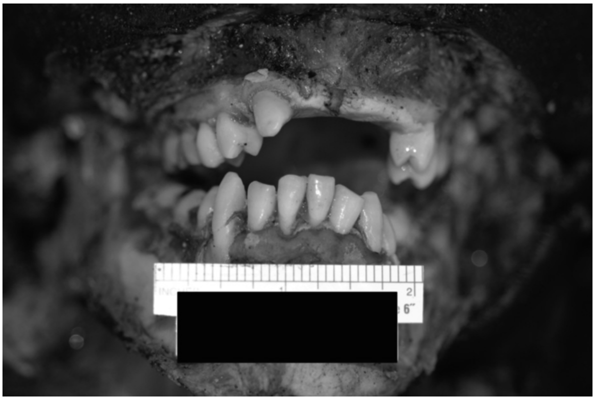

Fig. 2.3 Postmortem examination of the teeth of a badly burned body in order to assist in the positive identification of the decedent. Note that the soft tissues of the face (lips and cheeks) have been cut away in order to maximize the visibility of the teeth

or maggots) found on decomposing bodies can permit scientific estimation of the time of death (Fig. 2.4). In certain circumstances, information regarding the location of death may also be ascertained. Forensic pathologists do not consult with forensic entomologists in all decomposed cases, but will consult with them on select cases where estimating the time of death may be very important (for example, in homicides with decomposition and insect activity). Chapter 8 provides more details on how forensic entomologists may estimate the time of death. Board certification in forensic entomology is under the direction of the American Board of Forensic Entomology.

Fig. 2.4 Fly maggots on a decomposing body

Forensic Toxicology

Forensic toxicology is a discipline that involves the identification and quantification of drugs and other poisons or toxins in body tissues, including blood. “Screening tests” are said to be “qualitative,” where a test is either positive (indicating that the drug/toxin is present) or negative (indicating that the drug/toxin is not present). When specific levels of drugs or toxins are determined, the tests are said to be “quantitative.” For a result to have forensic significance, two separate methodologies are required, an initial (screening) test, and a confirmatory (quantitative) test. Another function of some toxicology laboratories is drug identification. For example, if a bag of white powdery substance is found in the pocket of a dead person, the substance can be submitted to the laboratory for identification. Forensic pathologists rely a great deal on the forensic toxicology laboratory. In many jurisdictions, toxicology testing is performed on a majority of the autopsy cases. In a significant percentage of forensic autopsy cases, the cause of death is related to the toxicology results. Forensic toxicology laboratories should be appropriately accredited by an officially recognized agency, such as the American Board of Forensic Toxicology. Toxicologists may have varying levels of education. Board certification in forensic toxicology is conferred by the American Board of Forensic Toxicology.

Forensic Psychiatry

Forensic psychiatry represents a discipline dealing with the evaluation of the mental state of criminals. Occasionally, forensic pathologists will interact with forensic psychiatrists and police investigators to form a “psychiatric profile” of a suspect in a particular murder or series of murders. A “psychological autopsy” is sometimes necessary when attempting to determine the state of mind of a suicide victim. Board certification in forensic psychiatry is available via the American Board of Psychiatry and Neurology.

Trace Evidence

Trace evidence is a general term used to describe various relatively small pieces of evidence that can be evaluated scientifically. Such evidence can include such items as hair (Figs. 2.5 and 2.6), fibers, paint chips, glass fragments, soil, gunshot residue (primer components, gunpowder, etc.), accelerants, and explosives. With certain types of evidence, the mere identification of the trace evidence may have significance in a particular case, for example, the identification of gunpowder on the clothing of a shooting victim. With other types of trace evidence, crime laboratory scientists may be able to “match” or “associate” a particular piece of evidence collected from a crime scene to a source, including the alleged perpetrator

