Fingerprints: History and Science
By Jeanette Hencken

A Little History

Fingerprints have been used for centuries. The Chinese used a thumbprint for centuries for identification on legal documents (Lennard & Patterson, N.D.) In the US the New York Civil Service Commission began to require fingerprints in 1901. At the 1904 World's Fair in St. Louis, MO, Scotland Yard officials provide security for a display of the royal jewels. While they were there, they trained St. Louis police officials in the collection and examination of fingerprints. In 1924, the FBI and Leavenworth prison combined their fingerprint records forming the beginning of fingerprint records for the present FBI -the largest set of fingerprint records in the world.

An interesting story about the Leavenworth prison's fingerprint system has made the rounds for many years. The story goes… In 1903 a man enters Leavenworth and is being processed. His photograph, name (Will West) and Bertillon number is recorded. Will West's information is taken to be entered into the prison files when it is discovered that a prisoner is already filed under that Bertillon number. "William West," a current prisoner, not only has the same Bertillon number and a very similar name, he looks like Will West! Major RW McGlaughry, Leavenworth's warden fingerprinted both men and found their fingerprints to be different. Major RW McGlaughry's son, MW McGlaughry had attended the St. Louis World's Fair in 1904 where he learned to use fingerprinting from Sergeant John K. Ferrier, of Scotland Yard. In November of 1904, the US Attorney General authorized Major RW McGlaughry to install the fingerprint system in the prison (Olsen, 1987.)

(Images of both Wests can be found at
http://www.canton.edu/ci/previous_lessons_3.html and
http://members.aol.com/SVG2254/West.htm.)

It is the uniqueness of fingerprints and the fact that they do not change during the life of a person that makes them valuable as evidence. The fact that prints do not change has not stopped enterprising criminal from trying to change their own prints. Three attempts stand apart from the others. The attempts to change their prints made by John Dillinger, Roscoe Pitts, and Marc Terrence George are quite interesting. John Dillinger, public enemy number one in the early part of the twentieth century, paid a doctor to remove his prints as part of his attempt to elude the FBI after he escape their capture. The doctor placed acid on his fingertips resulting in prints that were scarred on parts of the fingerprint. Enough of the print remained around the scarring to allow officials to use his fingerprints to identify Dillinger after he was killed in a hail of gunfire.

Roscoe Pitts, a longtime burglar in Texas, paid a doctor to remove his fingerprints. The doctor removed the skin from above the first knuckle and sewed his fingertips into incisions in his chest so chest skin would replace the removed skin. George paid a doctor to alter his prints. The Dr. sewed skin from his foot onto his fingers.

The Basics of Fingerprint Identification.
There are three general categories into which a print can fall: loops, whorls or arches (see figure 1.)


Loop Whorl Arch
Figure 1.

There are actually multiple types within these categories.

Loops.
Ulnar loops are loops in which the bottom opening of the loop opens toward the little finger-side of the hand. Radial loops are loops in which the bottom opening of the loop opens toward the thumb-side of the hand. An image of a loop can only be determined to be radial or ulnar if the viewer is told on which hand the print is found. For example, the loop in figure 1 is an ulnar loop if it is on the left hand and a radial loop if it found on the right hand.

Whorls
There are four types of whorls: Plain whorls, double loops, central pocket loops and accidental. Plain whorls are those like the whorl in figure 1. They can be described as a whirl pool or concentric circles. Double loops are prints that have an upside-down loop in them as shown in figure 2.

Double Loop
Figure 2.

Central pocket loops have a whorl or circular pattern found inside a loop as shown in figure 3.

Central Pocket Loop
Figure 3.

Accidental prints do not fit in any other category or seem to be combinations of other types as shown in figure 4.

Accidental
Figure 4.

Arches
Arches fall into two categories: Plain arch or tented arch. Plain arches are the simplest type of print. The ridges go across the print from one side to the other with an arch somewhere between. The arch shown in figure 1 is a plain arch. Tented arches have ridges that go across the print with an arch somewhere between and a ridge that seems to hold up the arch (see figure 5.)

