Module 2

Fingerprint Recognition

History of Fingerprint

- Use of fingerprints for identification since 7000 to 6000 BC by ancient Assyrians and Chinese (prints on pottery, clay, bricks).
- Fingerprinting of criminals for identification ~ Babylon around 1792-1750 BC.

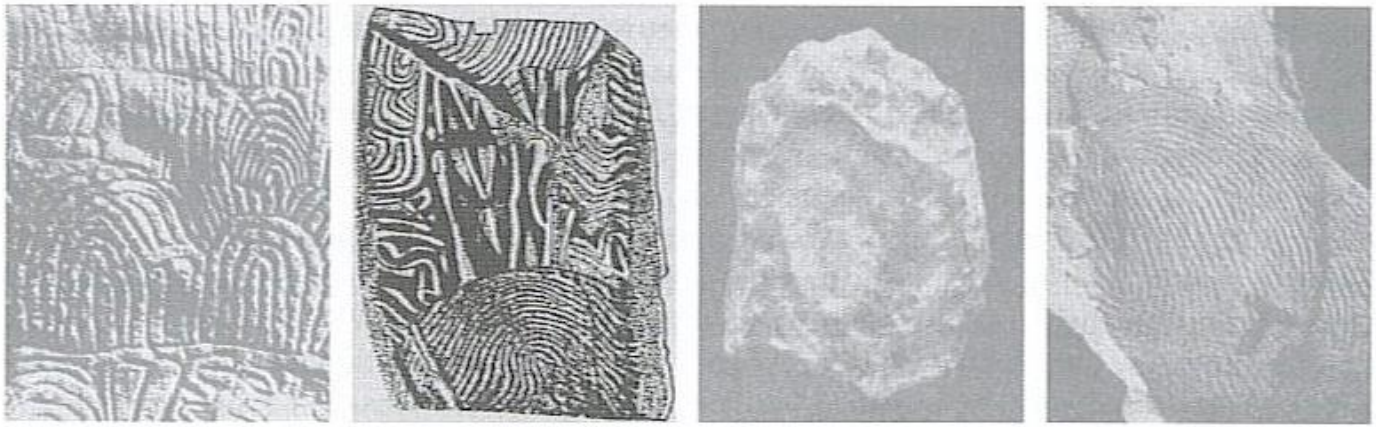


Figure 1.8. Examples of archaeological fingerprint carvings and historic fingerprint impressions: a) Neolithic carvings (Gavrinis Island) (Moenssens, 1971); b) standing stone (Goat Island, 2000 B.C.) (Lee and Gaensslen, 2001); c) a Chinese clay seal (300 B.C.) (Lee and Gaensslen, 2001); d) an impression on a Palestinian lamp (400 A.D.) (Moenssens, 1971). Although impressions on the Neolithic carvings and the Goat Island standing stones might not be used to indicate identity, there is sufficient evidence to suggest that the Chinese clay seal and impressions on the Palestinian lamp were used to indicate the identity of the providers. Figures courtesy of A. Moenssens, R. Gaensslen, and J. Berry.

- **Chinese** used fingerprints to sign legal documents as far back as **three thousand** years ago
- **William Herschel**, an English civil servant (India), required natives to sign contracts with an imprint of their right hand – Hindu custom?

- 1st attempt at a personal identification system
  - Introduced by French police expert Alhonse Bertillon in 1883
  - Called Bertillon system
  - Relied on a detailed description (**portrait parle**) of the subject, combined with full length and profile photographs and system of precise body measurement (**anthropometry**)

Anthropometry

- Rested on the premise that the dimensions of the human bone system remained fixed from the age of 20 until death
- It was thought that no 2 skeletons could have the same measurements
- 11 measurements of the human anatomy was recommended
  - Height, reach, width of head, length of left foot

William West

Will West

- By examining the photographs, one can see the failure of the Bertillon system.
- Compare the Bertillon measurements in particular, keeping in mind the various factors that would affect the measurements.
- This failure strengthened the science of fingerprints as the normally accepted method of personal identification.
- The authorities compared their fingerprints and determined that Will West was not the previously recorded William West

- Bertillon system was considered most accurate for 2 decade
- In the 1900's a new system of classification of finger ridge patterns emerged, known as fingerprints
- Fingerprints are the pillar of modern criminal identification

- 1st person to realize the potential application of fingerprinting to personal identification – Henry Fauld a scottish physician In 1880
- recognized the importance of fingerprints as a means of identification, but devised a method of classification as well.
- He discussed fingerprints as a means of personal identification, and the use of printers ink as a method for obtaining such fingerprints.
- he is also credited with the first fingerprint identification of a greasy fingerprint left on an alcohol bottle.

