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Optimizing Methods for Separation of Adhesive Tape from Fabrics and Obtaining Latent Prints from Adhesive and Non-Adhesive Sides

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Optimizing Methods for Separation of Adhesive Tape from Fabrics and Obtaining Latent Prints from Adhesive and Non-Adhesive Sides

by

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Abstract

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Fingerprinting is a valued part of forensic science analysis. It has been around for decades, and has advanced with the passing of time. There have been numerous studies of the different ways analysts have encountered fingerprints in the field—but none on those deal with the removal of tape from fabric. To investigate this, eight fabric types (a cotton/polyester mix, spandex, denim, jeans, fleece, flannel, polyester, and vinyl), three commercially available tapes (duct tape, black electrical tape, and packaging tape), have been stuck together and separated with four different techniques (manual pulling apart, Un-Du commercial adhesive remover, liquid nitrogen, and a 1:1 xylene-chloroform mix) and processed with WetWop to determine if usable prints can be obtained. Results have demonstrated that the best separation method for the widest range of fabrics and tapes is liquid nitrogen.

State University of New York College at Buffalo

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A Thesis in
Forensic Science

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I) Background Information

1.1) Fingerprint History

In the field of forensic science, one of the disciplines of greatest importance is fingerprint analysis. Fingerprint analysis involves marks obtained from latent fingerprints usually taken from a crime scene. Fingerprints can be used to determine who was at a scene, and potentially identify a suspect. Prints can be left in all locations, surviving longer or shorter depending on the medium they have been placed on. Most people may not even realize that they're leaving their fingerprints in places that forensic scientists can successfully analyze. There are numerous techniques that can be used to develop prints, and many have been utilized for years. Some are better than others, but the point is that fingerprints are everywhere in a crime scene, and at least one print is almost always obtained that can be used for positive identification of a suspect. Of course, it does not tend to turn out like the television shows intend, with an analyst identifying a suspect or victim within a half hour of obtaining a print and triumphantly shouting that there's a match. Generally, when someone examines prints it takes a little while, sometimes involving double checking with other analysts to see if they both obtain the same results. Even then, with the connotations that the word "match" has now thanks to popular media, I have been taught that nothing can ever be a true, 100% match. There is no way to determine that. But obtaining multiple points of analysis from the print increases the chance that two prints are extremely similar. The fingerprint analysis is very helpful, and like any science, there are new developments happening all the time.

According to Peterson et al. (2009), the actual analysis of fingerprints is founded on the ideas of every person having individual friction ridges details, unique to each person. They were observed as early as the 1700s, but it wasn't until Sir Francis Galton and Dr. Henry Faulds conducted several studies in the 1900s that the friction ridges were sufficiently established. The reason the ridges were so individual to each person lies in the human body's development during fetal growth. Their arrangements were initiated and developed during a process of differential growth at the boundary between the epidermal and dermal layers of skin. This accounts for their variability. In practice, statistics have shown that no two individuals have had the same fingerprints, not even twins. It is also important to realize that each fingerprint is specific to an individual that makes this analysis so useful. Fingerprints cannot be changed, as the way a human's skin develops allows for a renewal of ridge patterns throughout their lifetime. Barring permanent injury to the skin, a person's fingerprints are both unique and maintain the same pattern throughout their entire life (Peterson et al., 2009).

For a deeper understanding of what is going on with the biology of fingerprints, turn to Gaensslen et al. (2001). They describe the way the skin is generally divided into two separate layers. The epidermis, and the dermis. The epidermis is the outer layer. It consists of several layers of cells, with each one becoming progressively larger at it reaches the uppermost portion of skin. Roughly 1 g of these layers will be shed by a person per day. The dermis is the underlying layer of skin. It is dense and holds a system of blood, lymphatic and nerve vessels. It also contains numerous secretory glands; including those that make up the sweat left behind in a latent fingerprint. There are three of these glands, called eccrine, apocrine, and sebaceous. The eccrine glands are

found throughout the body but are most dense in the palms and soles. The apocrine glands are found in the armpit and groin regions. The sebaceous glands are generally found in places with hair follicles, including the face and scalp. The eccrine and sebaceous glands are the ones that secrete the sweat in a latent fingerprint (Gaensslen et al., 2001).

Peterson et al. (2009) goes into the differences and potential complications that can result when fingerprint analysis is done as a two-dimensional impression, when prints are 3-D. Two considerations have been introduced because of this limitation: the first is whether the impression transfers the individual characteristics of the ridge details, and what amount of information is present in the impression that allows for uniqueness. Because the friction ridges are a three-dimensional, pliable surface, information on the individual characteristics can be affected by or even potentially lost when the impression is transferred from 3-D to 2-D. Any number of factors can affect it. For example, the amount and pressure of a substance being transferred can obscure or lower the quality or quantity of the information contained in a print. If pressure is too hard then likely the friction ridge marks will be smudged, or pushed together, limiting the individual characteristics that could have been analyzed. Further studies have shown, however, that even with these factors (those potential distortions caused by pressure and placement of a latent print), careful examination has demonstrated that the information in the 3-D impression, the fingerprint as it exists in the world just by looking at a finger with your eyes, transfers reliably as an accurate representation of it in the 2-D impression (Peterson et al., 2009).

1.2) Examinations

With the fingerprint impression is judged suitable for accurate study, the scientific examination of these prints is possible. Peterson et al. (2009) explain the process of doing so. It is split into four different steps: analysis, comparison, evaluation, and verification. Coming up with a question(s), turning it into a hypothesis, conducting tests around that hypothesis, examine the data to form conclusions, confirm or deny support for the hypothesis based on the conclusions, and confirm those results through repetition and by scientists other than the one who originally came up with the idea.

A) Analysis

Analysis begins with the preliminary study of the fingerprint in question. This includes a visual examination to determine how best to obtain the necessary data for comparisons. One would look at the substrate the fingerprint is on: a piece of paper, a soda can, part of the wall or piece of glass. Each might be processed with different methods to develop the unknown fingerprint. For example, if there were suspected fingerprints on a piece of paper an examiner would likely use ninhydrin. The liquid can be sprayed/dipped/swabbed onto the paper, it reacts with the alpha amino acids, polypeptides and proteins left behind in a print and turns them a purple/indigo color. To analyze a soda can, one would likely use cyanoacrylate, more commonly called superglue fuming. While the exact process is unknown, it's been proposed that the glue reacts with the micelles from the fats in the fingerprint, sticking to it and developing a visible, white fingerprint with individual ridges. On a wall or piece of

glass, it's also possible to use powders, that stick to the oils in a fingerprint and create the classic patterns widely seen today. These can then be lifted using tape for further analysis in the lab. The substrate the fingerprint is on is important for analysis, so no evidence gets destroyed. This is why the protocols for porous (such as the piece of paper) and non-porous (such as the soda can) are different. After the preliminary steps are out of the way, the examiner can then develop their hypothesis.

Typically, something along the lines of "what is the origin of this unknown print?" the hypothesis helps determine the direction of the investigation. The examiner then begins observing the different characteristics of the print. What is the overall shape of the print: a loop, whorl, or arch? Which subcategory does it fall under: a radial loop, double whorl, or tented arch? There are several categories, as shown in Figure 1, and they can have two or three in each class. Loops are the most common in the human population, with roughly 60-65% of every fingerprint being a loop. Whorls are next, about 30-35%, with the rarest classification belonging to arches. They make up only 5-10% of the entire world's population of fingerprints. Analyzing the print further results in the individual characteristics that make up a print. These are patterns within the friction ridges, a few of the most common patterns shown in Figure 2. Bifurcations, islands, ridge endings and more are unique to each person, and detailed examination leads to comparisons. There is another form of examination that Peterson et al. (2009) describe, known as the holistic standard. The examiner doesn't just look at the patterns in a friction is, but also the overall shape of the print, the way the ridges flow, exactly how they bend and form around the pad of a finger. Several of these are shown in Figure 3. The 3A section is the size and overall shape

of the print obtained. This can indicate where the source of the print is. In this case, the size and shape are consistent with a print from the end of a finger joint. 3B highlights the areas where distortion occurred in the print. They deserve greater scrutiny than areas where there is no distortion. And the small line near the bottom of the fingerprint indicates friction ridge path misalignment, which also must undergo greater scrutiny. 3C indicates the overall flow of the fingerprint. This also helps determine the source of the print, in this case the flow is consistent with coming from the end of a finger. 3D shows arrows which indicate the different minutiae in the print (bifurcations, ridge endings, etc.). 3E highlights the paths of the print. The number, sequence, and lengths of each path can provide better information for an examiner. The areas where the path is unclear (such as those with distortion) are represented by the gaps in the pattern. 3F showcases the individuality created by all the aspects of a fingerprint. The bolded lines connect the characteristics in the center of the print, the ridge flow, the sequence of the ridges, and the features of the ridge in sequence. The clear lines indicate enough information for an identification to occur.

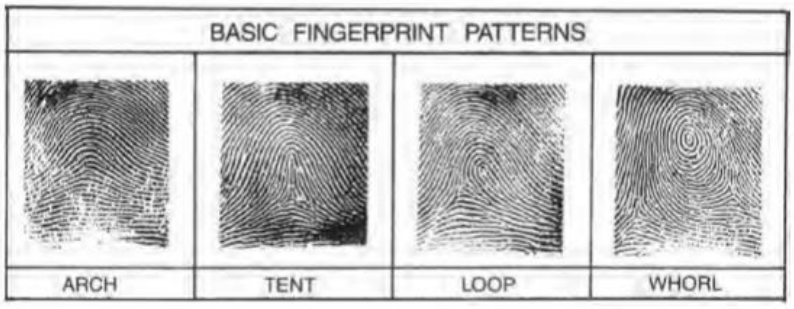

Figure 1: A chart showing several class characteristics of fingerprints (Gaensslen et al., 2001)

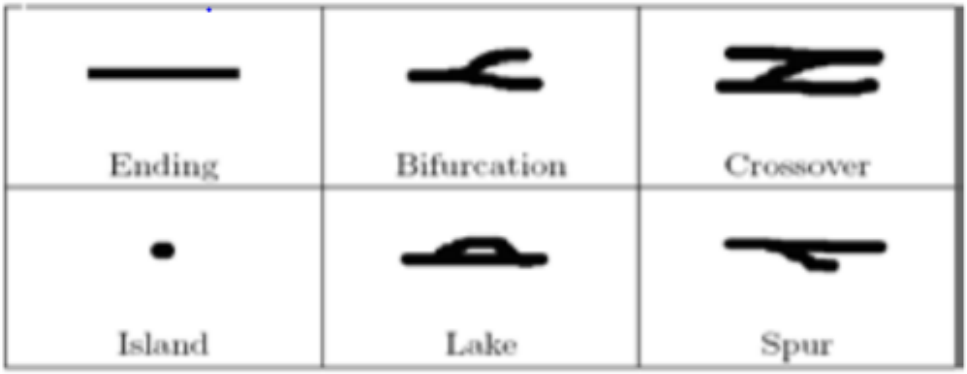

Figure 2: A chart looking at some of the different minutiae possible on a print (Bansal et al., 2011)

