Determination of a Recharge Time for

Eccrine Sweat Glands on Friction Ridge Skin

BY

KIALEE DANIELLE BOWLES
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THESIS

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Defense Committee:

A. Karl Larsen, Chair, University of Illinois at Chicago
Adam Negrusz, University of Illinois at Chicago
Charles Steele, Purdue University-Calumet and North Central Campuses
James Snaidauf, University of Illinois at Chicago

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ABSTRACT

A single fingerprint can provide a great amount of information. Latent prints, in particular, can help tell a story or identify a perpetrator in criminal and civil cases. Even though fingerprints have been a valuable tool in the field of forensic science since the early 1900s, there is still much to learn about their nature and evidentiary value (National Institute of Justice, 2011). The purpose of this study is to explore the natural, or uncharged, fingerprint and determine what point, if any, it will appear the same as a groomed, or charged, fingerprint.

This was carried out through the deposition of hundreds of prints at various time intervals on a porous substrate. After 5, 15, 30, and 60 minutes, an uncharged print was deposited onto plain white copy paper. It was then cut in half and processed by two different reagents: Ninhydrin and Oil Red O (ORO). These visualize the amino acids and lipids, respectively, which are commonly present in latent fingerprint residue found at crime scenes. After development, the prints were analyzed for color intensity and quality of ridge detail with the AATCC Gray Scale for Change and the Snaidauf Modified Bandey System, respectively. Results were documented and percentages, means, and standard deviations calculated for each time interval.

Overall, there were no significant changes across all time intervals. In addition, uncharged prints developed with ORO behaved much differently than charged prints. A recharge, or recovery time, was unable to be determined for the eccrine sweat glands. At no point will an uncharged fingerprint appear the same as a charged fingerprint within the conditions of a laboratory setting.

I. INTRODUCTION

Whether it be on a doorknob, a gun or a ransom note, latent fingerprints are among the most common forms of evidence collected at crime scenes. In this role, latent fingerprints are deposited unintentionally and can provide great insight as to the identity of the perpetrator of a crime. When a case goes to trial, latent fingerprint evidence can provide support to proving a connection between a person and a crime scene, a person and a physical piece of evidence, or even a crime scene and a piece of physical evidence. An example of this can be seen in the 1978 murder of Carroll Bonnett. Mr. Bonnett was brutally murdered almost forty years ago in his own apartment. Several latent fingerprints and palm prints were discovered in the bathroom where it was suggested the murderer tried to clean up. These prints were then compared to others on file within the state of Nebraska with no success and the case went cold. In March 2008 the case was reopened with a request to run the fingerprints through Nebraska Automated Fingerprint Identification System (AFIS) and the Integrated Automated Identification System (IAFIS). These are state-wide and national fingerprint databases that were not available at the time of the initial investigation. A partial match came back to a Jerry Watson, currently serving time in an Illinois prison for a previous burglary. A DNA sample was obtained and compared to a hair collected from the crime scene, also, resulting in a match. After a swift trial, Watson was convicted of first degree murder (FBI, 2012). Had these databases been around in 1978, the case likely would not have gone cold for thirty years. The latent prints were the key piece that connected Jerry Watson

to the crime. Technology just had to catch up to the evidence, first. While fingerprints have been utilized in this capacity in forensic investigations since the early 1900s (National Institute of Justice, 2011), there is more research to be done to understand and improve upon this valuable tool.

When a new fingerprint processing reagent or technique is developed, validation studies must be carried out to prove that this new technique is reproducible and reliable. These validation studies utilize latent fingerprints collected in the laboratory by donors. The latent fingerprints can either be natural and "uncharged", or groomed and "charged". An uncharged fingerprint is one that has been produced naturally from the eccrine sweat glands within the finger without having had contact with any other residue prior to deposition. A charged fingerprint is one that has had contact with residue created from the sebaceous sweat glands commonly found on the forehead, nose, or behind the ear. There has been much success regarding "charged", or groomed, fingerprints, while there are many unanswered questions about "uncharged", or natural fingerprints (Snaidauf, 2015).

A study in 2010 concluded that it is natural fingerprints that scientists should be focused on with further research projects. Groomed fingerprints can overcompensate for many residue components and could potentially compromise the accuracy of any research assessing a developing reagent (Croxton, Baron, Butler, Kent, & Sears, 2010). Because of this, it is important to understand every aspect of these natural fingerprints and the residues they produce. The purpose of this study is to determine at what point, if any, an uncharged fingerprint will

resemble a charged fingerprint under laboratory conditions. The results from this study will give scientists a more accurate idea of how the latent fingerprint is produced. Researchers will be able to use this information to advance fingerprint processing reagents and developing techniques.

II. REVIEW OF LITERATURE

A. Latent Fingerprints

A latent fingerprint is one that cannot be seen easily with the naked eye and must be visualized by chemical or physical means. It is formed when the sweat and oils created by the eccrine and sebaceous glands are transferred to another item in the design of the friction ridge skin. Three layers make up the structure of friction ridge skin: epidermis, dermis, and hypodermis. Embedded in the dermis and hypodermis are appendages called eccrine sweat glands. There are approximately 500 to 600 eccrine sweat glands per square centimeter on the volar, or palmar, surface of the finger (Pierard, et al., 2003, Taylor and Machado-Moreira, 2013). The purpose of these glands is to excrete metabolic waste and regulate body temperature. These simple tubular glands reach through the epidermis and open into a pore on the surface of the skin where the sweat can be excreted (National Institute of Justice, 2011). A study in 2013 concluded that the average individual with a surface area of 1.8 meters squared will sweat 0.6 to 2.3 liters each day. The hands contribute most to this sweat loss at a rate of 80 to 160 grams per hour (Taylor and Machado-Moreira, 2013). Because eccrine sweat is approximately 99% water, this is roughly equivalent to 80 to 160 milliliters per hour. In addition to water, eccrine sweat contains many trace components. These trace compounds tend to vary greatly depending on diet and exercise. The general breakdown of the remaining one percent includes the following with their corresponding abundance in weight percent: sodium chloride (43.83), lactic acid (29.22), urea (11.69), amino acids (7.79), others (4.97), monosodium phosphate (1.75), glucose (0.44), and

potassium phosphate (0.31) (Wargacki, et al, 2007). The other constituents can include zinc, copper, magnesium, proteins, lipids, drugs, and hormones (Frick, et al, 2013, Wilkinson, 2012).

