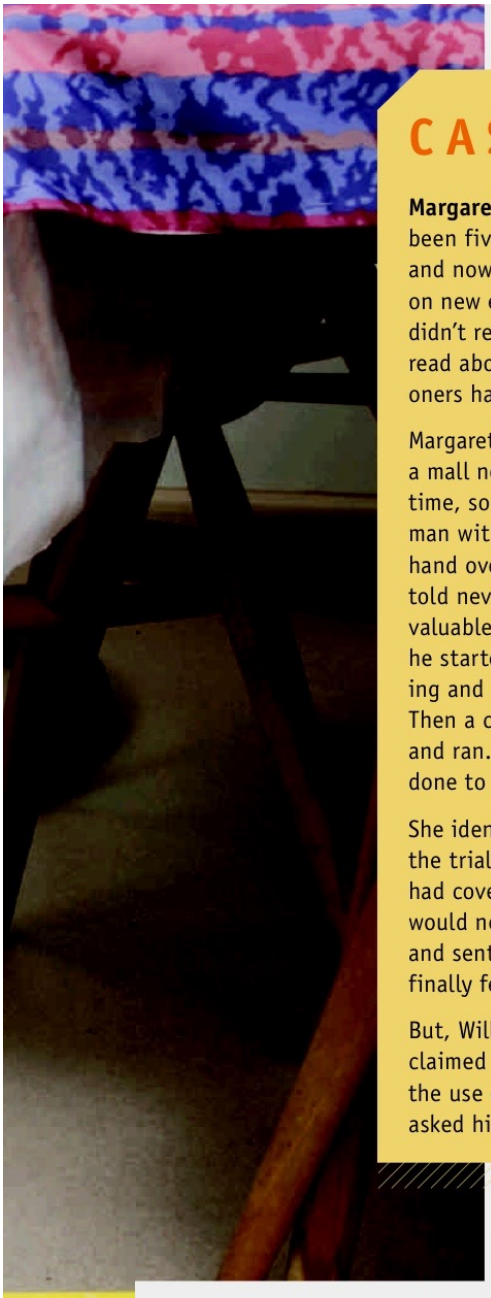


Alamy Limited

A Crime Scene Technician Gathers Evidence

CASE A: DNA Frightens Victim

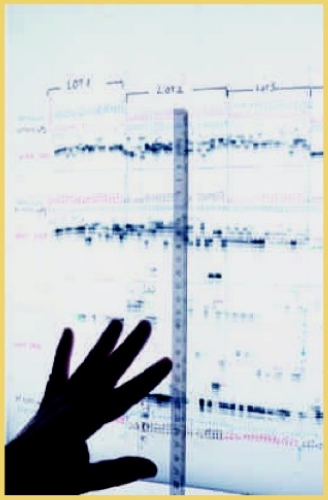
Margaret Sackler was really frightened. It had been five years since William Bern attacked her, and now he was asking to be released from jail on new evidence his attorney had presented. She didn't really understand the evidence, but she had read about it in the paper. A number of other prisoners had been released using DNA evidence.

Margaret had been walking in a parking lot outside a mall near her home. It was dark and near closing time, so there weren't too many people around. A man with a gun came up to her and ordered her to hand over her money and jewelry. She had been told never to fool around by trying to protect her valuables, so she gave him everything. But then he started to beat her. She fought back, scratching and hitting him. His blood was all over her. Then a car passed by, and her assailant got scared and ran. She always wondered what he might have done to her if the car hadn't come by.

She identified him in a lineup and testified at the trial. She had seen his eyes clearly, but he had covered the rest of his face with a mask. She would never forget his eyes. He was found guilty and sentenced to 25 years to life for assault. She finally felt safe.

But, William Bern, the man convicted, had always claimed he was innocent, so when he heard about the use of DNA testing to exonerate people, he asked his attorney to arrange testing of the blood on the blouse Margaret was wearing at the time of the attack.

The blood was 5 years old, but with a type of DNA testing called PCR, old DNA present in very small amounts can still be tested.



Phanie/Photo Researchers

A lab tech examining a DNA profile.

Margaret and William were asked to give a blood sample, and all the samples were tested. William's DNA did not match the blood on Margaret's shirt. Based on the results of the DNA testing, he was asking to be released from jail.

Margaret didn't care about the DNA test results—she was sure he was the one. She'd never forget his eyes.

Some questions come to mind when reading about this case. Before we can address those questions, let's look at the biology behind DNA forensics.

9.1 How Is DNA Testing Done?

In 1975 an English scientist, Dr. Alec Jeffreys (Figure 9.1), developed the first method of preparing what we now call DNA profiles and used them to compare profiles from different people. He called this method **DNA fingerprinting**. Soon after the method was developed, he used it to solve two murders in northern England by comparing DNA fingerprints from a number of men to fingerprints prepared from DNA found at the crime scenes (see "Spotlight on Law: Narborough Village Murders"). This spectacular discovery has revolutionized criminal investigations all over the world.

John Smock/AP Photos

Figure 9.1 **Alec Jeffreys**
He developed DNA fingerprinting, and this discovery led to the development and widespread use of DNA forensics across the globe.

DNA fingerprinting a method of DNA forensics

9.1 Essentials

- **DNA forensic testing began in England in 1975.**

9.2 What Is a DNA Profile?

Jeffreys's method of DNA fingerprinting was based on the discovery of small differences among people's DNA. These differences are present as variations in the length of certain DNA sequences called **minisatellites**. Minisatellites are repeated sequences of 10 to 100 base pairs (see "Biology Basics: DNA"). They are found at many different locations on all chromosomes and can be used in making DNA fingerprints because the repeats have different lengths in different people. Here is what one repeat of a minisatellite looks like:

```
...CCTGACTTAGGATTGCCA...
```

Later other, shorter sequences called **short tandem repeats (STRs)** were discovered. The repeats in STRs are much shorter than those in minisatellites and are only two to nine base pairs long. Clusters of STRs are found widely distributed on all human chromosomes. Variations in the number of repeats in STRs are used in preparing DNA profiles because they have different lengths in different people. Here is what an STR of the repeat TTCCC looks like:

```
...TTCCCTTCCCTTCCCTTCCCTTC...
```

In addition, **single nucleotide polymorphisms (SNPs),** pronounced "snips," are present in the genome. SNPs are single nucleotide differences in a DNA sequence. Because they consist of only *one* base pair, they can be specific to an individual. Here is what a SNP looks like compared with DNA sequences of others within a population:

```
...ATCGTCGAGCCTAAATA...
...ATCGTCGAGCCTAAATA...
...ATCGTCGAGCCTAAATA...
...ATCGTCGTGCCTAAATA...
...ATCGTCGAGCCTAAATA...
...ATCGTCGAGCCTAAATA...
```

As you can see from these sequences, each taken from a different person, there is a difference (see red T) in person #4.