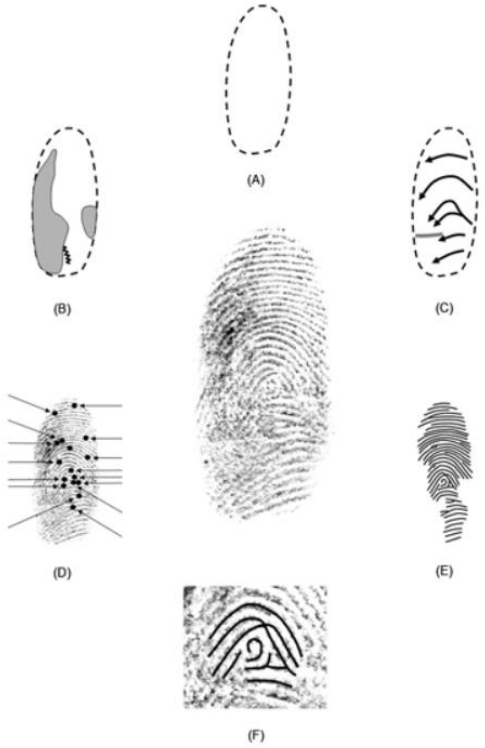

Figure 3: The information considered through the holistic method, referenced from Latent Prints: A Perspective on the State of Science

Gaensslen et al. (2001) lists several other types of identification as well. The Osborn Grid method involves photographing both inked and latent prints and enlarging each of them. The photos are imposed on a non-standard sized grid, and they are examined square by square. If all the available points between the prints are identical, then a positive conclusion can be reached. The Seymour Trace method happens when the latent and known prints are copied onto tracing paper, and then superimposed on each other. Comparisons are made by tracing points between both prints when viewing them with backlighting. The Photographic Strip method enlarges photos of both prints. The inked print is secured with a rigid mount, while the latent print is cut into lateral strips and placed over the enlarged inked print. They must be together in perfect conjunction. The Polygon method also enlarges photographs of inked and latent prints. Small holes are punched through the paper at minutiae points for both prints, which are then reversed and connected with straight lines. Comparison is between the geographic shapes produced by the lines. The final kind of identification is the Overlay method is sometimes approached by placing a transparent overlay over an enlarged photo of the latent print and marking ridge details. The same overlay is placed over an enlarged photo of the inked print, which should be the same scale as the latent print, and the comparisons between the two are noted. By using different colors of ink, this can make comparisons simple: the latent print characteristics marked with blue, while the inked print is marked with yellow. The points that match would be green, while nonmatching points would be either color.

Once these points are found and examined, it is then determined if the print is suitable for further comparisons. If the fingerprint is sufficient then it can be taken to the next step. Sufficiency is determined by the examiner and may be different for each crime lab.

There are no national standards, and thus the standards for sufficiency are based on the experience of the examiner and his or her belief in whether the fingerprint has enough detail for proper examination. In this study, it was determined that the questioned prints would be examined based on a scale of 0-11 individual spots (minutiae). Eleven is regarded as the highest, which guaranteed that there was enough information gained during analysis and led to the ability to continue in the investigation to comparisons. An examiner can use more than eleven if necessary, however because there is no worldwide standard for how many minutiae to use, eleven was selected as an amount that would grant sufficient data.

B) Comparisons

The unknown fingerprint has been examined and has been judged suitable for further examination. Its individual and class characteristics have been determined, and are sufficient enough for a comparison. A comparison is performed with a print of known origin. The known is analyzed in much the same way as the unknown fingerprint, with the exception of determining the proper method of development. Known samples are those that are obtained with full knowledge of what they are and where they came from. In the case of fingerprints, known samples are taken from a suspect by different methods. One is the typical inked print: the process of coating a person's fingertips in fingerprinting ink and rolling the fingertip onto a piece of cardstock. Another kind are scanned prints: a person can place their fingers on a scanning device that bounces light of the friction ridges and produces an electronic copy of a print. Taking a print in this manner results in high quality reference prints, used to make comparisons. An examiner

can analyze the print for individual minutiae, and compare it to those found in an unknown sample.

C) Evaluations

The examiner must come to a conclusion about the unknown sample now that enough data has been collected about the unknown and known. An examiner can choose between three results for their overall conclusion: individualization, exclusion, and inclusion. Individualization would be an identifying conclusion, in that it can be described, according to Peterson et al. (2009) as "the determination of an examiner that there is sufficient quality and quantity of detail in agreement to conclude that the two friction ridge impressions originated from the same source". The evidence has multiple points of reference and can be reproduced multiple times. Choosing individualization is essentially the point at which an examiner can say that the known and unknown fingerprints came from the same source and can be used to place a suspect or victim at a crime scene. Exclusion occurs when the opposite conclusion is reached. Lack of agreement in class and individual characteristics points to an exclusion. It can be said that there are several points that do not compare at all, or even that the class characteristic (such as loops, whorls, and arches) are different between samples. It means that the known and unknown prints do not come from the same source. This is unlike the findings, inconclusive. Here, the samples may have some similar characteristics, but they may also have unexplained dissimilar characteristics. The samples could be distorted or not fully visualized, leading to a smaller area of comparison and smaller number of available minutiae. In this scenario, there is not enough information for a conclusion.

The known and unknown samples cannot be included or excluded, unless more information becomes available.

D) Verification

Once a conclusion has been reached, the evidence must go through a verification process. Much like the reproducibly of a result in the scientific method, so too must the conclusion be confirmed by another examiner. There must be agreement in the conclusion, and there should also be similar data in the analysis and comparison of evidence as well. Perhaps not the exact data, as each examiner would have a different set of criteria and different levels of experience and therefore might use a different set of minutiae or a method than the original examiner used. But the most important aspect is that the conclusion can be reproduced, and that other expert examiners reach the same one as the original. Afterwards, the conclusion will be set at the official ending for the case and the examiner can move on to the next one.

II) Hypothesis

2.1) Scenario

Covering the history of fingerprints and their examinations is important before discussing what exactly is going to be done in this study. The scenario is thus: imagine someone breaking into a home and deciding that they cannot leave a witness to their crime. The victim is subdued, and their hands and feet bound to make it easier for the suspect to kidnap, hurt, or murder them. A commonly used item in the binding of the extremities is tape. It is usually available and very easy to obtain. Few people realize

fingerprints can be obtained from tape. There are generally two different spots on the tape where a suspect would leave multiple, likely full prints. At the beginning, when they are first placing the tape on the victim and sticking to skin or clothing and at the end, when they are finishing off the restraints. Would an examiner be able to use those prints for analysis? This study focuses on what would happen if an examiner attempted to obtain fingerprints from the adhesive side of tape after it has been stuck to a piece of fabric. There are three different types of tape: Duck brand grey duct tape, Duck brand black electrical tape, and Gorilla brand packaging tape. The composition of the fabric supports are: a 60% cotton/40% polyester blend, fleece, flannel, 100% polyester (exercise pants), spandex, 100% denim, jeans (77% cotton, 23% elasterell), and vinyl. The four separation techniques used: manually pulling the tape and fabric apart (control), a 1:1 xylene-chloroform mix, Un-Du commercial adhesive remover, and liquid nitrogen.

There are numerous studies of obtaining fingerprints from the smooth (non-sticky) side of tape, separating the tapes themselves (from the adhesive or sticky side stuck to the smooth side, from the adhesive side stuck to another adhesive side, and from the tape being stuck to a different substrate, such a cardboard). Taking prints from the adhesive side of tape, after it has been stuck to fabric has not been researched. Will removing tape from fabric interfere with other examinations conducted on the tape and can it be used in conjunction with other fingerprinting techniques?

2.2) Bloody Prints

One of the first things to consider about this technique is if it can be used on bloody prints, and if DNA evidence can still be obtained after the examination. Blood evidence

can often be found on a piece of tape wrapped around the victim, and as such should be analyzed at the same time as any fingerprints found on the tape. Bloodied fingerprints are generally enhanced with a couple different developers, the best being, according to the Fingerprint Source Book (2012) three different acid dyes: acid black 1, acid yellow 7, and acid violet 17. Acid black 1, also known as Amido Black, is a protein stain. Those proteins that are found in blood are given a blue/black color. Below is the chemical structure of acid black 1, and the appearance of a fingerprint developed with the acid (Fingerprint Source Book, 2012).

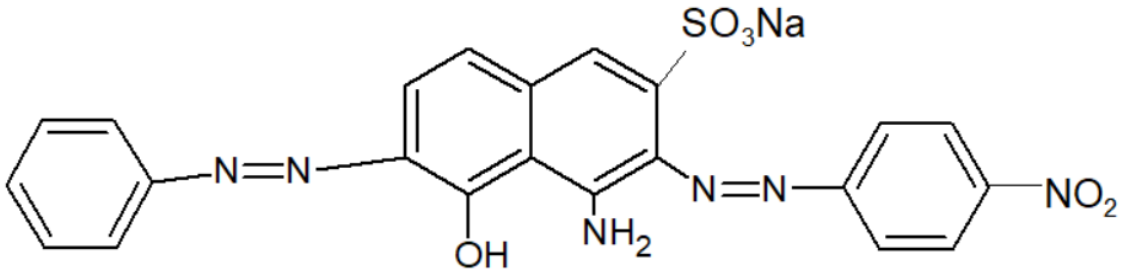

Figure 4: The structure of Acid Black 1

Figure 5: Acid Black 1 Stain with Developed Prints

Researchers have noted in their publication the Fingerprint Source Book (2012), that acid yellow 7 also stains the proteins in blood. Here, the fingerprint develops into a pale yellow color that fluoresces when viewed under the blue/green illumination (385-509nm). Acid yellow 7 provides excellent contrast and detail when used with fingerprints on darker, non-porous surfaces. However, it is more difficult to remove from the background of porous surfaces and such be used with caution in such cases. Below is the chemical structure of the dye, along with a developed fingerprint.

