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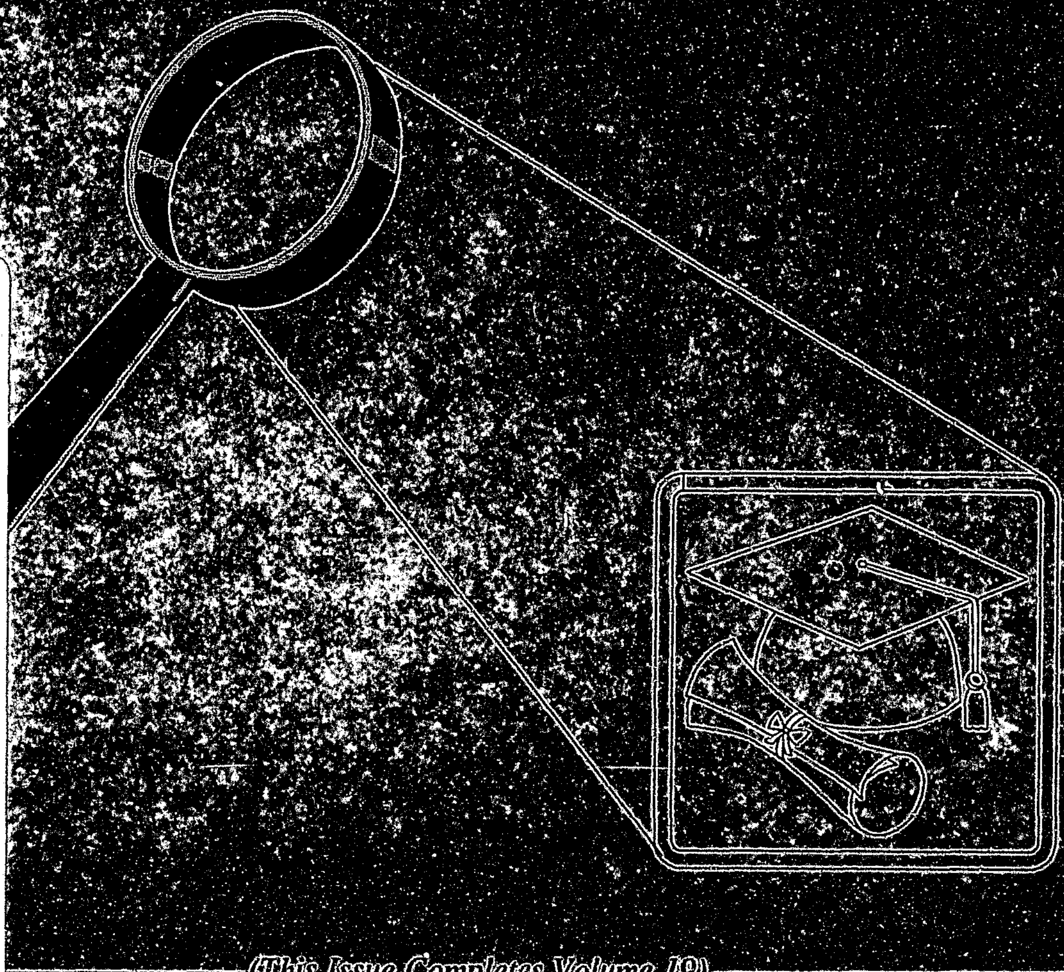

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Feature Article

Chemistry and Crime: From Sherlock Holmes to Modern Forensic Science – A Science Course for Non-Science Majors

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The forensic science course entitled "Chemistry and Crime: From Sherlock Holmes to Modern Forensic Science" was an outgrowth of my long standing interest in the scientific, technological and legal aspects of criminal investigations. While formally trained as a biochemist, a number of years ago I sensed that a course in forensic science would be an ideal vehicle to introduce students who were not science majors to the way in which scientists actually work, define a problem, collect data, analyze the results and present those results in meaningful ways. The course has been successful for several reasons. First, the many topics discussed with the class are very timely, as well as fun to teach. Second, the course is structured to stimulate student interest before presenting the "science" so many of them dread. Third, the laboratory component gives the students an opportunity for hands-on exposure to the material covered in class.

Throughout the course, "case studies" are highlighted to provide the students with an immediate application of the scientific and technological principles being discussed. Usually, a case is presented, and then the possible methods of resolution are discussed so that the students' interest is piqued before the fact. This is what my colleagues refer to as "science taught backwards." In this course, the students are not presented with 6 to 8 weeks of basic chemistry, organic chemistry and biochemistry and then asked to deal with a few applications during the final weeks of the course. Instead, crime situations are posed, and the class is challenged to suggest how it might go about solving them. For example, after discussing the questions surrounding the authenticity of the Shroud of Turin, the class is quite willing to learn the basic science needed to analyze the soil, pollen or fiber samples obtained from the Shroud, and even the details of radiocarbon dating, which was employed to date the Shroud.

While the case studies provide a focus and motivation for the study of forensic science, an additional dimension to the course is provided through discussions of the legal context in which the analyses are performed and their presentation in court.

Course Overview

The name of this course is a play on the name of the book edited by Samuel Gerber (1983), Chemistry and Crime: From Sherlock Holmes to Today's Courtroom. This book presents some interesting aspects of forensic science, but the most interesting chapters in the book deal with forensic science as a tool in literature, such as an analysis of the Dorothy Sayers novels. The course syllabus (Appendix A) is based upon the forensic science text by Saferstein (1990) and the basic chemistry text by Hill (1992). In addition, the course draws heavily from the book by Moenssens *et al.* (1986) which presents the scientific basis of evidence submitted in criminal cases and discusses the legal context in which that evidence can be obtained and presented in court. Another text which covers the same material as Saferstein is the basic forensic science book by DeForest *et al.* (1983). Other books have been especially useful in providing a general background in forensic science (Williams 1991; Zonderman 1990; Eckert 1980; Kirk 1974), processing a crime scene (Fisher 1992), analyzing the physical evidence (Ho 1990; Saferstein 1988; 1982) and presenting the results of those analyses in court (Imwinkelried 1981; Markle 1976). As mentioned previously, numerous special readings and books dealing with specific nationally and regionally famous cases are used. These case studies are highlighted to provide the students with an immediate application of the scientific and technological principles discussed in class.

The course includes a full scale laboratory program (see the table of contents for the laboratory manual in Appendix B) which helps the students acquire a practical "hands-on" understanding of many of the procedures discussed in class, as well as the operation of an actual crime laboratory. By performing the experiments themselves, they learn to determine the relative significance of the results obtained. This ultimately helps them to appreciate the reliability as well as the uncertainty of scientific data. Some of these experiments have been developed in the author's laboratory; others have been adapted from published manuals (Meloan *et al.* 1990), papers (Timmer 1986; Bonicamp 1985; Olesen and Hopson 1983) and company literature (Toxi-Lab® 1989; NIK 1987).

A unique feature of the laboratory experience is the assignment of students to an investigative unit. The students in a particular investigative unit are called to the scene of a simulated crime. They process the crime scene: securing the area, photographing and making a sketch of the scene, collecting physical evidence, and packaging and labeling the evidence to ensure the chain of custody. The experiments on the physical evidence collected at the scene and submitted by the police are performed during five weekly laboratory sessions, each lasting 4 hours. Crime scenarios such as a hit-and-run accident, a drug bust, or a burglary provide ideal situations for the students to discover the exciting aspects of forensic science.

In an earlier course format, the entire class was expected to attend all of the crime scenarios and to perform all of the experiments. Since this required the students to move quickly from one experiment to another with little time to become familiar with the equipment, the format mentioned in the previous paragraph was instituted. In this format, the students in each investigative unit are expected to analyze the physical evidence obtained from one crime scenario. While this limits the number of different experiments that individual students perform, it gives them an opportunity to repeat experiments, analyze controls and standards, and generally become proficient with a few pieces of equipment. Hence, what is lost in diversity of equipment and techniques is offset by a more thorough knowledge and understanding of a select number of procedures. The analysis of the physical evidence from the crime scene provides a focus and unifying theme for the experiments, as compared with the unrelated experiments usually performed in elementary science courses. The decision to use this pedagogical strategy was made after talking with senior chemistry majors about their laboratory experience as freshmen. Most of the students did not remember very much about the experiments they had performed 3 years earlier. This new course format is intended to provide an experience that will have a more lasting effect on the students.

