Turning Base Hits into Earned Runs: Improving the Effectiveness of Forensic DNA Data Bank Programs

Frederick R. Bieber

Forensic data banks contain biological samples and DNA extracts as well as computerized databases of coded DNA profiles of convicted offenders, arrestees and crime scene samples. When used for investigative and law enforcement purposes, DNA data banks have been successful in providing key investigative leads in hundreds of criminal investigations. A number of these crimes would never have been resolved without use of such data banks. In addition, in some limited number of investigations, the exclusion of known suspects whose DNA profiles are known to be in an offender database can save valuable investigative time.

Despite the above benefits, in hundreds of cases DNA samples are never collected and administrative and laboratory logjams delay prompt database searches. Furthermore, hundreds of DNA database matches (hits) languish, without any followup by law enforcement or prosecutors. These prevent or delay DNA matches and therefore can leave the public in grave risk of potential harm from recidivistic offenders who otherwise could have been apprehended and convicted if the process functioned more effectively. Data compilations on meaningful metrics of success are critically lacking. This leaves legislators and policy analysts with inadequate data on which to judge the overall effectiveness of DNA data banking programs. To improve effectiveness of DNA data banks in meeting the stated goals of enhancing public safety, data collection and research are urgently needed. Tracking database hits and prioritizing case management must become a high priority.

General Background

DNA testing has become the gold standard for forensic identifications since its introduction in the late 1980s. Having successfully withstood continuous legal admissibility challenges, particularly in the United States, its ability for individualization (i.e., its potential inculpating power and therefore its probative value) is beyond doubt, making DNA analysis a central part of routine criminal investigations around the world.[1] Moreover, the discriminating power of DNA technology permits rapid exclusion of suspects and has led to DNA-based exonerations of hundreds of individuals who stood trial and were convicted before the modern era of forensic DNA testing.[2] In addition to using forensic DNA test-

Frederick R. Bieber, Ph.D., *serves as Medical Geneticist at Brigham and Women's Hospital, and as Associate Professor of Pathology at Harvard Medical School. He serves on Advisory Boards of the Armed Forces DNA Identification Laboratory of the U.S. Department of Defense, the Department of Forensic Science of the Commonwealth of Virginia, and the National DNA Data Bank of Canada.*

ing for criminal investigations, it is also widely used for civil paternity testing, immigration and probate disputes, missing persons recovery efforts,[3] and for reunification of human remains in the aftermath of mass disaster or war.[4]

Most industrialized nations now collect biological samples from crime scenes and from those convicted of serious crimes for entry into government DNA data banks. These data banks consist of a variety of separate computerized databases which hold the DNA profiles of known convicted offenders, crime scene samples, missing persons, mass disaster samples, or of volunteers who may come forward in hopes of identifying loved ones lost after mass disaster.

The U.S. initiated widespread forensic DNA collections into data banks in the early 1990s, operated by state and local crime labs, but centralized by the Federal Bureau of Investigation, part of the U.S. Department of Justice.[5] The U.S. program is known as the Combined DNA Index System (CODIS), which began as a pilot project in 1990, first serving fourteen state and local laboratories. The FBI's authority to establish a national DNA index for law enforcement purposes was formalized by the DNA Identification Act of 1994 (Public Law 103 322). CODIS is organized as three separated hierarchical systems at the local, state, and national levels. While DNA profiles are generated at the local level (LDIS), they can then flow to the state (SDIS) and national (NDIS) levels. This tiered approach enables local or state agencies to operate their own databases in accord with specific statutory or regulatory mandates.

In 1995, the first European DNA database for offender identification was established in the United Kingdom as The National DNA Database (NDNAD), following amendments to the Police & Criminal Evidence Act 1984 by the Criminal Justice and Public Order Act 1994.[6] The NDNAD is independently governed by a tri-partite board comprised of the Home Office, the Association of Chief Police Officers, and the Association of Police Authorities, whereas the daily operation of the database is performed by another government agency, the Forensic Science Service (FSS), under contract. DNA databases were introduced in the Netherlands and Austria two years later, and Germany followed in 1998. Other European countries with such databases include Belgium, Denmark, Finland, France, Norway, Spain, Sweden, and Switzerland. The European DNA Profiling Group (EDNAP) was initiated in October 1988 in London by a group of forensic scientists from various European countries, joined together to organize use of DNA technology for crime investigation. Activities of EDNAP include work toward standardization of methods, techniques, and data sharing.[7]

The National DNA Data Bank of Canada was established by the DNA Identification Act (1998, c.37) to collect DNA from those convicted of certain designated offenses and from crime scenes. Opened in 2000, the Canadian DNA Data Bank is centrally administered by the Royal Canadian Mounted Police at their headquarters in Ottawa. All offender samples collected throughout the provinces and territories are processed there,[8] whereas crime scene samples are processed, and profiles are uploaded at one of several laboratories providing forensic laboratory services in Canada.

The Interpol DNA Unit was established in Lyon, France, following acceptance of Resolution Number 8 of the 67th General Assembly (Cairo, 1998) to advance international co-operation on the use of DNA in criminal investigations, to assist member states, and encourage DNA profile comparison across international borders. The stated objective of this Interpol DNA unit is to "provide strategic and technical support to enhance member states' DNA profiling capacity and promote widespread use in the international law enforcement environment."[9]

Initially, statutory legislation allowed collection of DNA only from those convicted of murder or sexual crimes, but inclusion criteria have steadily expanded to include all felonies, including non-violent property crimes, in the majority of U.S. states.

Regardless of the jurisdiction, laboratory and programmatic operations have standard features. Basically, computerized searching of archived DNA profiles allows comparison of DNA profiles from biological samples collected from different crime scenes and with those of known offenders or arrestees. In some cases the legally mandated collection of a DNA sample occurs after conviction and in others upon arrest. Blood samples or oral swabs are typically used for DNA collection. The DNA markers used for identification are various non-coding regions of the human genome showing DNA sequence or length variation among individuals in the population. Between ten and twenty of these regions are tested that contain a variable number of four or five DNA base pair short tandem repeats (STRs). These particular STR markers are not known to be associated with predilection to human disease and therefore the forensic DNA typing results do not predict

the present or future health status of the individuals from whom the samples are collected. Nevertheless, in the U.S. the samples and the extracted DNA are usually retained by the law enforcement laboratories – making additional genetic testing theoretically possible, though currently prohibited under most existing statues.[10]

DNA Database Expansion

Initially, statutory legislation allowed collection of DNA only from those convicted of murder or sexual crimes, but inclusion criteria have steadily expanded to include all felonies, including non-violent property crimes, in the majority of U.S. states,[11] following the U.K.'s lead. As criminologists have long known, recidivism rates for property crimes and many violent felonies are at least as high as for sexual offenses, and probably higher than for murders. Furthermore, many violent sex offenders have previous arrests and convictions for burglary and other property crimes. Such realization has led to revised statutes expanding the criteria for inclusion in offender DNA databases.