Tented Arch
Figure 5.

Type of print is only a class characteristic. However it is used to determine the Henry Number for a set of prints. Henry Number is a system developed for storing tenprint cards. Tenprint cards are the cards used for rolling inked prints. These cards are stored by their Henry Number. The Henry Number system uses the fact that whorls make up approximately 35 percent of all fingerprints. Prints that are whorls are given points. The points are recorded in the form of a fraction. These fractions are never reduced or simplified. The fingers are recorded in the "fraction" starting on the bottom of the fraction with the right thumb as follows:

R.Index +	R. Ring +	L.Thumb +	L. Middle +	L. Little +	1
R. Thumb	R. Middle	R. Little	L. Index	L. Ring	1
(16)	(8)	(4)	(2)	(1)	

A finger found in the first fraction is given a number 16 if it is a whorl. In the second pair it is given an 8, a 4 in the third, a 2 in the fourth and a 1 in the fifth. If there is not a whorl, on that finger, that part of the fraction is given a 0. Add all the numerators together, then add all the denominators together. Then add a 1 to both the number on top and the number on bottom. Do not simplify the "number." An 18/2 is not a 9!

For example, a set of prints with a whorl on the right index and the left index would be recorded as follows:

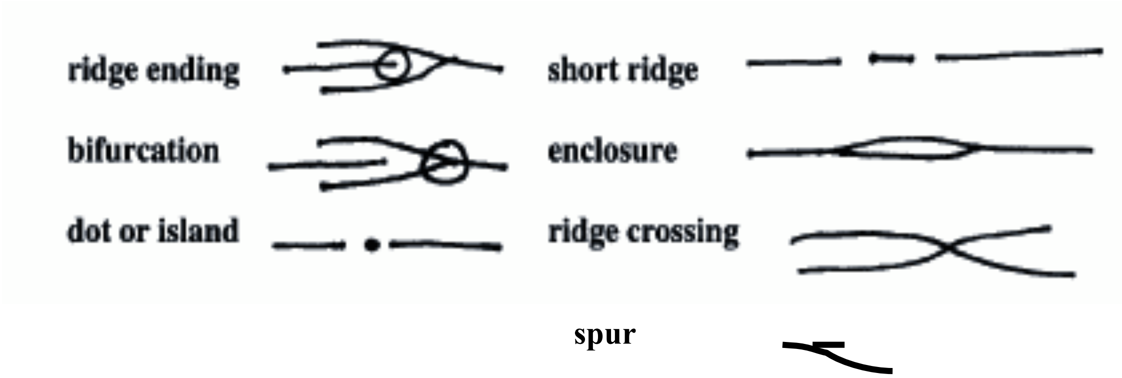
$$\frac{16}{0} + \frac{0}{0} + \frac{0}{0} + \frac{0}{2} + \frac{1}{0} = \frac{17}{2} + \frac{1}{1} = \frac{18}{3}$$

This procedure for classifying prints is called the Henry System. The number obtained is the Henry Number (18/3) for those prints.

This is a good point to hand out a set of fingerprints and ask your students to determine the type of each print and the Henry Number for that set of prints. (AT the end of this article is a lab for Henry Number)

Ridge Characteristics.
Fingerprints are unique to each person due to the way the ridges are formed. Fingerprints are formed while the fetus is developing in the womb. The final ridge pattern is influenced by the environment in which they are developing. Even identical twins do not experience the same set of forces inside the womb, resulting in their prints being unique. Although some sources have said that the general type of print is believed to be dependent on genetics, I have found no sources newer that the 1970's on this topic.

