SCIENCE AND SOCIETY

Legal and public policy issues in DNA forensics

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Since the 1980s, when DNA markers for identifying biological samples were first developed, the use of DNA evidence to convict defendants and to exonerate the wrongfully accused and wrongfully imprisoned has greatly increased. But the increase in databanks for storing DNA information on individuals convicted of certain crimes raises important legal and ethical issues on the use, collection and storage of DNA evidence. These issues have been the subject of a recent US National Commission, which will, hopefully, broaden public discourse about the future uses of DNA forensic technology.

The use of biological markers for forensic purposes dates back to the discovery of the ABO BLOOD GROUPS in the early twentieth century[1], which were soon adapted for use as evidence in disputed paternity cases. With time, these and other subsequently discovered biological markers were used to determine if a person could be excluded from involvement in a case (for more on the history of forensic markers, see link to the Forensic Science Timeline). However, they could not be reliably used to establish a match between two samples, and so were of limited use in the resolution of violent crimes. By the 1980s, more than 100 protein polymorphisms were known, but few were used for forensic purposes, partly because of insufficient data on their distribution within various populations. The advent of DNA forensics came in 1985, when, in the United Kingdom, Alec Jeffreys and others showed that the genome was rich in highly polymorphic stretches of DNA that were called VARIABLE NUMBER TANDEM REPEATS. The UK government moved quickly to develop these markers for use in DNA forensics, blazing a trail that, in the United States, the Federal Bureau of Investigation (FBI) was quick to follow.

After a string of early successes, however, the use of DNA evidence in criminal cases in the United States came under attack. During the late 1980s and early 1990s, several scientists teamed up with defence attorneys to challenge its reliability. Expert witnesses questioned the laboratory techniques that were used to type the DNA markers, the algorithms that were used to declare that two samples matched, and the relatively sparse population data that were used to calculate the probability that DNA from a randomly selected person would match the profile of a sample obtained from a crime scene. This controversy invigorated the FBI's research into DNA forensics. In the late 1980s, it initiated efforts to develop DNA-identification technologies, developed data on allele frequencies among reference populations and constructed uniform databanking practices. Arguments over rules for declaring a match between two typed DNA samples, especially uncertainty about the range of variation in allele frequency among population groups, dominated discourse in the early 1990s, which resulted in two reports from committees appointed by the National Research Council[2,3]. During this era, there was also much debate as to the proper way to provide expert testimony about DNA identification to a jury. By 1997, as more data were gathered from reference populations, considerable progress had been made towards resolving these key issues. Today, DNA evidence is widely used in courts throughout the United States and Europe. Although the work done by individual technicians on particular samples can still collapse under attack in a courtroom, more often the results of DNA testing constitute a powerful element of a prosecutor's case. During the mid- to late-1990s, a new issue emerged. The United Kingdom, various US states and several European nations began to build an infrastructure to support large DNA databanks composed of samples obtained from convicted felons (BOX 1). As a result, a host of questions, many framed as elements of a broader privacy debate, emerged.

Given their importance, the relative paucity of journalistic interest in (and public knowledge of) databanks containing DNA information on convicted criminals is curious. Between 1990 and 1999, all 50 US states enacted laws that require persons convicted of certain felonies (the list varies among the states) to provide a blood sample for DNA typing before parole. Owing largely to the influence of the FBI, most of the typing done at or on

Box 1 | International DNA databanking laws

In addition to the United Kingdom and the United States, DNA databanking laws have been enacted in Australia, Austria, Canada, China, France, Germany, the Netherlands and Switzerland. Perhaps the main difference in the application of these laws between the United States and Europe is that European nations permit 'sweeps' — the collection of large numbers (sometimes thousands) of ELIMINATION SAMPLES to help focus investigations. So far, more than 80 such sweeps have been conducted[12]. Although the citizens who provide DNA samples in these sweeps are not required to by law, the context is not without social coercion.