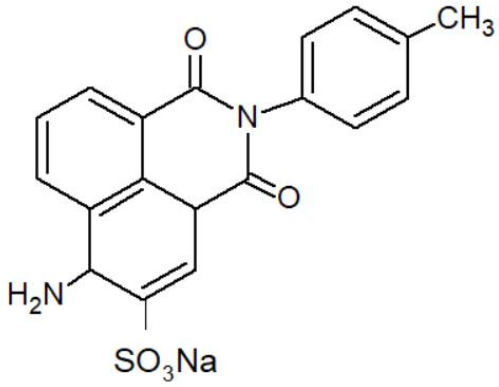

Figure 6: Structure of Acid Yellow 7

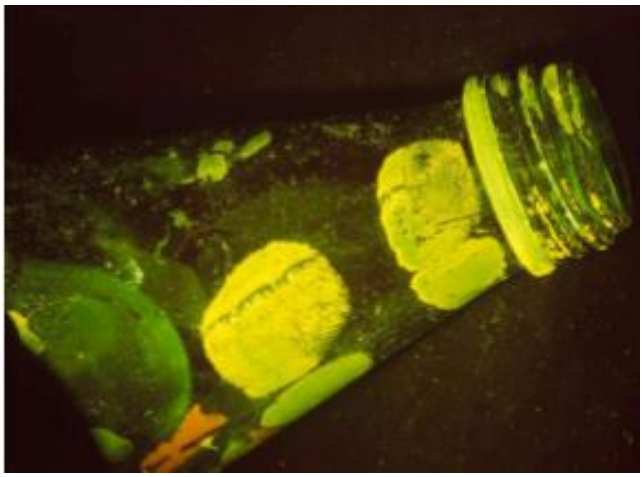

Figure 7: Developed Prints with Acid Yellow 7

Acid violet 17 turns the proteins in blood a bright violet color. It can also be absorbed by some porous surfaces, and as such there should be a control to determine just how deeply it stains on the specific substrate being examined (Fingerprint Source Book, 2012). Below is the chemical structure of acid violet 17, and the appearance of a print developed with it.

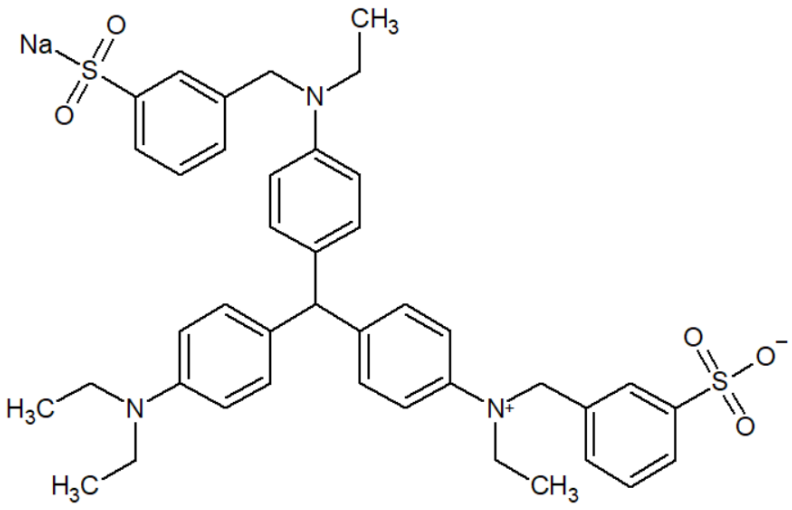

Figure 8: Structure of Acid Violet 17

Figure 9: Developed Prints Using Acid Violet 17

The theory behind how these acid developers work is explained in the Fingerprint Source Book (2012). Blood is made up of 45% red blood cells and 55% plasma. This

cellular fraction contains three different types of cells: red cells (erythrocytes), white cells (leukocytes) and platelets (thrombocytes). The red cells contain the hemeoglobin protein, but also have surface proteins that determine blood group. White cells are those that have a nucleus, and thus contain DNA. They are part of the immune system. In fingerprinting, the focus is on the hemeoglobin protein from the red cells. It is made up of four protein subgroups, each containing a heme group (Figure 10). This group of proteins is what reacts with the acid dyes. They do not react specifically with blood, but with proteins. Blood itself just happens to be made up of a lot of proteins, and as such the acid dyes have ample opportunity to react. They often have one or more sulfonate groups ($-SO_3$), which function in two ways. The first allows for solubility in water or alcohol, the preferred major solvents the acid dyes are applied in. The second is the negative (anionic) charge that attracts to proteins in acidic solutions as the solution slowly changes the blood protein charge to positive (cationic) thus attracting the acid dyes. It is possible that hydrogen bonding and Van Der Waals bonds may also help attract the dyes to the proteins. Applying these charges is done in a three-stage process. First, the marks are mixed with a 5-sulphosalicylic acid solution in water. Doing so precipitates the negatively charged proteins, and so prevents the diffusion of the marks and any potential loss of detail. This first fixing step also gives an edge to the fingerprint examination process, because it makes the acid dyes more sensitive, and often gives clearer and more sharply defined friction ridges. Secondly, the marks are treated with an acidic protein stain that dyes the precipitated negatively charged proteins to give the colored products. The last step is washing the evidence after staining. On non-porous substrates this removes excess dye, allowing an examiner to properly see the developed

print. On porous substrates, the washing also acts as a de-stainer, removing dye that has stained the background of the substrate. Because potentially washing away the dye from the target area might remove some of the dye from the fingerprint, or desaturate the color to the point of little contrast, this solution is generally the same (with perhaps a smaller concentration) as the staining dye (Fingerprint Source Book, 2012).

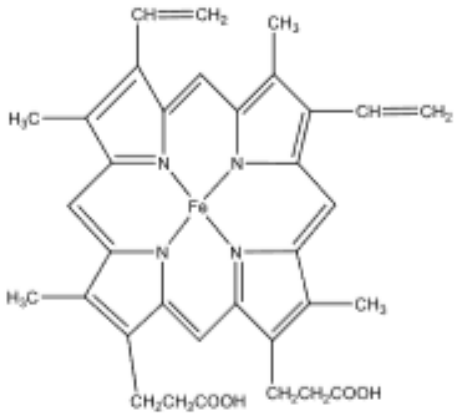

Figure 10: Structure of the Heme Group

The method of separating sticky tape from the substrate can also be important, as some of the most common solvents may degrade DNA. A study from Ridolfi (2002) shows that one of these solvents, a liquid adhesive removing spray called Un-Du, does not interfere with obtaining DNA from an envelope. It was determined that using Un-Du to separate the sticky part of the envelope did not cause any degradation of the DNA evidence collected after it was used. This is further supported by Spear et al. (2015). They analyzed about thirty different bloody prints using a variety of fingerprinting techniques, and then determined if it was possible to obtain a PCR based DNA profile after doing so. They used bloody fingerprints on different surfaces, such as newspaper,

glass, duct tape, and aluminum cans. The fingerprinting methods used Un-Du, Ninhydrin, Amido Black, Cyanoacrylate, Physical Developer, Leuco Crystal Violet, Genetian Violet, and Sticky Side Powder as well as various combinations of the above. Spear et al. obtained a working DNA profile in every instance, except for Un-Du and Sticky Side Powder, as their result show in Figure 11. They determined that even though it was possible to obtain DNA from the processed fingerprints, it was often a small amount, especially compared to the amount obtained from unprocessed prints.

Treatment of bloodstain on swab using:	**PCR-based DNA Typing**
Amido Black	OK
DFO (diaza-fluorenone)	OK
Fluorescin	OK
Leuco Crystal Violet	OK
Merbromin	OK
Ninhydrin (dihydroxyindane-1,3-dione)	OK
UV Light	Use with care
Fingerprint Processing of Single Bloody Prints with:	
Un-do	OK
Un-do + Ninhydrin	OK
Ninhydrin	OK
Vacuum Metal Deposition	OK
Amido Black	OK
Amido Black+ Leuco Crystal Violet	OK
Leuco Crystal Violet	OK
Physical Developer	Use with care
Genetian Violet	OK
Cyanoacrylate + Sudan Black	OK
Cyanoacrylate + Rhodamine 6G	OK
Cyanoacrylate + Rhodamine 6G + Powder	OK
Cyanoacrylate + Rhodamine 6G + Vacuum Metal Deposition	OK
Stickyside Powder	Not OK
Un-do + Stickyside Powder	Not OK

Figure 11: Part of the Table showing the DNA profiling results

This was also shown to be the case when examining bloodied fingerprints by Au et al. (2010). They used white sticky side powder to enhance a print on a dark surface, and

then attempted to gain a DNA profile from the print. It was determined that while possible, using the sticky side powder greatly decreased the amount of DNA obtained. Au et al. (2010) used an acid dye in conjugation with the sticky side powder for enhancement. The acid dyes are used to enhance fingerprints in blood, as they react with the proteinaceous components in blood and other body fluids. However, they can at times provide little contrast to the print on the substrate on which the mark was found, making it more difficult to analyze the print for any identifying characteristics. It was hoped that the sticky side powder could provide the necessary contrast, and it did, as shown below in Figure 12. In doing so, nearly all available DNA was lost (Au et al., 2010).

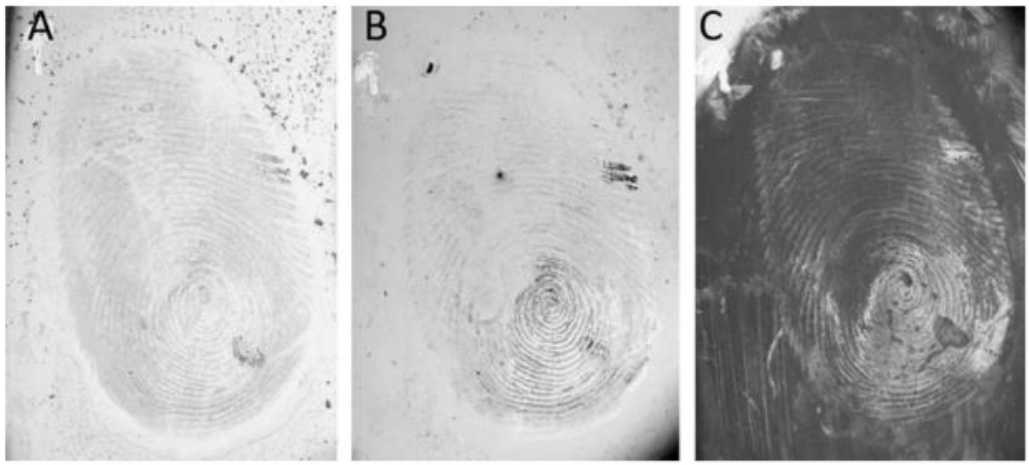

Figure 12: The developed fingerprints. A) No enhancements B) Acid Dye Enhancement C) Acid Dye and White Powder Suspension Enhancement

To put this all together in the context of the study, it is possible to obtain DNA evidence from bloodied prints. None of my four separation techniques should interfere with any DNA evidence, with the exception of the Un-Du, as that will be used in combination with sticky side powder, and as Spear et al. (2015) reported, there was no

useable information gained during that experiment. However, the liquid nitrogen separator was determined to be the best, and thus the one used for any laboratory analysis. It will not degrade or destroy any DNA evidence. The developer used in this study, the sticky side powder, will be able to obtain DNA evidence, though the amount available with be significantly decreased.

