CHAPTER 3

The Nature of Evidence

Table of Contents

Key Terms

class
coincidental associations
common source
comparison
contamination
demonstrative evidence
direct transfer
evidence
false negative (Type II error)
false positive (Type I error)
hypotheses
identification
indirect transfer
individualization
known evidence
Locard Exchange Principle
negative control
persistence
positive control
probative value
proxy data
questioned evidence
repeatability
scientific method
testability
trier-of-fact

Introduction

John Adams, in his *Argument in Defense of the Soldiers in the Boston Massacre Trials*, in December 1770, said, "Facts are stubborn things; and whatever may be our wishes, our inclinations, or the dictates of our passion, they cannot alter the state of facts and evidence" (Zobel, 1996, p. 293). Evidence is critical to a trial; it provides the foundation for the arguments the attorneys plan to offer. It is viewed as the impartial, objective, and, yes, stubborn, information that leads a judge or jury to their conclusions. Evidence is a complicated thing and much goes into getting evidence ready before it can go into court.

What Is Evidence?

In a trial, the jury or judge hears the facts or statements of the case to decide the issues; whoever determines guilt or innocence is called the **trier-of-fact**. During the trial, the trier-of-fact must decide whether or not the statements made by witnesses are true. This is done mainly through the presentation of information or evidence. **Evidence** can be defined as information—whether in the form of personal testimony, the language of documents, or the production of material objects—that is given in a legal investigation to make a fact or proposition more or less likely. For example, someone is seen leaving the scene of a homicide with a gun, and it is later shown by scientific examination that bullets removed from the body of the victim were fired from that gun. This could be considered evidence that the accused person committed the homicide. Having the association of the bullets to the gun makes the proposition that the accused is the perpetrator more probable than it would be if the evidence didn't exist. In this chapter we will explore the nature of evidence, how it is classified, and how we decide what value the evidence has in proving or disproving a proposition.

Kinds of Evidence

Most evidence is real; that is, it is generated as a part of the crime and recovered at the scene or at a place where the suspect or victim had been before or after the crime. Hairs, fingerprints, paint, blood, and shoeprints are all real evidence. Sometimes, however, items of evidence may be created to augment or explain real evidence. For example, diagrams of hair characteristics, a computer simulation of a crime scene, or a demonstration of bloodstain pattern mechanics may be prepared to help the trier-of-fact understand complex testimony. Such **demonstrative evidence** was not generated directly from the incident but is created later. Because it helps explain the significance of real evidence, it does help make a proposition more or less probable and is, therefore, evidence. "In More Detail: Kinds of Evidence" lists other varieties of evidence.

In More Detail: Kinds of Evidence

Circumstantial evidence: Evidence based on inference and not on personal knowledge or observation.

Conclusive evidence: Evidence so strong as to overbear any other evidence to the contrary.

Conflicting evidence: Irreconcilable evidence that comes from different sources.

Corroborating evidence: Evidence that differs from but strengthens or confirms other evidence.

Derivative evidence: Evidence that is discovered as a result of illegally obtained evidence and is therefore inadmissible because of the primary taint.

Exculpatory evidence: Evidence tending to establish a criminal defendant's innocence.

Foundational evidence: Evidence that determines the admissibility of other evidence.

Hearsay: Testimony that is given by a witness who relates not what he or she knows personally, but what others have said, and that is therefore dependent on the credibility of someone other than the witness.

Incriminating evidence: Evidence tending to establish guilt or from which a fact-trier can infer guilt.

Presumptive evidence: Evidence deemed true and sufficient unless discredited by other evidence.

Prima facie (**prī**-mə **fay**-shə) *evidence:* Evidence that will establish a fact or sustain a judgment unless contradictory evidence is produced.

Probative evidence: Evidence that tends to prove or disprove a point in issue.

Rebuttal evidence: Evidence offered to disprove or contradict the evidence presented by an opposing party.

Tainted evidence: Evidence that is inadmissible because it was directly or indirectly obtained by illegal means.

Source: Garner (2000).

Levels of Evidence

Not all evidence is created equal—some items of evidence have more importance than others. The context of the crime and the type, amount, and quality of the evidence will dictate what can be determined and interpreted. Most of the items in our daily lives are produced or manufactured *en masse,* including biological materials (you have thousands of hairs on your body, for example). This has implications for what can be said about the relationships between people, places, and things surrounding a crime.

Forensic Science Is History

Forensic science is a historical science: The events in question have already occurred and are in the past. Forensic scientists do not view the crime as it occurs (unless they're witnesses); they assist the investigation through the analysis of the physical remains of the criminal activity. Many sciences, such as geology, astronomy, archaeology, paleontology, and evolutionary biology, work in the same way: No data are seen *as they are created,* but only the remnants, or **proxy data**, of those events are left behind. Archaeologists, for example, analyze cultural artifacts of past civilizations to interpret their activities and practices. Likewise, forensic scientists analyze evidence of past

TABLE 3.1 Forensic science is a historical science because it reconstructs past events from the physical remnants (proxy data) of those events. In this way, forensic science is similar to other historical sciences such as geology, astronomy, paleontology, and archaeology.

	Forensic Science	Archaeology	Geology
Time frame	Hours, days, months	Hundreds to thousands of years	Millions of years
Activity level	Personal, individual	Social, populations	Global
Proxy data	Mass-produced	Hand-made	Natural

criminal events to interpret the actions of the perpetrator(s) and victim(s); Table 3.1 compares differences between some historical sciences.

Just as archaeologists must sift through layers of soil and debris to find the few items of interest at an archaeological site, forensic scientists must sort through all the items at a crime scene (think of all the things in your home, for example) to find the few items of evidence that will help reconstruct the crime. In this sense, crime scene evidence is like a pronoun, grammatically standing in for a noun; evidence at a crime scene "stands in for" the actual items or are indicative of the actions taken at the scene. The nature and circumstances of the crime will guide the crime scene investigators and the forensic scientists to choose the most relevant evidence and examinations. Many methods may seem "forensic," but the definition may occasionally be stretched; see "In More Detail: But Is It *Forensic* Science?" for a discussion of this issue.

In More Detail: But Is It *Forensic* Science?

Many people identify forensic science as "science applied to law" but in truth the definition isn't that simple. If a structural engineer is consulted to determine why a bridge failed, writes a report, testifies once, and then never works on a legal case again, is she a *forensic* engineer? Most people wouldn't think so, but what if that engineer did it 3, 9, or even 21 times in her career? Many forensic scientists don't work at government forensic laboratories, so the term can't be defined that way. At what point does the *application* of science in the legal arena shift to *forensic* science?

