Is Forensic Science Scientific?

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Crime lab errors and privacy issues raise concerns.

Over the past 15 years, enormously popular television broadcasts such as *CSI: Crime Scene Investigation* and its many spinoffs and imitators have told dramatic stories of highly trained investigators in up-to-date laboratories, patiently focusing on a single case at a time and always catching the correct perpetrator. But the state of science as practiced on television is often strikingly different from the reality of forensic laboratories.

More recently, sophisticated real-world forensic methods have drawn excited public attention. Private companies such as Parabon NanoLabs and the volunteer organization DNA Doe Project have combined advanced genomic testing, DNA analytics, and genealogical techniques to help police identify potential investigative leads and narrow searches to capture criminals.

"There are cases being solved right now that otherwise would never have been solved," says Cairenn Binder, a volunteer coordinator and genealogist with the DNA Doe Project. This new investigative methodology—called forensic genetic genealogy—has helped law enforcement identify dozens of missing persons and close scores of previously cold cases of murder and rape. "Violent criminals are going to jail, and genetic genealogy is the breakthrough."

But impressive new technologies can also mislead the public about how forensic science is actually practiced. Most forensic technicians work in local government crime labs that lack certification requirements, accreditation programs, or effective education opportunities for technicians. Major studies of forensic science have shown that many crime lab methods are unscientific and too often involve guesswork, contributing to false convictions. Meanwhile, privacy experts worry that genomic crime-fighting tools could be misused to surveil Americans who have never committed a crime or even taken a DNA test.

A footwear-impression cast made by the FBI Laboratory. Such traditional pattern or impression evidence can provide valuable information to police but has not been rigorously tested for accuracy and reliability. Photograph: Federal Bureau of Investigation.

The Innocence Project, launched in 1992 at Cardozo School of Law in New York, has been the most powerful force in revealing systemic weaknesses in crime labs. The Innocence Project has introduced DNA-matching evidence in court resulting in exonerations of 367 people previously convicted of murder and other crimes. The exonerated had served an average of 14 years. False or misleading forensic evidence was a major factor in false convictions in 45% of these cases.

DNA-supported exonerations convinced many in criminal-justice fields that forensic science needed a closer examination. A 2009 National Research Council (NRC) report, "Strengthening forensic science in the United States: A path forward," showed systemic

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problems in traditional forensic methods. Particularly criticized was "pattern analysis," which refers to ways of identifying hair, fibers, firearms, bite marks, skin burns, fingerprints, and other evidence. Pattern analysis, noted the report, is "introduced in criminal trials without any meaningful scientific validation, determination of error rates, or reliability testing to explain the limits of the discipline." The report points out that DNA analysis, however imperfect, is considered the "gold standard," the only forensic method that has been validated in well-designed, rigorous studies.

"DNA testing, because it was so good, exposed how bad much other forensic evidence was," writes Jed S. Rakoff, a senior US district judge for the Southern District of New York, in the 19 December 2019 issue of the *New York Review of Books*.

Still, traditional forensic methods are not necessarily inaccurate or unreliable, the NRC report noted. Depending on how forensic techniques are applied in investigations and presented in court, they can provide valuable information. It is a mistake to paint traditional forensic sciences with a broad brush, according to Betty Layne DesPortes, a former president of the American Academy of Forensic Sciences and a criminal defense attorney in Virginia. "The field of forensic science encompasses multiple and diverse areas of science, subdisciplines, and methodologies. You need to take into account the diversity of the field and the various methods used jurisdiction to jurisdiction."

Reliability of methods and labs

In the 1980s, scientists developed polymerase chain reaction machines that made it possible to copy DNA from tiny samples of blood or tissue to create volumes of the DNA large enough to study. Over decades, technological advances have dramatically improved the accuracy and reliability of genetic testing and analysis. Their costs have dropped too, resulting in a vast increase in genetic information generated, analyzed, shared, and stored.

A technician operates a polymerase chain reaction machine that copies DNA from tiny samples of blood or tissue to provide adequate volume to perform forensic testing. Photograph: Alenakopytova.

A fingerprint identification office at a city police department. Two different examiners can isolate and emphasize different fingerprint features and arrive at different conclusions about the strength of the evidence. Photograph: aeroplanepics0112.

DNA testing allows scientists to spot certain sequences in genetic material that occur with a known frequency in various populations. If a sizable DNA sample is handled and analyzed properly, a forensic lab can state with high statistical accuracy the chances of someone's DNA matching a sample from a crime scene.

