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Executive Brief July 1993

Forensic Science: Bringing New Technology into the Crime Lab

By Lois Pilant

Sir Arthur Conan Doyle probably had no idea he was opening the door to a new generation of law enforcement when he created the character of Sherlock Holmes. With dry humor and typically British reserve, this accidental detective solved crimes by way of keen observation, deduction, and a brilliant assembly of the facts. Readers were astonished with the simplicity of Conan Doyle's solutions and the fact that Holmes was always, uncannily, right.

The public's fascination with crime solving has not diminished. Witness the popularity of the old television series *Quincy*. Although the show did little to glamorize medical examiners in the same way others have buffed up the image of patrol officers and detectives, it was one of the first to popularize forensic science.

Forensic science, or criminalistics, is one of the few areas of law enforcement where science and crime solving meet. It is vastly different than the domain inhabited by the detective assigned to interview victims and witnesses. Criminalistics moves out of that messy and often emotional arena and into the sterile environs of the crime lab. Here, the laboratory scientist deals with inanimate objects that cannot lie, fight, or flee.

Forensic science is based in the theory of transfer; that is, when two objects meet, some evidence of that meeting generally can be established and verified at a later time. Fingerprints left inside a burglarized house, shoeprints outside a window, toolmarks around a door—there are thousands of examples of the minute bits of evidence found at a crime scene that are later used to incriminate, associate, establish, or convict. And with the advent of DNA profiling, those bits of evidence keep getting smaller and smaller, to the point that a link between a suspect and a crime can be made with as little as one skin cell.

Supporting the advancement of law enforcement and putting state-of-the-art technology in the hands of state and local police have been primary goals of the National Institute of Justice (NIJ) since its inception more than 20 years ago. As the research and development branch of the Department of Justice, the NIJ is the primary sponsor of criminal justice research in the United States.

The NIJ's Science and Technology Division has been instrumental in a number of areas, with grants that have advanced the science of DNA profiling and supported research into less-than-lethal devices. Forensic science has been an area of particular interest, with grants funding research as varied as photographing wound patterns that are invisible to the human eye, creating new fingerprint reagents, and developing comprehensive software programs on firearms or trace evidence.

One NIJ grant, funded in 1988, sponsored the successful development of a technique that revolutionized forensic odontology in the area of photographing bite marks. Dr. Elizabeth Robinson, formerly of the Case Western Reserve University Dental School, used a process called "toneline photography" to alleviate problems associated

SCIENCE AND TECHNOLOGY

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with tracing bite marks on acetate overlays. Robinson found that tracing the marks left too much room for human error and subjectivity. Tracings by four different people resulted in four widely disparate drawings. Some drew teeth as circles, some as squares; in addition, teeth were drawn at dissimilar angles.

Toneline photography removes the possibility of human subjectivity and interpretational bias. The result of this somewhat complicated process is a picture that looks almost like a pen-and-ink sketch on a transparent background that can be compared directly to a model of the suspect's teeth. The process is inexpensive, portable, and available to any crime lab with access to a dark room and basic camera equipment. Robinson's research was a breakthrough in the area of forensic odontology and was instrumental in convicting an Ohio man of child abuse when it was admitted into evidence for the first time.

Another NIJ grant, also funded in 1988, combined the area of photography with the high-tech world of computers. The development of Restoretool, by Dr. Murat Tekalp of the University of Rochester in New York, uses a software program to restore and enhance blurred, grainy, or poorly contrasted photographs. Restoretool digitizes scanned photographs and allows the examiner to focus on one identifiable point, and minutely and precisely correct it. The program then uses those parameters to correct, enhance, or restore the rest of the picture.

The NIJ has continued in its efforts to support the forensic sciences. By funding a variety of grants, the agency's Science and Technology Division has added a host of new tools to law enforcement's arsenal of crime-solving weapons and has helped to advance what Sir Arthur Conan Doyle so unwittingly started in the late 1800s.

Fingerprints

One of the most exciting breakthroughs in the area of fingerprints is the development of portable equipment that lets evidence technicians take the cyanoacrylate (superglue) fuming process to the crime scene. Even more exciting is the invention of a slender hand-held wand that, almost like magic, develops latent prints in 10 to 30 seconds.