Fingerprints are characterized by ridge characteristics or minutiae. Minutiae are the parts of a ridge that can be differentiated from others. There are six different types minutiae. They are as follows: ridge ending, enclosure, bifurcation, island, short ridge and ridge crossing. A ridge ending is simply where a ridge stops. An enclosure is a ridge that forms a circle or encloses an area within a ridge. A bifurcation is a ridge that splits into two ridges. An island is almost a dot formed by a ridge. A short ridge is a little longer than an island. A ridge crossing is formed by two ridges crossing over one another. (See Diagram Below)



Every place a minutiae is found is called a point. It is not often that an entire print is left at the scene of a crime. Fingerprint experts look for prints large enough to contain 8 to 12 points. If these points match the points found in a suspect's fingerprints, the chance of the print being from someone else is very slim. In order to make an identification, all points present in the print from the crime scene must match the suspect's print, and no others, that do not match, can be found.

At the end of this article is a lab for lifting prints with powder and identifying ridge characteristics.

Chemical Development of Latent Prints.
Fingerprints are left on surfaces due to many different circumstances. Latent prints can be made of more than 20 different components produced in the eccrine, sebaceous and apocrine glands. The components most frequently developed as latent prints are chlorides, water, amino acids and oils. Salt and water, produced in the eccrine glands in the skin of the palms and other areas of the body, can be deposited on an object in the shape of the ridges on the fingertips. Amino acids are also produced in eccrine glands. Oils are produced in the sebaceous glands. They can be transferred to the fingertips by touching areas of the body where hair can be found. Prints made with these colorless substances are called invisible or **latent** prints.

Visible prints are those made by touching a wet object and leaving that substance on another surface. Visible prints can be left with blood or colored oils. Prints left by impressing the ridges into a soft surface are called **plastic** prints. Some examples of visible prints are ones left in putty or a paint that is tacky.

Latent prints can be made visible using many different techniques. The most common technique is dusting. The prints are made visible by carefully brushing the area with a brush containing a powder. The color of the powder depends on the color of the surface the print is on. Black powder is the powder used most frequently but fluorescent powders in colors from red to green are also used to make the print more visible. A magnet can be used as a brush with iron powder to make prints visible on textured plastic or paper. These techniques use physical attachment of the powders to the liquids in the latent print to make the print visible.

(Dusting For Prints Lab to be completed here.)

There are many chemical methods used to make prints visible. Which one to use depends on what material the print is on and the substances that make up the print. The most common chemicals used are iodine, ninhydrin, silver nitrate and Super Glue[R].

Sublimation is the change from a solid to a gas without becoming a liquid. At room temperature, iodine sublimes. This change occurs more rapidly if the iodine is heated. This gaseous iodine makes fingerprints visible. It may be the oils or the water that it is reacting with but in either case the change is not permanent. Iodine fuming is used on porous surfaces, the most common of these is paper. This procedure is not permanent. Once the fuming is done the document, in a short time, begins to turn brown over the entire surface. It is therefore necessary to photograph the document before processing it with iodine. The visualization time can be extended by spraying the treated document with a one percent solution of starch. But this only adds a few hours to the visualization.

(Iodine Fuming can be completed here.)

Ninhydrin, in the presence of amino acids, forms a purple substance, called Ruhemann's purple. It is also used on porous surfaces. Unlike the iodine fuming, ninhydrin does not fade after a short time. It can last several months to a few years. The chemical reaction that takes place is a two step reaction. The ninhydrin reacts with the amino acids to produce a partially reduce ninhydrin molecule along with an aldehyde, NH_3 and CO_2 (Senese, n.d.). The second step of this reaction is where another ninhydrin molecule along with NH3 and the reduced ninhydrin molecule react to form the blue-purple pigment called Ruhemann's purple.

(Ninhydrin lab to be completed here.)

Silver nitrate reacts with chlorides found in perspiration to form silver chloride. In order to treat a print with silver nitrate, a 3% solution of silver nitrate in water is made. The suspected area, believed to contain a fingerprint, can then be sprayed with, dipped in or have the solution brushed onto it. The treated area is then exposed to ultraviolet light. This exposure causes the silver chloride to appear as a black/brown stain. Background staining can cause the development to be problematic.