Forensic disciplines grew out of two different investigative cultures. DNA testing came to crime labs from

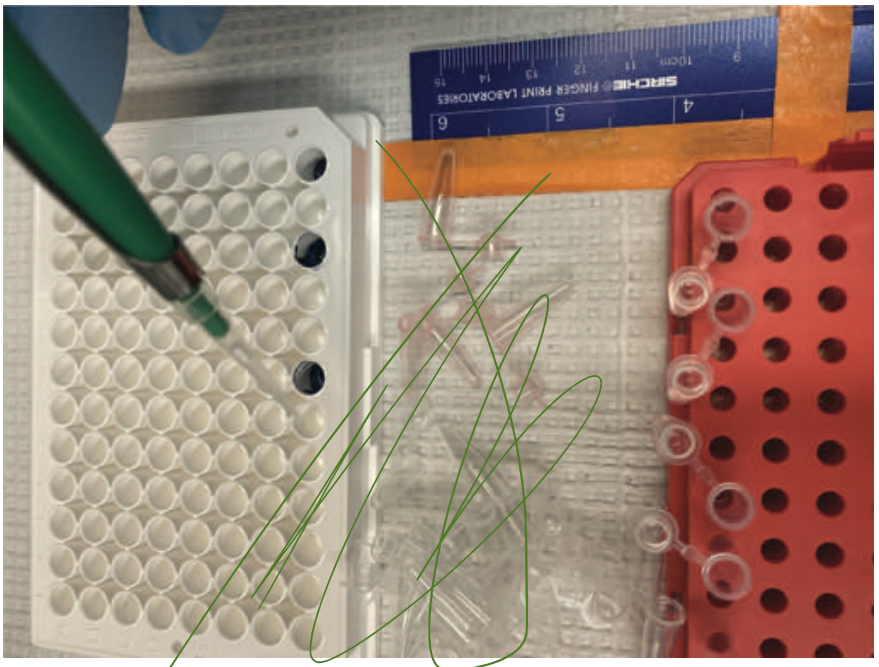
scientific laboratories, where it was legitimized by an array of statistical proofs and controls. More traditional forensic methods, including pattern analysis, grew up in crime labs under the auspices of law enforcement but without modern scientific testing to identify their strengths and limitations with precision.

A traditional forensic method can be used effectively if it is presented in court with realistic estimates of its reliability and accuracy, according to DesPortes. "The same forensic method can be misused or misrepresented in terms of overstating conclusions or reaching an unsupported conclusion." Traditional forensics are crucial in many cases because biological samples are often unavailable and some other common types of crime-scene evidence such as eyewitness accounts are notoriously error prone.

Public crime labs are run largely by local police departments, creating conditions ripe for confirmation bias. Technicians may unintentionally tilt interpretations of evidence in favor of their employers. Even experienced, high-level forensic personnel have been tripped up. In 2015, the Federal Bureau of Investigation (FBI) admitted that, for decades, investigators had overstated the accuracy of hair-sample matches more than 95% of the time in ways that benefited the prosecution.

Most forensic labs lack significant independent oversight that can identify bias, errors, or misconduct leading to wrongful convictions. Many criminal defendants are indigent, without the financial resources to challenge forensic methods and results in court. Successful challenges to forensic evidence in criminal cases are rare.

"We need to ensure that the human factor is minimized in forensic science, that we take as many steps as possible to shield it from bias or favoring one side or the other," says DesPortes. "We need to remove the forensic services and science laboratories from under law enforcement control. A forensic service should be an independent agency requesting budgetary resources



Tubes and wells for loading forensic DNA samples are so small that technicians can make errors such as swapping, mislabeling, or spilling evidence. Photograph: Greg Hampikian.

Test text label

Pedestrians may think twice about jaywalking in Orange County, where they can be ticketed for minor offenses. Some petty offenders "volunteer" a DNA sample as part of a deal to escape potential or harsher penalty. Photograph: WomEOS.

on its own. That view is embraced by the entire forensic science community."

Despite their weaknesses, traditional forensic sciences have improved since the pre-Innocence Project days, driven to reform by DNA typing that exposes wrongful convictions. "Many members of the forensic community have… changed their thinking about the rigor of the work they did in the

past," writes Peter Neufeld, cofounder and special counsel to the Innocence Project and an attorney in private practice, in the September 2019 issue of the *Duke Law Review Online*.

But DNA analysis is not infallible, either. Sloppy handling and misinterpretations of DNA evidence by some police and forensic labs have resulted in false convictions. In 2016, the US President's Council of Advisors on Science and Technology published a report, "Forensic science in criminal courts: Ensuring scientific validity of feature-comparison methods," sharply criticizing some DNA typing methods and procedures.