The cyanoacrylate process was developed in 1979 after the Japanese police inadvertently found a fingerprint on the inside of the lid of a jar of superglue. By 1981, the fuming process was being used in America and Japan, and currently has worldwide applications.

Cyanoacrylate fuming has always been tedious, cumbersome, and confined to the crime lab. Because nothing is portable, evidence, regardless of its size, must be lugged back to the crime lab inside closed containers for processing. Processing involves putting three or four drops of glue in a small plastic dish or on a hot plate and using heat to generate the fumes. Fingerprints develop when the fumes from the glue adhere to the print.

The goal of David E. Weaver, of Alaska's Scientific Crime Detection Laboratory in Anchorage, was to bring the fuming process to the crime scene. With funding from an NIJ grant, Weaver developed a portable vapor pump that allows technicians to process large crime scenes in one to two hours.

The vapor pump consists of a small compressor, a heat source, and a one-gallon vapor chamber. The compressor pumps air into the heated chamber, and vaporized cyanoacrylate is ejected through an exit hose inserted into the crime scene from an outside door, window, or a hole drilled through a wall. The device is controlled from the outside, with fingerprint development monitored via known prints on foil strips that have been placed near windows throughout the crime scene.

Weaver also developed a vapor pump for use inside a laboratory fume hood. This device uses heat acceleration and has the added feature of letting the technician control the direction of the spray. Prints can be developed in as little as 30 seconds. A crime lab can construct a similar apparatus by using an Erlenmeyer flask, a hot plate, and 1/2-inch flexible tubing. What makes both of these pumps so effective is their ability to move large quantities of cyanoacrylate at a higher rate than was ever possible with the old process.

Weaver then decided to miniaturize the process and came up with what may be the most extraordinary development in many years: the Vapor Wand. This device is slightly larger than a fountain pen and consists of a butane torch that has been fitted with a .223 brass cartridge casing that has been lined with steel wool and saturated, drop by drop, with methyl cyanoacrylate. The brass holder is fitted over the end of the butane torch and, when lit, emits a high concentration of the fumes to develop clear, indestructible, three-dimensional prints. One of the most exciting aspects of the Vapor Wand is that it is easy and inexpensive for crime labs to produce in-house.

Weaver also worked with the 3M Company's Graphics Research Team to modify the cyanoacrylate chemistry and produce dyes that could be mixed with it. By adding a magenta dye to the cyanoacrylate chemistry, a pink print appeared that fluoresced consistently under a laser. Lasers are not, however, the most cost-efficient way to visualize fingerprints. Less expensive is the use of ultraviolet light. According to Weaver, the next step in advancing the fuming process is to incorporate a dye that will fluoresce under ultraviolet light.

In another area of fingerprinting, an NIJ-sponsored effort is underway to develop versatile, affordable, and efficient reagents in the ninhydrin family. Dr. Madeleine M. Joullie', an organic chemist at the University of Pennsylvania in Philadelphia, is directing this research. Synthesizing compounds is nothing new to Joullie'; she has developed reagents for several federal and international law enforcement organizations.

Her work for the NIJ will be similar in that she and her team will create new reagents that are derivatives, or analogs, of the parent compound, ninhydrin, which is used to detect amino acids. Joullie' also has proposed the creation of a number of novel sulpha-containing compounds.

Characteristic of this kind of research is the unpredictable behavior of new compounds, a factor which necessitates a great deal of trial-and-error experimentation. Nevertheless, the possibilities for success are vast, primarily because the needs of the industry are so great. According to Joullie', fingerprint examiners have expressed the need for reagents that will fluoresce without a secondary treatment; do not require the use of a laser; are more sensitive; have increased resolution; have good solubility in non-toxic, affordable solvents; are environmentally friendly and safe to use; can be used on a variety of surfaces; and do not fade with time. Additional goals include the possibility of creating a polymer that will result in a permanent print—like that which results from cyanoacrylate fuming—as well as reagents that will increase the accuracy and speed of processing and thereby help law enforcement keep up with advances in computer technology and AFIS systems.

