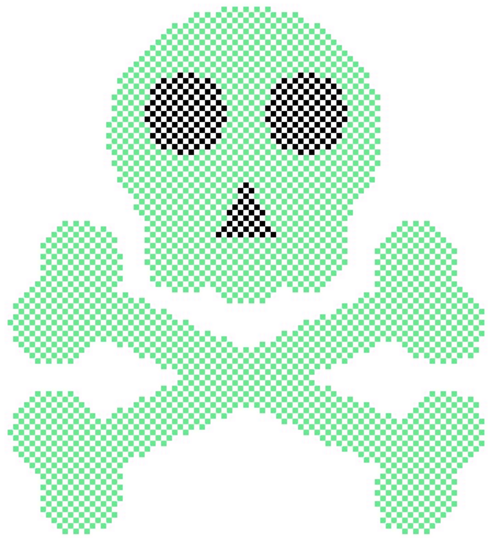

A Simplified Guide to Forensic Toxicology

Introduction

From Socrates, sentenced to drink hemlock in 399 B.C., to Russian mystic Grigori Rasputin reputedly living despite ingesting ten times the fatal amount of cyanide in 1916, and even fictional Sleeping Beauty, poisoning has been a popular way to bring an end to an adversary in real and imagined stories for thousands of years. Until 1840, poisoning was often thought to be a way to "get away with murder", and it worked because there were no visible signs of foul play. In that year, a French woman named Marie Lafarge became the first person to be convicted of murder by poisoning thanks to new methods for arsenic testing, and the field of forensic toxicology was born.

Toxicology is the study of the adverse effects of chemicals on living organisms. Forensic toxicology takes it a step further, including a number of related disciplines to assist in the detection and interpretation of drugs and poisons in medicolegal death investigations, human performance issues; e.g., driving under the influence, compliance and other related matters. In these investigations, the three main objectives (respectively) are to:

- Establish if toxicants are present and capable of contributing to death
- Establish if toxicants are present and capable of causing behavioural changes
- Establish if substances are present and whether or not they represent legitimate use or exposure, such as prescribed medications or workplace exposures

Forensic toxicology can also be used to determine drugs and dosing for hospital patients, for example in therapeutic drug monitoring and emergency clinical toxicology; identify crimes where toxicants are used to poison or sedate; resolve cases of driving under the influence; and establish whether drugs have been used to improve human performance, as in sport "doping". For the purposes of this module, we will be primarily discussing post-mortem forensic toxicology.

Principles of Post-mortem (Death Investigation) Forensic Toxicology

Sixteenth century scientist Paracelsus gave us the adage "the dose makes the poison". Basically, he surmised that a certain amount of every substance, even water and air, can be toxic and those amounts can differ somewhat from person to person and substance to substance. Therein lies one of the most basic challenges of toxicology: is it the quantity of the toxin or the make-up of the person?

Forensic toxicology applies analytical toxicology to the purposes of the law, and includes the analysis of a variety of fluids and tissue samples to determine the absence or presence of drugs and poisons. Once the analytical component is complete, the toxicologist has the equally challenging aspects of interpreting the findings.

Applications

Why and when is forensic toxicology used?

In post-mortem investigations, suspected drug overdoses are clear situations where toxicology is required to establish if an excessive intake of the drug occurred and, if so, whether this contributed to death. Conversely, toxicology can eliminate the possibility of a drug overdose if concentrations are not capable of causing death, given all other factors. This means that toxicology testing can produce a positive result even in cases where drug use is not mentioned in the police circumstances. This is not surprising given the wide availability of potentially toxic substances, both legal and illegal. In addition, concentrations of substances change after death making any interpretation difficult, no matter the concentration.

In many cases, poisons may be detected by the toxicology laboratory but are not necessarily a cause of death, rather their presence may be relevant in the circumstances of death. For example, alcohol and impairing drugs are found in about half of all drivers killed in motor vehicle crashes in Australia, nearly one-third (31%) of all traffic-related deaths in the United States and in a significant proportion of other accidental deaths. Alcohol and/or drugs are also found in a significant number of other deaths reported to the coroner; for example, in suicides that include non-drug related intentional deaths. In death cases where natural disease is partially to blame, drugs that indicate an underlying disease are often detected, such as drugs that have been used to treat a condition or pain. Sometimes these drugs are regarded as contributing to the cause of death.

