BLOCK 2
HUMAN IDENTIFICATION: ESTABLISHING IDENTITY-I

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UNIVERSITY

UNIT 4 BIOMETRICS*

Contents

LEARNING OBJECTIVES

After the completion of this unit you will be able to understand:

- biometrics, its scope and role in forensic anthropology;
- the use of human characteristics in personal identification with the help of computer technology; and
- characteristics and the methodology used in biometrics for the individual identification.

4.0 INTRODUCTION

'Forensics' means *'for the court'* and it relies on the evidence and identification. You are well aware that forensic analysis is dependent on the evidence collected from the crime scene for the identification of the criminal. With the increase in crimes new techniques for investigation like Biometrics based on artificial intelligence are being developed.

Biometrics consists of two words 'Bio' meaning 'life' and 'metric' is the measurement or quantitative based recognition and identification. In simple words if you have to choose a T-shirt for your blue jeans what you

*Contributor: Dr Kumud Sarin, Program Director at Bioinformatics Institute of India, Noida.

would do? You would choose from a pile and match, much the same way in Biometrics where we compare given pattern from the existing ones in the data base. Basically, it is related to brain recognition with its stored observations and is faster with more accuracy.

4.1 BIOMETRICS: DEFINITION AND SYSTEM

Biometrics, in simple terms is identification of humans by their traits related to different aspects of physiology, chemistry or behaviour. Biometrics is defined as the applicable means of identifying and authenticating individuals in a reliable and fast way through the use of unique biological characteristics and technologies that lead to the acceptable way of solving the crime. Biometrics includes two types of characteristics:

- **Physiological**: face, fingerprint, hand geometry and iris recognition, and
- **Behavioural:** gait, odour, signature and voice.

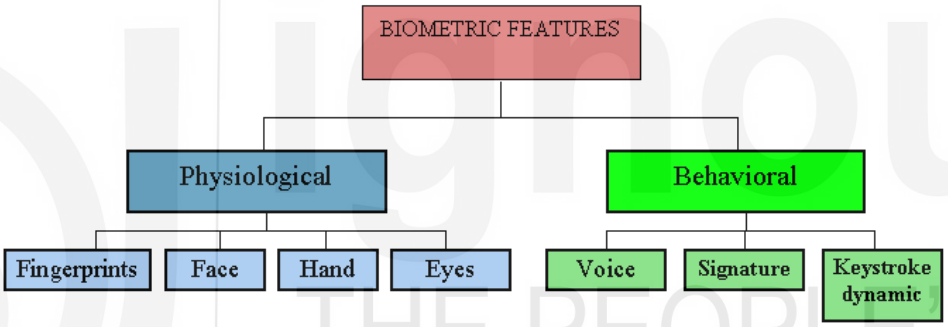

Figure1: Biometric Features

Source: http://www.biometrika.it/eng/wp_biointro.html

Biometric system use the following human characteristics as identifiers:

Common:

- Fingerprint Recognition
- Face Recognition
- Speaker Recognition
- Iris Recognition
- Hand Geometry
- Signature Verification

Others:

- DNA
- Retina Recognition
- Thermo Grams
- Ear Recognition

- Skin Reflection
- Lip Motion
- Body Odour
- Brain Wave Pattern
- Footprint and Foot Dynamics

Biometric system consists of device which works as a system shown in figure 2.

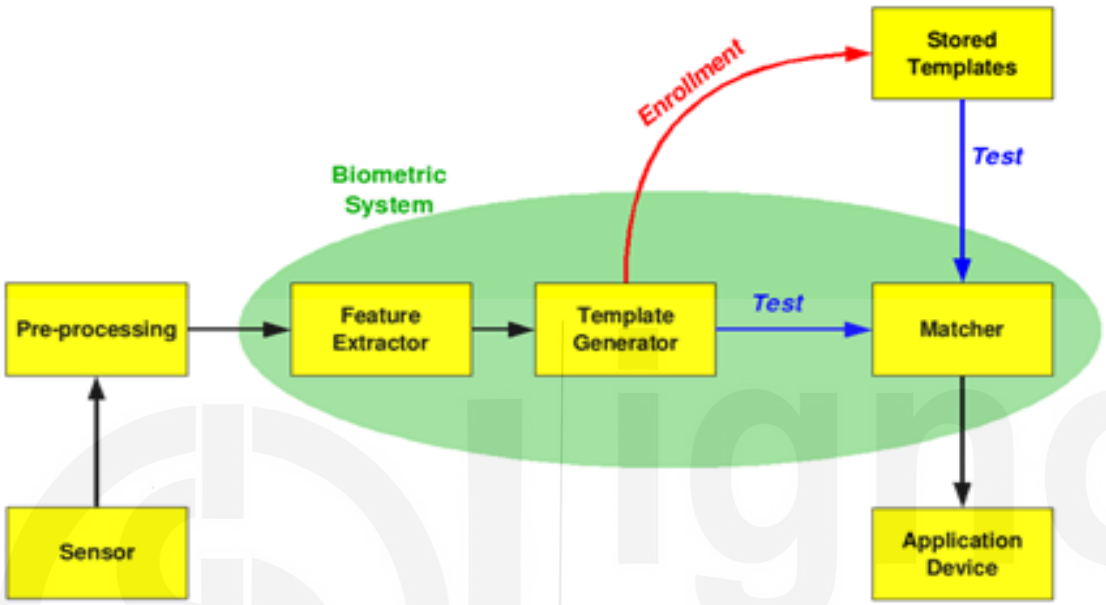

Figure 2: Biometric System

Source: https://en.wikipedia.org/wiki/Biometrics

From diagram you can see that a sensor recognises the information, then during pre-processing, it extracts information with template for matcher and identifies the information.

4.1.1 Advantages

Biometrics with any device, either system or characteristics are used with a common aim to collect the information and compare for identification. The advantages are:

- Universally found in all individuals and unique to differentiate one individual from another,
- Permanent, allowing for change over time
- Recordable (with or without consent)
- Measurable for future comparison
- Forgery-proof (a face, a fingerprint)
- Accuracy, improved security systems and quick authentication

4.1.2 Disadvantages

Biometric system has advantages nevertheless also has disadvantages like any other system. Some of the disadvantages are:

- Physical disabilities caused by injury, etc. leads to change the system
- Expensive
- Physical traits can't be altered
- Scanning is not reliable e.g. in retina scanning
- Software issues like power issues
- Remote access is lacking and security breaches

4.1.3 Applications of Biometrics

You would like to ask the question that when Biometrics has disadvantages then why it is developing. Biometrics has lot of commercial and daily life applications which creates innovative new systems which are precise and less erroneous. It is used in the:

- Identification and Authentication
- Legal applications: Justice and law enforcement
- Government applications
  - Border control and airport
  - Healthcare and Medical
- Commercial applications
  - Security
  - Attendance and Time Management
- Finance applications of biometric technology, financial identification, verification, and authentication in commerce to make banking, purchasing, and account management safer and more convenient and responsible.
- Mobile
- Eye movements tracking applications
- Automotive industry
- Screen navigation
- Aviation
- Detection and recognition of dynamic shapes
- Forensic Science Applications
- Physical and logical access (owner/user/employee/contractor/partner identification) identification
- Commercial applications (consumer/customer ion)

Check Your Progress 1

1) Define biometrics and state its importance in forensic science.

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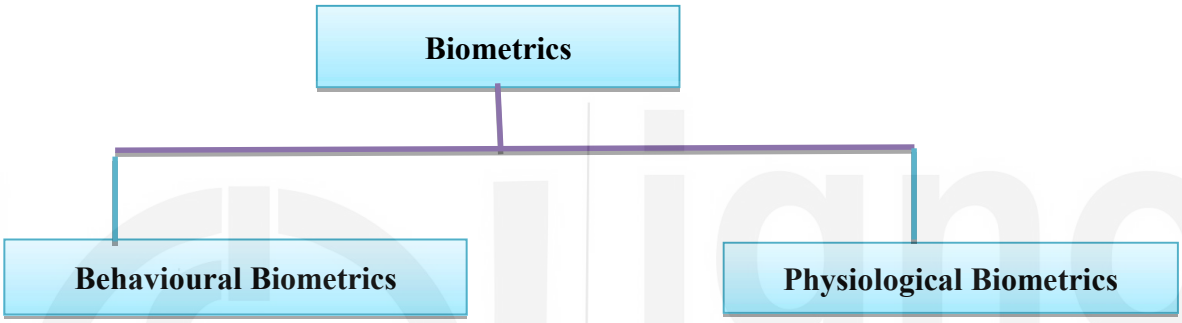
4.2 TYPES OF BIOMETRICS



Behavioural Biometrics is the scientific study of body function and is divided as:

- **Signature Recognition**: The biometric signature recognition system verifies an authorised user for authentication and authorisation.
- **Voice Recognition:** Voice is a behavioural as well as a physiological trait that depends on the physical structure of the throat and mouth and helps to distinguish the speaker as per the speech.
- **Keystroke:** Identification on the basis of striking the keyboard and its rhythm.

Physiological biometrics is based on physical characteristics like, ears, eyes, iris, fingerprints, and is divided as:

- **Ear authentication**: It is based on sound waves to determine the way of the ear canal of an individual.
- **Eye vein recognition:** Biometric identification method by employing pattern formed by veins on the sclera (the white outer coating of the eye).
- **Facial recognition:** 3D structure of face recognition.
- **Finger vein recognition:** Blood vessels pattern recognition under the skin of fingers.
- **Fingerprint recognition:** Fingerprint recognition is comparing the finger prints with available data as no two persons can have similar fingerprints.

- **DNA matching:** The identification based on the analysis of segments from DNA.
- **Footprint and foot dynamics:** Footprint is a unique physiological character with distinctive properties useful in personal identification
- **Gait recognition:** A gait is defined as the cyclic and coordinated combination of movements for human locomotion and a person can be identified by observing his/her gait as a distinguishable feature.

4.2.1 Finger Print Biometrics

4.2.1.1 Introduction

Fingerprint is defined as featured pattern of one finger of ridges and valleys on the surface of a fingertip. The uniqueness in the fingerprint of every individual is based on local ridge characteristics not evenly distributed.

Figure 3: Finger Print

Source: https://www.dreamstime.com/stock-images-fingerprint-image8262454

The differentiation of the fingerprints is minutiae i.e. prominent local ridge characteristics or abnormal points on ridges as mentioned below:

1) Ridge ending: the point where a ridge ends abruptly.
2) Ridge bifurcation: the point where a ridge forks or diverges into branch ridges.

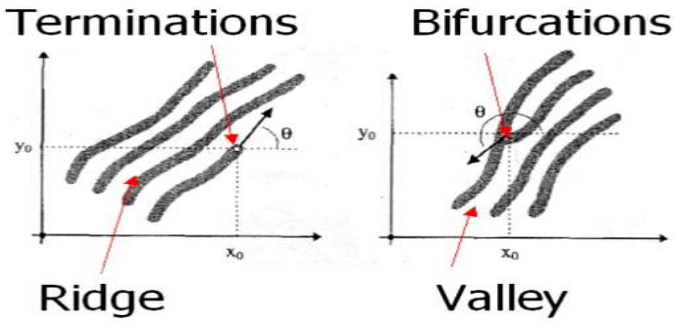


Figure 4: Ridge and Valley

Source:https://www.semanticscholar.org/paper/Fast-Enhancement-Algorithm-with-Improved-Clarity

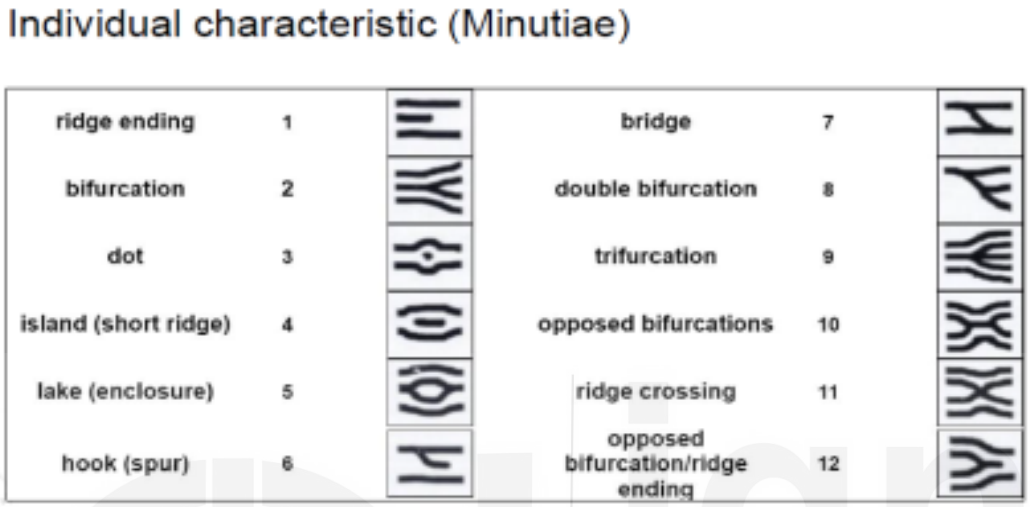


Figure 5: Three Levels of Finger Print Classification

Source:https://www.researchgate.net/publication/281372646_A_Minutiae_Count_Based_Method_for_Fake_Fingerprint_Detection/figures?lo=1

The uniqueness of fingerprints is due to furrows and friction ridges present on fingers or thumb. On the basis of ridge pattern finger prints are classified into three types:

Whorl: The spiral patterns giving an appearance of whirlpools is called whorl and has four types- double loop i.e. S –shaped pattern, concentric plain circles, loop along with whorl i.e. central pocket loop and irregular shaped whorl.

Loop: The patterns that recurve back to form radial or ulnar loops dependings on the pointing direction i.e. towards ulna or radius.

Arch: A wavy pattern i.e. tented (arch rise at sharp point) or plain arches.

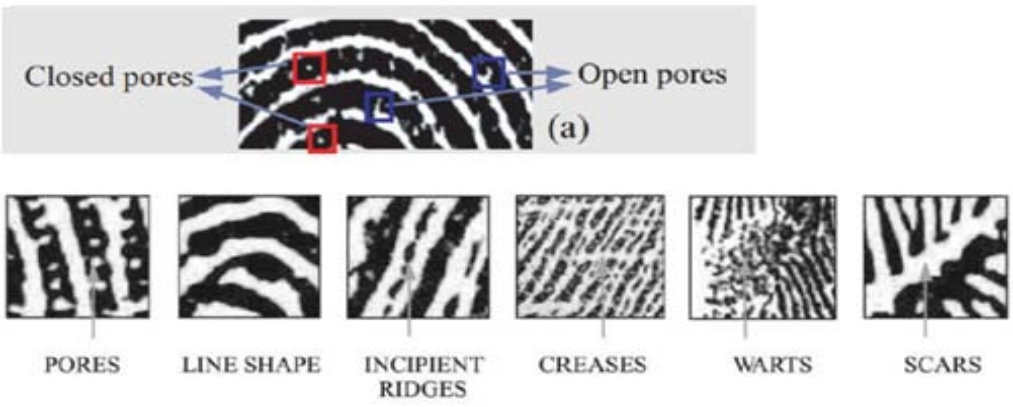


Figure 6: Pores and Ridges

Source:https://www.semanticscholar.org/paper/Pores-and-Ridges%3A-Fingerprint-Matching

4.2.1.2 Finger Print Biometrics Definition

Finger Print Biometrics is defined as the method of identifying finger print by employing the software on the basis of pattern of finger and location of the minutiae.

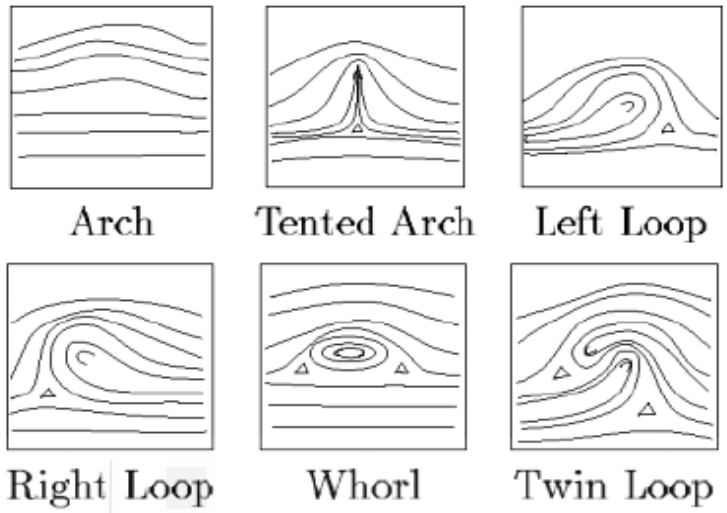


Figure 7: Six Patterns of Fingerprint
Source: https://www.popsci.com/science/fingerprint-patterns-genetics

Structure of Minutiae:

Crossover	two ridges cross each other
Core	center
Bifurcation	ridge separates
Ridge ending	end point
Island	small ridge between two spaces
Delta	space between ridges
Pore	human pore

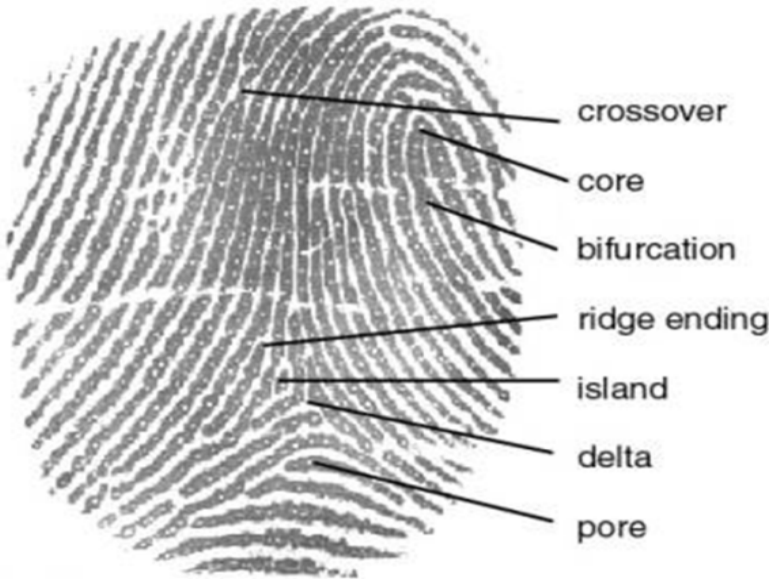


Figure 8: Structure of Minutiae
Source: *https://www.researchgate.net/*

4.2.1.3 Fingerprint Recognition (Physiological Trait)

The process of comparison between the known fingerprint against another in order to determine that it is of the same finger or palm is known as fingerprint recognition and consists of two parts.

Fingerprint Verification: to verify the authenticity of one person by his/her fingerprint.

Fingerprint Identification: to specify one person's identity by his/her fingerprint(s).

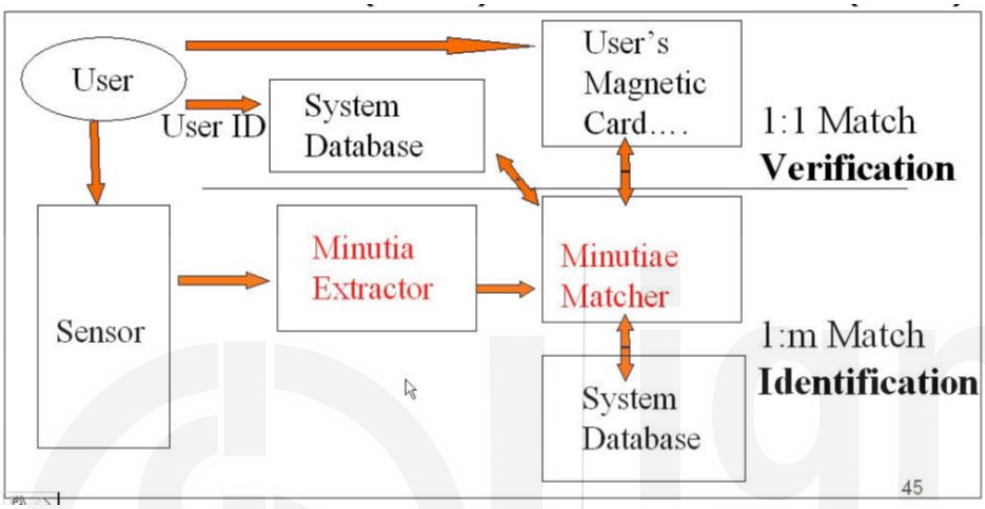


Figure 9: Fingerprint Recognition

Source: https://electricalfundablog.com/fingerprint-recognition-system-architecture-works

Three Stages of Fingerprint Recognition System

1) **Fingerprint Acquiring Device**: Optical or semiconductor sensors are employed for acquisition with high efficiency and acceptable accuracy while exceptions are dry or dirty fingers.