Latent fingerprints collected at a crime scene are rarely produced by the eccrine sweat glands, alone. Sebaceous glands are located all over the body except where friction ridge skin is present, i.e. soles of the feet and palms of the hands. The largest concentration of sebaceous glands can be found on the face and scalp. The main purpose of these glands is to keep the skin moist and lubricated through the secretion of sebum. Sebum is an oily residue comprised primarily of lipids and fatty acids. When a perpetrator touches his or her face or hair, the sebum is transferred to the fingertips which is then deposited onto a substrate. It is because of this transaction, that lipids are commonly detected in latent fingerprint residue at crime scenes (Frick, et al, 2013). A study conducted in 2015 focused on the sebaceous material in uncharged and charged fingerprints (Snaidauf, 2015). Results from these experiments (discussed further in section D) brought about questions regarding the recovery time for the uncharged fingerprint. It is proposed that by not allowing donors to touch their faces, hair, or other oily areas, a recharge time for the eccrine sweat glands can be determined.

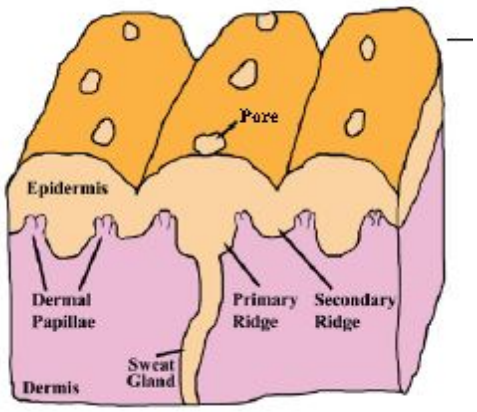


Figure 1: Structure of Friction Ridge Skin

Originally published by the National Institute of Justice, U.S. Department of Justice

Latent fingerprint evidence can appear on many different substrates. These can be categorized into three groups depending on their porosity, or the number of void spaces in the material: non-porous, semi-porous, and porous. The more porous a substrate is, the more residue it can absorb. Examples of non-porous substrates are plastic, metals, and glass, while semi-porous substrates have waxy or glossy surfaces. Porous substrates include paper, cardboard, or unfinished wood. This study will focus on porous substrates, specifically white copy paper due to its great success in previous fingerprint studies (Snaidauf, 2015).

In a porous substrate, the components of the latent fingerprint are absorbed. As the water evaporates, those components dry and become durable. The components of latent fingerprint residue can be broken down into water-soluble and water-insoluble. When developing a study, it is important to use reagents that will target each portion.

Amino acids are a prominent presence in the water-soluble category. The amount of amino acids in one fingerprint varies between donor and method of measurement. One study concludes that there are approximately 0.3 to 2.59 milligrams of amino acids per liter of sweat which converts into 250 nanograms of amino acids in each fingerprint (Hansen and Joullie, 2004). Another states that the range is greater with anywhere from 20.7 to 345.1 nanograms (Croxton, et al, 2010). Despite this variation, the amino acids present in the fingerprint residue will absorb into porous substrates and do not migrate. This property makes them a favorable target in the development process. One reagent, 1, 8-diazafluoren-9-one, or DFO targets these amino acids; however, a fluorescent light is required to visualize the reaction. Silver nitrate will detect the salts in the water-soluble portion, but can yield high background interference and is hazardous to work with. Ninhydrin is a tried-and-true method for developing amino acids and will be used for the purposes of this study.

Water-insoluble components primarily include lipids and proteins. Both of which can be detected successfully with several different reagents. Physical developer is a reagent commonly used to detect the lipids. As a disadvantage, this process can be expensive, time-consuming, and destructive to the evidence. Another option is Sudan Black B; however, it sometimes yields poor contrast and is better with more sebaceous components (National Institute of Justice, 2011). Oil Red O, a relatively new developing reagent, is growing in popularity among fingerprint analysts and has been chosen to develop the lipids in the water-insoluble portion of the samples in this study.

B. **Ninhydrin**

Ninhydrin is a crystalline solid that was “accidentally” created in 1910 by Siegfried Ruhemann. Shortly after, it was used to stain the water-soluble amino acids in biological samples. The deep purple product, diketohydrindylidene-diketohydrindamine, became known as Ruhemann’s Purple. For years, scientists were warned to take extra care when handling papers and chromatograms that would have contact with Ninhydrin because unwanted purple fingerprints would be visualized; however, its forensic applications were not realized until 1954. Amino acids are presumed to always be present in a latent fingerprint in some amount and have a high affinity for cellulose. These traits make Ninhydrin one of the most common fingerprint developing techniques used for porous substrates (National Institute of Justice, 2011).

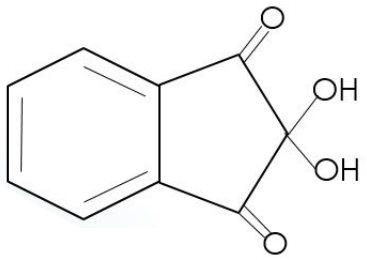


Figure 2: Chemical structure of Ninhydrin

Figure 3 illustrates the mechanism of Ninhydrin reacting with an amino acid. Once in equilibrium within the humidity chamber, the stable hydrated Ninhydrin compound will form the

anhydrous triketone molecule allowing the amino acid to bond. A dipolar ion is formed as water and carbon dioxide are released. The ion hydrolyzes and an aldehyde group leaves, forming an amine. The amine condenses with another Ninhydrin molecule to produce an ammonium salt, the Ruhemann's Purple. A disadvantage of this process is the Ruhemann's Purple will eventually degrade in light and oxygen so images must be captured immediately following development (National Institute of Justice, 2011).

