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ISSUES IN POLICING

Toward a Comparison of DNA Profiling and Databases in the United States and England

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Many senior U.S. law enforcement officials believe that the English criminal justice system has capitalized more fully on the crime-fighting potential of forensic deoxyribonucleic acid (DNA) evidence than the U.S. criminal justice system. This report explores the forensic DNA analysis systems in England and the United States to find out whether these perceptions are accurate. Some key findings that are fleshed out in the report include the following:

- The two forensic DNA systems have some fundamental differences, with England's being far more centralized and privatized than that of the United States.
- The English forensic DNA process has fewer steps than its American counterpart, but some of the extra steps—such as confirming identity and verifying report accuracy—were added to provide better checks in the interests of justice.
- England's forensic DNA analysis process has more fully integrated productivity-enhancing technologies—specifically, laboratory information management systems (LIMS) and automation—than do America's public laboratory processes.
- The data we have been able to gather and analyze (and information from our interviews) indicate that turnaround time is faster in England than in the United States, although labs in the United States can match England's turnaround time under exigent circumstances. England has no backlog of cases waiting to be analyzed, whereas the United States has a considerable backlog.
- In making turnaround and backlog comparisons, four factors in the U.S. system provide some needed context in assessing differences between the two systems: (1) the existence of justice-oriented confirmation checks; (2) the number and nature of requests for profiles (i.e., for crime-scene samples, the difficulty of extracting a profile); (3) discretion of law enforcement to decide what evidence to send for typing; and (4) the resources available in the labs to deal with the requests (i.e., staffing and time-saving technologies).
- The stringency of the United States's National DNA Index System (NDIS)[1] and the decision to use 13 loci[2] seem to reflect a belief that forensic DNA should be used as "a laser rather than a shotgun" and that matches, from the sheer improbability of a chance occurrence, should constitute strong evidence of culpability. This implies a difference in strategy and philosophy between the two systems about how to use law enforcement resources.
- In assessing how DNA analysis is used to aid investigations in the U.S. system, we found that database matches are more strongly related to the number of crime-scene samples than to the number of offender profiles in the database. This suggests that "widening the net," which research indicates has only a minimal deterrent effect, might be less cost-effective than allocating more effort to samples from crime scenes. Indeed, the UK Home Office reached this same conclusion in an analysis of its National DNA Database (NDNAD) performance.[3]

We would like to thank Los Angeles Police Department chief Charlie Beck and other members of the Center on Quality Policing consortium who proposed this topic and who supported us in conducting the research. We would like to thank the many individuals who graciously spent time speaking with us and providing data. Finally, we would like to thank our peer reviewers, Robin Williams, professor emeritus in the School of Applied Social Sciences at Durham University and professor of forensic science studies at Northumbria University, and Brian Jackson of RAND.

[1] The NDIS is the top tier of the Combined DNA Index System (CODIS), consisting of eligible samples from the databases of each state, Washington, D.C., and the U.S. military.

[2] A locus (plural *loci*) is a specific location on the DNA molecule. The term can refer to a coding region of DNA (gene) or a noncoding region, as in most forensic DNA tests.

[3] The Home Office is effectively the UK's counterpart to the U.S. Department of Homeland Security and aspects of the U.S. Department of Justice,

- Federal Bureau of Investigation (FBI) CODIS[4] reports relay only the size of the database and the number of matches recorded, along with selected anecdotes. Database size alone should not be viewed as a measure of "success" without considering concomitant trade-offs. The number of matches generated is an output measure, but it is often mistakenly conflated with the most desired "outcome"—namely, crimes solved. The NDNAD reports strive to provide the public with a more complete picture of the DNA database's contribution to the criminal justice system, by including such relevant metrics as the proportion of database matches that result in case clearances by crime type.

Introduction

Many senior U.S. law enforcement leaders believe that the English criminal justice system has capitalized more fully on the crime-fighting potential of forensic DNA evidence than the U.S. criminal justice system.[5] The perception is rooted in claims that England conducts forensic DNA analysis more quickly and inexpensively and has a higher "hit" rate (i.e., a higher likelihood of getting a probative DNA profile and of that profile being more likely to yield a match in the database). In comparison, the perception of the U.S. approach to forensic DNA analysis is of a relatively rigid, expensive, and bureaucratic system plagued by backlogs, longer turnaround times, and lower hit rates. Many believe, therefore, that there are lessons from England that could be applied in the United States to improve the speed and cost-effectiveness of the system and ultimately increase the number of serious crimes solved or prevented through the use of DNA analysis.

Members of the CQP research consortium asked RAND to compare the forensic DNA analysis systems[6] in England and the United States[7] to assess whether these perceptions are valid and, if so, to identify some of the factors causing the discrepancy.

Addressing this research question proved extremely challenging due to the lack of reliable data on which to base a comparison. On one hand, private labs in both countries would not share information that they considered to be commercially sensitive—and even some public labs in the United States were reluctant to provide information. On the other hand, the kind of information needed for robust comparison is, in many cases, not collected—or at least, is not collated centrally in an accessible format. It is much more difficult to get an impression of the forensic DNA system in the United States than in England because there are more publicly available data and vastly fewer institutional actors in England.

Therefore, in this report, we use the best available information to make preliminary comparisons between the two systems. This information confirms the basic perception that England does indeed have faster turnaround times, little or no unmet demand that would create an evidence backlog, and a database that has yielded more DNA matches than the U.S. DNA database. However, we argue that there is not enough information to contextualize and investigate the underlying causes of these differences and thus to build recommendations for action.

Thus, the aim of this report is to present available data about the differences in functioning of the two systems and to highlight the gaps in our knowledge that preclude further more meaningful (and policy-relevant) analysis.

Methodology and Approach

The report is based on three main data sources: interviews, a literature review, and publicly available data about DNA databases in the United States and England.

Interviews. In total, we conducted informant interviews with 17 forensic DNA experts and practitioners—seven from the UK and ten from the United States. Some interviews were by telephone and some were face-to-face. Our aim was not to speak to a representative sample of interviewees from the spectrum of agencies and professions;

though many of these were transferred to the new UK Ministry of Justice upon its creation in 2007. The Home Office is the UK's central government crime-fighting, border security, and counterterrorism agency. The NDNAD is the forensic DNA database for the United Kingdom. It is the repository for crime-scene DNA profiles and offender DNA profiles for England, Wales, Scotland, and Northern Ireland, although the laws regarding whose profiles can be uploaded and retained on the NDNAD differ among the UK's constituent nations.

4 CODIS is the name given to the network of national, state, and local forensic DNA databases in the United States. The custodian of CODIS is the FBI.

5 England was the birthplace of forensic DNA testing, and its debut was most auspicious (see Wambaugh, 1989), so it is perhaps no surprise that England would push the science forward and gain a reputation for being at the leading edge of forensic DNA analysis.

6 In this report, we use the phrase *forensic DNA analysis* to mean short tandem repeat (STR) testing—the predominant mode of DNA testing used in most criminal investigations.

7 There is some jurisdictional complexity to this study. The U.S. criminal justice system is, of course, comprised of federal, state, local, tribal, and special jurisdictions. The United Kingdom of Great Britain and Northern Ireland (UK) is a semifederal state comprised of England, Scotland, Wales, and Northern Ireland. Scotland has a criminal justice system and body of criminal law that are separate from the those of the rest of the UK, and its rules governing the collection, processing, and retention of DNA samples are different from those used by the other jurisdictions. We focus on the approach used by England, Wales, and Northern Ireland. For convenience, we refer to this approach as the English approach. However, our discussion of the UK DNA database applies to the entire United Kingdom, because the profiles that are uploaded into Scotland's DNA database are also uploaded into the UK's NDNAD.

rather, we made an effort to hear a variety of perspectives on both sides of the Atlantic at junior and senior levels—regulators, public- and private-sector practitioners, and police officials. We approached a nonrandom sample of these labs, beginning with departments that are members of the CQP consortium and then adding labs based on the "snowball approach," wherein interviewees were asked (or volunteered) to nominate other individuals who might provide a useful perspective or additional information. We note that some institutions denied our requests for interviews.

The research team devised an interview protocol with a list of broad topics to cover with each interviewee, but we left time for interviewees to raise issues not in the topic guide and for interviewers to add other questions. This approach was selected to achieve a balance between covering a core list of topics with each interviewee, thus ensuring a degree of comparability between interviews and ensuring that issues of which the research team were not aware could be raised. However, we also varied the questions according to the interviewee, both to ensure that we focused on their areas of knowledge and expertise and to deepen our understanding of the topic and the issues.

Literature Review. To understand the landscape of English and U.S. policies, structures, and processes, we conducted a review of academic literature and of the "grey" literature—government reports, statutes, and news items.

Data Analysis. We were able to gather some information on the English and U.S. DNA databases and their performance. Some was from publicly available sources (the FBI's NDIS webpage, the NDNAD's annual reports, the California Department of Justice), and some was collected during interviews and by making specific data requests to officials within forensic DNA labs and oversight bodies.

These data are insufficient to make robust statements about the U.S. system. Most of our data requests were denied, and several organizations that promised data did not provide any or all of what was promised. It appears that many of the key elements of data that would be essential for policy analysis in the field of forensic DNA analysis do not exist, while other elements are not easily accessible. Because of the fragmentation of the U.S. criminal justice system, there is no central repository of information about forensic DNA analysis.

In this report, our discussions of the U.S. forensic DNA system frequently highlight California and, in particular, the Los Angeles Police Department (LAPD) and Los Angeles County Sheriff (LASD) crime labs, for several reasons. First, both LAPD and LASD, which are housed in a shared facility, are represented in RAND's CQP, and Chief Charlie Beck, then chief of LAPD's Detective Bureau, initially suggested the topic for research. Second, these labs are in close proximity to RAND's headquarters in Santa Monica. Third, one of the authors of this report, Carl Matthies, was a criminalist at LAPD for several years and maintains close ties to staff at both labs. Fourth, we contacted several major metropolitan crime laboratories around the country, and most did not respond to or explicitly denied our requests for interviews and information. Fortunately, based on our survey of literature, the LAPD and LASD labs appear to be emblematic of the state of affairs in forensic DNA analysis nationwide, with many of the same alleged shortcomings. Fifth, Proposition 69[8] expanded California's DNA database to all adult felony arrestees, giving the state one of the most aggressive database statutes in the country and, thus, making it an interesting point of comparison with England.

Organization of the Document

The remainder of this document is organized as follows. We first provide an overview of the similarities and key differences in the way in which DNA evidence is collected, analyzed, processed, and stored in England and the United States. Next, we address the issue of turnaround time and backlog, providing comparative data and setting out what we think to be the contextual factors of each system that are necessary to better understand the differences. Third, we look at hit rates, which are commonly used as a metric of database performance. We set out the limited, comparative data we have collected but make two key arguments about the use of these data: There are differences between the U.S. and English databases that preclude straightforward comparison of hit rates, and we question the usefulness of hit rates as a metric of database performance. Finally, we present our conclusions, followed by some information about our interviewees and an outline of the common steps in forensic DNA analysis.

How Do the U.S. and English Systems and Processes Compare?

Before we delve into whether England is "better" at conducting forensic DNA analysis than the United States, we set out an overview of the process of DNA

[8] DNA Fingerprint, Unsolved Crime and Innocence Protection Act, November 2004.

analysis and databasing in the United States and England and highlight the main similarities and differences.[9] When we look across the steps of the forensic DNA process in the United States and England, we find the following:

- The forensic DNA systems have some fundamental differences, with England's being far more centralized than the one in the United States.
- The forensic DNA process in England has fewer steps than the American process. Some of the extra steps in the American system—such as to provide confirmation of identity and verify report accuracy—were inserted into the process to provide better checks in the interests of justice.
- England's forensic DNA analysis process has more fully integrated productivity-enhancing technologies—specifically, LIMS and automation—than have America's public laboratory processes.

Overview of the U.S. and English DNA Profiling and Databasing Landscapes

This section provides an introduction to how the two systems work. We structure the discussion under four headings: organization and structure; forensic DNA laboratories and privatization; regulation; and the processes of profiling and databasing.

Database Organization and Structure. The destination for many, but not all, DNA profiles is the DNA database. The UK has a single database, the NDNAD, which is maintained and operated by a semi-independent arm of the UK Home Office.

The U.S. DNA database structure was authorized by the DNA Identification Act of 1994,[10] which established the CODIS. The CODIS mirrors the structure of U.S. government. Local criminal justice agencies have a local database—or index system—called a local DNA index system (LDIS),[11] into which they load DNA profiles generated by the local DNA lab or outsourced to other labs. State agencies have their state DNA index systems (SDISs),[12] into which they load DNA profiles generated by state labs or outsourced to other labs. The NDIS is filled directly by tests from the DNA labs operated by federal law enforcement agencies, such as the FBI and the military's investigative agencies. In addition, profiles loaded into an LDIS might then be uploaded into the relevant state's SDIS and then into the NDIS, as long as the profile satisfies the technical requirements of the SDIS and NDIS, which are increasingly stringent (see "Powers to Take and Store Samples" later in this section). This filtered aggregation of DNA profiles is what makes CODIS a combined system (as shown in Figure 1).