2) **Minutia extractions:**

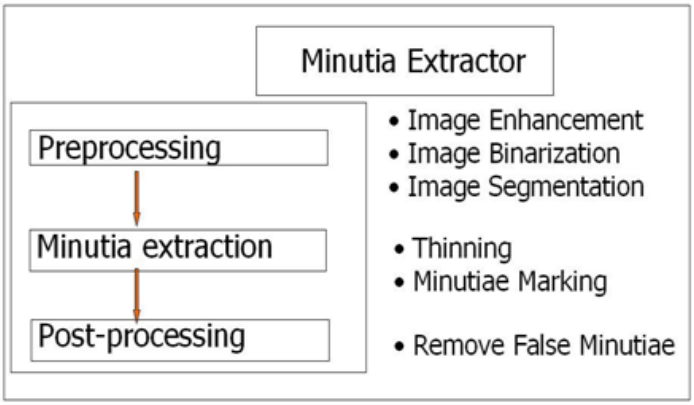
Uses the ridge endings and bifurcations on a person's finger to plot points are known as Minutiae. The variations in the number and location of minutiae occurs from person to person, finger to finger in any particular individual

Finger Finger+ Minutiae Minutiae

Figure 10: Extraction of Minutiae

Source: https://biometrics.mainguet.org/types/fingerprint/fingerprint_algo.htm

This level has three stages pre-processing, minutiae extraction and post processing stage.



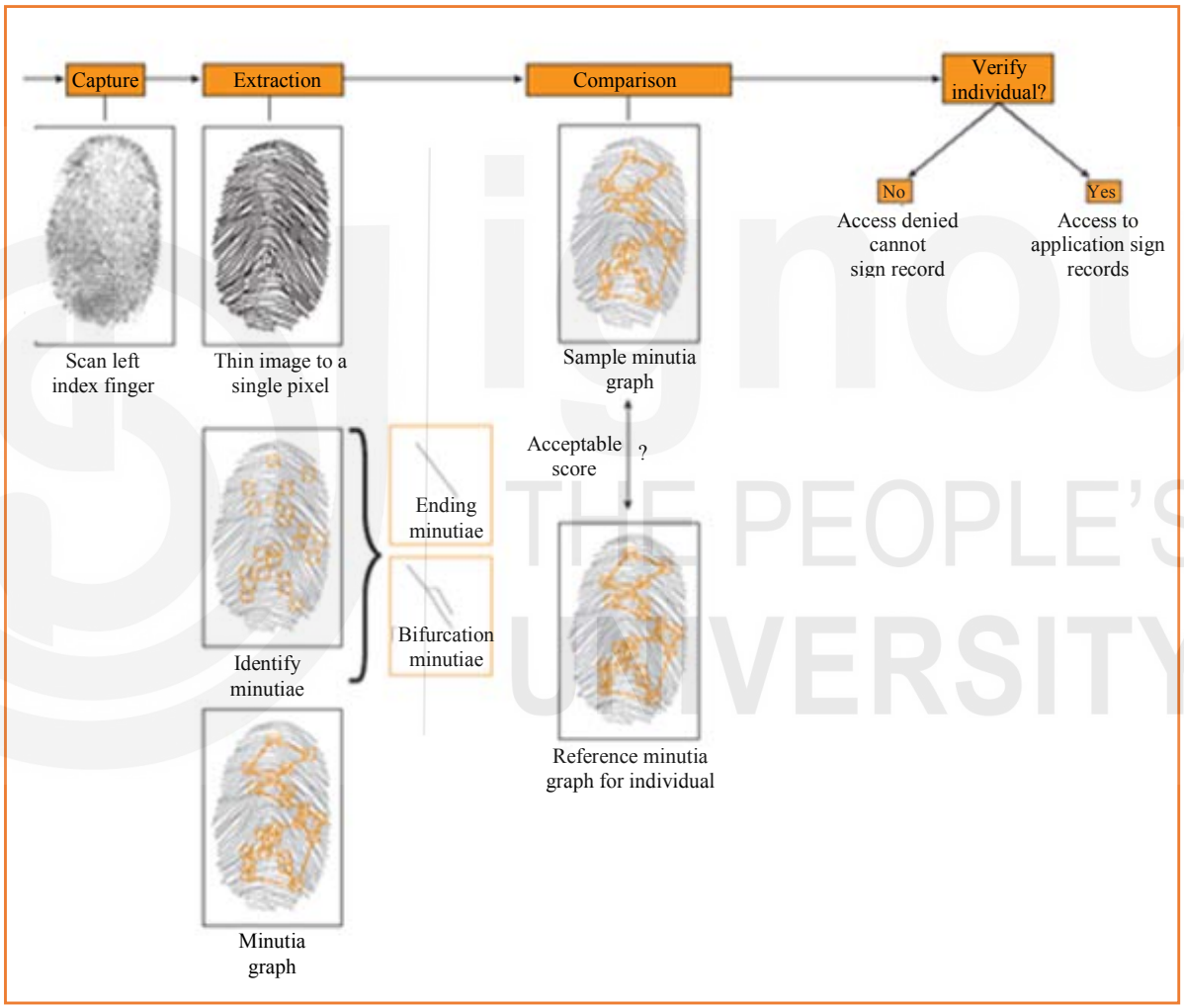


Figure 11: Finger Print Scanning

Source: https://slideplayer.com/slide/13213653/

3) Minutia Matching

Automatic finger print verification is achieved with minutia matching (point pattern matching) instead of a pixel-wise matching or a ridge pattern matching of fingerprint images. First of all, minutia matcher selects two minutiae as reference minutia pair after that matching of the ridges is done and finally on the basis of the ridge matching the image are aligned and matching of all minutiae is overseen.

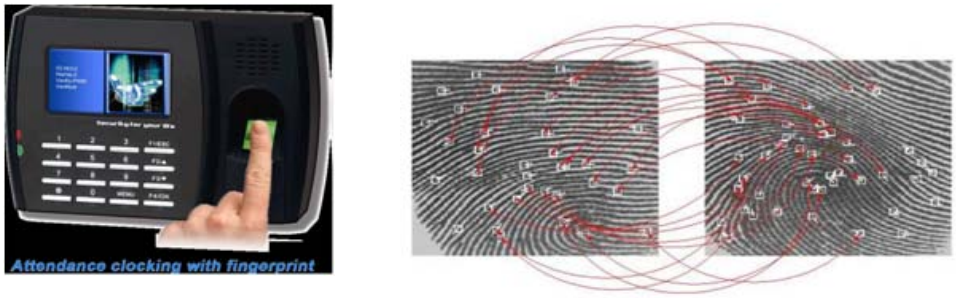


Figure 12: Finger Print Attendance and Minutiae Matching
Source: https://slideplayer.com/slide/13213653/

4.2.1.4 Advantages and Disadvantages of Fingerprint Biometrics

Advantages

- ❖ Fingerprint pattern remain stable throughout the lifetime, unique in nature.
- ❖ It is easily analysed and can be compared.
- ❖ Inexpensive device and oldest form of biometrics.

Disadvantages

- Wet or moist fingers, cut fingers, or dirt or grease can sometimes affect the authentication process.
- It is not right tool for those persons who work in chemical labs.

Applications of Finger Printing

- Banking Security - ATM security, card transaction
- Physical Access Control (e.g. Airport)
- Information System Security
- National ID Systems, Passport control (INSPASS), Voting
- Prisoner, prison visitors, inmate control
- Identification of Criminals and missing children
- Secure E-Commerce (Still under research)

A person's biometric identity is on the basis of one–to-one match or on other security measures like password, PIN etc.

Figure 13: Fingerprint Biometrics
Source: https://slideplayer.com/slide/13213653/

Check Your Progress 2

2) Explain fingerprint recognition with applications and advantages.

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3) Draw different patterns of fingerprint.

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4.2.2 Iris Patterns Biometrics

Eyes are important part of the individual and iris or the coloured part of the eye which has thick and thread-like muscles for Biometric recognition as shown in the figure 14.

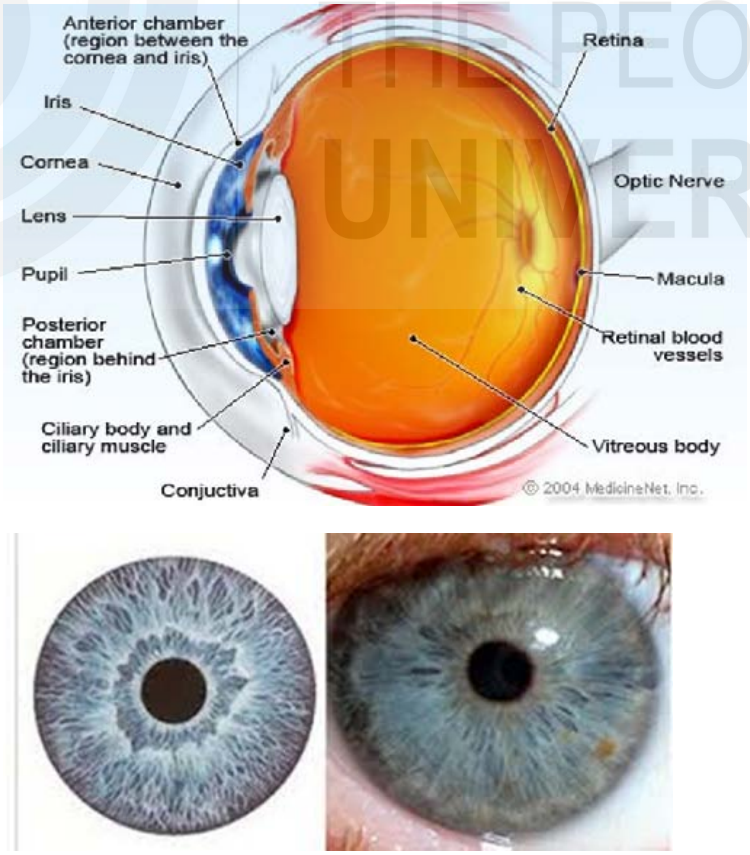


Figure 14: Iris Structure

Source: https://en.wikipedia.org/wiki/Iris_(anatomy)

Iris is made up of pigmented elastic tissue with an adjustable circular opening in the centre. The muscular pattern and colour is unique in every individual even the right and left eye is different thus it becomes a reliable biometric recognition character. Therefore you have to remember that the colour and muscular pattern is a feature for Iris Recognition along with distant technology applicable.

Iris recognition is an automated method of biometric identification by employing mathematical pattern recognition techniques on the images of the iris of an individual's eye or unique complex random patterns.

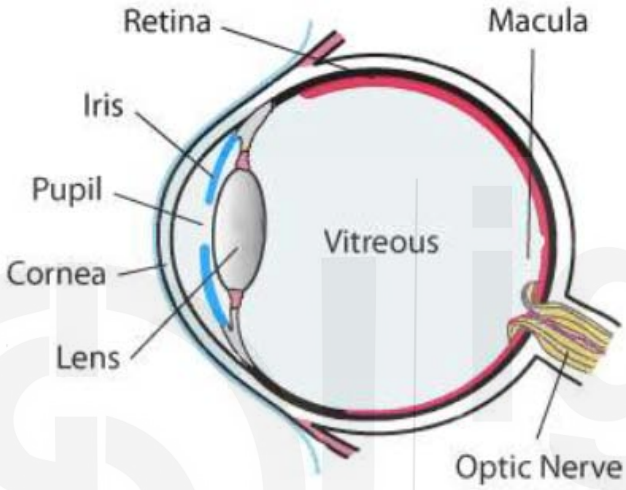


Figure 15: Eye Structure

Source: https://www.merckmanuals.com/home/eye-disorders/biology-of-the-eyes/structure-and-function-of-the-eyes

4.2.2.2 Iris as Biometric

Further you have to understand that the function of muscles is to provide shape to pupil and light that enters the eye. The uniqueness of the folds of muscles results into biometric authentication to confirm the identity with incredible accuracy. Other essentials you have to note is liveness detection like blink for scan enhance its accuracy and security. The technology has advantage of its applicability from a distance also. Note that the iris pattern is not subject to alteration with age, eye redness or alcohol consumption. Iris recognition can be used as Biometric because iris is the coloured portion of the eye surrounded by the pupil and its pattern is the result of meshwork of muscle ligament while colour and contrast are due to pigmentation.

4.2.2.3 Iris Recognition (Physiological Trait)

The recognition of Iris is carried out on the basis of the following traits:

- Iris scanning measures the iris pattern in the coloured part of the eye.
- Analysis of the iris of the eye, which is the coloured ring of tissue that surrounds the pupil of the eye.

- Based on visible features.
- Widely regarded as the most safe, accurate biometrics technology
- High speed, high accuracy.

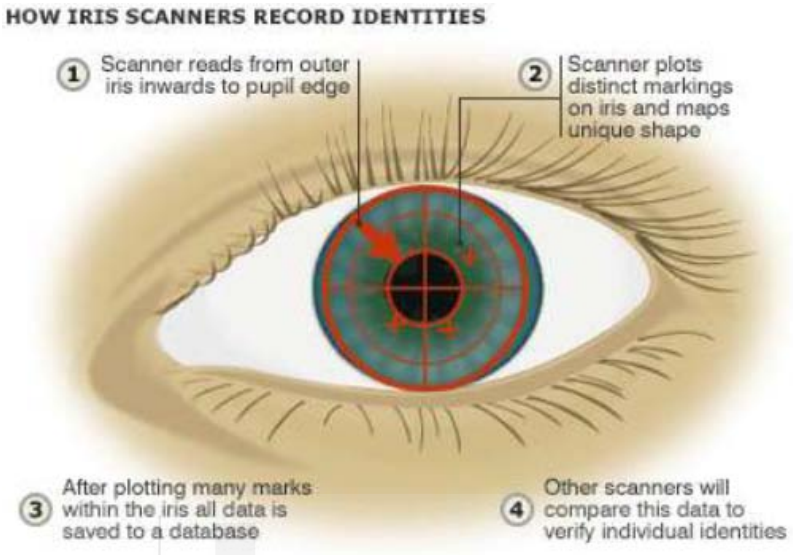


Figure 16: Eye

Source: https://www.merckmanuals.com/home/eye-disorders/biology-of-the-eyes/structure-and-function-of-the-eyes)

4.2.2.4 Iris Recognition Systems

Biometric Iris recognition is based upon the working of camera with the mathematical analysis of the random patterns. Imagine Iris as your phone camera where camera and light combine to take a photo. In the same way iris camera carries out a person's identity by combining computer vision, pattern recognition, statistical inference and optics.

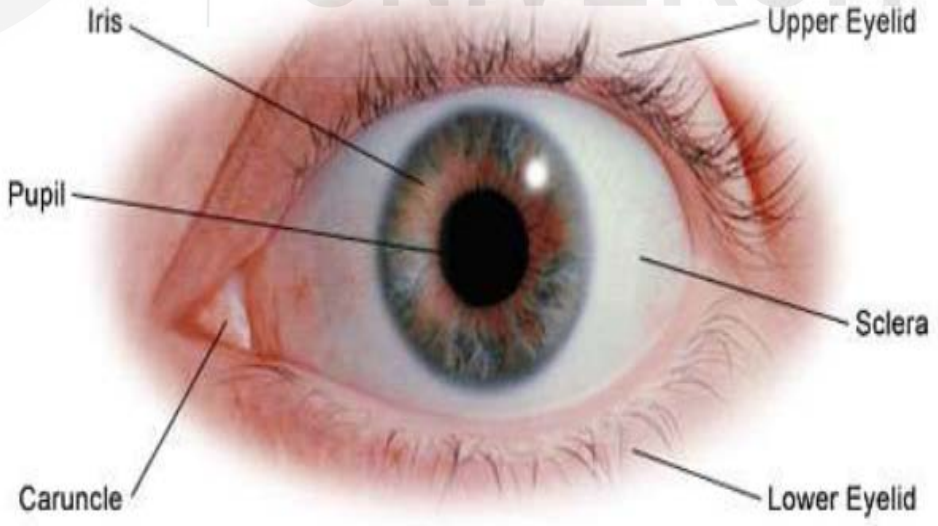


Figure 17: Eye Structure from Front

Source:https://www.dreamstime.com/structure-eye-anatomical-external-structure-iris-cornea-eye-pupil-structure-eye-anatomical-image168611026

This is how it happens:

1) A person stands in front of the iris identification system with a distance of one or three feet so that the wide angle camera calculates the position of their eye.
2) The function of the second camera is to zoom on the eye and takes a black and white image.
3) The focus of the iris overlays a circular grid on the image of the iris thus identifying the light and dark areas, like an "eye print".
4) Fake eye prevention or fool system is done by the devices which vary the light shine into the eye and watch for pupil dilation.

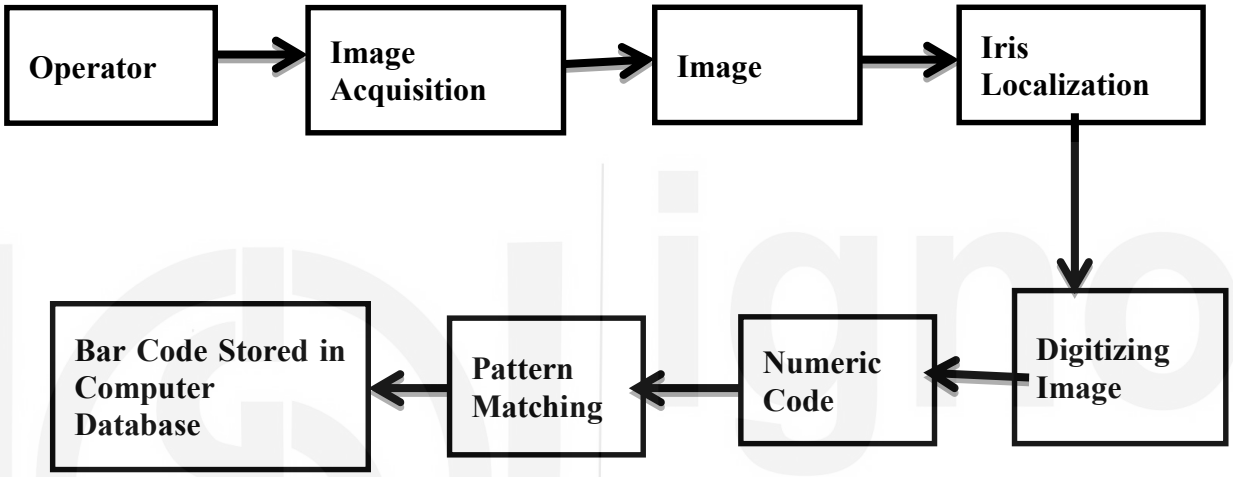


Figure 18: Block Diagram of Iris Recognition

Source:https://www.researchgate.net/publication/224597357_Iris_Segmentation_Using_Geodesic_Active_Contours/

4.2.2.5 Iris Recognition Function Steps

Four functional steps for Iris recognition are

1) Image Acquisition
2) Pre-processing
3) Image Analysis
4) Image Recognition

1) Image Acquisition

This is an important step as image acquired would lead to recognition and the characteristics required are:

- Good contrast,
- high quality image and
- high illumination.

Camera should be able to capture volume width on the order of 20–30 cm and more than 200 pixels across the iris for good quality as 100–150 pixels

results for marginal quality. Daughman's (1993) Algorithm described the methodology for image analysis i.e. Iris Segmentation as described: Iris is mapped into a rectangle in normalised polar coordinate system and segmentation normalises for scale change and pupil dilation.