Box 2 | DNA typing for forensic evidence

Short tandem repeats (STRs) are short stretches of highly repetitive DNA, typically of 2–7 base pairs (bp) in length, which are present in all humans and which vary widely between individuals
in their copy number (STR allele frequencies can range from 7 to 30 alleles), but which usually have a total length of less than 500 bp. This short length enables very small amounts (less than 1 ng) of DNA to be amplified by PCR, a method that also allows highly degraded DNA, which often cannot be used for Southern blot analysis, to be analysed. The amplified products are separated
by electrophoresis and detected either by silver staining, which binds to amplified DNA, or, increasingly, by the use of amplification primers that have fluorescent tags (enabling real-time detection). When two biological samples are demonstrated to have the same DNA profile, by assaying for many independently inherited loci, each with a high degree of allelic variation, forensic experts can testify with a high degree of confidence that they are from the same individual (excluding identical twins).

Because the United Kingdom uses 8 of the 13 loci used in the United States, evidentiary samples obtained in one country might be used to search the database of convicted felons compiled by another country. As other European nations begin to adopt some or all of these loci, it will become possible to conduct international DNA evidentiary searches.

behalf of the various state crime labs uses (or will soon use) a standard battery of 13 short tandem-repeat (STR) loci (BOX 2). Using the FBI data sets, James Crow, a population geneticist and a member of the recent national commission on DNA evidence (see below), calculated that the probability of a complete match between profiles of two unrelated persons in a randomly mating population of Caucasian Americans is 1.74×10^{-15}, or 1 in 575 trillion. Much work is being done to obtain the needed frequency data in population groups, ranging from the Vietnamese to the Trinidadians[4]. The 13 FBI core loci are now used throughout the United States and identification data derived from them are curated under a standard system known as the COMBINED DNA INDEX SYSTEM (CODIS).

In the United States, CONSTITUTIONAL CHALLENGES to the taking of a convicted felon's blood arose early in the 1990s and have persisted. By 2000, at least nine US federal or state APPELLATE (APPEAL) COURTS had heard a variety of arguments, most centred on the protections offered by the Fourth Amendment (which protects US citizens from unreasonable search and seizure). So far, all appellate courts have upheld the STATUTES as a valid exercise by the state of its police power. The recidivistic behaviour of many criminals provides a powerful rationale for obtaining tissue for DNA typing.

In 1997, after hearing about cases in which DNA evidence was used to exonerate erroneously convicted and imprisoned people, US Attorney General Janet Reno established a National Commission on the Future of DNA Evidence (BOX 3). In this article, I discuss the work of this commission and some of the legal and policy issues that it addressed. The opinions expressed are my own.

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Which samples to type?

One of the first issues to arise was: What is the proper scope of a law that mandates the collection of samples for DNA typing and data storage? Some of the older statutes mandate the collection of tissue for DNA typing only from persons convicted of sexual crimes or murder, whereas some newer ones cover a broader list of felonies. In the state of Virginia, for example, the law applies to all convicted felons. This in part reflects the growing awareness among law enforcement agencies that careful crime-scene investigation, combined with PCR technology, can yield DNA identification data at the scenes of many of the more common crimes, such as burglary and car theft. In essence, the early statutes were written in anticipation of only those crimes that provide abundant DNA evidence for investigation. More recently, states have enacted statutes that reflect the power of today's analytical techniques. It is likely that, unless appellate courts rule that the more inclusive statutes fail to protect individuals under the Fourth Amendment, most will gradually be amended to mandate DNA typing of all felons.

There are about 1.3 million felony convictions in the United States each year. Today, the US Department of Defense (DoD) has the world's largest collection of tissue samples stored expressly for DNA typing. This databank was created in the early 1990s to ensure that the remains of US soldiers could always be identified. Given the expanding scope of DNA felon databanking, the state forensic collections will together surpass the size of the DoD bank within the next few years.

The trend towards a wider application of DNA forensic typing will not stop at boundaries imposed by felony conviction. In the United Kingdom, police have the right to take a tissue sample for DNA typing from most arrestees (and are obligated to destroy DNA information upon exoneration of a suspect). Louisiana is the only US state that now has a law that permits taking a suspect's DNA sample for typing at arrest. However, both the mayor of New York City, Rudolph Guiliani, and the city's former Police Commissioner, have advocated such a policy. In New York City alone, more than 300,000 arrests are made each year[5]. Given the huge backlog of tissue samples that have been collected from felons but not yet typed (see below), most of the commissioners thought that, even if such an expansive approach could be justified, it would be financially impractical. However, it should be noted that in the United Kingdom, DNA sampling is permitted upon arrest and there is not a serious backlog problem. This is in part due to the smaller size of the population, the centralization of laboratory services and a history of these services being better funded than in the United States.