Forensic DNA Laboratories and Privatization. A big difference between the two systems is the extent of privatization. In England, all forensic services are provided to police forces by private or privatized labs. There is a National Forensic Framework Agreement—essentially, a list of approved suppliers of forensic services. Those approved suppliers compete to provide services to police forces. There are four major players in the market: the Forensic Science Service, LGC Forensics, Orchid Cellmark, and Key Forensic Services. There are also some smaller, more specialist forensic suppliers. These approved suppliers conduct DNA tests and then load the profiles onto the NDNAD themselves, and they also act as a go-between for police and the NDNAD.

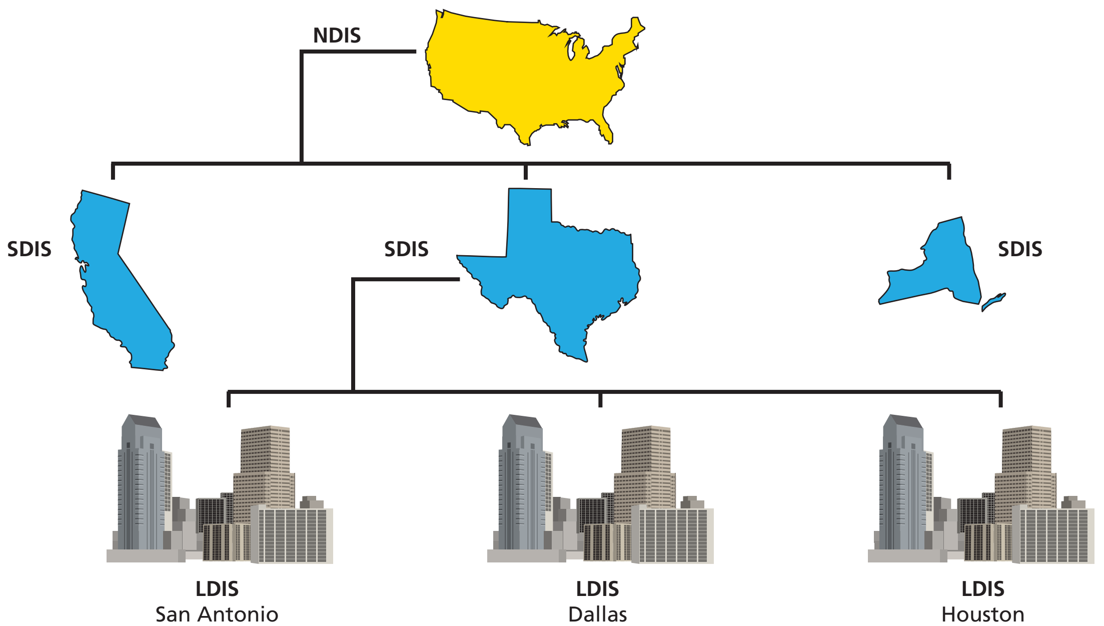
Private labs have a limited role in the United States; forensic services are predominantly provided by public labs. A number of private forensic firms handle excess demand, exigent requests, and specialized DNA analyses (e.g., nonhuman DNA, tests for determining ancestry or ethnicity).[13] Private forensic laboratories might conduct DNA typing for samples that will be uploaded into CODIS, but the actual use and management of CODIS (including profile uploads) rests with criminal justice agencies. CODIS has remained the exclusive purview of public-sector laboratories, despite entreaties from some in law enforcement and the private sector to allow private-sector laboratories to access CODIS directly.

Regulation. In England, there is a position called the *forensic science regulator*.[14] The regulator's role is to be a "single point of regulation of forensic science

[9] We use the term *databasing* to refer to the shape and use of a DNA database, including how profiles are added to it and how searches are run.
[10] Part of Public Law 103-322.
[11] Each CODIS-participating laboratory has an LDIS for storing DNA profiles generated by its analysts. A lab might include profiles in its LDIS that cannot be uploaded to the SDIS. For example, an LDIS might be used to house DNA profiles of lab employees to detect contamination events or, as in Orange County, nonviolent misdemeanor arrestees who agree to provide a DNA sample in exchange for having charges dismissed.
[12] Each state (and the FBI laboratory, Washington, D.C., and U.S. Army) has an SDIS, which is usually overseen by the agency responsible for enforcing the offender-DNA profiling statute in that state. Because each SDIS is smaller than the NDIS, the standards for which crime-scene samples can be uploaded is less stringent (partial profiles, mixtures). All CODIS-participating labs within the state can search SDIS for matches to each other's profiles.

[13] Another difference between English and U.S. approaches to DNA analysis is how they are funded. In England, the central government has provided funds for expansion, but, generally, police forces pay for DNA testing services, as well as forensic services, from their own budgets—negotiating their own contracts and deciding what to spend. In the United States, the federal government provides annual block grants to the 200 or so public laboratories that perform forensic DNA analysis. These block grants fund the work of the public labs, as well as work outsourced to other public or private labs.
[14] The regulator is a nonstatutory, non–civil service position appointed by the Home Secretary. The regulator's authority is delegated from the Home

Figure 1
CODIS Hierarchy



SOURCE: Based on FBI (2000a, p. 6).

for policing purposes from the scene of crime right through to the court processes" (National Policing Improvement Agency, 2009a). The regulator has a small staff and chairs the Forensic Science Advisory Council,[15] which includes police, lawyers, judges, scientists, and members of the Criminal Cases Review Commission. The NDNAD itself is currently "owned" by the National Policing Improvement Agency (NPIA), a semiautonomous agency of the UK Home Office that houses the NDNAD servers and employs the people who operate and maintain the database.[16] However, the NPIA is to be phased out starting in 2011, so the future home for the NDNAD is to be decided ("NPIA to Be Phased Out," 2010).

In the United States, regulation is less centralized. The key elements of regulation were established in the DNA Identification Act of 1994, which gave the FBI director a mandate to appoint a DNA Advisory Board (DAB) for the sole purpose of drafting quality assurance standards (QASs) for forensic DNA for the FBI director's approval.[17] Periodic revision of the FBI quality assurance standards is now the responsibility of the Scientific Working Group of DNA Analysis and Methods (SWGDAM), which is largely comprised of technical leaders from government laboratories and is chaired by an appointee of the FBI director.

Powers to Take and Store Samples. In England, DNA samples and profiles can be taken from anyone who is arrested.[18] The sample must be destroyed as soon as a DNA profile has been derived from it or within six months of it being taken from an individual. The rules regarding the retention of DNA profiles on a database are complicated. The period of retention depends on the person's age at the time of the alleged offense, whether the person has previous convictions, the offense for which he or she was

Office based on a written ministerial statement to Parliament. The post was created in February 2008 and oversees development and maintenance of quality standards for forensic science in England.

[15] A body composed of law enforcement leadership, prosecutors and defense lawyers, and forensic scientists that serves to advise the forensic science regulator.

[16] The NPIA is an executive, nondepartmental public agency sponsored and funded by the Home Office. The NPIA partners with the Association of Chief Police Officers, the Home Office, and the 43 constabularies comprising the Association of Police Authorities toward advancements in policing. Consistent with this goal, the NPIA oversees key information technology (IT) aspects of policing, as well as providing research, training, and policy recommendations. It was established by the Police and Justice Act of 2006 and launched in April 2007, at which time it assumed custodianship of the NDNAD and the Police National Computer.

[17] DAB membership was drawn from among nominations proposed by the National Academy of Sciences and the forensic community, including representatives from public and private laboratories and academia. Its mandate required that it be dissolved after five years (42 U.S.C. 14131).

[18] Powers to take and retain DNA samples are set out in the Crime and Security Act 2010, which was enacted in response to a ruling by the European Court of Human Rights that the UK's retention policy breached Article 8 of the European Convention on Human Rights (*S. and Marper v. United Kingdom*, 2008).

arrested, and whether he or she has subsequently been arrested or charged.

Broadly, however, where an adult is arrested or charged but not convicted (and has no previous convictions), his or her DNA profile can be retained for six years. If the individual is arrested or charged again in this period, the profile can be retained for another six years from that point—the clock "resets." For an individual who does have a previous conviction (whether or not for the offense for which the sample was taken), his or her DNA profile can be stored indefinitely. For young people (under 18), the provisions are similar, but their profiles can be stored for three years.

Shortly after the Crime and Security Act 2010 was passed, however, there was a general election in the UK. The result of this election was the formation of a coalition government between the Conservatives and the Liberal Democrats. Their coalition agreement contains an undertaking to adopt the retention policy used in Scotland for the DNA database.[19] Adopting the Scottish model would further restrict the retention of DNA profiles.[20]

The system for determining the scope of inclusion in the United States' DNA database is reflective of its governmental hierarchy. LDIS rules are made at the submitting lab's jurisdictional level (i.e., city or county); SDIS inclusion is determined by state statute; and NDIS inclusion is based on index crimes and areas of federal criminal jurisdiction (such as terrorism and immigration).[21] CODIS eligibility for DNA profiles obtained from crime-scene evidence depends on (1) not matching (belonging to) the crime victim or someone known to be an uninvolved third party, (2) the number of genetic markers in the profile that typed successfully, and (3) the number of potential contributors to the sample. Rule 1 applies equally to reference DNA profiles, which are DNA profiles obtained from biological samples of known individuals, with the exception that some LDIS databases will include laboratory personnel to check for laboratory or crime-scene contamination incidents. Apart from those excluded by rule 1, laws vary from state to state with regard to qualifying offenses and thresholds of suspicion for database entry, and the net has been widened over time. Currently, almost every state mandates DNA sample collection from all convicted felons; most require samples from individuals convicted of misdemeanor sex crimes, and statutory amendments are expanding DNA databases to include violent-felony arrestees or, as in California and ten other states, all adult felony arrestees.[22]

The tiered stringency of CODIS minimizes the number of adventitious (i.e., incidental) matches that would otherwise become more likely the larger the database. The drawback of excluding some DNA profiles from an SDIS or the NDIS is that genuine matches might be missed.[23]

Laws concerning the storage of samples and profiles also vary from state to state. For example, Virginia and eight other states automatically remove the profile and destroy the sample of anyone added as a felony arrestee but subsequently acquitted or not proceeded against, while, in California and 32 other states, samples and profiles of felony arrestees are retained even following acquittal or dismissal unless they petition (Berson, 2009; Axelrad, undated).

Overview of the Process of DNA Profiling and Databasing: Similarities and Differences Between England and the United States

Figure 2 provides an overview of six common stages involved in DNA profiling and databasing in both the United States and England, as well as the main differences at each stage. In Appendix B, we set out a detailed account of what happens at each stage.

How Do Turnaround and Backlog Compare in the U.S. and English Systems?

The data we have been able to gather and analyze (as well as information from our interviews) indicate that turnaround time is faster in England than it is in the United States, although labs in the United States can match England's turnaround time under exigent circumstances. England has no backlog of cases waiting to be analyzed, whereas the United States has a considerable backlog.

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[19] Coalition agreement available from Conservative Party (2010b).

[20] In Scotland, DNA is taken from every person who is arrested, and the sample and profile are retained if someone is convicted. However, if the arrestee is acquitted, the sample and profile are destroyed. The only exception to this is when an adult has been charged with a violent or sexual offense. In this case, the profile can be retained for three years, even if the arrestee is acquitted. After three years, the police can apply to a judge if they want to keep the DNA profile and information for another two years. The Scottish rules for retention were praised by judges from the European Court in the *Marper* judgment (*S. and Marper v. United Kingdom*, 2009, 48 EHRR 50 at 109–110).

[21] The Uniform Crime Report index crimes are murder, rape, robbery, aggravated assault, burglary, larceny, motor vehicle theft, and arson.

[22] See National Conference of State Legislatures (2010) for a list of what offenses and what individuals (convicts, arrestees, or suspects) qualify for inclusion in each state's offender database.

[23] Suppose that a serial perpetrator has his DNA profile added to an LDIS in Dallas as a suspect but is never charged, and later leaves his DNA at crime scenes in Houston and Oklahoma City. If either of the crime-scene DNA profiles is too mixed or degraded for its respective SDIS, there would be no case-to-case hit or case-to-offender hit.