Each of these different types of DNA variation can be used to create a DNA profile and identify individuals. The profiles developed from this information can be used in numerous ways, including criminal cases, paternity lawsuits, studies of human evolution, and identification of bodies. STRs are now routinely used, and the term *DNA fingerprint* has been replaced by the term **DNA profile**.

How are STRs used to make a DNA profile of individuals in a population?

Let's look at the steps in preparing a DNA profile. Each STR is a DNA sequence composed of two to nine nucleotides. Each allele of an STR contains a different and unique number of repeated copies of these nucleotides. For example, an STR might contain different copies of the sequence AGA. An allele of this STR (allele 1) might contain one copy of AGA, another might have three (allele 2), and yet another (allele 3) might have five, as shown below:

```
Allele 1: ...AGA...
Allele 2: ...AGAAGAAGA...
Allele 3: ...AGAAGAAGAAGAAGA...
```

In preparing a DNA profile, several different STR alleles obtained from an individual are analyzed and compared with information that shows how often a specific combination of these alleles is found among individuals in a population. Different populations may have different frequencies of these alleles. This analysis is done in a series of steps:

1. DNA samples from a population are analyzed to establish which STR alleles are present in members of the population.
2. The results are analyzed to see how often specific combinations of STR alleles are present in a population; this result is called the **population frequency** (discussed in more detail in Chapter 15).
3. The population frequencies for each STR allele are multiplied to estimate the probability that anyone who carries this specific combination of alleles is a match to the sample being tested (see Table 9.1).

The combined frequency shows that the combinations become more rare in the population as more alleles are analyzed. Later discussion will show how this applies to criminal cases.

minisatellites DNA sequences composed of 10 to 1000 base pairs that are scattered throughout the genome

short tandem repeats (STRs) DNA sequences that are two to nine base pairs long

single nucleotide polymorphisms (SNPs) DNA sequence variations that are only one base pair long

DNA profile the pattern of DNA fragments that can identify individuals

population frequency a measurement that determines how often specific combinations of alleles are present in a population

restriction fragment length polymorphism (RFLP) analysis one of the methods of DNA testing

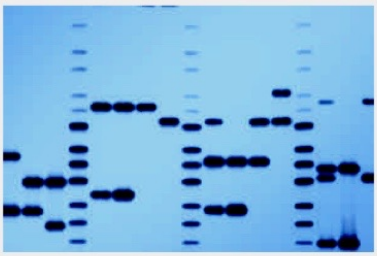
polymerase chain reaction (PCR) a molecular technique that allows production of many copies of a specific DNA sequence

Table 9.1 **Population Frequency Calculations**

STR	Allele	Frequency in Population	Combined Frequency
A	1	1 in 25	
B	2	1 in 100	A1 × B2 (1 in 25 × 1 in 100) = 1 in 2500
C	3	1 in 320	A1 × B2 × C3 (1 in 25 × 1 in 100 × 1 in 320) = 1 in 800,000
D	4	1 in 75	A1 × B2 × C3 × D4 (1 in 25 × 1 in 100 × 1 in 320 × 1 in 75) = 1 in 60 million

How are DNA profiles constructed? DNA profiles can be constructed using a number of methods. Two methods commonly used in DNA forensics are **restriction fragment length polymorphism (RFLP)** analysis (Figure 9.2) and the **polymerase chain reaction (PCR)**. RFLP analysis is used to detect differences in the number of copies of repeated DNA sequences.

Figure 9.2 The RFLP test makes it possible to identify samples found at a crime scene and match them to suspects. In this gel, the band pattern is produced by DNA fragments containing different numbers of repeats. The three sets of bands that run from top to bottom are size standards.



Martin Shields/Photo Researchers

How are RFLPs done? RFLP analysis uses blood samples or other relatively large amounts of biological material (biopsy specimens, semen, etc.). The process consists of the following steps (follow along using Figure 9.3, page 186):

1. DNA is extracted from cell samples. Each sample is from a different person.
2. The DNA is cut into fragments using restriction enzymes (see Chapter 10).
3. Each sample is loaded into a small slot, called a well, on a slab of a gelatin-like substance called agarose.
4. Electrical current is passed through the gel (which is immersed in a liquid). As the current moves through the gel, the DNA fragments migrate through the pores of the gel.
5. As they migrate through the gel, the DNA fragments separate by size. Smaller fragments move faster and further than the larger fragments, creating a distinctive pattern.
6. The resulting pattern of DNA fragments is visualized, photographed, and scanned into a computer. The patterns obtained from one individual are stored in a database and compared to patterns obtained from other individuals.

How does PCR work? PCR uses very small amounts of DNA to produce profiles, working in a way that is similar to DNA replication in a cell (see "Biology Basics: DNA"). During the process of PCR, DNA is heated and cooled. DNA responds to the temperature changes by opening up its helix; this creates two single-stranded molecules. After every round of replication, the amount of DNA is doubled. This process can be repeated many times. In this way, a single DNA fragment can be amplified to make millions of copies. These copies are separated by electrophoresis and used to prepare DNA profiles.