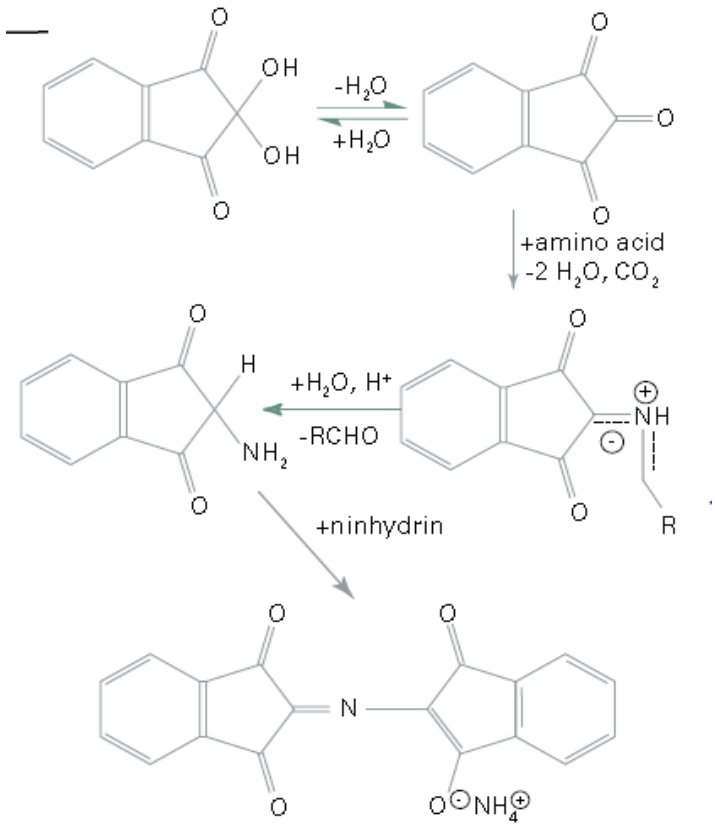


Figure 3: Mechanism of Ninhydrin reacting with an amino acid.

Originally published by the National Institute of Justice, U.S. Department of Justice

C. **Oil Red O**

Oil Red O is a fat-soluble dye, or lysochrome, that is commonly used to stain the water-insoluble lipid components of a latent fingerprint. It has been used to stain lipids in histological samples as early as 1926; however, its forensic use was not realized until 2004 (Beaudoin, 2004). Beaudoin has demonstrated much success with Oil Red O over Physical Developer, particularly with wet, porous surfaces. One of its greatest advantages is the simplicity of the technique. Developing a sample only requires three easy steps: coloration, neutralization, and drying. The dye dissolves into the fat, staining it. A buffer is used to neutralize the lipids, allowing for greater contrast and less background interference. When lipids are present in the print, it will turn red on a pink background (Beaudoin, 2011).

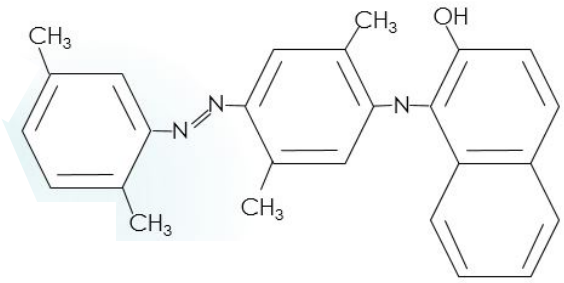


Figure 4: Chemical structure of Oil Red O

D. **Variables**

There are many different variables that can affect the production and deposition of a latent fingerprint. Control over these variables must be maximized during research in order to achieve valid results. A study in 2011 looked at the effect of the force applied during deposition.

It is thought that with greater application force, a larger surface area will come into contact with the substrate. In addition, with lesser application force, a smaller quantity of residue will be deposited. Previous studies would ask participants to deposit a print with “moderate” force; however, this is very subjective. Because of this, a measurable value must be determined to make the force applied consistent throughout a study. The researchers in this study created a “fingerprint sampler” with a see-saw mechanism and springs. They collected many charged latent prints both with and without the fingerprint sampler and made comparisons. It was concluded that a force equivalent to 300 grams is sufficient to produce a quality print with clear ridge detail (Fieldhouse, 2011).

Another variable that some may consider a factor is excessive sweat production. It could be thought that someone with sweaty hands would produce a more intense, clearer, and better quality print than someone with particularly dry skin. Almog, et al set out to determine if there is a correlating factor between palmar moisture and latent fingerprint quality. The scientists in this study used the Corneometer®, an instrument that detects skin moisture and is commonly used by dermatologists, to examine the palmar moisture of 77 participants from India and Israel. These participants then deposited uncharged latent prints onto A4 bond paper that were later processed with a Ninhydrin solution. The prints were then graded on a scale of one to four on the quality of “fingerprint donorship” then compared to the palmar moisture results. It was concluded that while there was a general positive trend, there were many prints that had high moisture levels, but very poor donorship grades and vice versa. Because the Ninhydrin targets amino acids, it can be said that excessive sweat production does not necessarily mean high amino acid levels. It

is the quantity of amino acids, not moisture that produces high quality latent fingerprints (Almog, Sheratzki, Elad-Levin, Sagiv, Singh, Jasuja, 2011)

In addition, factors such as gender, age, diet, and smoking are thought to affect the ability to produce a quality latent fingerprint. A study in 2010 sought to determine the magnitude of the impact. Researchers collected both charged and uncharged prints from 18 participants on Mylar® strips. The samples were then extracted and injected into a gas-chromatographer/mass-spectrometer to separate and quantify the various compounds present. Several interesting conclusions were drawn from the data. In general, females had a greater amount of amino acids than males, while males had a greater amount of fatty acids. However, neither of these results was statistically significant. In the uncharged samples, a few amino acids had higher mean levels in vegetarians than omnivores, although not significantly. This result was not observed in the charged fingerprints. Several fatty acids were statistically different between omnivores and vegetarians in the uncharged samples. For the charged samples, fatty acids were generally higher in omnivores; but only significant for one. Some statistically significant differences were seen in both amino acids and fatty acids between the older and younger age groups; however, it is not stated which was greater for each case. Overall, there were no significant differences to report in the smokers versus the non-smokers (Croxton, Baron, Butler, Kent, & Sears, 2010).

In recent years, there have been several attempts to improve upon the collection of latent fingerprints and our knowledge of how they are produced. A study in 2015 set out to compare three different reagents and various substrates across several time periods. The focus was

charged, sebaceous latent prints; however, uncharged, natural, eccrine latent fingerprints were collected, as well. Through conversations with several experts in the field, a two minute recharge time for the uncharged prints was determined to be sufficient for this study. Participants washed their hands, waited the one minute, and then created a charged fingerprint by wiping their fingers across their forehead. Latent fingerprints were deposited onto white copy paper, checks, envelopes, Kraft paper and thermal paper. The washing process was repeated, and the participants waited two minutes before placing their uncharged fingerprints on the same type of substrates. Fingerprints were processed with three reagents that target the sebaceous residue: Physical Developer, Oil Red O and Oil Blue A. Development was staggered across different time intervals: 7, 14, 28, 42, and 56 days. Developed latent fingerprints were analyzed with the Snaidauf Modified Bandey System to determine the quantity of clear ridge detail. It was concluded, that the charged prints produced the best results. Out of all three reagents, Oil Red O was determined to be the best processing technique, while Physical Developer did not meet expectations. Oil Blue A performed well; however, more research should be done to determine its best use. Samples processed out to 56 days did develop; however, those developed sooner had a more intense color. More importantly for the current study, Snaidauf found that the uncharged prints produced after two minutes were of very poor quality and many times not adequate for comparison. This indicates that two minutes is not long enough for the oils to completely replenish themselves (Snaidauf, 2015).