Enacted legislation now allows DNA collections from most felons convicted in federal and military courts as well as in criminal courts in over forty of fifty U.S. states and the District of Columbia. At least four states (Louisiana, Texas, Virginia, California) have passed laws to mandate DNA collections from arrestees for certain crimes, with similar pending legislation in several others (New Mexico, Minnesota). On January 5, 2006, President George W. Bush signed into law P.L. 109-162 (Table 1), allowing DNA collections from those arrested for certain federal crimes.[12] Federal and state monies have been provided for out-sourcing the backlog of DNA samples from convicted offenders to high-throughput commercial laboratories, leading to a rapid increase in the overall number of offender and crime scene profiles stored in the U.S. database CODIS.

As of December 2005, the FBI reports that the CODIS database has 2,952,820 DNA profiles, including 2,826,505 profiles from convicted offenders and 126,315 from crime scenes, with up to 50,000 new offender samples being added each month.[13] By comparison, the U.K. DNA database contained 3.45 million criminal justice profiles (from offenders and arrestees) and 263,923 from crime scene samples,[14] and The National DNA Data Bank of Canada contained 87,593 offender profiles and 25,575 in their crime scene index.[15]

Court challenges to maintaining offender DNA collections, based on issues relating to retroactive legislation, had some success at early stages.[16] Other challenges have been raised to DNA data bank programs in general and to expansion of existing criteria for DNA collections. In the U.S., none of the challenges to such collections based on Fourth Amendment considerations have prevailed on appeal.

Table 1

Summary of Title X Provisions
Violence Against Women and Department of Justice Reauthorization Act of 2005 (H.R. 3402)
Public Law Number 109-162
Signed into Law on January 5, 2006
by President George W. Bush

TITLE X – DNA FINGERPRINTING

Use of Opt-Out Procedure to Remove Samples from National DNA Index
Because this title expands the scope of the national DNA database to include DNA samples from arrestees, this particular section amends the current expungement protocols and directs the FBI to remove samples in the event of an overturned conviction, acquittal, or the charge was dismissed.

Expanded Use of CODIS Grants
To reduce the extraordinary backlog of rape kits and other crime scene evidence waiting for DNA testing, the Federal government makes available to states a targeted DNA grant program. Specifically, states may seek funding to reduce the backlog in crime scene evidence, to reduce the backlog in DNA samples of offenders convicted of qualifying state offenses, or to enhance the state's DNA laboratory capabilities. This section would expand the grant purpose regarding offender DNA samples to include all samples collected under applicable state law; accordingly, states could use Federal funding to test samples collected from arrestees or voluntary elimination samples.

Authorization to Conduct DNA Sample Collection from Persons Arrested or Detained under Federal Authority
Former Federal law allowed authorities to collect DNA samples from individuals upon conviction. This provision expands that authority to permit the Attorney General to collect DNA on arrest or in the case of non-United States persons, on detention.

Tolling of Statute of Limitations for Sexual Abuse Offenses
This amendment strikes a carve-out authorizing John Doe indictments in sexual assault crimes and makes uniform the Federal law that tolls the statute of limitations for all federal crimes where DNA evidence is collected (§ 3297).

Stated Goals of DNA Data Banking and Results to Date

Before discussion of evaluating effectiveness of offender DNA data banks, and the offender and crime scene databases, it is important to consider the stated mission of such programs. The goals and values inherent in DNA legislation vary somewhat, but do focus on efforts to apprehend criminals and reduce crime. According to the FBI, the goal of the U.S. program is to provide "an effective tool for solving violent crimes." This stated goal of *solving violent crimes* seems to have morphed considerably with the expansive nature of DNA collec-

tions from those convicted of (or arrested for) relatively minor property offenses. The commission of prior nonviolent property crimes by some who later commit serious violent offenses is used as a justification for the expansion of database inclusion criteria.

In the U.S., statutes governing DNA database collections differ in each of the fifty states and for federal offenders. While the agencies managing such programs may have had considerable input into formulating the laws, they did not write, sponsor or pass the enacting legislation. Rather, authorizing bills worked their ways through various public safety hearings, with public input, before legislatures voted, and before being signed into law by Governors or the President. Sometimes DNA legislation appears as a "rider" on other legislation considered at the state or federal level. The extent to which these legislative and programmatic goals are being met and can be improved is considered below.

Individual Successes

DNA comparisons using database searches have led to arrests and convictions of hundreds of criminals who would not, most probably, have been apprehended – or even identified as suspects – without such DNA collections. Also, if an individual is already in an offender DNA database, failure to find a match after comparison of a crime scene DNA profile against all those in the offender index can effectively exclude such individuals without the need to locate that person or collect another sample, thus allowing investigators to focus their attention on more promising investigative leads.

Before a general discussion of measuring efficacy, several examples of individual successes are important to note. In the U.S., one of the more dramatic successes occurred in Houston in November, 2003 when use of CODIS identified a match of DNA evidence to help apprehend a bike-riding predator who allegedly sexually assaulted young boys at knifepoint. For months authorities had no substantive leads, which forced many fearful parents to keep their children under close supervision or inside. However, evidence recovered from one victim was used to find a match in the DNA database to a known sexual offender in the CODIS database.[17]

Other noteworthy examples of successes include one in Wichita, Kansas in which police were able to solve two unsolved murder cases by matching DNA evidence to prisoners. One was charged for the 1995 murder of an elderly woman; the other for a fatal stabbing. In Massachusetts, authorities were able to charge a convicted murderer in the summer of 2003 with the 1998 death of an elderly Foxboro woman who was stabbed twenty-nine times. Also in 2003, the California database helped police solve the case of a sixteen-year-old boy who had disappeared in 1982. In Morrow County, Ohio, the BCI used DNA to link inmate Lamont Jam Wilks to a series of rapes that occurred from June 4, 1995, to December 22, 2003, in Cincinnati. In December 2004, thirty-eight year-old Jeffrey L. Mack was convicted on two counts of aggravated robbery and one count of misuse of a credit card. In October 2003, Mack assaulted two women in Medina County. BCI scientists matched his DNA to physical evidence recovered from a watch found at one of the crime scenes.

