MOLECULAR GENETIC EXAMINATION

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Abstract. In the modern world, new technologies which influence and help to find possible new ways to investigate crimes are developing at the speed of light. However, many problems exist with the practical application of these systems. Molecular genetic examination – an independent branch of forensic technology that helps to know with almost complete precision who is directly related to a crime and who is not – is one of the most popular methods of this nature for investigators. As a result of this technique, specialists weed out a circle of irrelevant people for any given situation. Today, there are many options for conducting such an examination, but they are still not entirely perfect. This research involved interviews with DNA lab specialists in Ukraine, who explained some of the main problems with this method and how they might be addressed in future. Therefore, the purpose of this article is to identify problematic elements of this method and to enlist scientists in eliminating them. These problems will be discussed in several ways to explain them more understandably. This article will also consider classical genetic approaches in this area and highlight the prospects for their further development.

Keywords: DNA analysis, molecular genetic examination, identification, criminal proceedings, genotype profiling, special knowledge in criminal proceedings, forensic technology, DNA testing.
Introduction

Molecular genetic examination is the most probative method for biological investigation in forensic examination. Working with biological traces is of prime importance in crime investigation around the world. This method of examination has helped solve difficult situations in criminal investigations by using traces of blood, semen, saliva, epithelial traces, particles of internal organs on murder weapons, and so on.

The tasks of genetic examination and research include:

- establishment of biological relationship (including the solution of issues of the controversial origin of children);
- personal identification;
- establishing certain facts that may have evidentiary value in a case.

Most of the latest genetic research is based on the latest achievements of molecular biology – the individuality of the genetic characteristics of the cells of the human body. This provides reliable answers to many questions.

Moreover, experts who carry out criminal proceedings have the task of introducing into the system of evidence more and more opportunities for forensic examination. The role of material evidence and the conclusions of experts as the most important objective sources of creating a reliable evidence base in the investigation of crimes are also growing significantly. These individuals are involved in the investigation of serious crimes, including murders, contract killings, grievous bodily harm, and abduction.

One of the most effective methods of biological investigation, which is used in molecular genetic examination, is DNA analysis. This topic is much-discussed among scientists, especially regarding using the possibilities of DNA management in forensic science, and has included the work of such domestic scientists as I. Yu. Gorbatenko, M. M. Didyk, O. V. Dunaev, N. M. Dyachenko, G. F. Krivda, R. G. Krivda, Yu. M. Sivolap, and others.

Every year the demand for genetic examination is increasing, because technological progress opens doors with the introduction of new features.
in this sphere. This type of examination rapidly infiltrates into forensic activity. This is turn causes many problems in law, in the development of some branches of criminalistics, and so on. For example, the procedure for taking biological samples in criminal proceedings needs to be improved, methods of forensic molecular genetic examination are slowly developing, and there are significant difficulties in verifying, evaluating, and using the results of molecular genetic research in criminal proceedings. These issues will be built upon in the following sections of this article.

During this research, aspects such as the theoretical nature of molecular-genetic examination, the history of this examination, and problems in the practical use of DNA analysis will be considered, and some solutions for problems in this sphere will be outlined.

1. The History of Molecular Genetic Examination

The structure of DNA began to be decoded in the 1950s, and in the last century a new era in biology began, creating the preconditions for finding new methods of identifying a particular living organism by its genetic characteristics.

English geneticist A. Jeffreys first observed the ability to study individual human traits via DNA in 1984, finding that in the structure of this molecule individual characteristics for each person are different in number, and observing that the length of this plot can be distinguished and compared. He and his co-authors tuned out well in identification mini-satellite DNA. In conclusion, they observed that DNA is individual for everyone, and used these identified sites for the identification of a person in forensic medicine. This helped to develop a technique for detecting and examining DNA to identify a person, which was called DNA fingerprinting. Since then, this area of forensic medicine has developed rapidly, and is called genotyping, DNA analysis, molecular genetic examination, forensic DNA analysis, and other names.