Although the state laws were enacted as part of a national effort to create an interconnecting set of DNA felon databanks, the files of which could be searched for a match to a new crime-scene sample, there are several other classes of people from whom it might be valuable to collect, type and store a DNA forensic profile. For example, when investigating a rape, police commonly ask a victim's sexual partner to provide a blood sample, one type of a so-called elimination sample. Similarly, sometimes in Europe (and, rarely, in the United States) police have asked hundreds of people (for example, adult men in a rural area where a rape with murder has been committed) voluntarily to provide samples for DNA analysis to exclude them as suspects. Should the DNA profiles from these samples be retained? Although the CODIS rules explicitly limit the inclusion of DNA profiles in the US national system to those from people convicted of a felony under state law, state or even local authorities might use different

criteria for storing a profile for local use. The National Commission was divided on the placement of DNA profiles from non-felons into CODIS. It did, however, conclude that DNA profiles compiled from living victims should not be placed there.

Another valuable use of DNA forensics is in the identification of human remains that have not been identified by other methods, the purpose of the DoD's tissue-banking programme. In 1999, Spain started a national programme, called the Phoenix Programme, to solve missing-persons cases. This project will create two databases: a reference database composed of mitochondrial DNA sequences from tissue provided voluntarily by the maternal relatives of a missing person and one that contains sequences derived from unknown human remains[6].

Exacerbating social inequity?

One of the most vexing policy issues considered by the National Commission comes from the disturbing fact that DNA felon databanking is practised in a criminal justice system that some US citizens believe is unjust. If, for example, African Americans are disproportionately apprehended, tried, convicted and sentenced for felonies, then they will be overrepresented in CODIS. Concerns for justice led some commissioners to wonder if the fairest policy might be to require that all citizens provide a sample for DNA typing (see FIG. 1). Even if the obvious concerns about privacy could be managed, however, such a programme would, at least with current technologies, be prohibitively expensive. However, if it were phased in over a few years, for example partly through integrating forensic typing into the already extant universal genetic screening of newborns for rare, treatable disorders, it might be economically feasible in the United States.

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Although many would oppose a policy that placed a DNA sample in the hands of the government, they might be willing to accept such a policy if legislation could limit the nature of the DNA analysis, require the destruction of the sample after a certain period, forbid its use outside law enforcement and severely punish those who violated the rules. With these safeguards in place, in time the public might come to view universal DNA databanking for identification purposes as providing social benefits, especially crime reduction, that more than counterbalance the threat to privacy. An inherent weakness in DNA felon databanking today is that entry into the database only comes with conviction for a felony. However, many of the individuals who are finally convicted of a felony might well have committed other crimes for which they were not apprehended. Universal DNA profiling at birth could, theoretically, reduce the amount of criminal activity by repeat offenders because they would be apprehended earlier. In addition to concluding that such a course would not be economically feasible, many on the commission thought that universal DNA databanking would raise widespread public concern about the potential for violation of privacy interests.

Should the DNA be stored?

Another question, one that divided the commission members, was: Should the sample acquired for DNA typing be retained or destroyed after the profile has been electronically stored? Some commissioners thought that because the sample provided by the felon as a condition of parole is not subsequently used in the investigation of crimes it should be destroyed. (It need not be used further because if tissue obtained at a crime scene yields a DNA profile that matches that of a digitally stored DNA typing in a state felon databank, the alleged perpetrator will, if apprehended, be forced to submit a new sample for analysis. This new sample is then used to establish a match with the crime-scene sample.) They asserted that destruction of the DNA from which the digitized profile is constructed would greatly diminish public fears about government threats to genetic privacy. Others argued that law enforcement must be allowed to retain the original tissue samples because they would be needed if the current 13 STR typing system was replaced with a system that necessitated retyping all samples then in the databank. Given the recent technological advances in typing single-nucleotide polymorphisms[7,8], this argument might have merit. However, the working group on the future of DNA forensic testing was confident that the current system could be successfully operated (at probably diminishing costs) without substantial modification for many years[4]. Crime-scene work will be supplemented, for example, with mitochondrial DNA and Y-chromosome analysis. The benefits of switching to an improved technology must be offset against the risk of increased costs and failing to render the system fully operational .