How was PCR discovered? Some think that because of its use in DNA forensics and biotechnology, PCR is *the* scientific breakthrough of the last 50 years. The process was discovered by Kary Mullis (Figure 9.4, page 186), who won the Nobel Prize in 1993 for his invention. He was working for Cetus (a biotech company) when he got his idea to work. He never owned the patent on the process, and Cetus paid him a $10,000 bonus for the invention. After winning the Nobel Prize, Mullis left science and spent

Figure 9.3 **RFLP Analysis** DNA is extracted from samples and cut into fragments with a restriction enzyme. The fragments from each sample are placed in different lanes on a gel and separated by size using an electric current. The various fragment sizes reflect differences in the number of copies of a DNA repeat.

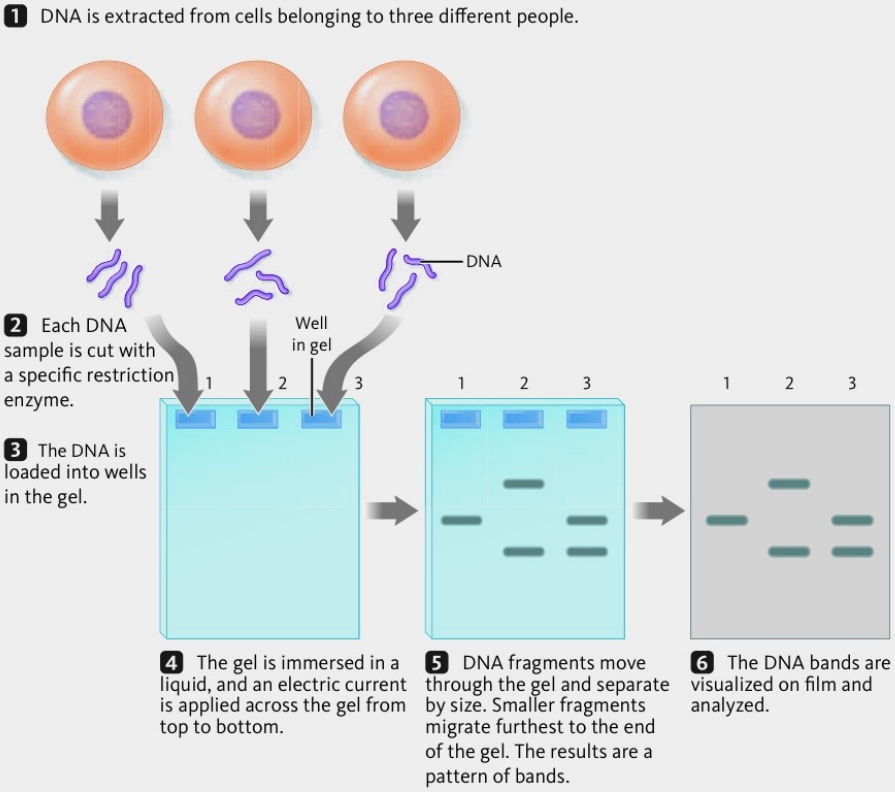


Figure 9.4 **Kary Mullis, the Inventor of the PCR Technique**

AP Photo/Joan C. Fahrenthold

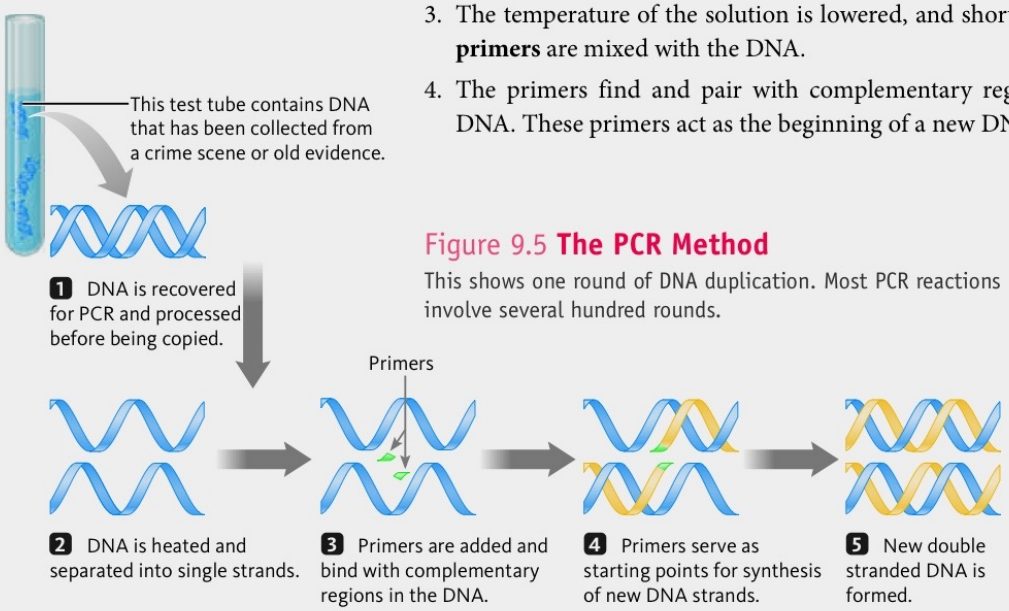
years as a surfer, stating that he had nothing left to win in science. Later he developed a company that made jewelry that contains DNA of dead celebrities copied by PCR.

The PCR process consists of the following steps (follow along using Figure 9.5):

1. DNA is extracted from the sample and placed in a solution.
2. The DNA is heated and separated into two single strands.
3. The temperature of the solution is lowered, and short nucleotide sequences called **primers** are mixed with the DNA.
4. The primers find and pair with complementary regions on the single-stranded DNA. These primers act as the beginning of a new DNA strand.

Figure 9.5 **The PCR Method**

This shows one round of DNA duplication. Most PCR reactions involve several hundred rounds.



primers short nucleotide sequences used in PCR

5. DNA polymerase (the enzyme involved in DNA replication) is added to the solution along with nucleotides (C, A, T, and G). The DNA polymerase uses these nucleotides to synthesize a double-stranded DNA molecule from each of the single-stranded DNA templates.