In April 2003, the National DNA Data Bank of Canada and Interpol Ottawa identified a convicted offender in an Alberta jail who would later be deported to Ohio to face sexual assault and homicide charges. A key tip came from a viewer in Western Canada of "America's Most Wanted" television broadcast, who thought the suspect in the Ohio murder looked familiar. The RCMP found that the suspect was one Thomas McCray, then serving time under an alias, in an Alberta prison for a secondary offense. The judge in the case had ordered a blood sample sent to the National DNA Data Bank. Interpol Ottawa then coordinated the comparison of DNA from the Ohio crime scene with that collected from McCray in Canada. The DNA profiles matched, linking McCray to the Ohio murder scene. He was deported to the U.S. for trial after his Canadian prison term was fully served.

The first hit on Europe's Interpol DNA database came after Slovenian authorities sent three new DNA profiles to the General Secretariat in Lyon, where they were checked against Interpol records and linked to a profile submitted by Croatian police in November 2003. The DNA match reportedly involved the search for an individual in connection with a series of thefts in Croatia.

Novel DNA Database Searching Methods – Familial Searching

Even more remarkable are cases solved after searches of the DNA database identify a suspect who is not actually in the database, but is closely related to someone who is. Such search successes can occur unexpectedly when close, but not quite identical, DNA matches are observed between crime scene samples and the profiles of known convicted offenders. For example, in North Carolina, retrospective DNA testing of evidence excluded Darryl Hunt who had been convicted of the 1984 murder of Deborah Sykes and had served eighteen years in prison. After Hunt's erroneous conviction was overturned, in 2003, laboratory scientists compared the crime scene DNA profile to the 40,000 offender profiles in the North Carolina state DNA database. While no perfect DNA matches were identified, incidentally an almost-perfect match was noted in

one of the offender profiles derived from one Anthony Brown. Police discovered that Brown had a brother, Willard, and after surveillance police secured a discarded cigarette butt from him for DNA comparison. A perfect match was found and Willard Brown subsequently confessed to the crime.[18]

In other cases "familial searching" is performed purposely in an attempt to identify suspects when no perfect DNA matches are found between crime scene samples and known offenders.[19] Familial searching can be performed simply by direct allele count comparisons, searching for rare alleles, or by formal genetic kinship analysis of the entire offender database.[20] In one remarkable case, the brutal 1988 Valentine's Day stabbing murder of sixteen- year-old Lynette White, in Cardiff, Wales was finally solved in 2003. Three men had their convictions quashed due to allegations of police misconduct. After their convictions were set aside, investigators went back to the crime scene evidence and used modern STR analysis which identified a single rare allele at one locus. Then, a search of the entire U.K. National DNA Database was performed by The Forensic Alliance to list all individuals in the database who had this particular allele at that locus. While the search identified over 600 such individuals, one, a fourteen-year-old boy, stood out, with a very similar overall DNA profile to that of the crime scene evidence. This led police to his paternal uncle, Jeffrey Gafoor, who had the same DNA profile as the evidence, and subsequently confessed to the crime.[21]

Apart from familial searching using DNA databases, simple kinship analysis in the form of paternity testing has been used to compare crime scene samples to a single possible relative/suspect. In the recent "BTK" serial killer investigation in Wichita, Kansas, once police suspected Dennis Rader, they reportedly obtained a warrant to obtain his daughter's medical biopsy sample, without her knowledge, for DNA analysis. DNA analysis was then reportedly performed on her biopsy and the crime scene evidence left by the perpetrator. This was followed by paternity analysis of the DNA results, confirming that the likely perpetrator of the murders could indeed be Rader. This led, in part, to Rader's arrest and to his subsequent confession.[22]

Through February 2006, more than 100 applications of familial searching of offender databases in criminal investigations have been reported around the world, principally in the U.K., with success in more than a dozen. In the U.S. despite the apparent lack of substantive Fourth Amendment issues involved in using such tools, to date, proactive family searching methods have not yet been widely embraced and are, to this point, under-utilized in most countries. This is surprising, given the potential power of such analysis to identify suspects indirectly, and the fact that legislation does not bar use of the databases in this manner.

The Other Side of DNA Evidence: An Innocent Man is Freed

Besides the forceful and often probative inculpating power of DNA evidence, its role in proving actual innocence cannot be overemphasized. Retrospective analysis of old evidence using modern DNA methods has led to reversals of convictions, based on DNA exclusions, for hundreds of persons whose convictions occurred in the era prior to DNA testing. Some of these exonerations occurred secondary to identification of the true perpetrator after searching offender DNA databases. Perhaps the most dramatic example of such use occurred in California when Kevin Green was freed after serving sixteen years in prison for the rape and beating of his pregnant wife, causing her to miscarry their near full-term fetus.[23] His fortune changed in 1996 when Orange County California forensic experts matched crime scene profiles from a string of unsolved rape-murders sent to the state lab for searching the database. The crime scene evidence matched that of a former Marine, Gerald Parker, who was in the database because of convictions in the 1980s for sex crimes. Parker then confessed to the 1970s murders and also admitted beating and raping Green's wife. The court not only freed Green but also found that he was completely innocent. Parker was sentenced to death in 1999.

Metrics of Success – Outcomes vs. Output

> *"Not all that counts can be counted,*
> *Not all that can be counted counts."*
> The Metricator's Maxim

Despite documented utility of forensic DNA data banks in helping solve hundreds of individual violent crimes, the actual outcomes of thousands of "cold hits" (i.e., DNA matches of crime scene evidence to known offenders in the database) to date are mostly unknown. That is, resolution of *bona fide* DNA matches is uncertain, as hits are not necessarily prioritized or followed up on by police or prosecutors – efficiently or at all.

The overall success of such programs simply has not been carefully evaluated in a systematic way by the justice system. This is lamentable as, without such monitoring, it is impossible to identify new ways to improve effectiveness of these data banks. Ultimately such evaluation must occur, as these collections constitute a costly government program and, with limited resources, law enforcement agencies must balance competing demands on budgets and personnel. Furthermore, these data banks have expanded greatly in

scope since their initial implementation and now mandate DNA collection for relatively minor offenses. This dramatic expansion seriously threatens to overwhelm the already overburdened public safety agencies.