Box 3 | National Commission on the Future of DNA Evidence

In the United States in 1997, Attorney General Janet Reno, as a result of her interest in the value of DNA evidence to exonerate wrongfully convicted persons, created the National Commission on the Future of DNA Evidence to advise the US Department of Justice on unresolved policy questions.

The commission, chaired by the Honorable Shirley Abrahamson, Chief Justice of the Wisconsin Supreme Court, created five working groups to report to it on specific issues: post-conviction DNA testing; the future of DNA-identification technologies; crime-scene investigation; the funding needs of forensic laboratories; and legal issues.

In November 2000, the Commission completed its three-year study. During its tenure, the Commission considered (but did not necessarily resolve) several important policy questions.

- What is the proper scope of felonies to be covered by a DNA felon databanking system?
- Should law enforcement officials be permitted to conduct DNA typing on arrestees?
- Do current state DNA felon databanking laws exacerbate inequities in the criminal justice system?
- What procedural changes are needed to accommodate legitimate appeals by convicted people on the basis of the existence of unanalysed crime-scene or other evidence that, if studied, could exonerate them?
- After DNA profiling is complete and the results stored electronically, should the tissue sample be retained or destroyed?
- Is DNA evidence so powerful that we should rethink the application of a statute of limitations in certain crimes?
- What must be done to train crime-scene investigators about the proper methods to collect evidence that might contain DNA information?
- What must be done to generate enough funds to solve the growing backlog of collected, but unanalysed, samples taken at parole from convicted felons?

Figure 1 | **UK Prime Minister Tony Blair having a DNA swab taken for Britain's national DNA database.** The photograph was taken while he was promoting the campaign for compulsory DNA testing of those arrested for any offence that carries a prison term. © Associated Press (1999).

Post-conviction testing

The criminal justice system places a high value on achieving 'finality' — the principle that once a criminal case has been tried, a verdict reached and appeals completed, the case is closed. This core principle is built on the presumption that verdicts reached by juries are fair and, because the ability to reconsider a case fades with time, victims deserve closure, and judicial resources are limited. Because DNA-identification testing is a powerful tool to exonerate the wrongfully convicted[9], it is forcing the criminal justice system to balance the need for 'finality' with the even more compelling quest for justice.

Today, there are almost certainly thousands of men serving time for crimes of sexual violence who steadfastly assert their innocence and who seek to reopen their cases on the grounds that among the retained evidence (typically, so-called 'rape kits') is material that, if subjected to DNA analysis, would exonerate them. The National Commission asked: Under what circumstances, if any, should convicted felons be permitted to reopen their cases to seek exoneration by DNA analysis? One of the most valuable outcomes of the National Commission is the report published on this matter by its post-conviction issues working group[10]. In addressing the question of when to analyse unanalysed evidence or that which was analysed with less robust techniques, the commission recognized several categories of petitions. By far the most important are situations in which exclusionary results would lead to a release from prison; for example, if a man has been convicted of rape by the victim's eye-witness testimony, but post-conviction DNA analysis of the biological evidence does not match his DNA profile. Of course, exclusion by DNA analysis need not result in exoneration. If a man has been convicted of having participated in a gang rape, the fact that post-conviction testing fails to find evidence of his semen does not mean he did not forcibly restrain the victim while others committed the rape. The National Commission has proposed guidelines for prosecutors, defence attorneys and judges on how to handle petitions for post-conviction DNA testing, and has approved a model statute to assist states to provide individuals with access to post-conviction testing.

