

DNA Typing in Action: Databasing in the Commonwealth of Virginia

Editor's Note: To highlight progress in implementation of STR typing and DNA databasing, Profiles in DNA introduces a new feature spotlighting work by various states in the U.S.A. and other countries to solve and prosecute crimes through DNA typing. In this issue, we focus on the tremendous success that the Commonwealth of Virginia has achieved not only in the size of their growing database but also in terms of solving several violent crimes and preventing others through "hits" in that state's DNA database.

In 1989 the Commonwealth of Virginia was the first state in the U.S. to pass a DNA databasing law, which required only certain sex and violent offenders to provide samples for inclusion in a DNA databank. In 1990, the law was expanded to include all felons. However, at that time, funding was granted only to type the samples that fell under the original 1989 statute. Six years later the law was expanded to include juveniles over the age of 14 who were found guilty of any crime that would constitute a felony if that crime were committed by an adult. DNA typing is performed by the Virginia Division of Forensic Science (DFS), which is a nationally accredited forensic laboratory system serving all state and local law enforcement agencies, medical examiners and Commonwealth's Attorneys in Virginia but is not part of any law enforcement agency. To get an inside perspective on the success of Virginia's program, we spoke to three key figures in this state's database implementation: Paul Ferrara, Director of the Virginia DFS; Jeffrey Ban, Forensic Biology Section Chief; and Kevin McElfresh, Vice President of Operations, The Bode Technology Group. Below are excerpts from our conversations with these men.

PAUL FERRARA, DIRECTOR, VIRGINIA DIVISION OF FORENSIC SCIENCE

Paul Ferrara joined the DFS 28 years ago and has been the Director since 1985. Under his leadership, the DNA typing and databasing program in the Commonwealth of Virginia has grown to become the largest database in the U.S.

Could you provide some history of DNA typing in Virginia?

Dr. Ferrara: The Commonwealth of Virginia was the first state to pass a DNA databasing law in 1989 because Virginia's General Assembly recognized that DNA databasing would be a powerful technology for prosecutors and a tremendous investigative tool. One year later (in 1990) they expanded the law, and sample collection began in earnest.

In a landmark case, DNA testing led to the conviction of Timothy Spencer for raping and murdering four women during a 10-week period in 1987. The Spencer case is notable for a number of reasons. Spencer was the first criminal convicted of capital murder on the basis of DNA evidence. Prior to committing these rapes and murders, Spencer had been convicted of an earlier burglary charge. Had he been in the database from his burglary charge, he would have been identified after the first rape and murder. Thus, his additional crimes would have been prevented. The case graphically demonstrated the efficacy of DNA typing technology. Further, the case established part of the rationale for the General Assembly to pass a resolution requesting that the Virginia State Crime Commission perform a study to determine whether expansion of the database to include other convicted felons (e.g., burglars) would be a worthwhile effort. Based on the report of the Commission, the statute was expanded to include all felons in the database.



Figure 1. The new Central Laboratory of the Virginia Division of Forensic Science is located in downtown Richmond, Virginia.

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In the early years of the database—from 1989 to July 1998—the database consisted of restriction fragment length polymorphism (RFLP) profiles. The first success of the database came in August 1993 with less than 1,000 profiles in the database. A “cold hit” (i.e., when there is no suspect for a crime, but DNA from biological material taken from the crime scene matches that of a convicted felon in the database) was identified as a known sex offender. This case was the first demonstration of the power of felon databases when there is no suspect known for a given crime.

While that early database topped out with less than 15,000 profiles and 31 cold hits made, more than 180,000 samples were collected over that 9-year period. In July 1998 funding was granted for using STR typing for all of the samples to be entered into the database. A contract was arranged with The Bode Technology Group to work on the large number of samples waiting to be included in the database. From July 1998 to the present, DNA typing using the GenePrint® PowerPlex™ 1.1 System has been performed for all samples in the database.

How successful has Virginia's database been?