Tallying Output (Hits and Investigations Aided)

It has been assumed, but not demonstrated, that the DNA data banks are effective on a broad scale in the manner intended. In fact, we know little about the outcomes of most "hits" or about how most of these investigations would have proceeded – or whether they would have eventually been resolved – if DNA database searches were not performed. Sadly, despite years of operation of these programs around the world, no peer-reviewed, hypothesis-driven research has been published to measure outcomes – only output has been measured.

Through February 2006, more than 100 applications of familial searching of offender databases in criminal investigations have been reported around the world, principally in the U.K., with success in more than a dozen.

Metrics of success for forensic DNA databanks have heretofore been limited to tallies of two outputs, "hits"[24] and "investigations aided."[25] Several types of hits are tallied: case to offender hits (DNA match between crime scene evidence and known offender in the database), and case-to-case hits (linking various crime scenes together). Output has been reported simply as database "hits," typically defined as a DNA match when comparing samples from different crime scenes, or by comparing crime scene samples to the DNA profiles in the offender databases.[26] In addition to such "hit" counting, if the agency determines that the DNA comparison "aids an investigation," it is included in the second tally. The FBI reported 28,300 "hits" and 30,203 "investigations aided" through December 2005, ranging from none at all in Vermont and Puerto Rico to over 3,000 in Illinois, Florida, New York, and Virginia. No data at all are provided about "how" the investigations were aided, about the outcomes of these investigations, or whether any of these hits actually solved the alleged crimes. The National DNA Data Bank of Canada reports 4,710 Offender Hits (Crime Scene to Offender) and 674 Forensic Hits (Crime Scene to Crime Scene) as of February 20, 2006.

While these two tallies of output are certainly interesting, reliance on them as indicators of overall success seems misguided, as they may provide only an incomplete picture of overall DNA database performance. Both hit counting and enumerations of investigations aided are, alone, rather poorly defined concepts with limited value for evaluation of the overall effectiveness of these programs.

First, not all database "cold hits" are truly unexpected, in the sense of providing the first identification of an individual criminal suspect. In fact, many times investigators have already identified a key suspect and, if he is already known to be in the offender database, they expect a database match – they simply wait for such a "hit" report before making further steps toward an arrest, search warrant, or other investigative step. There is no standardized mechanism in place to verify the true nature of purported "cold hits."

Second, DNA database matches are not necessarily probative, and it can certainly be argued that any investigative act whatsoever (including any DNA comparison) "aids an investigation" (whether or not a DNA match is identified from the database search). Moreover, it is well known that a single DNA "hit" could lead to several arrests or aid multiple investigations. We have little, if any information on which "hits" were used and which were not, and the reasons why.

Third, in Canada for example, the number of hits could be much higher if judges issued bench orders for collection of DNA after conviction. Only about fifty percent of the time do they do so now, even for primary offences. This fact alone seriously reduces the potential effectiveness of the data banks. The number of indirect hits could also be increased if familial searching tools were used routinely on selected cases. Regarding "investigations aided" there exist no clearly accepted criteria to define what precisely aids an investigation – e.g., if two crime scenes without known suspects are linked by DNA comparison, is this one investigation aided or two?

Most importantly though, counting "hits" or "investigations aided" does not help assess the most meaningful and relevant outcome, case resolution. Case resolution is largely a downstream activity that is the responsibility of police, prosecutors, and the courts.

Measuring Desirable Outcomes – Case Resolution, Crime Prevention, Societal Interests

Proponents of DNA databases discuss and champion numbers of cold hits and investigations aided as credible measures of success in solving crimes.[27] Legislators then use these data as a justification for further expansion of criteria for inclusion. However, aside from some admittedly dramatic successes, for the most part little, if any, follow-up of "hits" are actually documented, or

even attempted. The few U.S. states (New York and Virginia) that have followed up on a small number of hits have reported a low rate of convictions following their DNA database hits.[28] Some have argued that this low rate is disappointing,[29] yet data have not been available to make a fair assessment of whether the observed rate is low, the norm, or better than alternative practices. In other words, we do not know the counterfactual.

The connection between DNA "hits" generated by forensic database searches and the subsequent investigative follow-up of such hits (to resolution) deserves immediate and careful study to document the full value of DNA collections,[30] to examine weaknesses in the system, and, more importantly, to seek ways to improve such programs to make them even more effective in accomplishing their stated goals.

Possible outcomes from DNA database searches include solving or resolving crimes, reduction in future crimes, as well as benefits to personal and societal interests in public safety and collective security (Table 2). Resolving crimes is an important goal, but not necessarily the only one. Investigations can be aided in many other ways by searching offender databases, such as the elimination of suspects as likely perpetrators, thereby freeing investigators from wasted time chasing unproductive leads. Crimes that can be linked together across jurisdictional boundaries may be the first clue for investigators that the same perpetrator is offending in neighboring or distant locations. Research is needed to address these important questions.

Table 2

Possible Outcomes of Forensic DNA Data Bank Searches

Solve/resolve crimes
- Aid investigation(s)
  - Link crimes
  - Identify suspect(s)
  - Eliminate suspect(s)
- Increased convictions
- Save resources
  - Wasted investigative time
  - Cost savings

Reduce future crimes
- Incarceration after conviction
- Apprehension before next offense
- Deterrence

Personal/societal interest(s)
- Perception of public safety
- Perception of government intrusion
  - database expansion beyond original intent
  - discrimination
- Privacy
  - Value of non-hits
  - Familial searching

Case Resolution

A presumed benefit of DNA database hits is an increase in convictions, with subsequent sentencing of the offender. In fact, this may not be the outcome in a large proportion of cases. There are many possible explanations for limited conviction rates after DNA database hits (Table 3). First is the assumption, often incorrect, that finding a DNA match between a crime scene DNA profile and that from a known individual will be considered useful or probative to the finders of fact – the jury. This is certainly recognized by seasoned investigators and prosecutors, who may eventually decide to ignore a DNA database "hit" if the DNA match is unlikely to be a relevant key piece of evidence. It is hopefully, but not always, self-evident that finding someone's DNA at a crime scene does not necessarily reveal when or how it was deposited (obvious exceptions occur, as in sexual assaults of minors, brutal murders, etc.). Similarly, failure to find someone's DNA at a crime scene does not necessarily eliminate him as a viable or likely suspect.