Reconstructing events to assist the justice system happens all the time without being forensic science proper. A good example is the case of a Florida dentist who unwittingly passed on his HIV infection to several of his patients (Ou et al., 1992). Ou's group reported in 1990 that a young woman with AIDS had probably contracted her HIV infection during an invasive dental procedure. The dentist had been diagnosed with AIDS in 1986 and continued to practice general dentistry for two more years. The dentist went public for the safety of his patients, requesting that they all be tested for HIV infection. Out of 1,100 people who were tested, seven patients were identified as being HIV-positive.

HIV is genetically flexible and changes its genetic makeup during its life cycle, resulting in a variety of related viral family lines or strains (called quasi-species). Investigators used the degree of genetic similarity among the HIV strains in the seven infected patients, along with epidemiologic information, to evaluate whether the infections originated with the dentist or were from other sources. The investigators used genetic distance, constructed "family tree" diagrams, and developed amino acid "signature patterns."

Of the seven patients, five had no identified HIV risk other than visiting the dentist. These five patients were infected with HIV strains that were closely related to those of the dentist's infection; moreover, these strains were different from the strains found in the other two HIV-infected patients and 35 other HIV-infected people in the same geographical area. As the authors of the paper note:

> *In the current investigation, the divergence of HIV sequences within the Florida background population was sufficient to identify strain variation. . . . this investigation demonstrates that detailed analysis of HIV genetic variation is a new and powerful tool for understanding the epidemiology of HIV transmission. (Ou et al., 1992, p. 1170).*

They call it an "investigation"; they're doing DNA analysis; they're reconstructing the transfer of something from one person to others. But is this *forensic* science?

Don't be confused simply because a science is *historical*, because it uses proxy data to represent past events, or because it uses the same techniques or methods as a forensic science. Forensic science is the demonstration of relationships between people, places, and things involved in legal cases through the identification, analysis, and, if possible, individualization of evidence. Because nothing legal is at issue in the dentist "case," it isn't forensic. With the increased popularity of forensic science, students and professionals must be cautious about the use of "forensic" as a buzzword in the media and professional publications.

Source: Ou et al. (1992).

The Basis of Evidence: Transfer and Persistence

When two things come into contact, information is exchanged. Seems pretty simple and yet it is the central guiding theory of forensic science. Developed by Edmund Locard, a French forensic microscopist in the early part of the 20th century, the theory posits that this exchange of information occurs, even if the results are not identified or are too small to have been found (Locard, 1930). The results of such a transfer would be proxy data: not the transfer itself, but the remnants of that transaction. Because forensic science demonstrates associations between people, places, and things through the analysis of proxy data, essentially *all evidence is transfer evidence*. Table 3.2 lists some examples in support of this concept.

The conditions that affect transfer amounts include

- The pressure applied during contact;
- The number of contacts (six contacts between two objects should result in more transferred material than one contact);

TABLE 3.2 In a sense, *all evidence is transfer evidence* in that it has a source and moves or is moved from that source to a target/location. Note that there are levels to various types of evidence, from the fundamental (striations on the barrel-cutting tool) to the specific (the bullet in the victim's body identified by the striations).

Item	Transferred *From* (source)	Transferred *To* (target/location)
Drugs	Dealer	Buyer's pocket or car
Bloodstains	Victim's body	Bedroom wall
Alcohol	Glass	Drunk driver's blood-stream
Semen	Assailant	Victim
Ink	Writer's pen	Stolen check
Handwriting	Writer's hand/brain	Falsified document
Fibers	Kidnapper's car	Victim's jacket
Paint chips/smear	Vehicle	Hit-and-run victim
Bullet	Shooter's gun	Victim's body
Striations	Barrel of shooter's gun	Discharged bullet
Imperfections	Barrel-cutting tool	Shooter's gun's barrel

- How easily the item transfers material (mud transfers more readily than does concrete);
- The form of the evidence (solid/particulate, liquid, or gas/aerosol);
- How much of the item is involved in the contact (a square inch should transfer less than a square yard of the same material).

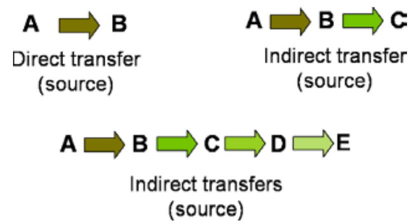


FIGURE 3.1 Direct transfer describes the movement of items from the source to the recipient (A to B), whereas indirect transfer involves an intermediate object that conveys the items to the recipient (A to C to B). Sometimes, direct transfer is referred to as *primary* transfer and indirect transfers are listed as *secondary*, *tertiary*, etc., but this terminology becomes clumsy after several exchanges. It may be more accurate to speak of direct and indirect *sources*.

Evidence that is transferred from a source to a location with no intermediaries is said to have undergone **direct transfer**; it has transferred from A to B. **Indirect transfer** involves one or more intermediate objects—the evidence transfers from A to B to C, as shown in Figure 3.1.

Indirect transfer can become complicated and poses potential limits on interpretation. For example, a person who owns two dogs pets them each day before going to work. At work, they sit at their desk chair and talk on the phone. This person gets up to get a cup of coffee; when they return, a colleague is sitting in their chair waiting to tell them some news. The dog-owner has experienced a *direct transfer* of their dogs' hairs from the dogs to their pants. The chair, however, has received an *indirect transfer* of the dogs' hairs–the dogs have never sat in the office chair! The colleague who sat in the dog owner's chair has also experienced an indirect transfer of anything on the chair, except for any fibers originating from the chair's upholstery. How should finding the dog hairs on the colleague's pants be interpreted if there was no knowledge of him sitting in the dog owner's chair? While direct transfer may be straightforward to interpret, indirect transfers can be complicated and potentially misleading. It may be more accurate to speak of direct and indirect *sources*, referring to whether the originating source of the evidence is the transferring item, but the "transfer" terminology has stuck. This leads to unsupportable statements regarding certain types of indirect transfer (secondary, tertiary, etc.); in almost no cases can a forensic scientist tell the difference between secondary (one intermediary) and tertiary (two intermediaries) transfer.

In More Detail: The Five-Second Rule

If a piece of food is dropped on the floor, how long can it sit there and still be edible? The prevailing popular joke is 5 seconds, leading to the Five-Second Rule. Some scientists, however, took this principle to heart and decided to test it. Dawson and coworkers found that bacteria (*Salmonella*) survived on wood, tiles, and carpet after 28 days (2007). After exposing the surfaces to the bacteria for 8 hours, the researchers found that bread and bologna were contaminated in under 5 seconds; after a minute, the contamination increased significantly.