A number of other historical discoveries also occurred in the sphere of molecular-genetic examination. For instance, the first patent for the method that forms part of the modern DNA profiling process was applied

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for in the USA by American biologist D. Glassberg.\footnote{Stepaniuk, supra note, 1.}

However, the most important influence was made by A. Jeffries, with his co-authors W. Wilson, S. Thein, P. Gill, and D. Verrett, in their research and articles which were published in 1985. The rapid and successful implementation of the method of identification of a person by their DNA into the forensic process began because of good, practical testing.\footnote{Ruslan Stepaniuk et al., \textit{Forensic DNA research: technologies and opportunities: textbook} (Ukraine, Kharkiv, 2020).}

Since that time, technology using molecular-genetic examination has become part of judicial science. The majority of the time, this involves performing tasks for the detection and investigation of crimes. Now, DNA analysis is considered around the world to represent a form of examination with the highest level of validity – a forensic technology.

In Ukraine, such a form of examination started to be used in 1992 in the State Research Forensic Center of the Ministry of Internal Affairs of Ukraine (N.M. Dyachenk). In the same year, the Odessa Regional Bureau of Forensic Medical Examination, under G. F. Kryvda, introduced the method of identification of various biological objects using PCR DNA typing. Currently, there are a number of departmental laboratories of forensic genetics in the state specialized expert institutions of the Ministry of Internal Affairs of Ukraine and individual forensic bureaus of the Ministry of Health of Ukraine. This is a very strong network, which provides huge opportunities to use various DNA analysis technologies. For this reason, the detection rate of murder and abuse is extremely high, but despite this success, a number of problems associated with this method of examination remain. To discuss and understand these problems, it is necessary to consider what molecular-genetic examination is, how it is used, and so on.

\section*{2. The Theoretical Background of Molecular Genetic Examination}

Firstly, let us consider what molecular genetic examination is. It should be observed that this is the most universal method of this type, because it can identify everything that contains DNA. Molecular genetic identification is new scientific knowledge that opens up prospects for
solving identification problems in criminal proceedings and the development of the evidence base, and has a number of advantages over traditional serological methods of research of human biological traces, such as:

1) the structure of the DNA molecule is more resistant to the action of physicochemical factors of the environment compared to proteins and other compounds;

2) the presence in DNA of complete information about the human genotype in each cell of the organism that contains the nucleus;

3) methods of research of such microtraces (cells in saliva, semen, hair follicles with a vaginal membrane, etc.) allow a person to be identified with an accuracy of 99.9%;

4) the possibility of differentiation of mixed traces and the fact of mixing the biological material of several persons.

Genetic examination signifies a study using methods of the molecular genetic individualization of a person, carried out in order to determine the individualizing characteristics of biological objects at the level of genomic DNA. In short, this is an examination which helps to identify a person by their biological, molecular, and genetic features.

As for the object of the molecular genetic examination, there is one agreed-upon definition presented across different articles and by different researchers. For example, V. V. Topchiy notes that the objects of molecular genetic research can be nuclear DNA obtained from blood, secretions (semen, saliva, buccal and other epithelium, etc.), hair (if a hair follicle is present), as well as parts of organs and tissues of the human body. Another article observes that “the object of molecular genetic research is deoxyribonucleic acid (DNA) obtained from blood, secretions (semen, saliva, vaginal secretions, etc.), hair, dandruff, epithelial cells, as well as parts of organs and other tissues of the human body removed during scene review”.

In conclusion, the objects of genetic examination are:

- material evidence – items with traces of biological origin (blood stains, semen, saliva, etc.);
- fragments of the human body (muscle tissue, bone material, hair with root bulbs, etc.);

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• examples of biological fluids (blood, saliva, semen, etc.) in liquid or dried form (gauze, cotton swabs, filter paper);
• materials of the criminal case – in coordination with the expert (information on the conditions of discovery and seizure of physical evidence, the results of forensic examination, etc.).

In using these objects, this form of examination tries to achieve the purpose of researching genetic material in order to establish the origin of biological traces from a specific person, as well as establishing a biological relationship (paternity, maternity).

This task involves establishing the nature of the object to be investigated, determining the species that the object belongs to, and ultimately identifying the person.