Dr. Ferrara: The DNA typing and databasing program in Virginia has been extremely successful. What is truly remarkable is how much was accomplished in the first six months that STR typing was performed. In the time from July 1998 to the end of the year, 30,000 profiles had been generated, and there are over 55,000 profiles at present. In the first four months of 1999, there have been 2 hits in January, 3 in February and 7 each in both March and April. The contractor, The Bode Technology Group, is adding to the database at a rate of approximately 8,000 per month. A best guess, based upon the current rate of expansion of the database and hits generated, is that there may be as many as 100 hits on the

database in 1999. The implementation of the database provides tremendous savings in terms of police investigative time and prevention of future crimes. The savings in terms of lives and investigative time are inestimable.

Have you been surprised by the results with Virginia's database?

Dr. Ferrara: In terms of the number of hits on the database, we are not surprised. The number of hits is strictly a function of the size of the database. What has been fascinating and somewhat remarkable is that greater than sixty percent of the hits from violent offender cases match database samples from convicted burglars—not violent offenders. This points to the fact that many violent offenders have been guilty of earlier nonviolent property crimes. Thus, a database that does not include property crime offenders limits its overall efficacy.

To what do you attribute the success of the database?

Dr. Ferrara: Clearly, the success of the database rests on two factors: first, the size of the convicted felon database, and second, concentration on DNA typing of crime scene material from cases where there is no suspect. Although there is a tendency to focus on cases where there are suspects going to trial, we must run biological samples from cold crime scenes. It's a problematic situation. The database has grown, but we must redouble our efforts to run crime scene samples soon after a crime has been committed.

There is a serious problem we must address. The demand for DNA testing is outstripping the ability of the laboratory to perform the tests. With approximately 200 cases received every month, the backlog increases. While the crime rate may be constant or decreasing, the number of samples to be analyzed is increasing.

What explains this increase in the number of samples?

Dr. Ferrara: Cases are much more complex today than ever before. Because the STR technology is so sensitive, we are able to perform testing on a much greater number of samples that the earlier technology could not handle. With STR analysis, a case examiner usually needs to process about ten, and sometimes as many as 20–50, samples per case.

How and when will the capabilities of laboratories in the U.S. meet the demand for DNA testing?

Dr. Ferrara: There might be as many as 100,000 unworked crime scene cases in labs throughout the country, and at least that many more coming. We face some significant challenges. On a national level, I see 1) states expanding their statutes and 2) a lot of new construction of laboratories. We need to:

- Move forensic laboratories out of the basements of police departments and build laboratories designed for this work.
- Train people. Over the next five years, we need to triple the number of DNA examiners available and increase the size of the database ten-fold.
- Remain focused on the 13 core loci, but streamline the technology to increase throughput.

JEFFREY BAN, FORENSIC BIOLOGY SECTION CHIEF, VIRGINIA DIVISION OF FORENSIC SCIENCE

Jeffrey Ban is the technical leader of the Forensic Biology Section for the Virginia Division of Forensic Science. He oversees all technical aspects of the section including research and development, implementation of new technologies, creating population databases, troubleshooting problems in the laboratory, implementing programs in casework and working with case examiners, the databank supervisor and The Bode Technology Group. In addition, he performs regular casework. Mr. Ban started at the Virginia DFS as the databank supervisor after working as a forensic scientist in Florida and a visiting scientist at the FBI.

How is the Virginia crime laboratory system organized?

Mr. Ban: The Virginia DFS DNA laboratory system has a Central laboratory in Richmond (shown in Figure 1), and three other regional laboratories: Northern (Northern Virginia), Tidewater (Southeastern Virginia) and Western (Western Virginia) (see Figure 2). The current forensic biology staff is 36 full-time employees. Eighteen of these full-time scientists, along with six part-time employees, work in the Central laboratory. Twelve of the full-time employees are casework examiners and testify in court to their findings in cases.

The remaining three full-time and six part-time employees work on the databank. The part-time staff receives samples, categorizes them and prepares samples for testing. All data generated from each sample are entered into the national Combined DNA Index System (CODIS).

What training does Virginia require of its laboratory employees?