What does this test have to do with forensic science? The Five-Second Rule is a popular example of the **Locard Exchange Principle**, which states that

(*Continued*)

information is transferred when two things come into contact. The rule also shows how the underpinnings of forensic science exist throughout other sciences. When critics claim that forensic science is not a "real" science or is only an "applied" science, think of the Five-Second Rule or some of the other examples offered in sidebars in this textbook, such as uniformitarianism and the drift of ocean currents. Forensic science is not just a bundle of techniques or methods from other sciences; it has unique principles and philosophy, as well as applications. Forensic science deserves to sit proudly alongside its sibling sciences.

Sources: McGee (2007); Dawson et al. (2007).

The second part of the transfer process is **persistence**. Once the evidence transfers, it will remain, or persist, in that location until it further transfers (and, potentially, is lost), degrades until it is unusable or unrecognizable, or is collected as evidence. How long evidence persists depends on

- What the evidence is (such as hairs, blood, toolmarks, accelerants);
- The location of the evidence;
- The environment around the evidence;
- Time from transfer to collection;
- "Activity" of or around the evidence location.

For example, numerous fiber transfer studies demonstrate that, from the time of transfer with normal activity, after about 4 hours, 80% of the transferred fibers are lost. Transfer and persistence studies with other evidence types have shown similar loss rates, as depicted in **Figure 3.2**.

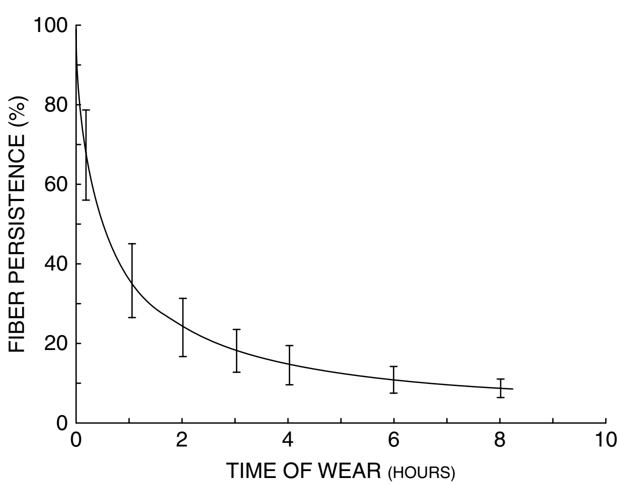


FIGURE 3.2 Trace evidence, such as fibers, tends to be lost at a geometric rate with normal activity. This graph shows a typical fiber loss curve (for acrylic and wool fibers) showing one standard deviation limits. *Source*: Pounds and Smalldon (1975, p. 34).

Contamination

Once the activity surrounding the crime has stopped, any transfers that take place may be considered **contamination**, that is, an undesired transfer of information between items of evidence. You would not want to package, for example, a wet bloody shirt from the victim of a homicide with clothes from a suspect; in fact, *every* item of evidence (where practical) should be packaged *separately*. Contamination is itself evidence of a kind; this is why it is so difficult to falsify a case or plant evidence. Based on Locard's Principle, *every* contact produces some level of exchange, including contamination. It is nearly impossible to completely prevent contamination, but it can be severely minimized through properly designed facilities, adequate protective clothing, and quality-centered protocols that specify the handling and packaging of evidence.

Identity, Class, and Individualization

All things are considered to be unique in space and time. No two (or more) objects are absolutely identical. Consider, for example, a mass-produced product like a tennis shoe. Thousands of shoes of a particular type may be produced in any one year. The manufacturer's goal, to help sell more shoes, is to make them all look and perform the same—consumers demand consistency. This effort is a help and a hindrance to forensic scientists because it enables them to easily separate one item from another (this red tennis shoe is different from this white one), but these same characteristics make it difficult to separate items with many of the same characteristics (two red tennis shoes). Think about two white tennis shoes that come off the production line one after the next. How would you tell them apart? An observer might say, "this one" and "that one," but if they were mixed up, he probably couldn't sort them again. He would have to label them somehow, like numbering them "1" and "2."

Now consider if the two shoes are the same except for color: One's white and one's red. Of course, they could be easily distinguished by color but would they be put in the same category? Compared with a brown dress shoe, the two tennis shoes would have more in common with each other than with the dress shoe. All the shoes, however, are more alike than if any of them is compared to, say, a baseball bat. Forensic scientists have developed terminology to clarify the way they communicate about these issues.

Identification is the examination of the chemical and physical properties of an object and using them to categorize the object as a member of a group. What is the object made of? What is its color, mass, and/or volume? The process of examining a white powder, performing one or two analyses, and concluding it is cocaine is identification. Determining that a small colored chip is automotive paint is identification. Looking at debris from a crime scene and deciding it contains hairs from a black Labrador retriever is identification (of those hairs). All the characteristics used to identify an object helps to refine that object's identity and its membership in various groups. The debris has fibrous objects in it, and that restricts what they could be—most likely hairs or fibers rather than bullets, to use an absurd example. The microscopic characteristics indicate that some of the fibrous objects are hairs, that they are from a dog, and the hairs are most like those from a specific breed of dog. This description places the hairs into a group of objects with similar characteristics, called a **class**. All black Labrador retriever hairs would fall into a class; these hairs belong to a larger class of items called *dog hairs*. Further, all dog hairs can be included in the class of *non-human hairs* and, ultimately, into a more inclusive class called *hairs*. Going in the other direction, as the process of identification of evidence becomes more specific, the analyst becomes able to classify the evidence into successively smaller classes of objects.

Class is a movable definition; it may not be necessary to classify the evidence beyond *dog hairs* because you are looking for human hairs or textile fibers. Although it is possible to define the dog hairs more completely, you may not need to do so in the case at hand. Multiple items can be classified differently, depending on what questions need to be asked. For example, an orange, an apple, a bowling ball, a bowling pin, and a banana could be classified, as shown in Figure 3.3, by *fruit v. non-fruit*, *round things v. non-round things*, *sporting goods v. edible*, and *organic v. inorganic*. Notice that the bowling pin doesn't fit into either of the classes in the last example because it is made of wood (which is organic) but is painted (which has inorganic components).

