**chapter 14**

# Fingerprints

## Key Terms

anthropometry

arch

digital imaging

fluoresce

iodine fuming

latent fingerprint

livescan

loop

ninhydrin

Physical Developer

pixel

plastic print

portrait parlé

ridge characteristics (minutiae)

sublimation

Super Glue fuming

visible print

whorl

**Learning Objectives**

After studying this chapter you should be able to:

- Know the common ridge characteristics of a fingerprint
- List the three major fingerprint patterns and their respective subclasses
- Distinguish visible, plastic, and latent fingerprints
- Describe the concept of an automated fingerprint identification system (AFIS)
- List the techniques for developing latent fingerprints on porous and nonporous objects
- Describe the proper procedures for preserving a developed latent fingerprint

# James Earl Ray: Conspirator or Lone Gunman?

**Since his arrest in 1968 for the assassination of Dr. Martin Luther King, Jr., endless speculation has swirled around the motives and connections of James Earl Ray. Ray was a career criminal who was serving time for armed robbery when he escaped from the Missouri State Prison almost one year prior to the assassination. On April 3, 1968, Ray arrived in Memphis, Tennessee. The next day he rented a room at Bessie Brewer's Rooming House, which was situated across the street from the Lorraine Motel where Dr. King was staying.**

**At 6:00 P.M., Dr. King left his second-story motel room and stepped onto the balcony of the Lorraine Motel. As King turned toward his room, a shot rang out, striking the civil**

**rights activist. Nothing could be done to revive him and Dr. King was pronounced dead at 7:05 P.M. As the assailant ran on foot from Bessie Brewer's, he left a blanket-covered package in front of a nearby building and then drove off in a white Mustang. The package was later shown to contain a high-powered rifle equipped with a scope, a radio, some clothes, a pair of binoculars, a couple of beer cans, and a receipt for the binoculars. Almost a week after the shooting, the white Mustang was found abandoned in Atlanta, Georgia.**

**Fingerprints later identified as James Earl Ray's were found in the Mustang, on the rifle, on the binoculars, and on a beer can. In 1969, Ray entered a guilty plea in return for a sentence of ninety-nine years. While a variety of conspiracy theories surround this crime, the indisputable fact is that a fingerprint put the rifle that killed Martin Luther King, Jr., in the hands of James Earl Ray.**

## HISTORY OF FINGERPRINTING

Since the beginnings of criminal investigation, police have sought an infallible means of human identification. The first systematic attempt at personal identification was devised and introduced by a French police expert, Alphonse Bertillon, in 1883. The Bertillon system relied on a detailed description (**portrait parlé**) of the subject, combined with full-length and profile photographs and a system of precise body measurements known as **anthropometry**.

The use of anthropometry as a method of identification rested on the premise that the dimensions of the human bone system remained fixed from age 20 until death. Skeleton sizes were thought to be so extremely diverse that no two individuals could have exactly the same measurements. Bertillon recommended routine taking of eleven measurements of the human anatomy. These included height, reach, width of head, and length of the left foot (see Figure 1–1).

For two decades, this system was considered the most accurate method of identification. But in the first years of the new century, police began to appreciate and accept a system of identification based on the classification of finger ridge patterns known as *fingerprints*. Today, the fingerprint is the pillar of modern criminal identification.

Evidence exists that the Chinese used the fingerprint to sign legal documents as far back as three thousand years ago. However, whether this practice was performed for ceremonial custom or as a means of personal identity remains a point of conjecture lost to history. In any case, the examples of fingerprinting in ancient history are ambiguous, and the few that exist did not contribute to the development of fingerprinting techniques as we know them today.

Several years before Bertillon began work on his system, William Herschel, an English civil servant stationed in India, started the practice of requiring natives to sign contracts with the imprint of their right hand, which was pressed against a stamp pad for the purpose. The motives for Herschel's requirement remain unclear; he may have envisioned fingerprinting as a means of personal identification or just as a form of the Hindu custom that a trace of bodily contact was more binding than a signature on a contract. In any case, he did not publish anything about his activities until after a Scottish physician, Henry Fauld, working in a hospital in Japan, published his views on the potential application of fingerprinting to personal identification.

In 1880, Fauld suggested that skin ridge patterns could be important for the identification of criminals. He told about a thief who left his fingerprint on a whitewashed wall, and how in comparing these prints with those of a suspect, he found that they were quite different. A few days later another suspect was found whose fingerprints compared with those on the wall. When confronted with this evidence, the individual confessed to the crime.

Fauld was convinced that fingerprints furnished infallible proof of identification. He even offered to set up at his own expense a fingerprint bureau at Scotland Yard to test the practicality of the method. But his offer was rejected in favor of the Bertillon system. This decision was reversed less than two decades later.

The extensive research into fingerprinting conducted by another Englishman, Francis Galton, provided the needed impetus that made police agencies aware of its potential application. In 1892, Galton published his classic textbook *Finger Prints*, the first book of its kind on the subject. In his book, he discussed the anatomy of fingerprints and suggested methods for recording them. Galton also proposed assigning fingerprints to three pattern types—loops, arches, and whorls. Most important, the book demonstrated that no two prints were identical and that an individual's prints remained unchanged from year to year. At Galton's insistence, the British government adopted fingerprinting as a supplement to the Bertillon system.

The next step in the development of fingerprint technology was the creation of classification systems capable of filing thousands of prints in a logical and searchable sequence. Dr. Juan Vucetich, an Argentinian police officer fascinated by Galton's work, devised a workable concept in 1891. His classification system has been refined over the years and is still widely used today in most Spanish-speaking countries. In 1897, another classification system was proposed by an Englishman, Sir Edward Richard Henry. Four years later, Henry's system was adopted by Scotland Yard. Today, most English-speaking countries, including the United States, use some version of Henry's classification system to file fingerprints.

Early in the twentieth century, Bertillon's measurement system began to fall into disfavor. Its results were highly susceptible to error, particularly when the measurements were taken by people who were not thoroughly trained. The method was dealt its most severe and notable setback in 1903 when a convict, Will West, arrived at Fort Leavenworth prison. A routine check of the prison files startlingly revealed that a William West, already in the prison, could not be distinguished from the new prisoner by body measurements or even by photographs. In fact, the two men looked just like twins, and their measurements were practically the same. Subsequently, fingerprints of the prisoners clearly distinguished them.

In the United States, the first systematic and official use of fingerprints for personal identification was adopted by the New York City Civil Service Commission in 1901. The method was used for certifying all civil service applications. Several American police officials received instruction in fingerprint identification at the 1904 World's Fair in St. Louis from representatives of Scotland Yard. After the fair and the Will West incident, fingerprinting began to be used in earnest in all major cities of the United States. In 1924, the fingerprint records of the Bureau of Investigation and Leavenworth were merged to form the nucleus of the identification records of the new Federal Bureau of Investigation. The FBI has the largest collection of fingerprints in the world. By the beginning of World War I, England and practically all of Europe had adopted fingerprinting as their primary method of identifying criminals.