(I don't have a silver nitrate lab written up)

Gentian Violet, also called crystal violet, is used to develop the fat from sebaceous glands left on the sticky side of tape in the shape of ridges. A purple stain is left on the tape in the shape of the minutiae. The dye molecule attaches itself to the fat molecule and dyes the skins cells remaining on the sticky-side of tape. To develop the print you dip or spray the material containing the print with a solution of 0.02 g of Gentian Violet dissolved in 80 mls of distilled water. The area is then rinsed with tap water. The process can be repeated multiple times to enhance the development of the print.

(Prints on Tape lab to be completed here)

Super Glue[R] fuming is used on nonporous surfaces like the inside of a car, a plastic bag or a firearm. The active ingredient is cyanoacrylate ester. It is believed that this component bonds to water in the fingerprint when it is heated to form a gas. A polymer coating is formed over the print. Fuming should be done in an exhaust hood. This fuming can be performed by placing a two centimeter diameter circle of glue on a pad that has been soaked in 50% sodium hydroxide solution (see directions in Super Glue[R] lab). Fuming can also be done by placing the same amount of glue on a hot, aluminum surface. A coffee mug warmer with a disposable aluminum pan or a light bulb with a soda can around it can be used. The prints appear as a white "stain". Fuming takes at least 45 minutes. Better prints can be developed over a period of 4-6 hours. All superglues are not the same. The cheaper containers are lower percentages of the active ingredient.

(Super Glue[R] fuming lab to be completed here.)

References

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Iodine Fuming Lab

Must wear gloves
Materials needed:

A tank that can be sealed
(can use a large beaker inside a sealable bag, or a TLC tank)
A few crystals of iodine, approximately 0.1 grams
A piece of paper 3 cm x 5 cm, for each pair of students

Procedure:

Place the crystals in the bottom of the beaker or tank along with the paper that has been touched by the students. Several pieces of paper can be placed in the beaker at one time. (or a small beaker can be used for one or two pieces of paper w/ only one or two crystals of iodine)

Seal up the container and allow to develop for 15-30 minutes, longer if no heat source. Keep a close watch on the development as the iodine can quickly over develop the sheet of paper and make the prints useless.

Results.
Determine which print came from which student by comparing ridge characteristics found on rolled prints.

Ninhydrin Lab

Materials Needed:
One pair of plastic gloves
0.2g of ninhydrin
150mls of methanol or etanol
one 250ml bottle w/ lid
one 15cm x 30cm tub
one 10cm x 10cm piece of paper per student
tweezers
an area to spread the pieces of paper out while they dry
Iron or steamer, optional

Procedure:
For Teacher:
Wearing gloves, dissolve the ninhydrin in the methanol and store in a bottle that can be sealed up. (Ninhydrin is a skin cell dye and a biological irritant. Care should be take to avoid getting it on your skin.)

Pour ~75mls of the solution into the tub (enough that the bottom of the tub is covered.)

Have each student place their name (with a pencil) and some fingerprints on the paper.

Using tweezers, dip each piece of paper in the solution. Lay the papers out to air dry. They will need 24 hours to develop. You can speed up this process by heating the prints with steam. If you repeatedly hold a hot steam iron about 1cm above the paper, the print may develop in 5-10 minutes.

The prints will remain visible for several days.

Fingerprints on Tape

Fingerprints on the outside (non-sticky side) of tape can be visualized by dusting with powders - you may want to use fluorescent powders if the tape is dark. To visualize the prints on the sticky side of tape, you need a different technique. The latent prints left on the smooth side are made by oils and salts left on the tape. The latent prints on the sticky-side are from skin cells and oils, left in the shape of the fingerprint, on the tape when the tape is removed from the roll. These skin cells and oils react with gentian violet (methyl violet) to form a purple residue on the tape.

In order to visualize the latent print with Gentian Violet (also called crystal violet) you make a solution with 0.02 g of Gentian Violet dissolved in 80 mLs of distilled water. Start with 20 mLs of water in a beaker and add the Gentian Violet. Fill the volumetric up to 80mL mark an mix the solution.
Pour the solution into a 600 mL beaker or any container that will allow you to dip the tape into the liquid. A shallow, wide container works best. Once the tape is dipped, rinse with tap water and the stain should be very visible.