Secondly, the degree and timeliness of law enforcement follow-up after the crime laboratory reports a DNA database match is highly variable. Laboratories may be so backlogged that samples sit waiting to be analyzed and entered into the database that the perpetrator remains at large, free to continue offending. Further delays may occur due to lag time after a hit is identified and it is received by the appropriate agency.[31] Detective and prosecutor caseloads vary widely and most often there is a lack of exclusively designated personnel for tracking hits. Breakdowns in reporting and overloaded detectives and prosecutors may have less incentive to follow-up on old cases from years ago, considering pressures to solve current cases. There are many problems associated with locating key witnesses years after the reported crimes. Other problems that contribute to failure to resolve cases (by arrest, indictment, and conviction) include deceased victims or suspects, memory lapse, witness intimidation, and missing evidence, even after *bona-fide* DNA matches link crime scene evidence to known offender profiles in the database.

Besides problems with failure of law enforcement to follow up on DNA matches, victims themselves may hesitate to testify years later, even with compelling evidence (including DNA evidence) that would almost assure conviction. For example, if the individual with the matching profile is already in prison serving a long sentence, the victim may choose not to testify or cooperate with the prosecution because she feels secure, now that the criminal is in jail. Some victims simply have moved on and do not wish to revisit the horror of the memory of the crime by testifying in open court. In other cases the statute of limitation has expired on the crime and, even with a convincing DNA match, no prosecution can proceed. Trial and evidentiary issues often preclude conviction. Pre-trial admissibility rulings, non-probative evidence, and non-credible testimony all can result in split jury verdicts or acquittals.

In the end, convictions alone are probably not the most reliable indicator of success toward the stated goal of solving crimes. Rather, case resolution may be a more suitable and reasonable metric, given the many reasons cited above for failure to observe or to document high conviction rates in the aftermath of DNA database hits or investigations aided. Clearly, very careful case tracking is needed to study these factors in more detail on a selected group of cases.

Table 3

Why DNA Data Bank Hits Don't Necessarily Result in Convictions?

Variable followup after DNA "hit" is reported
Detective(s)/DA(s) case load/priorities
No designated personnel
Breakdown in reporting
Overloaded DA (most DNA database hits not plead out)

Witness/Suspect Issues
Victim(s), police, other witnesses
- dead, missing, unable/unwilling to testify

Suspect(s)
- dead, ill, at-large, already incarcerated

Memory lapse
Witness intimidation

Time
"put it behind me"
Statute of limitations expired

Trial/Evidentiary Issues
Evidence not admitted
DNA evidence not necessarily probative
State's witnesses not credible to jury
Jury acquittal

Reduction in or Prevention of Future Crimes

Some proponents have argued that DNA databases will reduce or prevent crime. Whether systematic DNA collection for inclusion in offender databases can, by itself, reduce crime rates is probably impossible to verify with confidence. One of the main predictors of crime rates is simply age and demographics of males, as males between fourteen and thirty years of age commit most of the reported property and violent crimes. Interpreting crime rate statistics presents many challenges as definitions vary widely and reporting accuracy is uncertain. In addition, multiple crimes and uncompleted crimes complicate analyses that depend on crime rate measurements.

In the U.S., measurement of crime rates generally occurs through one of three major indices: the Uniform Crime Reporting Program of the FBI, the National Crime Victimization Survey (NCVS) administered by the Bureau of Justice Statistics of the Department of Justice, and the various National Youth Surveys.[32] While certainly useful, these reporting mechanisms have potential for substantive and unavoidable error. Many crimes go undetected or unreported, and definitions of crime may differ in different jurisdictions. Furthermore, plea-bargaining is so universally common such that pleas are frequently entered (and accepted) for offenses far less than the actual offense; also, reporting is voluntary, so some agencies do not report at all.

There are further potential problems with self-selection, exaggerations and confusing wording in the Youth Surveys, so these statistics are crude estimates, at best. Secular trends in crime reporting can lead to mistaken interpretations. For example, if cultural conditions allow victims to report date rape more readily, the statistics will indicate, perhaps falsely, that sexual assaults are increasing. Conversely, not reporting date rape may lower inappropriately the number of recorded sexual assaults.

If DNA database programs were evaluated with regard to effects on crime rate, it is unclear how to appropriately normalize the available data to assess the impact of DNA databases on such rates. If DNA databases produce the desired outcome at the micro level (i.e. increased suspect identifications, arrests and recorded convictions), then observed recidivism rates would appear to increase. Conversely, measured crime rates could fall because of DNA collections, perhaps due to a deterrence effect or to incarceration of offenders. Measuring age-adjusted secular trends in crime statistics would be of considerable interest given the age and gender associations of crime.

Certainly, when DNA hits lead to arrest and conviction of offenders, lengthy prison sentences might theoretically reduce crime rates by preventing crimes by these particular offenders (at least during the time they remain incarcerated). Nevertheless, prison crowding, light sentencing, conditional sentencing (or no sentencing), and early release programs probably account, in part, for increases in crime rates due to recidivism.[33] For example, the Canadian concept of "restorative justice" has resulted in one of the lowest worldwide incarceration rates after guilty verdicts – ranging from only twenty-four percent in Saskatchewan to fifty-eight percent in Prince Edward Island (the national average is thirty-five percent). If recidivistic, these criminals are then free to re-offend again and again. Evaluation of proper database performance metrics could provide insight into this issue.

A very high degree of re-offense is well documented for most categories of felony crime, including property crimes. Once released, re-offense rates by parolees and probationers are strikingly common for similar and

even more serious crimes. Estimates suggest that as many as one-third of all violent crimes are committed by those on probation and parole.[34] It seems clear that there are many factors that contribute to crime rates, and their changes. Thus, proof that any single new program in the justice system directly reduces crime rates would be difficult to convincingly demonstrate statistically. Nevertheless, we know that rapid apprehension and conviction of true perpetrators identified by DNA database matches will, at the very least, prevent some very serious crimes by those particular dangerous serial offenders. This underscores the need for rapid follow up of DNA hits.