Mr. Ban: Currently all employees are trained to the DNA Advisory Board (DAB) standards. All case examiners with the Commonwealth of Virginia are required to have at least a bachelor's degree with course work in molecular biology, genetics and statistics. Virginia goes one step further and requires that each case examiner has at least six graduate hours of molecular biology courses. In addition, there is a minimum of six months of in-house, hands-on training for each new scientist with the Virginia DFS.

For training the scientist in casework issues, there is training on identification of biological fluids, chain of custody issues for evidence, packaging of evidence and proper notetaking. All trainees undergo a mock trial where they are given a mock case to analyze and on which they testify in a courtroom setting. After completing this training, they begin DNA training.

For the DNA training, the trainee is given pure biological samples to analyze by extracting the DNA and performing STR typing. Samples include blood, vaginal fluid and seminal fluid. This allows the scientist to understand first-hand how much DNA can be recovered from each type of sample and how much to use in testing without under- or overloading the PCR amplifications. The training also addresses common mistakes in DNA handling and helps the scientists avoid problems that may arise in their work.

The next level of training involves mixed biological samples: determining what fluids are present and how to separate the components. The trainee works on validation of uncommon samples such as animal stains (to learn to distinguish them from those of human sources), teeth, bones, muscle tissue, hair roots, aged stains, samples with both biological and nonbiological contaminants or samples that are found on various substrates. In addition, throughout the training, each trainee spends time with different qualified examiners and may travel to each of the three regional laboratories to learn about slight differences between the labs. There are standard training and procedures manuals, but there are subtle differences in the way each examiner may analyze a case.

For the databank scientists, they are not trained on testing of all fluids because they deal with blood samples. The trainees are each given 200–250 blood samples to test, some of which are degraded. As part of the training, they perform STR typing on these samples, and a trainer verifies their results. After successfully completing the typing of approximately 200 samples, a question-and-answer competency test is conducted since databank scientists will be required to testify to fact in court. Each worker is trained up to the level required by the DNA Advisory Board standards and the American Society of Crime Laboratory Directors (ASCLD) Laboratory Accreditation Board.

How does Virginia process so many samples?

Mr. Ban: The laboratory has sufficient equipment and is designed so that all examiners can work there at the same time. The Virginia DFS has extremely high throughput because they have sufficient and effective equipment for increasing productivity. The

The Virginia DFS has extremely high throughput, in part due to the fact that they have sufficient and effective equipment for increasing productivity.

Hitachi FMBIO® Systems allow high throughput because the gels are not part of the instrument, so the data can be analyzed while other gels are running. Data from the scanner can be sent to another computer and analyzed, and the FMBIO® can be used to read more gels. The Virginia DFS has a number of Mac computers linked through Ethernet connection to the FMBIO® Systems. There are four FMBIO® Systems at the Central laboratory in Richmond and one at each of the other regional laboratories. Each laboratory has at least two thermocyclers and uses the Model SA-43 Vertical Electrophoresis Apparatuses (LTI) with 30-well combs. Turnaround time for a case is approximately two weeks. Because the Virginia DFS is ASCLD/LAB-accredited, their cases must be peer-reviewed by a qualified reviewer, which accounts for some of the time in that two-week period. They also use “second sizing” where an independent case examiner reassesses the analysis.

What are the key points of your quality assurance system?

Mr. Ban: On each typing gel, two controls are used. The first is the K562 cell line DNA, which is supplied with the GenePrint® PowerPlex™ System and has a known DNA profile. The second control is referred to as a “random sample.” This sample is one of 1,600 convicted felon database samples that are used by the DFS and have been previously

