**DNA Forensics**

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| **How does forensic identification work?**  Any type of organism can be identified by examination of DNA sequences unique to that species. Identifying individuals within a species is less precise at this time, although when DNA sequencing technologies progress farther, direct comparison of very large DNA segments, and possibly even whole genomes, will become feasible and practical and will allow precise individual identification.  To identify individuals, forensic scientists scan 13 DNA regions, or loci, that vary from person to person and use the data to create a DNA profile of that individual (sometimes called a DNA fingerprint). There is an extremely small chance that another person has the same DNA profile for a particular set of 13 regions.  **Some Examples of DNA Uses for Forensic Identification**   * Identify potential suspects whose DNA may match evidence left at crime scenes * Exonerate persons wrongly accused of crimes * Identify crime and catastrophe victims * Establish paternity and other family relationships * Identify endangered and protected species as an aid to wildlife officials (could be used for prosecuting poachers) * Detect bacteria and other organisms that may pollute air, water, soil, and food * Match organ donors with recipients in transplant programs * Determine pedigree for seed or livestock breeds * Authenticate consumables such as caviar and wine   **Is DNA effective in identifying persons?** [answer provided by Daniel Drell of the U.S. DOE Human Genome Program]  DNA identification can be quite effective if used intelligently. Portions of the DNA sequence that vary the most among humans must be used; also, portions must be large enough to overcome the fact that human mating is not absolutely random.  Consider the scenario of a crime scene investigation . . .  Assume that type O blood is found at the crime scene. Type O occurs in about 45% of Americans. If investigators type only for ABO, finding that the "suspect" in a crime is type O really doesn't reveal very much.  If, in addition to being type O, the suspect is a blond, and blond hair is found at the crime scene, you now have two bits of evidence to suggest who really did it. However, there are a lot of Type O blonds out there.  If you find that the crime scene has footprints from a pair of Nike Air Jordans (with a distinctive tread design) and the suspect, in addition to being type O and blond, is also wearing Air Jordans with the same tread design, you are much closer to linking the suspect with the crime scene.  In this way, by accumulating bits of linking evidence in a chain, where each bit by itself isn't very strong but the set of all of them together is very strong, you can argue that your suspect really is the right person.  With DNA, the same kind of thinking is used; you can look for matches (based on sequence or on numbers of small repeating units of DNA sequence) at many different locations on the person's genome; one or two (even three) aren't enough to be confident that the suspect is the right one, but thirteen sites are used. A match at all thirteen is rare enough that you (or a prosecutor or a jury) can be very confident ("beyond a reasonable doubt") that the right person is accused.  **How is DNA typing done?**  Only one-tenth of a single percent of DNA (about 3 million bases) differs from one person to the next. Scientists can use these variable regions to generate a DNA profile of an individual, using samples from blood, bone, hair, and other body tissues and products.  In criminal cases, this generally involves obtaining samples from crime-scene evidence and a suspect, extracting the DNA, and analyzing it for the presence of a set of specific DNA regions (markers).  Scientists find the markers in a DNA sample by designing small pieces of DNA (probes) that will each seek out and bind to a complementary DNA sequence in the sample. A series of probes bound to a DNA sample creates a distinctive pattern for an individual. Forensic scientists compare these DNA profiles to determine whether the suspect's sample matches the evidence sample. A marker by itself usually is not unique to an individual; if, however, two DNA samples are alike at four or five regions, odds are great that the samples are from the same person.  If the sample profiles don't match, the person did not contribute the DNA at the crime scene.  If the patterns match, the suspect may have contributed the evidence sample. While there is a chance that someone else has the same DNA profile for a particular probe set, the odds are exceedingly slim. The question is, How small do the odds have to be when conviction of the guilty or acquittal of the innocent lies in the balance? Many judges consider this a matter for a jury to take into consideration along with other evidence in the case. Experts point out that using DNA forensic technology is far superior to eyewitness accounts, where the odds for correct identification are about 50:50.  The more probes used in DNA analysis, the greater the odds for a unique pattern and against a coincidental match, but each additional probe adds greatly to the time and expense of testing. Four to six probes are recommended. Testing with several more probes will become routine, observed John Hicks (Alabama State Department of Forensic Services). He predicted that DNA chip technology (in which thousands of short DNA sequences are embedded in a tiny chip) will enable much more rapid, inexpensive analyses using many more probes and raising the odds against coincidental matches.  **What are some of the DNA technologies used in forensic investigations?**  **Restriction Fragment Length Polymorphism (RFLP)** RFLP is a technique for analyzing the variable lengths of DNA fragments that result from digesting a DNA sample with a special kind of enzyme. This enzyme, a restriction endonuclease, cuts DNA at a specific sequence pattern know as a restriction endonuclease recognition site. The presence or absence of certain recognition sites in a DNA sample generates variable lengths of DNA fragments, which are separated using gel electrophoresis. They are then hybridized with DNA probes that bind to a complementary DNA sequence in the sample.  