These steps make up one PCR cycle. The cycle can be repeated over and over, as shown in Figure 9.6. The amount of DNA present doubles with each PCR cycle. The power of PCR allows millions of copies to be made in hours from tiny amounts of DNA. These cycles are done quickly using specialized machines that are called PCR machines (Figure 9.7). Although they are expensive, most criminalists work in labs that have at least one.

Figure 9.6 **Multiple PCR cycles can create millions of copies of DNA in a short time.**

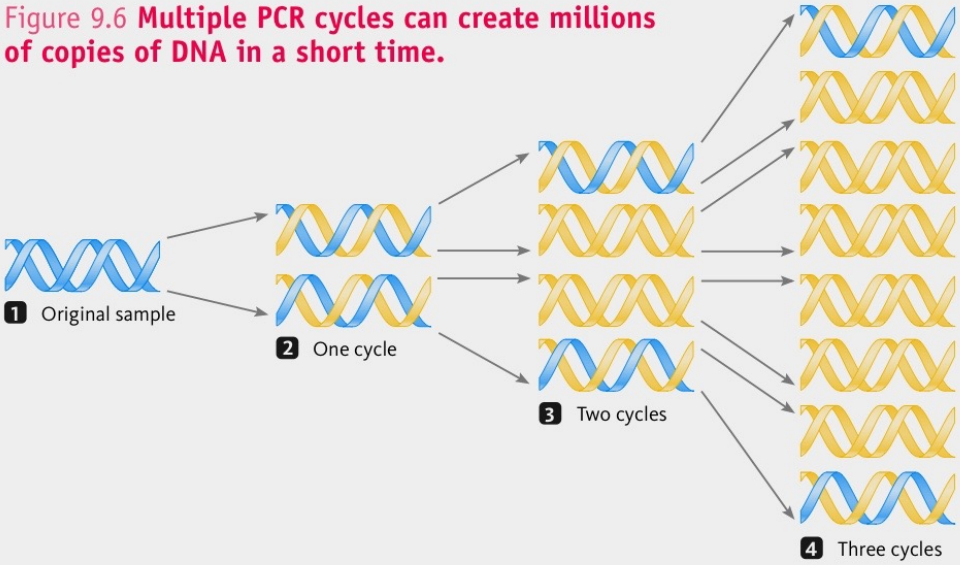


Table 9.2 shows how the amount of DNA increases with each PCR cycle.

Where do DNA samples come from? Unlike RFLP analysis, PCR can be used to prepare DNA profiles from very small DNA samples. Sources of DNA can include single hairs, licked envelope flaps, toothbrushes, cigarette butts, and dried saliva on envelope flaps (Figure 9.8, page 188).

Evidence from crimes including murder, rape, break-ins, and hit-and-run accidents can be used. Profiles can also be obtained from very old samples of DNA, increasing its usefulness in legal cases. In fact, DNA profiles have been prepared from mummies more than 2400 years old.

What are DNA microarrays? Many technologies first developed for laboratory use have been adapted to forensics. One of these is the use of DNA microarrays (also called DNA chips). Originally developed for quick DNA analysis by scientists, microarrays are now used in crime labs. Portable devices containing a DNA microarray allow small amounts of DNA at a crime scene to be analyzed quickly and efficiently, sometimes directly on the scene. Because these devices are small and able to process many DNA samples, police can carry them to crime scenes and work through evidence quickly. These and other handheld devices, including PCR machines (Figure 9.9, page 189), will revolutionize crime scene forensics. These devices also have a far-reaching future in other fields, especially in getting DNA sequencing out of research labs and into physician's offices where it can be used to tailor medical treatments to an individual's unique genetic makeup.

9.2 Essentials

- **Three types of DNA variations are used in DNA profiling: minisatellites, short tandem repeats, and single nucleotide polymorphisms.**
- **Two common methods used in DNA forensics are restriction fragment length polymorphism analysis and the polymerase chain reaction.**
- **DNA samples for profiles can come from any number of sources, including cheek swabs, semen, saliva, and blood.**
- **Once constructed, DNA profiles are compared with other profiles in forensic applications.**

Figure 9.7 **A Large-Scale PCR Machine**

Philippe Psaila/Photo Researchers, Inc.

Table 9.2 **Using PCR to Increase DNA**

Cycle	Number of Copies of DNA
0	1
1	2
5	32
10	1024
15	32,768
20	1,048,576
25	33,544,432
30	1,073,741,824

Figure 9.8 **Sources of DNA Evidence** (a) Skin cells deposited on the inside of the ski mask can be used to retrieve DNA. (b) When a suspect licks the back of the postage stamp, cells from the saliva serve as a source of DNA. (c) Saliva deposited while drinking from a soda can may also be used. (d) Saliva is also left on cigarette butts. (e) White blood cells can be recovered from blood samples, and DNA can be extracted from very small numbers of cells. (f) Skin cells inside a sock and other clothing can be used for DNA profiles. (g) Extraction of DNA from cells in hair roots can be used for nuclear DNA, but follicle cells also contain mitochondria, and that DNA can also be used. (h) Bone or bone fragments can be pulverized and exposed to chemicals that free the DNA from the calcium in bone. (i) Teeth can also serve as a source of DNA.


Kimber Rey Solana/Shutterstock

a.

Fambros/Dreamstime LLC

b.


Hermann Danzmayr/Shutterstock

d.

e.
Dmitriy Aseev/Shutterstock


Feng Yu/Shutterstock

c.


Tonis Valing/Shutterstock

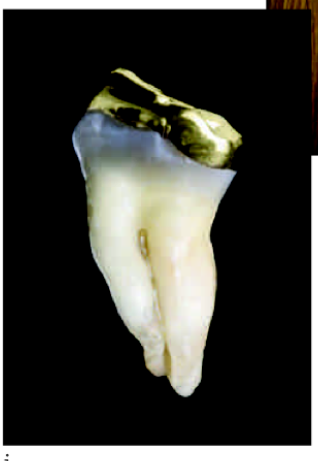
f.