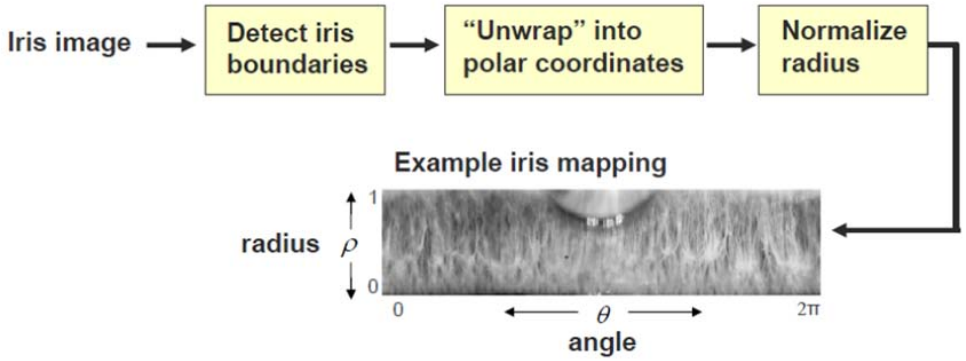
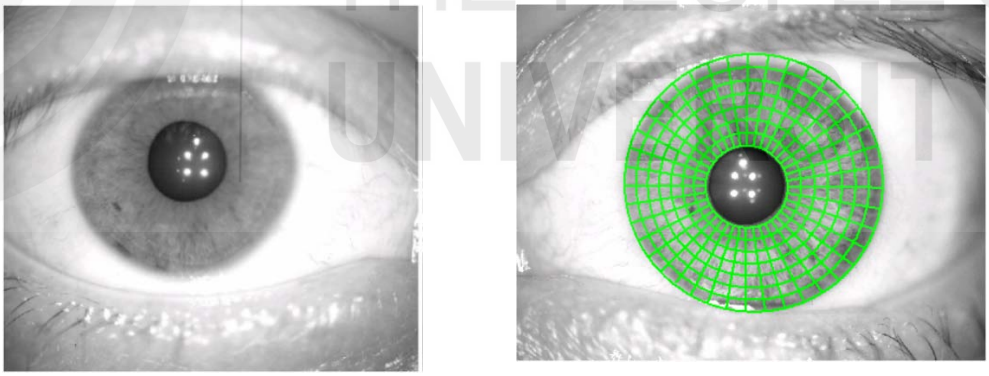


Figure 19: Mapping of Iris

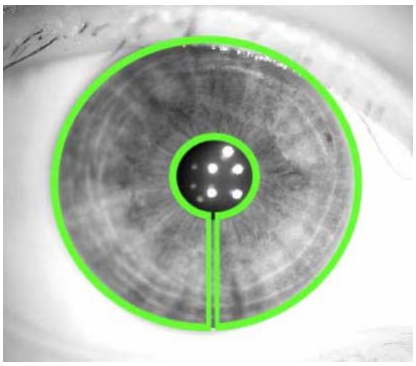
Source:https://www.researchgate.net/publication/224597357_Iris_Segmentation_Using_Geodesic_Active_Contours

Segmentation: Boundary Detection

- Segmentation is simplified by modelling the inner and outer iris boundaries as non-concentric circles.
- For each boundary, we must find 3 parameters: x and y of centre, and radius r.
- Search Criteria is based on intensities along with an expanding circular contour that become suddenly brighter (from red circles to green circles).

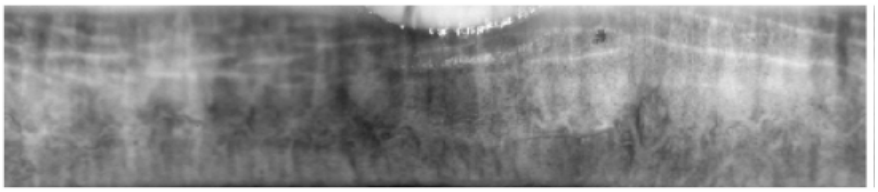


First Step: Iris Segmentation



"Unwrapping" the iris

Outer boundary (with sclera)



Inner boundary (with pupil)

Figure 20: Boundary Detection Example
Source:https://casvisualfoundation.wordpress.com/2015/03/24/tuesday-excursion-research-and-experiment-4/

2) Pre-processing

Next step is to classify whether the image acquired is useful or not which means the irrelevant parts e.g. eyelids or pupil and the pre-processing would remove the effect of the spots /holes lying on the pupillary area. This process also transforms the true colour into intensity image. The two steps of pre-processing are:

a) Iris Localisation

The outer and inner boundary of the Iris is considered as two circles that are not co-centric thus inner boundary between the pupil and the iris is detected. To detect the outer boundary due to its low contrast between the two sides is found by maximizing changes of the perimeter- normalised along the circle.

b) Edge Detection

The usage of Edge Detection is to evaluate complex object boundaries by marking potential edge point corresponding to places in an image where rapid change in brightness occurs and edge is defined by the discontinuity in grey values thus an edge separates two distinct objects.

3) Image Analyses

Image analysis visualises the features of Iris and digitised into a 512 byte (4096 bits) Iris Code record. Half Iris Code describes the features and another half controls the comparison process.

4) Image Recognition

The database is built by storing the different Iris Code. You can apprehend that the recognition is same as going to the market to buy a T-shirt of

particular colour by searching and comparing. Same way an iris is presented at a recognition point and process is repeated and compares it to every file in the Database Recording of Identities thus the Iris Code record is not stored.

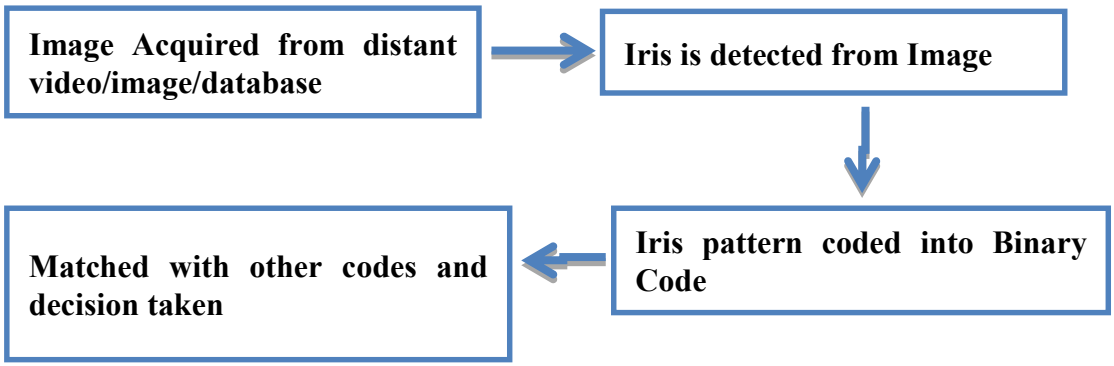


Figure 21: The Process Overview

4.2.2.6 Advantages of Iris Technology

Advantages of the technology are mentioned below:

- Accurency: Uniqueness of iris patterns hence improved accuracy.
- Highly protected: It is the internal organ of the eye.
- Stability: Persistence of iris patterns.
- Non-invasive: Relatively easy to be acquired.
- Unique: The probability of two rises producing the same code is nearly impossible.
- Flexible: Iris iris recognition technology easily integrates into existing security systems or operates as a standalone.
- Stability: Patterns apparently stable throughout life.
- Reliable: A distinctive iris pattern is not susceptible to theft, loss or compromise.

4.2.2.7 Disadvantages of Iris Technology

Iris Biometrics disadvantages are listed below:

- Small target (1 cm) to acquire from a distance (1m).
- Alcohol consumption causes deformation in Iris pattern.
- Illumination should not be visible or bright.
- Obscured by eyelashes, lenses, reflections.
- Difficult to capture an image of handicap people sitting on wheel chair as cameras are usually attached on the wall therefore can capture an image up to a certain height.
- Costlier iris recognition systems.
- Authentication is affected with glasses or direct sunlight.

4.2.2.8 Applications of Iris Recognition System

Iris recognition is playing an important role:

- in providing unique identification to the individuals for the bank accounts aadhar card etc.
- as living password for computer login.
- as living passport for national borders security.
- driving licenses and personal certificates.
- internet security, control of access to privileged information.
- premises access control (home, office, laboratory).
- anti-terrorism (e.g. security screening at airports).
- financial transactions (electronic commerce and banking).
- iris password for the bank cash machine accounts.
- credit-card authentication.
- automobile ignition and unlocking; anti-theft devices.

Real Life Applications

- Iris scanning forms the basis for Aadhaar Card.
- Border Patrolling in UAE.
- Iris scanning permits the passport in countries US, Canada.
- Iris scanners are employed to control access of Datacentres of Google.

Check Your Progress 3

4) Explain in detail about the image acquisition in iris scan technology.

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5) Draw the structure of Iris.

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4.2.3 Retinal Pattern Biometrics

Dr. Carleton Simon and Dr Isodore Goldstein in 1930-1935 conducted first scientific study to describe how every individual possesses a unique Retinal structure. Because of the differing distribution of blood vessels, they suggested the use of the Retina to confirm the identity of an individual. Dr. Paul Tower (1950) reported that even identical twins have a very distinct and unique set of Retinas and has DNA Strand leading to very stable Biometric modality and that hardly changes.

Human retina is a thin tissue composed of neural cells located in the posterior portion of the eye. Retina is a complex structure with a network of blood capillaries and vessels resulting into the unique feature for every person as identical twins do not have same features. Retinal patterns are altered due to medical morbidities otherwise it is same from birth to death. The unique Retinal patterns of the individual is used as biometric identifier and the blood vessels within the retina absorb light more readily than the surrounding tissue which forms the typical smallest template for the Biometric Technology. The principle for the Retinal scan is carried out by casting an unperceived beam of low-energy infrared light (IR) into a person's eye and beam traces a standardised path on the retina as retinal blood vessels are more absorbent than the rest of the parts of the eye, then this path is converted to computer mode.

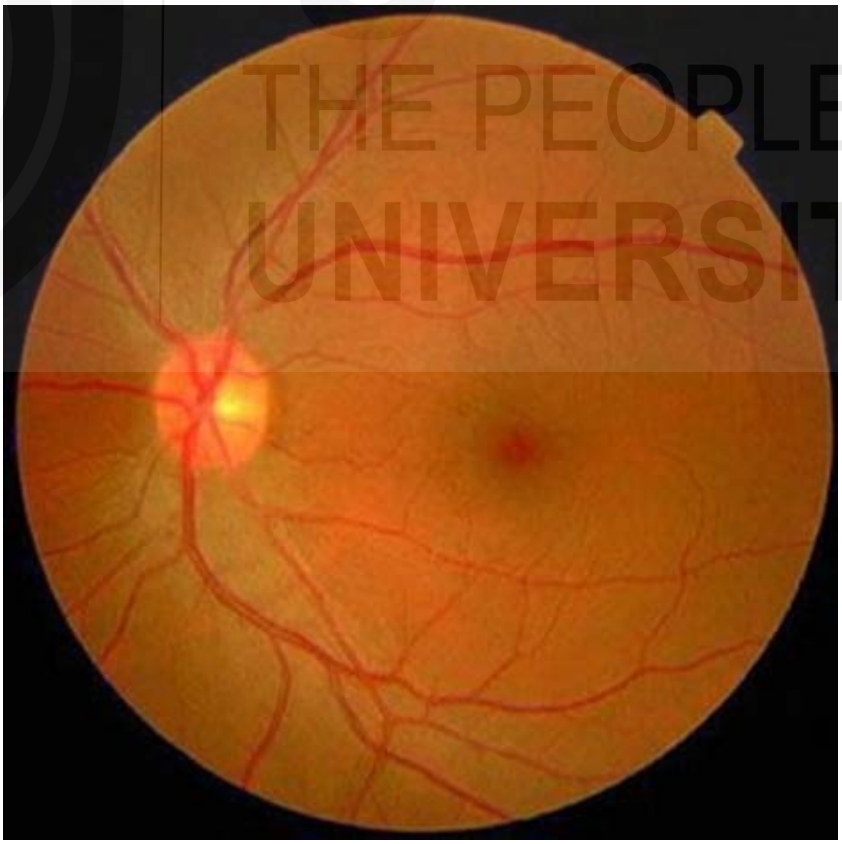

Figure 22: Retina Structure
Source:https://jackwestin.com/resources/mcat-content/vision/structure-and-function-of-the-eye

4.2.3.1 Process of Retinal Recognition

In comparison to Iris recognition where images are collected from a far distance but Retinal recognition requires end user must be in close proximity to retinal scanning device. The process has following steps:

1) Image/Signal Acquisition and Processing:

The individual eye resides on tiny receptacle to receive infrared light beam for the illumination of retina at 360^0. The duration of the process is few minutes with precaution that the individual must remain still till one rotation is completed. Five images are taken to create the composite image from which the unique features are extracted.

2) Enrolments and Verification Template Creation:

Retinal patterns are not genetically controlled thus 400 unique data points are captured from the Retina, unlike the fingerprint, where only 30-40 unique data points are captured to create the Enrollment Template with a size of 96 bytes. The small size makes it possible to store number of templates in a single database and same process leads to creation of Verification Template. Due to the close proximity of numbers of factors influence the quality of Enrollment and Verification Templates as mentioned below:

- Individual cooperation is lacking
- The individual's eye and the lens distance is more.
- The size of the individual's pupil:

Figure 23: Retinal Recognition

Source: https://platform.keesingtechnologies.com/retinal-recognition-pros-and-cons/

4.2.3.2 Advantages and Disadvantages

The advantages of Retinal Recognition are:

- Due to stability and hardly ever changes over the lifetime an individual retina is a reliable Biometric technology.
- Small sized images give quick results for the identity of the individual.
- More number of unique data points and makes error less identity.
- Retina is present within the eye thus not affected by the external environment like fingerprints.

Disadvantages

- The individuals are not comfortable to place their eye on the receptacle with the direct infrared light.

- Retinal Recognition requires high level of cooperation and motivation from the end user to capture high quality, raw images leading to low verification with a metric of 85% as compared to 100%.
- The cooperation of the end user leads one to take numerous attempts and a long time till the final result is obtained therefore there are many false rejections.

4.2.3.3 Criteria for Effectiveness and Viability of Retinal Recognition

Overall, the effectiveness and viability of Retinal Recognition is examined against seven criteria as mentioned below:

- Universality
- Uniqueness
- Permanence
- Collectability
- Performance
- Acceptability
- Resistance to circumvention

The retinal template generated is typically one of the smallest of any biometric technology.

4.2.3.4 Similarities and Differences:

While both iris and retina scanning are ocular based biometric distinct technologies but there are evident similarities and differences as mentioned below:

Similarities:

- Low occurrence of false positives.
- No two individuals have the same Iris and Retina pattern thus reliable technique.
- Identity of the individual is authenticated very fast.
- The capillaries in the iris and retina decompose too rapidly to use an amputated eye to gain access.

Differences:

- Retinal scan measurement accuracy can be affected by disease; iris fine texture remains remarkably stable.
- Taking a photograph is similar to iris scan from distance while for the retinal scanning the individual has to be near like seeing a slide under microscope.

- Iris scanning is more widely accepted as a commercial modality than retinal scanning
- Retinal scanning is invasive but not iris.

The primary function of Iris is to allow the requisite amount of light required for proper vision. The retina is located at the back of the eye and links front of the optic nerve to the brain therefore the function of retina is to send visual information and cues to the brain for processing.

In other words, at Retina, image is formed that means it acts like a film of camera.

Check Your Progress 4

6) Write a short note on retinal scanning technology.

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4.2.4 Facial Recognition Biometrics

Another Biometric Technology includes the Face Recognition a technique that is capable of identifying or verifying a subject through an image. This method employs measures of face and head to identify the identity of a person through the facial biometric pattern. The first facial recognition was carried out in 1960 based on the features of eyes, nose, etc. The 21 subjective markers e.g. hair colour, lip thickness were employed by Goldstein and Harmon in 1970 to automate the recognition. The standard linear algebra techniques were applied in 1988 by Kirby and Sirovich for face recognition. The reasons that Face Biometric is beneficial than the Biometrics are:

- No physical interaction on behalf of the user is required.
- Accurate with high enrolment and verification rates.
- No experts as such needed for interpretation of the results.
- Only biometric that allows passive identification in a one to many environments.

4.2.4.1 Facial Recognition System

Two types of comparisons are done

Verification- It is comparison of the given individuals who are similar by the system and then result is yes or no decision.

Identification- The given individual is compared to all the entities present in the database thus deciphering a rank list of matches.

There are four stages in Identification technologies i.e.

i) **Capture:** During enrolment or verification or identification process, the system captures a physical or behavioural sample.

ii) **Extraction:** The creation of template by extracting unique data.

iii) **Comparison:** Compare the template with a new sample.

iv) **Match/non-match**: Matching the features extracted from new sample and decide whether matched or not.

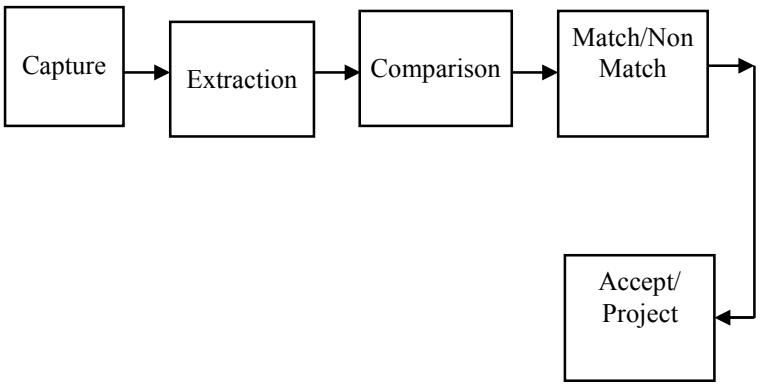

Figure 24: Four Stages of Identification

Source:https://www.researchgate.net/publication/328577882_Face_Recognition_Based_on_PCA_and_DCT_Combination_Technique/

4.2.4.2 Components of Face Recognition Systems

Enrolment Module: An automated mechanism that scans and captures a digital or an analog image of living personal characteristics

Database: Another entity which handles compression, processing, and storage of the captured data with stored data

Identification Module: The third interfaces with the application system

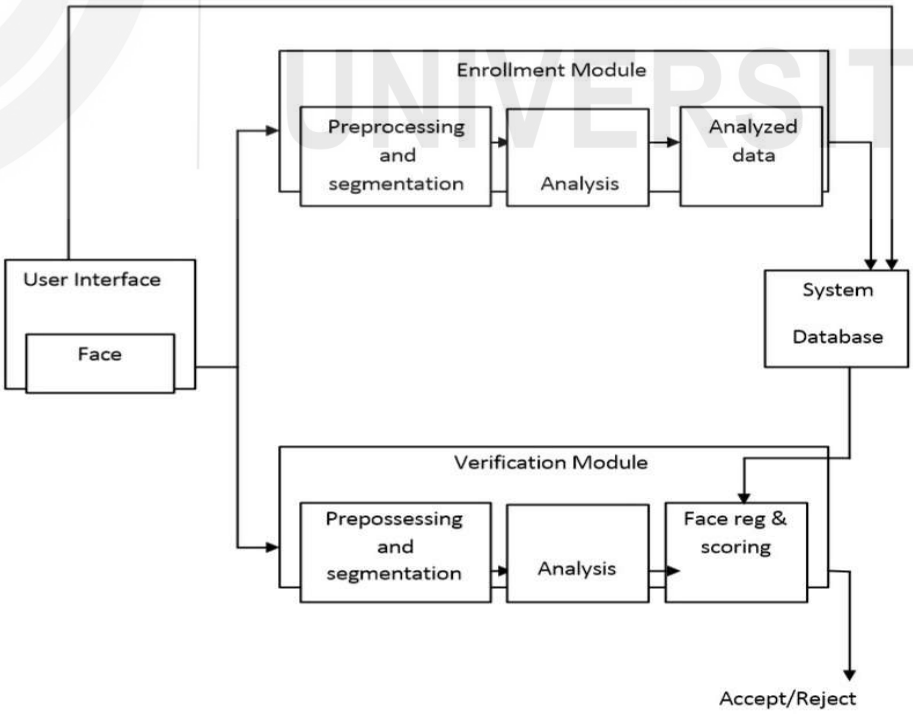

Figure 25: Components of Face Recognition

Source:https://www.researchgate.net/publication/328577882_Face_Recognition_Based_on_PCA_and_DCT_Combination_Technique/

4.2.4.3 Implementation of Face Recognition System

There are four stages in implementation process as mentioned below:

i) Image Acquisition
ii) Image Processing
iii) Distinctive Characteristic Location
iv) Template Creation And Matching

i) Image Acquisition

The static camera or video system acquires image of quality and resolution, an essential component for verification, identification and authentication.

ii) **Image Processing**

The image processing steps:

- Detect the face or faces at crime scene
- Normalise and localise the face to bring the dimensions in live facial sample
- Crop the image to get ovoid facial image
- Coloured images conversion to black and white
- Initial comparisons on grey scale basis
- Align the facial sample with the templates

Distinctive Characteristic Location

The features used for matching are upper ridges of the eye sockets, areas around the cheekbones, sides of the mouth, nose shape, and the position of major features relative to each other and these features hardly change.

Template Creation and Matching

Processed facial images help to create enrolment template of varying size from 100 bytes to 3K and larger templates are related to behavioural biometrics. Matching is done 1:1 verification within facial scan system and it is not as effective as other scans and many are returned.