Course Content

In the following discussion of the course, references are made to the syllabus (see Appendix A for the detailed syllabus) and to each of the numbered sections in it as units.

Rather than begin the course with a heavy dose of chemistry, we begin with an introduction to criminalistics: discussing the scope, history and development of the interdisciplinary field called forensic science. The students are particularly interested in learning that various areas of forensic science were developed in response to actual crimes (DeForest *et al.* 1983). For example, the students are intrigued by the alleged case of arsenic poisoning which led to the first attempt by a defense attorney to rebut the state's scientific evidence in 1840. One of the first systems of personal identification was based on a series of body measurements by Bertillon in the late 1800's. In the early 1900's, Vollmer developed the first forensic science laboratory in the United States to overcome problems associated with improper handling of evidence before laboratory examination. Kirk is usually cited as one of the pioneers in forensic science. As the result of public outcry following the well-known St. Valentine's Day massacre in 1929, Goddard was selected to direct a new forensic science laboratory. While he had extensive knowledge of firearm identification and examination, he had to develop the expertise to integrate law enforcement investigations with laboratory services. During the class discussion of the dimensions of forensic science which includes identification, individualization and reconstruction, it is important to point out that few other scientific disciplines require all of these stages of analysis.

By this time, the class is ready to begin its investigation of the crime scenarios, and the syllabus units discussing the processing of a crime scene and various types of physical evidence (Units 2 and 3) are introduced. As indicated in the syllabus, a number of case readings from Saferstein's text (1990), from the original literature and, of course, from Sherlock Holmes are discussed. In explaining the importance of securing and isolating the crime scene, it is important to emphasize that no matter how sophisticated and careful the crime laboratory may be, if the evidence is collected carelessly and/or the chain of custody is not maintained, the results are worthless from a legal perspective.

This point is later emphasized when a videotape dealing with the John F. Kennedy assassination is shown. In the program entitled, "On Trial: Lee Harvey Oswald," the defense attorney, Gerry Spence, questioned the expert witness, Dr. Vincent Guinn, about his atomic absorption spectroscopic analysis of the bullet fragments. The following is an excerpt:

Spence: "Are you aware of the fact, Doctor, that dishonest evidence can be honestly analyzed?"
Guinn: "Of course."
Spence: "But you're not testifying to this jury that you can vouch for their (the bullet fragments') authenticity, are you?"
Guinn: "No. You never can do that in any criminal case."
Spence: "Your testimony isn't to be interpreted to mean that you know that the bullets you examined actually came from the body of the President?"
Guinn: "No way. Unless I was the surgeon."

At this point in the course, the class also reads excerpts from some popular books detailing actual crimes and examines how the processing of crime scenes has changed over the past 100 years. One recent example is the Jeffrey MacDonald story as recounted in the book, Fatal Vision (McGinniss 1983). The section in the book which describes the discovery of the crime and the failure of the military officers to carefully secure the scene is particularly striking. For comparison with the manner in which a crime scene was handled 40 years ago, the Sam Sheppard case (Sheppard 1966) is introduced. Although the Lindberg baby kidnapping is covered extensively later in the course, the processing of that crime scene, in the 1920's, is a classic (Waller 1961). Discussion of the Lizzie Borden axe murders (Spiering 1984) provides an additional comparison to the other cases and portrays how the crime scene was handled 100 years ago. Most of the students are not familiar with the details of these cases, and their interest is aroused immediately. It is particularly convenient that dramatizations of these four cases are available on videotapes, thus allowing the students to observe dramatic portrayals of the cases. For an example of a meticulously handled crime scene, we discuss the bombing incident in Salt Lake City, as described in The Mormon Murders (Naifeh and Smith 1988).

As part of this study of the processing of a crime scene, I introduce the important forensic statement, the Locard Exchange Principle, "Every contact results in an exchange," and the quote from Ralph Waldo Emerson, "Wherever a man commits a crime, God finds a witness.....Every secret crime has its reporter," to lay the groundwork for future discussions.

During the unit on evidence and testimony (Unit 4), the legal aspects of forensic science are introduced, which captures the interest of many students. This section is used to introduce the concepts of general acceptance of scientific methods and the expert witness. These discussions provide an opportunity to use material from the television program, "Quincy" and compare Dr. Quincy with Sam. (You remember Sam — he's the guy back in the laboratory, doing the work while Quincy is out grandstanding and capturing the glory. Just like the real world, isn't it?) While we are discussing the qualifications of an expert witness, an amusing definition of an expert (Moenssens *et al.* 1986) is offered:

> An expert is a person who passes as an exacting authority on the basis of being able to turn out with prolific fortitude, infinite strings of incomprehensible formulae calculated with micromatic precision which are based on debatable figures taken from inconclusive experiments carried out with instruments of problematic accuracy by persons of doubtful reliability and questionable mentality.

A discussion of the principle of general acceptance of the admissibility of scientific evidence based on the *Frye* v. *United States* case and the newer Federal Rules of Evidence plays a very important part in this unit. The recent cases involving the new procedures for "DNA Fingerprinting" provide excellent examples of the problems that are likely to be encountered. Since the students generally assume that an expert witness would be treated with respect by the courts, they find the recent articles on the relationship between the scientific and legal communities to be interesting (Roberts 1992).

For some students, it seems that until this point in the course, we have not actually begun to discuss the science and technology. Actually, I have been introducing concepts such as the use of the scientific method, the importance of clearly identified samples, the use of controls and standards, and other aspects of "practicing good science."

The next two units (Units 5 and 6) address some basic concepts of chemistry, including atomic structure, which provide the background for the spectroscopic (and other) tools needed to resolve the cases reviewed in the unit on inorganic analysis (Unit 7): specifically, the atomic emission spectral analysis of samples from the Tylenol® scare in the early 1980's and the analysis of the Shroud of Turin, which includes the recent radiocarbon dating results. Remember the "science taught backwards" approach in which we discuss the cases first and then study the procedures used to resolve them. These cases require an understanding of emission and atomic absorption spectroscopy, neutron activation analysis and radiocarbon dating which, in turn, require an understanding of atomic structure.

During this time, the students are working in the laboratory on a series of experiments. Depending upon their assigned investigative unit, their studies may involve: 1) the analysis of soil, glass and fibers collected at the scene of a hit-and-run accident, as well as the analysis for alcohol in the blood or drugs in the urine of the suspect; 2) the analysis of drugs confiscated in a drug bust and the analysis of urine specimens collected from the suspects; or 3) the analysis of samples obtained during another drug bust for anabolic steroids and the analysis of the ink on notes also recovered in the drug busts. As stated previously, while working within the investigative units, the students process one crime scene and then analyze the physical evidence collected. The repeated use of a few pieces of equipment and the repeated analyses necessary to ensure the validity of the results create a relaxed atmosphere in which the students can work and feel comfortable with the equipment and procedures. The advantage is that they truly learn something about the methodology, including variations, strengths and limitations. As long as each student works with a few general analytical procedures, a chromatographic and a spectroscopic technique, they receive a good introduction to the crime laboratory and scientific analysis of evidence.

The experiments for the characterization of the glass, soil and fibers collected at the hit-and-run accident are the standard forensic procedures, including microscopic examination, determination of the density of the glass and soil, and determination of the refractive index of the glass samples. However, the students' involvement in the analysis of the crime scene adds excitement for them. To begin this crime scenario, a Williams College security officer informs me that a hit-and-run accident has just occurred, and I summon the students in the appropriate investigative unit to report to the crime scene.