The statute of limitations

Except for murder, most crimes have a STATUTE OF LIMITATIONS; if a criminal complaint is not filed within the statutory time (for example, within seven years of a rape in many states), the perpetrator is beyond the reach of the law. The principal reasons for this rule are obvious: as time passes, the likelihood of successful prosecution fades, victims often become reluctant to reopen terrible emotional wounds and the courts are overwhelmed with current cases. The power of DNA analysis challenges the wisdom of this rule. For example, DNA analysis of semen samples taken from many rape victims over several years in a particular city might show that the same man (excluding identical twins) committed all the crimes. If he is eventually caught, it might be possible to convict him of several of the older offences, as well as of the current one, which might result in the imposition of a heavier penalty. In 2000, a Milwaukee assistant district attorney filed a criminal complaint against one "John Doe, known more fully by a 13 STR profile". In effect, by claiming he had irrefutable evidence of the identity of the as yet unapprehended serial rapist, the prosecutor sought to block the application of the statute of limitations. The legal validity of filing such complaints must await the results of the legal challenge that will inevitably arise from someone who is prosecuted after the statute of limitations has expired.

Glossary

ABO BLOOD GROUPS
The principal antigens found on the surface of red blood cells. The co-dominantly inherited ABO system, discovered by Landsteiner in 1900, is the principal predictor of transfusion incompatibility.

APPELLATE (APPEAL) COURTS
In the United States, a national government and 50 state governments function in parallel according to powers and duties outlined in the US Constitution. Each government has a judicial branch, and each branch is tiered so that a party who is dissatisfied with the outcome of a case in a lower court can ask a higher court to review it. The constitutionality of new laws is often tested, and over time the higher courts resolve the key issues. The US Supreme Court is the ultimate judicial arbiter.

COMBINED DNA INDEX SYSTEM (CODIS)
In the United States, CODIS is a distributed database that is organized into three hierarchical levels: local, state and national. All three levels store indexed and searchable digitized representations of typed DNA samples. The hierarchical design allows state and local laboratories to configure CODIS to meet their specific needs.

CONSTITUTIONAL CHALLENGE
Typically, a lawsuit brought to contest a legislative act, which argues that the act violates a provision of a state constitution or of the US Constitution and so should be struck down.

ELIMINATION SAMPLE
A DNA sample collected from an individual not thought to be a suspect in a crime (such as the partner of a rape victim) to help investigators to analyse the evidence.

STATUTE
A law enacted by either a state legislature or the US Congress and signed by the governor or the president.

STATUTE OF LIMITATIONS
A law in criminal jurisprudence that defines the period of time during which a person can be prosecuted for a crime.

VARIABLE NUMBER TANDEM REPEATS
Loci containing variable numbers of short tandemly repeated sequences that are highly polymorphic. The length variations permit one to develop a composite DNA profile of an individual.

Crime-scene investigation

A practical set of guidelines, which is emerging from the work of the National Commission, is being generated by the crime-scene investigation working group. It found a huge disparity, varying largely with the resources available to the local law enforcement agency, regarding whether or not investigators thought that DNA evidence might be attainable from the crime scene. It also found that some local DNA crime-lab analysts were so swamped with casework that they do not carry out DNA analysis for many of the tougher (more time-consuming) cases. There is a need for funds to train personnel in crime-scene investigation, to maximize the chance of finding a relevant DNA sample and preserving it, as well as to assist crime labs to build the capacity for DNA analysis. DNA felon databanking will only pay the appropriate social dividends if those at crime scenes are expert in collecting the samples.

The backlog problem

The most important challenge faced by those who are implementing DNA felon databanking systems is 'backlog reduction'. For several years, in virtually every US state, the collection of samples from paroled felons has far outpaced sample analysis. Although the precise number is unknown, as of late 1999, this backlog in the United States probably consisted of 500,000 samples. In 1999, the US Congress provided $15 million to assist states with their backlog reduction, requiring that 1% of funds be used to address unsolved crimes (that is, to be allocated to current cases). It permitted the states to use grants to operate their own labs or to outsource DNA typing to qualified commercial laboratories (at least seven companies are working in this field, for example The Bode Technology Group in Virginia). This funding has had a significant impact. According to information supplied by the commission, 21 states have been awarded grants that are being used to type 288,647 samples (about $50 per sample) from convicted felons and to do 2,886 analyses on casework samples[11].

The apparent success in reducing the backlog of samples collected from felons does not extend to open casework. Across the United States, especially in high-crime areas, thousands of rape kits remain untested. This is a highly unsatisfactory state of affairs as these kits contain DNA evidence that would greatly assist in the apprehension of many criminals, and might also help to exonerate innocent suspects. Crime-scene analysis is more expensive than typing blood samples from parolees, but the benefits of its use to law enforcement could be considerable.