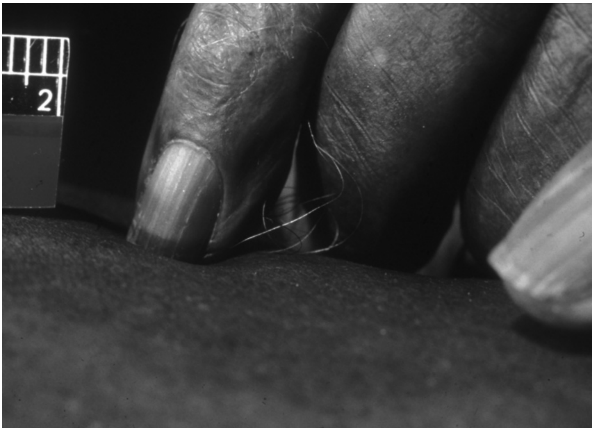

Fig. 2.5 A hair present on the fingers of a homicide victim

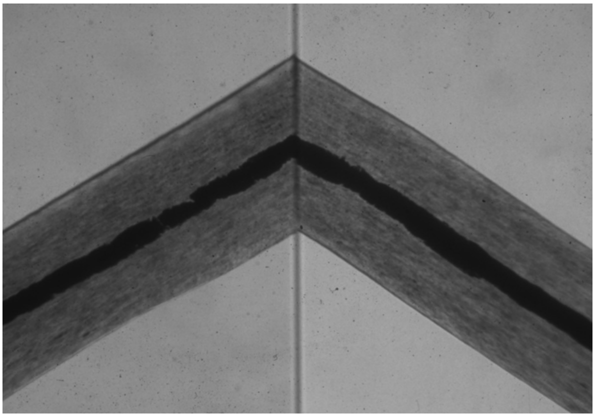

Fig. 2.6 Microscopic comparison of a strand of evidence hair, compared with a hair standard obtained from a suspect

of a crime. For example, a paint chip collected from the clothing of a hit-and-run pedestrian victim may be matched to a specific vehicle. Forensic pathologist interaction with trace evidence analysts is usually via the recognition and collection of pertinent trace evidence on a body by the forensic pathologist with subsequent submission of the evidence to the crime laboratory. Trace evidence evaluations typically occur within the larger setting of a crime laboratory. Crime laboratories must be accredited by the American Society of Crime Laboratory Directors (ASCLD). Trace evidence analysts can be certified via the American Board of Criminalistics (ABC).

Firearms and Toolmarks Examiners

Firearms and toolmarks examiners are forensic scientists with a specific expertise in the evaluation of firearms and ammunition. As part of their job, these scientists are able to match an evidence bullet (such as that collected from a body at autopsy) to a particular suspect weapon. The first step in attempting to determine whether or not a suspect weapon fired an evidence bullet is to determine the "class characteristics" of each. In regard to firearms having a rifled barrel (rifles and most handguns), the class characteristics include the caliber (diameter) of the barrel (and bullet), the number of lands and grooves (alternating raised and lowered areas within the inner surface of the barrel that spiral along the course of the barrel) of the barrel and imprinted on the sides of the bullet, and the direction of the spiraling (the "twist") within the barrel and imprinted on the sides of the bullet (Fig. 2.7). If an evidence bullet has different class characteristics than a particular suspect weapon, the weapon can be excluded as the one that fired the bullet.

Fig. 2.7 A deformed bullet collected at autopsy. Note the land and groove impression marks on the sides of the bullet

If the class characteristics are the same, then the firearms examiner has to make a more precise comparison. One way of doing this is to have the examiner fire a bullet from the suspect weapon (often into a watertank [Disc Image 2.3]). The examiner then collects the bullet (the exemplar) and compares the exemplar to the evidence bullet, using a "comparison microscope" (Disc Image 2.4). Besides creating marks that correspond to the lands and grooves of the barrel, rifled firearms produce unique, weapon-specific, microscopic marks ("striations") on the sides of bullets as the bullets travel through the barrel. These marks are created by the physical machine-produced make-up of the inside of the barrel. They are unique to an individual weapon (no two weapons are identical), and they produce essentially identical microscopic markings on every bullet fired from the same weapon. By comparing these "toolmarks" that are inscribed by the inside of the barrel on the sides of the exemplar bullet to those present on the evidence bullet, an examiner can determine if the evidence bullet was fired from the suspect weapon (Fig. 2.8).