In 1999, the admissibility of fingerprint evidence was challenged in the case of *United States* v. *Byron C. Mitchell* in the Eastern District of Pennsylvania. The defendant's attorneys argued that fingerprints could not be proven unique under the guidelines cited in *Daubert* (see pp. 17–18). Government experts vigorously disputed this claim. After a four-and-a-half-day *Daubert* hearing, the judge upheld the admissibility of fingerprints as scientific evidence and ruled that (1) human friction ridges are unique and permanent and (2) human friction ridge skin arrangements are unique and permanent.

## FUNDAMENTAL PRINCIPLES OF FINGERPRINTS

### First Principle: A Fingerprint Is an Individual Characteristic; No Two Fingers Have Yet Been Found to Possess Identical Ridge Characteristics

The acceptance of fingerprint evidence by the courts has always been predicated on the assumption that no two individuals have identical fingerprints. Early fingerprint experts consistently referred to Galton's calculation, showing the possible existence of 64 billion different fingerprints, to support this contention. Later, researchers questioned the validity of Galton's figures and attempted to devise mathematical models to better approximate this value. However, no matter what mathematical model one refers to, the conclusions are always the same: The probability for the existence of two identical fingerprint patterns in the world's population is extremely small.

Not only is this principle supported by theoretical calculations, but just as important, it is verified by the millions of individuals who have had their prints classified during the past 110 years—no two have ever been found to be identical. The FBI has nearly 50 million fingerprint records in its computer database and has yet to find an identical image belonging to two different people.

The individuality of a fingerprint is not determined by its general shape or pattern but by a careful study of its **ridge characteristics** (also known as **minutiae**). The identity, number, and relative location of characteristics such as those illustrated in Figure 14–1 impart individuality to a fingerprint. If two prints are to match, they must reveal characteristics that not only are identical but have the same relative location to one another in a print. In a judicial proceeding, a point-by-point comparison must be demonstrated by the expert, using charts similar to the one shown in Figure 14–2, in order to prove the identity of an individual.

If an expert were asked to compare the characteristics of the complete fingerprint, no difficulty would be encountered in completing such an assignment; the average fingerprint has as many as 150 individual ridge characteristics. However, most prints recovered at crime scenes are partial impressions, showing only a segment of the entire print. Under these circumstances, the expert can compare only a small number of ridge characteristics from the recovered print to a known recorded print. For years, experts have debated how many ridge comparisons are necessary to identify two fingerprints as the same. Numbers that range from eight to sixteen have been suggested as being sufficient to meet the criteria of individuality. However, the difficulty in establishing such a minimum is that no comprehensive statistical study has ever been undertaken to determine the frequency of occurrence of different ridge characteristics and their relative locations. Until such a study is undertaken and completed, no meaningful guidelines can be established for defining the uniqueness of a fingerprint.

In 1973, the International Association for Identification, after a three-year study of this question, concluded that "no valid basis exists for requiring a predetermined minimum number of friction ridge characters which must be present in two impressions in order to establish positive identification." Hence, the final determination must be based on the experience and knowledge of the expert, with the understanding that others may profess honest differences of opinion on the uniqueness of a fingerprint if the question of minimal number of ridge characteristics exists. In 1995, members of the international fingerprint community at a conference in Israel issued the Ne'urim Declaration, which supported the 1973 International Association for Identification resolution.

## Second Principle: A Fingerprint Remains Unchanged During an Individual's Lifetime

Fingerprints are a reproduction of friction skin ridges found on the palm side of the fingers and thumbs. Similar friction skin can also be found on the surface of the palms and soles of the feet. Apparently, these skin surfaces have been designed by nature to provide our bodies with a firmer grasp and a resistance to slippage. A visual inspection of friction skin reveals a series of lines corresponding to hills (ridges) and valleys (grooves). The shape and form of the skin ridges are what one sees as the black lines of an inked fingerprint impression.

Actually, skin is composed of layers of cells. Those nearest the surface make up the outer portion of the skin known as the *epidermis,* and the inner skin is known as the *dermis*. A cross-section of skin (see Figure 14–3) reveals a boundary of cells separating the epidermis and dermis. The shape of this boundary, made up of *dermal papillae*, determines the form and pattern of the ridges on the surface of the skin. Once the dermal papillae develop in the human fetus, the ridge patterns remain unchanged throughout life except to enlarge during growth.

Each skin ridge is populated by a single row of pores that are the openings for ducts leading from the sweat glands. Through these pores, perspiration is discharged and deposited on the surface of the skin. Once the finger touches a surface, perspiration, along with oils that may have been picked up by touching the hairy portions of the body, is transferred onto that surface, thereby leaving an impression of the finger’s ridge pattern (a fingerprint). Prints deposited in this manner are invisible to the eye and are commonly referred to as **latent fingerprints**.

Although it is impossible to change one’s fingerprints, there has been no lack of effort on the part of some criminals to obscure them. If an injury reaches deeply enough into the skin and damages the dermal papillae, a permanent scar will form. However, for this to happen, such a wound would have to penetrate 1 to 2 millimeters beneath the skin’s surface. Indeed, efforts at intentionally scarring the skin can only be self-defeating, for it would be totally impossible to obliterate all of the ridge characteristics on the hand, and the presence of permanent scars merely provides new characteristics for identification.

Perhaps the most publicized attempt at obliteration was that of the notorious gangster John Dillinger, who tried to destroy his own fingerprints by applying a corrosive acid to them. Prints taken at the morgue after he was shot to death, compared with fingerprints recorded at the time of a previous arrest, proved that his efforts had been fruitless (see Figure 14–4).

### Third Principle: Fingerprints Have General Ridge Patterns That Permit Them to Be Systematically Classified

All fingerprints are divided into three classes on the basis of their general pattern: **loops, whorls,** and **arches**. Sixty to 65 percent of the population have loops, 30 to 35 percent have whorls, and about 5 percent have arches. These three classes form the basis for all ten-finger classification systems presently in use.

A typical loop pattern is illustrated in Figure 14–5. A loop must have one or more ridges entering from one side of the print, recurving, and exiting from the same side. If the loop opens toward the little finger, it is called an *ulnar loop;* if it opens toward the thumb, it is a *radial loop*. The pattern area of the loop is surrounded by two diverging ridges known as *type lines*. The ridge point at or nearest the type-line divergence and located at or directly in front of the point of divergence is known as the *delta*. To many, a fingerprint delta resembles the silt formation that builds up as a river flows into the entrance of a lake—hence, the analogy to the geological formation known as a delta. All loops must have one delta. The *core,* as the name suggests, is the approximate center of the pattern.

Whorls are actually divided into four distinct groups, as shown in Figure 14–6: plain, central pocket loop, double loop, and accidental. All whorl patterns must have type lines and at least two deltas. A plain whorl and a central pocket loop have at least one ridge that makes a complete circuit. This ridge may be in the form of a spiral, oval, or any variant of a circle. If an imaginary line drawn between the two deltas contained within these two patterns touches any one of the spiral ridges, the pattern is a plain whorl. If no such ridge is touched, the pattern is a central pocket loop.