Jupiter Images

g.


Zafon404/Dreamstime LLC

h.


Joe Belanger/Shutterstock.com

i.

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BY THE NUMBERS

20,000
Number of civil cases that involve DNA forensics in the United States each year

luchschen/Shutterstock.com

1 in 100 trillion
Chance that two people will have the same 13 alleles in CODIS

6.6 billion
Number of people on Earth

federal and state levels. There is no national database, but some legislation has been written to allow cross-state testing.

A DNA sample is tested using STRs from the CODIS panel, and a profile is compared to stored samples and to samples from the crime scene (see Figure 9.10). In a criminal case, if a suspect's profile does not match that of the evidence, he or she can be cleared, or excluded, as the criminal. About 30% of DNA profile results clear innocent people by exclusion.

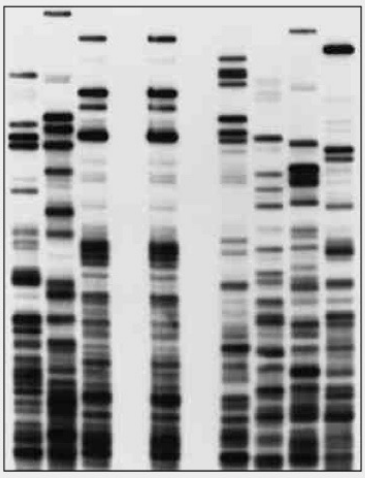
What is a DNA database? The FBI began cataloging DNA profiles and DNA samples obtained from convicted felons in 1998, and that database now contains more than 1,700,000 profiles. At first, samples were collected and profiles kept only from convicted felons. However, many states are now collecting DNA samples from anyone arrested for a felony and entering their DNA profiles into a database. Other states keep the DNA of anyone arrested. As they accumulate large numbers of profiles, DNA databases are becoming more important tools in solving crimes. Over a three-year period in Virginia, for example, matching DNA profiles from evidence at crime scenes with those in the state database solved more than 1600 crimes in which there were no suspects.

In other countries, DNA data banks are regulated differently. In the United Kingdom, a law requires that, if asked, an individual must submit a sample and that sample can be kept forever. Other countries are moving to create larger and larger databases to make identification easier and faster. It has been suggested that this would be a good idea for the United States, but it has not happened yet. Most of the databases contain samples from people in jail or those awaiting trial. However, if asked for DNA samples, ordinary people are usually willing to volunteer.

9.3 Essentials

- **DNA forensics entered the U.S. court system in 1989 and is now used in courts all over the country.**
- **Many people wrongly accused have been freed by DNA evidence with the help of innocence projects all over the United States.**
- **DNA databases are used to identify perpetrators from DNA left at crime scenes.**

Figure 9.10 These DNA profiles were prepared from blood samples taken from a crime scene and samples from several suspects. Which of the suspects' profiles looks most similar to the crime scene profile?



Courtesy, Cellmark Diagnostics, Abingdon, UK

9.4 What Are Some Other Uses for DNA Profiles?

DNA profiles have many uses outside the courtroom. **Biohistorians** use DNA analysis to correctly identify bodies and body parts of famous and infamous people whose graves have been moved several times or whose graves have been newly discovered. For example, Czar Nicholas II of Russia (Figure 9.11) and his family members were killed in 1917 and buried in unmarked graves. In 1991, remains found in Yekaterinburg, Russia, were identified as those of the czar and some of his family. In 2007, bones found at a nearby site were identified as those of two more of his children, accounting for all family members. For years previously, a woman claimed to be Anastasia, one of the czar's daughters. DNA testing from a lock of hair established that this woman, Anna Anderson, who died in 1984, was not one of the czar's children.

DNA profiles are used to identify the remains of military personnel killed in action and were used to identify people killed in the September 11, 2001, attacks in the United States. In the wake of the devastation caused by Hurricane Katrina in the southern United States in 2005, many of the dead were identified by DNA profiles. In

Hulton Archive/Getty Imagesv

Figure 9.11 **Czar Nicholas II of Russia** The Czar and his family were killed during the Russian Revolution. Years later their remains were identified using DNA forensics.

both the Katrina and the September 11 disasters, family members brought in hairbrushes, toothbrushes, pillows, and clothing for DNA testing and matching. After years of lab work, all remains from September 11 were identified.

Another important use of DNA profiling is paternity identification. Matching samples from the mother, father, and child allow 100% accuracy in identifying fathers. Use of DNA profiles in paternity testing ensures that many children will get the child support that they need. This is another area where DNA profiling has made a huge difference in legal proceedings. Before DNA testing, fathers could be eliminated in paternity claims only through the use of blood typing as an identifier (see Chapter 14). Today positive identification is done easily when samples can be obtained.

Paternity testing has become big business. Kits that collect DNA samples from the child, mother, and father are available over the counter in major drug stores. After collection, the samples are sent to a lab to be processed. Although the kits cost around 40 dollars, the test itself is much more expensive.

Several talk shows on television run episodes that help women find the fathers of their children. All the people involved come on the show and are tested. Then, on television, the truth is revealed!

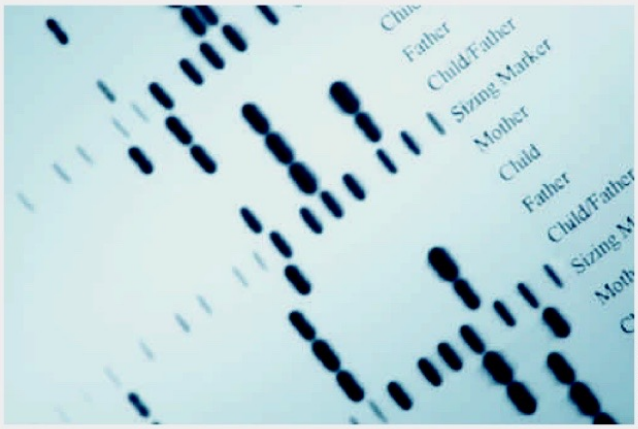
Figure 9.12 is a photo of a paternity test that compares the mother's, father's, and child's DNA.