Specifically, for this study, the circumstances are a bit different, though the overall results would be similar to those observed in the above articles. The bloodied marks on the adhesive side of a piece of tape are available for DNA profiling. The blood itself tends to slightly permeate the fabric when it is stuck to the tape, and is a source for DNA that wouldn't be interfered with the sticky side powder, only the separation techniques. None of the techniques will degrade the DNA based on previous studies. It is also seen that very wet prints tend to smear on the tape, and leave distorted ridge details. Prints that are bloodied but not completely wet, actually develop fingerprints with ridge detail that can be seen with the naked eye. Au et. Al (2010) have also noted that wet fingerprints tend to clump together when used with sticky side powder, resulting in a very large decrease in ridge detail. It is suggested then, that when examining a bloodied fingerprint using this technique, the analyst should separate the tape from the fabric first using liquid nitrogen. Then obtain a DNA sample before further developing the print with sticky side powder. One should first attempt to take a DNA sample from the fabric, and if not successful, move on to the print itself. Then the analyst should develop the print with sticky side powder and one of the acid dyes (depending on the color of the tape) and continue their examination from that point. This may reduce the quality of the print, and decrease the number of available minutiae, but DNA evidence would come

before fingerprints in terms of evidentiary value, as DNA tends to be more credible evidence when presented in court.

2.3) Cyanoacrylate

Another technique used to analyze fingerprints on tape is cyanoacrylate, more commonly called superglue fuming. It is typically used in conjunction with a fluorescent enhancer. The instrument design was simple, according to Bumbrah (2017). An analyst can stick their evidence sample into a large chamber with a small container of superglue, and a glass of water, and then heat the glue up. According to the Fingerprint Source Book (2012) it was first in the early 1980s, where the process was relatively slow, and provided less than optimum friction ridge detail. Advancements were made, and it was determined that heating the superglue was an important step. The relative humidity of the air inside the chamber was crucial to both the speed and the sensitivity of reaction. Eventually, a commercial chamber was developed that allowed for controlled humidity during the process. The instrument does not have to be a humidity-controlled chamber, as there were experiments with a vacuum chamber that were also successful. It is generally not used by itself, and several kinds of fluorescent enhancers came to be. The first was Rhodamine 6G (basic red 1), used in a methanol solvent. Unfortunately, methanol was very hazardous through skin absorption, and Rhodamine 6G was also a suspected carcinogen. Soon after basic yellow 40 was developed. In a solution with ethanol, it has very low toxicity, and yields high fluorescence under the blue region. It also makes the enhancements much stronger, leading to more fingerprints being found than could be seen with only superglue fuming (Fingerprint Source Book, 2012).

The exact mechanism behind superglue fuming is still unknown, though a theory has been proposed. According to the Fingerprint Source Book (2012) the fingerprints that become visible using superglue fuming as the developer do so because white deposits are much more likely to first form on the friction ridges. The white deposits are polycyanoacrylate, formed during a polymerization reaction with the cyanoacrylate monomer. Shown in Figure 13 below is the reaction to form ethyl cyanoacrylate (Fingerprint Source Book, 2012).

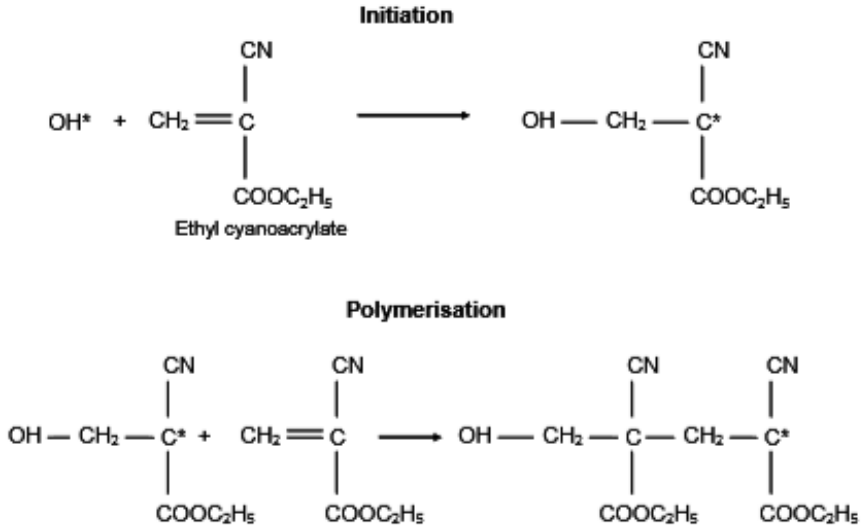

Figure 13: Chemical Reaction to form ethyl cyanoacrylate

The Fingerprint Source Book (2012) posits that the relative humidity it important in the development process. It has been seen that the poly-ethyl-cyanoacrylate forms long, fibrous growths at a relative humidity of 80% that were not present when the relative humidity was 40%. The growths make it easier to see the developed fingerprint with the naked eye. The actual polymerization reaction is initiated by bases; even water, a very weak base, can initiate polymer growth. By increasing the relative humidity to 80%, the

sodium chloride crystals in the fingerprint will take up water. If the sodium chloride solution is saturated with excess solid in an enclosed space, it will create a relative humidity above the solution of 75% at equilibrium (Fingerprint Source Book, 2012).

As such, the Fingerprint Source Book (2012) concludes, if the developing chamber has a relative humidity above that value, the sodium chloride crystals start to absorb water from their surrounding environment. This leads to the notion that the sodium chloride crystals inherent in a latent fingerprint will absorb water when in a space that has a relative humidity of 80%. This process is one of the explanations possible for the mechanism of polymer growth. There are potentially many other bases within the fingerprint residues which could also initiate polymerization. However, most fingerprints are left behind with a high concentration of water and chloride content, and so the mechanism proposed is more likely to be one occurring. Figure 14 shows a schematic of the mechanism. It may also be possible that short chains, such as oligomers, of cyanoacrylate are formed due to the atmospheric humidity, which could play a part further down the process for more polymerization on the fingerprint, or the substrate. If the relative humidity is lower than 75%, the fingerprints tend to be underdeveloped, while relative humidity levels above 80% overexpose the fingerprint; making it difficult to distinguish between the background and the print itself. It is possible to see these developments below, in Figures 15 and 16 (Fingerprint Source Book, 2012).

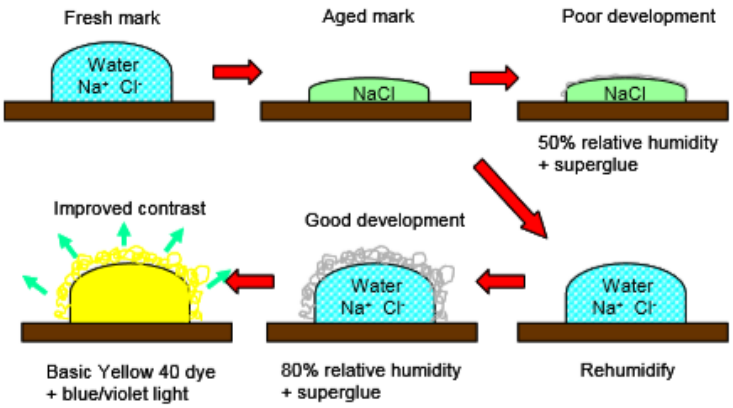

Figure 14: Schematic of the Polymerization Mechanism

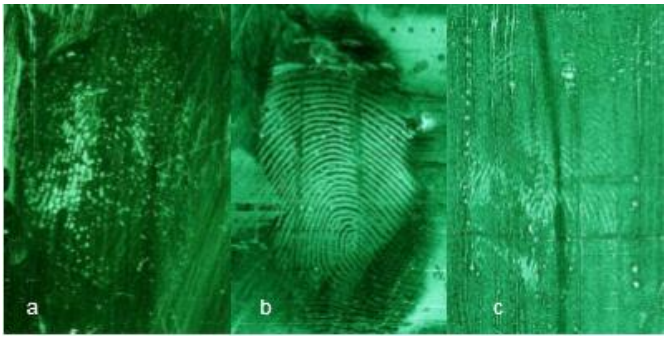

Figure 15: Fingerprints developed at A) 60% B) 80% and C) 100% relative humidity

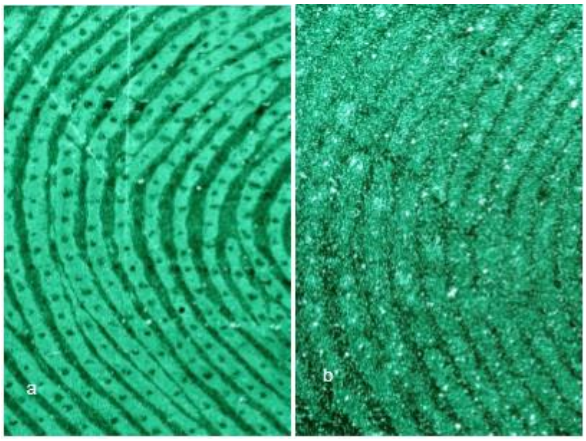

Figure 16: Closer view of a print at A) 80% relative humidity and B) 100% relative humidity

Superglue fuming is an important technique in regards to non-porous surfaces, as it tends to give excellent, highly developed fingerprints. It the preferred method used when developing prints on the non-sticky side of duct tape. It is important to ensure that the technique developed in this study does not interfere with subsequent examination of fingerprints using superglue fuming. Of primary concern is the separation techniques. Bumbrah (2017) states that the use of Un-Du had no effect on further testing with superglue fuming. Liquid nitrogen also did not affect it, as the freezing process does not permanently affect the latent fingerprint. Whether or not the 1:1 xylene-chloroform mix would be detrimental is unclear. However, it is completely possible to do superglue fuming before any separation is done. Doing so would not affect the fingerprints hidden underneath the fabric, as the oils that make up the print are not exposed to the air. The developed print would not be damaged by any of the separation techniques.

The development method for the fingerprints in also important, as they should not interfere with each other. The sticky side powder used in this study should be acceptable. The Technical Procedure for Sticky Side Powder (2013) states that the formula may be used after superglue fuming and can be followed with fluorescent dyes (to enhance any prints found from superglue fuming) or laser examinations. The procedure to be used with the technique in this study would then be to start with superglue fuming first, to develop any marks on the non-sticky side of the tape. Follow that with the separation of tape and fabric. Develop any prints on the adhesive side of the tape using sticky side powder. Once examination of the fingerprints on the adhesive side is concluded (including photographs), then further enhance the print on the non-sticky side with fluorescent dyes.

2.4) Sticky Side Powder

According to the Bleay et al., (2012) sticky side powder was developed in the mid 1990s, containing a pre-mixed powder combined with Kodak Photoflo surfactant and distilled water (The Fingerprint Source Book, 2012). The suspension is painted on the adhesive side of tapes and washed off using running water. At the time, it was compared to other techniques used to develop fingerprints on the adhesive side of tape. There were several studies to determine which powder would be the best to use in examinations. In the late 1990s, the Police Scientific Development Branch joined the fray, and carried out an assessment on the original sticky side powder formula using electron microscopy. It was determined that the base powder consisted of small, fine particles (about 1µm) of iron oxide, scattered with larger (10-20µm) flakes of aluminum. Other powder formulas were investigated. One was a black powder suspension with precipitated magnetic iron oxide, as well as a white powder suspension based on titanium oxide. They were tested against the original sticky side powder, and the black powder formula was determined to be superior. It was then tested against other techniques for adhesive tape, with results only slightly better than superglue or basic violet 3. For the white powder suspension, the titanium oxide formula was determined to be the best, though for best application the tape should be submerged in the solution, which was time consuming (Fingerprint Source Book, 2012).