Stating that two objects share a class identity may indicate they come from a **common source**. What is meant by a "common source" depends on the material in question, the mode of production, and the specificity of the examinations used to classify the object. A couple of examples should demonstrate the

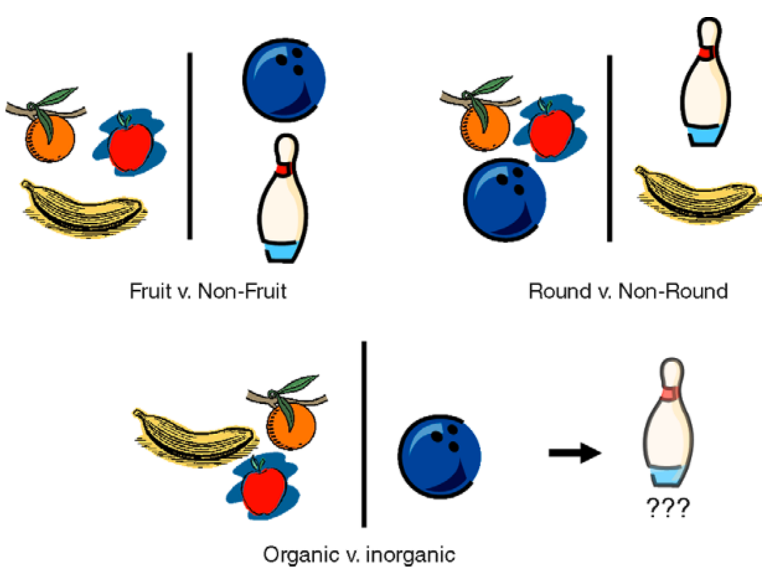


FIGURE 3.3 A class is a group of things with similar characteristics. The size of the class can vary widely depending on the characteristics used for definition, such as the class "all oranges" versus the class "all oranges in your refrigerator."

potential complexity of what constitutes a common source. Going back to the two white tennis shoes, what is their common source—the factory, the owner, or where they are found? Because shoes come in pairs, finding one at a crime scene and another in the suspect's apartment could be considered useful to the investigation. The forensic examinations would look for characteristics to determine if the two shoes were owned by the same person (the common source). If the question centered on identifying the production source of the shoes, then the factory would be the common source.

Another example is fibers found on a body left in a ditch that are determined to be from an automobile. A suspect is developed, and fibers from his car are found to be analytically indistinguishable in all tested traits from the crime scene fibers. Is the suspect's car the common source? For investigative and legal purposes, the car should be considered as such. But certainly it is not the only car with that carpeting. Other models from that car manufacturer or even other car manufacturers may have used that carpeting, and the carpeting may not be the only product with those fibers. But given the context of the case, it may be reasonable to conclude that the most logical source for the fibers is the suspect's car. If the fibers were found on the body but no suspect was developed, part of the investigation may be to determine who made the fibers and track what products those fibers went into in an effort to find someone who owns that product. In that instance, the common source could be the fiber manufacturer, the carpet manufacturer, or the potential suspect's car, depending on what question is being asked.

If an object can be classified into a group with only one member (itself), it is said to have been "individualized." An individualized object has been associated with one, and only one, source: It is unique. The traits that allow for **individualization** depend, in large part but not exclusively, on the raw materials, manufacturing methods, and history of use. Sometimes, sufficiently increasing class traits can lead nearly to individualization; for example, John Thornton's article (1986) on the classification of firearms evidence is an excellent, if overlooked, treatment of this issue.

On the Web

How Products Are Made: www.madehow.com. An excellent source to begin learning about the production and material characteristics of things that appear as evidence.

Individualization of Evidence

A definition for individualization was offered in the preceding section, that is, categorizing an item in a set or class that has one and only one member. To that extent, individualization is the logical extension of classification. The concept of individualization rests on two assumptions:

- All things are unique in space and time; and
- The properties by which a thing is classified are constant over time.

Without these assumptions being in effect, statements such as "Yes, that is a Phillips head screwdriver and it is mine," could not be properly understood. Questions ("What's a screwdriver? What's a "Phillips head" mean? How do you know it's yours?") would plague even the simplest statements. These two assumptions come with baggage, however.

First, the assumption of uniqueness of space is an inherently non-provable situation. The population size of "all things that might be evidence" is simply too large to account for; think of all the fingerprints on all the surfaces all over the world. A contributing factor to this is, throughout its history, forensic science has been casework-driven, not research-driven. Thus, many principles and concepts are derived from years of work-related experience, which is, regrettably, inconclusive from a research standpoint. A jury may reach a decision, a person may confess, and an accomplice may inform, but from a purely scientific perspective, *we do not know what really happened*. In a laboratory experiment, the scientist has control of all the variables of interest except one; any change in that variable leads to a stronger cause-and-effect statement. In forensic science, the scientist has absolutely no control over the circumstances during the crime. Put a bit more simply, casework is not research.

Forensic science is relegated to making interpretive statements based on statistical methods because it deals with so many uncertainties. As Schum clearly explains,

> *Such evidence, if it existed, would make* necessary *a particular hypothesis or possible conclusion being entertained. In lieu of such perfection we often make use of* masses *of* inconclusive *evidence having additional properties: The evidence is* incomplete *on matters relevant to our conclusions, and it comes to us from sources (including our own observations) that are, for various reasons,* not completely credible. *Thus, inferences from such evidence can only be probabilistic in nature. (1994, p. 2)*

Schum's point is that if scientists were absolutely certain of their samples or the accuracy of their methods, statistics would not be needed. Forensic science deals with the ultimate uncertainties in the real world of criminal activities with varying physical objects. The gap between the controlled laboratory and the real world is central to forensic science's fundamentals: Uncertainty is everywhere. Even in DNA analysis, where each person's genetic material—except for identical twins—is known to be unique, statistics are used. Statistics are, in fact, what give forensic DNA analysis its power.

Does this mean, then, that individualization is a bankrupt concept? Only if it is considered as a provable scientific statement. Consider two statements:

1. A forensic scientist says, "The questioned item came from the known source to the exclusion of any other similar object that currently exists, has ever existed, or will ever exist."
2. A friend says, "This is my friend Howard."

Both are statements of individualization. Statement #2 is provable in a personal sense; that person knows Howard to the exclusion of anyone else they might meet. Statement #1, however, is problematic in that one could not possibly check all other similar items currently in the world, let alone all that have ever existed or ever will exist (this is not an extreme statement taken out of context, some forensic examiners still testify this way) to absolutely ascertain that the questioned item came from the known source and only the known source.

Forensic scientists are beginning to recognize the complexity of their evidence and are adjusting their methods. Recent work on fracture matches, where an item has been physically broken into two or more pieces and those pieces are positively associated, promises hope for a statistical treatment of forensic interpretations. The innumerable variables, such as force used to break the object, shape of the object, microstructure and chemical nature of the material, and direction of the blow, all lead to those characteristics that forensic scientists use to compare the fragments. These can lead to exciting research and applications of physics, chemistry, materials science, and nanoscience.