Regardless how the individual died, toxicology testing can determine whether levels of toxic substances may have contributed to this death.

How It's Done

How the evidence is collected

Specimens sent for toxicology testing are usually collected by the forensic pathologist (who may also be an appointed "medical examiner" or "coroner" in some jurisdictions) or mortuary technician during an autopsy. Specimens must be properly identified, labelled and sealed as soon as practicable after collection. All specimens pertaining to a case must be collected and bagged separately in tamper-proof containers. Unique numbered seals are used to track all evidence for each case. Like any other evidence, the chain of custody must be preserved at all times, from the mortuary through the laboratory testing, reporting and storage, for court purposes. If the continuity of evidence is compromised, it can result in the case being dismissed in court.

Specimen collection

Table 1 (below) provides a snapshot of the kinds of samples commonly requested when investigating different manners of death, although there may be unique case needs that have to be addressed for some investigations. For example, exposure to volatile substances requires a sample of the fluid in the lung. Skeletal remains can be useful to determine prior exposure to drugs and other substances. In these cases hair can also be sampled.

Table 1. Recommended specimens collected in post-mortem cases.

Type of death case	*Recommended specimens*
Suicides, motor vehicle crashes, and industrial accidents	Blood, urine, vitreous humour, liver
Homicides and/or suspicious	Blood, urine, vitreous humour, gastric contents, bile, liver, hair
Drug-related	Blood, urine, vitreous humour, gastric contents, bile, liver, hair
Volatile substance abuse	Blood, urine, vitreous humour, lung fluid or tied-off lung, liver
Heavy metal poisoning and exposure to other poisons	Blood, urine, vitreous humour, liver, hair, kidney

Blood, Urine, Liver

Blood is often the specimen of choice for detecting, quantifying and interpreting drugs and other toxicant concentrations. Concentrations of drugs and other toxicants in blood may be useful for establishing recent drug ingestion and to determine the effect of a drug on the deceased at the time of death, or at the time the blood was taken. This can complicate the investigation when someone has been taking prescription medications for some time. For cases involving hospital treatment before death, blood samples taken soon after admission and immediately before death, should also be investigated particularly when poisoning is suspected before admission into hospital. Any treatment given can change the results of toxicology tests or be helpful in the investigation.

Post-mortem blood presents problems due to often variable condition and changes to concentrations from one place to another in the body after death. The degree of decomposition can also interfere with testing as these specimens can be difficult to analyse.

Urine is the most common sample used for drug testing in the workplace, but it is not always available for post-mortem testing. Urine testing results do not directly correlate to drug effects at the time of sample collection because of the time it takes the body to eliminate these drugs or their metabolites (the body's breakdown products) in the urine. Its usefulness lies in the fact that the presence of a substance in the urine is a sign that the substance had been in the blood at an earlier time (usually within a few days) and had been somewhat processed (detecting these metabolites gives proof that the drug had been ingested).

The liver is a primary solid tissue for use in post-mortem toxicology because it is where the body metabolizes most drugs and toxicants. Many drugs become concentrated in the liver and can be found even when there are no levels in the blood. In this latter situation, interpretation of findings is complex.

Vitreous Humour
Vitreous humour is the clear, gel-like substance that fills the eye. It can be a useful fluid to screen for a range of drugs. Vitreous humour is commonly analyzed for blood alcohol concentrations. This is of particular interest in motor vehicle trauma, workplace accidents, suicides and homicides. Vitreous humour alcohol concentrations are a little higher than blood (about 20% on average), assuming there has been no degradation. Interpretation of other toxicological findings in vitreous humour is somewhat more complex.

Other samples less commonly used for post-mortem toxicology
Stomach Contents - Because drugs and poisons can often be ingested, stomach contents can provide important investigative clues. In a case of potential overdose or acute poisoning, high concentrations of drugs or toxins may be detected, depending on how much time elapsed between

ingestion and death. In many cases of acute poisoning, undissolved capsules or tablets may be discovered, allowing relatively simple drug or poison identification. The total amount of a drug or poison present in the stomach is more important than its concentration because it has not been processed by the body yet.