Figure 2
Overview of the Process in the United States and England and Key Differences

Stage	Step 1. Collect DNA evidence	Step 2. Screen DNA evidence	Step 3. Conduct DNA analysis	Step 4. Upload DNA profiles onto database	Step 5. Search database	Step 6. Generate match reports
Overview of stage	DNA evidence is collected at the scene of a crime, transported to enforcement agency, registered as evidence, and delivered to screening staff. DNA evidence is collected from convicts, arrestees, and suspects.	Potential DNA evidence is screened by in-house police force DNA units in England and by DNA labs in the United States to isolate potentially useful samples to send onward for profiling.	Forensic DNA lab analyzes material with the goal of developing a "profile" of the samples.	DNA profiles created by the labs are then uploaded into the database.	The DNA database searches for matching profiles.	Novel matches between offenders and crime scenes, or between multiple crime scenes, generate a match report that is transmitted to the submitting agency.
Key differences between United States and England	• No significant difference for *crime-scene* samples. • In general, police have more extensive powers to take samples from people in England than in the United States. • In the United States, powers to take samples differ by jurisdiction.	• No significant differences.	• DNA analysis is conducted much more quickly in England (average 3 days) than in the United States (3 days to several months, depending on urgency). • More automation in England.	• United States employs more checks to ensure that correct profile is uploaded than England does. • United States experiences delay while profiles move up CODIS levels. • In England, private labs can upload directly to NDNAD; private labs cannot upload to CODIS.	• The database search happens immediately in England, compared with possible delay in the United States.	• United States has more steps and processes than England to confirm offender matches. • In England, matches between individuals and crime scenes or between crime scenes generate a match report, which is transmitted to the relevant police force electronically and automatically.

However, because turnaround time (and, therefore, backlog) depends on the demands placed on each system and on the resources available to each system, only by taking these into account can we make a more meaningful comparison of the two systems. We hypothesize that there are greater demands on the U.S. system. A lack of data means that we are unable to prove or disprove this hypothesis. Unfortunately, data are not available to make assessments of relative resources' strengths.

Turnaround Times in England and the United States

Our data on turnaround times in England come from interviewees and our literature review. A 2003 parliamentary report noted that, for one provider of DNA forensic services (the Forensic Science Service), average turnaround was 3.5 days for suspect samples and about two weeks for crime-scene samples (House of Commons Committee of Public Accounts, 2003). Despite increasing demand for DNA analysis, this level of service was a marked improvement over the situation of just a few years earlier, when profiling of suspects for the NDNAD were delayed up to a year in some cases (House of Commons, 1999). Since then, it appears that increased capacity has further shortened turnaround times. Our interviewees gave differing, but not highly variant, estimates that put turnaround times in England at between three and seven days. For example, one interviewee estimated about four days for the development of the profile and another one or two days for a search of the database.

The factors limiting turnaround time in England, mentioned to us in interviews, were the time it takes to actually run the scientific process (eight to ten hours, as suggested by one interviewee) and the frequency of collection of the samples for transport to the lab. Estimated cost for crime-scene samples was around £250, and one laboratory representative told us that the price of profiling an offender sample had dropped by half in the past ten years.[24]

In the United States, turnaround times in public labs are not nearly as fast—on the order of weeks or months, on average.[25] Within that broad esti-

[24] Offender samples are DNA samples collected from convicts (and sometimes arrestees or even suspects) for addition to CODIS. The English equivalent is a Police and Criminal Evidence (PACE) Act sample, which is a DNA sample collected from an individual arrested for a recordable offense, for addition to the NDNAD. PACE is legislation that authorized collection of DNA from offenders. Recordable offenses include any crimes that are punishable by a term of imprisonment in addition to lesser offenses, such as public drunkenness, trespassing, illegal possession of fireworks, and persistent begging.

[25] Interviews with LAPD, San Diego Police Department, and the New York Office of the Chief Medical Examiner; supplemented by a 2009 CBS News report on the sex-assault record backlog (Keteyian, 2009). Based on the reported backlog at the California Department of Justice lab (which operates the SDIS for California), its current turnaround time is approximately one month.

mate, there is a wide range of turnaround times. Actual DNA analysis time ranges from about five to ten days, although expedited analysis of reference samples in about three days is feasible. Private DNA labs in the United States charge a premium for analysis in this time frame. Orchid Cellmark, for example, adds a $600 surcharge for a 15-day rush, an $800 surcharge for a ten-day rush, and a $1,000 surcharge for a five-day rush. Regular turnaround is within 50–60 days, according to the provisions of its contract with LAPD, at a cost of $500 for reference samples and $825 for prescreened evidence.[26]

It should be noted that the concept of "turnaround time" is measured differently for public and outsourcing labs. Turnaround time for the contract lab would be the interval of time from receipt of the evidence samples to completion of the analysis. However, for a public lab, the turnaround-time clock begins at the moment that it receives the sample, includes the time of profiling a sample itself or the time that a contract lab performs its turnaround, and then involves further steps (described in Appendix B). Much of the turnaround time elapses in the delay between the request and when the case is assigned and between completion of analysis and completion of technical and administrative review.

The U.S. Backlog

In England, there is no backlog of cases for which the police are waiting for test results. In the United States, there is. The National Institute of Justice (NIJ) defines the DNA backlog as the number of cases still incomplete more than 30 days after the request for analysis. Over the past decade, several investigators have used survey methods to try to estimate the size and distribution of the DNA-evidence backlog for crime scenes in the United States. Table 1 summarizes their results.

The laboratory backlog estimates are consistently in the tens of thousands of cases, regardless of what year the study was undertaken or whether the study intended to provide a comprehensive estimate (e.g., CBS News was concerned only with sexual-assault cases).

With the realization that, for various reasons, law enforcement does not seek DNA analysis in every case that has testable crime-scene evidence, more-recent studies broadened the definition of the backlog to include cases in which investigators have not yet requested analysis. As the third column of Table 1 shows, under this definition, national backlog estimates increase by an order of magnitude to hundreds of thousands of cases. It is important to note that unrequested-DNA backlog estimates are not available for England, because such cases are not considered "backlogged." At least some of the unrequested backlog in the United States is a result of some detectives' perception that their request might never be processed or would be too delayed to be useful; it is possible that this is not a problem in England.

Backlogs also exist in the laboratories that conduct profiling of "offender" samples for the database. At the beginning of 2007, the national backlog for offender samples was 841,847 (Hurst and Lothridge, 2010). Offender backlogs have fluctuated as profiling labs adjust capacity to adapt to database-expanding statutes. For example, the California Department of Justice lab reported a backlog of 235,000 offender samples in 2005 (Bashinski, 2010). As shown in Figure 3, its backlog rose to more than 250,000 samples in September 2006, which the lab successfully reduced to less than 25,000 by the summer of 2008. The backlog rose again when Proposition 69 went into full effect and widened the scope of the state's offender database to felony arrestees, and it has since tapered downward to about 44,000.

Analysis of the Differences in Supply and Demand: The Need to Develop Better Indicators

Comparing the numbers of cases in the backlog in England and in the United States, or the number of days to develop a profile from a sample, does not give us a complete picture of comparative performance. It is also important to consider why these differences exist. We think that there are at least four factors to take into account in order to contextualize turnaround and backlog comparisons between the United States and England:

- justice-oriented confirmation checks
- the number and nature of requests for profiles (i.e., for crime-scene samples, how difficult it was to extract a profile)
- discretion of law enforcement to decide what evidence to send for typing
- the resources available in the labs to deal with these (i.e., staffing numbers and breakdown; time-saving technologies).

We discuss each of these in turn.

More Checks and Balances in the U.S. System. According to the information we have been able to collect, the U.S. system appears to have more steps built into the processes of profiling and databasing. In particular, the FBI QASs, which apply to all

[26] Interview with LAPD Scientific Investigation Division management.

Table 1
Summary of Studies on the Crime-Scene Backlog in the United States

Study	Requested but Not Yet Analyzed	Potential Cases Unrequested
Peterson and Hickman (2005)	48,811[a]	n.a.
Lovrich et al. (2004)	>57,000	221,000 crimes against persons; 264,000 property crimes[b]
Pratt et al. (2006)	57,349 homicide and rape cases[c]	48,324 homicides; 154,649 rapes; 253,931 property crimes
Durose (2008)	38,227[d]	n.a.
Hurst and Lothridge (2010)	68,543[e]	n.a.
Strom and Hickman (2010	n.a.	12,548 rapes and homicides; 563,939 property crimes[f]
Nelson (2010)	~100,000[g]	n.a.
Keteyian (2009)	15,500 rape kits[h]	Unknown

NOTE: The studies are listed in chronological order of when the surveys were administered, not in order of publication date.

[a] Extrapolated from 168 public DNA labs responding.

[b] Estimated for the years 1982–2002.

[c] Estimated from 1,692 law enforcement agencies responding.

[d] Extrapolated from 124 public DNA labs responding.

[e] Sample consisted of 153 public DNA labs.

[f] Estimated for the years 2002–2007; Strom and Hickman give only an estimate of the number of unsolved property crimes from 2002 to 2007 with untested forensic evidence of any kind. Using the figure of 11 percent of property cases yielding DNA, derived from the Home Office DNA Expansion report (Home Office, 2005), we include an estimate of 563,939 property cases.

[g] Sample consisted of 109 public DNA labs.

[h] Sample consisted of 30 jurisdictions in 24 states.

CODIS-user labs and to any private labs with which they contract, intentionally include oversight and redundancy. The QASs dictate that public labs "take ownership" of DNA results provided by private labs with which they contract. Electronic review of private lab work is the means by which this is accomplished. In addition, for DNA profiles that are judged to have potential probative value (either because they match a known suspect or because they do not come from a victim), when they are entered into the database, a second analyst must certify that the right profile was entered. The QASs are designed to prevent errors, with the by-product of adding to turnaround time.

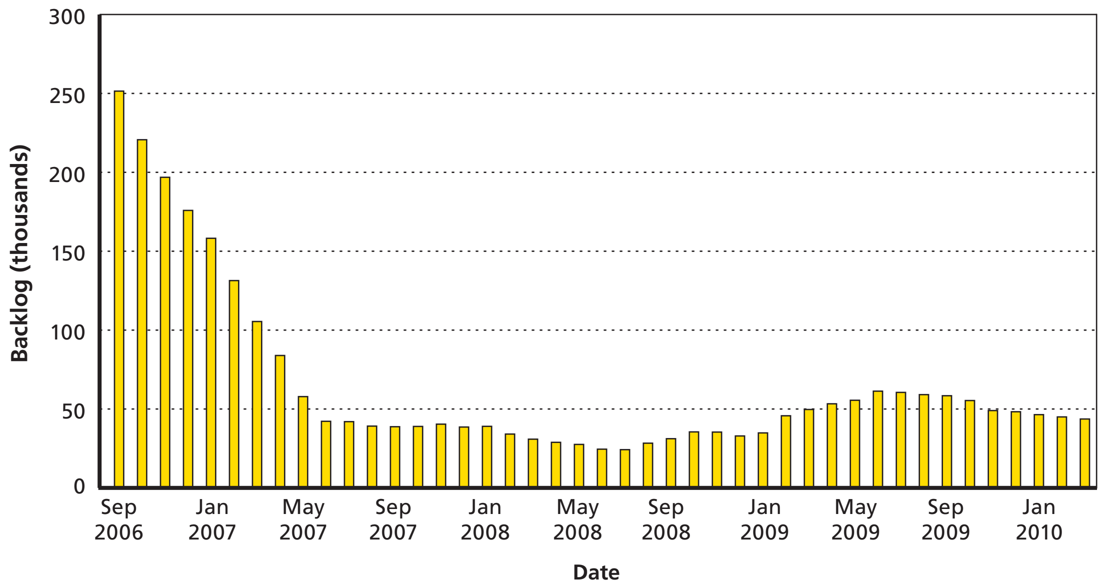
The electronic review requirement has, to date, withstood opposition from private labs and law enforcement agencies. Private labs argue that it creates a disincentive to outsource by increasing the cost; law enforcement officials are upset that it increases turnaround time when the point of outsourcing is to decrease turnaround time. Former LAPD chief William Bratton unsuccessfully petitioned the FBI to rescind the rule. The International Association of Chiefs of Police drafted a resolution in favor of eliminating the requirement. Lobbying by private labs led to a proposed amendment to the Debbie Smith Reauthorization Act of 2008,[27] authorizing feasibility studies for direct CODIS upload from private labs and more limited technical review, but the amendment was defeated in the Senate (interviewee 9).

In terms of the effect on turnaround time, public lab personnel with whom we spoke indicated that electronic review of a contract lab's data takes about 30–45 minutes per case. For laboratories that do a great deal of outsourcing, this can add up. The LAPD/Scientific Investigation Division, for example, currently devotes two of its ten analysts to electronic review full time.

Also, when it comes to generating match reports, the process in the United States has more steps than the one in England, with various processes in place to confirm offender matches. The first confirmation of the hit, performed by the SDIS or, sometimes,

[27] Public Law 110-360, October 8, 2008.