In 2014, Machado-Moreira, et al studied the production of eccrine sweat. The majority of research studies targeting the production of sweat secretion collect the sweat in bags, filters,

patches, and capsules. There is little knowledge about what is actually happening beneath the surface before the sweat secretes through the pores in the skin. Previous studies have found that there is a significant delay between the initiation of production and actual surface discharge. The sweat actually accumulates in the ducts before it breaks through to the surface. Machado-Moreira's study wanted to determine at what point the production of sweat is initiated when a subject is passively heated. Wearing a water-perfusion suit, participants placed both feet in a temperature-regulated water bath. The precursor sweat (low-levels present in the ducts) was monitored through electrodermal response with surface electrodes, while the discharged sweat was collected in ventilated capsules. Four different areas on the body were examined: fingers, hands, forehead, and forearms. As predicted, the initiation of precursor sweat was detected at a much lower mean body temperature than that of the discharged sweat. The resulting delay allowed researchers to determine that on average it takes 4.1 minutes for primary or precursor sweat to become secondary or discharged sweat that has broken through the surface (Machado-Moreira, Barry, Vosselman, Ruest, & Taylor, 2015).

III. METHODS

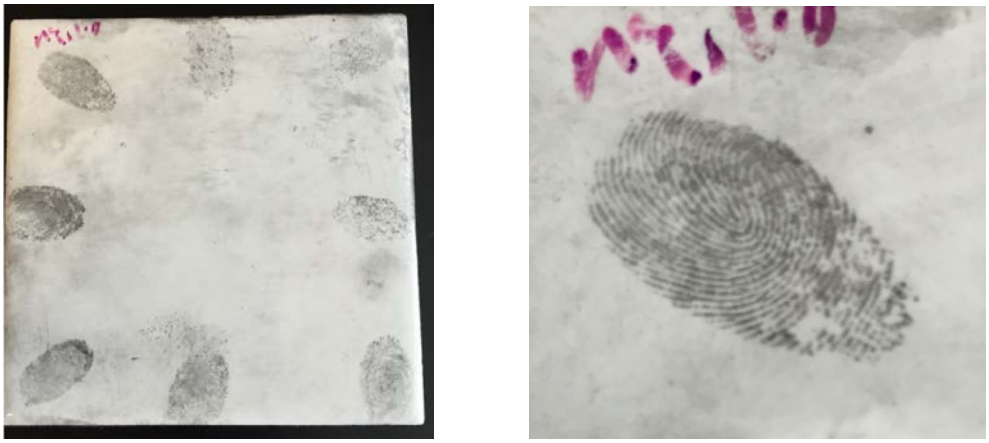
A. Preliminary Studies

Several preliminary studies were carried out in order to refine the experimental procedures. To support the conclusions of the 2011 Fieldhouse study, a pressure study was carried out with four volunteers. Latent fingerprints were deposited on white copy paper placed on an analytical balance. Participants deposited two sets of thumb prints: one at ~200 grams and one at ~400 grams. Samples were then processed with Ninhydrin and ORO as described in section E of this chapter. A brief visual examination concluded that a target pressure similar to ~300 gram would be sufficient for following studies.

A second preliminary study was conducted to determine the timeline for the main study. Following the procedures described in section D of this chapter, four volunteers deposited prints at 5, 15, 30, 60, and 120 minutes. These samples were processed just as the set before. A visual examination suggested there was very little change between the samples taken after 60 minutes and those taken after 120 minutes. It was concluded that 60 minutes was a reasonable maximum time interval.

To ensure fingerprint residue was being produced and deposited, an additional study was carried out. With the ten final participants, prints were deposited after an interval of 60 minutes onto a clean, white ceramic plate. They were then dusted with black magnetic powder and

photographed. Below are the pictures indicating that after 60 minutes, clear ridge detail from an uncharged fingerprint can be developed and identified on a non-porous surface.



a.) full view b.) close-up

Figure 5: Ceramic tile with dusted prints

B. **Sampling**

Samples were taken from 31 individuals of a variety of ages and backgrounds representative of the human population. For each time interval, an individual produced three fingerprints, creating several hundred samples to analyze. Participants were asked to complete a survey regarding age, sex, diet, health, and soap or lotion use.

C. **Data Collection**

At the start of the study, participants' hands were cleaned with a cotton ball and Purell™ hand sanitizer to remove all contaminants. A mini muffin cup was then placed on the finger of the individual's choice. This was to serve as a reminder not to touch anything with that finger for the duration of the study unless instructed otherwise. After the first recharge time of five minutes was complete, the participant was asked to deposit a set of prints on a sample strip created using white copy paper and designed similar to the diagram below. Three prints were deposited for a period of 10 seconds each at a pressure similar to 300 grams on the analytical balance. For each print in the series, the participant moved vertically down the paper. Prints were deposited in the center of each strip to allow for development by two different reagents when cut in half. Samples were allowed to dry for 24 hours at room temperature before being processed.

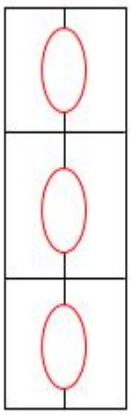


Figure 6: Model of sample strip

D. **Development of Samples**

Each sample strip was cut in half vertically to allow processing by two different reagents. One half of the strip was processed with Ninhydrin according to the Chesapeake Bay Division of the International Association for Identification (CBDIAI) procedure found in Appendix B. A Ninhydrin solution was sprayed onto the strips hanging in a fume hood until completely coated. They were then transferred to an oven set at 80 degrees Celsius to dry. It was not realized until after the study was complete, that exposure to recommended humidity levels of 60-70% was not achieved. Despite this, control samples behaved as expected.

The remaining half was processed with Oil Red O according to the CBDIAI procedure in Appendix C. The strips were placed in a pan of Oil Red O stain solution set on a shaker for one hour. Samples were then removed, drained, and placed in a phosphate buffer solution for five minutes. Again, they were removed and drained, then rinsed in distilled water. The strips were then spread out on the laboratory bench to dry overnight. All of the developed samples were then scanned at 1200 ppi and saved to a jump drive as a .TIF file. Samples were placed in a Ziploc bag and stored in a dark drawer for the duration of the study.