As the name implies, the double loop is made up of two loops combined into one fingerprint. Any whorl classified as an accidental either contains two or more patterns (not including the plain arch) or is a pattern not covered by other categories. Hence, an accidental may consist of a combination loop and plain whorl or loop and tented arch.

Arches, the least common of the three general patterns, are subdivided into two distinct groups: plain arches and tented arches, as shown in Figure 14–7. The plain arch is the simplest of all fingerprint patterns; it is formed by ridges entering from one side of the print and exiting on the opposite side. Generally, these ridges tend to rise in the center of the pattern, forming a wavelike pattern. The tented arch is similar to the plain arch except that instead of rising smoothly at the center, there is a sharp upthrust or spike, or the ridges meet at an angle that is less than 90 degrees.[1] Arches do not have type lines, deltas, or cores.

With a knowledge of basic fingerprint pattern classes, we can now begin to develop an appreciation for fingerprint classification systems. However, the subject is far more complex than can be described in a textbook of this nature. The student seeking a more detailed treatment of the subject would do well to consult the references cited at the end of the chapter.

## CLASSIFICATION OF FINGERPRINTS

The original Henry system, as it was adopted by Scotland Yard in 1901, converted ridge patterns on all ten fingers into a series of letters and numbers arranged in the form of a fraction. However, the system as it was originally designed could accommodate files of up to only 100,000 sets of prints; thus, as collections grew in size, it became necessary to expand the capacity of the classification system. In the United States, the FBI, faced with the problem of filing ever-increasing numbers of prints, expanded its classification capacity by modifying and adding additional extensions to the original Henry system. These modifications are collectively known as the *FBI system* and are used by most agencies in the United States today.

### The Primary Classification

Although we will not discuss all of the different divisions of the FBI system, a description of just one part, the primary classification, will provide an interesting insight into the process of fingerprint classification.

The primary classification is part of the original Henry system and provides the first classification step in the FBI system. Using this classification alone, all of the fingerprint cards in the world could be divided into 1,024 groups. The first step in obtaining the primary classification is to pair up fingers, placing one finger in the numerator of a fraction, the other in the denominator. The fingers are paired in the following sequence:

$$\frac{\text{R. Index}}{\text{R. Thumb}} \; \frac{\text{R. Ring}}{\text{R. Middle}} \; \frac{\text{L. Thumb}}{\text{R. Little}} \; \frac{\text{L. Middle}}{\text{L. Index}} \; \frac{\text{L. Little}}{\text{L. Ring}}$$

The presence or absence of the whorl pattern is the basis for determination of the primary classification. If a whorl pattern is found on any finger of the first pair, it is assigned a value of 16; on the second pair, a value of 8; on the third pair, a value of 4; on the fourth pair, a value of

2; and on the last pair, a value of 1. Any finger with an arch or loop pattern is assigned a value of 0.

After values for all ten fingers are obtained in this manner, they are totaled, and 1 is added to both the numerator and denominator. The fraction thus obtained is the primary classification. For example, if the right index and right middle fingers are whorls and all the others are loops, the primary classification is

$$\frac{16+0+0+0+0+1}{0+8+0+0+0+1} = \frac{17}{8}$$

Approximately 25 percent of the population falls into the 1/1 category; that is, all their fingers have either loops or arches.

A fingerprint classification system cannot in itself unequivocally identify an individual; it merely provides the fingerprint examiner with a number of candidates, all of whom have an indistinguishable set of prints in the system’s file. The identification must always be made by a final visual comparison of the suspect print’s and file print’s ridge characteristics; only these features can impart individuality to a fingerprint. Although ridge patterns impart class characteristics to the print, the type and position of ridge characteristics give it its individual character.

## AUTOMATED FINGERPRINT IDENTIFICATION SYSTEMS

The Henry system and its subclassifications have proven to be a cumbersome system for storing, retrieving, and searching for fingerprints, particularly as fingerprint collections grow in size. Nevertheless, until the emergence of fingerprint computer technology, this manual approach was the only viable method for the maintenance of fingerprint collections. Since 1970, technological advances have made possible the classification and retrieval of fingerprints by computers. Automated Fingerprint Identification Systems (AFISs) have proliferated throughout the law enforcement community. In 1999, the FBI initiated full operation of the Integrated Automated Fingerprint Identification System (IAFIS), the largest AFIS in the United States, which links state AFIS computers with the FBI database. This database contains nearly 50 million fingerprint records. However, an AFIS can come in all sizes ranging from the FBI's to independent systems operated by cities, counties, and other agencies of local government. Unfortunately, these local systems often are not linked to the state's AFIS system due to differences in software configurations.

The heart of AFIS technology is the ability of a computer to scan and digitally encode fingerprints so that they can be subject to high-speed computer processing. **The AFIS uses automatic scanning devices that convert the image of a fingerprint into digital minutiae that contain data showing ridges at their points of termination (ridge endings) and the branching of ridges into two ridges (bifurcations).** The relative position and orientation of the minutiae are also determined, allowing the computer to store each fingerprint in the form of a digitally recorded geometric pattern. The computer's search algorithm determines the degree of correlation between the location and relationship of the minutiae for both the search and file prints. In this manner, a computer can make thousands of fingerprint comparisons in a second; for example, a set of ten fingerprints can be searched against a file of 500,000 ten-finger prints (tenprints) in about eight-tenths of a second. During the search for a match, the computer uses a scoring system that assigns prints to each of the criteria set by an operator. When the search is complete, the computer produces a list of file prints that have the closest correlation to the search prints. All of the selected prints are then examined by a trained fingerprint expert, who makes the final verification of the print's identity. Thus, the AFIS makes no final decisions on the identity of a fingerprint, leaving this function to the eyes of a trained examiner.

The speed and accuracy of ten-print processing by AFIS have made possible the search of single latent crime-scene fingerprints against an entire file's print collection. Prior to the AFIS, police were usually restricted to comparing crime-scene fingerprints against those of known suspects. The impact of the AFIS on no-suspect cases has been dramatic. Minutes after California's AFIS network received its first assignment, the computer scored a direct hit by identifying an individual who had committed fifteen murders, terrorizing the city of Los Angeles. Police estimate that it would have taken a single technician, manually searching the city's 1.7 million print cards, sixty-seven years to come up with the perpetrator's prints. With the AFIS, the search took approximately twenty minutes. In its first year of operation, San Francisco's AFIS computer conducted 5,514 latent fingerprint searches and achieved 1,001 identifications—a hit rate of 18 percent. This compares to the previous year's average of 8 percent for manual latent print searches.

As an example of how an AFIS computer operates, one system has been designed to automatically filter out imperfections in a latent print, enhance its image, and create a graphic representation of the fingerprint's ridge endings and bifurcations and their direction. The print is then computer searched against file prints. The image of the latent print and a matching file print are then displayed side by side on a high-resolution video monitor as shown in Figure 14–8. The matching latent and file prints are then verified and charted by a fingerprint examiner at a video workstation.