Bone and Bone Marrow - Bone, in particular bone marrow, can be used for testing when necessary, but the availability and condition of bones in skeletal remains may limit their usefulness. There are no data to suggest that bones from one part of the body are better than others for toxicology tests. However, it is always easier to extract samples from larger bones. Interpretation of these findings is often difficult when assisting in a death investigation, because the time that these toxins were deposited in the bones cannot be determined with reasonable certainty.

Hair and Nails - Hair specimens, usually taken from the back of the head, can be used to test for exposure to heavy metals and drugs over a period of weeks to months. Hair is predominantly used to test for drugs such as amphetamines, cocaine, marijuana (THC) and heroin, and more recently tests have been created to determine if the deceased was drinking heavily in the last few months before death. Drug analysis can also be done on finger- and toenails in order to provide an even longer potential window of exposure than hair. However, relatively little is known about how the nails process toxins, so interpretation of results is more difficult. Hair is subject to external contamination issues that can mitigate its value, so special sample preparations in the lab may be needed for a given case.

Testing

The testing of biological fluids and/or tissues for drugs and other substances is a complex process requiring sophisticated instrumentation and specially trained analysts. In the typical autopsy, fluids and tissue samples are collected specifically for toxicology testing. The types of samples collected from the body, and the testing targets in these biological fluids and tissues, are determined by circumstances of the case and the condition of the body.

Once at the laboratory, a series of tests will be conducted, usually on blood, for a large range of over-the-counter, prescription and illicit drugs as well as alcohol and other toxicants; e.g., metals, inhalants, environmentals (pesticides, insecticides), carbon monoxide, cyanide and many other possible toxins depending on investigative clues or specific tests requested. Table 3 and the “Systematic Toxicological Analysis” section (both provided below) spell out the many materials the medical examiner might harvest from a body during autopsy, and how they can be quickly screened in “truly unknown” cases. The biological evidence from autopsies are needed to support both “common” lab tests and help investigate some very specific potential causes of death.

Routine testing, or testing without specific instructions to look for a particular substance, will generally include the drugs shown below in Table 1, but not all drugs. The list of the most common drugs detected is included in a standard attachment to all toxicology reports.

When urine is available, tests are also conducted for presence of drugs of abuse. Depending on the case and the results of initial testing other tissues may need to be analyzed, possibly including stomach contents, liver, etc., (see Table 2).

Table 2. Drugs included in routine post-mortem toxicology

Substance(s)	*Examples*
Alcohol	Chemically known as ethanol. Test also includes methanol and acetone[1].
Analgesics	Paracetamol (acetaminophen), tramadol 9(ConZip™, Ryzolt™, Ultracet, Ultram in the U.S.), Salicylates (aspirin)
Antidepressants	Tricyclics (e.g., imipramine, amitriptyline) ; SSRIs (fluoxetine [Prozac®], sertraline [Zoloft®])
Antihistamines (sedating)	doxylamine, chlorpheniramine, diphenhydramine
Antipsychotics	old and newer generation including depot injections (subcutaneous or intramuscular injections of long-lasting medication); Haloperidol; Risperidone
Benzodiazepines and “Z” drugs	all available (diazepam [Valium®], alprazolam [Xanax®]; zolpidem (Ambien®, Ambien CR, Intermezzo®, Stilnox®, and Sublinox®), zopiclone (Imovane®, Zimovane), zaleplon (Sonata® and Starnoc)
Cannabis	tetrahydrocannabinol (THC) (Marijuana, pot) and its metabolites
Cardiovascular drugs	Diltiazem (calcium channelblockers), Disopyramide (names Norpace® and Rythmodan®), propranolol (beta blocker)
Cocaine	cocaine and its metabolites

Narcotic analgesics	codeine, methadone, pethidine, morphine, hydrocodone, oxycodone, fentanyl
Stimulants	Amphetamine, methamphetamine, MDMA (ecstasy), pseudoephedrine, fenfluramine, phentermine, caffeine

[1] Acetone can derive from abnormal body metabolism in diabetic ketoacidotic states.

Additional or specific requests to the toxicology laboratory can be made, depending on the circumstances of a case. The most common examples of specific drugs that analysts may be asked to look for are outlined in Table 3, below.