- Sir Francis Galton, a British anthropologist and a cousin of Charles Darwin, began his observations of fingerprints as a means of identification in the 1880's
- According to his calculations, the odds of two individual fingerprints being the same were 1 in 64 billion.
- Galton identified the characteristics by which fingerprints can be identified. These same characteristics (minutia) are basically still in use today, and are often referred to as Galton's Details.

- In 1891, Juan Vucetich, an Argentine Police Official, began the first fingerprint files based on Galton pattern types. At first, Vucetich included the Bertillon System with the files. (see Bertillon below)
- In 1892, Juan Vucetich made the first criminal fingerprint identification. He was able to identify a woman by the name of Rojas, who had murdered her two sons, and cut her own throat in an attempt to place blame on another.
- Her bloody print was left on a door post, proving her identity as the murderer.

Summary

- In the mid-1800's two facts were established: (i) no two fingerprints have the same ridge pattern and (ii) fingerprint pattern have good permanence.
- Use of fingerprints for criminal identification in Argentina in 1892.
- Henry's fingerprint classification system was introduced in 1897.
- Computer processing began in 1960s with introduction of computer hardware.
- Since 1980s fingerprints are used in non-criminal applications (due to personal computers and optical scanners).
- Personal use ~ due to introduction of inexpensive capture devises and reliable matching algorithms.

Fingerprint Principles

According to criminal investigators, fingerprints follow 3 fundamental principles:

- A fingerprint is an **individual** characteristic; no two people have been found with the **exact** same fingerprint pattern.
- A fingerprint **pattern** will remain **unchanged** for the **life** of an individual; however, the print itself may change due to permanent scars and skin diseases.
- Fingerprints have general characteristic **ridge** patterns that allow them to be systematically identified.

Fingerprint Formation

Figure 1

- Fingerprints are fully formed at about **seven months of fetus development** and finger ridge configurations **do not change throughout the life of an individual** except due to accidents such as bruises and cuts on the fingertips (Babler, 1991).
- Unrelated persons of the same race have very little generic similarity in their fingerprints.
- Parent and child have some generic similarity as they share half the genes.
- Siblings have more similarity.
- The maximum generic similarity is observed in monozygotic (identical) twins.