Photography

Although dermatologists have known about it for 50 years, it wasn't until a police photographer used black and white film to photograph a child abuse victim that law enforcement learned ultraviolet photography could be used to document wound patterns.

As often happens in science, it was an accidental discovery. A photographer had been using the film to do outdoor landscape photography. His next assignment was to photograph an alleged child abuse victim who had been in official custody six months. The photographer apparently decided to finish the roll of film with pictures of the child. Subsequent color pictures showed no injuries. But the black and white pictures showed numerous injuries under the skin, many of which were months old.

Ultraviolet (UV), (meaning, literally, "beyond violet"), light exists at the low wavelength end of the color spectrum and is invisible to the human eye. It can, however, be used in photography and will show remarkable detail and contrast to injured areas, many of which cannot be seen under normal lighting conditions. In fact, experiments have shown that bite marks that are impossible to see under standard lighting 21 days after infliction are obvious when observed with UV light.

Research in this area has been pioneered by two forensic odontologists with support from an NIJ grant. Dr. Michael H. West, deputy medical examiner investigator in Hattiesburg, Miss., and Dr. Robert E. Barsley, a professor at Louisiana State University's Department of Oral Diagnosis, have helped to solve crimes that at one time would have been impossible. In one case, a child was admitted to the hospital in extremely critical condition. Although the mother denied beating the child, UV photographs showed the imprint of a belt buckle on the child's back. In another case, a live-in maid bit a man who burglarized her employer's home. Ten weeks later, the man was arrested. Although he denied the charge, UV photographs showed a distinct bite mark that matched the maid's teeth.

UV photographs are difficult to take because light at this wavelength is invisible. The spot of the injury must be marked, and even then the investigator does not know if he was successful in documenting the evidence until the pictures are developed. This was one of the problems Barsley and West tried to alleviate by incorporating fluorescence photography. With this technique, called "Alternative Light Imaging" or "Narrow-Band Illumination," investigators wear yellow goggles to filter out reflected light and use a high-intensity tunable light source to scan the victim with a blue light. This technique lets investigators see the changes brought on by a skin injury. The damage is then documented with a 35mm or video camera.

Alternative Light Imaging has been instrumental in solving a number of cases, including one in which a strangulation victim was found with the strap of her purse still wrapped around her neck. The slide-hook fastener on the purse strap broke during the assault. The murderer held the broken end in his hand as he tightened the noose around the victim's neck. Using Alternative Light Imaging, investigators were able to see the pattern the fastener left in the palm of the suspect's hand. In addition, shoeprints were much more clearly visible on the victim's face when viewed with Narrow-Band Illumination.