Can DNA profiles trace our ancestry?

The use of DNA in forensic identification in high-profile paternity cases and on television crime shows has raised awareness that DNA can be used to trace an individual's ancestry. Many companies now offer ancestry genetic testing on the Internet. Two types of testing are usually offered: mitochondrial DNA testing and **Y chromosome testing**.

Mitochondria are found only in the cytoplasm of a cell (see "Biology Review: Cells and Cell Structure"). Because the egg is the only gamete with cytoplasm, mitochondria are always passed from a mother (Figure 9.13) to all her children (males and females). Mitochondria contain small amounts

Figure 9.12 **This RFLP test is being used to determine paternity.** Although the entire test is not shown, the child and mother's DNA test are clearly visible.

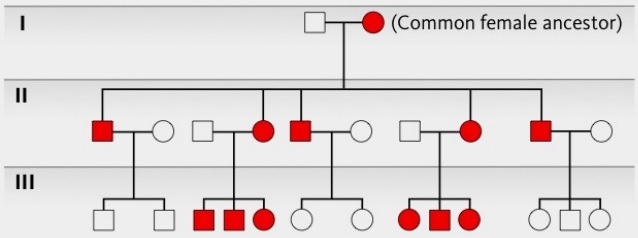


Martin Shields/Photo Researchers

of DNA, which contains a small number of genes. Because sperm have no cytoplasm, men do not contribute **mitochondrial DNA (mtDNA)** to their children. Differences in mitochondrial DNA sequences provide a series of markers called **haplotypes.** Each person has the same haplotype as his or her mother, so comparison of haplotypes can help trace ancestry through the mother's line.

Similar haplotypes can be grouped together to form **haplogroups.** When collected from large population groups such as European, Asian, or African, they can be used to provide

Figure 9.13 **Inheritance of Mitochondrial DNA** This pedigree shows the inheritance of mitochondrial DNA through a family. The red circles and squares show how the mitochondrial DNA from the woman in generation 1 is passed from one generation to the next.



biohistorian a person who specializes in the history of biology

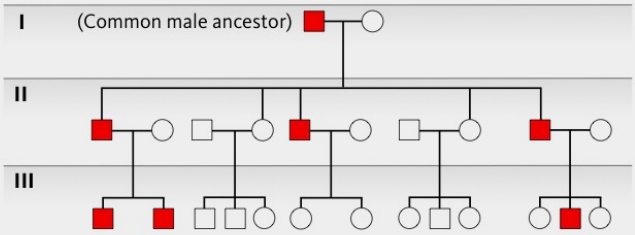
Y chromosome testing a process that maps sequence variations on the Y chromosome

mitochondrial DNA (mtDNA) DNA found in the mitochondria of a cell

haplotypes a series of markers that shows similarities and differences in the distribution of a specific DNA sequence

haplogroup groups of haplotypes from a specific region of the world

Figure 9.14 **Inheritance of the Y Chromosome**
This pedigree shows how the Y chromosome is passed through a family. The red squares show that all males in this family have the same Y chromosome.



information about ancestry. When someone's haplotype is similar to that of a specific haplogroup, he or she is said to have ancestry within that group. Therefore, we can use mitochondrial DNA to trace our backgrounds.

The Y chromosome is found in the nucleus of a cell and is passed on by the sperm. Only males receive a Y chromosome (Figure 9.14), which comes from their father (the mother carries two X chromosomes and no Y chromosome). In addition, because the Y chromosome is small, very few changes in DNA occur, and most Y chromosomes are passed from father to son virtually unchanged. Therefore, it is easy to trace male lineages through haplotypes on the Y. The Y chromosomal haplotypes are used to trace paternal ancestry.

DNA testing using mtDNA or Y chromosomes can be used to search haplogroup databases to provide information about one's ancestry. One of the largest projects to trace ancestry and the patterns of human migration out of Africa and across the globe is being sponsored by the National Geographic Society. This effort is called the Genographic Project. Interested individuals must pay to participate in this project. Those enrolled receive a vial and a swab to collect cheek cells. DNA from the swab is analyzed, and individuals receive information about their ancestry. The Genographic Project uses the results anonymously to construct a detailed chart of human migrations over the last 50,000 to 100,000 years.

9.4 Essentials

- **DNA profiles can be used to trace ancestry through the maternal and paternal lines.**
- **DNA profiles have many other uses in many areas of our society.**

CASE B: Samples Asked of All

There were very few clues to the murders of two women in a small rural community. The police had little evidence, but they did have skin samples from the killer, found under the fingernails of the victims.


© amana images inc./Alamy

Men waiting in line to give DNA samples in an investigation.

From these samples a DNA profile was created, but there were no suspects. Because the crimes had occurred out in the forest, presumably at night, there were no eyewitnesses. No fingerprints, footprints, or pieces of clothing were recovered from the crime scene. If investigators could find someone whose DNA profile matched the sample, they might solve the case.

The investigator in charge of the case, Lt. DeMato, decided to try a new technique being used in the United Kingdom called a DNA dragnet. He planned to ask all the male members of the rural community over the age of 17 to give a cell sample (obtained with a cotton swab scraped along the inside of the cheek) and do DNA testing on all of them.