Off line Fingerprint Acquisition

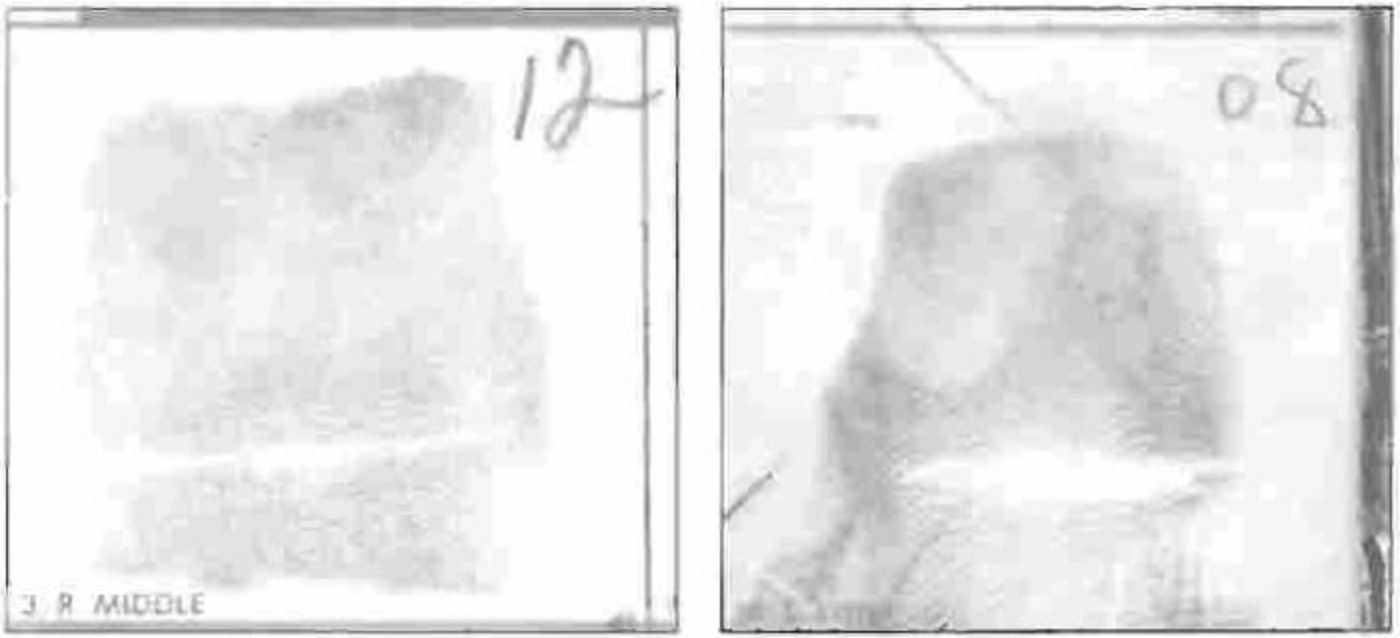
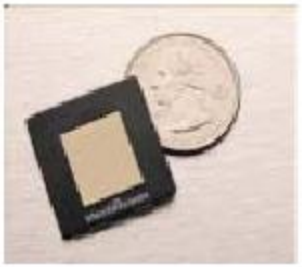
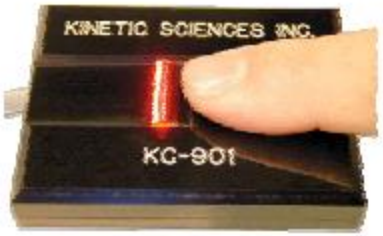
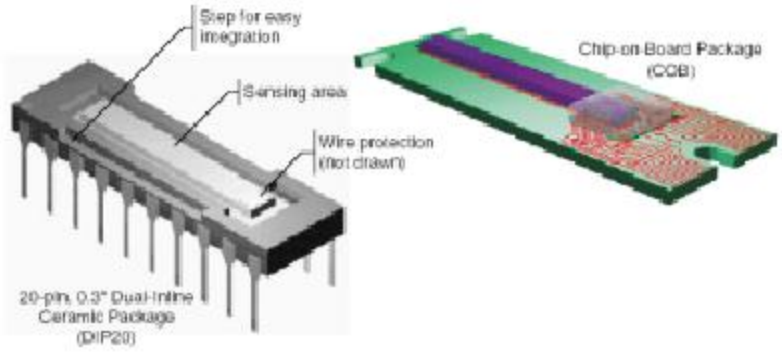


Figure 2.4. Rolled fingerprint images acquired off-line with the ink technique.

Fingerprint Sensors







Fingerprint Sensors

- Optical
- Silicon Based Capacitive Sensors
- Ultrasound
- Thermal

Optical Sensors

- Oldest and most widely used technology.
- Majority of companies use optical technology.
- The finger is placed on a coated hard plastic plate.
- In most devices, a charged coupled device (CCD) converts the image of the fingerprint, with dark ridges and light valleys, into a digital signal.
- The brightness is either adjusted automatically or manually, leading to a usable image.

Optical Sensors-contd..

Advantages

- They are the most proven over time.
- They can withstand, to some degree, temperature fluctuations.
- They are fairly inexpensive.
- They can provide resolutions up to 500 dpi.

Disadvantages

- Size, the sensing plate must be of sufficient size to achieve a quality image
- Residual prints from previous users can cause image degradation, as severe latent prints can cause two sets of prints to be superimposed.
- The coating and CCD arrays can wear with age, reducing accuracy.
- A large number of vendors of fingerprint sensing equipment are gradually shifting towards silicon-based technology.