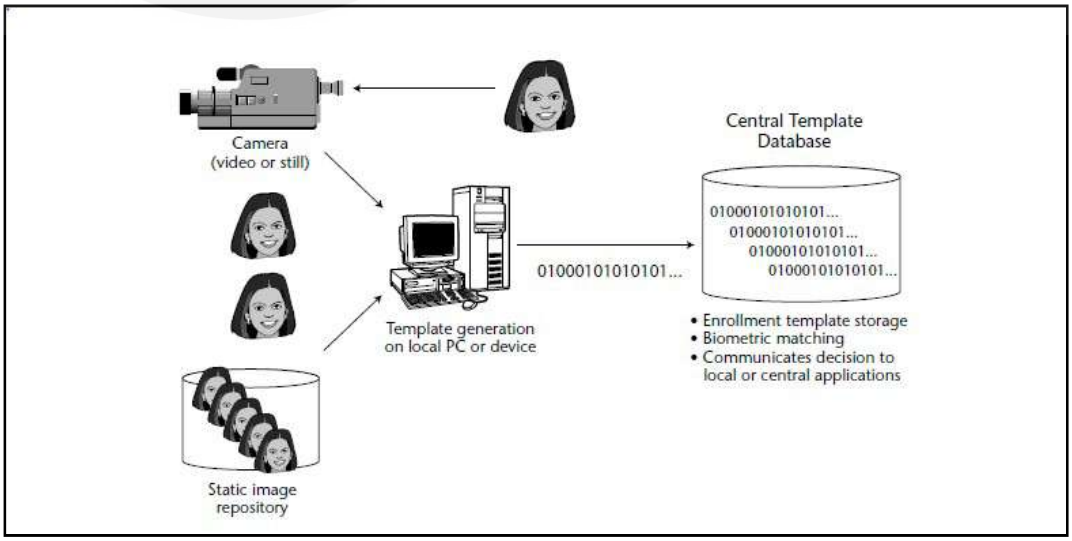

Figure 26: Template Creation

Source:https://www.researchgate.net/publication/328577882_Face_Recognition_Based_on_PCA_and_DCT_Combination_Technique

4.2.4.4 Face Recognition Systems Working

Everyone has distinguishable points on the face i.e. valleys and peaks which are defined as nodal points in software. There are 80 nodal points on human face that are measured by software i.e.

- distance between the eyes
- width of the nose
- depth of the eye socket
- cheekbones
- jaw line
- chin, etc.

For the general representation of face 70 nodal points are used to construct the face bunch graph and an image template is matched with this face graph in order to get the same points. The measured nodal points are given numerical code and strings of numbers represent a face in the database called face print.

Figure 27: Face Bunch Graph

Source:https://www.semanticscholar.org/paper/Face-Recognition-for-Smart-Environments-Pentland

4.2.4.5 Strengths and Weaknesses of Face Biometrics

The advantages of face biometrics are as:

- ❖ convenient and has social acceptability as only picture is required.
- ❖ person is not required only image can do.
- ❖ most inexpensive biometric and has leverage for existing image.
- ❖ searching can be done on basis of static image like license and can be performed without user cooperation.

This system has one weakness:

- cannot differentiate between identical twins.

4.2.4.6 Applications

Face recognition biometrics has replaced PIN naturally and other applications as listed below:

Government Use:

- Law Enforcement
- Security/Counter terrorism

- Immigration: Rapid progression through customs
- Voter verification

Commercial Use:

- Residential Security: Alert homeowners of approaching personnel
- Banking using ATM: Customer's face identified quickly with the software
- Physical access
- Face Recognition technology has now progressed and become cost effective, reliable and highly accurate thus being applied at many places.

4.2.5 DNA Biometrics

Behavioural or physiological traits in Biometric systems are pertaining to individual recognition and out of which DNA profiling and fingerprinting is the most reliable accurate method as it is intrinsically digital, and not altered during lifetime or death. DNA profiling is known as ultimate identifier.

DNA Biometrics is defined as a specific pattern obtained from a person or sample from the crime scene. DNA fingerprinting, is also known as DNA typing, DNA profiling, genetic fingerprinting, genotyping, or identity testing and it is the method of isolating and identifying variable elements within the base-pair sequence of DNA (deoxyribonucleic acid). British geneticist Alec Jeffreys (1984) developed the DNA Fingerprinting with a principle of isolating and identifying variable elements within the base-pair sequence of DNA which do not participate in functioning and highly variable called minisatellites. Jeffrey reported that unique pattern of minisatellites are present in every individual and only exception is identical twins from single zygote. At present DNA fingerprinting is making usage of microsatellites of short tandem repeats (STR) of 2-5 base pairs long.

Every individual has same chemical structure with a unique set of genes and 1% of DNA differs from person to person in sequence arrangement and it can be understood as STOP and POTS use same letters but meaning differ. DNA profiling is dependent on VNTR (Variable Number Tandem Repeats) which are of two types: minisatellites and microsatellites. DNA profiling uses repetitive sequences. VNTR loci are very similar between closely related individuals. The analysis of variable number of tandem repeats (VNTRs) is to detect the degree of relatedness to another sequence of oligonucleotides, making them ideal for DNA finger printing. There are two principal families of VNTRs:

a) Microsatellites

b) Minisatellites

Microsatellites are defined as repeating sequences of 2-6 base pairs of DNA which are also called Simple Sequence Repeats (SSRs) or Short Tandem Repeats (STRs). VNTR of 10-60 base pairs are named as minisatellites and their analysis has direct application genetics, forensics, biology and DNA fingerprinting.

4.2.5.1 Technique of DNA Fingerprinting

Step-1 Collection and Isolation of DNA

Reference Sample i.e. DNA sample of an individual of buccal swab or blood or biological samples collected from the crime scene. Significance of DNA analysis is that very small amount of sample is required in microliters. Alkali and salt treatment is done on sample to get purified DNA without proteins.

Step-2 Cutting, Size and Sorting

DNA is cut into small fragments by employing Restriction Enzymes which cut DNA at specific sites e.g. EcoR1 will cut DNA when the sequence5'..GAATTC..3' occurs.

Figure 28: Each Enzyme cuts at Specific Site

Source: sigmaaldrich.com/IN/en/product/sigma/r0260

Cutting of DNA yields short and long fragments which are sorted according to size

Step-3 Separation of Fragments

Agarose gel electrophoresis is used to separate the DNA fragments on the basis of size. The negatively charged DNA moves towards positive end and shorter segments move faster than the longer thus DNA is sorted on the basis of size. The electrophoresis to sort more than one sample at one time as different samples can be loaded in the wells. Ethidium Bromide is added to get fluorescent bands which can be visualized under UV illuminator.

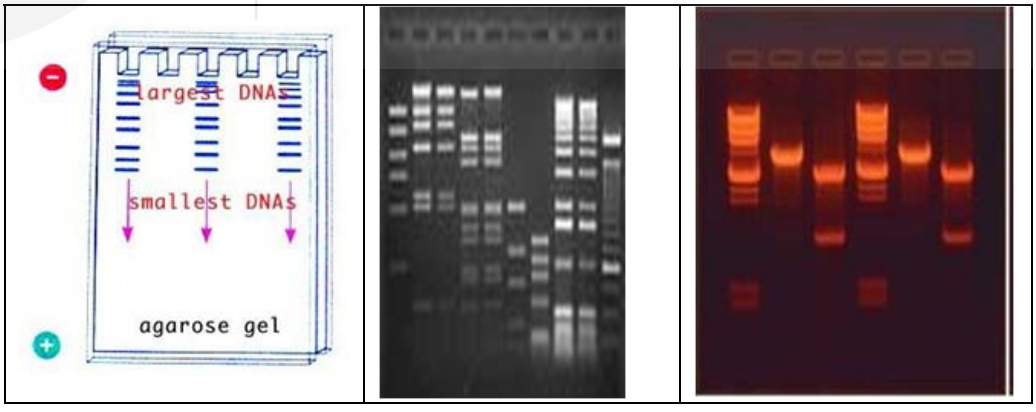

Figure 29: Agarose Gel Electrophoresis and Bands on the Gel

Source:https://www.researchgate.net/publication/280232114_Isolation_and_Characterization_of_Mercury_Resistant_Bacteria_from_Fly_Ash_Sample_of_Mejia_Thermal_Power_Plant_W_B_India_for_Application_in_Bioremediation_and_Phytoremediation/figures?lo=1

Step-4 Southern Blotting and Hybridisation

A Molecular technique used to transfer DNA from gel to nylon nitrocellulose membrane by applying blotting technique. Radioactive or coloured probes are added to nylon sheet which sticks to only one or two specific places thus probe is hybridised and pattern developed is DNAs fingerprint.

Step-5 DNA Fingerprint

The final DNA fingerprint is built by using several probes (5-10 or more) simultaneously and the bar codes are used like in shops. DNA Fingerprint is then analysed by comparing the victim and the suspect. The matching of the profile generates strong evidence that the suspect was at the crime scene but does not hint that he/she has committed the crime as it does not match, then eliminated from the enquiry.

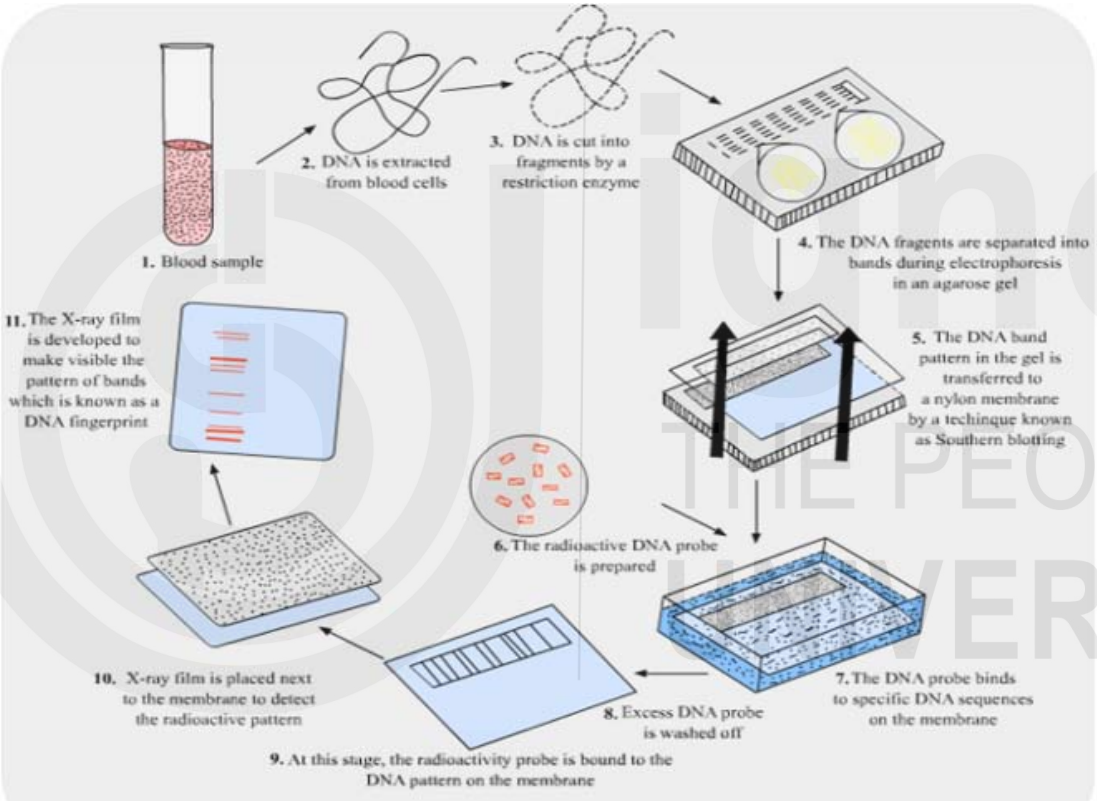

Figure 30: Steps in DNA Fingerprinting

Source: https://allaboutdnafingerprinting.weebly.com/steps-of-dna-fingerprinting.html

4.2.5.2 Applications of Fingerprinting

Diagnosis and Developing Cures for Inherited Disorders:

DNA fingerprinting is used to diagnose inherited disorders in both prenatal and new-born babies in hospitals around the world along with the probability of occurrence of the disease.

Biological Evidence to Identify Criminals:

DNA Fingerprinting is helpful in forensics as the biological specimens present at the crime are important source of DNA and proves to be valuable source of DNA of the criminal and innumerable cases are solved on this basis.

3) **Paternity Disputes:** DNA Fingerprint is utilised to solve paternity dispute cases in court as fingerprints unprecedented with accuracy and reliability.

4) **Personal Identification:** As same DNA is present in all the body tissues and organs thus DNA profiling is the best tool for personal identification

4.2.5.3 Advantages and Disadvantages of Fingerprinting

Advantages of DNA matching

- Accurate method of identification and has become a reliable and matured method of identification.
- Used for medical purposes e.g. the success of bone marrow transplant is dependent on DNA matching.
- No system performance issues.

Disadvantages of DNA matching

- DNA profiling requires a physical sample for collecting biometric data and has to be stored with appropriate environmental conditions.
- DNA Samples can be prone to contamination.
- It is not fully automated yet and fast unlike other biometric methods even expensive.

Let us see the Comparison

DNA	Conventional Biometrics
Requires an actual physical sample	Uses an impression, image, or recording
Not done in real-time; not all stages of comparison are automated	Done in real-time; automated process
Does a comparison of actual samples	Uses templates or feature extraction

Check Your Progress 5

7) Draw a diagram of the procedure of DNA fingerprinting.

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8) How can DNA be a useful tool in the forensic applications?

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4.2.6 Handwriting and Voice Biometrics

Voice recognition is a crucial Biometric identifier as it recognises the speaker as well as the speech. The measurable, physical characteristic or personal behavioural traits are applied to verify and authenticate an individual. The two components, Speech recognition and Speaker verification are different as former identifies what you are saying and the later verifies who you are.

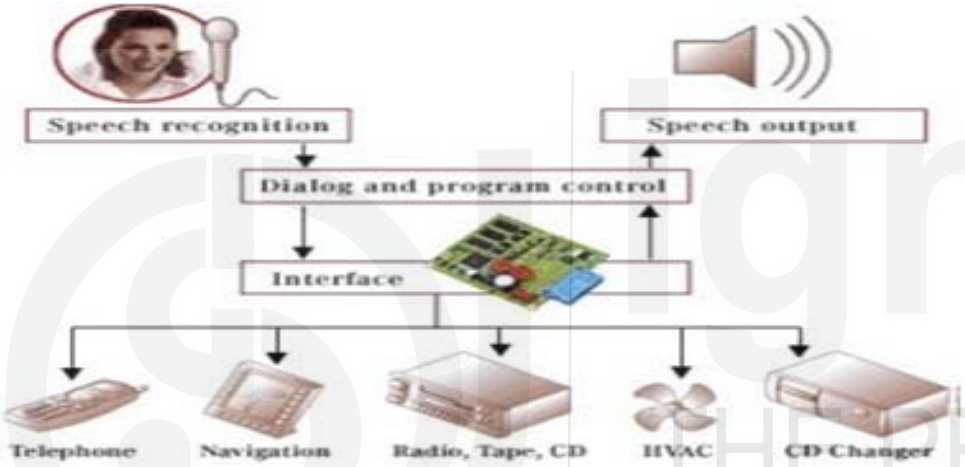

Figure 31: Speech Recognition

Source:https://www.researchgate.net/publication/334285447_Project_Report_On_AI_Speech_Recognition_System/

A speech recognition system assists the speaker in accomplishing what that person wants to do and to identify the speaker then the system has to authenticate the person and verify that he or she is in fact that person.

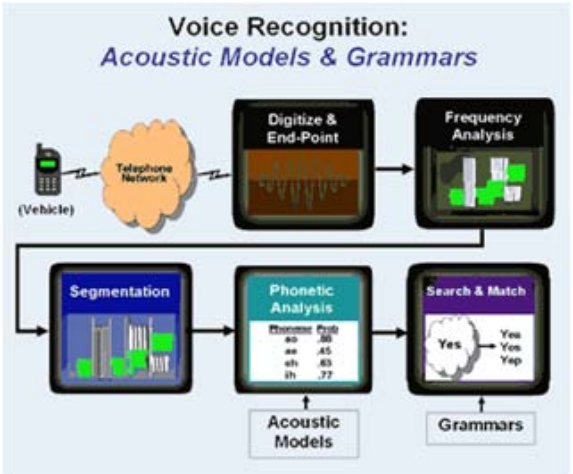

Figure 32: Voice Recognition Model

Source: https://developer.nvidia.com/blog/how-to-build-domain-specific-automatic-speech-recognition-models-on-gpus/

Biometric System is the combination of speech recognition and speaker verification systems

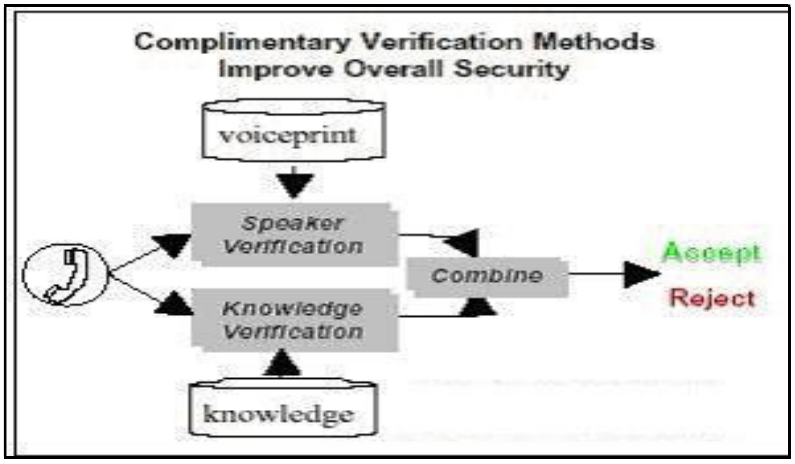

Figure 33: Biometric System
Source: *https://www.researchgate.net/*

Voices have unique features like frequency and intensity which is manipulated in the system to digitising a person's speech to produce a **"voice print".** See figure 35.

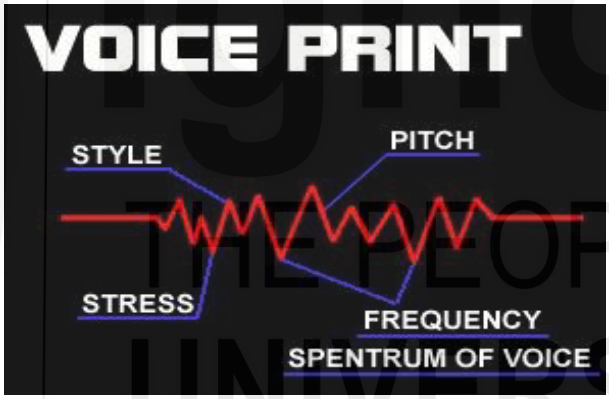

Figure 34: Voice Print
Source: https://developer.nvidia.com/blog/how-to-build-domain-specific-automatic-speech-recognition-models-on-gpus/

In the second step these smaller segments are "captured" in a digital form and plotted on a spectrum.

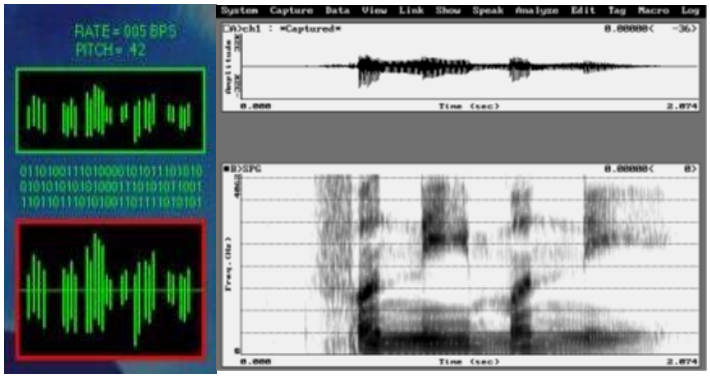

Figure 35: Voice Print Spectrum
Source: https://developer.nvidia.com/blog/how-to-build-domain-specific-automatic-speech-recognition-models-on-gpus/

Third step is the Verification Process stored in a table of numbers, where the presence of each dominant frequency in each segment is expressed as a binary number 0 and 1.

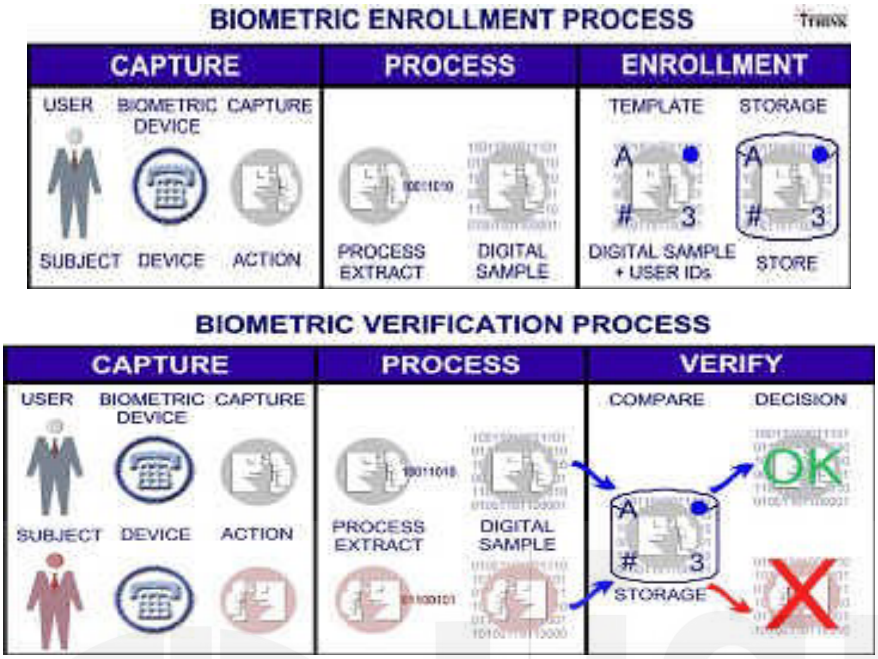

Figure 36: Biometric Process

Source: https://www.slideshare.net/kingsingh33/biometrics-50728903

Benefits of Voice Recognition Systems

Another layer of security for computer systems which are more efficient and cost effective adding up no ID access cards thus saves time.