Known and Questioned Items

Continuing with the hit-and-run example, say a motorist strikes a pedestrian with his car and then flees the scene in the vehicle. When the pedestrian's clothing is examined, small flakes and smears of paint are found embedded in the fabric. When the automobile is impounded and examined, fibers are found embedded in an area that clearly has been damaged recently. How can this evidence be classified? The paint on the victim's coat is **questioned evidence** because we don't know the original source of the paint. Likewise, the fibers found on the damaged area of the car are also questioned items. The co-location of the fibers and damaged area and the wounds/damage and paint smears are indicative of recent contact. When we analyze the paint on the clothing, we will compare it to paint from the car; this is **known evidence** because it is known where the sample originated. When we analyze the fibers on the car, we will compare them to fibers taken from the clothing, which makes them known items as well. Thus, the coat *and* the car are sources of *both* kinds of items, which allows for their re-association, but it is their *context* that makes them questioned or known.

Back at the scene where the body is found, there are some pieces of yellow, hard, irregularly shaped material. In the lab, the forensic scientist will examine this debris and will determine that it is plastic, rather than glass, and further it is polypropylene. This material has now been put in the class of substances that are yellow and made of polypropylene plastic. Further testing may reveal the density, refractive index, hardness, and exact chemical composition of the plastic. This process puts the material into successively smaller classes. It is not just yellow polypropylene plastic but has a certain shape, refractive index, density, hardness, etc. In many cases this may be all that is possible with such evidence. We have not been able to determine the exact source of the evidence, but only that it could have come from any of a number of places where this material is used—class evidence.

Suppose that the car suspected to be involved in the hit and run has a turn signal lens that is broken and some of the plastic is missing. The pieces are too small and the edges too indefinite for a physical match. Pieces of this plastic can be tested to determine if it has the same physical and chemical characteristics as the plastic found at the crime scene (color, chemical composition, refractive index, etc.). If so, it could be reported that the plastic found at the scene could have come from that broken lens. This is still class evidence because there is nothing unique about these properties that would be different from similar plastic turn signal lenses on many other cars.

Relationships and Context

The relationships between the people, places, and things involved in crimes are critical to deciding what to examine and how to interpret the results. For example, if a sexual assault occurs and the perpetrator and victim are strangers, more evidence may be relevant than if they live together or are sexual partners. Strangers are not expected to have ever met previously and, therefore, would not have transferred evidence before the crime. People who live together would have some opportunities to transfer certain types of evidence (head hairs and carpet fibers from the living room, for example) but not others (semen or vaginal secretions). Spouses or sexual partners, being the most intimate relationship of the three examples, would share a good deal more information. The interaction of these evidence environments is shown in Figure 3.4.

Stranger-on-stranger crimes beg the question of **coincidental associations**; that is, two things which previously have never been in contact with each other have items on them which are analytically indistinguishable at a certain class level. Attorneys in cross-examination may ask, "Yes, but couldn't [insert evidence type here] really have come from *anywhere*? Aren't [generic class-level evidence] very *common*?" It has been proven for a wide variety of evidence that coincidental matches are extremely rare. The variety of mass-produced goods, consumer choices, economic factors, and other product traits creates a nearly infinite combination of comparable characteristics for the items involved in any one situation. Some kinds of evidence, however, are either quite common, such as white cotton fibers, or have few distinguishing characteristics, such as indigo-dyed cotton from denim fabric. "Common," however, is a word to be used with caution and even then only after a thorough knowledge of how that material is produced, either naturally or

FIGURE 3.4 The significance of the interaction between the victim(s) and the criminal(s) at one or more crime scenes is largely determined by the relationships between the people, places, and things involved. Strangers have a different relationship than do spouses or family members. People who live together have more opportunities to transfer evidence on a regular basis than do strangers. Spouses or sexual partners, being more intimate, would share more information.

artificially, and how it varies. Even materials that are thought to be "common" can have a high variance (see Figure 3.5).

It is important to establish the context of the crime and those involved early in the investigation. This sets the stage for what evidence is significant, what methods may be most effective for collection or analysis, and what may be safely ignored. Using context for direction prevents the indiscriminate collection of items that clog the workflow of the forensic science laboratory. Every item collected must be transferred to the laboratory and cataloged—at a minimum—and this takes people and time. Evidence collection based on intelligent decision making, instead of fear of missing something, produces a better result in the laboratory and the courts.

Comparison of Evidence

There are two fundamental processes in the analysis of evidence. The first has already been discussed: identification. Recall that identification is the process of discovering physical and chemical characteristics of evidence with an eye toward putting it into successively smaller classes. The other process is **comparison**. Comparison is done to try to establish the source of evidence. The questioned evidence is compared with objects whose source is known. The goal is to determine whether or not sufficient common physical and/or chemical characteristics exist between the samples. If they do, it can be concluded that an association exists between the questioned and known evidence. The strength of this association depends on a number of factors, including

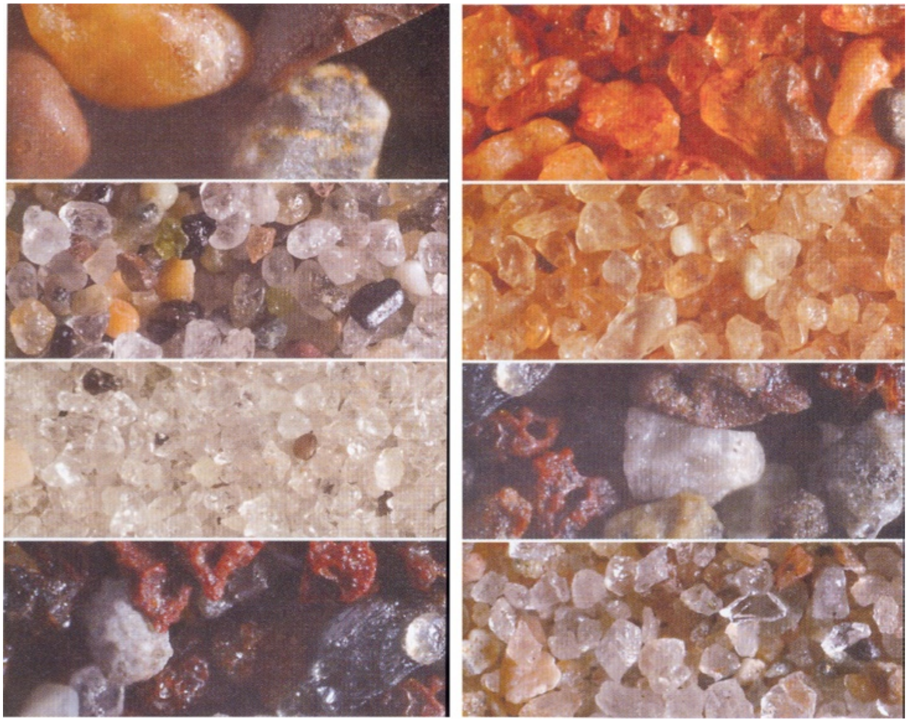


FIGURE 3.5 Forensic scientists need to learn the details about the materials they study and analyze as evidence—even something perceived to be very common, like sand, can have a wide variation. Top to bottom: Rodeo Beach, Marin County, CA; Agate Beach, OR; Daytona Beach, FL; Bermuda; Sanorini, Greece; Ayers Rock (Uluru), Australia; Sahara Desert, Mauritania; Old Course Beach, St. Andrews, Scotland. *Source:* Holman (2009).