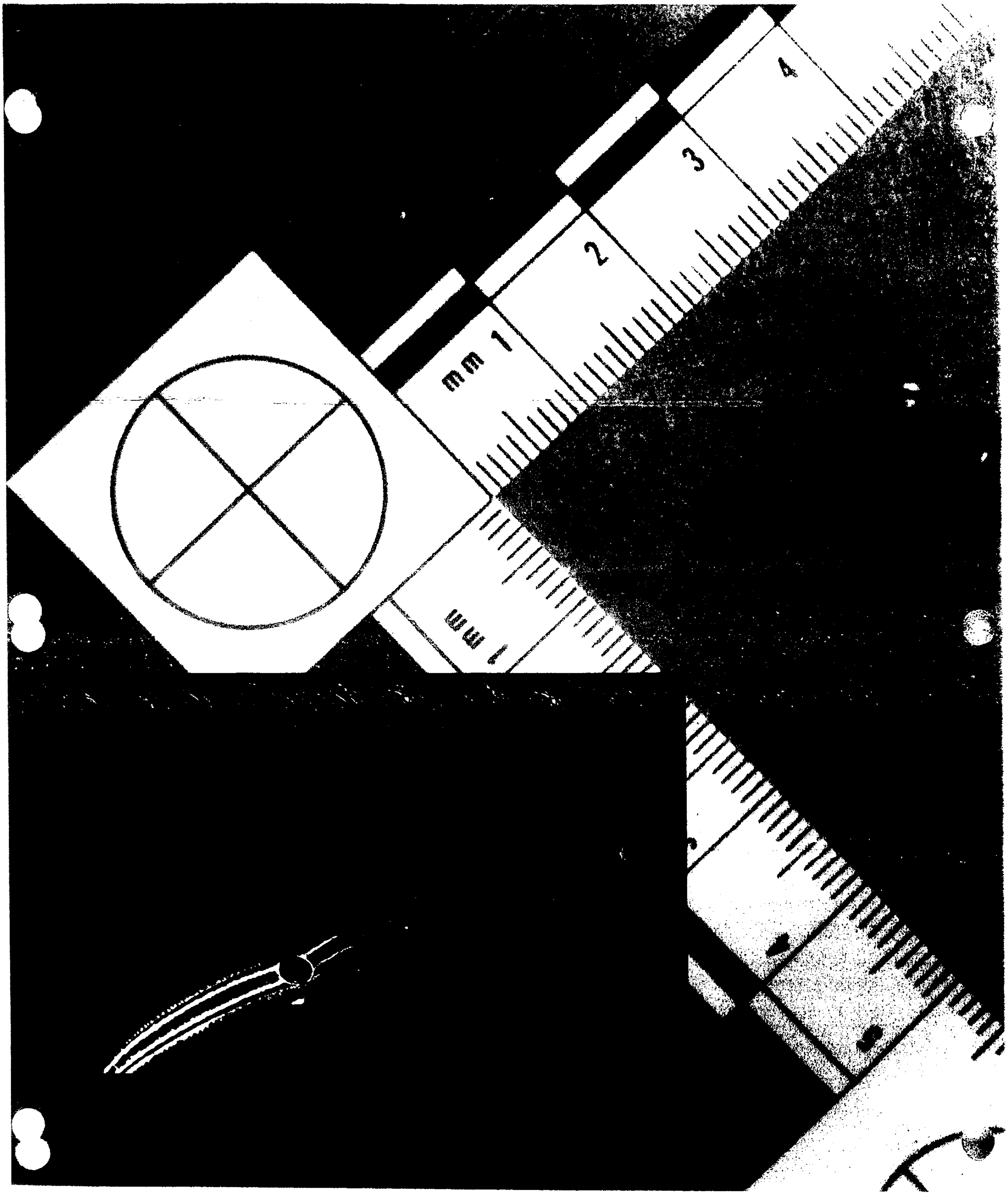
Gunshot Residue

Dr. Peter DeForest, professor of criminalistics at John Jay College in New York, is also working in the area of photography under one of the NIJ's most recently awarded grants. DeForest's work has three aspects, one being the use of high-speed photography to document gunshot residue (GSR) as it is being formed.

Over the past several years, tests designed to detect GSR on a suspect's hand have become more sensitive and sophisticated, able to detect minute traces of the compounds found in GSR, such as antimony, barium, and lead. Unfortunately, what has been sacrificed is the ability to map the pattern of distribution.

The original GSR test for hands used paraffin. Investigators cast the suspect's hand in hot wax, which, when cooled, was cut open and sprayed with a reagent. If areas inside the cast turned blue, it was an indication that the suspect had been in contact with nitrates, a reaction characteristic of firing a gun. The problem was that other substances, such as urine and cigarettes, caused the same reaction. Because the test results were too ambiguous, the procedure fell into disuse in the late 1950s.