For example, it is a common practice in some forensic labs to process a DNA swab from a suspect at the same time and room setting that they process evidence such as weapons or clothing from the crime scene. Tiny bits of DNA can be disturbed and float around a laboratory, contaminating evidence. "This is at a time in history when we can detect single molecules, which can transfer from one place to another in the laboratory," says Greg Hampikian, professor of biology and criminal justice at Boise State University in Idaho, director of the Idaho Innocence Project and a consultant for crime labs. "If you have a suspect's very rich buccal [cheek] swab sample out [for processing] at the same time as you have, say, a knife from a murder, molecules of DNA can transfer from the swab to the knife. Now that DNA on the knife will be indistinguishable from DNA that may have been on the knife at the time of the murder. These [technicians] are suited up, so careful about so many things, and then do this absolutely ridiculous practice of having the swab from the suspect out at the same time that they have the evidence out."

From 1976 to 1986, California police departments collected evidence such as fingerprints, shown here, and DNA from crime scenes of the Golden Gate Killer. DNA matching tests were not available at the time of the crimes. But decades later, California law enforcement used DNA typing, popular genetic databases, and genealogical techniques to narrow the search for the alleged killer, verify his identity, and capture him. Photograph: Federal Bureau of Investigation.

Big data: A new era of overreach?

The largest forensic genetic database in the United States is the Combined DNA Index System (CODIS), operated by the FBI. CODIS combines local and state DNA databases and contains more than 17 million profiles. Tight regulations cover whose profile belongs in CODIS, based on categories and seriousness of crimes, and whose profile can be expunged. Police look for matches between crime scene DNA profiles and genetic profiles in CODIS.

Some local police departments are beefing up their own genetic databases. California's Orange County law enforcement draws DNA samples not only from felons and other offenders of serious crimes, but also from people who have been arrested for petty offenses but never convicted—and that worries privacy experts. If someone is ticketed in Orange County for a petty misdemeanor such as jaywalking, littering, or walking a dog without a leash, prosecutors may offer a deal. The case could be dismissed, or the offender could face a minimal penalty if convicted—on one condition: volunteer a DNA sample. Petty offenders who agree to this deal must sign a waiver that their DNA will remain in county custody and can never be expunged.

The Fourth Amendment's protection against warrantless searches and seizures does not apply here. "Orange County is not subject to Fourth Amendment scrutiny, because they're getting your consent," says Andrea L. Roth, a professor at the University of California, Berkeley, School of Law, who published a study about the county's genetic database of 170,000 individuals in a 2019 issue of the *California Law Review*. "The county can take DNA from somebody arrested for a dinky little misdemeanor, and they can keep it forever, because you've agreed to it," she says.

Roth is troubled by Orange County's precedent. "Once the government can ask for DNA in exchange for a discretionary benefit and call that consensual, it could lead to major expansions of a genetic surveillance system. If this 'consensual' surveillance becomes the new normal, then I think that a genetic surveillance system could very quickly expand to people who have no contact with the criminal justice system whatsoever."