- Kind of evidence;
- Intra- and inter-sample variation;
- Amount of evidence;
- Location of evidence;
- Transfer and cross-transfer;
- Number of different kinds of evidence associated to one or more sources.

Individualization occurs when at least one unique characteristic is found to exist in both the known and the questioned samples. Individualization cannot be accomplished by identification alone.

Controls

Controls are materials whose source is known and which are used for comparison with unknown evidence. Controls are often used to determine if a chemical test is performing correctly. They may also be used to determine if a substrate where evidence may be found is interfering with a chemical or instrumental test. There are two types of controls: positive and negative.

Consider a case in which some red stains are found on the shirt of a suspect in a homicide. The first question that needs to be answered about these stains is: Are they blood? A number of tests can be performed to determine whether a stain may be blood. Suppose one of these tests is run on some of the stains and the results are *negative*. There are a number of reasons why this might happen:

- The stain isn't blood.
- The stain is blood, but the reagents used to run the test are of poor quality.
- Something in the shirt is interfering with the test.

Before concluding that the stain isn't blood, a number of additional steps could be taken. One might be to run a different presumptive test and see whether the results change. Another is to run the first test on a sample that is known to be blood and that should yield a positive test. This known blood is a **positive control**. It is a material that is expected to give a positive result with the test reagents and serves to show that the test is working properly. In this case, if the positive control yields a correct result, then it can be presumed that the reagents are working properly and there must be another reason for the negative result obtained on the blood-soaked shirt. It could be proposed that the shirt fibers contain some dye or other material that deactivates the blood test so that it will fail to react with blood. To test this hypothesis, some fibers from the shirt that have absolutely no stains on them could be collected and run the test on them. This would be a **negative control** for the shirt; it is expected that the results of the test would come out negative. If the test results are negative as expected, they could still mean that the shirt contains something that interferes with the test. This presumption could only be verified by running a different test on the stain. Other negative controls can be run on "blank" samples, that is, those prepared similarly to the test materials being used but without any sample present.

If the initial test for blood was done on the stained shirt and came out positive, we should not immediately assume that the stain is definitely blood. A sample of the unstained shirt fibers should be tested as a negative control. A negative result here would mean that the positive result on the stain most likely means that the stain is blood.

What is the consequence of not running a positive or negative control? If a negative control is not used, a **false positive** may be the result; that is, it may be concluded that the stain is blood when it is not. This gives rise to what statisticians call a **Type I error**. Type I errors are serious because they can cause a person to be falsely incriminated in a crime.

Failure to run a positive control can cause a **false negative** result. This can give rise to what is called **Type II error**. This type of error means that a person may be falsely exonerated from a crime that he or she really did commit. Any error is problematic, but from the criminal justice standpoint, a Type II error is less serious than a Type I error. We would rather have someone falsely released than falsely accused. Positive and negative controls are usually easy to obtain and should be used to minimize the chance of errors.

Analysis of Evidence: Some Preliminary Considerations

Science is a way of examining the world and discovering it. The process of science, the **scientific method,** is proposing and refining of plausible explanations about any unknown situation. It involves asking and answering questions in a formal way and then drawing conclusions from the answers. Science, through its method, has two hallmarks. The first is the questions that are asked must be testable (or have **testability**). Asking "How many angels can dance on the head of a pin?" or "Why do ghosts haunt this house?" is not scientific because a test cannot be constructed to answer either of these questions. The second hallmark of science is **repeatability**. Science is a public endeavor, and its results are published for many reasons, the most important of which is for other scientists to review the work and determine whether it is sound. If nobody but you can make a particular experiment work, it isn't science. Other scientists must be able to take the same kinds of samples and methods, repeat your experiments, and get the same results for it to be science (see "History: The Method of Science" for a discussion of scientific models).

History: The Method of Science

> *[An important person in the history of science] was not a scientist at all, but a lawyer who rose to be Lord Chancellor of England in the reign of James I, Elizabeth's successor. His name was Sir Francis Bacon, and in his magnum opus, which he called* Novum Organum*, he put forth the first theory of the scientific method. In Bacon's view, the scientist should be a disinterested observer of nature, collecting observations with a mind cleansed of harmful preconceptions that might cause error to creep into the scientific record. Once enough such observations have been gathered, patterns will emerge from them, giving rise to truths about nature.*
>
> *Bacon's idea, that science proceeds through the collection of observations without prejudice, has been rejected by all serious thinkers. Everything about the way we do science—the language we use, the instruments we use, the methods we use—depends on clear presuppositions about how the world works. At the most fundamental level, it is impossible to observe nature without having some reason to choose what is worth observing and what is not worth observing.*

In contrast to Bacon, [Sir Karl] Popper believed all science begins with a prejudice, or perhaps more politely, a theory or hypothesis. Popper was deeply influenced by the fact that a theory can never be proved right by agreement with observation, but it can be proved wrong by disagreement with observation. Because of the asymmetry, science makes progress uniquely by proving that good ideas are wrong so that they can be replaced by even better ideas. Thus, Bacon's disinterested observer of nature is replaced by Popper's skeptical theorist.

Popper's ideas . . . fall short in a number of ways in describing correctly how science works. Although it maybe impossible to prove a theory is true by observation or experiment, it is nearly just as impossible to prove one is false by these same methods. Almost without exception, in order to extract a falsifiable prediction from a theory, it is necessary to make additional assumptions beyond the theory itself. Then, when the prediction turns out to be false, it may well be one of the other assumptions, rather than the theory itself, that is false.

It takes a great deal of hard work to come up with a new theory that is consistent with nearly everything that is known in any area of science. Popper's notion that the scientist's duty is then to attack that theory at its most vulnerable point is fundamentally inconsistent with human nature. It would be impossible to invest the enormous amount of time and energy necessary to develop a new theory in any part of modern science if the primary purpose of all that work was to show that the theory was wrong.

Another towering figure in the twentieth century theory of science is Thomas Kuhn. A paradigm, for Kuhn, is a sort of consensual world view within which scientists work. Within a given paradigm, scientists make steady, incremental progress, doing what Kuhn calls "normal science."