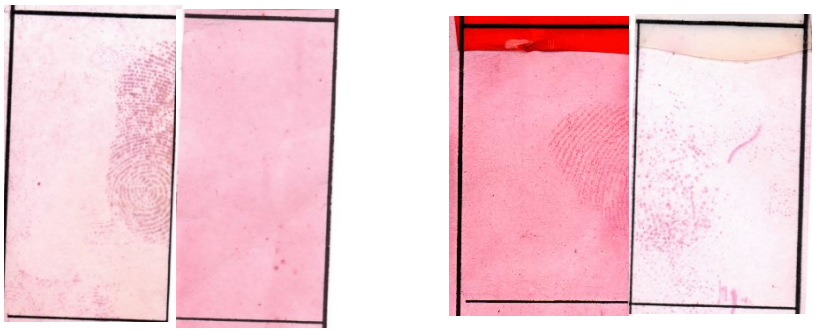


Figure 7: Images of developed latent fingerprints

E. **Analysis**

Developed prints were analyzed using two different scales. The Snaidauf Modified Bandey System shown in Table 1 below was used to determine the clarity of the print to be used for identification (Snaidauf, 2015). Prints that rated a 2, 3, or 4 were coded green and deemed to have at least a small section of clear ridge detail. A print that was coded red would most likely not be suitable for identification and not usable for this study.

TABLE I

SNAIDAUF MODIFIED BANDEY SYSTEM

(Snaidauf, 2015)

Grade	Level of Detail
0	No evidence of print
1	Some evidence of contact, but no clear ridge detail present
2	Less than 1/3 of print showing clear ridge detail
3	Between 1/3 and 2/3 of print showing clear ridge detail
4	Over 2/3 of print showing clear ridge detail

Prints were then analyzed for color intensity with the American Association of Textile Chemists and Colorists (AATCC) Gray Scale for Evaluating Change in Color. A score was assigned to a print based on the intensity of the print versus the intensity of the background (white copy paper). A print with a score between 1 and 3-4 would most likely be seen by the average fingerprint examiner. The closer the score is to 5, the more likely the print is to be overlooked.

Figure 8: Image of the AATCC Gray Scale for Change in Color

A set of 25 fingerprints representative of each rating were chosen from the original sample set and sent to three advisors close to this project, as well as six additional experts in the field, for analysis with both scales. The same fingerprints were then blindly analyzed by the

author with each scale, and the procedures were successfully validated. All data collected was entered into several Excel spreadsheets. Those prints coded with green on the Snaidauf Modified Bandey System or 1 through 3-4 on the Gray Scale were counted. Statistics including percentage of positives and standard deviation using the standard normal model were calculated and reported.

IV. RESULTS

A. Calculations

The raw data can be found in Appendices D and E for Ninhydrin and Oil Red O, respectively. Individual percentages were calculated for number of prints with a 3-4 score or above on the Gray Scale and green coded prints on the Snaidauf Modified Bandey System. These were performed for each time interval and each development method. Percentages were then calculated to determine how many fingerprints had an acceptable rating by both methods. This shows the reader how many prints of sufficient quality could be detected. The tables below reflect these calculations.

TABLE II

PERCENTAGES OF POSITIVES

	5 min.	15 min.	30 min.	60 min.
Gray Scale	59%	46%	65%	62%
SMBS	34%	29%	35%	42%
Both	34%	24%	33%	41%

a.) Ninhydrin

	5 min.	15 min.	30 min.	60 min.
Gray Scale	8.6%	6.5%	6.5%	7.5%
SMBS	6.5%	6.5%	6.5%	7.5%
Both	6.5%	6.5%	6.5%	7.5%

b.) Oil Red O

A mean rating and standard deviation was then calculated for each development method and each time interval to examine any major differences and the precision of each analytical methodology. The standard deviation formula shown below utilizes the "n-1" method because the results reflect a sample of the population.

$$\sqrt{\frac{\sum(x-\bar{x})^2}{(n-1)}}$$

Figure 9: Standard deviation formula where *x* is the mean and *n* is the sample size.

TABLE III

MEANS AND STANDARD DEVIATIONS

	Grayscale for Color Change				SMBS			
	5 min.	15 min.	30 min.	60 min.	5 min.	15 min.	30 min.	60 min.
Mean	3.5	3.6	3.4	3.3	2.3	2.0	2.3	2.0
SD	1.1	1.1	1.1	1.2	0.47	0.44	0.47	0.44

a.) Ninhydrin

	Grayscale for Color Change				SMBS			
	5 min.	15 min.	30 min.	60 min.	5 min.	15 min.	30 min.	60 min.
Mean	4.8	4.6	4.9	4.9	0.26	0.23	0.26	0.3
SD	2.3	1.6	2.4	2.4	0.87	0.87	0.99	1.00

b.) Oil Red O

B. **Interpretations**

From the table of percentages of prints with positive results, it has been determined these are representative of what is seen in previous studies and in the field (Snaidauf, 2015). The exception here is the prints developed with ORO. Very few prints were successfully developed, and the obvious explanation lies within the lipid levels. Other possible factors could include interdonor variation (age, metabolism, diet, disease, etc.). Reviewing the results by donor and the respective survey, no clear correlation can be seen as to specific factors creating positive results.

The low standard deviations show that the results are relatively precise within each time interval. However, the means of each time interval are all similar. One might expect as time lapses, more residue would be formed also increasing the quality and intensity of the fingerprints. This study has shown that this is not what happened in this particular case. Overall, there is very little to no difference across time intervals. In addition, a charged print produces an intense red color and clearly visible ridges with little difficulty. This result was not observed with uncharged fingerprints for even the longest recovery time of 60 minutes. Any longer than this, the chance of finding an uncharged fingerprint decreases significantly due to hand-washing and/or contact with the face, mouth, or other items. As a result of this study, no specific recharge time could be determined. An uncharged fingerprint will not resemble a charged fingerprint under laboratory conditions within these time intervals.

V. CONCLUSIONS AND RECOMMENDATIONS

A. Limitations

One issue discovered in this study evolved from the processing with Ninhydrin. Nitrile gloves were used to handle samples during deposition and processing. However, when handling the samples months after, gloves were not available. Residual Ninhydrin continued to faintly detect and develop the amino acids from this unprotected handling. Because of this some extraneous partial prints developed on the samples. Despite this, the placement and position of the donor prints made them stand out to avoid confusion.