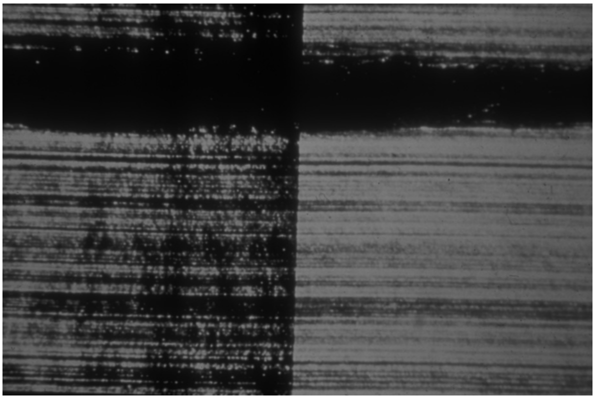

Fig. 2.8 An evidence bullet compared to a standard bullet fired from a suspect weapon. By aligning the striations, an evidence bullet can be matched to a specific weapon

Other toolmark patterns can allow examiners to "match" bullet casings to specific weapons (firing pin impressions, ejector marks, extractor marks, etc.). Marks left by other items, such as knife blades or blunt instruments, may also be specific enough to allow toolmarks examiners to match a suspect weapon to a crime scene or even occasionally to a body (via marks produced in cartilage or bone). Firearms and toolmarks examiners are also able to evaluate firearms regarding functionality, answering questions related to whether or not a firearm functions appropriately, etc. Forensic pathologists frequently collect and submit evidence from bodies for firearms and toolmarks examination, mostly in the form of firearm projectiles recovered during autopsy. The official certifying organization within this forensic discipline is the Association of Firearm and Tool Mark Examiners (AFTE).

Document Examination

Document examiners evaluate handwriting or machine-produced printing (typewriters, computer printer, copiers, etc.) and other documents. As such, these forensic scientists play a very important role in a variety of crimes, including forgeries, fraud cases, and counterfeit operations. Most interaction with forensic pathologists occurs in suicide cases, where document examiners can compare suicide notes with exemplars of the suicide victim's known handwriting to establish whether or not the victim actually wrote the suicide note (Disc Image 2.5). Document examiners occasionally perform other forensic tests, such as fingerprint analysis, impression analysis, or voice analysis. Board certification within this forensic discipline is available through the American Board of Forensic Document Examiners (ABFDE).

Fingerprint Evidence

Ever since fingerprints were discovered as a valuable means for identifying people, the discipline has been an important part of police and forensic investigations. Fingerprints represent unique patterns of the ridges on the pads of the fingers (including the thumbs). The ridges occur in the epidermis (the part of the skin closest to the surface) but extend into the dermis (the deeper part of the skin). Barring changes related to scar formation, which can obliterate portions of a fingerprint, fingerprints remain the same throughout an individual's life. The presumption, which has essentially been proven by decades of experience and casework, is that each individual has their own unique set of fingerprints. No two fingerprints have ever been found to be exactly identical even between identical twins. Therefore, a fingerprint represents a specific, individual characteristic of a particular person. Fingerprint examiners rely on various class characteristics (loops, whorls, and arches) as well as individual characteristics ("ridge characteristics" or "minutiae") of fingerprints in their examinations. An evidence fingerprint (such as a "latent" or invisible fingerprint) at a crime scene can be matched to a known print in a database. A variety of methods are used to collect and preserve evidence fingerprints. Several automated fingerprint identification systems (AFIS) are available: these are computerized databases of fingerprints that are on-file within various law enforcement agencies. For forensic pathologists, fingerprint comparison can be extremely useful in identifying an unknown corpse. In many offices, it is a standard operating procedure to create a fingerprint record of all bodies (Fig. 2.9). Certification of fingerprint analysts can be obtained via the International Association for Identification.