Lab:

1. Tear off a piece of masking tape about 4 inches long and using forceps dip the tape in the gentian violet solution. Rinse w/ water. Gently pat dry.
2. Place the tape, sticky-side-up on an index card. Cover w/ a 2 inch wide piece of clear tape.
3. Find, and mark, 4 ridge characteristics on the visualized print.
4. Can you determine which finger the print came from by matching these points?

Super Glue[R] Lab (with heating only)

Materials Needed:
superglue, each class must be fumed separately, need about 0.5 mls per class
tank- something that can be closed tightly and is large enough to hold the objects that have prints on them. Some Suggestions:
plastic tub, old fish tank with lid that seals, 2 liter bottles with top cut off (top to be used as a sealable lid), mason jars.

heat source (a light bulb or a mug warmer work well)
aluminum foil or disposable aluminum pan
surface with prints on it, carbonated beverage cans work well, as do plastic spoons.

Procedure:

A. Set up the tank, inside a hood, with the aluminum foil on the heating source inside the tank.

B. Carefully place the object in question (the one you think has fingerprints on it) into the bottom of the tank.

C. Place the glue on the aluminum. There should be enough glue to make a circle with a two centimeter diameter. Turn on the heat.

D. Seal up the tank and allow to fume for 40 minutes to 24 hours.

E. See **Dusting for Prints Lab** in order to lift the prints visualized w/ glue.

Notes
A one liter bottle with the top cut off at the top of the flat edge makes a great developing tank for a single soda can. You could also use a sealable bowl, a two liter bottle with the top removed (to be taped back on while fuming), a one quart jar with lid that seals or any other container that can be sealed and reused. Keep in mind, however that this container will permanently have super glue fumes all over it.

The super glue fumes are permanently attached to everything in the tank.

Soda cans make a great surface to fume - avoid white or gray cans, much bigger challenge since the cyanoacrylate ester deposited is white!
Caution: Super glue Fumes are caustic and should not be inhaled or come in contact with eyes. Be careful opening the "tank" as the fumes are very painful on the eyes! Best done in fume hood.

Super Glue^{R} Fingerprint Lab with Sodium Hydroxide

Teacher Instructions

Materials Needed:
superglue, each class must be fumed separately, need about 0.5 mls per class
tank, something that can be closed tightly and is large enough to hold the objects that
  have prints on them. Some Suggestions:
  plastic tub, old fish tank with lid that seals, 2 liter bottles with top cut off (top to be used as a sealable lid)
12cm x 12cm paper napkin, folded in four
50% (6M)sodium hydroxide solution, 200 mls
tongs, one pair per tank
surface with prints on it (carbonated beverage cans work well)
clear packing tape

Procedure:
A. Place 10 mls of 50% NaOH in the bottom of a beaker. Place the folded napkin in the beaker. Allow the napkin to absorb the NaOH and dry out over night.
B. Have a pair of students place their fingerprints on a 12 oz. beverage can, taking care to not overlap the prints. Label the can on the bottom with their initials. They will work with these prints during the next class period.
C. In a hood, set up your fuming Tank
D. Using tongs, in the bottom of the tank, place the NaOH saturated napkin. Try to place the pad to the side to allow optimum fuming conditions. Place enough

cyanoacrylate ester(super glue) on the pad to cover the pad. One pad will provide enough superglue fume for 12-14 cans all placed in a tank at one time.

E. Carefully place the cans with the prints on them into the tank. Cover the tank with its lid and seal the edges with packaging tape. Allow this to develop for approximately forty minutes or more. The now visualized latent prints can be used as evidence in one of two ways; the prints must be either photographed or lifted from the surface after dusting with print powder.

F. See **Dusting for Prints Lab** in order to lift the prints visualized w/ glue.

Notes

A one liter bottle with the top cut off at the top of the flat edge makes a great developing tank for a single soda can. You could also use a sealable bowl, a two liter bottle with the top removed, a one quart jar with lid that seals or any other container that can be sealed and reused. Keep in mind, however that this container will permanently have super glue fumes all over it.

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