B. Summary

This study sought out to determine at what point, if any, an uncharged fingerprint will resemble a charged fingerprint. On average, the prints deposited after five minutes were just as intense in color, with ridges just as clear, as the ones deposited after 60 minutes when developed with Ninhydrin. In addition, the uncharged prints developed with Oil Red O vary greatly from those of charged prints. This suggests a major difference in the chemical composition of the fingerprint residue, specifically in the lipid levels. Because we did not allow touching during the recharging period, the fingertips did not come into contact with any residue from the sebaceous glands. There would be very little lipids, if any, in the fingerprint residue deposited. As a result, a

recharge time for the eccrine sweat glands could not be determined. It appears at no point will an uncharged print ever look like a charged print within the conditions of a laboratory setting. If one were conducting research on uncharged fingerprints, alone, a recovery time of five minutes will yield latent fingerprints of equal quality to those produced from a longer recovery time.

C. **Implications**

Research studies in this field often utilize uncharged and charged fingerprints. Because of this, it is very important to fully understand the nature of each, how they are produced, and how they differ from each other. The findings from this study provide insight into these areas and are another step in refining the fingerprint collection process for the purpose of research. An uncharged latent fingerprint will never look like a charged latent fingerprint within a laboratory setting. If the lipid levels are the biggest reason behind this, uncharged latent fingerprints would not be the ideal sample to use in testing a reagent that targets the water-insoluble components of fingerprint residue. If the focus of the study is amino acids, uncharged fingerprints with a minimum recovery time of five minutes will produce representative results with a reagent targeting water-soluble components. A sound and knowledgeable collection procedure will aid in advancing fingerprint processing reagents and techniques.

D. **Suggestions for Future Work**

This study is another step in advancing our knowledge of latent fingerprints. Previous research has had great success with the collection of charged latent fingerprints in the analysis of several developing reagents (Snaidauf, 2014). This study demonstrated that uncharged fingerprints will behave differently in a laboratory setting. Fingerprint residue composition, as well as the glands' recovery time must be taken into consideration when preparing samples for research and validation studies. The points below are just a few of the many directions to be explored to increase the field's knowledge of latent fingerprints, with the possibility of creating a standard sample collection procedure to be used for the purposes of research.

- Attempt to pinpoint how the lipid levels vary in uncharged prints from charged prints. Are there any other differences in composition? A gas chromatograph-mass spectrometer could be used for this.

- Track the production of uncharged prints through weight rather than reaction to chemicals and compare to charged prints. A balance that detects to the ten thousandth gram would be necessary to complete this.

- Track the production of DNA in an uncharged latent fingerprint. If an uncharged latent fingerprint is not suitable for identification, at what point with it produce enough DNA material to yield a usable genetic fingerprint?

- Carry out a more specific study that targets different demographics and factors, specifically gender, age, and metabolic health, to attempt to determine differences.

These types of studies can be carried out utilizing routine instruments that are available to many forensic research labs. The biggest requirements for success are time and access to a large number of donors. With that in mind, many new findings can come from this research, further advancing the role of fingerprints in the field of forensics.

APPENDIX A

Dear Ms. Bowles,

Thank you for contacting the National Criminal Justice Reference Service (NCJRS).

All National Institute of Justice (NIJ) materials are in the public domain. We only ask that you adhere to the following when using our materials:

- Credit NIJ as follows: "Originally published by the National Institute of Justice, U.S. Department of Justice"

- Reproduce the materials in whole (do not revise the items)

In this case the figure you referenced is in the public domain, please be advised there are other figures in "The Fingerprint Sourcebook" that are not. You can identify these figures by the text below the figure that states that permission was received for NIJ to use the figure.

We hope the above information is helpful to you. Please let us know if you have any further questions.

Thank you,

Harrison

Information Specialist

National Criminal Justice Reference Service

https://www.ncjrs.gov

APPENDIX B

Ninhydrin

5 g Ninhydrin crystals

30 mL Methanol

40 mL 2-Propanol

930 mL Petroleum ether

PROCEDURE:

1. Mix solution with a magnetic stirring device.

2. Spray solution onto item until coated.

3. Heat up to 80 degrees Celsius and humidity exposure 60-70% relative humidity. Monitor for development, or use steam iron.

(Chesapeake Bay Division of the International Association for Identification, 2015)

APPENDIX C

Oil Red O

STAIN SOLUTION:

1.54 g Oil Red O powder dissolved in 770 mL Methanol

9.2 g Sodium hydroxide dissolved in 230 mL distilled water

Add the Sodium hydroxide solution to the Oil Red O solution. Mix and Filter the combined solutions. Store in a dark bottle.

PHOSPHATE pH 7 BUFFER SOLUTION:

101.55 g Sodium phosphate monobasic monohydrate dissolved in 1 L distilled water

338.79 g Sodium phosphate dibasic heptahydrate dissolved in 1 L distilled water

Shake both solutions until dissolved, then combine. Add distilled water to increase the combined buffer solutions volume to 4 L.

PROCEDURE:

1. Immerse the item in stain solution and soak completely. It is optional to agitate the solution on a shaker platform.

    -Ridge detail should begin to develop in 5 min.

    -Weak fingerprints (poor lipid content) may require 60-90 minutes of development time.

2. Remove and drain item. Immerse in the buffer solution for 5 minutes.

3. Remove item from buffer solution. Rinse in distilled water for 5 minutes.

4. Dry item at room temperature or heat in an oven at 50 degrees Celsius.

(Chesapeake Bay Division of the International Association for Identification, 2015)