RFLP was one of the first applications of DNA analysis to forensic investigation. With the development of newer, more efficient DNA-analysis techniques, RFLP is not used as much as it once was because it requires relatively large amounts of DNA. In addition, samples degraded by environmental factors, such as dirt or mold, do not work well with RFLP.  **PCR Analysis** Polymerase chain reaction (PCR) is used to make millions of exact copies of DNA from a biological sample. DNA amplification with PCR allows DNA analysis on biological samples as small as a few skin cells. With RFLP, DNA samples would have to be about the size of a quarter. The ability of PCR to amplify such tiny quantities of DNA enables even highly degraded samples to be analyzed. Great care, however, must be taken to prevent contamination with other biological materials during the identifying, collecting, and preserving of a sample.  **STR Analysis** Short tandem repeat (STR) technology is used to evaluate specific regions (loci) within nuclear DNA. Variability in STR regions can be used to distinguish one DNA profile from another. The Federal Bureau of Investigation (FBI) uses a standard set of 13 specific STR regions for CODIS. CODIS is a software program that operates local, state, and national databases of DNA profiles from convicted offenders, unsolved crime scene evidence, and missing persons. The odds that two individuals will have the same 13-loci DNA profile is about one in a billion.  **Mitochondrial DNA Analysis** Mitochondrial DNA analysis (mtDNA) can be used to examine the DNA from samples that cannot be analyzed by RFLP or STR. Nuclear DNA must be extracted from samples for use in RFLP, PCR, and STR; however, mtDNA analysis uses DNA extracted from another cellular organelle called a mitochondrion. While older biological samples that lack nucleated cellular material, such as hair, bones, and teeth, cannot be analyzed with STR and RFLP, they can be analyzed with mtDNA. In the investigation of cases that have gone unsolved for many years, mtDNA is extremely valuable.  All mothers have the same mitochondrial DNA as their offspring. This is because the mitochondria of each new embryo comes from the mother's egg cell. The father's sperm contributes only nuclear DNA. Comparing the mtDNA profile of unidentified remains with the profile of a potential maternal relative can be an important technique in missing-person investigations.  **Y-Chromosome Analysis** The Y chromosome is passed directly from father to son, so analysis of genetic markers on the Y chromosome is especially useful for tracing relationships among males or for analyzing biological evidence involving multiple male contributors.  **Some Interesting Uses of DNA Forensic Identification**   * [**Identifying September 11th Victims**](http://www.terradaily.com/reports/Sept_11_Panel_Makes_Recommendations_For_DNABased_ID_After_Mass_Disasters.html)  Identifying the victims of the September 11, 2001, World Trade Center attack presented a unique forensic challenge because the number and identity of the victims were unknown and many victims were represented only by bone and tissue fragments. At the time of the attack, no systems were in place for rapidly identifying victims in disasters with more than 500 fatalities. The National Institutes of Justice assembled a panel of experts from the National Institutes of Health and other institutions to develop processes to identify victims using DNA collected at the site. Panel members produced forms and kits needed to enable the medical examiner’s office to collect reference DNA from victims’ previously stored medical specimens. These specimens were collected and entered into a database. The medical examiner's office also received about 20,000 pieces of human remains from the World Trade Center site, and a database of the victims’ DNA profiles was created. New information technology infrastructure was developed for data transfer between the state police and medical examiner’s office and to interconnect the databases and analytical tools used by panel members. In 2005 the search was declared at an end because many of the unidentified remains were too small or too damaged to be identified by the DNA extraction methods available at that time. Remains of only 1585, of the 2792 people known to have died had been identified. In 2007, the medical examiner's office reopened the search after the Bode Technology Group developed a new methodology of DNA extraction that required much less sample material than previously necessary. The victim DNA database and the new methods have allowed more victims to be identified, and further identifications will be possible as forensic DNA technology improves.   **DNA Forensics Databases**  National DNA Databank: CODIS  The COmbined DNA Index System, CODIS, blends computer and DNA technologies into a tool for fighting violent crime. The current version of CODIS uses two indexes to generate investigative leads in crimes where biological evidence is recovered from the crime scene. The Convicted Offender Index contains DNA profiles of individuals convicted of felony sex offenses (and other violent crimes). The Forensic Index contains DNA profiles developed from crime scene evidence. All DNA profiles stored in CODIS are generated using STR (short tandem repeat) analysis.  CODIS utilizes computer software to automatically search its two indexes for matching DNA profiles. Law enforcement agencies at federal, state, and local levels take DNA from biological evidence (e.g., blood and saliva) gathered in crimes that have no suspect and compare it to the DNA in the profiles stored in the CODIS systems. If a match is made between a sample and a stored profile, CODIS can identify the perpetrator.  