AFIS has fundamentally changed the way criminal investigators operate, allowing them to spend less time developing suspect lists and more time investigating the suspects generated by the computer. However, investigators must be cautioned against overreliance on a computer. Sometimes a latent print does not make a hit because of the poor quality of the file print. To avoid these potential problems, investigators must still print all known suspects in a case and manually search these prints against the crime-scene prints.

AFIS computers are available from several different suppliers. Each system scans fingerprint images and detects and records information about minutiae (ridge endings and bifurcations); however, they do not all incorporate exactly the same features, coordinate systems, or units of measure to record fingerprint information. These software incompatibilities often mean that, although state systems can communicate with the FBI's IAFIS, they may not communicate with each other directly. Likewise, local and state systems frequently cannot share information with each other. Many of these technical problems will be resolved as more agencies follow transmission standards developed by the National Institute of Standards and Technology and the FBI.

The sterotypical image of a booking officer rolling inked fingers onto a standard ten-print card for ultimate transmission to a database has, for the most part, been replaced with digital-capture devices (**livescan**) that eliminate ink and paper. The livescan captures the image on each finger and the palms as they are lightly pressed against a glass platen. These livescan images can then be sent to the AFIS database electronically, so that within minutes the booking agency can enter the fingerprint record into the AFIS database and search the database for previous entries of the same individual. See Figure 14–9.

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## Forensics at Work

### The Mayfield Affair

On March 11, 2004, a series of ten explosions at four sites occurred on commuter trains traveling to or near the Atocha train station in Madrid, Spain. The death toll from these explosions was nearly 200, with more than 1,500 injured. On the day of the attack, a plastic bag was found in a van previously reported as stolen. The bag contained copper detonators like those used on the train bombs. On March 17 the FBI received electronic images of latent fingerprints that were recovered from the plastic bag. A search was initiated on the FBI's IAFIS. A senior fingerprint examiner encoded seven minutiae points from the high-resolution image of one suspect latent fingerprint and initiated an IAFIS search matching the print to Brandon Mayfield.

Mayfield's prints were in the FBI's central database because they had been taken when he joined the military, where he served for eight years before being honorably discharged as a second lieutenant. After a visual comparison of the suspect and file prints, the examiner concluded a "100 percent match." The identification was verified by a retired FBI fingerprint examiner with more than thirty years of experience who was under contract with the bureau, as well as by a court-appointed independent fingerprint examiner (see Figure 14–10).

Mayfield, age 37, a Muslim convert, was arrested on May 6 on a material witness warrant. The U.S. Attorney's Office came up with a list of Mayfield's potential ties to Muslim terrorists, which they included in the affidavit they presented to the federal judge who ordered his arrest and detention. The document also said that while no travel records were found for Mayfield, "It is believed that Mayfield may have traveled under a false or fictitious name." On May 24, after the Spaniards had linked the print from the plastic bag to an Algerian national, Mayfield's case was thrown out. The FBI issued him a highly unusual official apology, and his ordeal became a stunning embarrassment to the United States government.

As part of its corrective-action process, the FBI formed an international committee of distinguished latent-print examiners and forensic experts. Their task was to review the analysis performed by the FBI Laboratory and make recommendations that would help prevent this type of error in the future. The committee came up with some startling findings and observations (available at *http://www.fbi.gov/hq/lab/fsc/ backissu/jan2005/special_report/2005_ special_report.htm)*.

The committee members agreed that "the quality of the images that were used to make the erroneous identification was not a factor…. the identification is filled with dissimilarities that were easily observed when a detailed analysis of the latent print was conducted."

They further stated,

> the power of the IAFIS match, coupled with the inherent pressure of working an extremely high-profile case, was thought to have influenced the initial examiner's judgment and subsequent examination…. The apparent mindset of the initial examiner after reviewing the results of the IAFIS search was that a match did exist; therefore, it would be reasonable to assume that the other characteristics must match as well. In the absence of a detailed analysis of the print, it can be a short distance from finding only seven characteristics sufficient for plotting, prior to the automated search, to the position of 12 or 13 matching characteristics once the mind-set of identification has become dominant….
>
> Once the mind-set occurred with the initial examiner, the subsequent examinations were tainted…. because of the inherent pressure of such a high-profile case, the power of an IAFIS match in conjunction with the similarities in the candidate's print, and the knowledge of the previous examiners' conclusions (especially since the initial examiner was a highly respected supervisor with many years of experience), it was concluded that subsequent examinations were incomplete and inaccurate. To disagree was not an expected response…. when the individualization had been made by the examiner, it became

increasingly difficult for others in the agency to disagree.

The committee went on to make a number of quality-assurance recommendations to help avoid a recurrence of this type of error.

The Mayfield incident has also been the subject of an investigation by the Office of the Inspector General (OIG), U.S. Department of Justice (*http://www.usdoj.gov/oig/special/s0601/final.pdf*). The OIG investigation concluded that a "series of systemic issues" in the FBI Laboratory contributed to the Mayfield misidentification. The report noted that the FBI has made significant procedural modifications to help prevent similar errors in the future, and strongly supported the FBI's decision to undertake research to develop more objective standards for fingerprint identification.

An internal review of the FBI Latent Print Unit conducted in the aftermath of the Mayfield affair has resulted in the implementation of revisions in training, as well as in the decision-making process when determining the comparative value of a latent print, along with more stringent verification policies and procedures (Smrz, M.A., et al., *J.Forensic Identification, 56*, 402–34, 2006).

The impact of the Mayfield affair on fingerprint technology as currently practiced and the weight courts will assign to fingerprint matches remain open questions.

## METHODS OF DETECTING FINGERPRINTS

Through common usage, the term *latent fingerprint* has come to be associated with any fingerprint discovered at a crime scene. Sometimes, however, prints found at the scene of a crime are quite visible to the eye, and the word *latent* is a misnomer. Actually, there are three kinds of crime-scene prints: **Visible prints** are made by fingers touching a surface after the ridges have been in contact with a colored material such as blood, paint, grease, or ink; **plastic prints** are ridge impressions left on a soft material such as putty, wax, soap, or dust; and *latent* or *invisible prints* are impressions caused by the transfer of body perspiration or oils present on finger ridges to the surface of an object.

Locating visible or plastic prints at the crime scene normally presents little problem to the investigator, because these prints are usually distinct and visible to the eye. Locating latent or invisible prints is obviously much more difficult and requires the use of techniques to make the print visible. Although the investigator can choose from several methods for visualizing a latent print, the choice depends on the type of surface being examined.

Hard and nonabsorbent surfaces (such as glass, mirror, tile, and painted wood) require different development procedures from surfaces that are soft and porous (such as papers, cardboard, and cloth). Prints on the former are preferably developed by the application of a powder or treatment with Super Glue, whereas prints on the latter generally require treatment with one or more chemicals.

Sometimes the most difficult aspect of fingerprint examination is the location of prints. Recent advances in fingerprint technology have led to the development of an ultraviolet image converter for the purpose of detecting latent fingerprints. This device, called the Reflected Ultraviolet Imaging System (RUVIS), can locate prints on most nonabsorbent surfaces without the aid of chemical or powder treatments (see Figure 14–11). RUVIS detects the print in its natural state by aiming UV light at the surface suspected of containing prints. When the UV light strikes the fingerprint, the light is reflected back to the viewer, differentiating the print from its background surface. The transmitted UV light is then converted into visible light by an image intensifier. Once located in this manner, the crime-scene investigator can develop the print in the most appropriate fashion. See Figure 14–12.