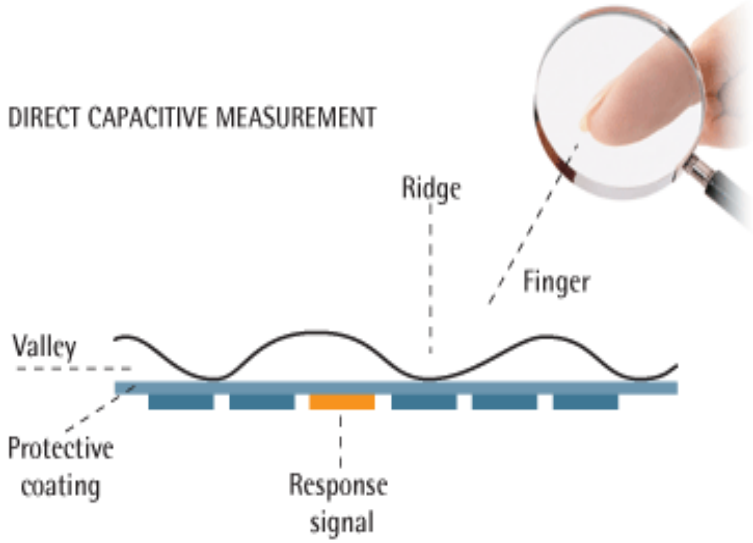
Silicon Based Sensors

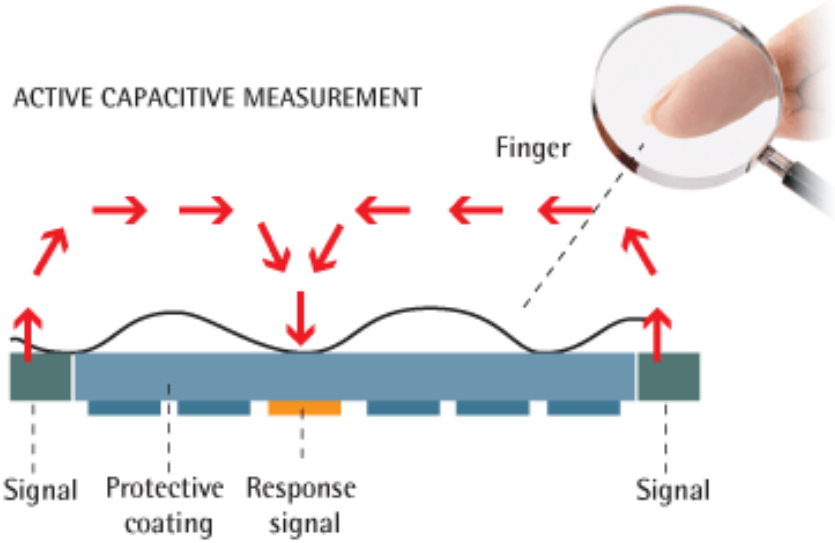
- Silicon technology has gained considerable acceptance since its introduction in the late 90's.
- Most silicon, or chip, technology is based on DC Capacitance, but some also use AC Capacitance.
- The silicon sensor acts as one plate of a capacitor, and the finger is the other.
- The capacitance between the sensing plate and the finger is converted into an 8-bit grayscale digital image.

Silicon Based Sensors-contd..

- Fingerprint cards contain numerous capacitive plates which measure the capacitance between the plates and the fingertip.
- When the finger is placed on the sensor extremely weak electrical charges are created, building a pattern between the finger's ridges or valleys and the sensor's plates.
- Using these charges the sensor measures the capacitance pattern across the surface.
- The measured values are digitized by the sensor then sent to the neighboring microprocessor.
- This can be done directly by applying an electrical charge to the plate or by using electronic pulses passed to the fingertip.

Direct v/s Active Capacitive Measurement





Silicon Based Sensors-contd..