Societal Interests

In addition to the admirable goals of DNA data banks towards resolution of unsolved crimes or to reductions in crime rates, there are several important societal interests potentially served by such programs. These include real and perceived public safety and security in homes and communities. These interests must be balanced in light of often-competing privacy interests. The extent to which expanded DNA collections become intrusive to individuals or to "categories" of people in society is discussed more extensively elsewhere.[35] DNA analysis very often results in less intrusion upon citizens than some traditional investigative methods, as individuals who might otherwise be under suspicion are easily excluded as sources of crime scene evidence.

Laboratories and police agencies have the responsibility to perform their work in a timely manner and to avoid intrusions on uninvolved parties. A good example of problems with errors and delays in the process of DNA analysis occurred on Cape Cod, Massachusetts, in the investigation of the January 2002 murder of Truro resident Christa Worthington. While a person of interest, rubbish hauler Christopher M. McCowen, agreed to give a DNA sample within weeks of the murder, the sample was not collected until March 2004 – and then sat in the Cape Cod police barracks for more than five months, due to a practice which held samples at the barracks for transport to the crime laboratory until there were ten of them. In 2005, as the investigation grew colder, police and the district attorney decided to initiate what became a very controversial (and completely unproductive) DNA dragnet, asking all 790 adult male residents in the area to "volunteer" a sample for comparison to crime scene evidence. Only after collecting several hundred samples and testing over forty did the State Police Crime Laboratory receive and – after further delay of several months in the laboratory – finally test the key sample from McCowen. Finding a DNA match, police finally arrested McCowen and he was indicted for the crimes.[36] A trial is scheduled for the summer of 2006. The "voluntary" exclusion samples collected from over 200 uninvolved Truro residents have been retained by the Massachusetts State Police.

Another example of the seriousness of delays in DNA data bank programs relates to the serious DNA backlogs that exist in many labs. These backlogs result in delays in processing old casework and in processing offender samples and quickly adding the profiles into the DNA databases. One such example gained widespread attention in June 2004 when police in Columbus, Ohio arrested Robert N. Patton Jr. in connection with dozens of rapes in one neighborhood. Patton was arrested based on DNA taken more than two years before, but which was delayed in being entered into the state DNA database. After this was finally done, police linked him to the crimes within hours. Altogether, Patton was indicted in the rapes of thirty-seven women – shockingly thirteen of whom were attacked while his DNA sample sat waiting to be processed. Patton's DNA was part of 11,000 convicted-offender samples that accumulated after a federal grant for Ohio expired in mid-2001.[37] Clearly, funding issues are crucial determinants of success.

Careful research is needed to determine the scope and nature of the above types of system failure and how program improvements through performance management practices can prevent recurrences.

Recommendations

To date, the public has had little input into standards of performance for DNA-related public safety programs, despite the expenditure of large amounts of public monies. Commitments for assessment and evaluation of such DNA collections have had little discussion in public forums, with little oversight by those outside the agencies responsible for their implementation.

The comments herein are not intended – and must not be interpreted – as a censure of forensic DNA laboratories or of the goals of DNA data banking programs themselves. The laboratories perform a Herculean task by responding to legislative mandates to collect, analyze, and to report results of DNA profiling on millions of offender/arrestee and crime scene samples. This is costly, difficult, and sometimes overwhelming work.

Nevertheless, a thorough audit and review of laboratory practices is in order to identify ways to speed throughput and timely identification and reporting of hits. Time lags between the collections of evidence, laboratory analysis, confirmation of a DNA hit, and subsequent investigative follow-up vary considerably and are very worrisome. In some U.S. states such lags are measured in months for the laboratory component alone. Any lags at all allow additional criminal

activity by offenders who could have been identified as suspects rapidly and then apprehended by quick follow-up by police and prosecutors. In the U.K. the Forensic Science Service (FSS) has pioneered an impressive program of rapid response to crime scenes by outfitting mobile vans with new technology allowing DNA analysis of evidence on-site. In this way the FSS has identified unknown perpetrators by finding DNA database matches and apprehending suspects within hours of arriving on the crime scene. Such response is not universal.

The many fruits of the collective labor of the laboratories must not be allowed to linger on the desks and in the files of overworked detectives and prosecutors who do not have the time, energy, or resources to prioritize leads and pursue each and every worthy DNA match to resolution. In addition, developing better ways to improve laboratory throughput and data entry into databases, as well as communication of results, should be actively pursued.

Several groups, convened with NIH funding by the American Society of Law, Medicine & Ethics, reached a consensus on the following issues: (1) the number of "hits" and "investigations aided" are inadequate measures of the effectiveness and efficiency of the use of DNA databases for crime fighting; and (2) outcomes of interest as potential measures of effectiveness and efficiency include: crimes solved that otherwise would not have been solved; deterrence of crime; speedier and cheaper resolution of investigations; avoidance of investigations of individuals who otherwise would have been suspects.[38]

Table 4

Monitoring Success of Forensic DNA Databanks

TRACK OUTCOMES, NOT OUTPUT

- Case resolution, not simply hit counting
- Test hypotheses, not just report anecdotes

Measure desirable endpoints

- Data feedback loop for policy analysis
- Consider all outcomes and cost effectiveness

ACHIEVING POSITIVE OUTCOMES

Increase utilization/awareness

- Awareness needed for deterrence
- Assign designated staff
- Move hits through the causal pathway

Evaluate/consider new technologies

- Robotics, Y-STRs, familial searching

Consider Policy/Privacy Implications

- Costs, other uses

To address the issues, the most pressing need is for collection of systematic follow-up data on outcomes of DNA database hits by police and prosecutors. Besides providing essential data for program evaluation, a critical reason for rapid follow-up of DNA database hits is rapid identification of suspects, subsequent apprehension and arrest of suspects and offenders, and therefore enhanced public safety.

A high priority must be given to *bona fide* DNA database hits. Not only will such prioritization lead to solving or resolving more crimes, but can prevent recidivistic offenders from committing additional crimes prior to apprehension. On January 10, 2006 the California District Attorney's Association, in conjunction with the Department of Justice Bureau of Forensic Services, announced their Cold Hit Outcome Project (CHOP). This project and others like it will be crucial in efforts to identify each of the stages in the DNA data bank programs at which follow up on laboratory results are being impeded or otherwise delayed. Designated personnel in police agencies and prosecutors' offices will be necessary to coordinate tracking hits. Public safety organizations responsible for implementing DNA data banking legislation must plan and dedicate resources for the deluge of data as arrestees are added to the databases, as even more hits can be anticipated.