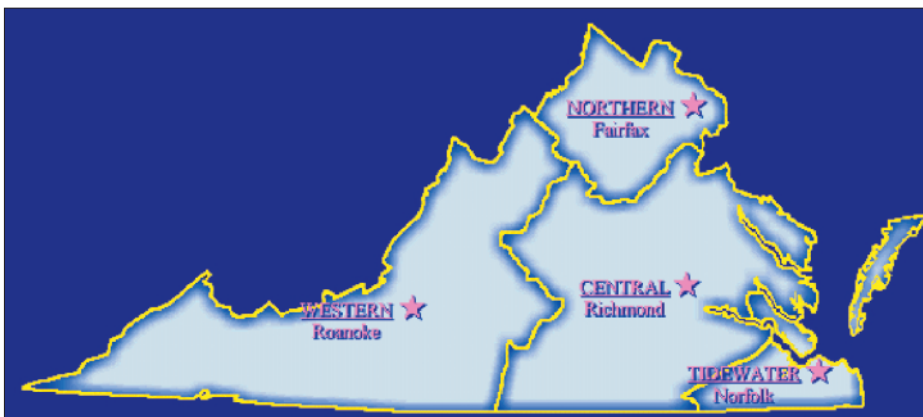


Figure 2. Map of the Commonwealth of Virginia showing the four regional laboratories.

From July 1, 1998, to April 1, 1999, 47,048 samples were analyzed by STR testing in the Commonwealth of Virginia and added to the CODIS database at a rate of greater than 1,000 samples per week.

typed. However, the DNA profile is unknown to the casework examiners at the time of their analysis. Upon completion of their analysis, the examiners will enter the DNA profile from the random sample into CODIS and conduct a search of the database. This sample should make a hit against the database and provide the DNA analyst with the unique database number that has been assigned to the sample. This number is then verified by the program manager against the sample list to ensure the correct answer has been obtained. This ensures two things: first that the gel is run properly, and second that CODIS is working properly. Gradually, other states are employing similar "positive extraction controls." In addition, because the Commonwealth of Virginia considers The Bode Technology Group to be an extension of the DFS, these random samples are provided to that laboratory so that they perform controls in the same manner as the state laboratory. In addition, the Virginia DFS audits The Bode Technology Group on a regular basis.

How is your DNA typing work split between the Virginia DFS and The Bode Technology Group?

Mr. Ban: In July 1998, in order to help reduce the backlog of STR typing, Virginia set up a contract with The Bode Technology Group to assist in the databasing work. The Bode Technology Group is typing the felons convicted of non sex-related offenses. Currently, 185,747 convicted felon blood samples have been collected, and approximately 2,400 new samples are received by DFS each month. The Bode Technology Group is analyzing approximately 8,000 convicted felon blood samples per month. From July 1, 1998, to April 1, 1999, 47,048 samples were analyzed by STR testing in the Commonwealth of Virginia and added to the CODIS database at a rate of greater than 1,000 samples per week.

All casework analysis is performed at one of the four DFS laboratories. In a one-month

period from mid-March to mid-April, 215 cases were analyzed. Next year it is expected that an average of 180–200 casework samples will be analyzed per month, and 70,000 database samples will be processed. The unfortunate side effect of casework productivity is that the examiners must spend time in court to testify in each case that they analyze, which takes away from the time that they can spend working on additional cases.

Why has Virginia's program been so successful?

Mr. Ban: First, Director Paul Ferrara has been extremely supportive of the DNA typing group and does a great job of promoting the program. The success of the database in terms of hits made is disseminated to the public. The public and legislators are more supportive of a program that has shown success. Second, Virginia takes time in training their staff and ensures that the staff share information from cases that may involve unusual circumstances. Virginia DFS requires more educational background than current DAB regulations and allows the staff to attend as many scientific meetings as possible. Among these is the Annual FMBIO® User's Group Meeting in Hilton Head, South Carolina. Opportunities to share experiences and to exchange information are ideal ways for the staff to continue training. It is important that scientists have experience with a number of biological samples and samples that have been exposed to a number of environmental insults. Third, Virginia is aggressive in implementing new cutting-edge technologies. Fourth, the laboratory does not cut corners. It is crucial to thoroughly examine and validate a system before its implementation. Finally, The Virginia DFS is not a police agency and is not competing for funds with law enforcement. There is only one crime laboratory system in the Commonwealth of Virginia, so everything is controlled through the central laboratory in Richmond. Only one person is accountable for the program decisions, thus keeping policies consistent at each of the regional laboratories.