Figure 3
California SDIS DNA Database Offender-Sample Backlog



SOURCE: Data in Bashinski (2010).

the NDIS laboratory, is done before the name of the offender is released to the laboratory that uploaded the crime-scene profile. The purpose is to verify that the offender's name and profile in the database are correct, preventing the debacle of an erroneous match report. The second confirmation involves the laboratory that originally uploaded the crime-scene sample testing a new reference DNA sample that detectives have obtained from the subject. The purpose here is to verify that the offender sample is from the purported individual and to provide independent confirmation of the database match.[28]

In the aggregate, turnaround time for this level of confirmation testing varies depending on the need for expedition (e.g., depending on whether the suspect is already in custody). This confirmation can be expedited on request, but it typically takes three to four weeks.[29] In California, turnaround time to get the name can take up to four to six weeks after the initial hit notification, although expedited confirmation is possible on request. Once the name is revealed, it falls on detectives to locate the individual—which they would do anyhow pursuant to their investigation for an at-large suspect—and obtain a new DNA cheek-swab sample. In some jurisdictions, it is incumbent on the laboratory to test the confirmation sample within ten days of its submission into evidence.

As a matter of public safety, law enforcement agencies would prefer to be notified of hits immediately (especially in the case of a dangerous, at-large offender) and would also rather use the database profile as a reference profile for offenders already known to be in the database. However, confirmation testing minimizes the probability of mistaken identity because of an error in initial database sample testing, labeling, or profile entry. This redundancy is meant to prevent embarrassment to law enforcement, damage to the credibility of the database, and, needless to say, miscarriages of justice. We found no reported incidents of either confirmation test failing to match the database profile, nor was anyone with whom we spoke able to cite a case in which the confirmation-testing delay led to additional victimization, although this seems a distinct possibility. It is therefore difficult to assess whether the additional assurance from confirmatory tests is worth the additional costs. (There have, however, been documented cases of further victimization occurring while the police failed to act on a hit notification; see Dolan and Felch, 2008.)

Number and Nature of Requests for Profiles. We hypothesize that a structural difference between the demands placed on English and U.S. labs is that U.S. labs face more requests for profiles from serious and violent offenses—which require more time and skill to develop and therefore take longer to profile than samples from other types of crime. We propose

[28] The second confirmation test also allows the local lab analysts to testify in court, absolving state lab analysts of the need having to travel to court.
[29] Interviews at LAPD and LASD crime laboratories.

this hypothesis because, first, more DNA samples are taken (as a proportion of all samples) in connection with serious and violent crime in the United States than in England, and, second, there appear to be higher rates of violent crime in the United States than in England.

Crime Rates. While comparing crime rates using official statistics between countries is complicated and should be approached cautiously,[30] a comparison of the Uniform Crime Reports for the United States and Home Office Statistics for England and Wales in the past decade suggests that rates of rape and, especially, homicide are considerably higher in the United States than in England (Home Office, 2008). The murder rate in the United States has been approximately 3.1 times the rate in England and Wales, and the rape rate has been 1.2 times the rate in England and Wales.[31] These rates align closely with reports from the United Nations Office on Drugs and Crime.

Index Crime for Profiles in the Databases. In England, data is published by the NPIA about the type of crime-scene samples loaded onto the NDNAD in 2009.[32] These data show that 5,765 DNA profiles were uploaded from crime scenes in serious offenses, compared with 43,765 DNA profiles uploaded from "volume"[33] crime scenes (National Policing Improvement Agency, 2009a, p. 23). Of the 5,765 profiles uploaded for serious offenses, only 11 percent were for murder and 16 percent were for sex crimes, or 1.3 and 1.8 percent, respectively, of total crime-scene profiles.[34]

While we do not have comparable data on the breakdown of CODIS crime-scene profile uploads by offense type, we can still be confident that sexual assaults and homicides make up the bulk of U.S. forensic DNA analysis. Surveys on law enforcement evidence backlogs found that property crimes were not routinely requested for analysis because, with limited capacity, more serious crimes have taken precedence, though this trend appears to be shifting (Pratt et al., 2006; Strom and Hickman, 2010; Hurst and Lothridge, 2010).

Data from analyzed cases indicate that homicides and sexual assaults require, on average, more DNA analysis than property crimes do. Over the past five years, the LAPD Scientific Investigation Division performed or outsourced DNA analysis on 1,235 homicides, with an average of 3.93 samples per case. Over the same period, the 1,309 sexual assaults the unit handled averaged 3.16 samples per case, whereas the 673 property crimes it handled averaged only 1.62 samples per case. This greater burden per case might be because there are no victim or witness accounts to guide analysis in many homicides, suspected drug-facilitated sexual assaults, and child molestations, and because there might be multiple victims and multiple suspects. In addition, sexual-assault cases typically involve separation of male and female cells, resulting in two DNA tests for each sample taken from the victim.

Law Enforcement Discretion on What Evidence to Send for Analysis. In England, police departments have discretion to choose which sex-assault cases should have their evidence subjected to DNA testing. For example, Feist et al. (2007, p. 29) reported that, in some cases (they were unable to quantify the percentage), the police might not submit forensic material for analysis when consent, not suspect identity, is at issue. Material that the police decide not to send for analysis in England does not count as part of the backlog.

In the United States, this discretion is disappearing in response to concerns raised by victim-advocate groups and Human Rights Watch (HRW). In 2008, HRW started inquiring about the backlog of untested rape kits in evidence-storage facilities around the country (Human Rights Watch, 2009). Framing the issue as not only a public safety concern but also a denial of rape victims' rights, HRW has drawn media attention to the backlog and pressured elected officials and law enforcement leaders to take action (Rubin, 2009b, 2009a). The response in several jurisdictions—including San Diego County, the city and county of Los Angeles, and the state of Illinois—has been to adopt policies of mandatory testing of all rape kits (Twohey, 2010; Davis, 2009).[35]

The campaign has led to evidence audits that have identified hundreds of cases with kits that should have been tested, such as stranger-rape cases, including some in which the statute of limitations had elapsed. However, mandatory rape-kit testing represents a sizable addition to the backlog. This broad approach is problematic insofar as it removes

[30] Crime numbers are affected by reporting and recording practices, as well as offense definitions.

[31] U.S. statistics come from annual FBI Uniform Crime Report data.

[32] Only crime-scene samples for which there are no immediate suspects are added to the NDNAD.

[33] Volume crimes are offenses that occur with the greatest frequency: robbery, larceny, assault, domestic burglary, and criminal damage (e.g., vandalism). The Association of Chief Police Officers of England, Wales, and Northern Ireland also includes drug crimes in this category (Criminal Justice Inspection Northern Ireland, 2006).

[34] Of those serious offenses for which a scene sample was loaded and data is available as to the offense.

[35] There are also efforts to expand this policy at the national level.

police and prosecutor discretion to not request DNA analysis for cases in which DNA evidence is unlikely to benefit the investigation or prosecution. Examples of such cases include those in which the perpetrator's identity is known and the critical question is consent, cases in which the victim elects not to pursue charges or declines to cooperate with an investigation, and cases that have been validly adjudicated in which the defendant does not request DNA testing (Twohey, 2010; Davis, 2009).[36] In some jurisdictions, these types of cases might add thousands of cases (each requiring multiple tests) to the backlog.

Lab Resources in the United States and England. We hypothesize that one reason the English system has no backlog is that it is resourced more optimally to meet the demands placed on it than is the U.S. system. Resources we attempted to compare include staffing, automation, and funding. Unsurprisingly, scarcity of information was a considerable impediment.[37] We were not able to gather enough information on staffing and resourcing in order to make comparative assessments. In an ideal world, we might want to know the number of full-time-equivalent analysts conducting forensic DNA work in public and private labs, as well as the total number of DNA tests performed. Attempting to compare by the number of cases handled is less useful because cases might differ markedly in the average number of samples tested.

From our interviews, we are, however, able to comment on automation. As is well recognized, technology and automation can be labor-saving "force multipliers," enabling employees to conduct a greater quantity of DNA analysis and to communicate test results in a given period of time more quickly than they would otherwise have been able to do. Using robotic apparatus to perform the tedious, repetitive sample manipulations and expert STR data-interpretation software to resolve mixtures can also prevent careless errors.

According to what we learned in our interviews, it appears that U.S. forensic DNA labs lag behind their English counterparts in matters of technology and automation. In England, the Forensic Science Service (FSS) faced a demand spike following the establishment of the NDNAD in 1995 and then another spike following the launch of the DNA Expansion Programme in 2000 (Kemp and Pinchin, 2007). On both occasions, the FSS scaled up its operation by investing in technology. It did so in two key aspects of its operation: DNA testing and case management (Kemp and Pinchin, 2007). Case management—which includes opening a case when analysis is requested, generating test reports, and then communicating the results of any NDNAD matches—requires dedicated information technology (IT) staff, while DNA testing automation requires robotics to handle samples.

Information technologies designed to improve laboratory workflow are generally referred to as LIMS. LIMS can receive and catalog requests, track evidence and sample location and status during analysis, and facilitate the creation, dissemination, and archiving of reports. For case management, the FSS created a LIMS that has allowed the English system to manage requests from police departments relatively easily.

With regard to the actual testing of DNA samples, English labs use more automated, high-throughput sample handlers than do U.S. labs (interviewees 1 and 6). Indeed, one interviewee (interviewee 6) confirmed that the analysis of reference samples is largely an automated process in the English labs.

After a profile is uploaded into the NDNAD in England, if a match is found, the relevant reports—NDNAD match reports (MRs), notification-of-elimination reports (NERs), and NDNAD match summary reports (MSRs)—are sent to NDNAD clients (i.e., police forces and private labs) electronically. Currently, this is done largely by email (faxing of results has recently been phased out), but the NPIA is in the process of introducing "eDNA": an automated system that will deliver results "quickly and securely" from the NDNAD to clients (National Police Improvement Agency, 2009b).[38] Several police forces in England are adopting a case-management system called SOCRATES, which will allow those forces to receive electronic MRs directly into their case-management systems. The significance of this is that it makes the process of delivering DNA results more efficient.

Among U.S. public crime labs that responded to the Bureau of Justice Statistics (BJS) surveys, 75 percent reported using LIMS in their operations in 2002, and 80 percent reported using LIMS in 2005,

[36] Comments from LAPD Scientific Investigation Division management.

[37] Data on funding was such an incomplete patchwork that they do not support even a proxy comparison. Therefore, we do not present any analysis of the comparative funding of the two systems. Some of the problems with the data include the following: Publicly available budget figures for U.S. crime labs include all lab operation, not just the costs of DNA testing; some figures are not publicly available; and the FBI would not disclose the budget for operating CODIS. Better data are needed to know exactly to what extent the U.S. forensic DNA analysis system is actually funded. This would be important for transparency and democratic accountability, as well as for research and comparison purposes.

[38] eDNA is an email notification system for apprising investigators of DNA analysis results and database matches that is currently in use in England.

but the proportion of municipal public labs using LIMS was considerably lower in both surveys, at just 29 percent and 45 percent, respectively (Peterson and Hickman, 2005; Durose, 2008).

Although we were able to learn about the analysis process from start to finish at only a few U.S. crime laboratories, we were given the impression that public crime laboratories in the United States have not yet integrated automation and LIMS to the degree that English labs have (interviewee 11). For example, communication of DNA analysis results even in large, urban U.S. jurisdictions is still accomplished with a signed report, either a hard copy scanned into an electronic format and emailed or a hard copy sent by interoffice mail or the U.S. Postal Service.[39] Even the New York City Office of the Chief Medical Examiner (NYC OCME) lab, which is lauded for having lower turnaround time than most of its public-sector counterparts, operates with comparatively little automation of its processes.

Interviewee responses indicate that the bureaucratic administrations of which many U.S. forensic DNA labs are part have made it more difficult to employ dedicated IT staff and to coordinate an approach to technology. Instead, labs typically are forced to rely on the analysts themselves or IT generalists within the agencies to formulate solutions, with mixed results. This finding might be related to recent research by Garicano and Heaton (2010) on the impact of IT on police productivity. Absent organizational features that complement IT, such as increases in technical support personnel and greater control and accountability at the divisional level, those authors found no significant impact of IT on crime or clearance rates.

As it happens, the contributions of LIMS and automation to decreasing turnaround time are difficult to quantify, because they usually *are* accompanied by other process improvements or increases in overall resources (particularly in staffing levels). For example, the director of biological science at the New York State Police Crime Lab credited LIMS and automation with helping to cut that lab's turnaround-time minimum from 11 days to four days and the average turnaround time from 82 days to 37 days, but the lab also hired an additional 35 analysts and technicians during the reporting period (Duceman, 2006).

From a qualitative standpoint, there was near consensus among interviewees—at both English and American and public and private labs—that superior LIMS and automation are key advantages of the English approach to DNA testing. This is not a new realization. Former U.S. attorney general John Ashcroft ordered a study of the sources of delays in forensic DNA analysis. One of the recommendations of the resulting 2003 report was to improve LIMS and automation in U.S. labs (National Institute of Justice, 2003). It is clear that efforts have been made to follow this recommendation in U.S. labs, but it appears that implementation has been slow and that some public labs lack the organizational complementarities to get the most out of these technologies.