Molecular genetic examination seeks to answer the following questions, among others:
— Does a blood or fluid stain contain genetic material suitable for identification?
— Does a blood or fluid stain (saliva, semen, etc.) on the clothes of a victim originate from a suspect?
— Who can be classified as a suspect?

There are a lot of methods of conducting molecular genetic examination, but the most popular and the most exact is DNA analysis. Every examination is based on DNA analysis, which will be considered in the following section of this article. These examinations allow us to put forward a version of the commission of a series of crimes by one person, to combine the available information on disparate crimes, and to approach its assessment and the compilation of the psychological profile of the offender from another angle.

3. DNA Analysis: Practical and Theoretical Aspects

DNA analysis, as previously discussed, is the most important method of these examinations, and forms part of molecular genetic examination.

DNA analysis, DNA profiling, or DNA fingerprinting as it is also known, is a process with the help of which there is the opportunity to identify a person (suspect or victim) on the basis of their unique genetic features. Even if people change their eye color, hair, and other aspects of their appearance, they will never be able to change their DNA. That is why
this form of examination is very useful in solving more explicit crimes.

DNA analysis is very specific because it can investigate even if only the smallest amounts of biological material are present. Sometimes, investigators can find only single hairs or tiny traces of material.

This analysis helps us to solve problems during investigations that are similar to the tasks of molecular genetic examination, because it is a part of this sphere. DNA analysis helps us: to establish the affiliation of biological traces (blood, semen, saliva, hair) found at the scene of the crime; to identify the person suspected of committing a crime; to establish that the biological traces removed from the places of unsolved crimes belong to one person; to compare biological traces extracted from the crime scene with DNA information databases generated by law enforcement agencies; and so on.

As such, it can be stated that DNA analysis is used in every kind of crime, because biological material can be found everywhere. For example, in cases of rape and subsequent conception, DNA analysis can be used to find the identity of the perpetrator. In cases of infanticide (including newborns), the abduction of children, and their replacement in maternity hospitals, DNA analysis can be used to determine whether the persons involved in the case are the child’s parents. DNA analysis can also be used to establish whether remains belong to one person, and research on samples from close relatives can be used to link different crimes by establishing that traces of biomaterial found at the sites of different crimes are left by the same person. These important purposes highlight the utility of DNA analysis.

This analysis is based not only on DNA, but also on genetic changes in the human body. Nucleotide substitutions in DNA make us all different and unique, and exist in different frequencies in the population. They exist differently in each body, hence serving as a unique DNA barcode.

Modern methods of DNA fingerprinting use a variety of genetic variants in different parts of the genome. For instance, analysis of tandem repeats shows paternity, or can find additional evidence against a suspect in a crime, while Y-chromosomal DNA markers can determine the sex of a person. All of these methods allow us to correctly identify a person. However, some problems occur in such analyses, because of issues in their first stages.

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The first stage of performing these examinations is to collect all biological material in the proper way. This procedure is not very difficult, but there are some problems associated with it.

Firstly, these objects are taken with sterile rubber gloves, sterile forceps, and scalpels. The objects on which traces are located must be removed entirely or removed with a part of the biological carrier. Alcohol treatment is carried out before each new sample. Traces of biological origin are packed in a paper envelope to prevent loss of identification material. The envelope is sealed and provided with an explanatory inscription. Packing of objects of biological origin in plastic bags is not allowed. Also, it should be noted that dried objects at room temperature can be submitted for examination.

In conclusion, the specificity of this method of DNA identification is determined by:

- The uniqueness of each individual set of deoxyribonucleic acid (this criterion does not apply to identical twins, which are to some extent clones);
- The genetic stability of our body. Genetic data, in contrast to the component composition of protein and fat cells, does not change throughout life.
- A highly sensitivity technique. Only a few drops of blood, saliva samples, semen stains, or biological material left on a smoked cigarette are necessary to perform a laboratory test.
- The relative stability of DNA molecules. Unlike protein molecules, which themselves belong to the class of unstable structures, the components of deoxyribonucleic acid are characterized by high resistance to environmental factors. This feature of DNA is very valuable in forensics because it allows laboratory tests to be conducted after a long period of time.7

4. Practical Problems With This Method of Examination

Despite the rapid development of DNA analysis and its relevance in modern forensic medicine, the question arises as to its shortcomings, problems, and ways to solve them. At each stage, there are some specific problems.