At the scene of the crime, we rope off the area, confirm that someone has called for an ambulance, photograph the scene and begin to collect samples for analysis. These samples are placed in evidence envelopes and numbered to correspond to sketches the students have made in their notebooks. In the laboratory, we review the situation: a hit-and-run accident occurred, and in addition to the various pieces of evidence we collected at the scene, we now also have the sweater the victim had been wearing. It was removed at the hospital and transferred to us through a carefully controlled chain of custody.

So far, the police have taken two suspects into custody and have submitted the broken headlights removed from their cars to us in the crime laboratory. Since both suspects were behaving erratically when apprehended, we also have urine samples to analyze for the presence of alcohol and/or other drugs. With regard to the glass, our job is to try to establish the basic dimensions of forensic science: identification, individualization and reconstruction, which includes determining any points of similarity between the fragments found at the scene and the two suspect headlights.

At this point, most of the students think this is a game; they presume they have to determine whether headlight A or headlight B is from the car involved in the accident. They are reminded that at the scene of the crime, somewhere on campus, it would be reasonable to find all sorts of glass, such as from eyeglasses worn by the victim, broken beer bottles, and even headlight glass from previous accidents. However, as they set to work with the microscope, the refractometer, the density gradients and the flotation vials, the students still think in terms of headlight A or B. After about 3 hours, they are beginning to sort out some confusing data but have been unable to reach any conclusions. Since they know they have 5 weeks to continue the analysis, they leave the laboratory, while planning the experiments for the following weeks.

At the end of the week, another college security officer comes into the laboratory with an evidence bag containing another headlight, removed from the car of a newly identified suspect. Over the groans of the class, it is necessary to point out that the investigation is continuing, and our task is still the same: to try to determine if there is a common origin of the glass fragments collected at the crime scene and the suspect headlights. By the end of the second laboratory period, the students are discussing and, in fact, arguing over the data and trying to make sense of the results they have obtained. Frequently, they go back and repeat some experiments or test samples analyzed by others in the investigative unit to ensure the validity of the data.

At the end of this series of experiments, a period is set for the investigative units to present their findings and compare their results with the rest of the class (students in other laboratory sections). By this time, they realize that they are not going to be told "the correct answer." They simply have to be confident of the results of their investigative unit — confident enough to present their findings in court!

The next unit (Unit 8) usually generates a great deal of student interest. During a discussion of firearms, we not only examine how one can identify a bullet through the use of a comparison microscope; we also address the neutron activation analysis of trace elements present in the lead bullet. Applying these methods to a study of the assassinations of both John F. Kennedy and Robert F. Kennedy usually stimulates interesting debates in class. Since the release of the movie, "JFK," directed by Oliver Stone, many students who previously knew little about the John F. Kennedy assassination are now familiar with the case. Since 1993 is the 30th anniversary of the assassination, several new programs have been produced which review the circumstances of the case and analyze the evidence. Some of the theories presented are based on those set forth in the constant flow of books about the case. An excellent presentation entitled "On Trial: Lee Harvey Oswald" was aired on the Showtime Cable Network in 1986. It portrays the trial that may have been conducted if Oswald had lived to stand trial. A number of interesting segments in this program deal with expert testimony regarding the bullet analysis and the details of the autopsy. This presentation also provides an extensive analysis of the Zapruder film, which recorded the assassination.

Two units address the fairly traditional aspects of chemistry, including chemical bonding, thus laying the groundwork for future discussions of organic chemistry. At this time, we also review the Lindberg baby kidnapping and the Wayne Williams case (Unit 11), which involve microscopy and microanalysis and the identification and comparison of small objects. It is pertinent to discuss the statistics and probability associated with identifying evidence, as with the green carpet fibers in the Williams case.

As we begin coverage of the issues related to the consumption of alcohol (Unit 14), we discuss organic chemistry (Unit 12) and organic analytical procedures, including chromatography, ultraviolet, visible and infrared spectrophotometry, and mass spectrometry (Unit 13). With this material, we also provide the background for later discussions on the analysis of drugs and poisons. The unit on alcohol intoxication (determining the blood and breath levels of alcohol) offers the students a chance to demonstrate the level of sophistication achieved in the course. We examine many of the commonly used methods for the detection and determination of blood alcohol levels by sampling blood, breath and saliva. Some of the equipment and the principles on which they operate are listed in Table 1.

While this material is being presented in class, in the laboratory, the students in some of the investigative units turn their attention to the detection and quantitation of alcohol. For these experiments, a number of breath alcohol detectors, two saliva alcohol devices and a spectrophotometer for blood analysis are available. Many of the students who are not assigned to those specific investigative units also want to work with the alcohol detecting equipment.

In the laboratory, we begin with a Passive Alcohol Sensor™ (PAS™) and a simple, at-the-scene pre-arrest breath test kit called Alcotest®. These are convenient devices for determining the approximate level of alcohol in the breath. The PAS™ is a fuel cell built into a flashlight which samples a portion of the suspect's breath and indicates the presence of alcohol. The Alcotest® is a glass tube containing potassium dichromate mixed with a small amount of sulfuric acid (and silver nitrate as a catalyst). With this device, the suspect (or someone wanting to determine his/her own alcohol level) blows into the tube for a fixed period of time and looks to see how much of the yellow material in the tube turns green: a more intense green indicates a higher alcohol level.

The same chemistry used in the Alcotest® is used in the well-known Breathalyzer®. Basically, the alcohol reacts with the yellow dichromate and

Table 1. Detection and Determination of Alcohol in the Body

Device	Procedure
Breath Analysis	
Alcotest Tube	oxidation with dichromate/sulfuric acid
Breathalyzer®	oxidation with dichromate/sulfuric acid-photometry
Alco-Analyzer®	gas chromatography
GC Intoximeter®	gas chromatography
Intoximeter®	infrared spectrometry
Alco-Sensor®	roadside breath tester; fuel cell sensing
Passive Alcohol Sensor™	fuel cell sensing
Blood Analysis	
Gas chromatography	analysis following extraction of alcohol
Spectrophotometer	wet oxidation with dichromate/sulfuric acid
Abbott TD_x®	radiative energy attenuation
Abbott Bichromatic Analyzer-100®	enzymatic reaction on mL of plasma
DuPont ACA III Discrete Clinical Analyzer®	alcohol dehydrogenase/NAD
Analysis of Other Body Fluids	
Q.E.D.® A150 Saliva Alcohol Test™	enzymatic reaction on saliva to produce color change
Toxi-Lab® On-Site™ Alcohol Device	reaction with CrO_3 following controlled diffusion
Eyealyzer	determination of alcohol content of eye vapor

Alcotest Tube and Breathalyzer®, National Draeger, Inc., 101 Technology Drive, Pittsburgh, PA, phone: 412-787-8383.

Alco-Analyzer®, Luckey Laboratories, Inc. 7252 Osbun Road, Bernardino, CA 92404, phone: 714-884-6235.

Intoximeter®, GC Intoximeter®, and Alco-Sensor®, Intoximeter, Inc., 1901 Locust Street, St. Louis, MO 63103, phone: 314-241-1158.

PAS™ Passive Alcohol Sensor, Sniffer Technologies Corp., 389 Johnnie Dodds Blvd., Suite 200, Mount Pleasant, SC 29464, phone: 803-849-1677.

Abbott TD_x® and Abbott Bichromatic Analyzer-100®, Abbott Laboratories, Chicago, IL.

ACA, DuPont Company, Inc. Diagnostic System Division, Wilmington, DE.

Q.E.D.® Saliva Alcohol Test™, Enzymatics, Inc. 500 Enterprise Road, Horsham, PA 19044, phone: 800-245-6845.

Toxi-Lab®, Toxi-Lab, Inc., 2 Goodyear, Irvine, CA 92718-2002, phone: 800-854-0277.

converts it to green chromium sulfate. So, the Breathalyzer® is nothing more than a photometer for detecting the yellow color: the less yellow, the more alcohol is in the breath.