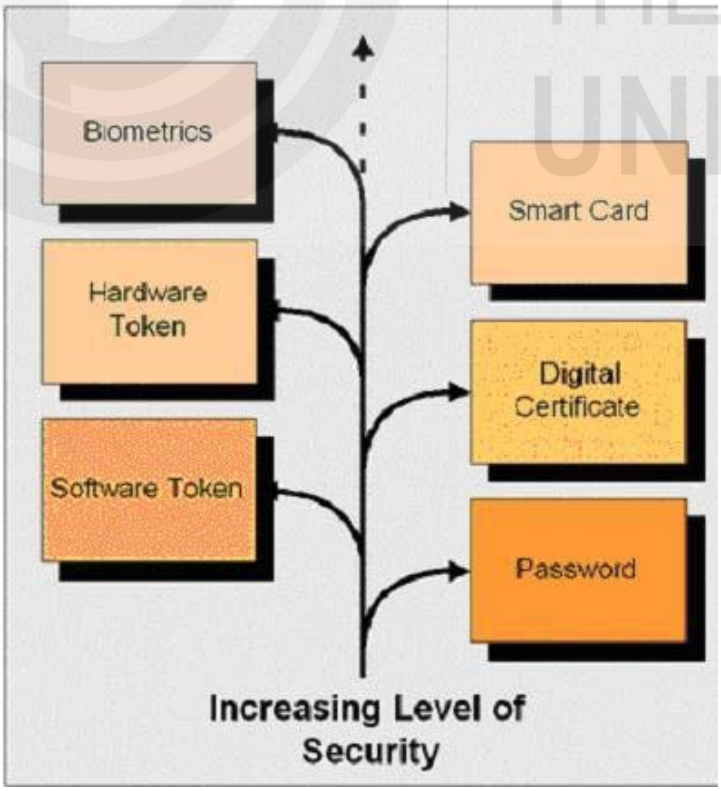

Figure 37: Increased Security Level

Source: https://www.slideshare.net/kingsingh33/biometrics-50728903

Drawbacks of Voice Recognition Biometrics

- Voice changes in the life time
- Uses of microphones along with environmental noise
- Poor phone, or cellular connections leading to Vocal variations: accents
- Voice samples are converted and transferred from an analog format to a digital format for processing by telephone devices.

Current Applications of Voice Biometrics

- Security system for physical access entry into a building, in telephone banking ATM machines and Voice verification in credit cards.
- Corrections industries: inmates on parole.
- Telephone companies use voice-enabling services.

The security provided by voice recognition is main benefit and further development can be make it most successful and largest applications of biometrics in the future to come.

Check Your Progress 6

9) Voice Recognition is becoming popular. Explain.

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4.2.6.1 Handwriting

Handwriting detection is a technique operated by Computers with the processes to receive and interpret intelligible handwritten input from sources e.g. paper documents, touch screen, photo graphs etc.

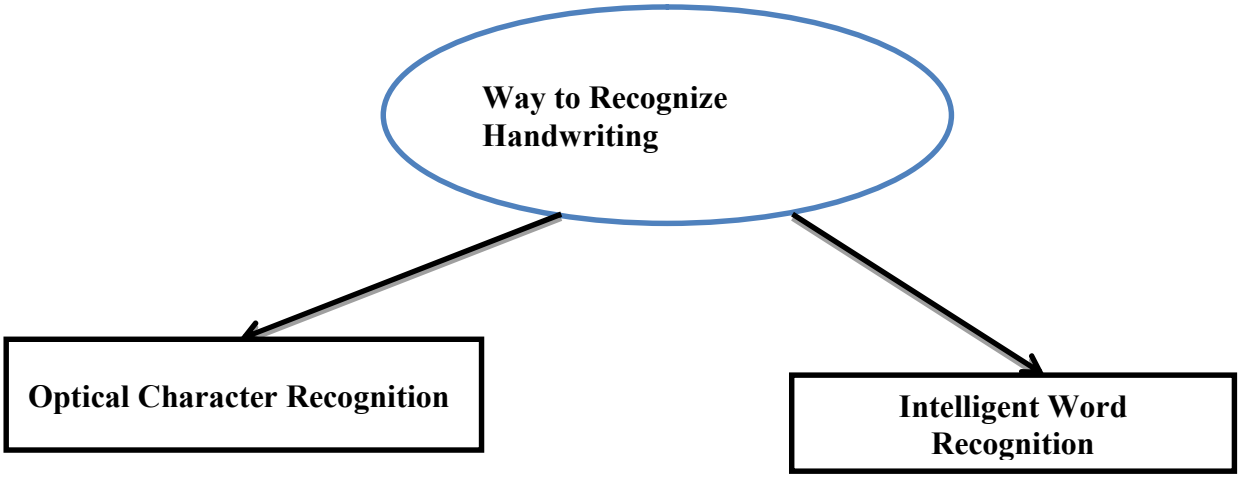

Fig. 38 Handwriting Detection

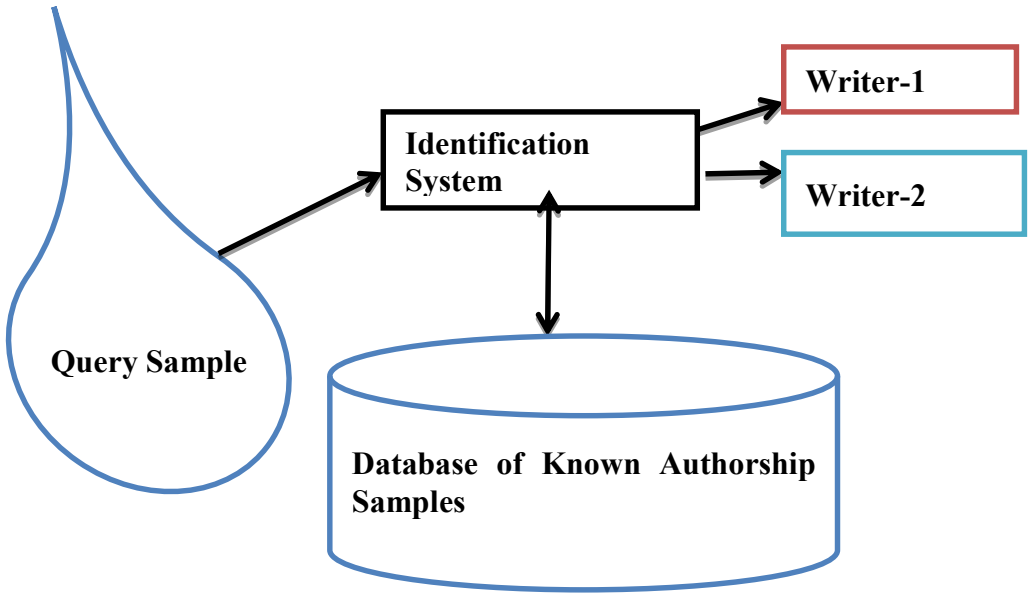

Figure 39: Working of Handwriting System (by author)

Two Types Recognition

- Online Recognition
- Offline Recognition

4.2.6.2 Online Recognition

On-line handwriting recognition is based on the automatic conversion of text which is written on a special digitiser and the sensor with it picks up the pen up and down movements known as digital ink, thus converted to letter codes. The elements of the online recognition are:

- User can write with stylus or pen.
- A touch sensitive surface integrated with, or adjacent to, an output display.
- The interpretation of the movements of the stylus across the writing surface or translation of stokes into digital text is done by software.

4.2.6.3 Off-Line Recognition

Off-line handwriting recognition consists of the automatic conversion of text in an image into letter codes by the computers for text-processing applications regarded as static representation of handwriting. The different styles of writing make offline process difficult. Recognition strategies are based upon the type of data and writing and first step is Character Recognition which is based on following criteria:

Pre-processing Methods on the data and includes the use of global transforms (correlation, Fourier descriptors, etc.), local comparison (local density, intersections with straight lines, variable masks, etc.); geometrical or topological characteristics

The type of the decision algorithm relies on various statistical methods, neural networks, and structural matching

Two strategies are employed for the word recognition:

1) **The Holistic Approach** - recognition is globally performed on the whole representation of words without segmentation thus an advantage of the method.

2) **The Analytical Approach** - deals with several levels of representation i.e. words are understood as sequences of smaller size units and easily related to characters in order to make recognition independent.

Handwriting Recognition objective is to design systems for recognition of handwriting of natural language. Methods and recognition rates depend on the level of constraints on handwriting and characterised by the:

- types of handwriting
- number of scriptors
- size of the vocabulary
- spatial layout

4.2.6.4 Advantages and Disadvantages of Handwriting Recognition

Advantages:

Offline handwriting recognition has varied benefits like reading postal addresses, bank check amounts, and forms. It forms the basis for digital libraries, allowing the entry of image textual information into computers by digitization, image restoration, and recognition methods.

Disadvantages

The disadvantage of Handwriting is that information related to data or about the type of the input cannot be obtained. First, the text has to be separated into characters or words to match these words in a sequence of data by usage of algorithms.

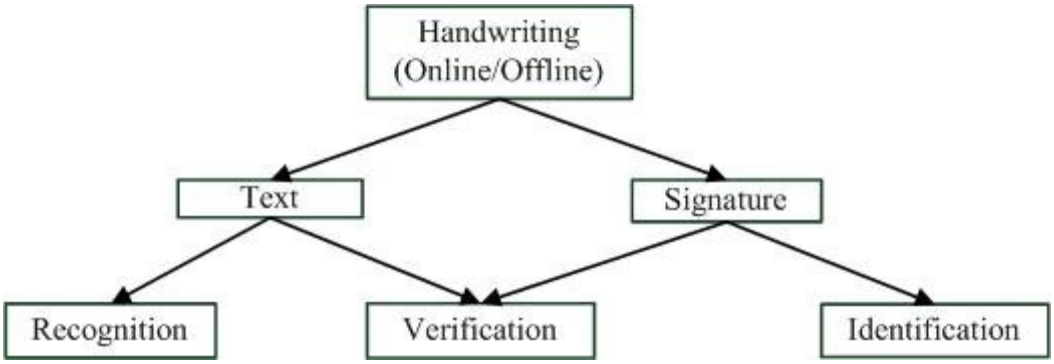

Figure 40: Handwriting Recognition Steps

Source:https://www.researchgate.net/publication/350286160_A_Review_of_Various_Handwriting_Recognition_Methods

Handwriting methodologies are difficult to operate but generate accurate data.

Check Your Progress 7

10) Describe offline and online handwriting systems.

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4.3 SUMMARY

Biometrics helps to establish a person's identity on the basis of personal traits by employing information technology techniques with accuracy. Biometrics is a technique employed to measure, compare, analyse and identify the person in terms of characteristics features like fingerprints, face, retina etc. The personal characteristic attributes like hand geometry, colour of iris, or behavioural characteristics etc. make every individual different thus biometrically scan, compare and identify with following three types modalities:

- Physiological
- Behavioural
- Both physiological and behaviour

The authentication, verification, security and accuracy has led many applications of Biometrics in technology world like:

- Workplace access control
- Identification citizenship and immigration systems of the persons
- Secrecy and confidentiality of the information
- Forensic application in criminal Identification
- E-commerce secure transactions
- Reduction in fraud and theft
- Enforcement of law

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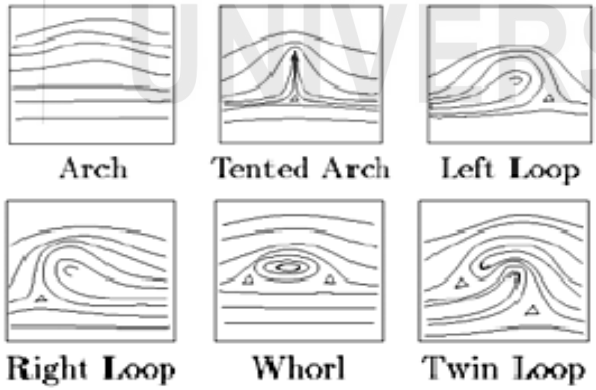
Parmar, D.N, & Mehta, B.B. (2014). *Face recognition methods and applications.*

4.5 HINTS/ ANSWERS TO CHECK YOUR PROGRESS

1) Biometrics is defined as the applicable means of identifying and authenticating individuals in a reliable and fast way through the use of unique biological characteristics and technologies that lead to the acceptable way of solving the crime. The identification of persons based on unique and definite characteristics leads to its application in forensic science. Refer to section 4.1.3 for detail.

2) The process of comparison between the known fingerprint against another in order to determine that it is of the same finger or palm is known as fingerprint recognition. Refer to section 4.2.1.4 for other parts of answer.

3) Finger Print Biometrics is defined as the method of identifying finger print by employing the software on the basis of pattern of finger and location of the minutiae. There are 6 patterns of fingerprints-Arch, Tented Arch, Left Loop, Right Loop, Whorl and Twin Loop.



4) This is an important step as image acquired would lead to recognition and the characteristics required are: Good contrast, and high quality image and high illumination. Refer to section 4.2.2.5.

5) Iris is made up of pigmented elastic tissue with an adjustable circular opening in the centre. Refer to section 4.2.2, Figure 14.

6) Retinal recognition requires that the end user must be in close proximity to retinal scanning device. The process has following steps:

- Image/Signal Acquisition and Processing:
- Enrolments and Verification Template Creation.

Refer to section 4.2.3.1 for details.

7) Procedure of DNA fingerprinting involves the main steps of- Collection and isolation of DNA, Cutting, size and sorting, Separation of fragments, Southern blotting and hybridisation, and DNA Fingerprint. Refer to section 4.2.5.1, Figure 31.

8) The double helical structure of the DNA present on saliva, hair follicles, bones, blood and sperm serve as a useful tool in the forensic studies. This can be done as the DNA from an individual's tissue shows the same degree of polymorphism. These polymorphic characters are inheritable from parents to their children.

9) Benefits of voice recognition systems:

   - Another layer of security for computer systems which are more efficient and cost effective adding up no ID access cards thus saves time.
   - Security system for physical access entry into a building, in telephone banking, ATM machines and voice verification in credit cards.
   - Correction industries: inmates on parole.
   - Telephone companies use voice-enabling services.
   - The security provided by voice recognition is the main benefit and further development can make it most successful and largest application of biometrics in future.

10) On-line handwriting recognition is based on the automatic conversion of text which is written on a special digitiser and the sensor with it picks up the pen up and down movements known as digital ink, thus converted to letter codes.

    Off-line handwriting recognition consists of the automatic conversion of text in an image into letter codes by the computers for text-processing applications regarded as static representation of handwriting.

UNIT 5 ESTABLISHMENT OF COMPLETE AND PARTIAL IDENTIFICATION*

Contents

LEARNING OBJECTIVES

After going through this unit, you will be able to learn about:

- different components of biological identity of unknown human remains found in forensic anthropological scenarios;
- age, sex, stature and ethnicity estimations from different morphometric techniques;
- significance of bones and teeth in identification of victims of mass-disasters, accidents, massacres, wars or war-related conflicts; and
- role of surgical implants and artefacts in individualising badly damaged, fragmented and commingle human remains, particularly burnt or recondite bones.

5.0 INTRODUCTION

Forensic anthropology is an applied sub-discipline of physical anthropology concerned with the identification of human remains found in medico-legal contexts, using standard scientific methods and techniques developed in physical anthropology or skeletal biology, with main focus to identify the deceased and the circumstances surrounding death and manner of death. In the recent decades, the scope of forensic anthropology has spread from identification to human rights violation investigations, encompassing criminal, civil as well as humanitarian cases. Despite its high level of sophistication and specialisations in various sub-fields, identification of human remains still remains the most important aspect in the forensic anthropological investigations, especially in cases where use of DNA analysis, biometrics and other such methods are limited either due to the

*Contributor: *Dr. Jagmahender Singh Sehrawat, Assistant Professor, Department of Anthropology, Punjab University Chandigarh.*

condition of the remains or non-availability of reference or comparative data. The improved techniques and methodologies have facilitated the task of forensic experts involved in identification of both the dead and living individuals. The generally encountered human remains are not always complete and are often fragmented, charred, decomposed, etc., due to traumatic or taphonomic effects.

Forensic anthropology plays a major role in establishing the biological profile of unknown human remains thereby assists in narrowing down the possibilities leading to putative identification. Due to their inherent expertise in human osteology, they can quantify subtle differences between individuals and other anomalies or features to distinguish skeletonised remains. Biological profile consists of four primary components: assessment of racial affinity, sex, age and stature. The other elements are individualistic characteristics such as osseous anomalies, pathological conditions, dental restorations, specific scars, occupational patterns caused by repetitive or long term activities, etc.

Establishing biological identity of unknown skeletal remains is always crucial and usually complex, especially in an incomplete or a juvenile skeleton. Populations differ in the physical characteristics of body size, shape and skeletal framework and accordingly, these differences can affect the metric and non-metric characters that are used in assessment of their profile. The identification of badly damaged commingled remains is a challenging task for the forensic experts whose identity establishment is essential from legal, moral, social and, sometimes, political reasons. Forensic anthropologists are generally warranted or called upon when an already skeletonised or severely decomposed human body is found during excavation or building activities or when a forensic pathologist, fingerprint specialist or even the sketch artist fail to assess the identity of the victim/s. Due to complex nature of remains or contexts, complete identification may not always be possible but the information extracted by forensic anthropologists may be sufficient enough to create a partial profile of the victim, which has its merits, especially in case of remains with no information. The main domain of forensic anthropology is basically to assist in the identification of human remains and in the interpretation of what happened to them. It attempts to answer four prime questions about the skeletal remains:

- **what** (whether remains are human or not),
- **when** (whether past or present),
- **who** (if they are human then whose remains are these) and
- **how** (how these remains are formed).

Thus a forensic anthropologist attempts to establish 'big fours' of human identity i.e. sex, age, stature and racial affinity of skeletal remains while trying to answer the above said basic questions. The common bones of

interest for a forensic anthropologist are either missing (usually) or are badly damaged, commingled or weathered and hence he/she has to depend on other less informative skeletal elements with wide range of skeletal maturations and subtle variations. The ability to assign commingled skeletal remains to specific individuals and to correct side of the body depends upon the detailed knowledge of human osteology, the relative size and robustness of the bones, their pathological conditions or skeletal trauma and callosities and lastly the expertise of the investigator.

In addition to being the framework of the human body, bones also contain much information about man's adaptive mechanism to his environment, and have been increasingly used to figure out biological profile of an individual or people who lived in the past. Bones often survive the process of decay and other morphological variations and, thus provide the main available evidence of human-form after death. When a human skeleton/its elements are recovered from the site of mass-disasters or unearthed during some human activities like archaeological excavation or some construction activities (road, canal or building) a forensic anthropologist is generally warranted or consulted to identify such remains, the minimum number of causalities, old skeletal trauma or alteration/damage of any kind inflicted to the skeleton, etc. Although most anatomists and skeletal biologists are well versed in classical methods of profiling of such skeletal remains, a forensic anthropologist is expected to be more skilled and cautious in a forensic context. Osteology, in forensics, requires more focus, more accuracy levels than in anthropological situations and here such identification has some significant legal consequences.

Check Your Progress 1

1) Define osteobiography and its components.

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5.1 MORPHOMETRIC TECHNIQUES

The morphological and morphometric assessment of retrieved human remains are the two commonly used methods for skeletal assessment in forensic anthropology. Morphoscopic or non-metric methods are based on gross observation of skeletal features. Although easy and less time consuming, these methods have limited applications in cases where features are not obvious and are mostly dependent on the experience of the observer which becomes the essential part of the analysis. The morphometry focuses on the size and proportion variations, providing a good level of discrimination between populations. Morphometric methods, on the other

hand, deal with the quantification of forms and thus do not rely on observer's interpretation. Due to their objectivity and reproducibility, they are often favoured over non-metric methods (Bidmos and Dayal, 2004). Anthropometry is the general term for physical measurement of the humans. The measurements on the living are called somatometry whereas the measurements on the skeletal remains are called craniometry and osteometry, former being the measurements of the skull and latter measurements of the human skeleton. The morphometric analysis quantifies and evaluates the differences in size and shape through a set of measurements which may not be visualised by the naked eyes. Metric analysis includes univariate or multivariate methods as tool for biological affinity determination such as sex, age, stature, racial affinity (Berg and Ta'ala, 2015). Univariate methods take into account a single variable for analysis whereas multivariate methods use multiple variables and their correlation to gain more information; thus, latter is preferred over the former (Mays and Cox, 2000). FORDISC is one such example of a window based software program which uses multivariate analysis for establishing biological affinity (race, sex, stature) using cranial and postcranial elements but is limited to the population of American Blacks, Whites Hispanics, Chinese and Vietnamese (Berg and Ta'ala, 2015).