A variety of tests later were developed, each with their own attributes but also their own deficiencies. And though the science of detection advanced, the ability to map a GSR pattern on a subject's hand was lost when police stopped using the paraffin test. DeForest's work will address that problem, and will, with the help of high-speed photography, document GSR clouds and the effect on a subject's clothes and his surroundings. DeForest plans to use cameras, including a 4x5 large-format camera and a microflash that emits an extremely short, intense burst invisible to the human eye to document exactly what happens when a shot is fired. The resulting photographs should show how far particulates travel at a certain velocity, how they distribute in space, what happens to the GSR cloud when high-velocity ammunition is used, the differences between various types of ammunition, and the differences between a clean weapon and a dirty one.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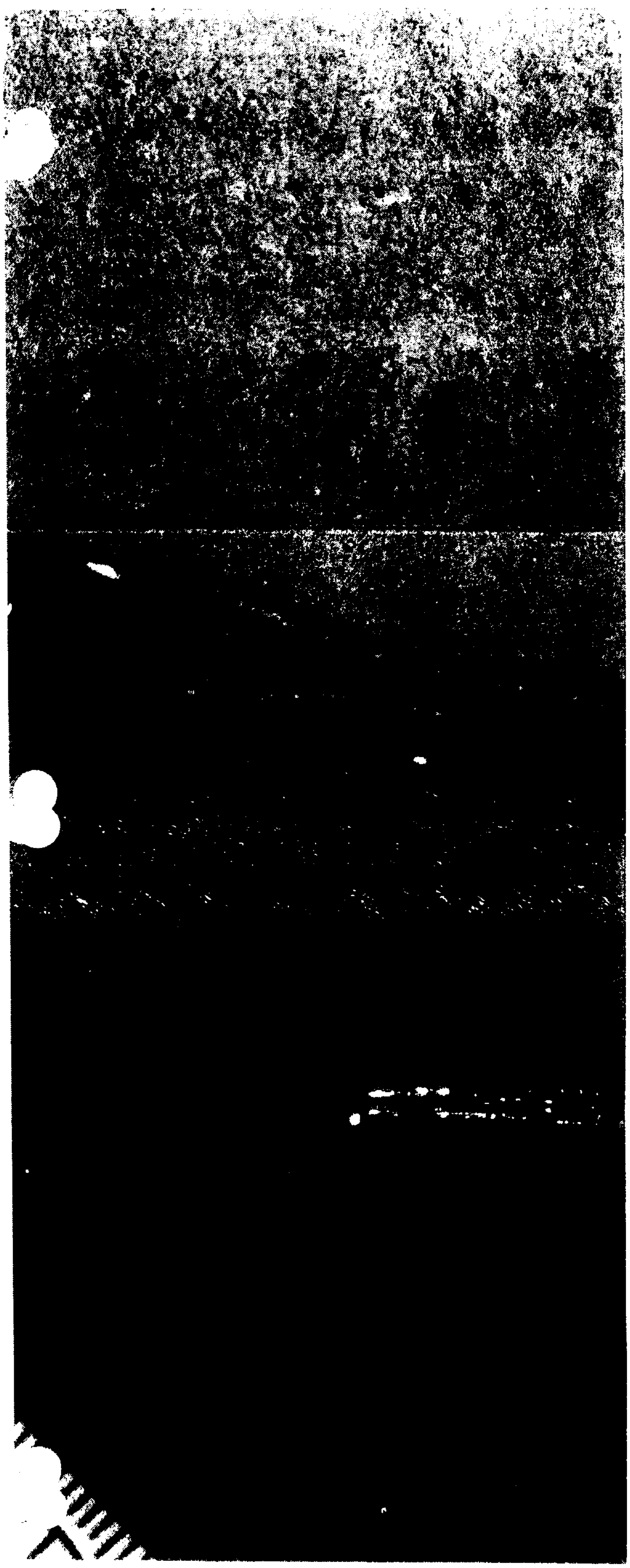

DeForest may even try sonic wave photography, a technique that can photograph shock waves caused by supersonic rifle rounds.

He will also delve into the world of organic chemistry by trying to develop two reagents: a fluorescent reagent for use on GSR and a reagent that will let investigators map the distribution pattern on such surfaces as clothing, and then subject it to other scientific techniques for a quantitative analysis of GSR levels.

Toxicology

The 1991 drug tampering case in Seattle, Wash., shocked the nation. The deaths of two people who took the cyanide-laced Sudafed capsules not only forced the drug's manufacturer into a nationwide recall, it spurred the company to repackage Sudafed in coated tablets, considered less vulnerable to tampering. Joseph Meling, a 31-year-old Seattle man, ultimately was convicted of the near-fatal poisoning of his wife and the deaths of the people who took the capsules he planted in nearby cities to make his wife's attempted murder look like a random act.