Fingerprint powders are commercially available in a variety of compositions and colors. These powders, when applied lightly to a nonabsorbent surface with a camel's-hair or fiberglass brush, readily adhere to perspiration residues and/or deposits of body oils left on the surface (see Figure 14–13). Experienced examiners find that gray and black powders are adequate for most latent-print work; the examiner selects the powder that affords the best color contrast with the surface being dusted. Hence, the gray powder, composed of an aluminum dust, is used on dark-colored surfaces. It is also applied to mirrors and metal surfaces that are polished to a mirrorlike finish, because these surfaces photograph as black. The black powder, composed basically of black carbon or charcoal, is applied to white or light-colored surfaces.

Other types of powders are available for developing latent prints. A magnetic-sensitive powder can be spread over a surface with a magnet in the form of a Magna Brush. A Magna Brush does not have any bristles to come in contact with the surface, so there is less chance that the print will be destroyed or damaged. The magnetic-sensitive powder comes in black and gray and is especially useful on such items as finished leather and rough plastics, where the minute texture of the surface tends to hold particles of ordinary powder. Fluorescent powders are also used to develop latent fingerprints. These powders fluoresce under ultraviolet light. By photographing the fluorescence pattern of the developing print under UV light, it is possible to avoid having the color of the surface obscure the print.

Of the several chemical methods used for visualizing latent prints, **iodine fuming** is the oldest. Iodine is a solid crystal that, when heated, is transformed into a vapor without passing through a liquid phase; such a transformation is called **sublimation**. Most often, the suspect material is placed in an enclosed cabinet along with iodine crystals (see Figure 14–14). As the crystals are heated, the resultant vapors fill the chamber and combine with constituents of the latent print to make it visible. The reasons why latent prints are visualized by iodine vapors are not yet fully understood. Many believe that the iodine fumes combine with fatty oils; however, there is also convincing evidence that the iodine may actually interact with residual water left on a print from perspiration.[2] Unfortunately, iodine prints are not permanent and begin to fade once the fuming process is stopped. Therefore, the examiner must photograph the prints immediately on development in order to retain a permanent record. Also, iodine-developed prints can be fixed with a 1 percent solution of starch in water, applied by spraying. The print turns blue and lasts for several weeks to several months.

Another chemical used for visualizing latent prints is **ninhydrin.** The development of latent prints with ninhydrin depends on its chemical reaction to form a purple-blue color with amino acids present in trace amounts in perspiration. Ninhydrin (triketohydrindene hydrate) is commonly sprayed onto the porous surface from an aerosol can. A solution is prepared by mixing the ninhydrin powder with a suitable solvent, such as acetone or ethyl alcohol; a 0.6 percent solution appears to be effective for most applications. Generally, prints begin to appear within an hour or two after ninhydrin application; however, weaker prints may be visualized after twenty-four to forty-eight hours. The development can be hastened if the treated specimen is heated in an oven or on a hot plate at a temperature of 80–100°C. The ninhydrin method has developed latent prints on paper as old as fifteen years.

**Physical Developer** is a third chemical mixture used for visualizing latent prints. Physical Developer is a silver nitrate–based liquid reagent. The procedure for preparing and using Physical Developer is described in Appendix IV. This method has gained wide acceptance by fingerprint examiners, who have found it effective for visualizing latent prints that remain undetected by the previously described methods. Also, this technique is very effective for developing latent fingerprints on porous articles that may have been wet at one time.

For most fingerprint examiners, the chemical method of choice is ninhydrin. Its extreme sensitivity and ease of application have all but eliminated the use of iodine for latent-print visualization. However, when ninhydrin fails, development with Physical Developer may provide identifiable results. Application of Physical Developer washes away any traces of proteins from an object's surface; **hence, if one wishes to use all of the previously mentioned chemical development methods on the same surface, it is necessary to first fume with iodine, follow this treatment with ninhydrin, and then apply Physical Developer to the object.**

In the past, chemical treatment for fingerprint development was reserved for porous surfaces such as paper and cardboard. However, since 1982, a chemical technique known as **Super Glue fuming** has gained wide popularity for developing latent prints on nonporous surfaces such as metals, electrical tape, leather, and plastic bags.[3] See Figure 14–15. Super Glue is approximately 98–99 percent cyanoacrylate ester, a chemical that actually interacts with and visualizes a latent fingerprint. Cyanoacrylate ester fumes can be created when Super Glue is placed on absorbent cotton treated with sodium hydroxide. The fumes can also be created by heating the glue. The fumes and the evidential object are contained within an enclosed chamber for up to six hours. Development occurs when fumes from the glue adhere to the latent print, usually producing a white-appearing latent print. Interestingly, small enclosed areas, such as the interior of an automobile, have been successfully processed for latent prints with fumes from Super Glue. Through the use of a small handheld wand, cyanoacrylate fuming is now easily done at a crime scene or in a laboratory setting. The wand heats a small cartridge containing cyanoacrylate. Once heated, the cyanoacrylate vaporizes, allowing the operator to direct the fumes onto the suspect area (see

Figure 14–16).

One of the most exciting and dynamic areas of research in forensic science today is the application of chemical techniques to the visualization of latent fingerprints. Changes are occurring very rapidly as researchers uncover a variety of processes applicable to the visualization of latent fingerprints. Interestingly, for many years progress in this field was minimal, and fingerprint specialists traditionally relied on three chemical techniques—iodine, ninhydrin, and silver nitrate—to reveal a hidden fingerprint. Then Super Glue fuming extended chemical development to prints deposited on nonporous surfaces. The first hint of things to come was the discovery that latent fingerprints could be visualized by exposure to laser light. This laser method took advantage of the fact that perspiration contains a variety of components that **fluoresce** when illuminated by laser light. Fluorescence occurs when a substance absorbs light and reemits the light in wavelengths longer than the illuminating source. Importantly, substances that emit light or fluoresce are more readily seen with either the naked eye or through photography than are non-light-emitting materials. The high sensitivity of fluorescence serves as the underlying principle of many of the new chemical techniques used to visualize latent fingerprints.

The earliest use of fluorescence to visualize fingerprints came with the direct illumination of a fingerprint with argon–ion lasers. This laser type was chosen because its blue-green light output induced some of the perspiration components of a fingerprint to fluoresce (see Figure 14–17). The major drawback of this approach is that the perspiration components of a fingerprint are often present in quantities too minute to observe even with the aid of fluorescence. The fingerprint examiner, wearing safety goggles containing optical filters, visually examines the specimen being exposed to the laser light. The filters absorb the laser light and permit the wavelengths at which latent-print residues fluoresce to pass through to the eyes of the wearer. The filter also protects the operator against eye damage from scattered or reflected laser light. Likewise, latent-print residue producing sufficient fluorescence can be photographed by placing this same filter across the lens of the camera. Examination of specimens and photography of the fluorescing latent prints are carried out in a darkened room.