APPENDIX D

Raw Data with Ninhydrin

	Grayscale for Color Change					Bandey Scale				
	5 min.	15 min.	30 min.	60 min.		5 min.	15 min.	30 min.	60 min.	
1	1.5	3.0	2.5	2.0	3.0	4.0	2	1	4	1	1	4	2	1	4	1
2	4.0	5.0	4.0	3.5	4.0	4.0	3.5	4.5	4.5	4.5	1	1	0	1	1	1	1	1	1	1	2	1
3	3.5	4.0	4.5	4.5	5.0	5.0	3.0	3.5	5.0	5.0	1	1	1	0	1	1	3	1	0	0	2	0
4	5.0	4.5	5.0	3.5	3.5	4.0	2.0	3.5	3.5	4.0	2.0	1	1	0	1	1	3	1	2	1	4	2
5	3.5	4.5	5.0	2.5	5.0	5.0	3.5	3.5	5.0	3.0	3.5	2	1	0	2	1	1	0	1	1	1	1
6	1.0	3.5	4.5	1.0	3.5	4.0	1.5	4.5	5.0	1.5	4.5	4.5	3	2	1	0	2	1	1	0	3	1	0
7	3.5	4.5	4.5	3.5	4.5	3.5	2.5	3.5	3.5	2.5	4.5	4.5	1	1	2	1	2	1	2	1	2	1	2
8	4.5	3.5	1.5	4.0	4.5	4.5	5.0	3.5	5.0	4.5	1.5	4.5	1	0	1	1	2	1	2	1	1	1	1
9	2.5	2.5	4.5	3.0	2.5	4.5	2.0	2.0	3.5	3.5	3.5	2	1	1	1	0	3	2	2	2	2	1
10	2.5	3.5	2.5	2.5	4.5	4.5	1.5	3.5	4.0	1.5	3.0	3.0	3	2	1	1	4	1	4	2	4	2	0
11	3.0	4.5	4.5	2.0	2.5	5.0	1.5	3.5	3.5	1.0	2.0	4.5	4	1	1	4	3	1	4	1	2	3	1
12	3.0	4.5	4.5	2.5	3.5	4.5	2.0	3.0	4.5	1.5	3.5	1.0	2	1	1	3	1	0	3	2	1	4	2
13	2.0	3.0	3.0	2.0	4.0	3.5	4.0	4.0	3.5	1.5	3.0	3.5	1	1	2	3	1	0	3	2	4	2	1
14	5.0	4.5	5.0	4.0	5.0	4.0	5.0	4.5	5.0	3.5	4.0	4.5	0	1	0	2	1	0	1	1	1	1	1
15	5.0	5.0	4.5	4.0	4.5	4.0	4.5	4.0	3.5	3.0	4.0	2.5	0	1	0	2	1	1	2	1	1	1	1
16	3.0	2.5	2.0	1.5	2.0	1.0	2.0	3.0	3.0	2.0	3.0	3.0	2	1	1	2	1	1	1	1	2	1	1
17	3.5	5.0	3.0	5.0	5.0	5.0	2.5	3.5	3.5	2.0	4.5	5.0	1	1	1	1	1	0	1	1	2	1	0
18	2.0	1.5	2.0	2.5	4.0	3.0	2.0	3.0	3.0	2.5	3.5	3.5	1	2	2	2	1	1	3	1	3	1	1
19	3.0	5.0	5.0	3.5	4.0	4.0	3.5	4.5	4.5	4.0	5.0	5.0	2	1	0	1	1	1	1	1	1	1	0
20	1.0	3.0	3.5	1.0	3.5	3.5	1.5	3.5	1.0	1.0	3.5	4.5	4	3	1	4	1	1	4	2	4	2	1
21	3.0	2.5	4.0	4.0	4.5	4.5	3.0	3.5	4.5	3.5	4.0	4.5	3	2	1	1	1	0	1	1	1	0	0
22	1.5	2.5	3.0	1.0	3.5	3.0	2.0	3.5	4.0	1.5	2.5	3.5	4	2	2	4	1	1	4	2	4	2	1
23	3.0	5.0	5.0	3.5	4.5	5.0	3.5	4.5	5.0	4.0	4.5	4.5	2	0	0	1	0	0	1	1	1	1	0
24	2.5	3.0	4.0	2.5	4.0	4.5	2.0	3.5	4.0	3.5	3.5	3.0	3	2	1	3	2	1	4	2	4	3	2
25	3.5	4.5	5.0	3.5	3.5	4.5	3.0	4.5	4.0	2.0	3.5	4.0	1	0	0	2	1	1	3	1	4	1	1
26	2.5	4.0	3.5	2.0	4.0	4.5	1.5	3.0	4.5	1.5	3.0	4.5	2	1	1	2	1	1	3	2	3	2	1
27	3.5	4.5	4.0	3.5	5.0	4.5	3.5	4.5	4.5	4.0	5.0	3.0	1	1	1	1	1	0	1	1	1	1	1
28	3.0	3.5	3.5	4.5	5.0	5.0	3.5	4.0	4.5	3.0	4.0	4.0	1	1	0	1	0	0	2	1	2	1	0
29	2.0	2.0	2.5	1.0	3.5	3.5	1.0	3.5	4.0	1.0	2.5	3.5	3	3	2	3	2	2	3	1	3	2	2
30	1.5	3.0	3.0	1.5	3.5	4.5	2.0	3.5	4.0	2.0	3.0	3.0	2	2	1	3	1	0	3	1	3	1	1
31	1.5	3.5	4.5	1.5	4.0	4.5	2.5	4.0	4.5	1.5	3.0	4.5	2	1	0	2	1	1	2	1	1	0	1

APPENDIX E

Raw Data with Oil Red O

	Grayscale for Color Change											
	5 min.			15 min.			30 min.			60 min.		
3	2.5	4	4	2.5	3	3.0	1.5	2.0	2.5	2.0	2.5	2.5
12	5.0	5	5	5	5	5.0	5.0	5.0	5.0	3.5	4.0	4.0
15	1.0	2	2	2	3	2.5	2.5	2.5	2.5	3	3.5	3.5
24	2.5	4	5	5	5	5	4	5	5	5	5	5
26	2.0	3	3.5	5	5	5	4	5	5	5	5	5

Bandey Scale											
5 min.			15 min.			30 min.			60 min.		
4	1	1	4	3	3	4	4	4	4	4	4
0	0	0	0	0	0	0	0	0	2	0	0
4	4	4	4	3	4	4	4	4	4	4	4
2	1	0	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0

APPENDIX F

Results from Validation Study #1

Sample	Grayscale		Bandy Scale			
	KB	CS	KB	CS	JS	KL
A	2-3	2	4	2	3	
B	4-5	4-5	1	1	1	
C	3	3-4	2	2	2	
D	2	1-2	1	2	4	
E	3	1-2	1	1	0	
F	1	4-5	4	3	4	
G	1	1	1	2	1	
H	2	2	3	3	2	
I	5	2	0	2	0	
J	3-4	3-4	2	2	4	
K	3-4	3-4	1	1	3	
L	4-5	5	1	1	0	
M	1	1	4	4	3	
N	3	4-5	1	1	1	
O	3-4	3-4	1	1	0	
P	1-2	2	2	3	2.5	
Q	5	1	0	0	0	
R	1-2	2	3	3	2	
S	2-3	3	2	3	1	
T	4	1	1	1	0	
U	3	3	3	3	4	
V	1-2	1-2	4	3	4	
W	3	3-4	2	2	3	
X	3-4	4	2	2	2	
Y	2	2-3	4	4	4	