It wasn't until the mid 2000s, that the only application for sticky side powder was on the adhesive side of tapes (Bleay et al., 2012). A study showed that sticky side powder was the most effective developer of fingerprints in regards to marks on cars, including

ones that were wet prior to being painted with the solution. There have also been studies regarding their use for the treatment of articles recovered from the scenes of an arson, where the powder removed soot deposits and developed marks. An analyst may also use sticky side powder when examining plastic bags, and surfaces contaminated with drugs. When determining if it was possible to use the sticky side powder with superglue fuming, results were not encouraging. It was found that no matter which order it occurred in, trying to enhance the prints developed with sticky side powder with superglue fuming or vice versa, the two techniques were mutually exclusive. Further, it was discovered that though the components for the white powder suspension still gave the best results, there was a new formula that beat out the iron oxide formula. Using a black powder that was carbon based instead was more effective in obtaining well developed fingerprints on lighter colored adhesive tape (Fingerprint Source Book, 2012).

The mechanism behind sticky side powder is still unknown, though the Fingerprint Source Book (2012) has developed a potential theory. It is believed that the micelles are formed around the particles by the surfactant. Some unknown component or property of the fingerprint weakens these micelles, leading to the particulates more likely depositing on the friction ridges in a latent print. Figure 17 shows the particles developing on the ridges, but not on the background of the surface the print is on. However, there are some small differences in how the sticky side powder works compared to small particle reagent, which is likely contributed to the fact that there are much higher concentrations of powder in the sticky side powder solution. Carbon based black sticky side powder, along with titanium oxide based white sticky side powder is recommended for the examination of fingerprints on adhesive surfaces (Fingerprint Source Book, 2012).

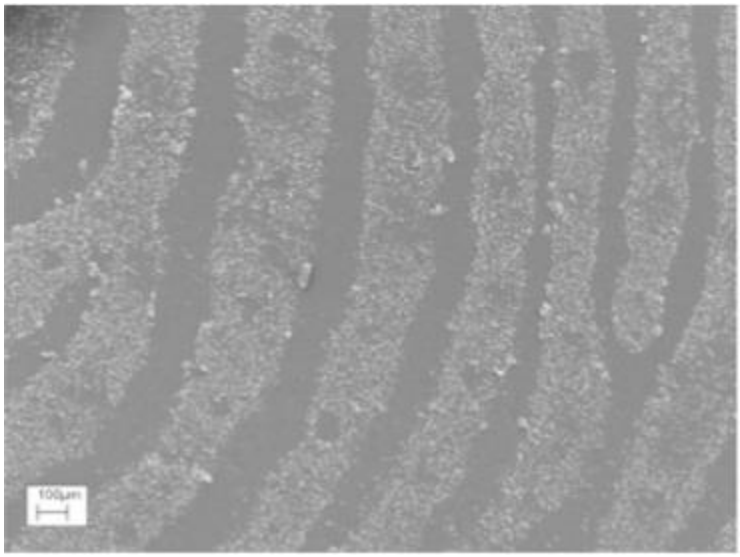

Figure 17: Scanning Electron Microscope image of the particles on the friction ridges of a fingerprint with sticky side powder

III) Experiment

3.1) Methods and Materials

There was some discussion about which materials to use in this study, and whether they would provide accurate results or even work. The tapes used are three very common ones, Duck brand grey Duct Tape, Duck brand black Electrical Tape, and Gorilla Packaging Tape. The articles of clothing were common ones, worn all the time by most people. This is why items with the same consistency as regular t-shirts and jeans are included, along with the spandex and exercise pants, for victims out exercising that may be easier prey to a suspect.

The methods used for separation were also chosen as options for adhesive removals. The Un-Du has been shown to provide good separation, according to Stimac (2002). When attempting to separate the tape from the substrate it is stuck to, the scrapper on all

commercially available bottles of Un-Du can be troublesome. It is possible to destroy some of the latent print doing so, and it is easy to oversaturate the tape in this manner as well (Stimac, 2002). Before moving on to the actual experiment, trials using different methods of separation with the Un-Du were conducted. I tried to use the scrapper (bottle and scrapper shown in Figure 18), putting it all the way under the tape to lift it off the fabric. I also only lifted corners of the tape, and tried to drip the Un-Du solution between the tape and the fabric. I performed a combination of the two, where I slowly dripped the Un-Du between the two layers while lifting it with the scrapper. Finally, I also tried the process recommended by Stimac (2002) for porous surfaces. Here, the Un-Du was applied to the side of the fabric without tape, so that the solution would soak through the fabric and remove the adhesive sticking the tape and the fabric together. It was easy to peel off in this manner, and also greatly reduced the possibility of oversaturating the tape and potentially washing away any latent fingerprints. The first three trials gave fingerprints with some detail, though very clearly obscured in spots. The last trial, soaking the fabric, gave the best results and was used in the actual study. The 1:1 xylene-chloroform mix was suggested by a seasoned forensic scientist, Professor Ridolfi, as a possible adhesive separator as well.

Figure 18: Commercial Un-Du adhesive remover with attached scrapper

The liquid nitrogen as a separator has several articles devoted to it, though there was some concern with regards to the duct tape potentially falling apart after it has been submerged in the liquid nitrogen (Bergeron, 2008) as shown in Figure 18. Bergeron showed that the different brands of tape reacted in unpredictable ways. Some brands would hold up under the strain of separation after liquid nitrogen was applied, while others did not. It was also decided that the best time for submerging the sample and obtaining good results was 30 seconds (Bergeron, 2008). Another, more recent study used a liquid nitrogen spray, instead. There, the samples did not break apart, and also gave fingerprints with well defined friction ridge detail after being developed with sticky side powder (Bailey and Crane, 2011). I conducted several trials as well, to determine how long the samples should be submerged in the liquid nitrogen to give readable results. I dipped samples into the liquid nitrogen for about 5 seconds, 10 seconds, and 30 seconds. While there was no discernible different between the sample for 5 and 10 seconds, the 30 second trial was harder to peel apart, with potential cracks developing on

the tape (mostly the Packaging Tape) that could obscure the latent fingerprints. In the actual experiment, I briefly dipped the samples in the liquid nitrogen before separating them.

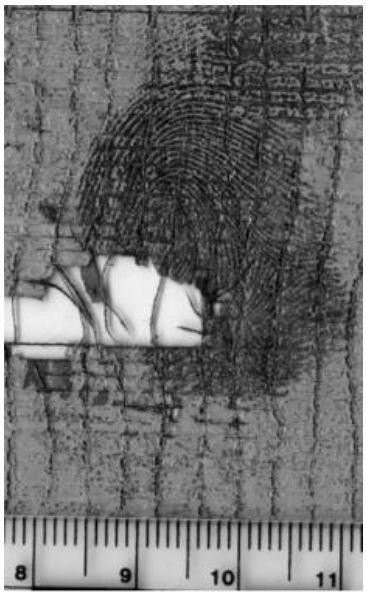

Figure 19: Example of a piece of duct tape having torn after separation with liquid nitrogen

The developer used was black, carbon based and white titanium oxide based WetWop. With sticky side powder by itself, the analyst has to prepare it, according to the Processing Guide for Developing Latent Prints (2000). This means mixing one teaspoon of the sticky side powder with a 1:1 mix of Kodak Photoflo 200 and distilled water (about 30mL each) to make the solution have a consistency of thin paint. WetWop is essentially sticky side powder, except pre-mixed.

3.2) Sample Preparation

The preparation of samples was simple. Square pieces of fabric were cut in triplicate and separated into four groups for separation. I impressed my fingerprint into the three different kinds of duct tape (rubbing my fingertip across an oily surface on my face is necessary) and placed them on each piece of fabric. I placed the tapes into a brown paper bag with the correct label and let them sit for no longer than two days. This created a total of 96 samples. I also mixed the 1:1 xylene-chloroform mixture together, and stored it inside a brown, glass bottle. Black WetWop was used for the Packaging Tape and Duct Tape, while white WetWop was used for the black Electrical Tape.

3.3) Procedure

Using the pulling apart separation first, I carefully pulled the tape from the fabric with tweezers, and then set it aside. I painted the adhesive sides of the tape with WetWop and let it sit for about 15 seconds. The tape was then rinsed under cold, gently running water, with as much excess WetWop removed as possible. I then set it aside to dry. After doing so, I placed each piece of tape on a blank, white sheet of computer paper to have good background contrast and took a photograph using my phone.

The procedure for the Un-Du and 1:1 xylene-chloroform mix was the same. To separate the fabric from the tape, I dripped small amounts of each solution onto the back of the fabric (enough to slightly wet the fabric but not soak it), and then pulled the two layers apart using tweezers. The only exception was for the vinyl samples here. They would not soak through, and so, I pulled a corner up using the tweezers, and slowly added the liquid between the two layers, pulling them apart without completely saturating the adhesive. I did have to dispose of the fabrics for the 1:1 xylene-chloroform mix

quickly, as the fumes were permeating the air. After the tapes were dried, I processed them with a thin layer of WetWop, and then took pictures on a white piece of paper.

I dipped each sample into the liquid using metal tongs, and then carefully pulled them apart using tweezers. The easiest way to do this with was the black Electrical Tape, as the tape itself would completely freeze, and I could simply tilt my fabric and have the tape slide off. The most difficult to separate from the fabric was the packaging tape, as it tended to freeze to some of the fabric, particularly the vinyl. I had to wait for it to start melting again before I could fully separate the two.

For each separation test, I had a reference tape as well, that was created and developed at the same time as the sample. My reference print was done by rolling my index finger (the same finger used in all my samples) in fingerprinting ink, and then depositing it on a cream-colored piece of cardstock.

3.4) Data

The photos of the prints have been edited using a free online software, pixlr. Mainly changes in the background color and contrast to produce a sharper image. Not all taken images were included, these are some of the best from each separation test.