Advantages

- The Silicon chip comprises of about 200*200 lines on a wafer the size of 1cm*1.5cm, thus providing a pretty good resolution for the image.
- Hence, Silicon generally produces better image quality, with less surface area, than optical.
- Also, the reduced size of the chip means lower costs especially with the dropping costs in Silicon chip manufacturing.
- Miniaturization of Silicon chips also makes it possible for the chips to be integrated into numerous devices.

Disadvantages

- In spite of claims by manufacturers that Silicon is much more durable than optical, Silicon's durability, especially in sub-optimal conditions, has yet to be proven.
- Also, with the reduction in sensor size, it is even more important to ensure that enrolment and verification are done carefully.

Ultrasound Sensors

- Ultrasound technology is perhaps the most accurate of the fingerprint technologies.
- It uses transmitted ultrasound waves and measures the distance based on the impedance of the finger, the plate, and air.
- Preliminary usage of products indicates that this is a technology with significant promise.

Ultrasound Sensors-contd..

Advantages

- Ultrasound is capable of penetrating dirt and residue on the sensing plate and the finger.
- This overcomes the drawbacks of optical devices which can't make that distinction.
- It combines a strength of optical technology-large platen size and ease of use, with a strength of silicon technology-the ability to overcome sub-optimal reading conditions.
- It is also virtually impossible to deceive an ultrasound system.

Disadvantages

- The quality of the image depends to a great extent on the contact between the finger and the sensor plate which could also be quite hot.

Thermal Sensors

- Uses Pyro Electric material.
- Pyro-electric material is able to convert a difference in temperature into a specific voltage.
- This effect is quite large, and is used in infrared cameras.
- A thermal fingerprint sensor based on this material measures the temperature differential between the sensor pixels that are in contact with the ridges and those under the valleys, that are not in contact.

Thermal Sensors-contd..

Advantages

- A strong immunity to electrostatic discharge
- Thermal imaging functions as well in extreme temperature conditions as at room temperature.
- It is almost impossible to deceive with artificial fingertips.

Disadvantages

- A disadvantage of the thermal technique is that the image disappears quickly.
- When a finger is placed on the sensor, initially there is a big difference in temperature, and therefore a signal, but after a short period (less than a tenth of a second), the image vanishes because the finger and the pixel array have reached thermal equilibrium.
- However, this can be avoided by using a scanning method where the finger is scanned across the sensor which is the same width as the image to be obtained , but only a few pixels high.

Touch Vs Sweep

- Drawbacks of Touch method
  - Sensor can become dirty
  - Visible latent fingerprints remains on the sensor
  - Rotation of the fingerprint may be a problem
  - Strict trade-off between the cost and the size of the sensing area