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Conclusion

The reports produced by the National Commission on the Future of DNA Evidence (some of which have yet to be published) will, hopefully both in the United States and in other countries, draw attention to the power of DNA felon databanking and crime-scene sample analysis towards reducing crime and achieving just outcomes in the resolution of criminal investigations and prosecutions. Large-scale DNA forensic databases will almost certainly result in significant changes to long-established rules in criminal justice in the United States and many other nations, for example, to the inviolability of the finality principle and the use of statutes of limitation. Given the likelihood that DNA forensic databanks will become more comprehensive in size and application, we need broad public discourse on the conflicting interests of preserving personal privacy and protecting citizens from crime. Given the costs involved in operating a system of 50 state forensic databases and the strong public concern about the privacy risks associated with DNA databanking, there might be cogent reasons in the United States to centralize gradually to a single storage facility. However, this suggestion would probably meet substantial resistance owing to the state-based nature of the US criminal justice system. DNA forensics will not provide its maximum social benefit until most citizens in the nations that use this technology conclude that the risks they perceive to be associated with it are offset by the benefits.

The current policy of having the criminal justice system retain tissue samples is a core issue in the privacy debate. It would be possible to operate the system without retaining DNA samples indefinitely, but there would be strong resistance to such a course in some law enforcement circles. In those nations in which DNA felon databanks are in use, it might be helpful to create a permanent commission to oversee the integrity of their operation, which could review and monitor all requests to use samples for purposes other than forensic identification. If we cannot enhance public understanding of DNA felon databanking systems so that citizens can have confidence in them, we must at least show that safeguards are in place to limit the potential for misuse of the information stored in them.

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Links

FURTHER INFORMATION Forensic Science Timeline | Alec Jeffreys | Federal Bureau of Investigation | National Research Council | James Crow | CODIS | The Bode Technology Group

1. Landsteiner, K. Zur Kenntnis der antifermentaiven lytischen and agglutinierenden Wirkungen des Blutserums und der Lymphe. *Sent. Bact.* **27**, 357–621 (1900).
2. Committee on DNA Technology in Forensic Science, National Research Council. *DNA Technology in Forensic Science* (National Academy, Washington DC, 1992).
3. Committee on DNA Forensic Science, National Research Council. *An Update: The Evaluation of DNA Forensic Evidence* (National Academy, Washington DC, 1996).
4. National Commission on the Future of DNA Evidence (research and development working group). *The Future of Forensic DNA Testing: Predictions of the Research and Development Working Group* (US Department of Justice, NIJ (NCJ 183697), Washington DC, 2000).
5. Editorial. DNA, not d.o.a. *Nature Genet.* **21**, 243–244 (1999).
6. Lorente, J. *et al.* Missing persons identification: genetics at work for society. *Science* **290**, 2257–2258 (2000).
7. Buetow, K. H., Edmonson, M. N. & Cassidy, A. B. Reliable identification of large numbers of candidate SNPs from public EST data. *Nature Genet.* **21**, 323–325 (1999).
8. Nakatani, K. *et al.* Scanning of guanine–guanine mismatches in DNA by synthetic ligands using surface plasmon resistance. *Nature Biotechnol.* **19**, 51–55 (2001).
9. Sheck, B., Neufeld, P. & Dwyer, J. *Actual Innocence: Five Days to Execution and Other Dispatches from the Wrongfully Convicted* (Doubleday, New York, 1999).
10. National Commission on the Future of DNA Evidence (post-conviction working group). *Post-conviction DNA Testing: Recommendations for Handling Requests* (US Department of Justice, NIJ (NCJ 177626), Washington DC, 1999).
11. Forman, L. *Testimony before the National Commission on the future of DNA evidence, November 19, 2000* (Cambridge, Massachusetts, 2000).
12. Kimmelman, J. Risking ethical insolvency: a survey of trends in criminal DNA banking. *J. Law Med. Ethics* **28**, 209–221 (2000).

The opinions expressed in this article are solely those of the author. They do not necessarily represent the views of the full commission or any of its members.