As time goes on, difficulties and contradictions arise that cannot be resolved, but one way or another, they are swept under the rug, rather than be allowed to threaten the central paradigm. However, at a certain point, enough of these difficulties have accumulated so that the situation becomes intolerable. At that point, a scientific revolution occurs, shattering the paradigm and replacing it with an entirely new one.

If a theory makes novel and unexpected predictions, and those predictions are verified by experiments that reveal new and useful or interesting phenomena, then the chances that the theory is correct are greatly enhanced. [However, science] does undergo startling changes of perspective that lead to new and, invariably,

(*Continued*)

better ways of understanding the world. Thus, science does not proceed smoothly and incrementally, but it is one of the few areas of human endeavor that is truly progressive. [Science] is, above all, an adversary process. The scientific debate is very different from what happens in a court of law, but just as in the law, it is crucial that every idea receive the most vigorous possible advocacy, just in case it might be right.

Excerpted from Goodstein, D. (2000) "How science works," in *Reference Manual on Scientific Evidence*, 2nd ed., Federal Judicial Center, Washington, DC, pp. 67–82.

In the language of science, the particular questions to be tested are called **hypotheses**. Suppose hairs are found on the bed where a victim has been sexually assaulted. Are the hairs those of the victim, the suspect, or someone else? The hypothesis could be framed as follows: "There is a significant difference between the questioned hairs and the known hairs from the suspect." Notice that the hypothesis is formed as a neutral statement that can be either proven or disproven.

After the hypothesis has been formed, the forensic scientist seeks to collect data that shed light on the hypothesis. Known hairs from the suspect are compared with those from the scene and the victim. All relevant data will be collected without regard to whether it favors the hypothesis. Once collected, the data will be carefully examined to determine what value they have in proving or disproving the hypothesis; this is the **probative value** of the data. If the questioned hairs are analytically indistinguishable from the known hairs, then the hypothesis is rejected. The scientist could then conclude that the questioned hairs could have come from the suspect.

But suppose that *most* of the data suggest that the suspect is the one who left the hairs there, but there are not enough data to associate the hairs to him. It cannot be said that the hypothesis has been *disproved* (there are some similarities), but neither can it be said that it has been *proved* (some differences exist, but are they significant?). Although a scientist would like to be able to prove unequivocally that someone is or is not the source of evidence, doing so is not always possible. As previously mentioned not all evidence can be individualized. The important point to note here is that evidence analysis proceeds by forming many hypotheses and perhaps rejecting some as the investigation progresses.

Some preliminary questions must be answered before we even begin to formulate hypotheses. Is there sufficient material to analyze? If the amount of the evidence is limited, then choices have to be made about which tests to perform and in what order. The general rule is to perform non-destructive tests first because they conserve material. Most jurisdictions also have evidentiary rules that require that some evidence be kept for additional analyses by opposing experts; if the entire sample will be consumed in an analysis, then both sides must be informed that not enough evidence will be available to have additional analyses performed.

If extremely large amounts of material are submitted as evidence, how are they sampled? This situation often happens in drug cases in which, for example, a 50-pound block of marijuana or several kilograms of cocaine are received in one package. The laboratory must have a protocol for sampling large quantities of material so that samples taken are representative of the whole. In other kinds of cases in which this situation occurs, many exhibits may appear to contain the same thing, for example, 100 0.5-ounce packets of white powder. The laboratory and the scientist must decide how many samples to take and what tests to perform. This decision is especially important because the results of the analyses will ascribe the characteristics of the samples to the whole exhibit, such as identifying a thousand packets of powder as 23% cocaine based on analysis of a fraction of the packets.

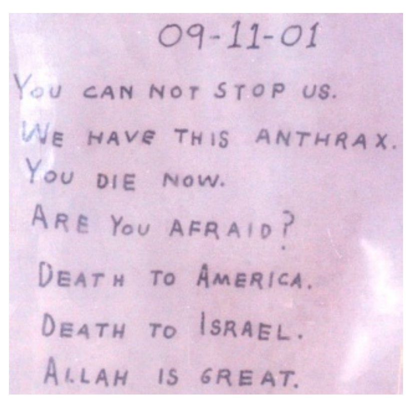
What happens in cases in which more than one kind of analysis must be done on the same item of evidence? Consider a handgun received into evidence from a shooting incident; it has red stains and possible fingerprints on it. This means that firearms testing, serology, latent print, and possibly DNA analysis must be performed on the handgun. These analyses should be put into an order such that one exam does not spoil or preclude the subsequent exam(s). In this case, the order should be first serology, then latent print, and finally firearms testing.

It is important to note that one seemingly small piece of evidence can be subjected to many examinations. Consider the example of a threatening letter, as depicted in **Figure 3.6**, one that supposedly contains anthrax or some other contagion. The envelope and the letter could be subjected to the following exams, in order:

- *Disease diagnosis*, to determine if it really contains the suspected contagion;
- *Trace evidence*, for hairs or fibers in the envelope or stuck to the adhesives (stamp, closure, tape used to seal it);
- *DNA*, from saliva on the stamp or the envelope closure;
- *Questioned documents*, for the paper, lettering, and other aspects of the form of the letter;
- *Ink analysis*, to determine what was used to write the message, address, etc.;
- *Handwriting, typewriter*, or *printer analysis*, as appropriate;
- *Latent fingerprints*;
- *Content analysis*, to evaluate the nature of the writer's intent and other investigative clues.

In this example, the ordering of the exams is crucial to ensure not only the integrity of the evidence, but also the safety of the scientists and their coworkers. Other evidence can also be very, very large—ocean currents, for example (see "In More Detail:

FIGURE 3.6 Even one small item of evidence can be subjected to multiple examinations and may travel through most of a forensic laboratory. A threat letter, like this one, could pass through bacterial diagnosis, trace evidence, DNA, questioned documents, latent print analysis, and content analysis. ©Yahoo News, with permission.



Rubber Duckys and Human Remains"). It is important to realize that *anything* can become evidence and forensic scientists must keep open minds if they are to solve the most difficult of crimes.

In More Detail: Rubber Duckies and Human Remains

In January 1992, a container ship en route from Hong Kong to America encountered a storm, and several containers broke free from their moorings and dropped into the water. At least one, containing 29,000 plastic bath toys, split open. Drifting at the whim of the wind and ocean currents, the ducks, along with red beavers, green frogs, and blue turtles, moved up the western coast of North America, crossed the waters of the North Pole, and headed toward the United Kingdom, as shown in **Figure 3.7**.