KEVIN C. McELFRESH, VICE PRESIDENT OF OPERATIONS, THE BODE TECHNOLOGY GROUP

The Bode Technology Group was founded by Tom Bode who had spent better than 20 years as Vice President of IIT Research Institute overseeing life science projects. Kevin McElfresh is the Vice President of Operations for The Bode Technology Group and is responsible for running and supervising all of the scientific operations of the

company. His background is in molecular and population genetics, and he has worked in identity testing at both Lifecodes Corporation and IIT Research Institute.

The Bode Technology Group was one of the first laboratories to perform STR typing. How did The Bode Technology Group start STR typing, and what is the relationship with the Commonwealth of Virginia?

Dr. McElfresh: Back in 1990, while at a meeting of one of the first Human Genome Conferences, I heard a talk by Tom Caskey about work done with short tandem repeats (STRs) and ³²P-labeling. In addition, he showed work using fluorescent STR multiplexes. I thought that this fluorescent detection was a more informative way of handling STR analysis.

I joined Tom Bode in a newly formed company in 1993, which later split off in 1995 to become The Bode Technology Group. By 1994, Bode's earlier company was performing database work using silver monoplexes and the CTT triplex system. In 1996 The Bode Technology Group purchased an FMBIO® System and soon purchased the FMBIO® II System. We have been successful because we are always ready to make a move when the timing is right. For example, we are ready to go online with the GenePrint® PowerPlex™ 2.1 System, Promega's newest megaplex system. Because we have been working in STR typing using successive systems, we do not need to completely revalidate every step of the process with each new system used. For example, it was quite easy to move from the CTT silver platform to the CTTv fluorescent platform. The validation is performed to make certain that the systems give the same answer at the end of analysis.

The Bode Technology Group became involved in databasing work with the Commonwealth of Virginia when the state decided that it needed assistance with its backlog of samples. In July 1998, Bode won a contract to work on the convicted felon database for Virginia. There is a fundamentally close relationship between this contracting company and the state. Because the Commonwealth of Virginia considers The Bode Technology Group to be an extension of the Virginia laboratory, it makes the relationship work quite successfully. It is an honor to be associated with an organization (Virginia DFS) that has been at the forefront of using DNA typing and technology. Because the state saw the need to get this work done for the good of society, they enlisted the help of industry to get the

databasing work performed. Virginia sends convicted felon samples to The Bode Technology Group, who in turn performs the analysis and returns the data and original samples to the state laboratory.

For the contract work with Virginia, where do you stand today and what resources do you use?

Dr. McElfresh: Currently, we are processing 2,000 samples per week for a total of 70,000 samples in the first year alone. We will continue with this database work until the Commonwealth of Virginia has effectively eliminated its backlog. We perform all of the STR typing work using Promega's PowerPlex™ 1.1 System. Our resources include two FMBIO® II Fluorescent Analysis Systems, and we run 22 gels per day using SA-43 gel boxes. There are ten full-time people, all trained to meet the DNA Advisory Board guidelines, working on this project. It is important to note that they work strictly an eight-hour day and do not run gels overnight or do shift work.

How do you assure and maintain quality?

Dr. McElfresh: Three of the ten people who work on the Virginia databasing project are dedicated to quality assurance. In addition to the guidelines set forth from the state, they manually reread 10% of the sample gels shipped each week to verify that the machines are reading the gels correctly. The use of the FMBIO® Fluorescence Imaging Systems makes it easier for them to do quality assurance. Because we are used to looking

at gels, the scientists in the laboratory can easily check the analysis. This system is amenable both to high throughput and quality control procedures.

What are the key elements that make your partnership with the Commonwealth of Virginia successful?

Dr. McElfresh: The relationship between Virginia and The Bode Technology Group is very strong because:

- People in the state and industrial laboratories on both sides have great respect for each other.
- We talk about issues at a fundamental level, and we work well together. The dialog between the state and contractor lab is as good as it can be.
- There are dedicated, top-notch people at both ends of this work who know that what we do has a large societal impact.

From our point-of-view, it is an honor to work with the Commonwealth of Virginia. The central theme of our success is that we have an honorable working relationship of colleagues to achieve an important goal that is of great value to the public.

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