Comparing the U.S. and English Databases and Thinking About Match Rates

In this section, we explore one of the key perceptions that motivated the current study: that English database policies lead to a higher "hit" rate (i.e., a higher likelihood of getting a probative DNA profile and of that profile being more likely to yield a match in the database) than their U.S. counterparts.

The data we have been able to collect indicate that England has a higher hit rate. In addition, England has a larger database (in terms of proportion of the population represented). Even so, we question whether this indicates that England's system is "better." First, there are trade-offs to having a large database that should be considered. Second, hit rates might not be a good measure of database performance, and, even if they were, there are differences between the U.S. and English databases that preclude straightforward comparison.

In this section, we discuss both of these contextual factors, but we begin by clarifying the role that DNA databases play in the criminal justice system.

What Can a DNA Database Do . . . and Not Do?

Forensic DNA analysis and DNA databases are heralded as remarkable tools for fighting crime, and this belief is evident in both political rhetoric and the statutory justifications for establishing and widening the scope of the databases. Tony Blair, who was prime minister during the DNA Expansion Programme, argued that the database was so vital for catching criminals that it ought to include every citizen (Jones, 2006). In defending his proposal to expand Maryland's DNA database in 2008, Governor Martin O'Malley stated, "We can solve more crimes and take these people off the streets so they cannot murder, rape, and harm more citizens among us" (Farmer, 2008). The head of the Washington Association of Sheriffs and Police Chiefs, who advo-

[39] Lab personnel with whom we spoke indicated that a move to a largely paperless LIMS is planned.

cated unsuccessfully for his state legislature to adopt an arrestee databasing policy in 2009, was confident enough in the cost-benefit ratio of database expansion to proclaim,

> We [in law enforcement] view the database as a tremendous crime-prevention tool. . . . People get focused on the idea of individual freedoms and protecting privacy, but most of the public, if they understood how the database works, would gladly trade that off for the crime prevention benefits. (D'Ambrosio, 2009)

DNA databases are also touted as vital to the protection of the innocent. Among the Declarations of Purpose for California's Proposition 69 is a clause stating, "Expanding the statewide DNA Database and Data Bank Program is the most reasonable and certain means . . . to exonerate persons wrongly suspected or accused of crime" (California Penal Code §§ 295–300.2, amended November 3, 2004). Darryl Hunt, who was imprisoned in North Carolina for more than 18 years following his conviction for the rape and murder of Deborah Sykes, credited the DNA database for his exoneration after a partial database match led police to the real killer (Schorn, 2007).

But what can DNA databases actually do, and what are their limitations? What a DNA database can do is provide intelligence and investigative leads:

- Crime-scene DNA profiles thought to belong to the perpetrator can be uploaded to a DNA database and matched to an offender, providing a crucial investigative lead.
- Crime-scene DNA profiles uploaded to a DNA database might match other crime-scene DNA profiles, sometimes in other jurisdictions, which can provide information about the suspect's movements over time and promote intra- or interagency intelligence sharing.
- In the absence of an exact case-to-offender match, partial database matches can be exploited to infer a perpetrator's kinship to an offender in the database, thus enlarging the effective size of the database to include offenders' blood relatives.

Forensic DNA is not a "truth machine," and neither are the databases; the information they provide to an investigation or prosecution is usually insufficient on its own to prove guilt or innocence. Time and resources spent collecting and processing DNA samples might not generate a worthwhile investigative return—for example, a crime-scene DNA sample uploaded to the database might not belong to the perpetrator or, even if it does, might not provide sufficient proof to charge or convict him. Highly degraded or mixed DNA samples cannot be loaded onto large databases because they will yield a high number of spurious matches.

There are also investigative benefits of DNA analysis that do not involve a database of DNA samples. Police often make an arrest early in the investigation, in which case the suspect's DNA can be compared directly to any DNA evidence from the crime scene to corroborate or refute police suspicions. The frequency of occurrence of this scenario is one factor that confounds comparison of database performance, as a database might end up looking more valuable if police are not as good at identifying suspects through other investigative means.

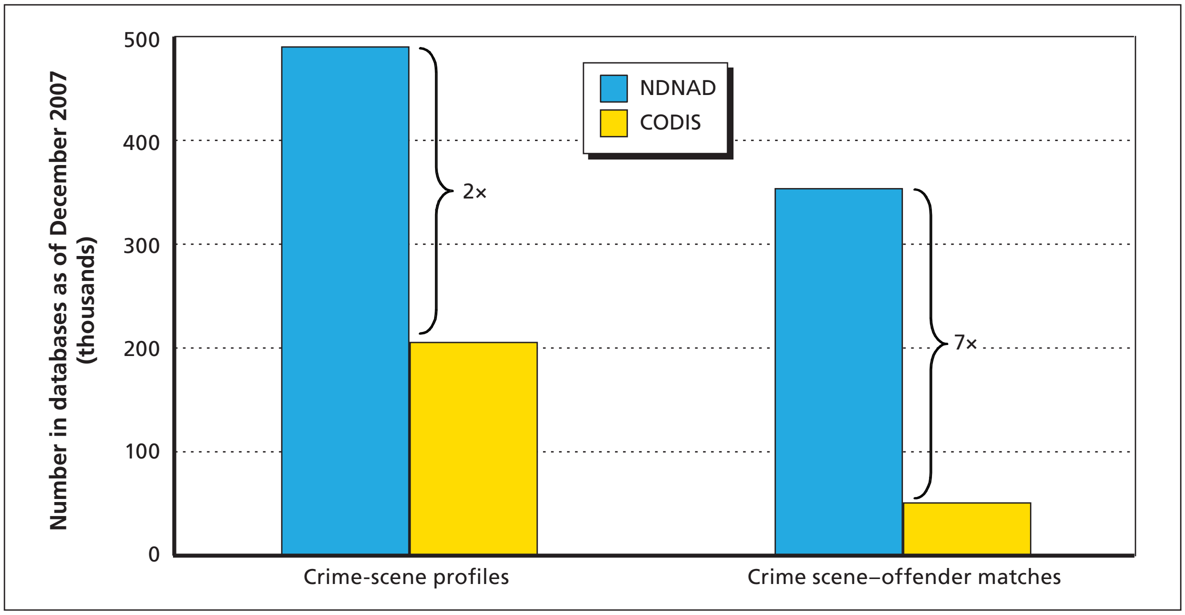
A DNA database is not necessary for exonerating the innocent unless an individual is being prosecuted or imprisoned despite weak or exculpatory DNA evidence, and the database helps identify the actual perpetrator. For example, in the Sykes case, biological samples were collected at the time of her murder in 1984, and authorities learned that the DNA markers from the semen found in Sykes' body did not match Darryl Hunt's as soon as DNA testing became available in 1994. However, Hunt was not exonerated until 2004, after the real perpetrator was caught and confessed in 2003. It seems very unlikely that Hunt would have been charged had DNA testing been available at the time of the murder, yet, in 1994, the judge ruled that the mismatch was not enough to prove Hunt's innocence. While defendants in both countries are considered innocent until proven guilty, once a defendant *is* proven guilty, the database might be moving the standard for exoneration toward "guilty until someone else is proven guilty"; the effect of recent legislation to ensure that postconviction DNA testing is available and can be used to seek exoneration remains to be seen.

Hit Rates and Their Limitations as a Metric for Database Performance

At the end of 2007, both the U.S. and English databases included more than 5 million offender profiles. But, as Figure 4 shows, the NDNAD had more than twice as many crime-scene profiles and had more than seven times as many crime scene–to–offender matches.

According to the NDNAD annual reports, the "instantaneous" match rate (i.e., the rate of matching immediately upon upload to the database) for crime-scene profiles to offenders already in the database was 58.7 percent in 2008–2009, rising from 45 percent in 2003–2004 (National Policing Improvement Agency,

Figure 4
NDNAD Versus CODIS, as of December 2007



2009a). Conversely, when a new offender profile is uploaded, the instantaneous hit rate to existing crime-scene profiles hovered around 1.6 percent between 2004 and 2008 but jumped to 2.3 percent in 2008–2009.

Instantaneous matches, per se, are not tallied for CODIS.[40] Instead, CODIS statistics look at annual and total matches over time. When measured the same way in which CODIS hit rates are measured, the NDNAD hit rate is even higher, as shown in Table 2.[41]

It appears, when measured this way, that the NDNAD's annual and cumulative crime scene–to–subject rates are converging at around 74 percent, although the subject–to–crime scene match rates are gradually decreasing as the database grows. For CODIS, both the annual and the *cumulative* ratios of crime-scene profiles to offender hits rose steadily between 2001 and 2007—from 14 percent to 40 percent and from 9 percent to 25 percent, respectively—but they remained well below the NDNAD rate of around 74 percent (Federal Bureau of Investigation, 2008b). Clearly, the NDNAD has a higher hit rate than CODIS.

Problems of Direct Comparisons of Hit Rates from CODIS and NDNAD. We highlight four reasons that direct comparisons of hit rates between the United States and England give a misleading impression of comparative performance:

1. The NDNAD holds profiles from more of the population.
2. The NDNAD uses a DNA typing system that has fewer markers.
3. The NDNAD holds more profiles related to property crimes.
4. Hits do not take into account cases with DNA evidence solved without recourse to the database.

The NDNAD Casts a Wide Net. As of February 2009, the NDNAD contained profiles from approximately 7.4 percent of the UK population;[42] as of February 2010, CODIS represented only about 2.4 percent of the U.S. population, making the likelihood of a database match almost certainly higher with the NDNAD (House of Lords Select Committee on the Constitution, 2009). The United States has been steadily moving toward the English databasing model with support from private laboratories, DNA

[40] A further cause of delay in the U.S. system is that profiles are not uploaded from LDIS to SDIS or SDIS to NDIS immediately, as they are in the United Kingdom, but rather in batches on certain days of the week (except upon request). Hence, UK matches might be more "instantaneous," in the word's common meaning.

[41] When crime scene–to–subject hit rates are reported or discussed with CODIS, it is usually in reference to a simple ratio of the number of crime scene–to–subject matches over the number of crime-scene profiles in the database. Offender–to–crime scene profile hit rates, which are rarely discussed, would be the ratio of crime scene–to–subject matches over the number of offender profiles in the database. Using these formulas, NDNAD match rates have the annual and cumulative values reported in Table 2.

[42] It should be noted that, although the NDNAD contains the DNA of a higher percentage of the population, it recently emerged (after the opposition put questions to the government in Parliament) that the Home Office does not know how many members of the prison population in England had their DNA in the database. The NDNAD also contains profiles from about 975,000 people who have never been convicted of an offense (Casciani, 2010).

Table 2
NDNAD Match Rates, by CODIS Definition (annual and total matches over time)

Data	Year						
	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009
Subject profiles	2,099,964	2,575,261	3,096,379	3,811,524	4,534,000	5,125,028	5,705,202
Crime-scene profiles	193,138	253,364	312,611	381,385	436,602	476,181	536,753
Crime scene–to–subject matches	144,286	189,545	229,714	274,935	316,652	354,028	390,755
Annual crime scene–subject match rate	0.81	0.75	0.68	0.66	0.76	0.74	0.74
Cumulative crime scene–subject match rate	0.75	0.75	0.73	0.72	0.73	0.73	0.73
Annual subject–crime scene match rate	0.10	0.10	0.08	0.06	0.06	0.06	0.06
Cumulative subject–crime scene match rate	0.02	0.02	0.01	0.01	0.01	0.01	0.01
SOURCES: NPIA (2006, 2009a); Yexley, undated.							

analysis reagent and instrument manufacturers, victims' groups, and law enforcement. Some stunning success stories have helped popularize database expansion in both the United States and England. The United States can widen the scope of CODIS by expanding the number of qualifying offenses, thereby capturing more individuals in the offender index, or by including arrestees—not just convicts—for all qualifying offenses. Both strategies have already been implemented in some states and at the federal level, although the costs and benefits of widening the net are not completely clear. This is discussed further under "Ethical Issues and Trade-Offs of Database Size" later in this section.

Profiles on the NDNAD Use Fewer Markers. England uses the second-generation multiplex plus (SGM+) system, which has fewer loci than the CODIS 13 typing system.[43] The NDNAD also accepts scene-of-crime samples[44] with fewer loci than does CODIS. Both of these policies increase the likelihood of obtaining coincidental database matches (i.e., spurious matches), thereby reducing the validity of CODIS-NDNAD comparisons of case-to-offender and case-to-case match rates.

There are approximately 10,000 times as many possible genotypes (3.09×10^{23}) in the CODIS 13 DNA typing system as in the SGM+ system (1.8×10^{19}).[45] That means that, with SGM+, the most common DNA profile has a frequency of occurrence on the order of one in 1 trillion, an order of magnitude lower than the most common profile in CODIS 13.[46] A crime-scene sample must have typed at a minimum of ten loci to qualify for upload to the NDIS, while the NDNAD requires crime-scene samples to have successfully typed at only six loci (National Forensic Science Technology Center, undated).