Table 3. Drugs not routinely included in death investigation toxicology screens

Anti-convulsants	*(some only) lamotrigine (Lamictal®), valproate, phenytoin*
Barbiturates	Phenobarbital, butalbital, many other prescribed (or otherwise obtained) Barbs
Designer drugs	synthetic cathinones and synthetic cannabinoids ('bath salts', 'plant food', 'spice', etc.)
Digoxin	used to treat arrhythmias and heart failure
GHB	gamma-hydroxybutyrate("Juice", "Liquid Ecstasy", Fantasy)
LSD	hallucinogen rarely seen in coroners cases
Environmental Toxicants	carbon monoxide; cyanide; pesticides; herbicides ; metals

Poison

Death by poison can happen in a variety of ways, for example through recreational exposure by inhaling solvents such as butane lighter fluid or fuels, ingesting plant-derived substances like Angel's Trumpet, accidental exposure to a substance used in the workplace or even accidently produced in the home (like carbon monoxide), or suicidal ingestion of a poison such as strychnine, pesticides, cyanide, etc. These all require specialized tests and the laboratory is alerted to their possible usage or involvement in the death when requests for toxicology testing are submitted.

Who conducts the analysis?

Scientists/toxicologists analyze the specimens submitted and then provide interpretation of the significance of the results based on information received about the case. These analysts may work in crime laboratories, medical examiners' offices, government health laboratories or even independent providers, depending on the criminal justice structure in a given community.

Certification for individuals in the United States and Canada as a forensic toxicology specialist or diplomate is available through the American Board of Forensic Toxicology (ABFT). Certification is based upon the candidate's personal and professional record of education and training, experience, achievement and a formal examination. In Europe, individuals may become part of the European Register of Toxicologists through EuroTox (www.eurotox.com), through a similar process. In Japan, the *Japanese Society of Toxicology* (JSOT) has a diplomate process. International discussion and participation in toxicology is widespread.

How and Where the Analysis is Performed

Forensic toxicologists employ a large number of analytical techniques to determine the drugs or poisons relevant to a case investigation; †he capacity of a laboratory to conduct routine toxicological analysis will vary dependent upon equipment, technical capability and analyst experience. When needed, there are specialty toxicology labs that can test for virtually any potential toxin or metabolite in almost every kind of post-mortem sample.

A laboratory should be accredited to perform the analytical work and must be subject to regular inspections by approved accreditation personnel. Certification for forensic toxicology laboratories in the United States and Canada is also available through ABFT, and is voluntary and additional to accreditation. All laboratory tests must be validated, fully documented and fit for purpose. This will ensure that laboratory can reproduce accurate and reliable results for medicolegal investigations. All laboratory tests should conform to standard operating procedures, results are confirmed to meet standards, and reported results are peer reviewed by a second toxicologist before being released. In fact, the American toxicology community recently completed a two-year effort to improve these standards, under the name of "Scientific Working Group on Toxicology" (SWGTOX), in order to meet more stringent legal and scientific challenges.

Immunoassays

Most commonly used drug screening tests involve immunoassay techniques. Immunoassays are laboratory tests that use antibodies to detect a reaction with specific substances. Immunoassay screening tests are designed to detect whether a sample is positive or negative for the targeted drug. Four interpretations of a screening drug test are possible:

- a **true-positive** result occurs when the test correctly detects the presence of a drug

- a **false-positive** result is one where the test incorrectly detects the presence of a drug where no drug is present
- a **true-negative** result occurs when the test correctly confirms the absence of a drug
- a **false-negative** result is one where the test fails to detect the presence of a drug when it is present

For those samples that give positive screening results, confirmation tests should be performed, preferably using mass spectrometry (MS) detection. Specific immunoassay tests are available for many drug classes including all the drugs of abuse as well as a range of novel compounds such as buprenorphine, “Bath Salts” and “Spice” and other new synthetic drugs.

Chromatographic techniques

Chromatographic detection is an analytical procedure used for separation of compounds/drugs and is frequently based on either high performance liquid chromatography (HPLC) or gas chromatography (GC) coupled with MS. This is the definitive technique used in toxicology to establish proof of structure of unknown substances. With the extensive development of commercial MS technology at an affordable cost, GC/MS and HPLC-MS (commonly known as LC/MS) have become increasingly popular tools in the modern toxicology laboratory.