5.1.1 Racial Affinity

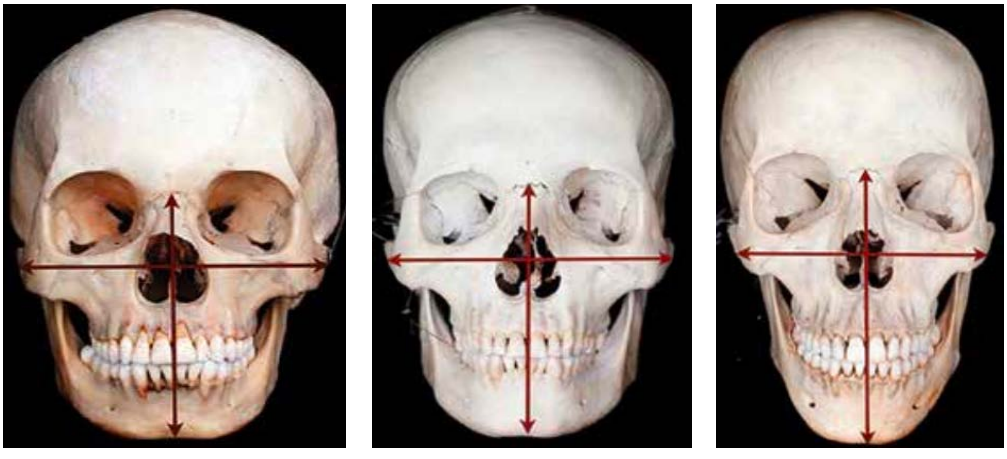
Deciphering racial affinity of unknown skeletal remains is another important aspect for identification of an individual. All forensic anthropological standards developed on the basis of morphometric methods are population-specific and are applicable to the individuals of population for which these standards were developed. Race is defined as any group of people classified together based on their common history, religion, territory, nationality or geographic distribution. Thus biologically, races do not exist but for anthropological and forensic purposes, they are broadly categorised as Caucasoids, Mongoloids and Negroids. Intra-race variations are much greater (accounting for more than 90% genetic variation) than inter-race variations (only 3%-5%). This, along with the fact that existence of numerous heterogeneous populations, is one of the probable reasons for lack of research studies conducted on the subject matter. Race determination is foremost in biological profiling due to its importance in assessing other demographic characteristics. As, any population standard is only valid for the individuals belonging to that particular population, it is essential that the remains are first identified as to their racial/population affiliations or geographic origin and then specific population standard are applied for establishing their identity (Bruzek and Murail, 2006). Population specific nature of sexual dimorphism necessitates the determination of racial affinity of an unknown individual; similar is the case of stature and age estimations (Spradley, 2015). Skull bears various traits indicating racial affinity of an individual. These traits (described in Box 1) are primarily utilised for the accurate and scientific racial differentiation. The most common technique used for this purpose is discriminant function analysis (DFA). DFA result gives a classification

function that allows the user to use one or more measurements from a bone of an unknown individual into a specific formula to obtain the possible ancestry of the individual.

Box 1: Race Specific Skull Traits				
Skeletal Element	**Feature**	**Caucasoids**	**Mongoloids**	**Negroids**
Skull	Length	Long	Long	Long
	Breadth	Narrow	Broad	Narrow
	Height	Moderately high	Average	Low
	Nasal cavity	Tear shaped	Narrow	Round and broad
	Face height	Medium-high	Medium	Low
	Type (cranial index)	Mesocephalic (medium)	Brachycephalic (short)	Dolichocephalic (long)
	Eye orbit shape	Circular with squared margins	Circular	Square or rectangular
	Sagittal contour	Rounded	Arched	Flat
	Palate shape	Narrow	Moderately wide	Wide

5.1.1.1 Skull:

Ancestry determination from cranium is foremost as it shows the most variations amongst the racial groups. Cranial length is said to be maximum in Negroids, Mongoloids are believed to have the largest bizygomatic breadth whereas Caucosoids are considered to have the largest maximum frontal breadth (Steyn and Iscan, 2005). Cephalic index (maximum breadth of skull/ maximum length of skull × 100) is another tool in differentiating the races (brachycranic, mesocranic, dolichocranic) (Burns, 2013). Mandible shape and size also vary greatly among the races (Figure 1 and 2.



A B C

Figure 1: Facial features and facial index in Caucasoids (A), Mongoloids (B) and Negroids (C)

***Source**: Farkas et al., 2005*

Figure 2: Some cranial morphological features in different ethnic groups
Source: www.faceanalyics.com

5.1.1.2 Postcranium

In case of missing or damaged cranium, postcranium (skeletal parts other than the skull) elements are utilised to determine race which includes long bones such as humerus, radius, ulna, femur and tibia (Shirley et al., 2015). The length, breadth and diameter as well as certain indices of these bones vary from population to population but variations are more varied intra-

population than inter-population. Also, these features are highly influenced by external factors, making them unreliable atleast in forensic context.

Box 2: Skeletal Measurement for Racial Differentiation	
Post-cranium	
Pubic height	Bi-iliac breadth
Transverse breadth of the pelvic inlet	Antero-posterior breadth of the pelvic inlet
Maximum length of pelvis	Iliac height
Inferior pubic ramus height	Maximum length of the femur
Circumference of mid-shaft of femur	Epicondylar breadth
Platymeric index	
Skull	
Cephalic index	Bizygomatic breadth
Cranial breadth	Cranial Length
Maximum frontal breadth	Maximum frontal breadth
Nasal breadth	Nasal height
Mastoid height	Basion-nasion length
Basion-bregma length	Basion-prosthion length
Chin height	Bigonial width
Mandibular length	Mandibular angle
Mandibular body height at mental foramen	Mandibular body breadth at mental foramen
Minimum ramus breadth	Maximum ramus height
Bi-condylar breadth	

Assessment of racial affinity has its limitations due to issues such as biological, taphonomic or lack of population specific data (Berg and Ta'ala, 2015). It is a complicated task since the increased accessibility has led to a heterogeneous population; thus, a single individual can exhibit traits of the three major categories. The genetic diversity is a continuum and thus, difficult to be defined into discrete categories. In the past decade, the population demographics have shifted considerably and the absence of or limited skeletal collections of certain populations to derive methodologies adds to the limitations of the ancestry determination (Spradley, 2015). Therefore, standard data based on contemporary population and validation of morphometric methods is required for more accuracy in racial differentiation for forensic purposes.

5.1.2 Age

Age estimation is of paramount importance for establishing identity of an unknown individual but is also challenging in case of adults. The standards for various age estimating methods are population-specific, thus it is important to take into account the racial or population group to which the skeleton belongs for accurate age estimation (Kimmerle et al., 2008). Age also serves as key baseline for assessing the applicability and reliability of other identity parameters like sex and stature. The age estimation methods are based on dental and skeletal growth and remodeling of the bones such as ribs and pelvic region (Berg and Ta'ala, 2015).

5.1.2.1 Teeth:

Teeth are the hardest substance of the body and being less susceptible to taphonomic factors and postmortem longevity, they are valuable forensic evidence. Teeth are reliable age indicators for the children as well as the adults since the developmental and degenerative changes in dentition occur in predictive time period and thus, are correlated to age. In children, the commonly used methods for age estimation include dental charts (Moorrees et al., 1963) and developmental stage scoring (Nolla, 1960; Demirjian et al., 1973; Willems et al., 2001). These non-metric methods suffer from observer bias and are non-reproducible. The Cameriere's method (Cameriere et al., 2006) provide a valid metric method for estimating age in children which takes into account development stages of tooth root and its completion. It measures the distance between the sides of open apices and normalises it by dividing it with the tooth length. The value obtained for these measurements for the seven permanent teeth is used in a pre-determined formula to calculate the estimated age providing fairly accurate results. In adults, the metric dental methods are mostly based on the negative correlation of pulp cavity size with age due to secondary dentine apposition. Kvaals method (Kvaal et al., 1995) measures different lengths and widths ratio for age estimation. Tooth Coronal Index (TCI) is the measure of the crown height and coronal pulp cavity height (Jain et al., 2017); pulp chamber tooth height ratio (PCTHR) measures the ratio of pulp chamber height and crown root trunk height (Mathew et al., 2013). In addition to these, various methods have been proposed which uses area estimation and volumetric assessment of pulp chamber. The values used by these methods are used in regression equations developed for specific population to obtain the estimated age of an individual.

5.1.2.2 Postcranium:

Age estimation from the post cranium bones mostly utilises the fusion and epiphyseal union of these bones as they follow a defined or predictive development pattern. Although development of bones is related to age but since their growth rate is unpredictable or uniform within or among populations, the metric analysis of bones is not a suitable technique for age estimation.

5.1.3 Sex

Determination of sex halves the search for an unknown, missing or dead individual (Scheuer, 2002; Albanese, 2003). Pelvis, long bones and skull are the most sexually dimorphic elements of human skeleton; the others include clavicle, sternum, ribs, etc. Forensic anthropologists rely upon expected size differences (or sexual dimorphism) between two sexes of different populations for sex determinations using discriminant function analysis and multivariate regression analysis of various skeletal measurements, which reduces subjective judgments as well as level of expertise and experience needed for sex determination. Sexual dimorphism is population specific and thus, it is crucial to have reference data or standard for the population under study to determine sex of the individual (Spradley and Jantz et al., 2011).

5.1.3.1 Postcranium

Osteometric method for sex determination is method of choice in cases of unclear distinction or definable shape variants and is considered more diagnostic than skull (encyclopedia pp. 258). Combination of measurements are selected from each bone to maximize sex diagnosis using DFA; epiphyseal measurements being better indicators of sex than length or diaphyseal dimensions. But the standards utilised are population specific indicating variations between and within the group due to the influence from various external factors such as physical activity, nutrition, temporal change and occupational stress. Sometimes metric overlap may occur between the two sexes and thus, the accuracy of these methods is frequently questioned. The most dimorphic bones for metric analysis are pelvis, femur, sternum and clavicle.

5.1.3.2 Skull

These possess salient morphological traits for sexual differentiation but in terms of metric analysis, their utility is limited. Some of the skull measurements used in sex determination include: bi-condylar width, mandibular length, gonial angle, etc.

5.1.3.3 Teeth

Dental development in males and females vary slightly; female being ahead than males in calcification and eruption. In terms of metric assessment, males, on an average, have larger teeth than females. The main reason for the size differences is believed to be up-regulation of mitosis rate in response to elevated androgen levels present in males (Harris and Christensen, 2015). But the dental dimensions are extremely variable throughout the population and despite the considerable difference, tooth dimensions may not always yield a statistically significant separation of the sexes leading to frequent overlap of these dimension between the sexes rendering it indecisive and inaccurate (encyclopedia pp. 254). Still, determination of sex is an important component in identification and in absence of other usable information; teeth are used for

assessing sex of an individual. The mesio-distal and bucco-lingual dimensions (crown length and diameter) are considered mostly sexually dimorphic especially for mandibular canines (Rai and Kaur, 2013; Harris and Christensen, 2015).

Box 3: Sex determination skeletal features			
Skeletal Element	**Feature/region**	**Male**	**Female**
	Forehead	Receeding	Vertical
	Orbits	Square	Round
	Fronto-nasal angulation	Distinct	Smooth curve
	Glabella	Prominent	Not prominent
	Frontal and parietal eminences	Not prominent	Prominent
	Zygomatic arch	Prominent	Not prominent
	Palate shape	U-shape	Parabolic
	Mandible	Large and thick	Small and thin
	Gonial angle	Right or acute	Obtuse
	Ascending Ramus	Broad	Narrow
	Chin	Squarish	Roundish
Femur	Mean length	More	Less
	Neck-shaft angle	Acute	Right angled
	Articular head	More than 2/3rd of sphere	Less than 2/3rd of sphere
	Bicondylar width	74-89mm	67-76mm
	Head vertical diameter	More than 48mm	Less than 44mm
Pelvis	Ilium	High and upright	Low and flared
	Ischium length	More	Less
	Pubic ischial ratio	Small	Great
	Obdurator foramen	Large and oval	Small and triangular
	Ischial tuberosity	Everted	Inverted
	Acetabulum	Large and forwardly placed	Small and laterally
	Greater sciatic notch	Deep and acute angled	Shallow and wide
	Pelvic index	Dolicho-pellic	Brachy- or mesati-pellic
	Pelvic inlet	Heart shaped	Elliptic
	Pubic symphysis	High, broad, triangular and biconvex antero-posteriorly	Low, narrow, rectangular and anterior convex and posterior flat

5.1.4 Stature

Stature is one aspect of an individual's physiognomy and may aid in identification of an individual. There exists some biometrical and proportional relationship between every human bone or body segment and this forms the basis of stature estimation using the bones of a body. It mostly involves determining the length of long bones (sometimes miniature long bones) or some sutural lengths or craniofacial dimensions, which are then used individually or in combination in regression equations to predict the living stature of the victim whose bones were measured. A number of formulae have been put forth for calculating stature from various body parts (Berg and Ta'ala, 2015) but the proportion of bones to the stature vary considerably in racial groups (Jantz et al., 2008). It must be noted that most of the formulae are based on the skeleton collection which are decades old. Thus, there is a need for contemporary reference set since the secular changes in height have affected the growth rate as well as proportion of body to its stature (Frisancho et al., 2001). The most accurate stature estimation can be made in case of availability of complete skeleton by measuring the skeletal height which involves the cranium, all vertebrae, sacrum, femur, tibia, talus and calcaneus and adding a correction factor for the missing soft tissue. But such cases are few and due to unavailability of all the bones, most of the methods are based on long bones of upper and lower extremities; other bones are also utilised in case of unusable, unavailable or badly damaged long bones. Studies have been published on rate of skeletal development considering intra and inter-populations variations but the uncertainty of these variations makes it less precise. Sexual dimorphism, nutrition, health condition, genetical factors, etc., are other factors influencing the stature of an individual.

Long bone measurements: humerus (maximum length), radius (maximum length), ulna (maximum length), femur (maximum length, physiological length), tibia (maximum length, physiological length), fibula (maximum length) (encyclopedia, 281).

Check Your Progress 2

2) Morphometric methods provide more objective identity than the morphoscopic assessment of remains found in forensic contexts. Do you agree with this statement and why?

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3) Discuss sexual and racial differences in human skull.

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5.2 SURGICAL ARTIFACTS

After thoroughly examining and documenting the retrieved human remains, anthropologists attempt to provide positive identity to them through radiographic comparison of unique bone features, healed trauma, or prosthetic devices and DNA analysis. Medical and dental artifacts can provide evidence of procedures performed and events during the course of the life of the decedent. Medical artifacts consist of medical devices, orthopedic implants, and surgical metals such as vascular clips and surgical sutures or staples. Dental artefacts like dental implants, crown, dentures, root canal material, and other dental implements, survive the cremation or decomposition processes. These materials may have melted or altered shape due to the intense heat, but nonetheless may be recognisable. In cases where dental artifacts are present, it is advantageous to confirm the type and model of implants from a forensic odontologist. Medical and dental care and treatment have changed significantly over the years and may present a quick and obvious way to determine whether human remains are contemporary. The presence of modern surgical devices such as hip replacements or sternotomy wires and dental treatments such as restorations, bridges, and crowns reflect that the remains are contemporary. It may become possible more precisely to date certain appliances or techniques based on their known time of manufacture or implementation in certain cases. On the other hand, evidence of trephination (cranial surgery) or other ancient medical practices are indicative of a non-contemporary origin. If there are surgical implements that supposedly don't belong to the putative victim/s, then there are possibilities of commingling that the remains don't belong to a particular incident. It is also possible to detect the presence of medically implanted devices through elemental analysis also. The increased levels of titanium in one of the samples of known human cremated remains was found associated with the presence of a surgical ligation clip in the said material it is possible to detect the presence of medically implanted devices (Warren et al., 2002).

Though most forensic anthropologists are supposed not to be experts in orthopedics, yet they may be able to provide some information about the surgical implants as part of their skeletal analysis. Surgical implants (surgical implements, devices, artifacts, or appliances) generally have a lot number,

serial number, or insignia of the manufacturer stamped onto them (Ubelaker, 1995, Wilson et al., 2011). Local or national registries or the manufacturer may be contacted for information associated with such device. In few instances, it may be possible to link the retrieved device to a specific individual. In most other cases, the devices may help in narrowing the search as all devices don't have a unique serial number and thus, registries may not necessarily provide adequate information to associate the device with a particular individual. Linking the device to an individual requires information about the manufacturers, importers, and user facilities, to be able to detect and correct any adverse effects of medical devices.

Artificial devices associated with various medical disciplines are frequently implanted into the body during surgical interventions. These may be in the form of metal (mostly titanium, chromium alloy or stainless steel), polymer or fabrics (such as silicone, teflon, etc.) and ceramics (bone cement hydroxyapaptite) or their combinations (Clarkson and Schaefer, 2007). These may include prosthesis of hip joints, metal clips and/or wiring in sternum, stunts and artificial valves of heart, artificial blood vessels, silicone implants for cosmetic surgeries, etc. Being relatively uncommon, they are crucial in identifying of an unknown individual. Examination and comparison of antemortem medical records with the post-mortem data has long been accepted as an established method of identification in forensic anthropology. Surgically implanted devices have become increasingly common in modern skeletal material. So, the knowledge about various types of implanted orthopaedic devices, their manufacturer, geographical area of their distribution, identity numbers and marks, etc., can assist in the identification strategies when traditional methods are inconclusive. The manufacturer information on the recovered orthopaedic devices can help trace and associate the surgeon who implanted the device who, in turn, can supplement crucial information about the deceased. Anthropological examination of skeletal features and associated finds and their correlative comparison with antemortem medical records presents an excellent basis of identification of the deceased. The comparison of antemortem and post-mortem dental radiographs provides reliable basis of identification (Mundorff et al., 2006), though inconsistency in the radiographs is a challenge for the experts. Identification of an unknown individual bearing such artifacts may be possible if the logo, lot details and unique serial number of the prosthetic devices is available. But these may not always have an identification number thus, posing a problem in tracking the manufacturer and recipient of the device (Steyn and Iscan, 2009). The presence of medical devices in the skeletal assemblage may reveal that an injury or disease existed which required device implantation, the victim had access to resources needed for major surgical intervention or the possible middle or advanced age of the individual depending upon the type of implant found (Wilson et al., 2011).

Figure 3: Traumatic fixation of lower extremity bones
Source: Wilson et al., 2011

Various cases have been reported involving identification of an individual using orthopedic implants associated with the skeleton. Bodies have also been identified with the help of implants bearing no identification numbers. In such cases, the radiographs of the skeleton with these devices were compared with the ante-mortem radiographs of the persons who were believed to be the possible victims. Comparison of right hip prosthesis in radiographs of an incinerated body with the antemortem radiograph of the person believed to be the victim was a match; Harrington rods connecting T4

and L3 vertebrae were crucial in identification of unidentified skeletal remains of an individual when the postmortem radiographs were compared to antemortem records of the assumed victim; postmortem radiograph of orthopedic plate fixed to left ulna was compared to the antemortem radiograph of the presumed victim and was found to be a match (Simpson, 2007). The medical implants are sometimes not scrutinised and may not be noticeable. One such case involves chance discovery of surgical clips, staples from the matrix surrounding the skeletal remains. This led to thorough search of the matrix and metal ceramic fixed bridge was also obtained. Their availability and surgical wounds on the skeletal remains corresponding to that of the supposed victim's was helpful in positively identifying the victim (Scott et al., 2010). Surgical devices are generally deep fitted in human body which remain protected from fire or chemicals. They had played crucial role in identification of the victims of Victoria Bushfire of Australian 2009 as several bodies scanned possessed identifiable medical devices. These devices included hip and knee prostheses, pacemakers and coronary artery stents. Despite severely burnt conditions of the bodies, some of the victims were positively identified by matching surgical implants with medical records of those missing in the fire.

Cochlear implants (aid hearing) which bear unique serial numbers that can be used to assist with identification of bodies that are not visually identifiable (Berketa et al, 2013). Surgical sutures can also provide valuable information about identity of unknown human remains found in forensic contexts as surgical suture and orthopedic implant manufacturers can provide clues about specific catalogs and product details to reveal identity of the hospital, supplier, surgeon and the victim. Such devices are commonly used for cardiovascular, abdominal, bronchial/tracheal or orthopedic surgeries. Non-absorbable sutures, which are designed to be implanted in the human body for longer periods of time than the absorbable sutures, have more forensic significance than the later.