Sweeping Method

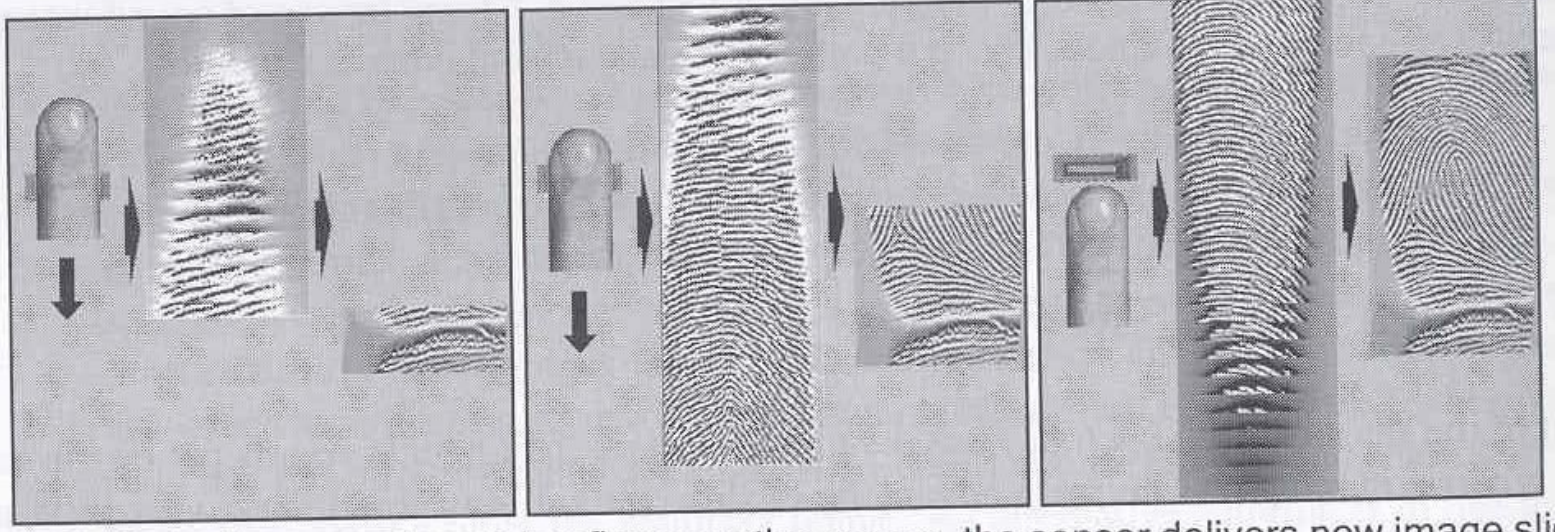


Figure 2.12. As the user sweeps her finger on the sensor, the sensor delivers new image slices, which are combined into a two-dimensional image.

Advantages of Sweeping Method

- Equilibrium is continuously broken when sweeping, as ridges and valleys touch the pixels alternately, introducing a continuous temperature change
- Sensors always look clean
- No latent fingerprints remain
- No rotation

Drawbacks

- Novice user may encounter difficulties
- Interface must be able to capture a sufficient number of fingerprint slices
- Reconstruction of the image from the slices is time consuming

3 basic types of fingerprint impressions

- Latent
  - Most frequent
  - Visible to eye
  - Formed by sweat
  - Developed by grey or black powder or iodine fuming
- Durability of a latent print is variable and governed by several factors but if made on a hard, protected surface and left untouched, it is virtually permanent
- Have been found & developed on objects in ancient tombs

- Visible
  - Most legible kind
  - Results from fingers stained with blood or ink or similar medium
  - Rarely found at crime scene

- Plastic or molded
  - Impression made on a soft surface such as cheese, soap or putty

Common Types of Fingerprint Pattern

- Fingerprint patterns are divided into three main groups consisting of:
  - Arches,
  - Loops and
  - Whorls.

Interesting Info

Fingerprint Factoid:

60% of people have loops, 35% have whorls, and 5% have arches

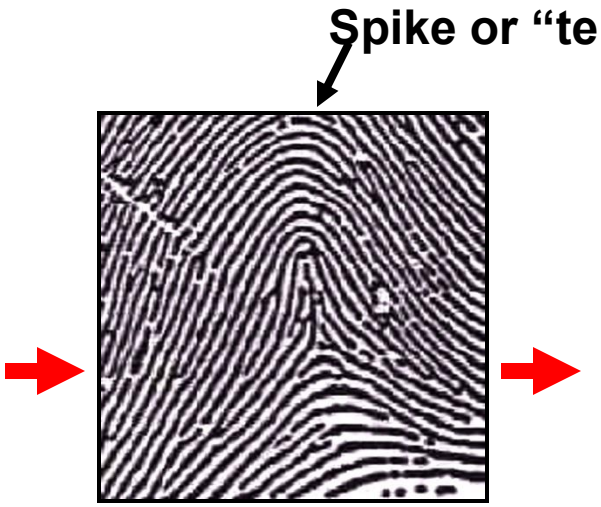
Did you know?

Dactyloscopy is the study of fingerprint identification. Police investigators are experts in collecting "dactylograms", otherwise known as fingerprints.

Arches

Arches are the simplest type of fingerprints that are formed by ridges that enter on one side of the print and exit on the other. No deltas are present.

Plain Arch
Ridges enter on one side and exit on the other side.