Oddly, very little is known about how winds and currents move drifting objects. Two scientists, Curtis Ebbesmeyer, an oceanographer in Seattle, and James Ingraham, a scientist at the National Marine Fisheries Service, carefully recorded each reported sighting of the plastic toys to better understand the phenomena. Beachcombers reported sightings of finds to http://beachcombersalert.org/, and the data were entered into Ingraham's ocean modeling program, OSCUR (**O**cean **S**urface **C**urrents **S**imulation). OSCUR uses air pressure metrics dating back to 1967 to calculate wind speed, direction, and surface currents. The floating toy finds helped the scientists to check and improve the performance of OSCUR.

Ebbesmeyer and Ingraham have tracked the journeys of everything from toy cars, balloons, ice hockey gloves, even five million pieces of Lego, all lost from ships over the years. They even processed data from 33,000 Nike shoes that fell off a ship near California. OSCUR estimated a landing for about 1,600 of the shoes (roughly 2% of the dunked shoes)—this is as accurate an estimate as that of oceanographers who deliberately release objects to measure currents.

But are cute bath toys and scientific ingenuity *forensic*? Using OCSCUR, Ebbesmeyer predicted the final resting place of George Karn, a crewman lost from the *Galaxy*, a freezer long-liner that caught Pacific cod with miles of baited hooks, which sunk in the Bering Sea in 2002. Starting from the location of the *Galaxy's* sinking, the model ran forward in time and came up with a location—an island 430 nautical miles southwest of the disaster. On June 9, 2003, while working at Portage Bite, a seldom-visited site on Tanaga Island far west in the Aleutians and 1,400 nautical miles due north of Hawaii's Midway Island, a beachcomber spotted a lower jawbone—the extensive dental work told him it was human. Upon subsequent search of the area, an orange survival suit was discovered. State troopers traced the suit's serial number to the *Galaxy*. Karn's body drifted in an unusual way, possibly

FIGURE 3.7 Calculated drifts of bathtub toys lost at sea. Even seemingly obscure information like this can be of use in solving crimes and finding victims. (C. Ebbesmeyer, with permission)

leading to his delayed discovery. The two calculated where Karn would have drifted if lost on the same day (October 20) of each year from 1967 to 2002. These drifts terminate after 3.5 months, the time interval between the disaster and Tanaga Island. All but 3 of the 36 drifts headed west toward Siberia, nearly the opposite direction of where Karn drifted. If George had perished in most years except 2002, he would have drifted west toward Kamchatka and then south into the wide North Pacific, never to be found.

Summary

Anything can be submitted for scientific analysis in an investigation, becoming the samples that yield data for forensic scientists to interpret. As evidence, however, these samples and data follow different rules than in other scientific, non-forensic laboratories. The context of the evidence is central to how it is analyzed and interpreted in the reconstruction of the criminal events. The scientific method still applies, however, and forensic scientists still employ that approach as do other non-forensic scientists. These differences and similarities will follow forensic scientists into the courtroom and either support, if done well, or weaken, if done poorly, the fruits of their scientific labors.

Test Your Knowledge

1. What is a "trier of fact"?
2. What is evidence?
3. Name four kinds of evidence.
4. What is exculpatory evidence?
5. What are "proxy data"?
6. How is direct transfer different from indirect transfer? Give an example.
7. What is persistence in relation to evidence?
8. Is contamination evidence? Why or why not?
9. What is class-level evidence?
10. What does it mean to identify something?
11. What is a "common source"?
12. If you have individualized two pieces of evidence, how many common sources could they have come from?
13. What is the difference between questioned and known evidence?
14. What is a control? How is it different from known evidence?
15. What is the probative value of an item of evidence?
16. What is the difference between a Type I and a Type II error?
17. What are the two hallmarks of science?
18. What is a cross-transfer?
19. Name three ways an association between a questioned and known item can be strengthened.
20. Name three ways an association between a questioned and known item can be weakened.

Consider This …

1. How do transfer and persistence relate? How would this relationship affect the collection of evidence? What would be the difference in processing a crime scene 1 hour after the crime and 48 hours afterward?
2. Why is context important to forensic science? How does this determine what evidence should be collected and analyzed?
3. Why is forensic science a historical science? Does this make it inferior to non-historical sciences? What are the limits of historical sciences?

Bibliography and Further Reading

Collins, HM, and Pinch, T (1998) *The Golem: What You Should Know About Science*, Cambridge University Press, Cambridge, UK.

Dawson, P, Han, I, Cox, M, Black, C, and Simmons, L (2007) Residence time and food contact time effects on transfer of *Salmonella typhimurium* from tile, wood and carpet: Testing the five second rule, *Journal of Applied Microbiology* 102: 945–953.

Goodstein, D (2000) How science works, in *Reference Manual on Scientific Evidence*, 2nd ed., Federal Judicial Center, Washington, DC, pp. 67–82.

Federal Judicial Center (2000) *Reference Manual on Scientific Evidence*, 2nd ed., Washington, DC.

Garner, BA (ed.) (2000) *Black's Law Dictionary*, 7th ed., West Group, St. Paul, MN.

Holman, R (2009) Many worlds in tiny grains, *Science* 323: 1291.

Klotter, J, and Ingram, JL (2003) *Criminal Evidence*, 8th ed., Anderson Publishing, Albany, NY.

Locard, E (1930) Analysis of dust traces, *American Journal of Police Science* 1(3): 276–298.

McGee, H (2007) The Five-Second Rule Explored, or How Dirty Is That Bologna? *New York Times* May 9, page F3.

Ou, C, Ciesielski, CA, Myers, G, Bandea, CI, Luo, C, Korber, BTM, Mullins, JI, Schochetman, G, Berkelman, RL, Economou, AN, Witte, JJ, Furman, LJ, Satten, GA, MacInnes, KA, Curran, JW, and Jaffe, HW (1992) Laboratory Investigation Group, Epidemiologic Investigation Group, "Molecular epidemiology of HIV transmission in a dental practice," *Science* 256: 1165–1171.

Pounds, CA, and Smalldon, KW (1975) The transfer of fibres between clothing materials during simulated contacts and their persistence during wear, Part II—fibre persistence, *Journal of the Forensic Science Society* 15: 29–37.

Rose, S, and Schlager, N (2003) *How Things Are Made: From Automobiles to Zippers*, Black Dog, London.

Schum, DA (1994) *Evidential Foundations of Probabilistic Reasoning*, John Wiley and Sons, New York.

Thornton, JI (1986) Ensembles of subclass characteristics in physical evidence examination, *Journal of Forensic Sciences* 31(2): 501–503.

Zobel, HB (1996) *The Boston Massacre*, W.W. Norton, New York City.