These differences mean that the NDNAD is virtually guaranteed to have a higher hit rate than CODIS but not necessarily a higher rate of hits to the actual perpetrator.

English law is explicit that DNA matches are meant to provide investigative leads and are not sufficient evidence alone to try an individual. The lower

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[43] England uses the SGM+ DNA typing system, which consists of the amelogenin gender marker and ten STR markers (six developed by FSS, four developed by Applied Biosystems in the United States). The U.S. forensic DNA typing system is known as CODIS 13. As the name implies, it consists of 13 STR markers plus the gender marker amelogenin. Most CODIS 13 loci overlap with the SGM+ loci (those that do not are part of the 15-locus Identifiler kit, now in use at many U.S. forensic labs).

[44] Scene-of-crime samples are DNA profiles obtained from evidentiary items. They are the English equivalent to forensic samples in the United States.

[45] This is the LASD Biology Unit estimate, derived by calculating the number of possible genotypes at each locus using the formula $(n^2 + n)/^2$ and multiplying the results. This calculation does not include rare, off-ladder alleles.

[46] Computed from the most common alleles at each locus for each system by consulting Butler et al. (2003).

stringency of the NDNAD reflects a philosophy that database matches are not definitive proof of guilt. Although the United States professes the same philosophy, the stringency of the NDIS and the decision to use 13 loci seems to reflect a belief that forensic DNA should be used as "a laser rather than a shotgun" and that matches, from the sheer improbability of a chance occurrence, should constitute strong evidence of culpability. This is a difference of strategy and philosophy regarding how to use law enforcement resources.

The NDNAD Has More Property-Crime Samples. Another difference between the two databases is the higher percentage of offender and crime-scene profiles that come from serious violent or sex crimes in the United States. (This difference was discussed earlier in Section 3.) We can make this inference even without hard data from the United States, because we know that property-crime DNA evidence has gone largely unanalyzed in the United States. Volume criminals tend to be much more prolific than more-serious offenders are, making match rates predictably higher in England.

The vast majority of NDNAD matches are to volume crimes. Between 2003 and 2009, the NDNAD accrued more than 240,000 hits, but only 2.6 percent were to violent offenses. Unlike the data in NDNAD reports, FBI data on CODIS do not feature breakdowns of database matches by crime type, which would allow for some comparison of the CODIS and NDNAD in terms of their relative contributions to the investigation of different offenses. However, using New York state and Virginia data as representative, we see a very different set of percentages. For New York, 80 percent of its first 1,000 database hits related to homicides or sex offenses, with another 4.5 percent related to assault or robbery, and only about 14 percent for burglaries (New York State Division of Criminal Justice Services, 2003). Virginia's match rates included a higher proportion of property crimes (such as burglary, breaking and entering, and larceny) at 47 percent, but 37 percent of hits were to homicides or sex offenses, and a further 6.7 percent related to assault or robbery (Bureau of Justice Statistics, undated; Ferrara, 2003). Accordingly, although CODIS match rates are considerably lower than NDNAD match rates, a higher proportion of CODIS matches than of NDNAD matches are to serious crimes.

The Database Is Not Always Necessary. Police often make an arrest early in the investigation, in which case the suspect's DNA can be compared directly with any DNA evidence from the crime scene to corroborate or refute police suspicions. The relative frequency of using DNA evidence to solve crimes independently of the database is one unknown that confounds comparison of database hits, as a database will yield fewer matches if police are successful at identifying suspects through other investigative means. As England generates profiles and uploads samples more quickly than the United States, inspectors there would have less time to identify suspects using other methods.

General Problems of Using Hit Rates as a Performance Metric. On one level, it seems reasonable to assume that hit rates are correlated with the more-important downstream outcomes of crimes solved and prevented, suspects apprehended, and cases adjudicated, yet one must be cautious about equating more database matches with improved public protection. Hit rates are output measures, not outcome measures. Matches are not intrinsically valuable: In order to improve public safety and improve efficiency of the criminal justice system, we would need to know whether a hit resulted in an offender being apprehended and prosecuted (and whether the offender would have been apprehended as quickly—or at all—but for the database).

Database Size: Its Limitation as a Performance Metric

In addition to hit rates, a commonly used metric for database performance is the sheer size of a database or the speed at which it is growing. There are two factors to take into account when using this as a metric. The first are the trade-offs in terms of human rights and the ethics of having a large database. The second is to consider the cost-effectiveness of increasing database size and, particularly, the relative proportion of offender to crime-scene samples. We address each of these factors in turn.

Ethical Issues and Trade-Offs of Database Size. It is beyond the scope of this report to review what has been written about the justifications (legal and ethical) for typing and storing individuals' DNA for a forensic DNA database. We merely seek to make the point that database size should not be considered as a measure of the "success" of DNA profiling without also considering the concomitant trade-offs that might result from widening the net. Similarly, the value of net-widening should be established with evidence rather than conventional wisdom. For instance, some argue that widening the offender net has a deterrent effect: An individual who knows that his or her DNA profile is in the database will refrain from committing crimes for fear of detection. Research has demonstrated that the deterrent value of having one's DNA profile in the database is small, estimated at 1 to 3 percent for burglary and robbery and insignificant for other types of offenses (Bhati, 2010).

The trade-offs primarily engage rights to privacy and noninterference by the state and whether these ought to be forfeited when an individual has been convicted or merely charged or arrested. Biometric data can reveal an immense level of detail about a person (Ball, 2005), including race, sex, ethnicity, and susceptibility to certain diseases (Froomkin, 2000). They can probe more deeply than forms of personal data traditionally held by the state (Marx, 2002) and, thus, engage the issue of the right to private life in a more profound way (Roberts and Taylor, 2005). In 2008, the European Court of Human Rights ruled that England's previous policy of indefinitely retaining the fingerprints and DNA of all people who have been charged but not convicted was in breach of Article 8 of the European Convention on Human Rights;[47] England has now changed its law in relation to the retention of DNA profiles.

There is the potential that casting the net of the DNA database wider exacerbates the existing overrepresentation of young men from ethnic minorities on the database. It is argued that this subjects minorities to heightened risk of stigmatization "attendant on being known to have a profile on the NDNAD" (Nuffield Council on Bioethics, 2007), to say nothing of the small but definite possibility of a spurious match leading to wrongful suspicion, accusation, or conviction and significant damage to reputation. Racial disparities in arrest rates have been a persistent finding in the United States as well (Cureton, 2000), and, regardless of whether the finding is a reflection of racial profiling, a substantial fraction of arrestees are ultimately acquitted or never charged. The disparate impact that arrestee databasing has on minorities has led some to characterize the DNA database as a racially biased surveillance tool (Rosen, 2010), and this objection has intensified with the increasing use of a technique known as familial or partial-match searches.[48] Familial searches involve identifying individuals in the database whose DNA profiles show a significant commonality with a profile from a crime-scene sample but do not exactly match it, indicating their possible kinship with the perpetrator. Partial-match searches constitute a novel form of net-widening, effectively "bootstrapping" offenders' relatives into the database without their knowledge.

A DNA databasing regime that pushes the envelope and disparately affects minorities might have implications for community cohesion and perceptions of police legitimacy. Larger databases inevitably raise ethical concerns—and these intangible costs must be taken into account alongside any possible crime-control benefits of large and expanding DNA databases.

Cost-Effectiveness of Bigger Databases: Suspect or Crime-Scene Samples? One of the few areas of investigation in which we found sufficient data to conduct quantitative analysis regards how to improve the value of matches. In this section, we explore the data at some length. In the United States, available evidence indicates that focusing on uploading proven offenders and crime-scene profiles has a greater impact on database matches ("investigations aided") than uploading suspected offenders at the point of arrest. That is, the marginal value of adding more suspects or arrestees to the database is lower than the value of adding more crime scenes, under existing legislation. Therefore, even though we caution that match rates are not a good measure of performance, if law enforcement agencies continue to focus on increasing match rates, there are ways to make match rates marginally more useful.

This conclusion is drawn from a comparison of California with other large states—namely, Florida, Illinois, New York, Texas, and Virginia.[49] With the passage of Proposition 69, California created one of the most inclusive DNA databases in the country, encompassing all felony arrestees, including juveniles, and convicted sex-offense misdemeanants. It is now the largest state database in the nation, with 1.3 million offender profiles, about 3.5 percent of its population.

As Table 3 indicates, California's offender database is not the largest simply because of the state's relative population size but also because of its wide scope.

In terms of absolute number of hits, California's database has yielded more than any state except Florida. However, when analyzing the efficacy of its sheer size, states with smaller offender databases appear to perform better on a match basis. Figure 5 plots CODIS investigations aided at three points in time as a function of the number of offender profiles for the 50 states. Early 2008 references a period before

[47] *S. and Marper v. the United Kingdom*, 2008.

[48] Familial searching is using statistical kinship algorithms to detect perpetrators through partial DNA matches to their relatives in the database. In effect, the practice increases the size of the database to include offenders' family members. For example, a crime-scene sample is found to have at least one allele at each locus in common, suggesting a filial relationship to the offender. Y-STR or mitochondrial testing confirms that the offender and the source of the crime-scene profile are at least distantly related. Detectives track down the offender's children and obtain DNA samples in the hopes of finding an exact match.

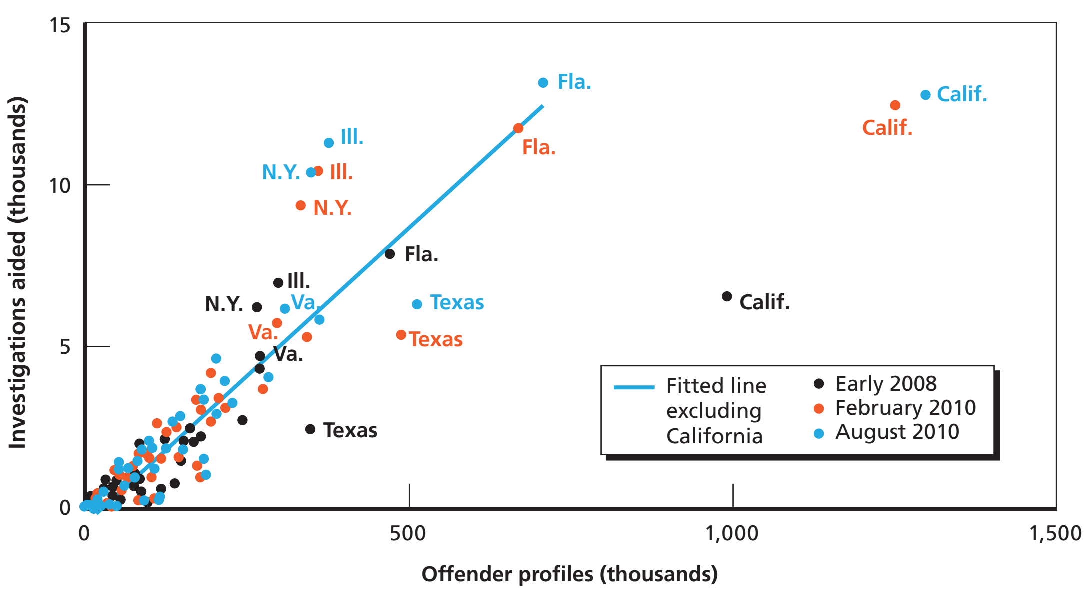
[49] We selected these states because they differ on database policies, but all are populous enough to have large databases.

Table 3
Database Policies from Some of the Largest States

Database Policy	Calif.	Fla.	Ill.	N.Y.	Texas	Va.
Convicted felons	All	All	All	All	All	All
Juvenile adjudications	Yes	Yes	Yes	No	Yes	Yes
Retroactive	Yes	Yes	Some	Yes	Yesa	Yes
Convicted sex-crime misdemeanants	Yes	Yes	Yes	Yes	Yes	No
Other convicted misdemeanants	No	No	No	Yes	No	No
Felony arrestees	All[a]	All[a]	None	None	Some	Some[a]

[a] Changed since mid-2007. California and Florida expanded to all felony arrestees (from homicide and sex-crime felony arrestees only) in 2009. Texas added retroactivity to obtain DNA from parolees and prisoners. Virginia added felony-burglary arrestees.