We discuss the essential chemistry, the spectroscopic principle of the method and the mechanics of a spectrometer. Since this determination is based upon the following chemical equation:

$$2\ K_2Cr_2O_7 + 3\ C_2H_5OH + 8\ H_2SO_4 \longrightarrow 2\ Cr_2(SO_4)_3 + 2\ K_2SO_4 + 3\ CH_3COOH + 11\ H_2O,$$

for a thorough appreciation of how the instrument works, the students must understand stoichiometry as well as the Beer-Lambert Law:

Absorbance = extinction coefficient × path length × concentration.

The PAS™ and a Breathalyzer® certainly increase the students' interest in the determination of breath alcohol. In earlier years, before the change in the legal drinking age in Massachusetts, this laboratory provided the class with a unique opportunity. The students in each laboratory section were divided into groups. For example, one group was designated by body weight, with students ranging in weight from 120 to 240 pounds. A few groups of similar weight were defined by what they had eaten during the day. One group had nothing to eat all day; the students in other groups had eaten foods rich in carbohydrates or lipids or proteins. The laboratory would begin with the students in each group drinking a bottle of beer. After 15 to 20 minutes, their breath was analyzed with the Breathalyzer® or the PAS™. They would then drink another bottle of beer, followed by another breath analysis. This process continued until a pattern emerged — usually after three or four beers. Our data indicated that breath alcohol level rises much more rapidly in a 120-pound individual than in a 240-pound individual. In fact, we obtained a linear relationship between the individual's weight and the alcohol level, beginning after the second beer. We also found that the breath alcohol concentration increased much more rapidly in individuals who had not eaten, compared to those with full stomachs, although our study of the type of food eaten was inconclusive.

While demonstrating with the Breathalyzer® and the PAS™, the effect of recently consumed alcohol can be shown if one student swishes some beer in his/her mouth and then spits it out. Breath tests over a period of time indicated that almost 20 minutes are needed for the Breathalyzer® to indicate a return to background in the breath alcohol level. A simulation of this type of experiment can be performed using the breath fresheners available at drug stores. Since these sprays contain a considerable concentration of alcohol, even students under the legal age for alcohol consumption have an opportunity to experiment with the Breathalyzer® and the PAS™.

The students learn some more traditional chemistry by performing a wet chemical analysis using dichromate/sulfuric acid and a spectrophotometer on a simulated blood sample and relating the amount of alcohol in the blood to the amount in the breath. The relationship of 2100 (the alcohol content of 2100 mL of breath is equivalent to alcohol content in 1 mL of blood) is used to compare the value obtained by the wet chemical method with that from the Breathalyzer® using a breath alcohol simulator. Once again, the students must understand the Beer-Lambert Law and the stoichiometry to calculate the results from their data.

Two devices which employ saliva provide a rapid preliminary screening for alcohol in the body. The Toxi-Lab® On-Site™ Alcohol Device is about the size of a credit card containing two circular wells. The wells are connected with an absorbent material so the alcohol can diffuse from the specimen well to the detection reagent well. This unique delivery system allows the ethanol in the sample to be drawn into the detection reagent well by capillary action. The detection reagent well contains the yellow potassium dichromate reagent, as used in the Breathalyzer®. It is added to the well from an ampule which is broken in a plastic protective housing. The saliva sample is introduced by saturating a swab and placing it in the specimen well. After about 30 seconds, the development of a blue color (from the chromium sulfate formed) on the yellow background indicates a 0.02% or greater alcohol level. If the reagent well remains entirely yellow, the result is negative.

The newly marketed Q.E.D.® (Quantitative Enzyme Diagnostic) A150 Saliva Alcohol Test™ (Enzymatics, Inc., Horsham, PA) is designed for the rapid and quantitative determination of ethanol in saliva. The test utilizes a coupled enzyme reaction to produce a purple color on a thermometer-like device. In the first reaction, alcohol dehydrogenase, immobilized on a solid matrix, catalyzes the oxidation of ethanol to acetaldehyde with the simultaneous reduction of nicotinamide adenine dinucleotide (NAD) to NADH. An alkaline pH and an acetaldehyde trapping reagent force the reaction to generate 1 mole of NADH for each mole of alcohol present. The enzyme diaphorase then catalyzes the reaction between the NADH and a tetrazolium salt chromogen to produce a colored formazan dye. The length of the resulting color bar is proportional to the concentration of ethanol in the specimen and can be read from the scale on the "thermometer." The device indicates a quantitative blood alcohol level over the range of 0 to 0.150%.

Although the laboratory exercise does not include a gas chromatographic or infrared spectroscopic determination of alcohol, the students are taught the fundamental concepts of these methods and their application to the determination of breath alcohol levels. We also discuss the differences between instruments which might be used in a stable environment, such as a forensic laboratory, and those which are used in more variable settings, such as a police car. A considerable level of technology is necessary to produce an instrument which is dedicated to one purpose and can tolerate variations in conditions, be operated by police officers with only fundamental training, and still produce reliable, accurate results.

With the diversity of methods available, a major segment of a course in analytical chemistry could be based upon the identification and quantitation of alcohol.

In addition to the scientific methodology of the various procedures, we also address the implications of the laws governing driving while intoxicated. Specifically, we discuss the laws regarding the 4th and 5th Amendment rights — freedom from unlawful search and seizure and freedom from self-incrimination — as well as due process and the implied consent laws. This leads us into a discussion of the Miranda rights and how they apply to actual cases, not how they are portrayed on television.

Since the class discussions shift from scientific methods to case studies to the legal aspects of forensic science, the students are motivated to learn the science because they are consciously applying the concepts learned in class to the resolution of interesting cases.

The study of the pharmacological effects of alcohol and the metabolism of the drug is relevant to the material covered in the biochemistry unit (Unit 15), which lays the groundwork for later material on neurochemistry and drugs, as well as for the units on toxicology and serology. Therefore, we discuss the basics of protein and nucleic acid structure in some detail, so the class will understand the functions of an enzyme and the action of endonucleases on DNA.

The detection of drugs is always an interesting topic, especially for college students, but it becomes more exciting when they realize that they will perform drug detection experiments in the laboratory. There are actually a number of experiments available for the detection, identification and quantitation of drugs (both pharmaceutical and controlled substances). The laboratory is equipped with the NIK™ Narcotics Identification System (produced by Bectin-Dickinson Public Safety, Ivers-Lee Division, 147 Clinton Road, West Caldwell, NJ 07006 telephone: 800-631-1122), for the presumptive identification of drugs — that is, to identify the actual powdered substances.

The Narcotics Identification System introduces a series of wet chemical reactions packaged in a neat, portable, safe system. Each packet contains all of the reagents, in glass ampules, which are needed to perform the test. After the suspect drug is introduced into the packet, the ampules are crushed, one at a time, in order. Depending upon the colors which develop, the presence of specific drugs is indicated.

We confirm the identity of powdered drugs with infrared spectroscopy (IR). With this procedure, it is important to separate the drug from other agents present, such as those used to "cut" the drug, or excipients such as binders and stabilizers in pills and capsules. With the Fourier transform infrared (FTIR) spectrometer, the students must prepare KBr pellets after a simple chloroform extraction of the drug from contaminating material. For identification of the drug, they compare the IR spectrum obtained to literature spectra (Mills and Roberson 1987). To understand the reason for the location of the peaks, we discuss the dependence of the IR spectrum on the mass of the atoms and the strength of the bond(s) connecting them. With this background, and the location of the peaks associated with some of the functional groups, such as the hydroxyl, amino and carbonyl, the class can predict general structural features of the drug whose IR spectrum they have obtained.

The laboratory also is equipped with two urine drug screening devices. The Toxi-Lab® Drug Detection System, produced by Toxi-Lab®, Inc. (Irvine, CA), is based upon thin layer chromatography (TLC). With two systems, Toxi-Lab® can be used to detect analgesics, stimulants and tranquilizers (using Toxi-Lab® A for basic and neutral drugs), and barbiturates and other hypnotics (using

Toxi-Lab® B for acidic and neutral drugs). The system consists of a thin layer plate with small holes, where toxi disks can be "inoculated." These disks either are standards already impregnated with various drugs or blanks which can be used for unknown samples. After extracting the drugs from the urine in a toxi tube, the solvent containing the drugs is evaporated in a spot plate onto a toxi disk. This disk is inoculated into one of the holes in the toxi gram, and then the separation takes place in a TLC chamber. Following the chromatography, four development procedures are used to visualize the drugs which are present. This produces impressive colors as the result of the reactions, and the visualization is dramatic. This entire system yields a rapid, reproducible identification of drugs in urine.