A lack of integration between the DNA laboratories and the other components of the justice system responsible for following up on results is perhaps the biggest weakness, in that desirable outcomes have not been clearly defined or carefully researched. Systems of performance management[39] are greatly needed to implement ongoing assessment for data collection relating to outcome performance assessment (Table 4). This would enable database managers, investigators, and prosecutors to work together more closely to relate specific DNA collection program activities to specified outcomes. An integrated approach would facilitate real hypothesis testing, rather than anecdotal stories of success in individual cases, which may not be representative of the majority of outcomes. Working together, these efforts cannot fail to produce improvements for the public good.

Dedication and Acknowledgments

This manuscript is dedicated to the memory of the late Dorothy Wertz, whose intellect, scholarship, and love of learning remain an inspiration. The author gratefully acknowledges the American Society of Law, Medicine & Ethics, through a grant from the National Human Genome Research Institute of the NIH (Grant # 1RO1 HG002836), which sponsored a series of workshops to consider DNA Fingerprinting and Civil Liberties. Participants from a wide variety of academic and law enforcement backgrounds participated in round-table discussions at one or more of four workshops. In 2005, at Workshop 2 and at an additional one-day meeting, participants discussed issues surrounding measuring the effectiveness of DNA data bank programs (see www.aslme.org). The author is there-

fore indebted to all of the participants of these ASLME workshops, and especially to colleagues Bruce Budowle, Rockne Harmon, Carll Ladd, Joseph Varlaro, and Maureen Thyne, for much appreciated discussions. The opinions and ideas expressed herein are those of the author and are not made to necessarily reflect endorsement by colleagues acknowledged herein, or to represent any of the institutions or organizations with which the author is affiliated.

References

1. F. R. Bieber, "Science and Technology in Forensic DNA Profiling," in D. Lazer, ed., *DNA and the Criminal Justice System: The Technology of Justice* (Cambridge, MA: MIT Press, 2004): 23-62.
2. S. R. Gross, et al., "Exonerations in the United States, 1989 through 2003," *Journal of Criminal Law and Criminology* 95 (2005): 523-560.
3. L. G. Biesecker, J. E. Bailey-Wilson, J. Ballantyne, H. Baum, F. R. Bieber, et al., "DNA Identifications from the 9/11 World Trade Center Attack," *Science* 310 (2005): 1122-1123.
4. B. Budowle, F. R. Bieber, A. Eisenberg, "Forensic Aspects of Mass Disasters: Strategic Considerations for DNA-Based Human Identification," *Legal Medicine* (*Tokyo*) 7, no. 4 (2005): 230-243.
5. FBI, CODIS webpage, Mission Statement and Background, *at* <http://www.fbi.gov/hq/lab/codis/program.htm> (last visited February 28, 2006).
6. R. Williams, P. Johnson, and P. Martin, "Genetic Information & Crime Investigation: Social, Ethical and Public Policy Aspects of the Establishment, Expansion and Police Use of the National DNA Database," School of Applied Sciences, University of Durham web site, 2004, *available at* <http://www.dur.ac.uk/p.j.johnson> (last visited February 28, 2006); R. Williams and P. Johnson, "Forensic DNA Databasing: A European Perspective, Interim Report," School of Applied Sciences, University of Durham web site, June 2005, *at* <http://www.dur.ac.uk/p.j.johnson> (last visited February 28, 2006).
7. P. Gill, L. Fereday, N. Norling, P. M. Schneider, "The Evolution of DNA Databases – Recommendations for New European STR Loci," *Forensic Science International* 156 (2006): 242-244.
8. For details on the National DNA Databank of Canada, see National DNA Databank website, *at* <http://www.nddb-bndg.org/main_e.htm> (last visited February 28, 2006); National DNA Databank of Canada, Annual Report, 2004-2005, *at* <http://www.nddb-bndg.org/train/docs/Annual_2005_e.pdf> (last visited February 28, 2006); for details on the Canadian DNA Identification Act of 1998, see Department of Justice Canada, Updates to Justice Laws website, *at* <http://laws.justice.gc.ca/en/D-3.8/185698.html> (last visited February 28, 2006).
9. Interpol Resolution 8, DNA Profiling, *available at* <http://www.interpol.int/Public/ICPO/GeneralAssembly/AGN67/Resolutions/AGN67RES8.asp> (last visited February 28, 2006).
10. See S. Axelrad, *Survey of DNA Database Statutes* (as of July, 2005), *at* <www.aslme.org>.
11. See S. Axelrad, *supra* note 10; following the U.K. lead, in the U.S. there has been steady growth in the size of convicted offender DNA databases (e.g., an approximately five-fold increase in the past four years) due in large part to an expansion of the statutory criteria for inclusion. In the U.S., forty-three states have amended their criminal codes to provide for DNA collections from all felons and six states (CA, LA, TX, and VA) now include arrestees as well. Currently there are almost three million DNA profiles and samples in the U.S. offender/arrestee databank.
12. Codified at 42 U.S.C. &14135a (2005). President George W. Bush, on January 5, 2006, signed into law the Violence Against Women and Department of Justice Reauthorization Act of 2005 (H.R. 3402). Public Law Number 109-162 (See Table 1 for summary of DNA provisions).
13. For the official statistics on the U.S. DNA database, see CODIS home page, *at* <http://www.fbi.gov/hq/lab/codis/index1.htm> (last visited February 28, 2006), also, NDIS Statistics, *at* <http://www.fbi.gov/hq/lab/codis/clickmap.htm> (last visited February 28, 2006).
14. Parliamentary Office of Science and Technology, The National DNA Database PostNote, February 2006, Number 258, *at* <http://www.parliament.uk/documents/upload/postpn258.pdf> (last visited March 5, 2006).
15. See *supra* note 8.
16. *U.S. v. Kincade,* 354 F.3d 1095 (9th Cir. 2003), vacated en banc 379 F.3d 813 (9th Cir. 2004).
17. J. Solomon, "A.P.: FBI's DNA Database Gets Heavy Use," March 9, 2004, *available at* <http://www.boston.com/news/nation/washington/articles/2004/03/09/ap_fbis_dna_database_gets_heavy_use?mode=PF> (last visited February 28, 2006).
18. R. Willing, "Suspects Get Snared by a Relative's DNA," *USA Today,* June 7, 2005.
19. J. Bright, *Familial Database Searching – a New Zealand Case Study,* paper presented at Promega Human Identity Symposium, Scottsdale, AZ, 2004.
20. F. R. Bieber, D. Lazer, "Guilt by Association," *New Scientist,* October 23, 2004, *available at* <http://www.newscientist.com/article.ns?id=mg18424703.000>; F. R. Bieber, C. H. Brenner, D. Lazer, unpublished.
21. See BBC News, "How Police Found Gafoor," *at* <http://news.bbc.co.uk/1/hi/wales/3038138.stm> (last visited February 28, 2006).
22. T. Potter, "Source: Daughter's Records Were Subpoenaed," *Wichita Eagle,* March 3, 2005.
23. C. Goodyear, E. Hallissy, "The Other Side of DNA Evidence: An Innocent Man is Freed," *San Francisco Chronicle,* October 19, 1999, *at* <http://www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/1999/10/19/MN03DNA.DTL> (last visited February 28, 2006).
24. See *supra* note 8.
25. See *supra* note 13.
26. Various jurisdictions report "cold hit" rates – the percentage of crime scene DNA profiles that connect to a catalogued offender in the database – of from ten percent to as much as sixty percent. The variation depends on the rules for database inclusion, the maturity of the database, and on how the statistics are defined.
27. D. Adams, "National DNA Database is Well-Worth Taxpayers' Investment," *USA Today,* November 30, 2005, *at* <http://www.usatoday.com/news/opinion/editorials/2005-11-30-letters-dna-database_x.htm>.
28. J. A. Gilmer, D. J. van Alstyne. "The First 100 Hits – Forensic-Offender Matches on the New York State DNA Data Bank," NYS Division of Criminal Justice Services, January 2002, *at* <http://criminaljustice.state.ny.us/crimnet/ojsa/100_hits/> (last visited February 28, 2006).
29. R. Willing, "DNA Matches Win Few Convictions in VA," *USA Today,* November 7, 2005, *USA Today* website, *at* <http://www.usatoday.com/news/nation/2005-11-07-dna-convictions_x.htm?csp=34> (last visited February 28, 2006).
30. DNA is left at the majority of sexual assaults, but the extent to which it is available at other types of crime is quite variable. This alone can preclude use of DNA testing.
31. C. Goodyear, E. Hallissy, "Dangerous Delay on DNA. State Struggles to Gather Genetic Profiles of Violent Felons," *San Francisco Chronicle,* October 19, 1999, *at* <http://www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/1999/10/19/MN05DNA.DTL> (last visited February 28, 2006).
32. FBI website, *Uniform Crime Reports, at* <http://www.fbi.gov/ucr/ucr.htm> (last visited February 28, 2006); U.S. Department of Justice, Bureau of Justice Statistics, *Crime and Victims Statistics, at* <http://www.ojp.usdoj.gov/bjs/cvict.htm#summary> (last visited February 28, 2006).
33. L. B. Schlesinger, *Serial Offenders* (New York: CRC Press, 2001); D. Farrington, "The Development of Offending and Antisocial Behavior from Childhood: Key Findings from the Cambridge Study of Delinquent Development," *Journal of Childhood Psychology and Psychiatry* 36 (1995): 929-964; A. Putkonenen, O. P. Ryynanen, M. Eronen, and J. Tiihonen, "The Quantitative Risk of Violent Crime And Criminal Offending: A Case-Control Study among the Offspring of Recidivistic Finnish Homicide Offenders," *Acta Psychiatr Scand* 106 (Suppl 412) (2002): 54-57;