Extensive publicity resulted in copycat incidents, attempted suicides, and a public panicked by the idea of poisoned drugs. State and federal officials were inundated with thousands of sample capsules that were pulled from store shelves and had to be tested. Previously unexplained deaths had medical examiners taking old samples to toxicologists with requests to test for the deadly poison.

The testing for such chemicals has been the focus of an NIJ grant funded in the area of toxicology. Dr. Barry Logan, a toxicologist and clinical professor at the Washington State Toxicology Lab at the University of Washington in Seattle, has found a more sensitive way to measure the amount of cyanide and carbon monoxide in blood. Logan began looking at the two compounds because they can be detected with the same tests and, as gases, have some similar chemical properties.

Traditional methods for measuring carbon monoxide rely on the use of spectroscopic techniques, which entail diluting a blood sample and shining light through it at a series of known wavelengths. In a normal blood sample, these wavelengths interact in a way that can be measured. But when the body has begun to decompose, the resultant bacteria, or putrefaction, can interfere and cause the wavelengths to interact differently, which often gives the toxicologist a false reading.

Testing for cyanide was complicated and time-consuming, taking as long as a day to run one sample. In addition, the reagents used in the process were toxic and difficult to work with.

Logan found that cyanide and carbon monoxide had something in common: They could be liberated from the blood as a gas. By using a method called "Gas Phase Electrochemistry," Logan has been able to keep putrefaction from distorting the test. This method also has cut test time considerably and increased the accuracy of the test for carbon monoxide.

Logan then automated the process with an autosampler. Twenty-four samples can be loaded in the autosampler's carousel and a test run at the rate of about a minute per sample. Not only has this reduced testing time, but the test results are reproducible and show a comparable rate of sensitivity when compared to the older, more time-consuming methods. The final phase of Logan's research will focus on increasing the sensitivity of the tests to determine lower levels of cyanide and carbon monoxide than were previously detectable.

Questioned Documents

The Internal Revenue Service could recoup millions of dollars every year if NIJ-sponsored research in the area of questioned documents comes to fruition.

It is the classic case of scientific crossover. Dr. Ian Tebbett, a toxicologist, pharmacist, and associate professor at the University of Florida in Gainesville, has used toxicological methods and equipment to come up with a new way of determining when documents were written, something researchers have been trying to do since the 1950s.

The underlying principle of dating inks is that the longer the ink has been on the paper, the more tightly bound it becomes and the more difficult it is to extract. In the traditional process of Thin Layer Chromatography, examiners use a solvent to extract the ink and determine the age by measuring the amount extracted. The less ink there is, the older it is.

To get a more specific result, examiners look at the patterns created as the solvent separates the chemical components of the ink. From those patterns they can determine when the ink was manufactured by comparing them against formulas used by ink companies.

The process, which has been in use for the last 50 years, has its limitations. It is operator dependent and, therefore, subject to human error. It is not always reproducible and does not take into account a number of variables, including the conditions under which documents are stored.

Because ink is a chemical, Tebbett figured some toxicological methods were applicable. Using sophisticated equipment found in the toxicology lab, Tebbett experimented with Supercritical Fluid Extraction, a process that takes about 20 to 30 minutes and uses liquified carbon dioxide instead of a solvent to extract the ink. Because carbon dioxide is a gas, it evaporates immediately and leaves nothing but the ink, which can then be measured. The process eliminates the step of separating the solvent and the ink, and can be programmed into a computer, a factor that reduces the possibility of human error and makes the test reproducible.

Once the ink is extracted, it is analyzed with High Pressure Liquid Chromatography (HPLC), a toxicological technique that uses yet another piece of sophisticated equipment to determine the ink's chemical components. HPLC yields more specific results and takes about eight minutes.

Tebbett said his work is not yet finished. Additional research will determine how different storage conditions affect different inks. He also plans to do a statistical analysis to build a data base of various inks.

Sexual Assault Evidence

Processing sexual assault evidence is done differently in nearly every part of the country. Procedures depend on state laws, the circumstances of the case, varying levels of police and victim services, hospital protocol, department policy, and community sentiment. Any number of variables can affect how a department handles a case and whether or not those methods are successful.