Figure 5
State DNA Matches Versus Offender Database Size, 2008–August 2010



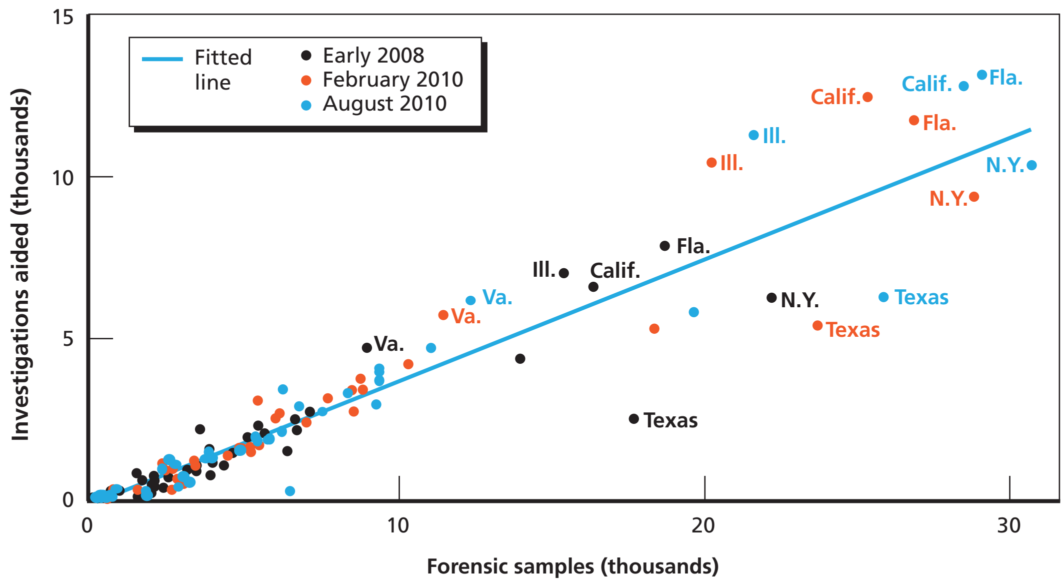
SOURCE: FBI (undated).

California and Florida had implemented all-felony-arrestee DNA databasing. Two months from 2010 are included because the FBI NDIS statistics are apparently not updated every month for every state.

California is anomalous in the relatively low number of investigations aided for such a large number of offender profiles. The most likely explanation is found in Figure 6, which compares the numbers of investigations aided in each state as a function of crime-scene database size.

As of August 2010, the state of Illinois—which does not include any felony arrestees and includes only those misdemeanants who are convicted of sex crimes—had an offender database about 29 percent the size of California's but had 88 percent the number of investigations aided. New York, despite adding numerous categories of convicted misdemeanants to its database, had an offender database just over one-quarter the size of California's, yet it had 80 percent as many matches as California. This is most likely because New York's crime-scene sample database was 8 percent larger than California's, while Illinois' was only 24 percent smaller at the same point in time (FBI, 2010). Florida's database policies became

Figure 6
State DNA Matches Versus Crime-Scene Database Size, 2008–August 2010



SOURCE: FBI (undated).

basically the same as California's after it enacted an all-felony-arrestees provision in mid-2009. The state's population is roughly half California's; it has seen about half as many murders and sexual assaults in the past decade as California, and the offender database is likewise only 53 percent as large as California's. And yet, it had 3 percent more investigations aided as of August 2010. California would likely have more database matches if crime-scene samples, not just offender samples, were more quickly uploaded to the database.

Analysis of offender profiles and crime-scene profiles gives us the elasticities for each component of the database. A 1-percent increase in the number of offender profiles increases the percentage of investigations aided by 0.53 percent, while a 1-percent increase in the number of crime-scene profiles increases the percentage of investigations aided by 0.86 percent. Database matches are more strongly related to the number of crime-scene samples than the number of offender profiles in the database. Indeed, the Home Office reached this same conclusion in an analysis of NDNAD performance (Home Office, 2005).

If aiding investigations is indeed the goal, it would seem to be a wiser use of California's resources to devote them to analyzing the backlog of crime-scene evidence rather than keeping pace with felony-arrestee samples. This is a near-even exchange. The training and QASs are tougher for performing DNA analysis on crime-scene evidence, but the same technology, people, and labs could readily be used to process crime-scene evidence instead of offender samples. Further net-widening (e.g., many misdemeanants) should not be contemplated until the state has the capacity to deal with the demand for DNA testing on probative evidence samples.

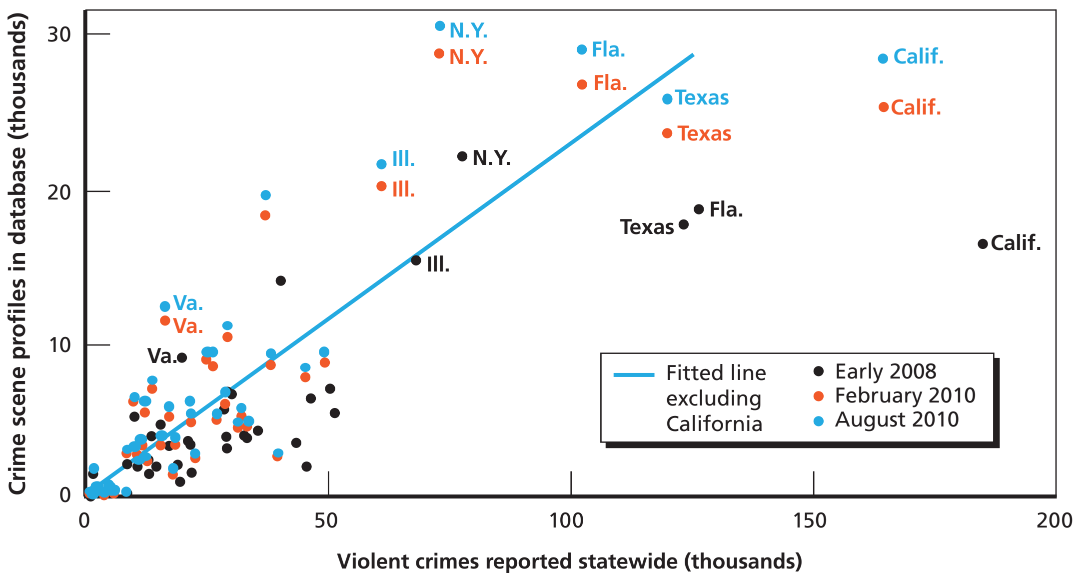
A third indication that California is devoting too few resources to DNA testing of crime-scene evidence is shown in Figure 7, which plots the number of crime-scene samples in the database against the number of violent crimes reported annually statewide (2010 are estimates assuming that trends between 2008 and 2009 persist). Although the ratio is improving, California is again an outlier, as states with far fewer violent crimes (such as New York) have uploaded as many or more crime-scene profiles.

Accordingly, based on these limited data, it appears that a more effective means of increasing hit rates is to increase the number of crime-scene profiles uploaded into the database rather than continue to add more suspects and arrestees (and convicts to lesser crimes) to the database net. The latter does improve the hit rate somewhat, but the former improves it much more. We reiterate, however, that hit rates per se are not an especially good measure of database performance.

Our Suggestions for Better Metrics

Ideally, one would want to know whether a hit resulted in an offender being apprehended and prosecuted (and whether the offender would have

Figure 7
Forensic Profiles in Database Versus Annual Violent Crimes, 2008–August 2010



SOURCE: FBI (undated).

been apprehended as quickly—or at all—but for the database).[50]

In this regard, several metrics might be more probative of a DNA database's contribution to the criminal justice system, including the following:

- the percentage of offenders who match to crime-scene profiles (offender-to-case hit rate)
- the number of crimes with DNA evidence that are solved independently of the database, to verify that a low hit rate is not an artifact of good detective work
- the database match rates, as a function of the offense for which individuals were added to the offender index (for example, the number of hits to persons whose qualifying offense was homicide over the total number of persons in the database whose qualifying offense was homicide, or the number of hits to persons whose qualifying offense was larceny over the total number of persons in the database whose qualifying offense was larceny; this would more clearly define the specific contribution of net-widening, with respect to increased qualifying offenses, to hit rate and prosecutions)
- the database match rates, and subsequent prosecutions, as a function of the stage in the criminal justice process at which individuals were added (for example, each SDIS could separately tally the number of hits to individuals added postconviction in proportion to the total number of convicted felons in the database and, separately, the number of hits to persons at point of arrest over the total number of persons added to the database at the point of arrest who were not subsequently convicted; the hits in each category could be further broken down according to whether they resulted in a prosecution, which would more clearly define the specific contribution of net-widening, with respect to lower suspicion threshold, to hit rate and prosecutions)
- the types of crimes matched to an offender with the aid of the database, cross-referenced with the crime for which the offender was placed on the database, which would more clearly define the specific contribution of both types of net-widening to public safety
- the number of volume or serious crimes in which detection or prosecution and subsequent conviction used DNA evidence and a database match
- circumstances of volume or serious crimes under which database matches led to convictions
- recidivism rate among individuals in the database, as a measure of deterrent effect
- rates of violent crime and volume crime as a function of database size and DNA databasing statutes

[50] The Cold Hit Outcomes Project (CHOP), a LIMS being beta-tested in California, will provide an important source of data and accountability downstream of database matches. Once online, the system will enable the SDIS lab, LDIS labs, law enforcement agencies, and prosecutors to track and update the status (e.g., arrest made, charges filed) of cases in which DNA database matches have been obtained.

- costs associated with the growth and management of the DNA database.

These sorts of metrics might enable criminal justice decisionmakers, legislative appropriators, and the general public to better gauge the utility and success of a database.

Differences in Available Information on Database Functioning and Performance

Overall, there is more information available about the English NDNDA than there is about CODIS.

Annual reports on the NDNAD report on the composition of the offender and forensic databases, the number of database matches in various crime categories that translated into cleared cases, and costs of operating the NDNAD (introductory remarks of Home Secretary David Blunkett, in Yexley, undated, p. 3).

By contrast, CODIS is quite opaque. There seems to be little effort to measure the value of the database beyond reporting its size, the number of matches or investigations aided, and a few selected anecdotes. In fairness to the FBI, which, as administrator of CODIS, currently collects some national statistics, reporting is an easier task for the NDNAD; in England, there are only a handful of labs approved in the forensic framework agreement and only 43 police forces, whereas, in the United States, there are 193 CODIS-participating labs serving approximately 18,000 law enforcement agencies.

While the network of laboratories and agencies under the CODIS umbrella is too extensive for the FBI to track on its own, it would be straightforward for the FBI to request more information from the SDIS laboratories as part of its auditing process. Currently, it is not incumbent on the states to disseminate more detailed data related to the operation of their DNA databases, and only a few apparently do.

Conclusions

Our analysis shows that U.S. law enforcement officials are basically correct in the perception that drove this report. The English forensic DNA analysis system does indeed have an average turnaround time that is far shorter than the U.S. average: approximately three to five days rather than weeks to months. The English system also has essentially no backlog (as measured in England) compared to the high backlog in the United States, measured both as requested but as-yet-unstarted analysis on samples and as samples that have not yet been requested. And the NDNAD has a much higher hit rate than does CODIS.

However, as we carried out the comparison, it soon became apparent that the reality is more nuanced than these perceptions allow. Truly understanding why the English system appears to perform “better” than the U.S. system requires a deeper comparison of their design and process. Our research finds that the two systems are very different, and, in some respects, the perception of apparent superiority of the English system is based on comparisons that overlook these important differences. For instance, there are some contextual differences, such as the centralized approach used in England and the decentralized U.S. approach.

Particularly important is the realization that data are seriously lacking in the U.S. system. Inadequate and insufficient data are captured by the various labs and CODIS organizations. Very little of the data that do exist and are publicly available are reported to a central repository, such as the FBI. Instead, data are fragmented and challenging to access. The Home Office in England has made a more meticulous effort to be transparent with regard to the NDNAD (but not to the private labs that are conducting the actual analysis), and the FSS and NPIA issue annual reports that provide limited but considerably better data than do the annual reports issued by any U.S. institution related to forensic DNA analysis. Of course, the NDNAD is not composed of multiple parts like CODIS is, so reporting on the NDNAD is most likely an easier proposition. Even so, improving the quality and amount of data on the U.S. forensic DNA analysis system and databases, and reporting it to a central repository that would issue regular public reports, would offer a considerable contribution toward the assessment and improvement of the system and the democratic goal of transparency. In addition, there should be greater transparency and reporting from the private labs that are performing what are essentially public duties in the criminal justice system.

As U.S. and UK criminal justice leaders continue to promote the value of DNA databases, greater clarity is needed on the value of the database and of the costs and benefits of net-widening, and better efforts are needed to collect and disclose data that can adequately measure the performance of their forensic DNA analysis and database systems. ■

Appendix A: Interviewees

We interviewed individuals in supervisory, management, and executive roles at the following public and private organizations. Because some interviewees requested anonymity and the inclusion of their job title would effectively identify them, we list only their organizations (see Table 4).

Appendix B: What Are the Common Steps in the Forensic DNA Analysis Process?

The first step, collecting DNA evidence, is actually a multistep process, starting with collecting DNA at the scene of the crime and then taking the collected DNA to the law enforcement agency, checking it into evidence, and delivering it to the relevant staff for the next step.