Systematic toxicological analysis

The usual practice in toxicological examination begins with the preliminary identification of alcohol and screening of a wide spectrum of acidic, neutral and basic organic drugs or poisons. If a toxin is detected, confirmatory and, if necessary, quantitative testing has to be performed. Quantitative testing determines how much of the substance is involved. In general, a positive identification is achieved using at least two independent analyses and preferably using different testing methods. For example, using an immunoassay for initial testing and then GC-MS or LC-MS to confirm results would suffice. A chromatographic confirmation test could also determine quantification, simplifying the testing process.

Frequently Asked Questions

What kind of results should I expect from forensic toxicology?

The interpretation of results can often be the most difficult job of the toxicologist. The analyst must understand the effects of a particular substance, what possible interactions it may have with other drugs or natural disease processes, and an understanding of what happens to toxins in the body over a period of time.

Coroners and medical examiners are responsible for determining the cause and manner of death, and they use all aspects of the case to do so, including circumstances, autopsy findings, crime scene details and any information from laboratory testing. With regard to toxicology, they need to be aware that unusual test distortions can occur that affect the interpretation of blood concentration. Biological samples can be unstable and can change or further degrade after they are collected for testing. Factors that can alter readings of drug concentration include quality of specimen due to decomposition, redistribution of drugs from other tissues, contamination or degradation of the drug after death. The effects of the concentration vary from person to person, and all factors must be considered when determining whether a substance found in the system can be identified as causing or contributing to behavioural changes or death.

What are some of the limitations of post-mortem toxicology?

Other limitations to toxicology for death investigations include the availability of specimens and the range of tests that can be conducted. If a death was not initially considered to be suspicious, an autopsy may not be performed. Even if the post-mortem examination occurs, appropriate samples are not always collected (and bodies may be quickly cremated or buried following this autopsy). As discussed above, there is almost an unlimited number of tests that can be conducted, but there may not be time, funds or the ability to perform these tests in many post-mortem labs. Also, many drugs or other toxins can move from one area of the body to other areas in a process known as post-mortem redistribution. Death trauma can change post-mortem levels so that test results are no longer clearly associated with levels before death. Even emergency / terminal life-saving procedures can add and change the ability to properly interpret results. These limitations can all be made more difficult if insufficient time is available for proper communications between the lab, pathologists and other investigators involved.

How is quality control and assurance performed?

To ensure the most accurate analysis of evidence, the management of forensic laboratories puts in place policies and procedures that govern facilities and equipment, methods and procedures, and analyst qualifications and training. Depending on the state in which it operates, a crime or toxicology laboratory may be required to achieve accreditation to verify that it meets quality standards. There are two internationally recognized accrediting programs focused on forensic laboratories: The American Society of Crime Laboratory Directors Laboratory Accreditation Board and ANSI-ASQ National Accreditation Board / FQS.

In disciplines such as toxicology, quality control is achieved through confirmation testing, technical review and verification of conclusions. As discussed above, the Scientific Working Group on Toxicology (SWGTOX) publishes methodology validation standards and guides for professional conduct. In addition, specific laboratory accreditation is offered by the American Board of Forensic Toxicology (ABFT), which uses peer-based consensus standards developed by the Society of Forensic Toxicologists (SOFT) and the Toxicology Section of the American Academy of Forensic Sciences (AAFS) to guide QA and QC in post-mortem examinations. ABFT (and SOFT-AAFS) standards are subject to international harmonization efforts with many other societies, and have long supported legal actions in death investigations.

What information does the analysis report contain?

The analysis report may contain a variety of information depending on the type of testing requested. For example, a report for a court file may need to be broader than for a negative drug test in drug abuse monitoring. The report should contain a list of the specimens analyzed and the tests performed on them. The methods used for the testing should be clearly stated and include information regarding the reliability of the test, for example, whether a confirmatory test could be done and if not, clarify the limitations of the information presented.

The final results must be clearly stated and characterized by the corresponding statistical degree of certainty. Medicolegal case investigations are confidential in nature and every precaution should be taken to ensure that information is released only to properly authorized personnel. Each laboratory must have its own policy for the retention and release of information.

Are breath alcohol tests a form of toxicology?

Obviously, post-mortem breath tests are not possible, but breath alcohol tests are a screening tool that allows police officers, corrections officials, civil accident investigators and others to determine a course of action with regard to a person who appears to be intoxicated. Breath analyzers do not directly measure blood alcohol content or concentration, which requires the analysis of a blood sample. However, the technologies involved and the consistent relationship between the alcohol in one’s breath and the blood level allow results from these breath alcohol tests to be used regularly in legal proceedings. These non-invasive breath tests are not able to identify other potential causes of observed behavior, as blood testing may be able to do.