In an effort to find out how it is done throughout the country and to determine the most successful and efficient techniques, the NIJ has funded a grant to Dr. Robert Gaensslen, professor and director of forensic science at the University of New Haven in Connecticut. Gaensslen will conduct a survey and put the results in a guidebook that will detail procedures used to investigate sexual assault cases.

Survey sites include the states of Maine, Alaska, and Connecticut, and Peoria, Ill., Chicago, Birmingham, Ala., Palm Beach County, Fla., and Washoe County (Reno), Nev. Gaensslen will work with a coordinator at each site to discuss various procedures with police, prosecutors, defense attorneys, laboratories, hospitals, and victim services personnel. He will incorporate into this information UCR statistics, which are based on reported crimes, and data from the Bureau of Justice Statistics, which are based on random interviews.

When the survey is completed, Gaensslen will synthesize the information and write a guidebook on how each department handles a case based on department procedures and variables in each city. He will also provide information on the best way to handle a sexual assault case with accommodations made for local differences. This guidebook will not be Gaensslen's first; he has also written a comprehensive sourcebook on forensic serology.

Computer Technology

Dr. Ferdinand Rios, a forensic scientist and president of Sapien Technologies, Inc., in California, is helping to bring law enforcement into the information age by merging sophisticated technology with forensic science. With funding from the NIJ, Rios and Dr. John Thornton, project director at the University of California at Berkeley, are putting the finishing touches on a firearms evidence sourcebook that will put a vast array of firearms and ballistics information at the fingertips of forensics scientists. At the same time, they are working on similar sourcebooks on trace evidence, serology, and fingerprints.

The firearms sourcebook is a comprehensive data base that can help examiners with a number of tasks, such as identifying different types of weapons and ammunition. An examiner could, for example, enter the number of lands and grooves on a particular bullet and come up with a list of weapons that could have fired it. In some cases, the program can produce a picture of the weapon or a list of manufacturers and models. It can also do trajectory analysis, provide qualitative and evaluative assessments of various techniques, and help examiners prepare for court by condensing the number of sources of firearms information.

Still in development are similar sourcebooks on trace idence, serology, and fingerprints. The trace evidence urcebook will be much like the firearms sourcebook in that will include a large data base with information on glass agments, various chemicals and drugs, images and class haracteristics of some of the most common fibers, several undred different types of woods including pictures of nicroscopic tangential and cross sections, and a host of related race evidence information. The serology sourcebook will be based on Dr. Robert Gaensslen's book and will include the most recently published articles on the subject. The fingerprint sourcebook will be similar to serology, with information on techniques and technology.

The goal of the sourcebooks, which ultimately will be linked to each other, is to provide the examiner with a comprehensive explanation of the effectiveness of the evidence, provide ready access to the full range of related information, and help the examiner develop and present the evidence in court. To do this, the sourcebooks are in hypertext form with a user-friendly format that allows the examiner to move from one section to another by choosing or highlighting related words or pictures. For example, the examiner can bring up the image of a particular weapon and by choosing just one small portion, zoom in for an enlarged version or get a picture of the weapon broken down into pieces. If the user is studying DNA and wants more information, simply highlighting one or more words will bring up a list of related articles that will facilitate more in-depth research. The idea of hypertext, said Rios, is to have varying levels of information and a system that lets the user explore to whatever depth is required to understand the subject. An important feature is that each of the sourcebooks will let the user move information and images from the data base into a report.

Scientists will no longer have to pay hundreds of dollars to search an on-line reference service; the sourcebooks will run on a 386 PC. To keep costs down and to make the programs easy to use, Thornton and Rios have used Microsoft Windows. The firearms program currently takes 25 megabytes of disk space; one reason it is so large is that it contains at least 1,800 pictures of firearms. Other programs will be of similar size.

According to Rios, the ultimate goal is to publish the programs on CD-ROM. These look like the typical compact disks sold in music stores, but they hold 650 megabytes of information, as opposed to a hard disk, which contains anywhere from 100 to 200 megabytes. ROM stands for Read Only Memory, which means that the computer can only read information from the disk; it cannot write to it or store new information on it. To use a CD-ROM, the operator need only insert the disk and launch the program through Windows, the operating system.