The second step entails "screening" the DNA evidence for which detectives request analysis. Screening is the process of identifying biological material (e.g., sperm, blood, epithelial cells) among evidence, determining whether there is enough biological material to support DNA testing, and then preparing it for testing. This might be a relatively simple process for offender swabs or bloody knives or a more complex one if it involves hunting for biological material on, say, items of clothing. Items that screen *negative*—meaning that there is no or inadequate biological material detected in the item—typically are not subjected to DNA testing. (An exception might be touch-DNA analysis, in which the expectation of detecting biological material is minimal.[51]) Those DNA samples that contain biological material are then sent on for DNA analysis.

In step 3, the forensic DNA lab will analyze (which is also called *DNA typing* or *genetic fingerprinting*) the material with the goal of developing a profile of the samples. A profile is a series of numbers corresponding to an individual's genetic-marker types at specific locations of his or her DNA. Not all screened samples (and only about half of crime-scene samples) will yield a usable profile.

In step 4, DNA profiles created by the labs are then uploaded into the database; in step 5, the DNA database is searched for matching profiles; and, in step 6, novel matches between offenders and crime scenes, or between multiple crime scenes, generate an MR that is transmitted to the submitting agency.

Table 4
Key-Informant Interviews

Number	Organization	Country
1	NPIA	UK
2	NDNAD	UK
3	LGC Forensics	UK
4	UK Home Office	UK
5	CPS Policy Directorate	UK
6	Forensic Submissions Unit, UK police force	UK
7	Metropolitan police	UK
8	NPIA	UK
9	Orchid Cellmark	US/UK
10	LAPD Scientific Investigation Division	US
11	FBI CODIS Unit	US
12	FBI CODIS Unit	US
13	LASD Scientific Services Bureau	US
14	LASD Scientific Services Bureau	US
15	San Diego Police Department	US
16	LAPD Scientific Investigation Division	US
17	LAPD Scientific Investigation Division	US
18	NYC OCME	US

Finally, a DNA sample can be used as a basis for arrest and as evidence in a prosecution.

How Does the Forensic DNA Analysis Process Differ Between the Two Systems?

In this section, we compare the forensic DNA analysis process in England with what we find in the United States. In doing so, we move through the common steps just described and identify the differences both within those steps and among the steps themselves.[52]

Step 1: Collect the DNA Evidence

There are two basic channels for collecting DNA evidence: at crime scenes and directly from the "offenders"—convicts, arrestees, and suspects.

For crime scenes, the United States and England follow a similar process. In the *United States*, detectives or crime-lab personnel will identify and

[51] *Touch DNA* refers to DNA transferred to objects just by handling them. Touching objects typically transfers a minuscule amount of DNA; thus, touch-DNA cases often require use of low-copy-number techniques and are less likely to yield a complete DNA profile.

[52] This process comparison is based on information provided by interviewees.

collect evidence at the scene of the crime, bagging individual items that might contain probative DNA. These items are packaged and booked into the agency's evidence or property warehouse. Detectives might then request that the crime lab perform DNA analysis on specific items. In cases of serious crimes, crime-lab personnel are more likely to have had an involvement in processing the crime-scene evidence and might advise about which evidence to analyze.

In *England*, a crime-scene investigator (CSI) or scene-of-crime officer (SOCO) will identify and collect evidence, bagging individual items that might contain DNA. These are taken back to the police station and prioritized, according to the likely value of the evidence. The CSI does the relevant paperwork and enters information about the samples into police information systems. In cases of serious crimes, scientists from private labs might be involved at the crime scene and might advise about which evidence to analyze.

For offenders, both the United States and England follow a similar process, but the U.S. process entails jurisdictional differences. In the *United States*, the offender's DNA is taken by swab in the detention facility. In California, this does not occur until staff check the Automated Criminal History System (ACHS) to see whether a DNA sample has already been collected from the individual. Depending on the law of the particular jurisdiction, the sample might be collected from suspects, upon arrest, or only upon conviction.

In *England*, an individual, on arrest, is taken to a police custody suite. A check will be conducted on the Police National Computer to see whether a DNA profile is currently held for that person. If not already in the system, the arrestee will then have a DNA sample taken. The DNA sampling kit contains two identical swabs and is uniquely identified with record cards and labels, which carry a bar code, as proof of chain of custody.[53]

Step 2: Screen the DNA Evidence

Potential DNA evidence is screened by in-house police force DNA units in England and by DNA labs in the United States to isolate potentially useful samples to send onward for profiling. In the *United States*, typically the DNA unit at the crime lab serving the investigating law enforcement agency[54] will "screen" evidence items requested by detectives. For items that screen *positive*, meaning that microscopic and chemical tests indicate that the items contain potentially probative DNA, prepared samples will be tested by the lab or will be packaged and sent to outside laboratories for DNA analysis.

In *England*, although no English police force has an in-house forensic laboratory, most have a force DNA unit that coordinates analysis of samples and can also screen samples. Individual police forces have discretion about how crime-scene samples are dealt with, about the level of prescreening they undertake, and which items they choose to send for profiling. Force DNA units triage the available potential evidence sources and send only those that they have assessed as having a high chance of yielding a sample. If those do not yield a DNA profile, or they yield a DNA profile that is nonprobative (e.g., victim's blood in victim's home), other evidence can be sent for analysis later, thus potentially saving money without wasting too much time, given quick turnaround times.

Step 3: Conduct DNA Analysis and Profiling

DNA analysis is conducted much more quickly, on average, and using more automation, in England than in the United States. In the *United States*, public and private DNA laboratories receive screened samples for DNA analysis, along with paperwork describing the contents. The lab tests the sample using the lab's particular techniques and technology. If possible, this yields a profile. Analysis time is a function of current demand, staff availability (for public labs), and the price paid (for private labs). It appears to range from three days to several months, depending on the urgency of the request. Reports, unconsumed evidence, and electronic data generated in the analysis are returned to the requesting law enforcement agency.

In *England*, the agency's contract lab receives the sample and undertakes DNA analysis. This appears to take an average of three days. The private lab creates a profile report, which is sent directly to the NDNAD Service Centre (not to the police force).[55]

[53] Pursuant to the passage of the Criminal Justice and Police Act of 2001, volunteer samples obtained from victims, third parties, and subjects of investigatory sweeps can also be uploaded to the NDNAD with the individual's consent, which, once given, cannot be withdrawn. Volunteer samples are DNA profiles obtained from individuals who consent to have their profiles uploaded to the DNA database. Volunteer samples might be acquired in the course of performing a DNA dragnet to winnow down the suspect pool.

[54] If the agency does not have an in-house forensic crime lab with DNA analysis capability, it can make use of other public labs for free (such as the FBI's lab) or for a fee, or it can use private labs. Hence, "outsourcing" DNA analysis does not necessarily mean that it is being outsourced to a private lab.

[55] Two interviewees indicated that, for crime-scene samples, approximately 50–60 percent of samples recovered from the scene and sent to labs would result in a profile that could be uploaded into the NDNAD. Offender samples consistently yield profiles because of the means by which their

Step 4: Upload DNA Profiles into the Database

When it comes to uploading DNA profiles into the database, the process in the United States has more protective steps than the one in England, as well as possible extra days of delay for profiles moving up CODIS levels. In the *United States*, all DNA profiles are reviewed before uploading into the database. Only public labs can enter profiles into CODIS. For DNA analysis performed at public labs, all reports are subjected to peer review and administrative review. For DNA analysis performed by a contract lab, the electronic data from the contract lab must be reviewed and approved by a qualified DNA analyst at the public lab before the profile can be added to the database.

Once the reviews are completed, DNA profiles that are judged to have potential probative value (either because they match a known suspect or because they do not come from a victim) are entered into the database, with a second analyst certifying that the right profile was entered. In California, LDIS samples are uploaded to the SDIS at the end of the work week, although expedited uploads are possible.

In *England*, the NDNAD Service Centre loads the profile into the database, after checking that there is consistency in the unique reference numbers that have accompanied the sample (to confirm that it is the "right" sample). There is no administrative or peer review by the NDNAD Service Centre.

Step 5: Conduct the Database Search

The database search happens immediately in England versus possible delay in the United States. In the *United States*, searches are not run as soon as a profile is uploaded. In California, the SDIS database is searched over the weekend, although a midweek search is feasible under exigent circumstances. The frequency of NDIS searches is not public information.

In *England*, once loaded, the profile is automatically searched against all preexisting profiles in the database.

Step 6: Generate Match Reports

When it comes to generating MRs, the process in the United States has more steps than the one in England, with various processes in place to confirm offender matches. The communication process is more automated in England. In *California*, as a U.S. example, after the weekly search, novel SDIS matches between offenders and crime scenes or between multiple crime scenes generate an MR that is sent through the U.S. Postal Service to the submitting agency. However, in the case of matches to offenders, no name is attached to the initial MR. Instead, a confirmation process begins—a safeguard that is not part of the system in England.

Following a case-to-offender match, the SDIS lab will retrieve the offender's buccal swab sample and conduct a new test to confirm the match. Once confirmed, a new MR is generated with the offender's name and California Inmate Identification (CII) and sent (by standard mail) to the submitting agency. After the submitting lab receives the name and the suspect's CII, it notifies a department point of contact (the detective investigating the case or a designated cold-hit coordinator) and requests that a new DNA sample from the suspect (who might be at large or already in custody) be provided to do an in-house confirmation of the database match. The initiating lab will analyze the new reference sample, run it against the matching sample, and issue a cold-hit confirmation report. This second confirmation is necessitated by the right to confront one's accusers provided by the Sixth Amendment of the U.S. Constitution, which, according to a recent U.S. Supreme Court decision, requires all lab personnel who were involved in analyzing forensic evidence to be available to testify in court.[56] This second confirmation prevents state lab personnel from having to travel to court in the local jurisdiction by making the local confirmation test the one that would be entered into evidence in court. With the second confirmation, it need not be revealed at trial that the defendant was identified through an offender database, which could prejudice the jury.

In *England*, matches between individuals and crime scenes or between one or more crime scenes generate an MR, which is transmitted to the relevant police force electronically and automatically. There is no confirmation process for matches to individuals.

samples are collected. No comparison of these rates can be made with the United States for lack of available data.

[56] In June 2009, the Supreme Court issued a ruling in *Melendez-Diaz v. Massachusetts* (2009). The court held that submitting laboratory results in lieu of having the analyst testify violated the defendant's Sixth Amendment right to confront his accusers. The decision has been very strictly construed in some jurisdictions, going so far as to require that everyone in the evidence chain of custody appear in court to testify. Strict interpretation of the decision discourages the more efficient assembly-line DNA analysis, which has long been standard operating procedure in England and where the laboratory report is considered the "best" evidence.

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About This Report

Many senior U.S. law enforcement officials believe that the English criminal justice system has capitalized more fully on the crime-fighting potential of forensic deoxyribonucleic acid (DNA) evidence than the U.S. criminal justice system. They contend that the English system is much faster at testing DNA samples and at uploading the test results into its forensic DNA database and that the English national DNA database provides more database "hits" that might help law enforcement solve and prevent crimes. Members of the RAND Center on Quality Policing (CQP) asked RAND researchers to explore the forensic DNA analysis systems in England and the United States to find out whether these perceptions are accurate.

This report presents our best efforts to undertake this comparative analysis, which was severely hampered by a lack of data on the U.S. and English forensic DNA systems and the unwillingness of some U.S. agencies to share their data. We make use of the limited available information to undertake comparisons of the two systems, highlighting the limitations of these comparisons. Additionally, we discuss broader issues that arose during the course of our analysis as to the appropriate metrics that should be used for comparison and the contextual factors that we think should be taken into account in any international comparison of DNA database systems.

This report will be of particular interest to criminal justice leaders and policymakers and civil servants involved in public safety policy, particularly forensic DNA laboratory analysts and management, and law enforcement officers, including detectives up to agency heads.

The RAND Center on Quality Policing

This research was conducted under the auspices of Center on Quality Policing, part of the Safety and Justice Program within RAND Infrastructure, Safety, and Environment (ISE). The center's mission is to help guide the efforts of police agencies to improve the efficiency, effectiveness, and fairness of their operations. The center's research and analysis focus on force planning (e.g., recruitment, retention, and training), performance measurement, cost-effective best practices, and use of technology, as well as issues in police-community relations.

The mission of ISE is to improve the development, operation, use, and protection of society's essential physical assets and natural resources and to enhance the related social assets of safety and security of individuals in transit and in their workplaces and communities. Safety and Justice Program research addresses occupational safety, transportation safety, food safety, and public safety—including violence, policing, corrections, substance abuse, and public integrity.

Questions or comments about this report should be sent to Jeremiah Goulka (Jeremiah_Goulka@rand.org). Information is available online about the Safety and Justice Program (http://www.rand.org/ise/safety) and the CQP (http://cqp.rand.org). Inquiries about the CQP or research projects in the CQP or Safety and Justice should be sent to the following address:

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