1. **What might happen if a man didn't want to come in and give a sample?**
2. **Suppose that after samples were taken from all area men over age 17, no match was found. What would you do next if you were Lt. DeMato?**
3. **Amazingly, a match was found in the samples taken in the dragnet. The district attorney questioned whether the dragnet would be accepted as evidence by the court during the trial. Give three arguments the prosecution could use to have the evidence from the dragnet admitted.**
4. **Give three arguments that the defense could use to keep the evidence from being admitted.**
5. **After Lt. DeMato sent out a letter to all men in the area, he began testing. The 23rd man on the list, Irving Tomston, didn't respond. A second letter was sent, and there was still no response. What should Lt. DeMato have done?**

9.5 What Are the Legal and Ethical Issues Associated with DNA Forensics?

What are some of the unforeseen consequences of DNA forensics? In an interesting twist of fate, another huge change in the criminal justice system has come about as a result of the use of DNA forensics. When DNA evidence was first used in U.S. courts, it seemed obvious to some that prisoners convicted before 1989 were not able to use this method to establish their innocence. When approved by a *Frye* hearing, should scientific discoveries be retroactive? In 1993, an attorney named Barry Scheck and his partner Peter Neufeld

Figure 9.15 Peter Neufeld (left) and Barry Scheck (right) began the Innocence Project at Yeshiva University in New York. This project has reviewed evidence in hundreds of DNA exoneration cases. This organization led to the formation of innocence projects across the country that work to free wrongly convicted prisoners.

The Innocence Project/NLM

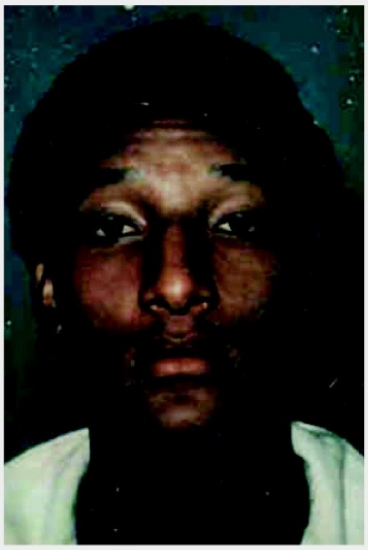
began the Innocence Project at the Cardoza School of Law at Yeshiva University (Figure 9.15) to address this issue.

Soon after the inception of the project, Scheck and Neufeld appeared on the "Phil Donahue Show." They talked about DNA forensics and the possibility of using it to reopen cases that had already been decided as a way to help free those who had been wrongly convicted. At the end of the interview, Scheck turned to the camera and said, "Anyone who thinks they are wrongfully convicted of a crime, write to us."

This was the first time that many members of the general public had heard of DNA forensics and how it might be applied to past cases. Since its inception, the Innocence Project has freed over 300 people, there are more appeals pending, and there are still more ready to be filed. In addition, other innocence projects have sprung up throughout the United States (there are over 100) at various law schools.

The Margaret Sackler and William Bern case described at the beginning of this chapter (Case A) was actually based on a real case, the case of Ronald Cotton (Figure 9.16). The Cotton case is one of the most interesting DNA exoneration cases because of how it was resolved.

Ronald Cotton heard that his name was on a list of men to be interviewed in a rape case. Instead of waiting for the police to come to him, he went in to tell them he was innocent. He was asked to do a lineup and was identified by the victim and arrested. Ronald Cotton was convicted of rape and assault of two victims, and this verdict was upheld in a number of retrials. All through these trials Cotton claimed his innocence. But, before the second trial was about to begin, an inmate in prison told another inmate that he had committed



AP Photo/HO/Burlington Police Department

Figure 9.16 Ronald Cotton was released after 10 years in prison for a crime he did not commit. DNA testing led to his release.

the rapes. The judge, however, refused to allow this evidence, and Cotton was convicted again.

In 1994, two new attorneys were appointed to represent Cotton, and they asked for the DNA collected at the time of the crime to be tested. The evidence had been saved, and they showed Cotton was not a match. He was released in 1995 and was given $5,000 by the state of North Carolina. After his release, Jennifer Thompson-Canino (Figure 9.17), the victim who identified Cotton, came forward and met with Cotton; together they now tour the country discussing the problem of wrongful conviction.

You can read more about Ronald and Jennifer in her book *Picking Cotton*, published in 2009.

One alarming aspect of these cases is that some of the prisoners released were on death row awaiting execution. One such case was that of Kirk Bloodsworth (Figure 9.18, page 194).

Figure 9.17 Jennifer Thompson-Canino was the woman who was raped and wrongly identified Ronald Cotton.

AP Photo/Chuck Burton

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Figure 9.18 Kirk Bloodsworth was on death row waiting for execution when DNA analysis established his innocence.

Photograph by Dan Mullen, The Justice Project/National Library of Medicine

After an anonymous tip and eyewitness testimony placed him near the crime scene, Kirk Bloodsworth was sentenced to death in Maryland for the 1984 sexual assault, murder, and mutilation of 9-year-old Dawn Hamilton. From the beginning, Bloodsworth insisted on his innocence. In prison, he learned about DNA profiling. Eventually his attorney, Bob Morin, with support from the Innocence Project, persuaded officials to compare Bloodsworth's DNA with the DNA of dried sperm found on the victim.

Testing on the DNA samples was done using PCR, which at the time was still a new forensic method. The results exonerated Bloodsworth. He was freed from prison in June 1993—the first death-row prisoner to be exonerated by post-conviction DNA testing.

In 2003, after much prodding from Bloodsworth and Innocence Project lawyers, Maryland authorities finally searched their DNA database for a "cold hit" match of the evidence in the Dawn Hamilton case. The search turned up Kimberley Shay Ruffner, a convicted rapist whom Bloodsworth had known in prison; Ruffner was then tried and found guilty of the 1984 murder.

The Bloodsworth case and other death-row exoneration cases have many states rethinking the death penalty. In 2000, Illinois Governor George Ryan stopped executions in his state because of the possibility that some prisoners were wrongfully convicted. In 2003, he commuted the death sentences of all 156 prisoners awaiting execution, and in 2011, Governor Pat Quinn signed legislation ending the death penalty in Illinois.

Another question that comes from these cases is this: have we already executed innocent prisoners who did not have the opportunity to use DNA forensics? The answer seems to be yes, but we cannot answer this question directly because of the difficulty of postexecution DNA testing, given that one major party of the case has already died.