Shepherd et al. (2010) reported a forensic anthropological case history wherein the suture's manufacturer, construction material, color, diameter, size and its medical use helped in identification of a male. Sometimes, forensic death investigations become extremely complicated due to presence of extremely unique and identifiable surgical sutures, but difficult to trace to the individual. Suture data is not easily accessible and referenced, so forensic experts and law enforcement agencies remain in a dilemma. When surgical sutures are encountered in association with human remains, investigators are able to utilise this process to narrow down the manufacturer and aid in determining the individual's identity and time since death (Shepherd et al., 2010).

Figure 4: Surgically implanted devices

Source: Christensen et al., 2014

Thus, careful and thorough sifting through the area near the remains is crucial for obtaining evidences and artifacts associated with the body. But presence of such medical implants does not always lead to positive identification of the victim. This may arise either due to lack of any identifying feature on the implant or non-availability of antemortem data for comparison. With the advancement in molecular techniques and consequent increased reliance on DNA comparisons, the forensic experts and law enforcement agencies heavily depend upon the collection and comparisons of DNA samples from the retrieved human material and the putative relatives of the deceased. However, molecular identification is not always feasible due to the unavailability or insufficient amount of quality DNA in many situations (Simpson et al., 2007). So, comparison of antemortem and postmortem data and artefacts proves crucial in these circumstances. Postmortem identification

can be facilitated positively if serial codes etched onto the surgical implants can be traced to their manufacturers, surgeons and the recipients of such devices.

Figure 5: Suture with identifiable features

Source: Shepherd et al., 2010

Check Your Progress 3

4) "Surgical devices are crucial evidences for establishing biological identity of unknown human skeletal remains". Comment on the statement and justify your answers.

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5.3 BURNT BONES

Identification of fairly complete and intact skeleton is easy but such cases are rare since most of the remains encountered by forensic anthropologists are considerably influenced by traumatic or taphonomic factors. Thus the remains are mostly decomposed, highly fragmented, commingled or incomplete. One such condition which makes the identification of the skeleton more complex is burnt bones. Forensic anthropologists encounter many cases where burnt bones are presented for identification. Burnt bones show significant alterations both in their physical and chemical properties due to the drastic heat effects inflicted during burning which may cause difficulties in forensic identification of such challenged evidences. Physical changes like deformation and fragmentation from high temperature and heat-induced shrinkage disguise or damage the morphological indicators that are critical for anthropometric analysis of sex, age, and stature estimations. In addition to the physical alterations, heat in the burning process also induces

chemical modification of bones due to combustion and pyrolysis of chemical substances. The degree of modification increases with rising temperatures which may degrade DNA, thus compromising forensic utility of osseous remains.

Burnt bones may be the result of vehicle accidents, mass disasters, accidental fires, arson, etc., and may be deliberate or accidental (Krogman and Iscan 1986; Imaizumi, 2015). The heat destroys the soft tissues and along with it, any other evidence of trauma, lesions and identifying features present on the surface. Burnt bone is a unique artifact. The reaction of bone to heat follows a sequential progression, resulting in structural and compositional changes in the bone. Dehydration leads to loss of organic matter of bone, thus, a remarkable change in overall shape and size (up to 20%) of the bone called warpage. Combined exposure to fire and heat lead to complete loss of its organic portion making the bone brittle and friable. Color changes depend upon fire exposure, temperature gradients, and its duration (Walker, 2008) and are outward reflection of occurrence of chemical changes in the bone; color gradation may occur in sequence from yellow, to reds, purples, followed by including black, grays, and white (the more recognisable "neutral hues" of burnt bone) and may assist in deducing the approximate temperature range (Bonucci and Graziani, 1975). Extended exposure to heat and fire typically results in bone that is charred (carbonisation and blackening of bone due to thermal alteration); charred bone usually does not exhibit shrinkage or warpage and often will retain diagnostic features. Thus, heat-induced modifications cause the bones to shrink, develop fracture patterns and become discoloured and brittle. The fractures commonly confronted includes longitudinal and transverse which may occur from trauma as well heat and thus, are difficult to trace the origin; curved transverse or thumbnail fractures being specific to burned remains and are indicative of pattern progression of loss of soft tissue during heating (Symes et al., 2008). This alters the morphological indicators of the bones critical for anthropometric analysis of the race, age, sex and stature of the victim (Imaizumi, 2015). The extent and types of changes that take place in the body is attributable to complex interaction of various factors, key factors being duration and intensity of the fire as well as condition of the material prior to heat exposure (Binford, 1963; Dehaan and Nurbakhsh, 2001). The weight of burnt or heat induced bone is reduced considerably because of water vaporization and combustion of organic materials. The complete cremation of a human body leaves approximately 2,000 and 3,000 gm of cremated female and male bones, respectively. Several studies have monitored the weight reduction of experimentally burnt bones and showed immediate weight reduction after heating. The burnt bone loses water and a significant amount of the organic matrix by 400°C and loses the organic matrix completely approximately by 700°C.

The teeth show similar modifications as bones on exposure to heat. Enamel tissue begins to flake at temperature less than 600˚C; on reaching to 700˚C,

the teeth show dark-greyish brown discoloration and exposure to just 30 minutes to temperature of 800˚C causes separation of crown from dentine (Beach et al., 2008). The recovery and transport of such remains is a challenge and should be handled with utmost care while moving from the scene to the morgue for the post-mortem analyses. The remains are wrapped in paper bags instead of plastic or metal cans as they may destroy the evidence by encouraging moisture or initiating further fragmentation, respectively. The burning often renders the DNA in the bones contaminated making it unsuitable for identification of the individual. Thus, anthropologists have a specific and unique role to play in such cases to recover the remains and identification of the same. The use of metrics is highly inappropriate for biological profiling due to shrinkage of the bones and thus, mostly morphoscopic analysis is done for identification purposes. Although burnt bone poses many difficulties for forensic identification, current advancements in chemical and physical analysis, X-ray imaging, and DNA analysis have the potential to provide higher scientific certainty for the results of identification attempts.

Efficiency and outcome of all these methods and techniques depends largely on the conditions and completeness of the remains in question. So, they may not always provide the positive identity of an unknown victim but may aid in narrowing down the identification range by providing a general assessment giving a partial identity of the individual.

Check Your Progress 4

5) Discuss various methods employed for identification of burnt human bones.

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5.4 SUMMARY

Identification of unknown human remains found in forensic or bioarchaeological contexts is a challenging task. Establishing biological identity of badly damaged, fragmented, commingled, burnt or recondite remains is one of the major tasks of forensic anthropologists. Bones and teeth play crucial role in identification strategies of such remains as the former are able to resists all sorts of taphonomic destructions and degradations due to the longest postmortem longevity of these osseous tissues. The surgical implants and artefacts can help in positive identification of burnt human remains.

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5.6 ANSWERS/ HINTS TO CHECK YOUR PROGRESS

1) Osteobiography may be defined as establishing biological identity of the deceased on the basis of bones and teeth retrieved from forensic or bioarchaeological contexts. Determination of sex, estimation of age, reconstruction of stature and deciphering ethnicity are four major components of biological identity of an individual.

2) Morphometric values can be subjected to statistical analyses for objective analysis of differences in metric features of two sexes, so the former are considered more reliable than the morphoscopical methods.

3) Human skull is more informative forensic anthropologically as it harbors a number of sexual and ethnic differences in its metric as well as non-metric features. Male skull is larger, heavier and rougher than a female skull. The three major sub-divisions of mankind (caucasoids, mongoloids and negroids) have remarkably different craniofacial features and an unknown skull can be easily attributed to any of the group based on features of skull only.

4) Surgical implants and devices including dentures can help in establishing positive identity of an unknown skeleton as they bear specific serial numbers and lot numbers and can be traced to an individual to whom they were implanted antemortem.

5) The burnt bones can be identified using different chemical and physical analyses, X-ray imaging, DNA analysis and feature comparisons.

UNIT 6 PERSONAL IDENTIFICATION OF LIVING PERSONS-I*

Contents

LEARNING OBJECTIVES

After going through this unit you will be able to:

- understand the basic concept of personal identification;
- illustrate the identification process in the living;
- explain somatometric and somatoscopic methods of identification;
- elaborate fingerprints, footprints and lip prints; and
- differentiate between bodily marks such as occupational marks, scars, tattoo marks and their role in identification.

6.0 INTRODUCTION

Identification can be referred to as the process of application of scientific methods and techniques to authenticate the identity of humans for medico-

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legal purposes. The real aim of forensic science is to establish individuality or to approach it as closely as the present state of science allows (Kirk, 1963). Identification can also be defined as the process of correlating an unknown evidence to a known individual based on unique characteristics of the recovered material which can be any biological fluid whether blood or semen, fingerprints, bite marks, handprints, skeletal evidence, wounds, moles, etc. (Christensen et al., 2013). It is a subset of forensic identification. Evidence for human identification can be categorised into three types–

- Token-based human identification where documents and identity cards are used to establish identity;
- Knowledge-based human identification where identity was established with the information which are only known by the individual; and
- Biometric identification where physical characteristics are used to identify an individual (Clarke, 1994).

Personal identification may be defined as the determination of individuality on the basis of unique, fixed, and unaltered characteristics of an individual that distinguish him/her from every other individual leading to their recognition or authentication. Recognition or authentication of a concerned individual is considered as the mainstay in anthropological domain, in forensic jurisdiction and in criminal identification. Article 6 of the Universal Declaration of Human Rights states that every individual has the right to be recognised as a person before the law. Therefore, every citizen of a member state of the United Nations has a right to possess his personal identity, unquestioned.

> *In India, the Unique Identification Authority of India which was part of the Planning Commission of India was established in 2009. Its aim is to provide a unique identification number or Aadhaar number (12 digit unique code) to all Indians that will establish his/her identity containing several basic, demographic and physiological aspects of the individual including retina scan and ten-digit fingerprint scan that could be accessed through a central data bank. This UID card can be used to impact the process of tracking the identity of the person through the hitherto known methods of forensic medicine.*

Identification can be divided into two types, complete or total identification and incomplete or partial identification. Complete or Total identification implies exact specification or the absolute fixation of the personality of an individual. Partial or Incomplete identification means to discover or determine some aspects or facts about the identity while others remain still unknown or recording certain information which will ultimately help in complete authentication of the individual.

Identification may have to be established in two types of individuals – Living and Non-living or dead individuals. Identification of the dead is essential in cases of sudden and unexpected death such as fires, explosions, aircraft or railway accidents, foul play, war, natural calamities like flood, earthquake, tsunami, etc. and mutilated or hidden decomposed bodies often need great medico-legal acumen. The identification and interpretation of recently dead persons with the skin intact comes under the canopy of medical science while the study and identification of decomposed, mutilated and fragmentary skeletal remains fall under the domain of forensic anthropology (Mant, 1984).

Personal Identification of living persons/individuals is necessary in both civil and criminal cases. Civil cases involve the cases of imprisonment in order to unlawfully secure property, alleged putative father of illegitimate child, in marital misconduct, validation of the passport, missing person, disputed sex, and in case of life insurance claims or to prolong a lapsed pension. Criminal Cases involve the cases of absconding criminals, soldiers, and persons accused of interchange of new born babies in hospitals and nursing homes, rape, assault, sodomy, murder etc. (Bardale, 2011). The National Bureau of Criminal Investigation (NBCI) founded in 1896 by National Chiefs of Police Union as an agency to record identifying information of criminals and share that information with the law enforcement agencies to detect and apprehend criminals and support the criminal justice system in the prosecution, adjudication and correctional supervision of offenders (Panek, 1990).

Human identification can be established by various means such as by anthropometry of various human body parts, somatoscopy or the descriptive analysis of the features of head, face, hair, nose, ear, teeth, nail, etc.; genetic methods, dermatoglyphics such as fingerprints, sole prints, ear prints, lip prints, foot prints, hand prints, handwriting, mannerisms, peculiar bodily marks such as moles, warts, scars, deformities, tattoo marks, etc.

In the following sections you will learn about these components in detail.

6.1 METHODS OF IDENTIFICATION IN LIVING PERSON

Identification of an individual is the mainstay in forensic investigation. The identification process is a narrowing down process that reduces the number of hypotheses or the possible victim matches. In 1882, the Bertillon method of identification with eleven anthropometric measurements made brilliant success in identifying the criminals who attempted to hide their identity. In 1888, Bertillon invented yet another idea to enhance identification- *Portrait Parle* or, the speaking picture which combines in addition to anthropometric measurements and other descriptive data, the full-face and profile photographs of the criminals. It helps to trace lost persons, kidnapped victims and fugitive criminals.

An effective identification medium or trait should possess the following qualities:

- Universality – the trait should be possessed by every individual;
- Uniqueness – the trait should be distinguished from one another;
- Permanence – the trait should be fixed and non-changeable by deformation or replacement;
- Measurability– the trait should be easily collectable and measurable with subsequent processing and extraction of relevant features; and
- Classifiable – the trait should be classified so that each individual has a unique identification and can be classified as identical groups on the basis of trait features.

The important data generally employed for identification of cases are age, gender, race, stature, body built, religion, nationality, complexion, hair, features of eyes, facial features, dental features, congenital and acquired peculiarities such as malformations, tattoo marks, moles, scars, deformities, occupational marks, wounds, etc., anthropometric measurements of human body parts, handwriting, voice, gait, manners, photography, nail print, lip print, palate print, sole print, fingerprint and handprint, etc.

Forensic anthropologists employ various techniques or methods for identification of the living such as somatometry and somatoscopy of skin, hair, eyes, nose, ear, hand, etc.; latent prints such as fingerprints, footprints, lip prints, nails, handwriting, bodily marks such as occupational marks, scars, tattoo marks, deformities, etc. In the following sections, various techniques/methods of identification of the living persons/individuals will be discussed in detail.

Check Your Progress 1

1) Differentiate between complete and incomplete identification?

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2) What are the qualities to become an effective identification trait?

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6.2 SOMATOMETRY

The word 'Soma' in somatometry refers to 'living' and the term 'metric' denotes measurement. Thus, somatometry as a discipline of anthropometry can be simply defined as systematic techniques for measuring living beings including head and face. A number of somatometric measurements which are based on specific anatomical landmarks are devised by the anthropologists for describing the morphology of humans. The physical dimension and the gross composition of human body, which is affected by a number of characters, essentially by varying degrees of nutrition and chronic illness, can be studied with the help of somatometry. Somatometric measurements are utilised for comparing individuals belonging to varied geographical locations in order to study variability in terms of body types as well as for racial comparisons; for studying and monitoring the growth, nutritional status and development among children, young and adults, etc. can be determined. Somatometric surveys of different populations generate database which has proved to be an asset for designing appropriate instruments and equipments utilised in industrial purposes, ergonomically designed spaceships, and well fitted garments, etc. The Somatometric or anthropometric surveys provide us certain norms and guidelines or parameters about the physical anatomy of any population and trends in morphological traits.

"Bertillon System" also known as "Anthropometry" was introduced in 1879 by Alphonse Bertillon, a French anthropologist, who utilised anthropological techniques of anthropometry for the first time for law enforcement in order to identify criminals. The system gained almost immediate acceptance worldwide for identifying individuals on the basis of physical measurements. The Bertillon system includes bodily measurements of the individuals such as standing and sitting height, length and breadth of the head, breadth of the face, length of the ear, forearm, middle finger, little finger, hand, foot, span of the outstretched arms; photographs including observation and description of peculiar bodily marks such as moles, warts, birth marks, scars, tattoo marks or acquired deformities, etc.; and physical description of individual characteristics such as shape, size and colour of eyes, ears, nose, pattern of hair, complexion, etc. to produce a detailed description of the individual or *Portrait Parle'*.

6.3 SOMATOSCOPY

The detailed description of the various parts of the human body such as orientation and shape of eye, ear, nose, etc., skin colour, hair colour and form, etc. is only possible through scientific observation as these are not applicable for metric analysis. Such characteristics are called somatoscopic characteristics and such scientific observations for concealing identification are referred to as 'somatoscopy' or somatoscopic observations. The standard charts and models highlighting possible somatoscopic variations in individual characteristics have been developed for comparison purposes. Martin, Saller,

Steindamm, Brown, Schultz, Topinard, etc. are some of the pioneers who developed standard charts and models for somatoscopic reference, in forensic identification of individuals or suspected criminals; in reconstruction of deformed body parts; in comparing different morphological human groups; in identification of abnormalities, if any and for discriminating racial groups, somatoscopic observations or perception of various parts of the body has gained immense utility.

List of Somatometric Parameters for Personal Identification of the Living Persons

- ***Skin colour:*** The skin colour is determined after comparison from standard charts as represented in figure 1. Many authors have classified the skin colour on the basis of surveys, however the most well-known and standardised charts for skin colour are Luschan chart or Broca chart. In these charts, colours of the skin are classified as follows:
  - Greyish Black;
  - Blackish Brown;
  - Dark Brown;
  - Reddish brown;
  - Brown;
  - Light Brown;
  - Olive Brown;
  - Yellowish white; and
  - Carmine White.

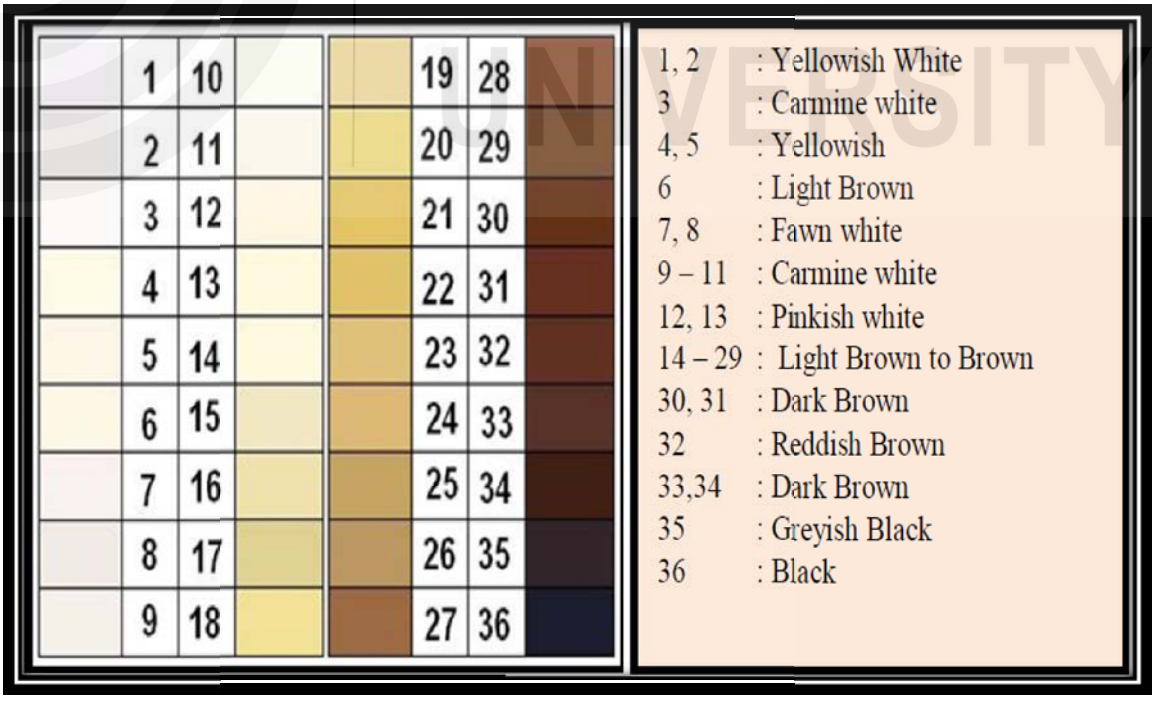

Figure 1: Luschan's Skin Colour Chart

Source:https://epgp.inflibnet.ac.in/epgpdata/uploads/epgp_content/anthropology/07._forensic_anthropology/21._identification_through_somatometric_and_somatoscopic_observations/et/8373_et_et_21.pdf

At least 4-5 sites of the human body should be observed for determining the colour of the skin as there are potential factors which affect skin colour such as presence of melanin, chromophores, hair & wrinkles, haemoglobin level in blood, exposure to sunlight, etc. Also, in daytime and with sufficient light, skin colour should be observed and compared with the standard charts. The sites of the body including forehead, cheeks, chest, shoulders, inner side of the upper arm, palm, abdomen above the navel, inner side of the thigh, sole, etc. should be observed for determining skin colour. With consent or permission of the individual or subject under consideration, colour photographs of the portions of the skin are taken for efficient comparison with the charts. In recent times, with the advent of advanced technologies, spectrophotometry, which is regarded as the best and modern method, is used for somatoscopic analysis of skin colour. However, the biggest drawback of the spectrophotometry method is that it requires financial resources and expensive infrastructure and can only be done in laboratories.

- ***Hair:*** Identification through hair includes visual somatoscopic observation about its colour, form, texture & quantity and presence of whorls. Hair can be observed on various body parts such as hair on head, face, eye brow ridges, beard, eye lashes, and genitals.

Hair colour: Fischer and Saller Hair colour chart (Figure 2) of 30 different shades has been utilised effectively for comparing colour of hair.