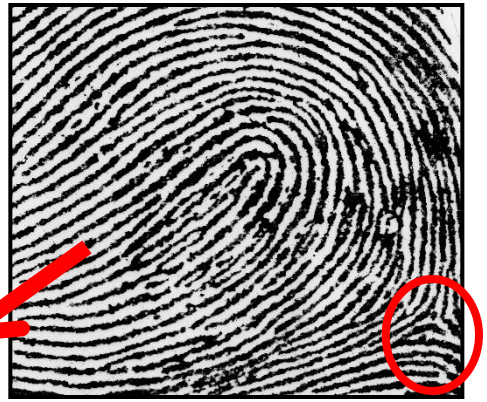
Tented Arches
Similar to the plain arch, but has a spike in the center.

Loops

Loops must have one delta and one or more ridges that enter and leave on the same side. These patterns are named for their positions related to the radius and ulna bones, i.e. the bone the loop opening is facing towards.

L – Radial Loop
R - Ulnar Loop

Delta



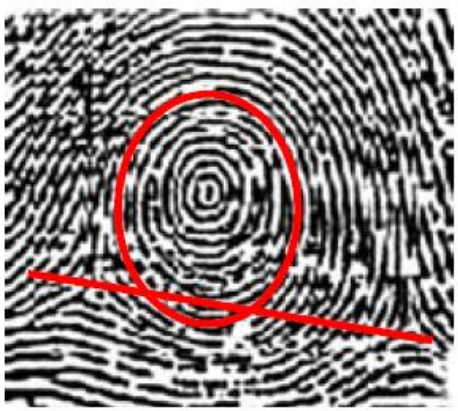
L – Ulnar Loop
R - Radial Loop

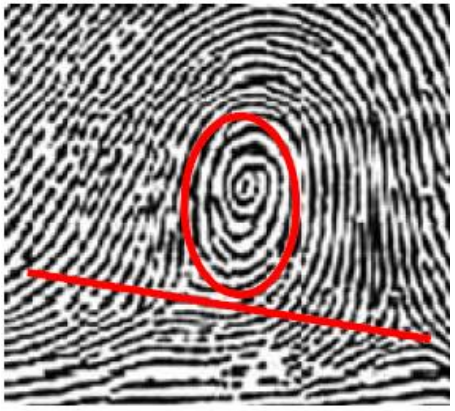
X-Ray Imagine: http://www.tooloop.com/wp-content/uploads/2013/12/Radius-Ulna-X-Ray.jpg

Whorls

Whorls have at least one ridge that makes (or tends to make) a complete circuit. They also have at least two deltas. If a print has more than two deltas, it is most likely an accidental.

Plain Whorl



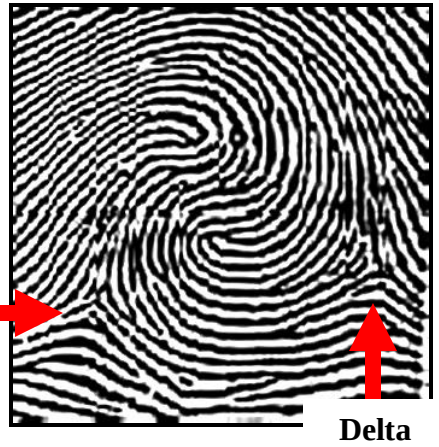


Central Pocket Whorl

Draw a line between the two deltas in the plain and central pocket whorls. If some of the curved ridges touch the line, it is a plain whorl. If none of the center core touches the line, it is a central pocket whorl.

Whorls (contd..)