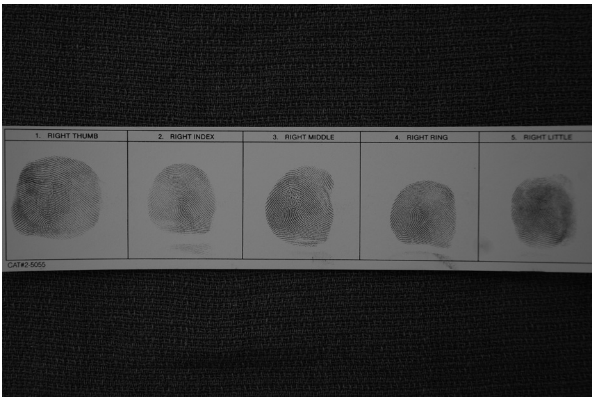

Fig. 2.9 A fingerprint card collected from a body in the morgue

Serology/DNA

Blood and other bodily fluids can be transferred from one person to another, or identified at crime scenes. Forensic serologists can perform tests to determine if a suspicious fluid or stain is saliva, semen or blood. Tests are available to determine if the evidence, such as blood, is of human origin. Once it is identified as human, then DNA (deoxyribonucleic acid) testing can be attempted. Forensic DNA testing is sometimes referred to as "DNA fingerprinting." With the exception of identical twins, no two individuals' DNA is exactly alike. Like other comparison tests within the forensic sciences, a standard sample from a suspect is required in order to make a comparison. Alternatively, if a known standard is not available (for example, when an unidentified body is thought to be a particular person, but no standard of that person is available for comparison), then samples from close relatives (parents, siblings) can be used. It is beyond the scope of this text to adequately explain DNA testing, but an attempt will be made to provide the basic concepts.

Our genetic information is contained within structures called genes, which are made-up of DNA. Each gene can be considered a template for the production of a specific protein. Proteins are substances that perform all sorts of functions within our bodies; without them, life would be impossible. Our genes are mostly contained within structures called chromosomes, which reside within the nucleus of our cells. A few genes are present within mitochondria, a subcomponent of cells that reside outside of the nucleus within the cytoplasm of our cells. All humans (excluding those with certain genetic abnormalities) have a total of 46 chromosomes within each of their nucleated cells (cells that have a nucleus). It should be mentioned here that most blood cells (normal red blood cells) do *not* have nuclei, although white blood cells do have nuclei, so the DNA testing performed on blood relies on the DNA contained in the white blood cells. Almost all other cells of the body *do* have nuclei. The 46 chromosomes are composed of 22 pairs of "autosomes" (numbered 1–22) and a pair of "sex chromosomes." In females, there are two X chromosomes, while in males, there is a single X chromosome and a single Y chromosome. Each person receives 23 chromosomes (22 autosomes and one sex chromosome) from their mother and 23 chromosomes from their father.

Each chromosome has its own complement of genes. For a given gene, its location is always on a specific chromosome at a specific location. We refer to this specific location as the gene's "locus" (plural: "loci"). In females, each specific gene actually occurs in two places, one on each of the 23 pairs of chromosomes. For males, each gene present on the autosomes (chromosomes 1–22) occurs twice, while the genes occurring on the X and Y chromosomes have only one copy. Genes can have different subtypes. The specific subtypes are referred to as "alleles." Some genes only have a couple of possible alleles. Others have many possible alleles. The differences in gene alleles are what contribute to the variations that exist amongst individual persons. The gene subtypes are determined by the specific sequence of molecules that make up the genes. A chromosome is a very long double-chain of DNA molecules (a "double helix") that represents many genes connected to each other but separated by other DNA molecules that can be thought of as "spacers" between the DNA that makes up the genes. DNA segments that are part of specific genes are said to be "coding" regions of the DNA, since they "code for" a protein. The spacer areas are referred to as "non-coding" regions.