How many wrongfully accused men and women are still in prison? It is difficult to ascertain. DNA forensic testing is expensive, and funding problems do not allow states to pay for it. Therefore, private funding, like that of the Innocence Project, is necessary to keep these cases going. In addition, when someone is convicted by testimony from an eyewitness, it is difficult for victims, juries, and the public to accept that these criminals were wrongly convicted, and that the real criminal went unpunished. To review the current situation, cases are available on the Innocence Project Web site at www.innocenceproject.org.

The results of DNA forensic testing are also being used with something called a John Doe warrant. When someone is suspected of a crime, a warrant may be issued for his or her arrest. This warrant would include a physical description of the person and other pertinent information. Beginning with New York, many states have allowed warrants to be issued when only a DNA profile is available. In this situation, the DNA profile replaces the physical description and other details usually included in an arrest warrant. This practice allows police more time to find a perpetrator.

Table 9.3 addresses some of the ethical and legal questions in DNA profiling.

9.5 Essentials

- **DNA profiling has been used to secure the release of hundreds of wrongfully convicted prisoners.**
- **Most states and the federal government have constructed DNA databases for use in solving crimes.**

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Table 9.3 **Ethical and Legal Questions in DNA Forensics**

Question	How Are These Questions Decided?	Related Case or Legal Issue
If asked to give a sample in a DNA dragnet (in which many people are asked), can you refuse?	In most cases, one has the right to refuse, but police can look into your background if you do not comply.	In some cases, subjects in a DNA dragnet have been harassed and often lost their jobs if they didn't comply. No legal case has yet resulted.
Who must give DNA in a DNA database?	Most states have passed legislation requiring convicted criminals to give samples. The armed services require members to give samples for identification in case of war.	New York recently passed legislation that allows the collection of DNA from people suspected in a crime, but these samples cannot be kept. The Pentagon has one of the largest DNA databases in the world. In 2000, two marines sued for the right *not* to contribute DNA to this database. They were compelled to give it or be dishonorably discharged.
Can old evidence be investigated and tested years after a crime has been committed?	It has definitely happened. If the crime is murder, no statute of limitations exists, and PCR can be used to increase the amount of DNA available for testing.	In one case, old evidence was used to convict a man of a 40-year-old murder.

Spotlight on Law

Narborough Village Murders

DNA fingerprints were first used as scientific evidence in a criminal case that began in 1983. In the small English village of Narborough, Leicestershire, England, two girls were raped and murdered within a three-year period. Both girls, Dawn Ashworth and Lynda Mann, were 15 years old, and their bodies were found in a field.

The prime suspect was a local boy, Richard Buckland, who after questioning revealed previously unreleased details about Dawn Ashworth's body. He later confessed to the murder of Lynda Mann but denied any involvement in the first murder.

Convinced that Buckland had committed both crimes, officers from Leicestershire Constabulary contacted Dr. Alec Jeffreys at Leicester University, who had recently developed DNA fingerprinting as a way to match DNA samples. They asked him to match samples recovered from both crime scenes with Buckland. Dr. Jeffreys compared semen samples from both murders against a blood sample from the suspect, which conclusively proved that the same man killed both girls, but it was not Buckland.

Richard Buckland became the first person in the world to be exonerated of murder through the use of DNA profiling. Dr. Jeffreys said, "I have no doubt whatsoever that he would have been found guilty had it not been for DNA evidence. That was a remarkable occurrence."

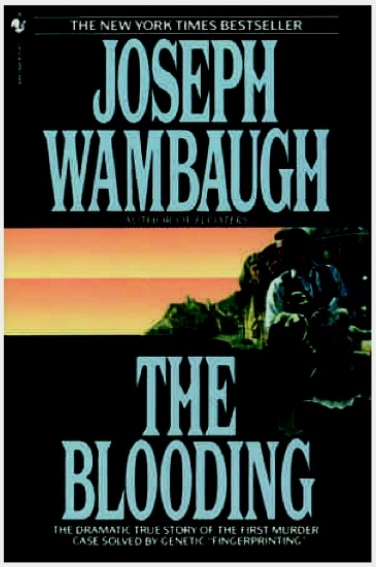
At this point, the police were at a loss. To find the man who matched the killer's DNA, police conducted a DNA dragnet. They asked more than 4000 men from the surrounding area to provide DNA samples for analysis. Unbeknownst to the police, the killer paid another man to give a DNA sample in his place. Colin Pitchfork told a fellow worker, Ian Kelly, that he could not give a blood sample. Kelly used a doctored passport and successfully gave blood in Pitchfork's name.

Oddly enough, Pitchfork would have escaped detection, but he was caught when Kelly bragged about the deception in a pub. A woman overheard the conversation and went to the police.

This historic case was described in the book *The Blooding* (Figure 9.19, page 196) by Joseph Wambaugh.

QUESTIONS

1. This case is important for a number of reasons. It was the first to use DNA profiling in a criminal case, and it broke new ground in forensics and in the use of DNA dragnets. What do you think might have happened if investigators had not used Dr. Jeffreys's technique?
2. Today DNA dragnets are used all over the United Kingdom. Why do you think they are not used very much here in the United States?



Jacket Cover from THE BLOODING by Joseph Wambaugh. Used by permission of Bantam Books, a division of Random House, Inc.

Figure 9.19 *The Blooding* is a nonfiction book about the Colin Pitchfork case and the first use of DNA fingerprinting in the United Kingdom.

3. Do some research on the laws concerning DNA dragnets in the United Kingdom. Do you agree with them?
4. In Truro, Massachusetts, in the summer of 2005, Christa Worthington (Figure 9.20) was murdered in her home, and her 2-year-old daughter was found sitting by the body. The entire state was in an uproar because she was a popular newspaper columnist. Police asked all men who lived around Truro (on Cape Cod) to give DNA samples. The dragnet got a lot of press coverage. Oddly, the killer (who was her garbage collector) gave blood and waited in the area for two years for the samples to be tested. What do you think he was thinking?

Massachusetts State Police/AP Photos

Figure 9.20 The murder of Christa Worthington in Truro, Massachusetts, led to one of the first DNA dragnets in the United States, which eventually led to the arrest of her murderer.