For further experimentation in addition to the crime scenarios, the students are encouraged to bring a sample of their own urine for analysis with Toxi-Lab®. The Toxi-Lab® system is sensitive enough that a couple of Tylenol® tablets will provide sufficient acetaminophen for detection, a few No-Doz® or cups of coffee will provide the needed caffeine, and a few cigarettes (for smokers) will provide the necessary nicotine. Of course, other drugs could also be detected if they were present (Bonicamp 1985).

A one-step urine drug screening system called microLine™ (Drug Screening Systems, Inc., 603 VPR Commerce Center, 1001 Lower Landing Road, Blackwood, NJ 08012, telephone: 800-247-3784) supplies a test for cocaine, heroin/opiates, methamphetamine, marijuana and PCP. The test employs an antibody attached to colored microbeads, which migrate by capillary action induced by the urine sample. The competition for the limited antibody sites between the drug in the sample and a drug conjugate immobilized on a porous membrane support gives rise to colored lines which indicate either a positive or negative response for the presence of the drug. (The microLine™ drug screen is based on a principle similar to the one used in the new one-step pregnancy tests).

For confirmation of drugs in the urine, we perform a gas chromatographic-mass spectrometric analysis on an aliquot of the urine extract, obtained with the Toxi-Lab® extraction tube. With gas chromatography-mass spectrometry (GC-MS), the investigative unit learns how to predict a few of the major cleavage points of the drug molecules. Since they compare the mass spectrum obtained with a library of data on the computer, the details of identification are fairly simple. However, they must be aware that the drug yielding the best match (with the computer algorithm) is not always the "right one." They also must consider other supporting data, such as from the Toxi-Lab® analysis and the microLine™ drug screen, and apply common sense as to what drugs are likely to be used in their final determination of the drug present.

These wet chemical procedures, coupled with the more sophisticated instrumental techniques of FTIR and GC-MS, require knowledge of a broad range of both theoretical concepts and practical laboratory procedures for a true understanding of the analyses performed. Here, as with the unit on the determination of alcohol levels, the students acquire an appreciable understanding of the theory and application of these methods, although the level of sophistication obviously is not that of a chemistry major. NOTE: For those considering these experiments, the drugs are available as standard solutions from Sigma Chemical Company (P.O. Box 14508, St. Louis, MO 63178, telephone: 800-325-3010) and Alltech Associates, Inc. (2051 Waukegan Road, Deerfield, IL 60015, telephone: 800-255-8324) without a Drug Enforcement Administration license.

The toxicology unit (Unit 17) is introduced with case studies of the Jascalevich murder, involving the detection of curare by radioimmunoassay (Hall and Hirsch 1979; Siegel *et al.* 1985), and the Cappolino case, in which a doctor was accused of murdering his wife with injections of succinylcholine chloride, which acts as a competitive inhibitor for acetylcholine esterase (MacDonald 1968). We also examine the controversies surrounding the deaths of celebrities such as Janis Joplin, Marilyn Monroe and John Belushi. Obviously, to discuss these cases, the students must learn the basics of chemical toxicology and understand the process of nerve transmission, including the action and metabolism of neurotransmittors and the action of drugs which have their effect at the synapse.

In this unit, the students learn about drug dose versus response curves and how to interpret numbers such as the LD_{50} and the ED_{50}. The significantly different effects of isomers of the drugs are discussed, with the class acting out sections of the Dorothy Sayers novel, The Documents in the Case (Sayers and Eustace 1930). Is it a case of mistaken mushroom identity or murder which leads the victim to consume the toxic isomer of muscarine? Only optical rotation will allow us to determine if the sample was pure isomer (as would be produced by the mushroom) or the racemic mixture (as would be produced synthetically in the laboratory). We discuss the action and potency of dexedrine and benzedrine as another example of the isomer effect. Finally, we review the so-called "cocaine isomer defense." Since the Federal statute (until 1984) declared that it was a crime to use "coca leaves and any salt, compound, derivative, or preparation thereof which is chemically equivalent or identical with any of these substances," it was the burden of the prosecution to prove that the substance was l-cocaine, the only naturally produced derivative of coca leaves, and not any of the synthetically produced forms (Moenssens *et al.* 1986).

In the serology unit (Unit 18), we study the established procedures, as well as the newer ones. Since proteins were studied in the biochemistry section, the class is prepared to learn about antibodies and their interaction with antigens on the surface of blood cells.

Of the established procedures, we study methods for the identification of a substance as blood, the factors for the determination of human blood and, finally, the determination of blood type. This becomes more complicated when we consider the procedures used on dried bloodstains. While a series of serological experiments have been developed, it is inadvisable to use blood and blood products in the undergraduate laboratory. A number of simulated experiments are now available (Biology 1992; Kemtec 1992) which are safe alternatives to introduce the basic procedures.

The class is referred to earlier course reading assignments regarding the Jeffrey MacDonald case, the Sam Sheppard case and the Lizzie Borden axe murders. Each of these cases involved an analysis of blood and blood spatters. The Sheppard case was eventually analyzed by Paul Kirk, who was able to show, through the use of models, the origin of the blows that killed Marilyn Sheppard and the location of the person striking the blows. In the MacDonald case, an unusual situation occurred in which each of the family members had a different blood type: Jeff was B, Jeff's wife (Colette) was A, one daughter (Kim) was AB and the other daughter (Kris) was O. This diversity of blood types found at the crime scene enabled the formulation of an hypothesis about when and where the fatal blows were struck.

The class also discusses the analysis of other body fluids, such as saliva, seminal fluid and vaginal fluid. This leads into a discussion of rape cases and the medical procedures involved in the treatment of a patient suspected of being raped, as well as the analysis of the body fluids of the suspected rapist. While these issues would be of interest to almost any segment of the population, again, they are of particular concern to 18- to 22-year-olds.

At this point in the course, it is pertinent to introduce the technique of DNA Profiling. This is a particularly interesting unit from a technological viewpoint because, as the DNA analysis method made the transition from the research laboratory to the service laboratory, several problems developed. While the scientific basis of the procedure is solid, and the results are very accurate if it is done correctly, one has to be careful to develop a standard protocol for routine use.

While DNA profiling has played a significant role in many cases, as always, appropriate standards and controls must be employed on samples collected at the crime scene, and the chain of custody must be intact. The Castro case that went to trial a few years ago in the Bronx (New York) involved a man accused of murdering a woman and her daughter. From a dried spot of blood found on the suspect's watchband, the prosecution attempted to connect him to the murders through DNA profiling. In this case, scientists testifying for the defense and prosecution collaborated and, after reviewing the scientific evidence, advised the court. Their conclusion, based partially on the fact that the laboratory performing the assays did not employ appropriate controls and standards, was as follows:

> All experts have agreed that the Frye test and the setting of the adversary system may not be the most appropriate method for reaching scientific consensus. The Frye hearing is not the appropriate time to begin the process of peer review of the data. Initiating peer review at this time wastes a great deal of the courts' and experts' time. The setting also discourages many experts from agreeing to participate in the careful scientific review of the data (Lewin 1989).

Based partially on their report, the court ruled that the evidence could not be used in an inclusionary manner.

More recently, DNA analysis has been challenged on the basis used to predict the probability of more than one person having a particular profile. This has brought many scientists into contention with one another, as well as drawing the scientific community into battle with the legal community (Roberts 1992). This is where we began our course in forensic science — with a discussion of the testimony of the expert witness.