Figure 20: Pulling Apart Separation from Packaging Tape with Fleece Fabric

Figure 21: Pulling Apart from Cotton/Polyester Mix with Packaging Tape

Figure 22: Pulling Apart from Polyester with Black Electrical Tape

Figure 23: Pulling Apart from 100% Denim with Duct Tape

Figure 24: Pulling Apart from Spandex with Packaging Tape

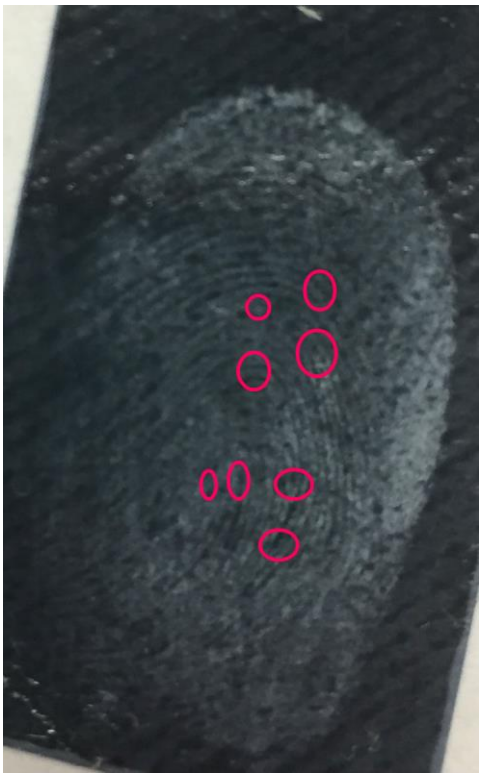

Figure 25: Un-Du from Denim with Black Electrical Tape

Figure 26: Un-Du with Polyester from Black Electrical Tape

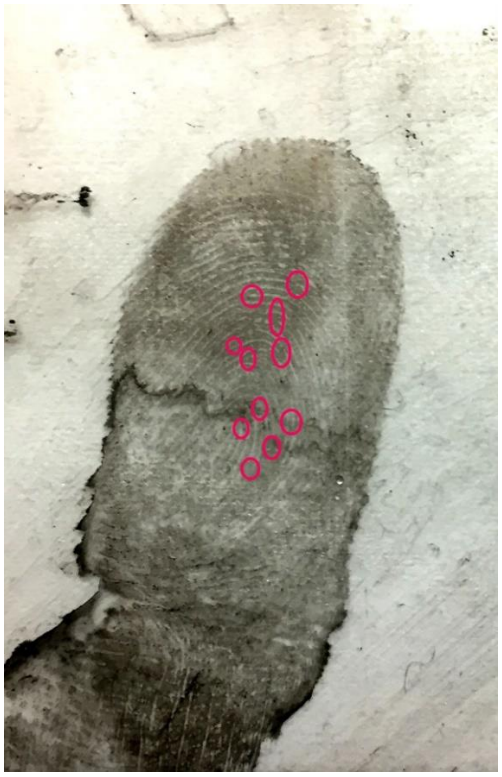

Figure 27: Un-Du from Spandex with Packaging Tape

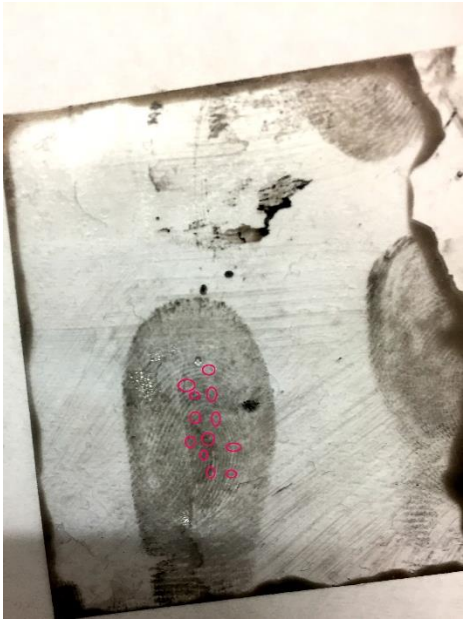

Figure 28: Un-Du from Jeans with Packaging Tape

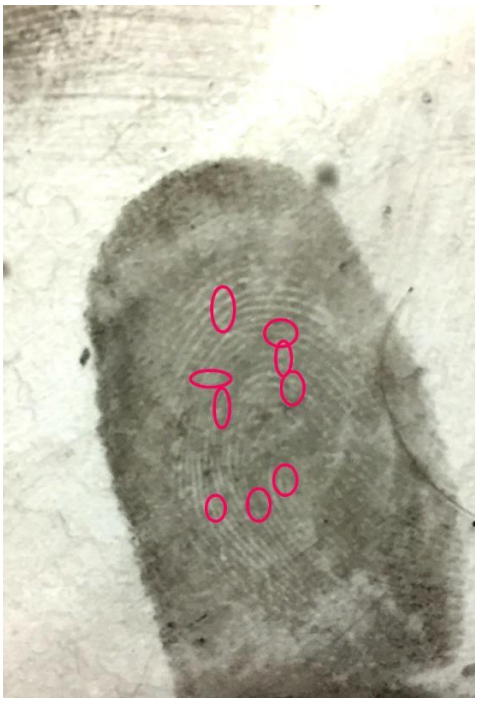

Figure 29: Un-Du from Fleece with Packaging Tape

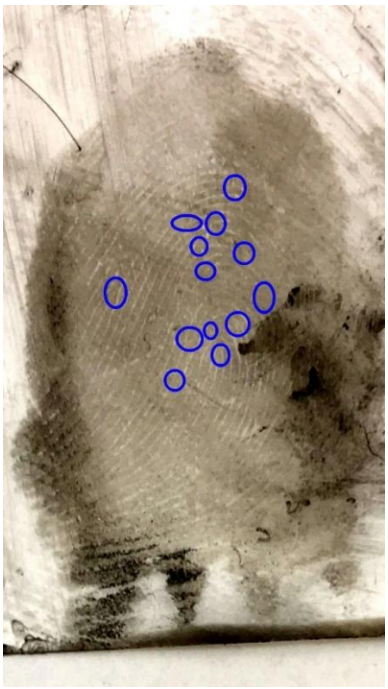

Figure 30: 1:1 Xylene-Chloroform Mix Cotton/Polyester Mix Packaging Tape

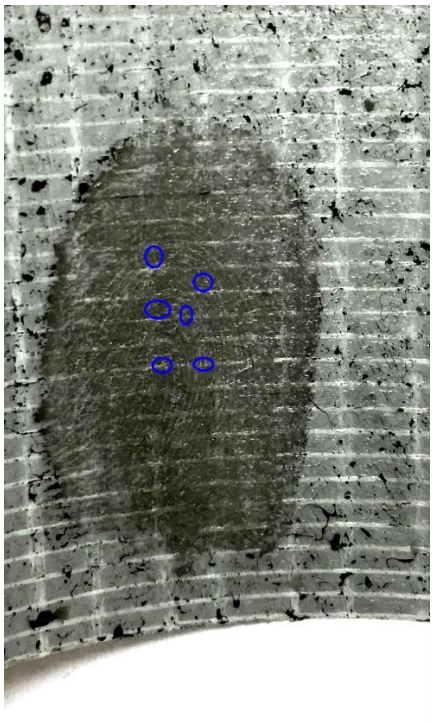

Figure 31: 1:1 Xylene-Chloroform Mix with Fleece from Duct Tape

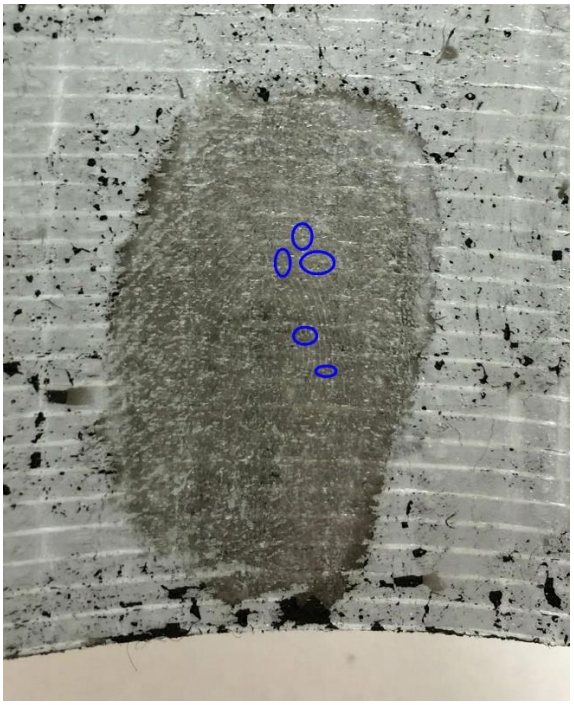

Figure 32: 1:1 Xylene-Chloroform Mix with 100% Polyester from Duct Tape

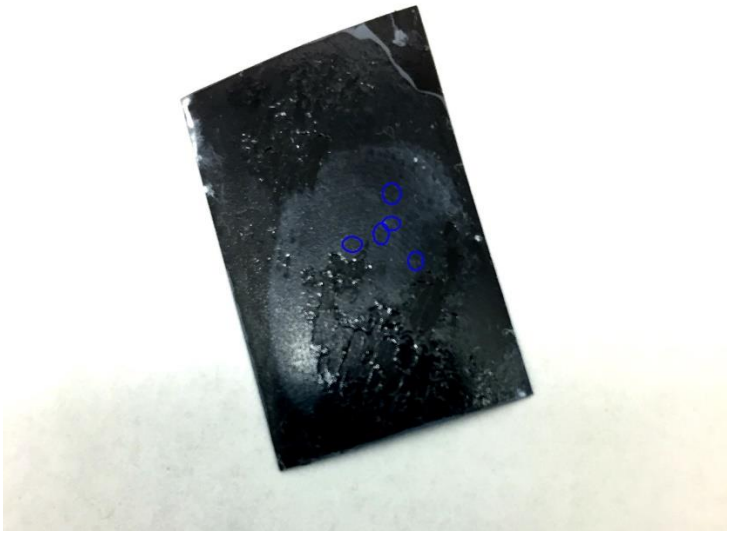

Figure 33: 1:1 Xylene-Chloroform Mix from Cotton/Polyester Mix with Black Electrical Tape