Are there any misconceptions or anything else about this topic that would be important to the non-scientist?

Toxicology results by themselves are no more than numbers; the final interpretation of post-mortem test results should only be reached after all of the factors in a case have been drawn together. These factors can include (but are not limited to) the histological evidence, the autopsy findings, the contribution of natural disease, the known circumstances of the case and the medical history of the deceased. It is ultimately the pathologist who assigns and officially reports the investigative determination as to the cause and manner of death.

Common Terms

The following list of common terms is just the start of toxicology definitions. There are a number of online glossary resources, including toxicology.org - **http://www.toxicology.org/teachers/toxterms.asp** and Toxipedia - **http://toxipedia.org/display/toxipedia/Glossary**

Chain of custody - ensuring evidence is secure and traceable at all times.

Chromatographic techniques - analytical procedure used for separation of compounds/drugs

Derivitization - process of modifying original compound/drug for enhanced analytical detection

Drug or toxin concentration - the amount of drug, metabolite or other toxin in a given volume of plasma, urine, other fluid, tissue homogenate, etc. (e.g., number of micrograms, nanograms or picograms per millilitre).

Forensic practitioner - A person, usually police officer, scientist or physician who is engaged in forensic investigations.

Hazard - the biological effects produced by substances (i.e., toxicity). Hazards pose risks only if the exposure is sufficiently high.

Histalogical - pertaining to the minute structure of animal and plant tissues as discernible with the microscope.

Homogenization - process of preparing tissue for analysis by grinding a known amount of tissue in a known amount of water.

Immunoassays - a biochemical test that measures the presence or concentration of a substance in solutions that frequently contain a complex mixture of substances.

Medico-legal death investigation (MDLI) - A medical investigation performed by especially trained forensic medical practitioners, often in conjunction with forensic scientists, to determine the cause and manner of death.

Metabolism - the sum of the processes by which a particular substance is handled in the living body

Metabolite - a product of metabolism

Poison - a substance that through its chemical action usually kills, injures, or impairs an organism

Post-mortem redistribution - recognised toxicological phenomenon of an increase in drug concentration after death.

Specimens - Biological samples collected from a living or deceased person that can be analysed for one or more substances relevant to the matter.

Toxic - containing or being poisonous material especially when capable of causing death or serious debilitation

Toxicant - a toxic agent

Toxicity - the biological effect of a substance. In this context, toxicity and hazard are used interchangeably.

Toxicology - a science that deals with poisons and their effect and with the problems involved (as clinical, industrial, or legal)

Resources and References

You can learn more about this topic at the websites and publications listed below.

The International Association of Forensic Toxicologists (TIAFT) - **www.tiaft.org**

Scientific Working Group for Forensic Toxicology (SWGTOX) **www.swgtox.org**

Society of Forensic Toxicologists (SOFT) (USA) - **www.soft-tox.org**

Society of Toxicology (USA) – **www.toxicology.org**

American Board of Forensic Toxicology (ABFT) - **www.abft.org**

International Association of Therapeutic Drug Monitoring and Clinical Toxicology (IATDMCT) - **www.iatdmct.org**

Society of Hair Testing (SoHT) - **www.soht.org**

Society of Toxicological and Forensic Chemistry (GTFCh) - **www.gtfch.org**

References

Dept of Transportation (US), National Highway Traffic Safety Administration (NHTSA). Traffic Safety Facts 2010: Alcohol-Impaired Driving. Washington (DC): NHTSA; 2012 [cited 2013 May 24].

Dinis-Oliveira RJ, Carvalho F, Duarte JA, Remiao F, Marques A, Santos A, et al. Collection of biological samples in forensic toxicology. Toxicol Mech Methods. 2010 Jul 8.

Baselt RC. Disposition of toxic drugs and chemicals in man. 7th ed. Foster City, Calif.: Biomedical Publications, 2004.

Dinis-Oliveira RJ, Carvalho F, Duarte JA, Remiao F, Marques A, Santos A, et al. Collection of biological samples in forensic toxicology. Toxicol Mech Methods. 2010 Jul 8.