Conclusion

Many scientific methods and applications have been discussed in one semester, and undoubtedly the students more fully understand the relationship of science to real life situations. They have learned about numerous facets of chemistry and related disciplines. When the course is over, many students comment on how a potentially boring subject has been made interesting, even exciting, and how they are encouraged that they will be able to successfully read and comprehend scientifically oriented material in the future.

If I have accomplished what is indicated in this quote from Sherlock Holmes' "A Scandal in Bohemia" (Doyle 1967),

> I could not help laughing at the ease with which he explained his process of deduction. "When I hear you give your reasons," I (Watson) remarked, "the thing always appears to me to be so ridiculously simple that I could easily do it myself, though at each successive instance of your reasoning I am baffled, until you explain your process. And yet I believe that my eyes are as good as yours." "Quite so," (Holmes) answered, lighting a cigarette, and throwing himself down into an arm-chair. "You see, but you do not observe. The distinction is clear....,"

then I can assume that I have trained my students to be observers, and that is what a scientist is — an observer and interpreter.

In closing, it should be noted that forensic science presents an opportunity to weave scientific and technological aspects into every level of the science curriculum. It offers an enormous amount of material to draw from in almost every branch of the natural sciences, and it provides the opportunity to develop legal, as well as social and philosophical, considerations of the scientific and technological developments.

Acknowledgements

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Appendix A

SYLLABUS

(with minor changes from that given to the class)

CHEMISTRY 113 **FALL 1992**

CHEMISTRY AND CRIME
FROM SHERLOCK HOLMES TO MODERN FORENSIC SCIENCE

Instructor

Professor L. J. Kaplan
Office: 40 Thompson Chemical Laboratory, Extension 3303

Course Description

In an article on forensic science in Chemistry in Britain, the editor stated, "The most tangible way in which science, especially chemistry, can be concerned with the well-being of society is its use in the maintenance of the fabric of society as expressed in the constant vigil against crime." While this may be an overstatement, it is true that science has had an enormous impact on the definition and enforcement of the laws enacted to regulate society. Specifically, forensic science is the application of scientific principles to criminal and civil laws within a criminal justice system with the goal toward the establishment of guilt or innocence.

This course was designed to introduce some of the specialized fields of forensic science, to learn the fundamental principles of science and technology upon which they are based, and to apply them to a number of suspicious situations and criminal cases. We will explore aspects of forensic science involving the examination of physical, chemical, and biological items of evidence. The forensic analysis of substances such as glass, soil, hair, ink, bullets, gunpowder and drugs will be understood after an introduction to the concepts of basic chemistry, analytical chemistry, and organic chemistry. The methods used for the analysis for alcohol, carbon monoxide, and drugs and for the characterization of blood and other body fluids will be discussed in the context of the principles of biochemistry, toxicology, pharmacology, and serology.

Since forensic scientists also must have an understanding of the legal system to insure that their actions and results are within the rules of law and are admissible in the courts, we will discuss: the scope of expert investigation and the matter of expert qualifications, the nature of the results which may be expected from the laboratory, and the law as it applies to the admission of test results in evidence. This area has taken on dramatic new dimensions with the issues surrounding the acceptance of DNA profiling results in the court.

While the scientific and technological background will allow us to analyze a number of interesting specific cases, it is hoped that the course will instill an appreciation for chemistry as a discipline intimately related to one's life, and for science in general, as an open-ended field of study through which one can understand everything from nutrition to nuclear energy. In a larger sense, however it is hoped that the course will serve as a vehicle for understanding the nature of science and the function of a scientist, including what he/she does, how he/she does it, and the consequences of his/her actions.

Criminalistics: Application of scientific techniques in collecting and analyzing physical evidence in criminal cases.

– Webster's Ninth Collegiate Dictionary

Primary Texts

Richard Saferstein, Criminalistics: An Introduction to Forensic Science, 4th edition, Prentice-Hall, New Jersey, 1990.

John W. Hill, Chemistry for Changing Times, 6th edition, Macmillan, New York, 1992.

Primary References

A. A. Moenssens, F. E. Inbau, and J. E. Starrs, Scientific Evidence in Criminal Cases, 3rd edition, Foundation Press, Mineola, New York, 1986. (An authoritative text on law and forensic evidence providing both the scientific background for the work of a forensic scientist and the legal application of the results obtained.)

A packet containing selected articles will be handed out in class. The cost of this packet will be charged to your term bill. The packet consists of articles which discuss certain cases or illustrate specific points of forensic science and are listed at the appropriate place in the syllabus and noted with an asterisk (*).

Supplementary References (on the reserve shelf in the Sawyer Library)

Arthur Conan Doyle, The Annotated Sherlock Holmes, Baring-Gould, W. S., editor, 2 vol., Clarkson N. Potter, Inc., New York, 1967. (The quotations in the syllabus to the Sherlock Holmes stories are from this book.)

John W. Poulos, The Biography of a Homicide: A Case Study from Arrest through Trial, Foundation Press, Mineola, New York, 1976. (This book illustrates the dynamics of criminal justice by following a homicide case from the moment the police are called through the conviction of the defendant in a trial by jury.)

Various articles on specific cases designed for supplementary reading and to expand your appreciation of the applications of forensic science. Some of these are noted in the syllabus as *Supplementary Reading,* and some will be announced in class.

You can lead a jury to the truth but you can't make them believe it. Physical evidence cannot be intimidated. It does not forget. It doesn't get excited at the moment something is happening – like people do. It sits there and waits to be detected, preserved, evaluated, and explained. This is what physical evidence is all about. In the course of the trial, defense and prosecuting attorneys may lie, witnesses may lie, the defendant certainly will lie. Even the judge may lie. Only the evidence never lies.

– Herbert Leon MacDonell (from Lewis, A. A. and MacDonell, H. L., (1984). *The Evidence Never Lies: The Casebook of a Modern Sherlock Holmes,* Dell Publishing, New York)

SYLLABUS

1. Forensic Science

   a. Definition, scope, history and development

   b. Organization of crime laboratory

   c. Functions of the crime laboratory and the forensic scientist

   Saferstein, Chapter 1, "Introduction"

   C. Carlson, "Analyzing the Evidence," Sciquest, 16-21, April 1981.*

You did not know where to look, and so you missed all that was important. I can never bring you to realize the importance of sleeves, the suggestiveness of thumb-nails, or the great issues that may hang from a bootlace.
– A Case of Identity

2. The Crime Scene

   a. Processing the crime scene

   b. Legal considerations

   Saferstein, Chapter 2, "The Crime Scene"

   CASE READING: THE ATTEMPTED ASSASSINATION OF ARCHBISHOP MAKARIOS: A FORENSIC SCIENCE CASE STUDY
   Saferstein, Case Readings, pp. 462-473.

   SHERLOCK HOLMES: THE REIGATE SQUIRES
   Arthur Conan Doyle, The Annotated Sherlock Holmes, Baring-Gould, W. S., editor, 2 vol., Clarkson N. Potter, Inc., New York, 1967.