The next advancement in latent-fingerprint development occurred with the discovery that fingerprints could be treated with chemicals that would induce fluorescence when exposed to laser illumination. For example, the application of zinc chloride after ninhydrin treatment or the application of the dye rhodamine 6G after Super Glue fuming caused fluorescence and increased the sensitivity of detection on exposure to laser illumination. The discovery of numerous chemical developers for visualizing fingerprints through fluorescence quickly followed. This knowledge set the stage for the next advance in latent-fingerprint development—the *alternate light source*.

With the advent of chemically induced fluorescence, lasers were no longer needed to induce fingerprints to fluoresce through their perspiration residues. High-intensity light sources or alternate light sources have proliferated and all but replaced laser lights. See Figure 14–18. High-intensity quartz halogen or xenon-arc light sources can be focused on a suspect area through a fiber-optic cable. This light can be passed through several filters, giving the user more flexibility in selecting the wavelength of light to be aimed at the latent print. Alternatively, lightweight, portable alternate light sources that use light-emitting diodes (LEDs) are also commercially available (see Figure 14–19). In most cases, these light sources have proven to be as effective as laser light in developing latent prints, and they are commercially available at costs significantly below those of laser illuminators. Furthermore, these light sources are portable and can be readily taken to any crime scene.

A large number of chemical treatment processes are available to the fingerprint examiner (see Figure 14–20), and the field is in a constant state of flux. Selection of an appropriate procedure is best left to technicians who have developed their skills through casework experience. Newer chemical processes include a substitute for ninhydrin called DFO (1,8-diazafluoren-9-one). This chemical visualizes latent prints on porous materials when exposed to an alternate light source. DFO has been shown to develop 2.5 times more latent prints on paper than ninhydrin. 1,2-indanedione is also emerging as a potential reagent for the development of latent fingerprints on porous surfaces. 1,2-indanedione gives both good initial color and strong fluorescence when reacted with amino acids derived from prints and thus has the potential to provide in one process what ninhydrin and DFO can do in two different steps. Dye combinations known as RAM, RAY, and MRM 10 when used in conjunction with Super Glue fuming have been effective in visualizing latent fingerprints by fluorescence. A number of chemical formulas useful for latent-print development are listed in Appendix IV.

Studies have demonstrated that common fingerprint-developing agents do not interfere with DNA-testing methods used for characterizing bloodstains.[4] Nonetheless, in cases involving items with material adhering to their surfaces and/or items that will require further laboratory examinations, fingerprint processing should not be performed at the crime scene. Rather, the items should be submitted to the laboratory, where they can be processed for fingerprints in conjunction with other necessary examinations.

## PRESERVATION OF DEVELOPED PRINTS

Once the latent print has been visualized, it must be permanently preserved for future comparison and possible use in court as evidence. A photograph must be taken before any further attempts at preservation. Any camera equipped with a close-up lens will do; however, many investigators prefer to use a camera specially designed for fingerprint photography. Such a camera comes equipped with a fixed focus to take photographs on a 1:1 scale when the camera's open eye is held exactly flush against the print's surface (see Figure 14–21). In addition, photographs must be taken to provide an overall view of the print's location with respect to other evidential items at the crime scene.

Once photographs have been secured, one of two procedures is to be followed. If the object is small enough to be transported without destroying the print, it should be preserved in its entirety; the print should be covered with cellophane so it will be protected from damage. On the other hand, prints on large immovable objects that have been developed with a powder can best be preserved by "lifting." The most popular type of lifter is a broad adhesive tape similar to clear adhesive tape. When the powdered surface is covered with the adhesive side of the tape and pulled up, the powder is transferred to the tape. Then the tape is placed on a properly labeled card that provides a good background contrast with the powder.

A variation of this procedure is the use of an adhesive-backed clear plastic sheet attached to a colored cardboard backing. Before it is applied to the print, a celluloid separator is peeled from the plastic sheet to expose the adhesive lifting surface. The tape is then pressed evenly and firmly over the powdered print and pulled up (see Figure 14–22). The sheet containing the adhering powder is now pressed against the cardboard backing to provide a permanent record of the fingerprint.

## DIGITAL IMAGING FOR FINGERPRINT ENHANCEMENT

When fingerprints are lifted from a crime scene, they are not usually in perfect condition, making the analysis that much more difficult. Computers have advanced technology in most fields, and fingerprint identification has not been left behind. With the help of digital imaging software, fingerprints can now be enhanced for the most accurate and comprehensive analysis.

**Digital imaging** is the process by which a picture is converted into a digital file. The image produced from this digital file is composed of numerous square electronic dots called **pixels.** Images composed of only black and white elements are referred to as *grayscale images*. Each pixel is assigned a number according to its intensity. The grayscale image is made from the set of numbers to which a pixel may be assigned, ranging from 0 (black) to 255 (white). Once an image is digitally stored, it is manipulated by computer software that changes the numerical value of each pixel, thus altering the image as directed by the user. *Resolution* reveals the degree of detail that can be seen in an image. It is defined in terms of dimensions, such as 800 × 600 pixels. The larger the numbers, the more closely the digital image resembles the real-world image.

The input of pictures into a digital imaging system is usually done through the use of scanners, digital cameras, and video cameras. After the picture is changed to its digital image, several methods can be employed to enhance the image. The overall brightness of an image, as well as the contrast between the image and the background, can be adjusted through contrast-enhancement methods. One approach used to enhance an image is *spatial filtering*. Several types of filters produce various effects. A low-pass filter is used to eliminate harsh edges by reducing the intensity difference between pixels. A second filter, the high-pass filter, operates by modifying a pixel's numerical value to exaggerate its intensity difference from that of its neighbor. The resulting effect increases the contrast of the edges, thus providing a high contrast between the elements and the background. Frequency analysis, also referred to as *frequency Fourier transform* (FFT), is used to identify periodic or repetitive patterns such as lines or dots that interfere with the interpretation of the image. These patterns are diminished or eliminated to enhance the appearance of the image. Interestingly, the spacings between fingerprint ridges are themselves periodic. Therefore, the contribution of the fingerprint can be identified in FFT mode and then enhanced. Likewise, if ridges from overlapping prints are positioned in different directions, their corresponding frequency information is at different locations in FFT mode. The ridges of one latent print can then be enhanced while the ridges of the other are suppressed.

Color interferences also pose a problem when analyzing an image. For example, a latent fingerprint found on paper currency or a check may be difficult to analyze because of the distracting colored background. With the imaging software, the colored background can simply be removed to make the image stand out (see Figure 14–23). If the image itself is a particular color, such as a ninhydrin-developed print, the color can be isolated and enhanced to distinguish it from the background.

Digital imaging software also provides functions in which portions of the image can be examined individually. With a scaling and resizing tool, the user can select a part of an image and resize it for a closer look. This function operates much like a magnifying glass, helping the examiner view fine details of an image.