Dolan K, Rouen D, Kimber JO. An overview of the use of urine, hair, sweat and saliva to detect drug use. Drug and Alcohol Review. 2004;23(2):213-7.

Drummer OH, Gerostamoulos J, Batziris H, Chu M, Caplehorn JR, Robertson MD, et al. The incidence of drugs in drivers killed in Australian road traffic crashes. Forensic Sci Int. 2003 Jul 8;134(2-3):154-62.

Drummer OH, Gerostamoulos J. Postmortem drug analysis: Analytical and toxicological aspects. Therapeutic Drug Monitoring. 2002;24(2):199-209.

Flanagan RJ, Connally G, Evans JM. Analytical toxicology: guidelines for sample collection postmortem. Toxicol Rev. 2005;24(1):63-71.

Forrest AR. ACP Broadsheet no 137: April 1993. Obtaining samples at post mortem examination for toxicological and biochemical analyses. J Clin Pathol. 1993 Apr;46(4):292-6.

Moffat, A.C., Clarke's analysis of drugs and poisons : in pharmaceuticals, body fluids and postmortem material. 4th ed. 2011, London ; Chicago: Pharmaceutical Press.

Rutty GN. Essentials of autopsy practice. London ; New York: Springer, 2001.Skopp G, Potsch L. A case report on drug screening of nail clippings to detect prenatal drug exposure. Ther Drug Monit. 1997 Aug;19(4):386-9.

Suesse S, Pragst F, Mieczkowski T, Selavka C, Elian A, Sachs H, Hastedt M, Rothe M, Campbell J. Practical experience in application of hair fatty acid ethyl esters and ethylglucuronide for detection of chronic alcohol abuse in forensic cases. Forensic Sci Int. 2012; 218: 82-91.

Wennig R. Potential problems with the interpretation of hair analysis results. Forensic Sci Int. 2000 Jan 10;107(1-3):5-12.

Williams KR, Pounder DJ. Site-to-site variability of drug concentrations in skeletal muscle. Am J Forensic Med Pathol. 1997 Sep;18(3):246-50.

Acknowledgments

The authors wish to thank the following for their invaluable contributions to this forensic guide:

Dimitri Gerostamoulos, Ph.D.
Chief Toxicologist and Manager, Toxicology Section, Forensic & Scientific Services
Victorian Institute of Forensic Medicine, Victoria Australia

Robert A. Middleberg, Ph.D., DABFT, DABCC-TC
Vice President, Quality Assurance, Laboratory Director & Forensic Toxicologist
NMS Labs

Carl M. Selavka, PhD., D-ABC
Forensic Scientist and Director
Northeastern Bioscience Associates, Charlton MA USA

Forensic Evidence Admissibility and Expert Witnesses

How or why some scientific evidence or expert witnesses are allowed to be presented in court and some are not can be confusing to the casual observer or a layperson reading about a case in the media. However, there is significant precedent that guides the way these decisions are made. Our discussion here will briefly outline the three major sources that currently guide evidence and testimony admissibility.

The *Frye* Standard – Scientific Evidence and the Principle of General Acceptance

In 1923, in *Frye v. United States*[1], the District of Columbia Court rejected the scientific validity of the lie detector (polygraph) because the technology did not have significant general acceptance at that time. The court gave a guideline for determining the admissibility of scientific examinations:

Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while the courts will go a long way in admitting experimental testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be **sufficiently established to have gained general acceptance** *in the particular field in which it belongs.*

Essentially, to apply the "*Frye* Standard" a court had to decide if the procedure, technique or principles in question were generally accepted by a meaningful proportion of the relevant scientific community. This standard prevailed in the federal courts and some states for many years.

Federal Rules of Evidence, Rule 702

In 1975, more than a half-century after *Frye* was decided, the Federal Rules of Evidence were adopted for litigation in federal courts. They included rules on expert testimony. Their alternative to the *Frye* Standard came to be used more broadly because it did not strictly require general acceptance and was seen to be more flexible.

The first version of Federal Rule of Evidence 702 provided that a witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:

[1] 293 Fed. 1013 (1923)

a. the expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
b. the testimony is based on sufficient facts or data;
c. the testimony is the product of reliable principles and methods; and
d. the expert has reliably applied the principles and methods to the facts of the case.