Lestrade showed us the exact spot at which the body had been found, and indeed, so moist was the ground, that I could plainly see the traces which had been left by the fall of the stricken man. To Holmes, as I could see by his eager face and peering eyes, very many other things were to be read upon the trampled grass.
– The Boscombe Valley Mystery

3. Physical Evidence

   a. Types and significance of physical evidence

   Saferstein, Chapter 3, "Physical Evidence"

For a long time he remained there, turning over leaves and dried sticks, gathering what seemed to me to be dust into an envelope and examining with his lens not only the ground, but even the bark of the tree as far as he could reach.
– The Boscombe Valley Mystery

4. Evidence and Testimony

   a. The nature and purpose of expert evidence and testimony

      P. C. Giannelli, "General Acceptance of Scientific Tests - *Frye* and Beyond," in Scientific and Expert Evidence, 2nd edition, E. J. Imwinkelried, ed., Practicing Law Institute, New York, 1981.*

      Refer to the articles listed under "Legal and Scientific Issues of DNA Profiling"

      L. Roberts, "Science in Court: A Culture Clash," Science 257 (5071), 732-736 (August 7, 1992).*

   b. Disclosure and discovery rights and obligations

      J. Kaplan and J. H. Skolnick, "An Overview of the Criminal System," Chapter III, pp. 88-104, in Criminal Justice: Introductory Cases and Materials, Third Edition, Foundation Press, Mineola, New York, 1982.*

   c. The expert at trial

      Moenssens, Chapter 1

      M. J. Saks, "Accuracy v. Advocacy: Expert Testimony Before the Bench," (MIT) Technology Review 90, 43-49 (1987).*

      CELEBRITY CASE: FATTY ARBUCKLE AFFAIR
      T. T. Noguchi, "Medicolegal Investigations in Hollywood," Journal of Forensic Sciences 31, 378 (1986). *

5. Chemistry: A Science for all Seasons

   a. The International System of Measurement
   b. Exponential notation
   c. Solving problems by dimensional analysis

      Hill, Chapter 1, Appendices A, B, and C

6. Atomic Structure

   a. Atoms

      Hill, Chapter 2, "Atoms: Are They for Real?"

   b. The structure of the atom

      Hill, Chapter 3, "Atomic Structure: Images of the Invisible"

   c. The nucleus

      Hill, Chapter 4, "Nuclear Chemistry: The Heart of the Matter"

7. Inorganic Analysis

a. Emission spectrum of elements

CASE STUDY: THE TYLENOL® SCARE
K. A. Wolnik, F. L. Fricke, E. Bonnin, C. M. Gaston, and R. D. Satzger, "The Tylenol® Tampering Incident – Tracing the Source," Analytical Chemistry 56, 467A-474A (1984).*

_____, "The Tylenol® Scare," various articles from Newsweek between October and December 1982 and Newsweek, October 12, 1987, p. 10.*

b. Atomic absorption spectroscopy of toxic elements

S. Manahan, Chapter 10, "Toxic Elements," in Toxicological Chemistry, 2nd edition, pp. 249-268, Lewis Publishers, Boca Raton, 1992.*

c. Radiocarbon dating

Saferstein, Chapter 6, "Inorganic Analysis"

Moenssens, Chapter 9

P. A. Budinger, T. L. Drenski, A. W. Varnes, and J. R. Mooney, "The Case of the Great Yellow Cake Caper," Analytical Chemistry 52, 942A-948A (1980).*

CASE STUDY: THE SHROUD OF TURIN
A. Burden, "Shroud of Mystery," Science 81 2, 76-83 (1981).*

K. F. Weaver, "The Mystery of the Shroud," National Geographic, June 1980.*

C. Murphy, "Shreds of Evidence," Harpers, November 1981.*

J. H. Heller and A. D. Adler, "Blood on the Shroud of Turin," Applied Optics 19, 2742-2744 (1980).*

J. H. Heller and A. D. Adler, "A Chemical Investigation of the Shroud of Turin," Canadian Society of Forensic Science Journal 14, 81-103 (1981). *Supplementary Reading*

L. A. Schwalbe and R. N. Rogers, "Physics and Chemistry of the Shroud of Turin: A Summary of the 1978 Investigation," Analytica Chimica Acta 135, 3-49 (1982). *Supplementary Reading*

P. E. Damon, D. J. Donahue, B. H. Gore, A. L. Hatheway, A. J. T. Jull, T. W. Linick, P. J. Sercel, L. J. Toolin, C. R. Bronk, E. T. Hall, R. E. M. Hedges, R. Housley, I. A. Law, C. Perry, G. Bonani, S. Trumbore, W. Woelfli, J. C. Ambers, S. G. E. Bowman, M. N. Leese, and M. S. Tite, "Radiocarbon Dating of the Shroud of Turin," Nature, 337, 611-615 (1989).*

d. Neutron activation analysis

CASE READING: EVIDENCE IN THE ASSASSINATION OF PRESIDENT KENNEDY
Saferstein, Chapter 6, pp. 135-137 (see next topic for a more extensive study of this case).

8. Firearms, Toolmarks and Other Impressions

No one had heard a shot.
And yet there was the dead man,
and there the revolver bullet,
which had mushroomed out, as
soft-nosed bullets will, and so
inflicted a wound which must
have caused instantaneous death.
– The Empty House

a. Bullet comparisons

CASE STUDY: ASSASSINATION OF PRESIDENT JOHN F. KENNEDY
V. P. Guinn, "JFK Assassination: Bullet Analysis," Analytical Chemistry 51, 484A-493A (1979).*

______, "Reexamination of Acoustic Evidence in the Kennedy Assassination," Science 218, 127-133 (1982).*

D. L. Breo, "JFK's Death – The Plain Truth from the MDs Who Did the Autopsy," J. American Medical Association 267(20), 2794-2803 (May 27, 1992).*

D. L. Breo, "JFK's Death, Part II – Dallas MDs Recall Their Memories," J. American Medical Association 267(20), 2804-2807 (May 27, 1992).*

______, Report of the President's Commission on the Assassination of President John F. Kennedy, Government Printing Office, Washington, 1964. *Supplementary Reading*

E. J. Epstein, Inquest: The Warren Commission and the Establishment of Truth, Viking, New York, 1966. *Supplementary Reading*

Many books have been written on this subject and will be discussed in class.

b. Gunpowder and primer residue

Saferstein, Chapter 15, "Firearms, Tool Marks, and Other Impressions," pp. 386-403

Moenssens, Chapter 4

CASE READING: TEAMWORK IN THE FORENSIC SCIENCES: REPORT OF A CASE
Saferstein, Case Readings, pp. 473-483.

9. Chemical Bonds

Hill, Chapter 5, "Chemical Bonds: The Ties that Bind"

10. Chemical Nomenclature

Holmes was seated at his side
table clad in his dressing gown
and hard at work over a chemical
investigation. A large retort was
boiling furiously in the bluish flame
of a Bunsen Burner, and the distilled
drops were condensing into a two-litre
measure.
– The Naval Treaty

a. Names, formulas and equations

Hill, Chapter 6, "Names, Formulas and Equations"

11. Physical Properties: Identification and Comparison of Small Objects and Particles

Microanalysis

a. Glass

b. Soil

Saferstein, Chapter 4, "Physical Properties: Glass and Soil"

Microscopy

c. Fibers

W. Fong, "Fiber Evidence: Laboratory Methods and Observations from Casework," Journal of Forensic Sciences 29, 55-63 (1984).*

CASE READING: FIBER EVIDENCE AND THE WAYNE WILLIAMS TRIAL
Saferstein, Chapter 3, pp. 56-70.

N. Petraco, "Trace Evidence-The Invisible Witness," Journal of Forensic Sciences 31, 321-328 (1986).* (Same as the Case Readings in Saferstein, Chapter 8, pp. 201-202 and 209-212.)

d. Hair

Saferstein, Chapter 7, "The Microscope," selected pages

Saferstein, Chapter 8, "Hairs, Fibers, and Paint"

Moenssens, Chapter 8

CASE READING: MICROSCOPIC TRACE EVIDENCE – THE OVERLOOKED CLUE (THE LINDBERG BABY KIDNAPPING)
Saferstein, Chapter 7, pp. 173-181.

SHERLOCK HOLMES: THE ADVENTURE OF SHOSCOMBE OLD PLACE
Arthur Conan Doyle, The Annotated Sherlock Holmes, Baring-Gould, W. S., editor, 2 vol., Clarkson N. Potter, Inc., New York, 1967.