An important and useful tool, especially for fingerprint identification, is the compare function. This specialized feature places two images side by side and allows the examiner to chart the common features on both images simultaneously (see Figure 14–24). The zoom function is used in conjunction with the compare tool. As the examiner zooms into a portion of one image, the software automatically zooms into the second image for comparison.

Although digital imaging is undoubtedly an effective tool for enhancing and analyzing images, it is only as useful as the images it has to work with. If the details do not exist on the original images, the enhancement procedures are not going to work. The benefits of digital enhancement methods are apparent when weak images are made more distinguishable.

## Chapter Summary

Fingerprints are a reproduction of friction skin ridges found on the palm side of the fingers and thumbs. The basic principles underlying the use of fingerprints in criminal investigations are that (1) a fingerprint is an individual characteristic because no two fingers have yet been found to possess identical ridge characteristics; (2) a fingerprint remains unchanged during an individual's lifetime; and (3) fingerprints have general ridge patterns that permit them to be systematically classified. All fingerprints are divided into three classes on the basis of their general pattern: loops, whorls, and arches. Fingerprint classification systems are based on knowledge of fingerprint pattern classes. The individuality of a fingerprint is not determined by its general shape or pattern, but by a careful study of its ridge characteristics. The expert must demonstrate a point-by-point comparison in order to prove the identity of an individual. AFIS aids this process by converting the image of a fingerprint into digital minutiae that contain data showing ridges at their points of termination (ridge endings) and their branching into two ridges (bifurcations). A single fingerprint can be searched against the FBI AFIS digital database of 50 million fingerprint records in a matter of minutes.

Once the finger touches a surface, perspiration, along with oils that may have been picked up by touching the hairy portions of the body, is transferred onto that surface, thereby leaving an impression of the finger's ridge pattern (a fingerprint). Prints deposited in this manner are invisible to the eye and are commonly referred to as latent or invisible fingerprints.

Visible prints are made when fingers touch a surface after the ridges have been in contact with a colored material such as blood, paint, grease, or ink. Plastic prints are ridge impressions left on a soft material, such as putty, wax, soap, or dust. Latent prints deposited on hard and non-absorbent surfaces (such as glass, mirror, tile, and painted wood) are preferably developed by the application of a powder; prints on porous surfaces (such as paper and cardboard) generally require treatment with a chemical. Examiners use various chemical methods to visualize latent prints, such as iodine fuming, ninhydrin, and Physical Developer. Super Glue fuming develops latent prints on nonporous surfaces, such as metals, electrical tape, leather, and plastic bags. Development occurs when fumes from the glue adhere to the print, usually producing a white latent print.

The high sensitivity of fluorescence serves as the underlying principle of many of the new chemical techniques used to visualize latent fingerprints. Fingerprints are treated with chemicals that induce fluorescence when exposed to a high-intensity light or an alternate light source.

Once the latent print has been visualized, it must be permanently preserved for future comparison and for possible use as court evidence. A photograph must be taken before any further attempts at preservation are made. If the object is small enough to be transported without destroying the print, it should be preserved in its entirety. Prints on large immovable objects that have been developed with a powder are best preserved by "lifting" with a broad adhesive tape.

## Review Questions

1. The first systematic attempt at personal identification was devised and introduced by ___________.

2. A system of identification relying on precise body measurements is known as ___________.

3. The fingerprint classification system used in most English-speaking countries was devised by ___________.

4. True or False: The first systematic and official use of fingerprints for personal identification in the United States was adopted by the New York City Civil Service Commission. ___________

5. The individuality of a fingerprint (is, is not) determined by its pattern.

6. A point-by-point comparison of a fingerprint's ___________ must be demonstrated in order to prove identity.

7. ___________ are a reproduction of friction skin ridges.

8. The form and pattern of skin ridges are determined by the (epidermis, dermal papillae).

9. A permanent scar forms in the skin only when an injury damages the ___________.

10. Fingerprints (can, cannot) be changed during a person's lifetime.

11. The three general patterns into which fingerprints are divided are ___________, ___________, and ___________.

12. The most common fingerprint pattern is the ___________.

13. Approximately 5 percent of the population has the ___________ fingerprint pattern.

14. A loop pattern that opens toward the thumb is known as a(n) (radial, ulnar) loop.

15. The pattern area of the loop is enclosed by two diverging ridges known as ___________.

16. The ridge point nearest the type-line divergence is known as the ___________.

17. All loops must have (one, two) delta(s).

18. The approximate center of a loop pattern is called the ___________.

19. If an imaginary line drawn between the two deltas of a whorl pattern touches any of the spiral ridges, the pattern is classified as a (plain whorl, central pocket loop).

20. The simplest of all fingerprint patterns is the ___________.

21. Arches (have, do not have) type lines, deltas, and cores.

22. The presence or absence of the ___________ pattern is used as a basis for determining the primary classification in the Henry system.

23. The largest category (25 percent) in the primary classification system is (1/1, 1/2).

24. A fingerprint classification system (can, cannot) unequivocally identify an individual.

25. True or False: Computerized fingerprint search systems match prints by comparing the position of bifurcations and ridge endings. ___________

26. A fingerprint left by a person with soiled or stained fingertips is called a ___________.

27. ___________ fingerprints are impressions left on a soft material.

28. Fingerprint impressions that are not readily visible are called ___________.

29. Fingerprints on hard and nonabsorbent surfaces are best developed by the application of a(n) ___________.

30. Fingerprints on porous surfaces are best developed with ___________ treatment.

31. ___________ vapors chemically combine with fatty oils or residual water to visualize a fingerprint.

32. The chemical ___________ visualizes fingerprints by its reaction with amino acids.

33. Chemical treatment with ___________ visualizes fingerprints on porous articles that may have been wet at one time.

34. True or False: A latent fingerprint is first treated with Physical Developer followed by ninhydrin. ___________

35. A chemical technique known as ___________ is used to develop latent prints on nonporous surfaces such as metal and plastic.

36. ___________ occurs when a substance absorbs light and reemits the light in wavelengths longer than the illuminating source.

37. High-intensity light sources known as ___________ are effective in developing latent fingerprints.

38. Once a fingerprint has been visualized, it must be preserved by ___________.

39. The image produced from a digital file is composed of numerous square electronic dots called ___________.

40. A (high-pass filter, frequency Fourier transform analysis) is used to identify repetitive patterns such as lines or dots that interfere with the interpretation of a digitized fingerprint image.

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**Portrait Parlé**

A verbal description of a perpetrator's physical characteristics and dress provided by an eyewitness.

**Anthropometry**

A system of identification of individuals by measurement of parts of the body, developed by Alphonse Bertillon.

**Ridge Characteristics (Minutiae)**

Ridge endings, bifurcations, enclosures, and other ridge details, which must match in two fingerprints in order for their common origin to be established.

**Latent Fingerprint**

A fingerprint made by the deposit of oils and/or perspiration. It is invisible to the naked eye.

**Loop**

A class of fingerprints characterized by ridge lines that enter from one side of the pattern and curve around to exit from the same side of the pattern.

**Whorl**

A class of fingerprints that includes ridge patterns that are generally rounded or circular in shape and have two deltas.