This technology is authorized by the DNA Identification Act of 1994. All 50 states have laws requiring that DNA profiles of certain offenders be sent to CODIS. As of August 2007, the database contained over 5 million DNA profiles in its Convicted Offender Index and about 188,000 DNA profiles collected from crime scenes but not connected to a particular offender. (source <http://www.fbi.gov/hq/lab/codis/clickmap.htm>).  As more offender DNA samples are collected and law enforcement officers become better trained and equipped to collect DNA samples at crime scenes, the backlog of samples awaiting testing throughout the criminal justice system is increasing dramatically. In March 2003 President Bush proposed $1 billion in funding over 5 years to reduce the DNA testing backlog, build crime lab capacity, stimulate research and development, support training, protect the innocent, and identify missing persons. For more information, see the U.S. Department of Justice's [Advancing Justice Through DNA Technology](http://www.usdoj.gov/ag/dnapolicybook_cov.htm).  **Ethical, Legal, and Social Concerns about DNA Databanking**  The primary concern is privacy. DNA profiles are different from fingerprints, which are useful only for identification. DNA can provide insights into many intimate aspects of people and their families including susceptibility to particular diseases, legitimacy of birth, and perhaps predispositions to certain behaviors and sexual orientation. This information increases the potential for genetic discrimination by government, insurers, employers, schools, banks, and others.  Collected samples are stored, and many state laws do not require the destruction of a DNA record or sample after a conviction has been overturned. So there is a chance that a person's entire genome may be available —regardless of whether they were convicted or not. Although the DNA used is considered "junk DNA", single tandem repeated DNA bases (STRs), which are not known to code for proteins, in the future this information may be found to reveal personal information such as susceptibilities to disease and certain behaviors.  Practicality is a concern for DNA sampling and storage. An enormous backlog of over half a million DNA samples waits to be entered into the CODIS system. The statute of limitations has expired in many cases in which the evidence would have been useful for conviction.  Who is chosen for sampling also is a concern. In the United Kingdom, for example, all suspects can be forced to provide a DNA sample. Likewise, all arrestees --regardless of the degree of the charge and the possibility that they may not be convicted--can be compelled to comply. This empowers police officers, rather than judges and juries, to provide the state with intimate evidence that could lead to "investigative arrests."  In the United States each state legislature independently decides whether DNA can be sampled from arrestees or convicts. In 2006, the New Mexico state legislature passed Katie's Bill, a law that requires the police to take DNA samples from suspects in most felony arrests. Previous New Mexico laws required DNA to be sampled only from convicted felons. The bill is named for Katie Sepich, whose 2003 murder went unsolved until her killer's DNA entered the database in 2005 when he was convinced of another felony. Her killer had been arrested, but not convicted, for burglary prior to 2005.  Opponents of the law assert that it infringes on the privacy and rights of the innocent. While Katie’s Law does allow cleared suspects to petition to have their DNA samples purged from the state database, the purging happens only after the arrest. Civil liberties advocates say that Katie's Bill still raises the question of Fourth Amendment violations against unreasonable search and seizure and stress that the law could be abused to justify arrests made on less than probable cause just to obtain DNA evidence.  As of September 2007, all 50 states have laws that require convicted sex offenders to submit DNA, 44 states have laws that require convicted felons to submit DNA, 9 states require DNA samples from those convicted of certain misdemeanors, and 11 states—including Alaska, Arizona, California, Kansas, Louisiana, Minnesota, New Mexico, North Dakota, Tennessee, Texas, and Virginia—have laws authorizing arrestee DNA sampling.  **Potential Advantages and Disadvantages of Banking Arrestee DNA**  Advantages   * Major crimes often involve people who also have committed other offenses. Having DNA banked potentially could make it easier to identify suspects, just as fingerprint databases do. * Innocent people currently are incarcerated for crimes they did not commit; if DNA samples had been taken at the time of arrest, these individuals could have been proven innocent and thereby avoided incarceration.. * Banking arrestees' DNA instead of banking only that of convicted criminals could result in financial savings in investigation, prosecution, and incarceration.   Disadvantages   * Arrestees often are found innocent of crimes. The retention of innocent people's DNA raises significant ethical and social issues. * If people’s DNA is in police databases, they might be identified as matches or partial matches to DNA found at crime scenes. This occurs even with innocent people, for instance, if an individual had been at a crime scene earlier or had a similar DNA profile to the actual criminal. * Sensitive genetic information, such as family relationships and disease susceptibility, can be obtained from DNA samples. Police, forensic science services, and researchers using the database have access to people’s DNA without their consent. This can be seen as an intrusion of personal privacy and a violation of civil liberties. * Studies of the United Kingdom’s criminal database, which retains the DNA samples of all suspects, show that ethnic minorities are over represented in the population of arrestees and are, therefore, overrepresented in the criminal DNA database. This raises the concern of an institutionalized ethnic bias in the criminal justice system. * Even the most secure database has a chance of being compromised. |

http://genomics.energy.gov.