Each specific DNA molecule is called a nucleotide and is composed of three parts, a sugar (deoxyribose), a phosphorus molecule, and a base. Nucleotide bases come in four possible types: adenine (A), thymine (T), cytosine (C), and guanine (G). Each strand of DNA is a chain of nucleotides joined end-to-end. In the double-helix that makes a chromosome (composed of two chains or strands of bases), a base on one strand is always paired (connected) to a complimentary base on the other strand. Adenine is always paired with thymine, while cytosine is always paired with guanine. So, for a given segment of a chromosome (whether it is within a specific gene or in one of the non-coding regions), the base-pair sequence might look like:

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– A – T – T – C – A – G – C – T – (one strand)
  |   |   |   |   |   |   |   |
– T – A – A – G – T – C – G – A – (corresponding strand)
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The "base-pair" configuration and the variations that exist between one person's sequence of base pairs and another person's sequence is the basis by which DNA testing works, whether for medical diagnosis of disease (identifying a "defective gene") or for forensic DNA testing. Forensic DNA experts rely on the fact that in many different locations within human chromosomes, there are sequences of DNA base-pairs that demonstrate a great deal of variation from one individual to another. If a forensic scientist is able to evaluate and identify the exact base-pair sequences from a sufficient number of these variable regions, then from a statistical standpoint, the forensic scientist is able to determine a unique "DNA profile" for any individual evaluated.

The reader is referred to other resources regarding the descriptions of the evaluation methods used to detect the DNA variations that exist between different people. Terms such as restriction fragment length polymorphism (RFLP), variable number of tandem repeats (VNTR), short tandem repeats (STR), Southern blot analysis and polymerase chain reaction (PCR) refer to some of the types of variable DNA regions that have been or are currently tested, as well as the methods used to identify and characterize the individual variations within these regions. DNA testing can be an incredibly discriminating tool for identification. Forensic pathologists may rely on the technology to determine the positive identification of a particular decedent. In other cases, DNA analysts rely on the pathologist collecting standard DNA samples (usually in the form of "blood spot" cards) at autopsy (Fig. 2.10) so that other crime scene evidence (like blood spatter) can be matched to or excluded from the decedent. Certification of DNA analysts occurs via the American Board of Criminalistics.

Fig. 2.10 A "blood spot" card from an autopsy, used to preserve a blood sample for potential DNA testing

Other Disciplines

Blood Spatter Analysis: Blood spatter analysis encompasses the evaluation of blood drops at a crime scene (or sometimes on a body or elsewhere). Based on the size, shape, character, density, and location of blood spatter, forensic scientists are able to determine possible causes of, or scenarios responsible for creating the particular pattern. Specific features that are able to be determined include the direction of travel, the relative velocity, and the angle of impact of the blood droplets. High velocity, low velocity, arterial, cast-off, and other patterns have specific characteristics. Persons performing blood spatter analysis are of varying backgrounds, including crime scene police officers. Some are crime laboratory personnel who have other responsibilities, such as trace evidence examiners. Occasionally, it may be important to evaluate blood spatter on the body or on the clothing of a dead person (Fig. 2.11 and Disc Image 2.6). In these cases, the pathologist is responsible for identifying, documenting, and, in the case of clothing, preserving such evidence for subsequent blood spatter analysis. Certification in blood spatter analysis is available via the International Association for Identification.

Fig. 2.11 Blood spatter on a shoe

Impression Analysis: Impression evidence includes items such as tire tracks, footprints (Disc Image 2.7), and shoeprints, although many different objects may cause impression evidence. Toolmark evidence as described above is a form of impression evidence. As with firearms examiners being able to include or eliminate a particular weapon as being the source of a particular bullet based on class characteristics, investigators evaluating other types of impression evidence can frequently include or exclude a suspect item (like a shoe) based on class characteristics. For example, if a shoe print found at a crime scene is consistent with a size 12 athletic shoe, a suspect shoe that is a size 9 work boot can be excluded. Unlike the situation with bullet examination, where it is relatively common for a firearm examiner to conclusively "match" or exclude a weapon as the source of a bullet, it is less common for shoe or tire imprint evidence to contain enough individual characteristics to absolutely match the evidence to the object. Some firearms and toolmarks examiners perform analysis of other imprint evidence. Sometimes, other forensic scientists, such as document examiners or other crime laboratory employees, perform these examinations. Certain police crime scene personnel may also do this. Depending on the case being evaluated, a forensic pathologist may discover imprint evidence at autopsy, either on the clothing or on the body. In such cases, the pathologist must document the evidence and preserve it, if possible. Examples include a bloody footprint on a body or a tire tread imprint on a pedestrian's clothing (Fig. 2.12). Certification in footwear impression analysis is available via the International Association for Identification.