C. Smith and D. Farrington, "Continuities in Antisocial Behavior and Parenting Across Three Generations," *Journal of Child Psychology and Psychiatry* 45, no. 2 (2004): 230-247; D. Farrington, D. P. Barnes, and S. Lambert, "The Concentration of Offenders in Families," *Legal and Criminological Psychology* 1 (1996): 47-63; 17.1% of jail inmates surveyed reported a father, 4.4% a mother, 30.3% a brother, 6.2% a sister, 3.3% a spouse, and 1.3% a child having been, at some point, in a correctional facility, A. Beck, D. Gilliard, L. Greenfeld, C. Harlow, T. Hester, L. Jankowski, T. Snell, J. Stephan, D. Morton, *Survey of State Prison Inmates,* Bureau of Justice Statistics, U.S. Dept. Justice, Correctional Populations in the United States, 1996, at 62, Table 4.18.

34. R. McCleary, *Dangerous Men: The Sociology of Parole* (Albany, NY: Harrow and Heston, 1992).
35. See *supra* note 18; D. Lazer, M. Meyer, *DNA and the Criminal Justice System: Consensus and Debate,* in D. Lazer, ed., *DNA and the Criminal Justice System: The Technology of Justice* (Cambridge, MA: MIT Press, 2004): 357-390; D. H. Kaye, M. S. Smith, "DNA Databases for Law Enforcement: The Coverage Question and the Case for a Population-Wide Database," in *DNA and the Criminal Justice System: The Technology of Justice,* D. Lazer, ed., (Cambridge, MA: MIT Press, 2004): 247-284; R. Williams, P. Johnson, "Inclusiveness, Effectiveness and Intrusiveness: Issues in the Developing Uses of DNA Profiling in Support of Criminal Investigations," *Journal of Law, Medicine & Ethics* 33 (2005): 545-550. Reprinted in this issue, *Journal of Law, Medicine & Ethics* 35 (2006): 234-247.
36. B. McGrory and M. Levenson, "Worthington Probe Eyed Higher-Profile Leads," *The Boston Globe,* April 17, 2005, *available at* <http://www.boston.com/news/local/massachusetts/articles/2005/04/17/worthington_probe_eyed_higher_profile_leads/> (last visited February 28, 2006).
37. L. Foreman, "Ohio Attorney General Uses Victims' Fund To Ease DNA Backlog," August 9, 2004, WCPO TV website, *at* <http://www.wcpo.com/news/2004/local/08/09/dna.html> (last visited February 28, 2006).
38. *Available at* <http://www.aslme.org/dna_04/work2/report.php>.
39. A. C. Daniels, J. E. Daniels, *Performance Management: Changing Behavior that Drives Organizational Effectiveness,* 4th ed., (Atlanta, GA: Performance Management Publishers, 2004).