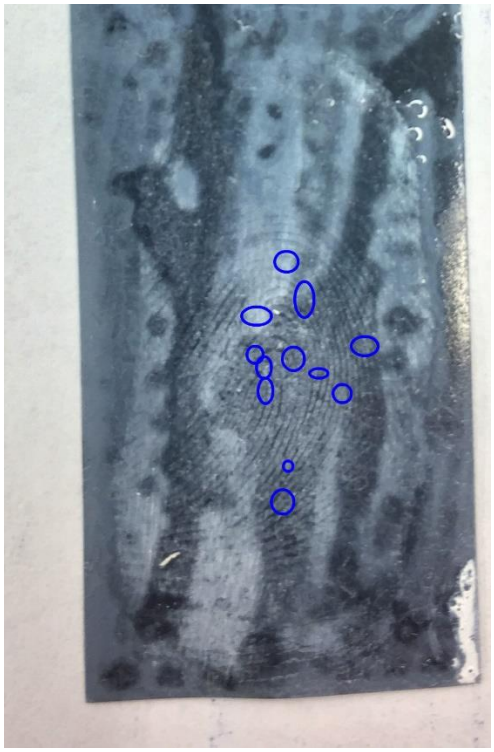

Figure 34: Liquid Nitrogen from Fleece Black Electrical Tape

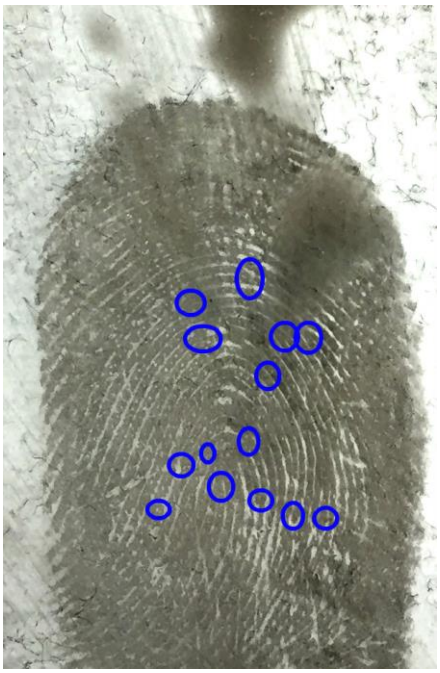

Figure 35: Liquid Nitrogen from Jeans with Packaging Tape

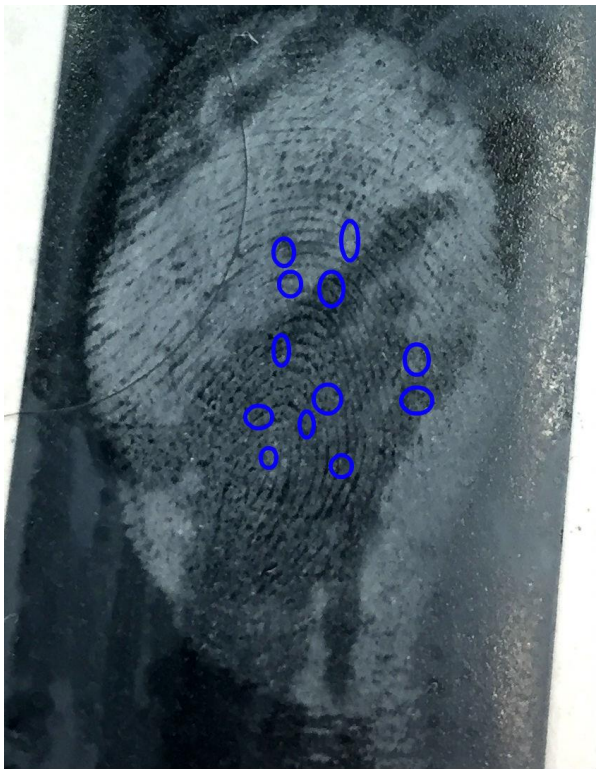

Figure 36: Liquid Nitrogen from Spandex with Black Electrical Tape

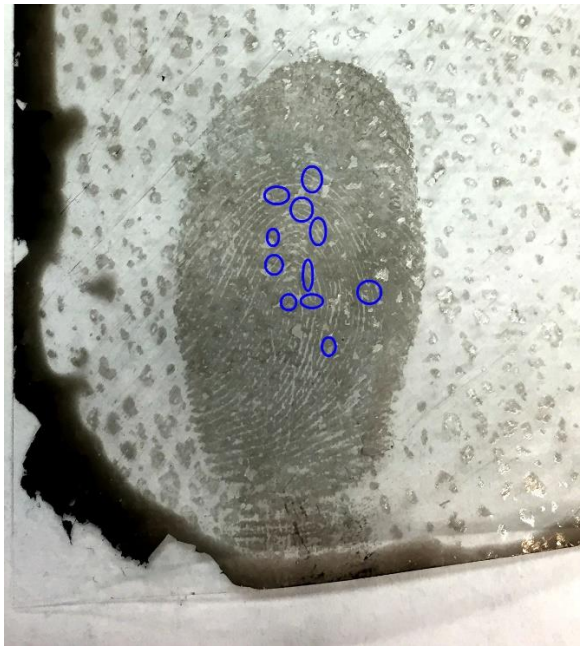

Figure 37: Liquid Nitrogen from Vinyl with Packaging Tape

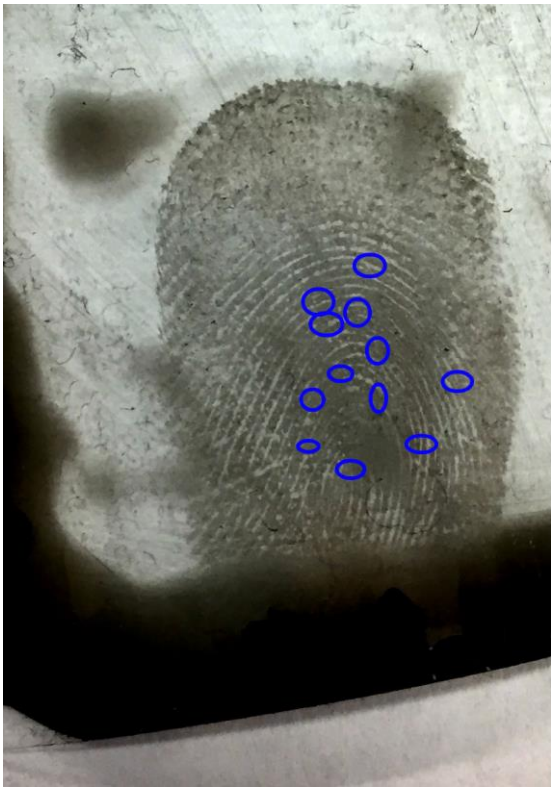

Figure 38: Liquid Nitrogen from 100% Polyester with Packaging Tape

		Fabric Type							
		Cotton/Polyester	Spandex	Denim	Jeans	Fleece	Flannel	Polyester	Vinyl
Tapes	Separation Techniques								
Duck Brand Duct Tape	Control	5	2	0	1	0	0	1	1
	Un Du	8	0	0	0	2	0	2	0
	1:1 xylene-chloroform	0	0	2	5	6	6	5	0
	Liquid Nitrogen	5	5	5	1	5	2	1	4
Duck Brand Black Electrical Tape	Control	3	1	5	12	1	5	12	5
	Un Du	6	9	6	7	1	9	12	3
	1:1 xylene-chloroform	5	0	0	0	0	0	0	0
	Liquid Nitrogen	12	12	7	0	5	12	12	5
Gorilla Brand Packaging Tape	Control	12	12	6	2	3	12	12	12
	Un Du	7	12	8	12	8	12	12	4
	1:1 xylene-chloroform	12	12	5	6	6	6	2	5
	Liquid Nitrogen	7	12	12	12	5	12	12	12

Table 1: The results for the minutiae found on all samples. Red spaces are considered no prints (gave 0-4 minutiae). Orange spaces are partial prints (gave 5-11 minutiae). Green spaces are considered full prints (12+ minutiae).

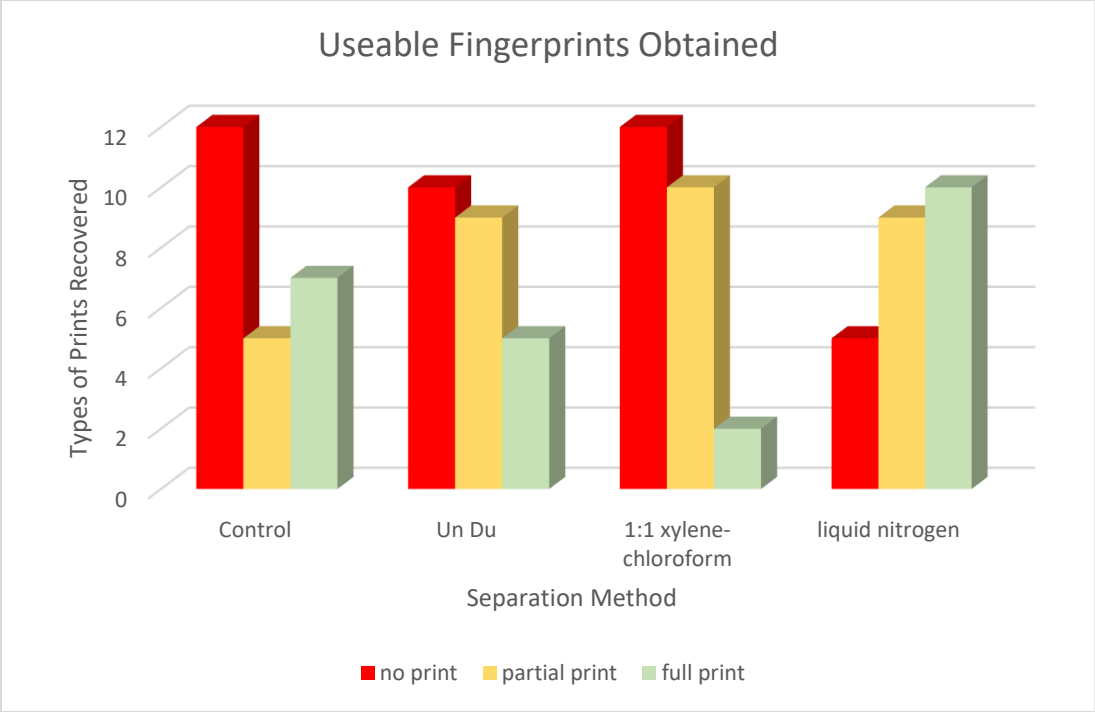

Figure 39: Collected Information on the Separating Methods

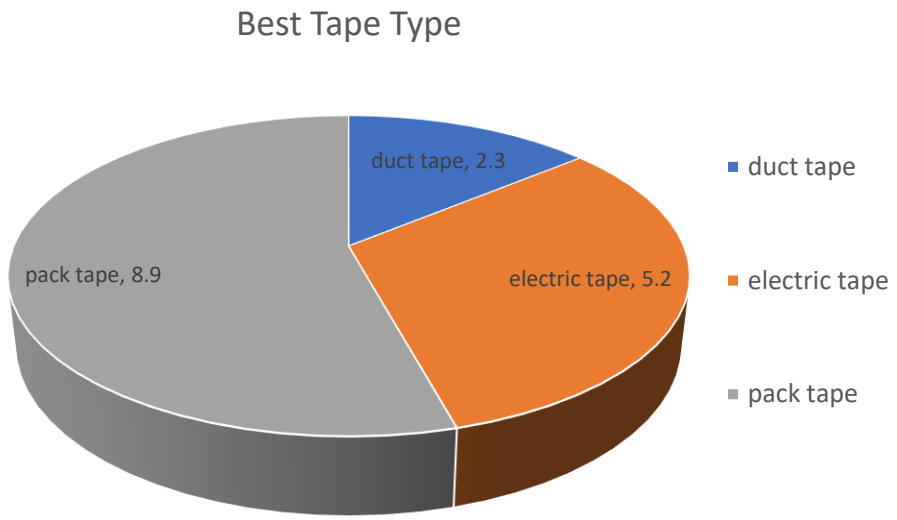

Figure 40: Collected Information on the Tapes, showing the average amount of useable (green prints) obtained from each tape