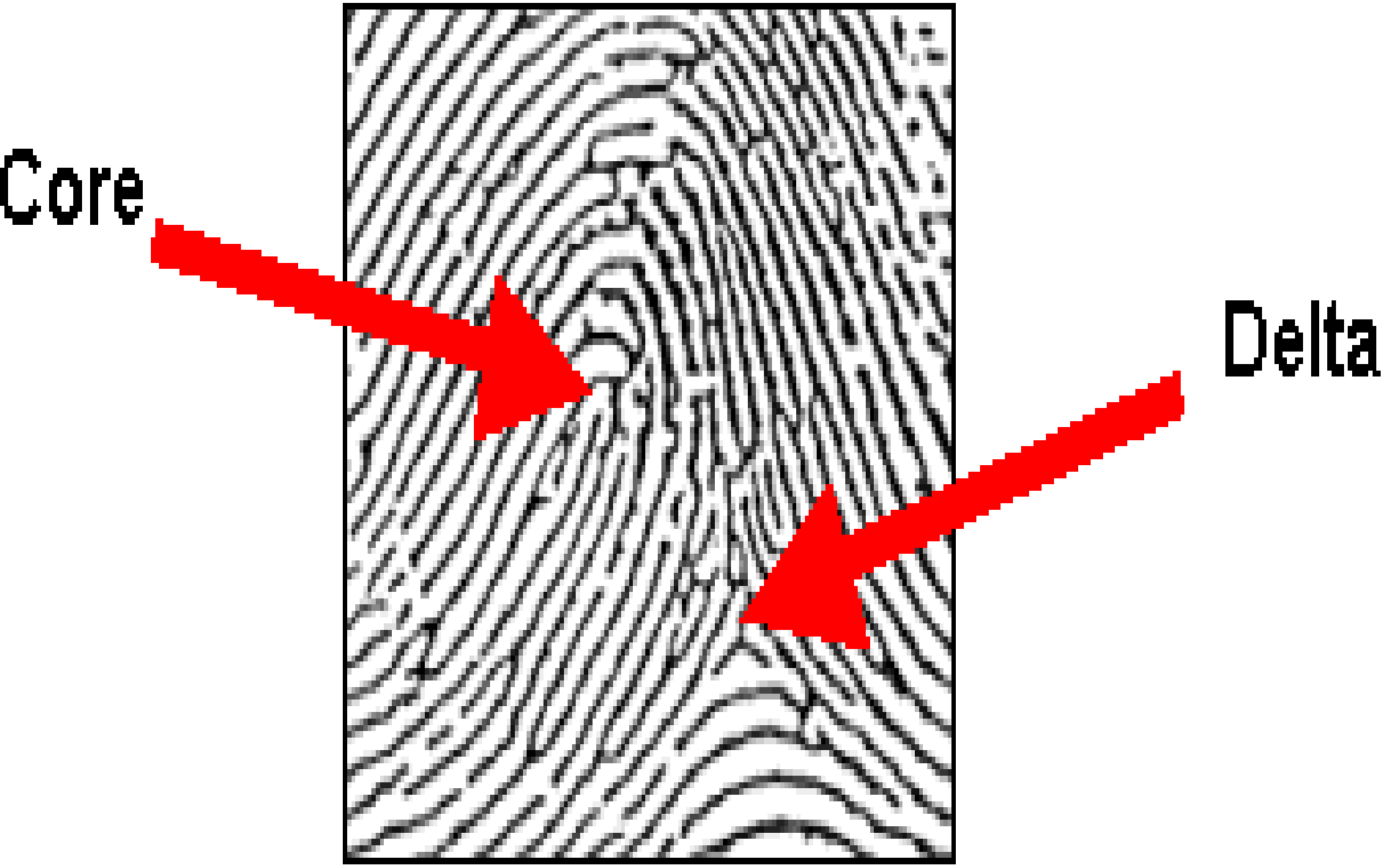
Double Loop Whorl



Double loop whorls are made up of any two loops combined into one print.

Accidental Whorl

Accidental whorls contain two or more patterns (not including the plain arch), or does not clearly fall under any of the other categories.


Core
Delta

Identify each fingerprint pattern.

A

Left Hand

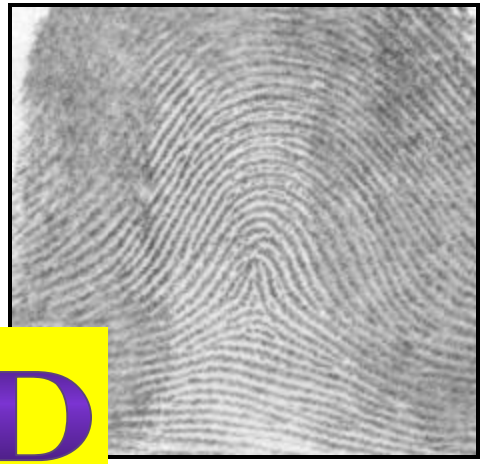
?

B

Right Hand

C

Right Hand



D

Right Hand

E

Left Hand