The most significant problem, according to experts, is at the first stage of gathering materials from the crime scene by investigators. There are a lot of biological materials at crime scenes, so investigators must be careful when collecting materials and not take traces from places where many people have touched. If this is not adhered to, then the percentage chance of finding the correct person will be low, because analysis will be conducted on all traces. These places include the handles of entrance doors, handles on the outside of apartment doors, railings, doors, tablecloths in restaurants (if they are not changed after each guest), and so on. Moreover, sometimes investigators do not follow the procedure for collecting biological materials, which sometimes even leads to investigators themselves leaving their DNA on these things. This makes the procedure and the work of the experts much longer and much more difficult.

The solution to this problem is to teach investigators and experts how to collect biological material for DNA analysis.

The second problem is that investigators and experts sometimes take too many things from crime scenes that are irrelevant to determining the location of the criminal and the investigation of the case.

The solution to this is that things should be divided into blocks when inspecting a crime scene. Some things, for example, can be sent to immunological examination or other areas. Failing to follow this guidance can create work for DNA experts that they are not trained for.

In conclusion, while many more practical problems exist, the most important – according to experts – have been outlined above. These issues must be resolved, because this form of examination plays a huge role in criminal investigations. For this reason, the issue of how to collect biological material for DNA analysis should made a special subject for investigators and criminalistic experts when teaching.

5. Situations Connected With DNA Analysis

In 2004, DNA analysis shed new light on the mysterious disappearance in 1912 of Bobby Dunbar, a four-year-old boy who went missing while fishing. He was allegedly found alive eight months later, but a woman named Julia Anderson claimed that the boy was her son, Bruce Anderson. The court did not believe her, and the boy was transferred to the Dunbar family. However, a DNA test in 2004 determined that the boy, discovered in 1912, was not Bobby Dunbar, whose real fate remains unknown.8

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In March 2011, unknown persons abducted 16-year-old Victoria Teslyuk, the daughter of a well-known businessperson, in the Moscow region. The search for the girl gave no results. When the body, presumably of Victoria, was discovered at the end of April of the same year, it could not be visually identified due to damage to the corpse by forest animals and natural putrefactive changes. After an examination of the DNA of the corpse, its identity was unambiguously established as the missing Teslyuk.9

Another interesting case concerns the “Boston strangler”. This case dated from 1964, but was finally solved in 2013. After the rape and strangulation of 11 women, a man later confessed to their killing. After a few days, he started to recant his confession, casting doubt on his guilt. In 1973, he was killed by other inmates, after having been sentenced to life in prison on other rape charges. Very little evidence for his guilt existed until 2013, when new evidence finally linked the Boston Strangler to the last victim. The NIJ has funded the examination of “cold cases” through its Solving Cold Cases with DNA program, sometimes solving very old cases such as this. With the help of this program, experts performed DNA analysis and found evidence almost 50 years after the death of the last victim.10

Conclusion

After a theoretical discussion, it can be stated that this is a fairly young field of examination. The popularity of molecular genetic expertise is growing every year, and the field continues to develop in line with technological developments around the world. As far as DNA analysis is concerned, this is one of the most widespread methods of molecular genetic examination. However, despite rapid development in this direction, a number of problems persist, some of which were mentioned in the previous sections of this paper. DNA analysis is one of the most accurate methods of analysis. It provides near-certain probability of correctly identifying an attacker, victim, or, in some situations, a corpse. Currently, molecular genetic (the genotyposcopic method of DNA analysis) examination is quite flexible in carrying out the required significant material.

9 Julia Khozhateleva, “The girl killed in the suburbs is the daughter of Lukoil’s top manager Victoria Teslyuk”, Komsomolskaya Pravda, accessed April 7, 2022, https://www.msk.kp.ru/daily/25684.4/889043/.