Catching criminals and finding missing persons

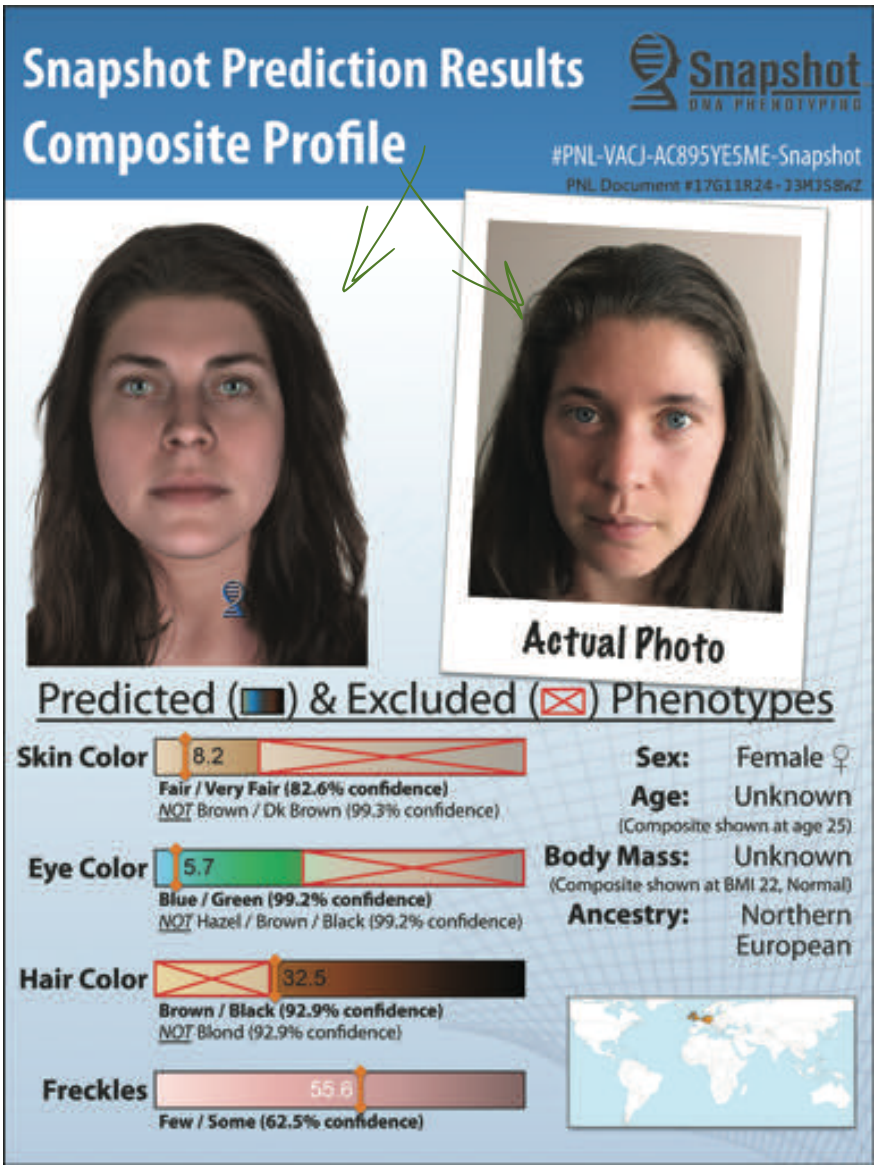
The new discipline of forensic genetic genealogy burst into US public view

in April 2018 when California police announced capture of a suspect, Joseph James DeAngelo, a former police officer, and identified him as the Golden Gate Killer, who had rampaged through the state from 1976 to 1986. Victims' families expressed relief that a suspect who had allegedly committed 12 unsolved murders and at least 45 rapes had been caught and was behind bars.

Under a false name, California investigators had uploaded a crime scene DNA profile to GEDmatch, a recreational genealogical database that did not know of the deception. GEDmatch is a public site where 1.3 million users have uploaded their genetic testing results, which are done by companies such as 23andMe and Ancestry.com. GEDmatch's algorithms can identify matches of near and distant relatives, which genealogists can use to build complex family trees and help thousands of people find biological relatives lost through adoption, abandonment, or anonymous sperm or egg donation.

California used GEDmatch's algorithm to find partial matches between the DNA profile of the Golden Gate Killer suspect and those of distant cousins. Investigators painstakingly built extensive family trees until they identified a common ancestor between the suspect and a distant cousin, filling in tree branches by searching public records such as marriage and birth registries, social-media profiles, and obituaries. Eventually, the search narrowed to one family branch in California. Investigators further winnowed suspects by geography, age range, and sex. Finally, police acquired DNA samples from a few suspects' garbage cans and other sources until they found a clear match. GEDmatch has since changed its terms of service, allowing users to opt out of law enforcement searches.

California investigators took advantage of an advanced forensic DNA profiling method known as SNPs (or single nucleotide polymorphisms) genotyping. An SNPs profile includes 600,000 to 800,000 markers. SNPs are the coding region of the genome,



A cutting-edge service called Spotlight analyzes DNA material from crime scenes to create composite images of criminal suspects. This flyer by Parabon NanoLabs shows a volunteer's real-life photograph and her composite image derived from genotyping. Image: Parabon NanoLabs.

telling important information about people. SNPs profiles can be used to identify a suspect's general ancestry, propensity to some diseases, and phenotypes such as eye and hair color, face shape, height, age, and skin tone. Large-scale medical studies use SNPs for genetic research, and DNA testing companies such as 23andMe and Ancestry.com develop these profiles for their customers.

By contrast, crime labs typically look at STRs (or short tandem repeats) of only 13 to 20 markers, which are mostly "junk genes." Police use STR profiles to identify subjects, but they are not useful for "familial searches" beyond a suspect's parents and siblings. STRs cannot be reliably used to test a biological connection between a child and grandparents, uncles, or half-siblings.

While California investigators pursued the Golden Gate Killer, Ellen Greytak worked a parallel track. In 2012, Greytak, director of bioinformatics at