APPENDIX G

Results from Validation Study #2

	KB	1	2	3	4	5	6
A	3	3	2	3	2	3	3
B	1	1	1	1	0	0	0
C	2	2	1	2	2	1	1
D	3	3	1	3	2	2	2
E	1	2	1	1	1	1	1
F	4	4	4	4	4	4	4
G	1	2	1	2	2	1	1
H	4	4	2	4	2	4	4
I	3	2	3	3	2	2	2
J	4	4	4	4	4	4	4
K	1	1	1	1	2	0	0
L	1	1	0	1	0	0	0
M	3	4	3	4	2	3	3
N	1	2	1	2	1	1	1
O	3	3	3	3	2	2	3
P	3	3	2	3	2	3	3
Q	0	0	0	0	0	0	0
R	3	3	2	4	2	2	3
S	2	2	1	2	2	1	1
T	1	1	1	2	1	0	1
U	4	2	2	3	2	3	2
V	4	4	3	4	3	4	4
W	2	2	2	3	2	3	2
X	1	2	2	2	2	2	1
Y	4	3	4	4	2	4	4

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VITA

WORK EXPERIENCE

Montgomery County Coroner's Office/Miami Valley Regional Crime Laboratory, Dayton, Ohio

September 2015-Present

Forensic Toxicologist

- Accession biological specimens and maintain proper chain of custody.
- Perform screening analyses on post-mortem and ante-mortem specimens for the presence of drugs and alcohol.
- Provide testimony regarding the analyses performed when required to do so.

McCrone Research Institute, Chicago, Illinois

September 2014-August 2015

Intern

- Set up microscopes and other equipment for new classes each week.
- Kept research laboratories in a neat, orderly condition.
- Carried out miscellaneous, organizational tasks for the Institute.

Biopharmaceutical Sciences Department, University of Illinois at Chicago,

Chicago, Illinois

August 2014-August 2015

Teacher's Assistant

- Prepared solutions and organize equipment for the Forensic laboratories.
- Ordered necessary supplies for Forensic laboratories and current research projects.
- Maintained a clean laboratory and functional working environment.

Chemistry Department, St. Ambrose University, Davenport, Iowa

April 2012-May 2014

Laboratory Prep Worker

- Stocked and cleaned the General Chemistry, Organic Chemistry, Instrumental, and Research labs for the University.
- Updated the chemical inventory list for the Chemistry and Biology departments.

- Prepared all solutions and gathered equipment for General Chemistry and Organic Chemistry lab sections.

Davenport Police Department, Davenport, Iowa

Summer 2012

Intern

- Shadowed many officers from several departments.
- Observed various chemical tests and the collection of evidence with the Crime Scene Technicians.
- Attended several meetings with the administration in a professional setting.

ACADEMIC PREPARATION

Master of Science in Forensic Science (Expected Graduation: August 2016)

University of Illinois at Chicago, Chicago, Illinois

GPA: 4.0/4.0

Bachelor of Arts in Chemistry (Graduation: May 2014)

Bachelor of Arts in Criminalistics (Graduation: May 2014)

St. Ambrose University, Davenport, Iowa

Magna Cum Laude

GPA: 3.8/4.0

ACADEMIC HONORS/LEADERSHIP HONORS

American Chemical Society Student Leadership Award, 2013

- Selected to attend the American Chemical Society Leadership Conference with twenty other student leaders.
- Networked and brainstormed with professionals in the field.

American Chemical Society Student Chapter President, 2012-13

- Planned monthly business meetings and social activities.
- Completed the American Chemical Society Student Chapter Report

Ambrose Scholar, 2010-2014

Dean's List, 2010-2014

Phi Eta Sigma National Honor Society, Social Chair 2012-13

RESEARCH

St. Ambrose University, Davenport, IA

Research completed under the direction of Dr. Gillian Miller

Summer 2013

Project: "Examination of Toxic Heavy Metals in Consumer Products" B. Anderson, **K. Bowles**, A. Ducray, Z. Harris, G. Miller

- Determined presence of toxic heavy metals in a variety of consumer products by a portable X-Ray Fluorescence Spectrometer.
- Results: Many consumer products, including children's jewelry, vintage toys, and dishware contain toxic amounts of lead and cadmium. Their use must be carefully monitored until the U.S. passes stricter regulations.

Research completed under the direction of Dr. Andrew Axup and Dr. Kelly Gierlus

Spring 2011

Project: "Cadmium Levels in Children's Toys from China, Germany and the U.S."
K. Bowles, H. Fettkether, R. McDonnell, S. Thorpe, K. Gierlus, A. Axup

- Utilized Flame Atomic Absorption Spectroscopy to determine cadmium levels in children's toys.
- Results: As hypothesized, the toy samples from China had much higher levels of cadmium when compared to those from Germany and the U.S. While cadmium levels exceeded the EPA's accepted short term toxicity level, a child would have to ingest the entire toy to experience any adverse effects.

CONFERENCES/PRESENTATIONS

Attendee, Midwest Association for Toxicology and Therapeutic Drug Monitoring, St. Louis, Missouri, 2016

Attendee, American Academy of Forensic Science National Meeting, Orlando, Florida, 2015

American Chemical Society Illinois-Iowa Section Undergraduate Research Conference, Davenport, Iowa 2013

Presented research: "Examination of Toxic Heavy Metals in Consumer Products"

B. Anderson, **K. Bowles**, A. Ducray, Z. Harris, G. Miller

Presented poster: "St. Ambrose University Chemistry Club" **K. Bowles**, V. Dumitru, K. Gierlus

American Chemical Society National Fall Meeting, Indianapolis, Indiana 2013

Presented poster: "St. Ambrose University Chemistry Club" **K. Bowles**, V. Dumitru, K. Gierlus

Attendee, American Chemical Society Leadership Conference, Dallas, Texas 2013

American Chemical Society Illinois-Iowa Section Undergraduate Research Conference, Davenport, Iowa 2011

Presented research: "Cadmium Levels in Children's Toys from China, Germany and the U.S"

K. Bowles, H. Fettkether, R. McDonnell, S. Thorpe, K. Gierlus, A. Axup

VOLUNTEER EXPERIENCE

Chemistry Club

Sexual Assault Awareness Team

Children's Miracle Network Dance Marathon

Biology Club

St. Jude's Up 'til Dawn

BEE the Difference Day

Habitat for Humanity

CSI Night for Project Renewal

National Chemistry Week

PROFESSIONAL MEMBERSHIP

Generation Dayton Young Professional Network – Member since 2016

Midwest Association for Toxicology and Therapeutic Drug Monitoring –Member since 2016