12. Organic Chemistry

Hill, Chapter 10, "Hydrocarbons: An Introduction to Organic Chemistry"

Hill, Chapter 11, "Organic Chemistry: Some Hors d'Oeuvres"

13. Organic Analysis

A formidable array of bottles and test-tube, with the pungent cleanly smell of hydrochloric acid, told me that he had spent his day in the chemical work which was so dear to him.
– A Case of Identity

a. Chromatography

1. Thin layer and high pressure liquid chromatography of drugs

2. Gas chromatography of accelerants

Saferstein, Chapter 11, "Forensic Aspects of Arson and Explosion Investigation," pp. 290-294

b. Spectrophotometry

c. Mass Spectrometry

1. GC-MS characterization of drugs

Saferstein, Chapter 5, "Organic Analysis"

T. C. Kram, D. A. Cooper, and A. C Allen, "Behind the Identification of China White," Analytical Chemistry 53, 1379A-1386A (1981).*

A. P. Bentz, "Who Spilled the Oil?," Analytical Chemistry 50, 655A-658A (1978).*

14. Alcohol Intoxication

a. Toxicology of Alcohol

b. Alcohol Intoxication Testing

c. Evidence of Alcohol Intoxication

Saferstein, Chapter 10, "Forensic Toxicology," pp. 248-267

Moenssens, Chapter 2

CELEBRITY CASES: NATALIE WOOD AND WILLIAM HOLDEN
T. T. Noguchi, "Medicolegal Investigations in Hollywood," Journal of Forensic Sciences 31, 382-383 (1986).*

15. Biochemistry

a. A molecular view of life

Hill, Chapter 13, "Biochemistry: A Molecular View of Life"

b. Chemotherapy

Hill, Chapter 22, "Chemical Therapy: From Colds to Cancer"

16. Neurochemistry and Drugs

a. Drugs

Hill, Chapter 23, "Drugs: Chemistry and the Human Mind"

b. Drug dependence

c. Narcotics, hallucinogens, depressants and stimulants

d. Anabolic steroids

____ "Pumped Up – Muscle Drugs: Hooked on Steroids," U.S. News and World Reports, 122 (21), pp. 55-63, (1992).*

Saferstein, Chapter 9, "Drugs"

Hill, Chapter 24, "Fitness and Health: The Chemical Connection"

Moenssens, Chapter 6, pp. 360-386, 396-407

T. A. Dal Cason, R. Fox, and R. S. Frank, "Investigations of Clandestine Drug Manufacturing Laboratories," Analytical Chemistry 52, 804A-806A (1980).*

L. S. Eichmeier and M. E. Caplis, "The Forensic Chemist as 'Analytical Detective'," Analytical Chemistry 47, 841A-844A (1975).*

e. Drug abuse laws and drug identification

17. Toxicology

a. Chemical toxicology

Hill, Chapter 25, "Chemical Toxicology: Hemlock, Anyone?"

b. Forensic toxicology

Saferstein, Chapter 10, "Forensic Toxicology," pp. 267-277

Moenssens, Chapter 6, pp. 328-334, 386-391

CASE STUDY: CURARE AND THE JASCALEVICH MURDER CASE
L. H. Hall and R. F. Hirsch, "Detection of Curare in the Jascalevich Murder Trial," Analytical Chemistry 51 812A-819A (1979).* (Same as the Case Reading in Saferstein, Chapter 1, pp. 20-27.)

H. Siegel, F. Rieders, and B. Holmstedt, "The Medical and Scientific Evidence in Alleged Tubocurarine Poisonings. A Review of the So-Called Dr. X Case," Forensic Science International 29, 29-76 (1985). *Supplementary Reading*

SHERLOCK HOLMES: THE ADVENTURE OF THE RETIRED COLOURMAN
Arthur Conan Doyle, The Annotated Sherlock Holmes, Baring-Gould, W. S., editor, 2 vol., Clarkson N. Potter, Inc., New York, 1967.

CELEBRITY CASE: MARILYN MONROE
T. T. Noguchi, "Medicolegal Investigations in Hollywood," Journal of Forensic Sciences 31, 381 (1986).*

18. Serology

a. Characterization of blood and bloodstains

SHERLOCK HOLMES: A STUDY IN SCARLET
Arthur Conan Doyle, The Annotated Sherlock Holmes, Baring-Gould, W. S., editor, 2 vol., Clarkson N. Potter, Inc., New York, 1967.

CELEBRITY CASE: CHARLIE CHAPLIN – JOAN BARRY
T. T. Noguchi, "Medicolegal Investigations in Hollywood," Journal of Forensic Sciences 31, 380 (1986).*

b. Preservation of blood evidence

Saferstein, Chapter 12, "Forensic Serology"

Moenssens, Chapter 6, pp. 335-350, 391-394

> Holmes held up a crumpled branch of flowering gorse. To my horror I perceived that the yellow blossoms were all dabbed with crimson. On the path, too, and among the heather were dark stains of clotted blood.
> – The Priory School

c. Characterization of semen

d. Collection of rape evidence

Saferstein, Chapter 12, "Forensic Serology"

Moenssens, Chapter 6, pp. 351-360, 395

A. F. Schiff, "Rape: Wife vs. Husband," Journal of Forensic Science Society 22, 235-240 (1982).*

e. Other biological fluids

O. R. Idowu and B. Caddy, "A Review of the Use of Saliva in the Forensic Detection of Drugs and Other Chemical," Journal of Forensic Science Society 22, 123-135 (1982).*

19. DNA Profiling

'Never mind,' he said, chuckling to himself. 'The question now is about haemoglobin. No doubt you see the significance of this discovery of mine?' 'It is interesting, chemically, no doubt,' I answered, 'but practically —.' 'Why, man, it is the most practical medico-legal discovery for years. Don't you see that it gives an infallible test for blood stains.'
– A Study in Scarlet

a. DNA - Structure and Interactions

b. DNA Profiling

Saferstein, Chapter 13, "DNA: A New Forensic Science Tool"

A. J. Jeffreys, V. Wilson, and S. L. Thein, "Hypervariable 'Minisatellite' Regions in Human DNA," Nature 314, 67-73, (1985). *Supplementary Reading*

A. J. Jeffreys, V. Wilson, and S. L. Thein, "Individual-specific 'Fingerprints' of Human DNA," Nature 316, 76-79, (1985). *Supplementary Reading*

A. J. Jeffreys, J. F. Y. Brookfield, and R. Semeonoff, "Positive Identification of an Immigration Test-Case using Human DNA Fingerprints," Nature 317, 818-819, (1985). *Supplementary Reading*

P. Gill, A. J. Jeffreys, and D. J. Werrett, "Forensic Application of DNA Fingerprints," Nature 318, 577-579, (1985). *Supplementary Reading*

c. Legal and Scientific Issues of DNA Profiling

A. Schmitz, "Murder on Black Pad," Hippocrates, January-February 1988, pp. 48-58.*

R. Lewis, "DNA Fingerprints: Witness for the Prosecution," Discover 9, 44-52 (1988).*

S. G. Michaud, "DNA Detectives," The New York Times Magazine, November 6, 1988, p. 70.*

R. Weiss, "DNA Takes the Stand," Science News 136, 74-76 (1989).*

P. J. Neufeld and N. Colman, "When Science Takes the Witness Stand," Scientific American, 262(5), 46-53 (1990).*

L. Roberts, "Fight Erupts over DNA Fingerprinting," Science 254(5039), 1721-1723 (December 20, 1991).*

R. Chakraborty and K. K. Kidd, "The Utility of DNA Typing in Forensic Work," Science 254(5039), 1735-1739 (December 20, 1991). *Supplementary Reading*

R. C. Lewontin and D. L. Hartl, "Population Genetics in Forensic DNA Typing," Science 254(5039), 1745-1750 (December 20, 1991). *Supplementary Reading*

G. Kolata, "U.S. Panel Seeking Restriction on Use of DNA in Courts — Labs' Standards Faulted," The New York Times, pp. A1 and C7, April 14, 1992.*

G. Kolata, "Chief Says Panel Backs Courts' Use of a Genetic Test — Times Account in Error," The New York Times, pp. A1 and A23, April 15, 1992.*

L. Roberts, "DNA Fingerprinting: Academy Reports," Science 256, 300-301 (April 17, 1992).

L. Roberts, "Science in Court: A Culture Clash," Science 257 (5071), 732-736 (August 7, 1992).*

Appendix B

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for
A LABORATORY MANUAL FOR
AN INTRODUCTION TO THE CRIME LABORATORY