**Arch**

A class of fingerprints characterized by ridge lines that enter the print from one side and flow out the other side.

**Livescan**

An inkless device that captures the digital images of fingerprints and palm prints and electronically transmits the images to an AFIS.

**Visible Print**

A fingerprint made when the finger deposits a visible material such as ink, dirt, or blood onto a surface.

**Plastic Print**

A fingerprint impressed in a soft surface.

**Iodine Fuming**

A technique for visualizing latent fingerprints by exposing them to iodine vapors.

**Sublimation**

A physical change from the solid directly into the gaseous state.

**Ninhydrin**

A chemical reagent used to develop latent fingerprints on porous materials by reacting with amino acids in perspiration.

**Physical Developer**

A silver nitrate–based reagent formulated to develop latent fingerprints on porous surfaces.

**Super Glue Fuming**

A technique for visualizing latent fingerprints on nonporous surfaces by exposing them to cyanoacrylate vapors; named for the commercial product Super Glue.

**Fluoresce**

To emit visible light when exposed to light of a shorter wavelength.

**Digital Imaging**

A process through which a picture is converted into a series of square electronic dots known as pixels. The picture is manipulated by computer software that changes the numerical value of each pixel.

**Pixel**

A square electronic dot that is used to compose a digital image.

**Figure 14–1 Fingerprint ridge characteristics.** *Courtesy Sirchie Finger Print Laboratories, Inc., Youngsville, N.C., www.sirchie.com*

**Figure 14–2 A fingerprint exhibit illustrating the matching ridge characteristics between the crime-scene print and an inked impression of one of the suspect's fingers.** *Courtesy New Jersey State Police.*

**Figure 14–3 Cross-section of human skin.**

**Figure 14–4  The right index finger impression of John Dillinger, before scarification on the left and afterward on the right. Comparison is proved by the fourteen matching ridge characteristics.** *Courtesy Institute of Applied Science, Youngsville, N.C.*

**Figure 14–5  Loop pattern.**

**Figure 14–6  Whorl patterns.**

**Figure 14–7  Arch patterns.**

**Figure 14–8  A side-by-side comparison of a latent print against a file fingerprint is conducted in seconds and their similairity rating (SIM) is displayed on the upper-left portion of the screen.** *Courtesy Sirchie Finger Print Laboratories, Inc., Youngsville, N.C., www.sirchie.com*

**Figure 14–9  Livescan technology enables law enforcement to print and compare a subject's fingerprints rapidly, without inking the fingerprints.** *Printrac International*

**Figure 14–10  (a) Questioned print recovered in connection with the Madrid bombing investigation. (b) File print of Brandon Mayfield.** *Courtesy www.onin.com/fp/problemidents.html#madrid.*

(a)

(b)

**Figure 14–11  A Reflected Ultraviolet Imaging System allows an investigator to directly view surfaces for the presence of untreated latent fingerprints.** *Courtesy Sirchie Finger Print Laboratories, Inc., Youngsville, N.C., www.sirchie.com*

**Figure 14–12  Using a Reflected Ultraviolet Imaging System with the aid of a UV lamp to**

**search for latent fingerprints.** *Courtesy Sirchie Finger Print Laboratories, Inc., Youngsville, N.C., www.sirchie.com*

**Figure 14–13 Developing a latent fingerprint on a surface by applying a fingerprint powder with a fiberglass brush.** *Courtesy Sirchie Finger Print Laboratories, Inc., Youngsville, N.C., www.sirchie.com*

**Figure 14–14 A heated fuming cabinet.** *Courtesy Sirchie Finger Print Laboratories, Inc., Youngsville, N.C., www.sirchie.com*

**Figure 14–15 Super Glue fuming a nonporous metallic surface in the search for latent fingerprints.** *Courtesy Sirchie Finger Print Laboratories, Inc., Youngsville, N.C., www.sirchie.com*

**Figure 14–16 (a) A handheld fuming wand uses disposable cartridges containing cyanoacrylate The wand is used to develop prints at the crime scene and (b) in the laboratory.** *Courtesy Sirchie Finger Print Laboratories, Inc., Youngsville, N.C., www.sirchie.com*

(a)

(b)

**Figure 14–17 Schematic depicting latent-print detection with the aid of a laser. A fingerprint examiner, wearing safety goggles containing optical filters, examines the specimen being exposed to the laser light. The filter absorbs the laser light and permits the wavelengths at which latent-print residues fluoresce to pass through to the eyes of the wearer.** *Courtesy Federal Bureau of Investigation, Washington, D.C.*

**Figure 14–18 An alternate light source system incorporating a high-intensity light source.** *Courtesy Melles Griot, Inc., Carlsbad, Calif.*

**Figure 14–19  Lightweight hand-held alternate light source that uses an LED light source.** *Courtesy Foster & Freeman Limited, Worcestershire, U.K., www.fosterfreeman.co.uk*

**Figure 14–20  (a) Latent fingerprint visualized by cyanoacrylate fuming. (b) Fingerprint treated with cyanoacrylate and a blue/green fluorescent dye. (c) Fingerprint treated with cyanoacrylate and rhodamine 6G fluorescent dye. (d) Fingerprint treated with cyanoacrylate and the fluorescent dye combination RAM.** *(b) Courtesy 3M Corp., Austin Texas*

(a)

(b)

(c)

(d)

**Figure 14–20** *(cont'd.)* **(e) Fingerprint visualized by the fluorescent chemical DFO. (f) Fingerprint visualized by Redwop fluorescent fingerprint powder. (g) A bloody fingerprint detected by laser light without any chemical treatment. (h) A bloody fingerprint detected by laser light after spraying with merbromin and hydrogen peroxide.** *(f) Courtesy Melles Griot Inc., Carlsbad, Calif. All other photographs courtesy of North Carolina State Bureau of Investigation, Raleigh, N.C.*

(e)

(f)

(g)

(h)

**Figure 14–21  Camera fitted with an adapter designed to give an approximate 1:1 photo-**

**graph of a fingerprint.** *Courtesy Sirchie Finger Print Laboratories, Inc., Youngsville, N.C., www.sirchie.com*

**Figure 14–22 "Lifting" a fingerprint.** *Courtesy Sirchie Finger Print Laboratories, Inc., Youngsville, N.C., www.sirchie.com*

**Figure 14–23 A fingerprint being enhanced in Adobe Photoshop. In this example, on the left is the original scan of an inked fingerprint on a check. On the right is the same image after using Adobe Photoshop's Channel Mixer to eliminate the green security background.** *Courtesy Imaging Forensics, Fountain Valley, Calif., www.imagingforensics.com*

**Figure 14–24 Current imaging software allows fingerprint analysts to prepare a fingerprint comparison chart. The fingerprint examiner can compare prints side by side and display important features that are consistent between the fingerprints. The time needed to create a display of this sort digitally is about thirty to sixty minutes.** *Courtesy Imaging Forensics, Fountain Valley, Calif., www.imagingforensics.com*

[1] A tented arch is also any pattern that resembles a loop but lacks one of the essential requirements for classification as a loop.

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