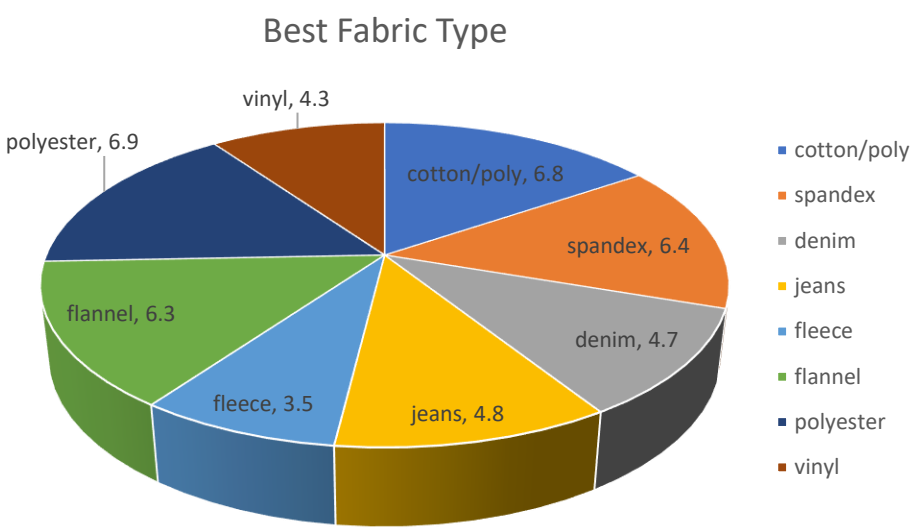

Figure 41: Composition of Backing of Fabric Tapes

3.5) Results

The overall results across the experiment indicated that the separator best used was the liquid nitrogen, as it provided more full prints than the other three. The best tape, that again gave the most prints with 12+ comparison points, which was the packaging tape. And the best fabric, that gave the highest amount of comparison points, after averaging those collected for each type of fabric was the 100% polyester (exercise pants) with the 60% cotton/40% polyester mix coming in at a very close second.

Curiously, many of the samples that were separated using the 1:1 xylene-chloroform mix appeared to have their adhesive almost melt, destroying the friction ridges in those areas. While unsure of the exact process occurring, I am proposing this theory: like dissolves like. Essentially, because the adhesive is made out of a natural rubber,

comprised of non-polar hydrocarbons and the 1:1 xylene-chloroform mix was also mainly composed of non-polar hydrocarbons, that when the two met, they started to dissolve in some spots. When a solution is applied in drops on a piece of fabric, it tends to soak the spot where it was originally hit, with the edges starting to spread and dilute through the fabric, instead of being wet all the way through. The 1:1 xylene-chloroform mix was applied in drops at the edges of the fabric and so those spots where it originally hit could have soaked through all the way to the adhesive, causing the dissolution of the rubber on the tape. Those areas that did not experience the original spot, but rather the spread out version, did tend to give very good results. In the field, it would be impossible to guess where exactly a fingerprint is, so it might be worthwhile to drip the solution just along the outer edges of the tape. The type of fabric is also relevant, because the thinner the piece of fabric, the more likely it is that all of the 1:1 xylene-chloroform mixture will soak through and dissolve the adhesive.

The Un-Du had the same problem, to a lesser degree. It evaporated quicker than the 1:1 xylene-chloroform mix, so there was less exposure between the adhesive of the tape and the wet fabric. It was very promising, though the liquid nitrogen still came out on top. Likely, the adhesive is frozen, and starts to contract, releasing the fabric and making it easier to pull apart with giving more complete fingerprints.

The duct tape has weak adhesive, which contributed to more incomplete prints when it was separated. The packaging tape, however, had very strong adhesive. It was noticeable when placing the fingerprints on the tape and tended to capture much more oil than the other two tapes.

Polyester being the best fabric (it was the one with the most complete prints in all trials) was a bit of a surprise. Before any actual mathematical analysis was found, I believed it was going to by the vinyl. However, I can see why it it's actually the polyester instead. Part of it could simply be due to the fact that for both the Un-Du and 1:1 xylene chloroform mix, it simply wasn't possible to wet the fabric enough to have the solutions soak through to the adhesive. During the separations I could have oversaturated the adhesive, or even used too little solution, causing the tape to separate from the fabric like it would if I was just pulling it apart. It was also seen that the more thin pieces of fabric gave better results.

Overall, the proposed technique to separate tape from fabric stuck together would be with liquid nitrogen and then analyzed with sticky side powder and or WetWop. The liquid nitrogen was the best separator across the board, generally giving more points of comparisons with each of the three tapes over the other separations, and with the eight different types of fabric.

IV) Conclusions

4.1 Summary

The proposed process does work. It gives good results, appropriate for the type of fabric and the kind of tape. The liquid nitrogen will not interfere with any of the collections that could be possible. It will not interfere with the superglue fuming, nor will it degrade the DNA profile in a bloody print. The sticky side powder developer can also be used, as it either won't interfere with development (Superglue fuming and

fluorescent enhancer) or can be used after the separation (in terms of DNA evidence). The technique itself can be done simultaneously with the other developing processes, as shown in the flowchart below. It can be incorporated into a laboratory procedure (Table 2, a flowchart procedure).

4.2) Further research

To reach further into this process, I can delve deeper into exactly how the different kinds of fabric react with a fingerprint. For example, if it is possible to take a cross section of a piece of tape already stuck fabric (in the middle of a fingerprint) and compare it to a cross section of one without a fingerprint, perhaps under a scanning electron microscope it would be possible to see a difference. Any kind of outdoor conditions should also be considered. Will the rain or snow destroy the fingerprint? What about the heat? If the fingerprint is already stuck to fabric, then it does have that insulation against the elements, to a certain extent. In theory, it should be possible for a latent fingerprint to survive even in outdoor conditions because of this insulation. This is further supported by a recent experiment by Dhall and Kapoor (2016). They wanted to determine if it was possible to obtain prints from detonated explosives. For example, they used five different substrates (glass, aluminum foil, ceramic tiles, tin cans, and metal spoons) and exposed them to the following conditions: arson, buried under soil, buried under snow, immersed in drainage water, and caught in an explosion. It was possible to obtain latent prints in all cases except for the explosion. The key factors were making sure the substrate the fingerprint was on survived whatever happened to it (arson and the explosion), and the time elapsed from exposure to collection. The longest time period was 15 days, and that

was for being buried under soil. The time period for being buried under snow was 6 days, though the period was only 120 hours for the drainage water. The fingerprints were analyzed with three different wet powder suspensions ($ZnCO_3$, ZnO and TiO_2), and showed relatively good quality prints (Dhall and Kapoor, 2016). So the main question would not be whether or not the fingerprints from a piece of tape stuck to a piece of fabric would exist, but how long would they survive in destructive conditions.

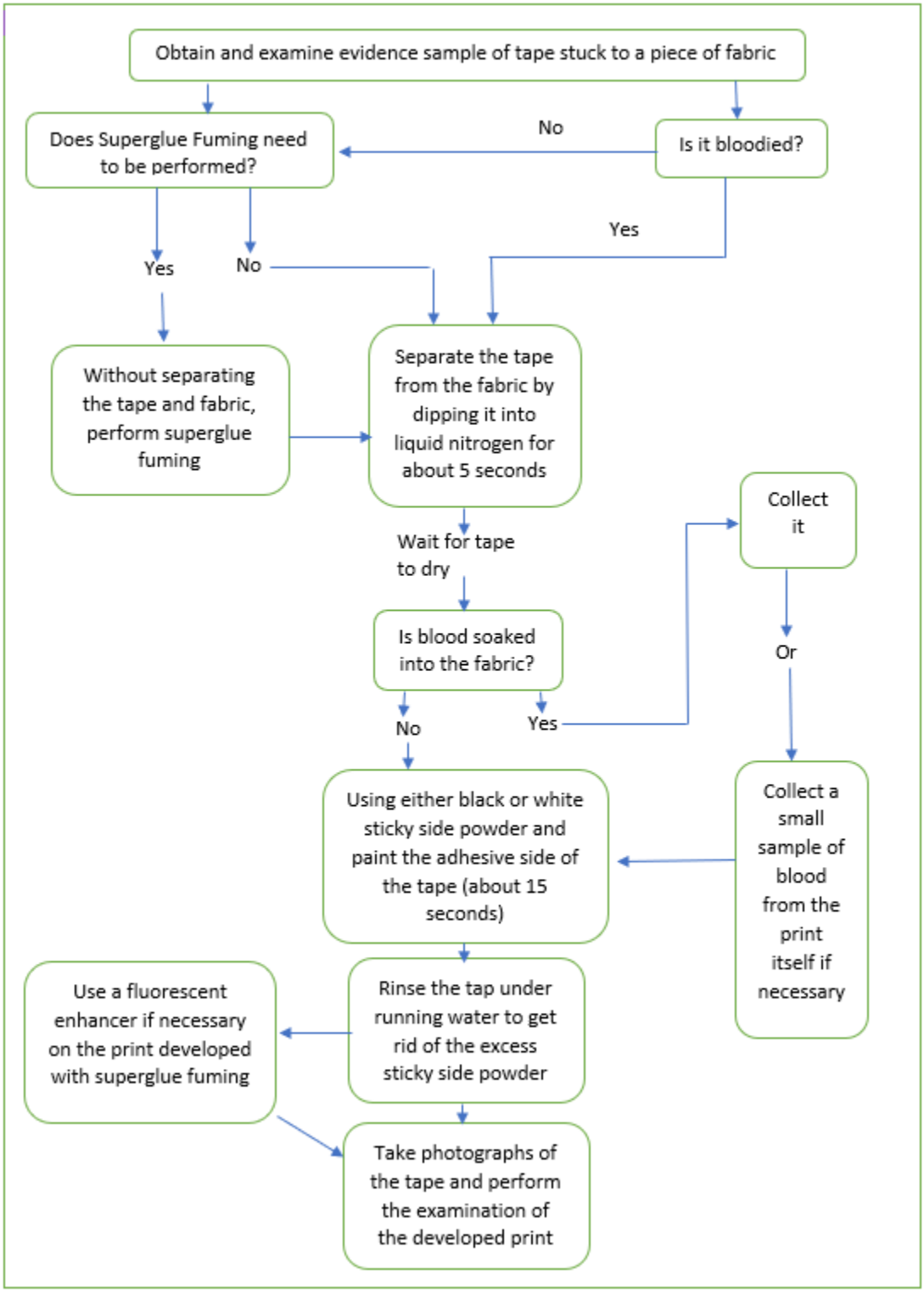

Figure 42: Flowchart Procedure

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