While the states are allowed to adopt their own rules, most have adopted or modified the Federal rules, including those covering expert testimony.

In a 1993 case, *Daubert v. Merrell Dow Pharmaceuticals, Inc.,* the United States Supreme Court held that the Federal Rules of Evidence, and in particular Fed. R. Evid. 702, superseded *Frye's* "general acceptance" test.

The *Daubert* Standard – Court Acceptance of Expert Testimony

In *Daubert* and later cases[2], the Court explained that the federal standard includes general acceptance, but also looks at the science and its application. Trial judges are the final arbiter or "gatekeeper" on admissibility of evidence and acceptance of a witness as an expert within their own courtrooms.

In deciding if the science and the expert in question should be permitted, the judge should consider:

- What is the basic theory and has it been tested?
- Are there standards controlling the technique?
- Has the theory or technique been subjected to peer review and publication?
- What is the known or potential error rate?
- Is there general acceptance of the theory?
- Has the expert adequately accounted for alternative explanations?
- Has the expert unjustifiably extrapolated from an accepted premise to an unfounded conclusion?

The *Daubert* Court also observed that concerns over shaky evidence could be handled through vigorous cross-examination, presentation of contrary evidence and careful instruction on the burden of proof.

In many states, scientific expert testimony is now subject to this *Daubert* standard. But some states still use a modification of the *Frye* standard.

[2] The "Daubert Trilogy" of cases is: **DAUBERT V. MERRELL DOW PHARMACEUTICALS**, **GENERAL ELECTRIC CO. V. JOINER** and **KUMHO TIRE CO. V. CARMICHAEL**.

Who can serve as an expert forensic science witness at court?

Over the years, evidence presented at trial has grown increasingly difficult for the average juror to understand. By calling on an expert witness who can discuss complex evidence or testing in an easy-to-understand manner, trial lawyers can better present their cases and jurors can be better equipped to weigh the evidence. But this brings up additional difficult questions. How does the court define whether a person is an expert? What qualifications must they meet to provide their opinion in a court of law?

These questions, too, are addressed in **Fed. R. Evid. 702**. It only allows experts "qualified … by knowledge, skill, experience, training, or education." To be considered a true expert in any field generally requires a significant level of training and experience. The various forensic disciplines follow different training plans, but most include in-house training, assessments and practical exams, and continuing education. Oral presentation practice, including moot court experience (simulated courtroom proceeding), is very helpful in preparing examiners for questioning in a trial.

Normally, the individual that issued the laboratory report would serve as the expert at court. By issuing a report, that individual takes responsibility for the analysis. This person could be a supervisor or technical leader, but doesn't necessarily need to be the one who did the analysis. The opposition may also call in experts to refute this testimony, and both witnesses are subject to the standard in use by that court (*Frye, Daubert*, Fed. R. Evid 702) regarding their expertise.

Each court can accept any person as an expert, and there have been instances where individuals who lack proper training and background have been declared experts. When necessary, the opponent can question potential witnesses in an attempt to show that they do not have applicable expertise and are not qualified to testify on the topic. The admissibility decision is left to the judge.

Additional Resources

Publications:

Saferstein, Richard. **CRIMINALISTICS: AN INTRODUCTION TO FORENSIC SCIENCE**, Pearson Education, Inc., Upper Saddle River, NJ (2007).

McClure, David. Report: Focus Group on Scientific and Forensic Evidence in the Courtroom (online), 2007, https://www.ncjrs.gov/pdffiles1/nij/grants/220692.pdf (accessed July 19, 2012)

Acknowledgements
The authors wish to thank the following for their invaluable contributions to this guide:

Robin Whitley, *Chief Deputy*, Appellate Division, Denver District Attorney's Office, Second Judicial District

Debra Figarelli, *DNA Technical Manager*, National Forensic Science Technology Center, Inc.

About This Project

This project was developed and designed by the National Forensic Science Technology Center (NFSTC) under a cooperative agreement from the Bureau of Justice Assistance (BJA), award #2009-D1-BX-K028. Neither the U.S. Department of Justice nor any of its components operate, control, are responsible for, or necessarily endorse, the contents herein.

National Forensic Science Technology Center®
NFSTC *Science Serving Justice*®
8285 Bryan Dairy Road, Suite 125
Largo, Florida 33777
(727) 395-2511
info@nfstc.org