Computer Forensics: Computer forensics is a rapidly evolving discipline that is concerned with computer and electronic crimes. Examples of the types of crimes investigated include identity theft, credit card and other financially motivated fraud, child pornography, etc. Forensic pathologists may interact with computer forensic specialists in a variety of situations, especially with regard to specific death

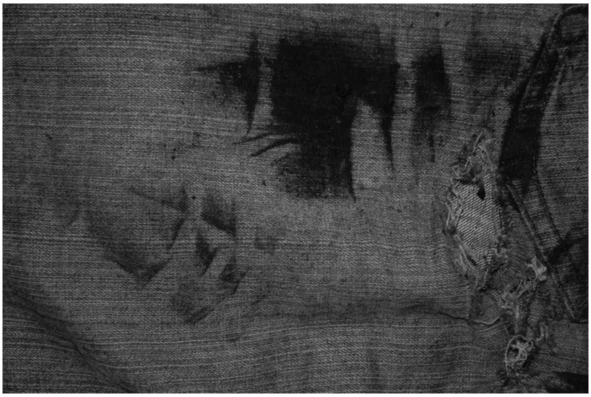

Fig. 2.12 A tire track mark on the clothing of a pedestrian

investigations. For example, if a death is determined to be a suicide using an unusual method, an analysis of the person's personal computer may disclose how the individual learned of that particular method of suicide.

Forensic Artistry: Forensic artistry relies on an artist's ability to draw or sculpt an image of how a suspect or victim might appear. The appearance may be created on the basis of witness recollections of a suspect or on other criteria, some of which may have more scientific basis, such as occurs with computer assistance when an attempt is made to show how a missing person or suspect might appear several years later. The most common situation for forensic pathologist interaction with forensic artists is when the pathologist has an unidentified skeleton. Anthropological evaluation can provide estimates of race, gender, and age. A forensic artist can attempt to reconstruct the facial appearance by literally sculpting a face of clay over the skull. A picture of the reconstructed face can then be published to the public, with the hope that someone might recognize who the person might be. Chapter 9 will provide more details regarding this method of identification. Forensic art certification is available via the International Association for Identification.

Forensic Engineering: Forensic engineering is a discipline that can encompass virtually any type of engineering. Examination of collapsed buildings, bridges, and other structures is one area of forensic engineering. Other topics include vehicular collisions and accident reconstruction, evaluation of engines or other devices for defects responsible for injuries/death, and evaluation of electrical appliances or sources of electricity in cases of suspected electrocutions. Forensic pathologists may call upon a forensic engineer when a specific death is related to any of these or other engineer-related issues. Board certification in forensic engineering is regulated by the International Institute of Forensic Engineering Sciences, Inc.

Disc Image Legends

Disc Image 2.1 A partially skeletonized corpse at autopsy (seen from the back). Following autopsy, with careful evaluation of the soft tissues, consultation with a forensic anthropologist in such a case can provide valuable information.

Disc Image 2.2 A dental model of a suspect's teeth used by a forensic odontologist to compare with a bite-mark on a victim.

Disc Image 2.3 A firearms examiner firing a bullet into a watertank at the Southwestern Institute of Forensic Sciences in Dallas, Texas. The bullet is collected from the tank and compared to an evidence bullet.

Disc Image 2.4 A firearms examiner at the Southwestern Institute of Forensic Sciences in Dallas, Texas using a comparison microscope to compare an evidence bullet to an exemplar bullet fired from a suspect weapon.

Disc Image 2.5 A suicide note collected at the scene of an alleged suicide. A document examiner can compare the handwriting in the note to known standards from the victim to determine if the person actually wrote the note.

Disc Image 2.6 Blood spatter on the foot of a decedent, as seen at autopsy.

Disc Image 2.7 A footprint found at the scene of a crime.

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