Thornton and Rios are currently completing work on the trace evidence, serology, and fingerprint sourcebooks. Information must first be scanned in, edited, and then converted to hypertext. They also are working on a way to keep the programs updated. Because new information is published constantly in all of these disciplines, a mechanism must be found to incorporate it into the existing programs. Finally, Thornton and Rios are trying to find ways to communicate with the users. The programs must be easy to use, Rios said, and the only way to accomplish that is to get feedback from the users on what the problems are and how the programs can be improved. The firearms evidence sourcebook is nearing publication; the trace, serology and fingerprint evidence sourcebooks should be complete by the end of the year.

Certification Programs

The NIJ's interest in training was evident in the early 1970s when the agency sponsored research on testing and certifying forensic scientists. That interest is still strong, as is evident by its sponsorship of a project headed by Rick Tontarski, chief of the Alcohol, Tobacco and Firearm's Forensic Science Laboratory. Working in conjunction with the American Board of Criminalistics and forensic scientists throughout the country, Tontarski has expanded the NIJ's early efforts and devised a testing and certification program that will cover forensic biology (serology and DNA), drug identification, fire debris analysis, and trace evidence.

Certification programs are common in other disciplines—accounting, medicine, law—but are a relatively new concept in forensic science. Admittedly, the idea has not been easy for some to accept and there are those within the profession who are against it entirely. Yet many have had to face one of the greatest criticisms of crime labs in recent years—that crime lab personnel are not certified. There has never been a licensing agency or any structure or organization to test lab personnel. That void has been filled with the creation of the ABC and the seed money provided by the NIJ grant to develop a certification program.

Tests include an exam covering general knowledge and specialty exams in various disciplines. A Diplomate certificate will be awarded to those who successfully complete the general knowledge examination. Fellow certificates will be awarded to those who complete the general knowledge exam, at least one specialty exam, and who meet proficiency testing standards. For example, a specialty examination in forensic biology would consist of a core set of questions on fundamental principles, with two separate specialty question modules offered in DNA and traditional serology. Those who want to be certified in DNA would take an exam that consists of the core and DNA modules. A similar approach is used for trace evidence, with a test based on core principles and a module in paints and polymers, hairs, or fibers. Requirements are that lab personnel have an earned bachelor's degree in a physical science, have a certain number of years' experience before taking the general examination, and additional experience in their chosen specialty.

The ABC asked regional forensic association members to identify the duties required in their jobs, the knowledge needed to perform the work, and finally, to develop test questions within their own specialties. The community was also asked to identify and endorse key elements of the certification program, such as experience and educational requirements. This move forced the profession to define its own standards, Tontarski said.

ABC members also worked with the Educational Testing Service to review and finalize examinations. In February, the organization gave its first general examination at the annual meeting of the American Academy of Forensic Sciences. Specialty tests are still being developed, as is the proficiency program. Tontarski said he expects these two components to be completed by February 1994.

The primary goal of the program is to establish professional levels of expertise. Additional goals include developing a recertification program so Diplomates and Fellows can keep up to date with continuing education; encouraging and promoting adherence to high standards of ethics, conduct and professionalism; promoting growth within the profession; securing general recognition and acceptance of certification; making the ABC program self-supporting; and creating a reciprocity program with the United Kingdom.

The Future

Many of the forensic sciences were completely unknown in the early 1920s. Although such a brief history makes criminalistics a relatively new discipline, it has enjoyed rapid growth, increased credibility, and steady acceptance by the courts. The NIJ continues to foster that growth with research grants.

Additional benefits come from continued cooperation between science and law enforcement. Scientists must not be "blinkered," as one scientist put it, to other methods, equipment, or techniques that might be applicable to criminalistics. Neither should law enforcement be intimidated by disciplines that sometimes seem too complicated or difficult to understand. If law enforcement and science work together, forensic science can continue to achieve state-of-the-art technology and keep police on the cutting edge of law enforcement.

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