It is to be assured that the subject's colour of hair should not be artificially dyed while recording. Use of hair care products such as hair oil, dyes, hair spa, etc. and ageing may affect its colour and texture. If any of these factors is recovered, then it has to be mentioned. According to Fisher and Saller thirty shades of hair colour can be classified under three broad categories:

- Blond (Ash Blond [A], Light Blond [B – E], and Blond [F – L]);
- Dark Brown (Dark Blond [M – O], Brown [P – T], and Dark Brown [U – Y]); and
- Red (Red [I – IV] and Reddish Brown [V – VI]).

Figure 2: Hair Colour Chart by Fisher - Saller

Source:https://www.google.com/url?sa=i&url=http%3A%2F%2Ffyletika.blogspot.com%2F2015%2F08%2Ffischersaller.html&psig

Hair Form: Identification and differentiation of hair forms can be done by plucking one hair of the subject with consent. It can be broadly divided under three headings:

- *Lissotrichous* or Straight hair: Straight or sleek;
- *Cymatotrichous* or Wavy hair: flat or broad or narrow waved or curly; and
- *Ulotrichous* or Frizzly/woolly hair): Frizzly or widely knit or closely knit or peppercorn or spiral.

Figure 3: Hair Form

Source:https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.reddit.com%2Fr%2Fcoolguides%2Fcomments%2Fk4hyf2%2Fguide_to_hair_types%2F&psig

Hair Texture & Quantity: Hair texture can be categorised into three categories i.e. coarse or medium or fine. On the basis of the quantity of hair, it can be classified as Thin or Thick or Medium or Dense.

Hair Whorl: It can be referred to as the centre of hair distribution on the head. There can be single, double or multiple hair whorls present in an individual. However, it generally lies towards the top-most portion at the back of the head or may also occur near the hairline above the forehead. Hair whorl can be differentiated on the basis of direction of distribution of hair as either clockwise or anticlockwise or irregular as depicted in the following figure 4.

Figure 4: Hair Whorl – Clockwise, Anti-clockwise and Irregular

Source:https://www.researchgate.net/publication/228690514_Laterality_in_children_Cerebellar_dominance_handedness_footedness_and_hair_whorl

❖ ***Head Form:*** Head form can be classified in accordance with the following categories as shown in figure 5:

- Ellipsoid
- Pentagonoid
- Rhomboid
- Ovoid
- Sphenoid
- Spheroid and
- Pear-shaped.

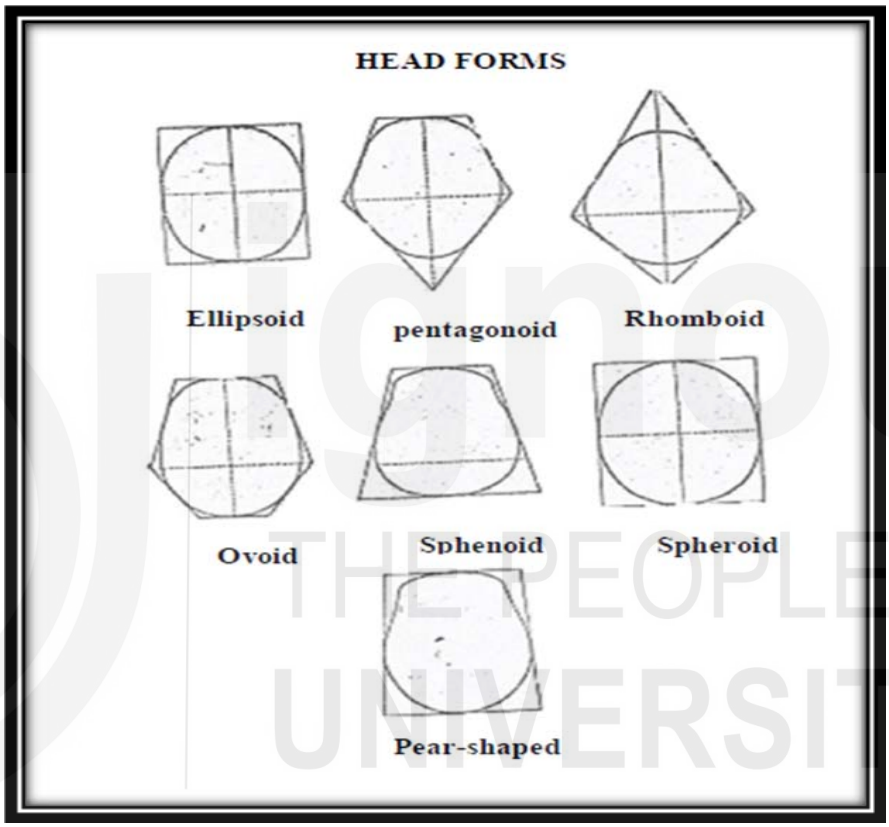

Figure 5: Head Forms (after Martin & Saller)

Source:http://epgp.inflibnet.ac.in/epgpdata/uploads/epgp_content/anthropology/07._forensic_anthropology/21._identification_through_somatometric_and_somatoscopic_observations/et/8373_et_et_21.pdf

❖ ***Facial Form:*** Facial forms as depicted in figure 6 can be categorised as :

- Elliptical
- Oval
- Inverted Oval
- Round
- Rectangular
- Quadrangular
- Rhomboid

- Trapezoid
- Inverted Trapezoid and
- Pentangular

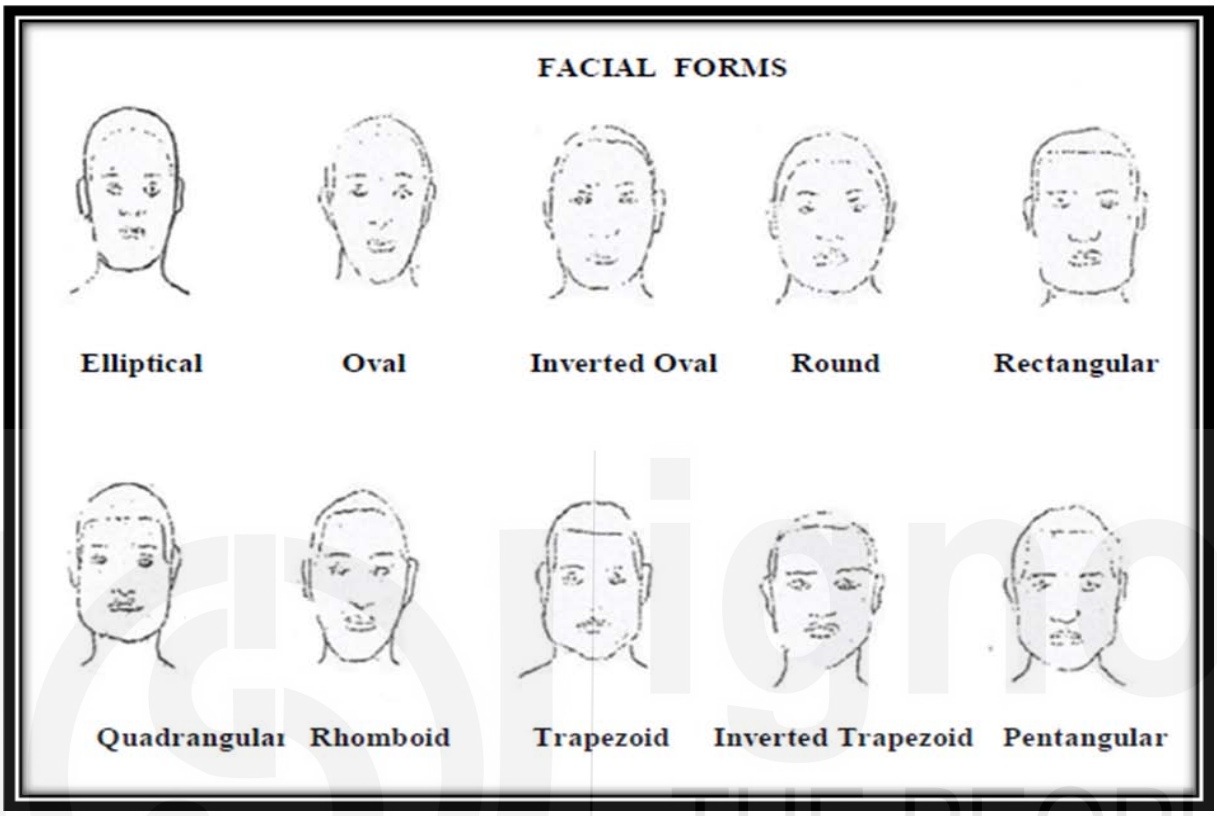

Figure 6: Facial Forms (after Martin & Saller)

Source:http://epgp.inflibnet.ac.in/epgpdata/uploads/epgp_content/anthropology/07._forensic_anthropology/21._identification_through_somatometric_and_somatoscopic_observations/et/8373_et_et_21.pdf

❖ ***Eyes:*** Scientific observation of the eyes can be done by recording the following features:

- Eye opening axis: Slanting or oblique or horizontal
- Direction: Inwards or outwards
- Eye folds
  - Type 1- Complete or medium or light
  - Type 2- Lateral ascending (external) or lateral descending (internal) or narrow or upper eyelids
  - Type 3- Absent and
  - Type 4- Asymmetric
- Colour of sclera: Clear or yellow or speckled or dull;
- Colour of iris: Black or Dark brown or Brown or Light brown or dark grey or Greenish or Light grey or dark blue or blue or light blue or crimson red;

❖ ***Nose:*** On the basis of the following characteristics, somatoscopic observation of the nose can be performed. These characteristics includes:

Tip of nose:

- Profile of tip –Fully rounded or rounded at point or flat; and
- Projection – Upwards or downwards.

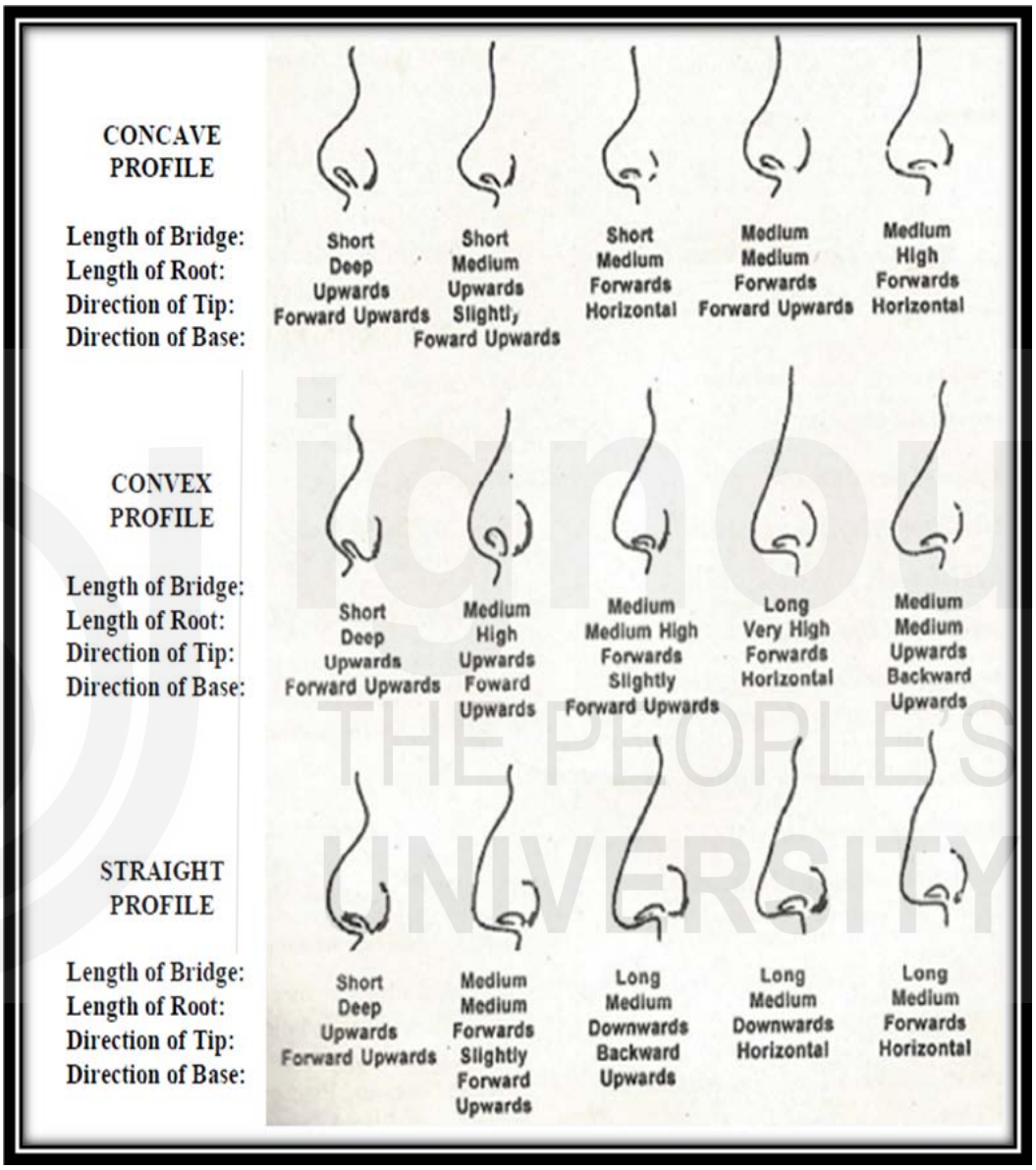

Figure 7: Nose Forms (after Martin & Saller)

Source:https://epgp.inflibnet.ac.in/epgpdata/uploads/epgp_content/anthropology/07._forensic_anthropology/21._identification_through_somatometric_and_somatoscopic_observations/et/8373_et_et_21.pdf

Nasal root:

- Shape –Very high or high or medium or quite flat
- Depth from Glabella – Deep or medium or High
- Breadth – Broad or Medium broad or Narrow and
- Height above the inner angle of eye – High or Medium or Low

- **Nasal bridge:**
  - Shape from profile – Concave or Vertical or Convex
  - Nasal bridge profile – Continuous or Angular or Wavy and
  - Size – Broad or Medium or Narrow
- **Nasal wings:**
  - Bulge –Strongly bulging or slight bulging or flat
  - Thickness – Thin or Medium or Thick and
  - Height – High or Low
- **Nasal septum:**
  - Profile – Septum visible or Septum Invisible
  - Direction – Upwards or Downwards or Horizontal
  - Size –Short Medium or Long and
  - Breadth – Narrow or Broad
- **Nasal cavity:**
  - Shape & Size –Narrow or Oval or Round or Broad and
  - Size & Length – Small or Big

❖ ***Lips:*** Somatoscopic observations of both the upper and lower lips is done on the basis of the following features:

- *Integumental upper lips*
  - Form– Convex or Straight or Concave;
  - Membral Lip– Thick or Medium or Puffed-up or Thin and
  - Mentolabial Fold– High or Medium or Broad.

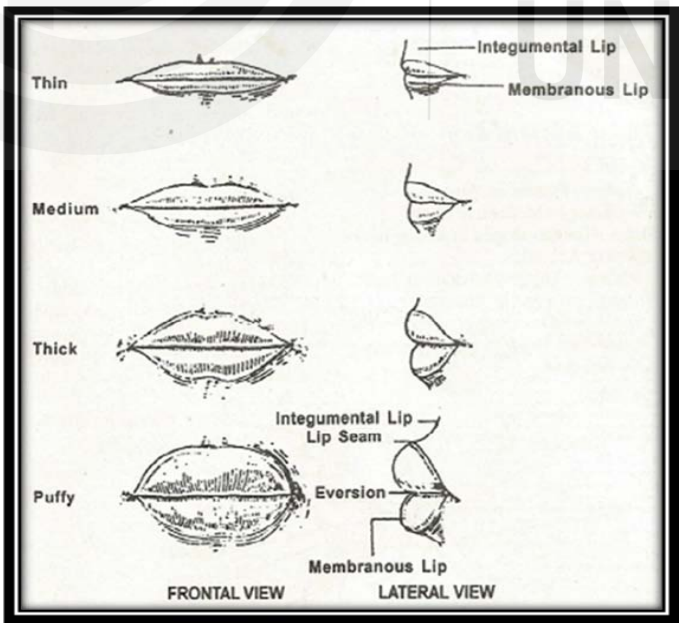

Figure 8: Forms of Integumental Lips (after Martin & Saller)

Source:https://epgp.inflibnet.ac.in/epgpdata/uploads/epgp_content/anthropology/07._forensic_anthropology/21._identification_through_somatometric_and_somatoscopic_observations/et/8373_et_et_21.pdf

- *Integumental lower lips*:
  - Form– Straight or Bulging Downwards
  - Membral Lip– Thick or Medium or Puffed-up or Thin and
  - Mentolabial Fold– High or Medium or Broad

❖ ***Mouth:***

- Thickness – Thick or Medium or Thin
- Breadth of Mouth – Broad or Medium or Narrow
- Tip –Round or Pointed
- Tongue: Length – Large or Medium or Small and
- Gums – High or Broad or Folded

❖ ***External Ear:***

- Ear lobe – Present or Absent; Size – Long or Medium or Short; Shape – Triangular or Square or Tongue -shaped or Arched; Thickness – Thick or Medium or Thin; Attachment – Free or Attached
- Darwin's Tubercle – Present or absent
- Antihelix Curvature – Strong or Medium or Weak
- Antitragus – Strong or weak or angularly developed
- Helix and Antihelix – Equal to each other or narrower or broader
- Tragus or Antitragus: Size – Small or weak or medium; Shape – long or round or knob-shaped
- Scaphoid: Size –broad or middle or narrow Shape – flat or medium or deep

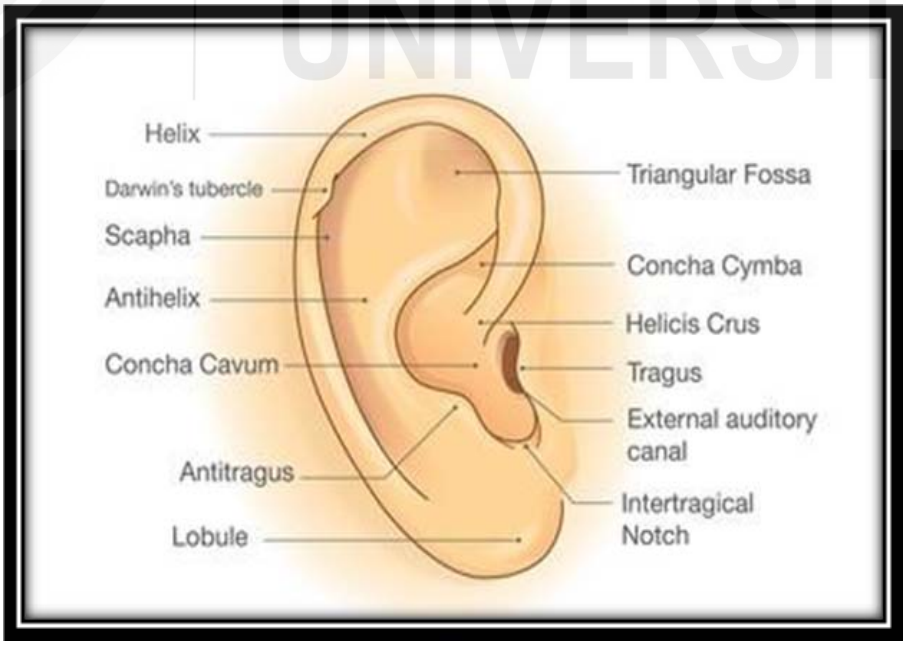

Figure 9: Morphology of External Ear

Source:https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.shutterstock.com%2Fsearch%2Fouter%2Bear&psig

Check Your Progress 2

3) Define somatometry.

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4) Differentiate between somatometric and somatoscopic methods of identification.

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6.4 FINGERPRINTS

Fingerprint is the visual reproduction of the ridge patterns and furrows present on the palmar surface of the human finger. The human skin on the palmar and plantar surface of hand and foot differs from the skin on the rest of the body in texture and appearance. The skin has creases that roughly run parallel to each other but frequently change direction forming clearly defined patterns, minutiae, furrows and are completely devoid of any hairs.

There are three fundamental principles of fingerprints:

- Fingerprints are unique i.e. no two persons can have exactly the same or identical fingerprint.
- Fingerprints can be systematically classified due to definite ridge patterns or characteristics.
- Fingerprints remain permanent and do not change throughout the lifetime of an individual.

Identification on the basis of fingerprints is performed by analysing pattern types of fingers and ridge characteristics. According to the classification reported by Henry in 1900, there are four basic group of patterns recognized in fingerprints (Figure 10):

- **Arches:** in which the ridges run from one side to the other with lower peaks at the center.
- **Loops:** the ridges start from one side, move towards the center, curve backwards forming a hairpin and terminate on the same side. There are

two fixed points in the loop pattern – the delta and the core. Loops are further classified into ulnar loop (if the curve of loop opens at the ulnar bone or little finger) or radial loop (if the curve of loop opens towards the radial bone or at the thumb).

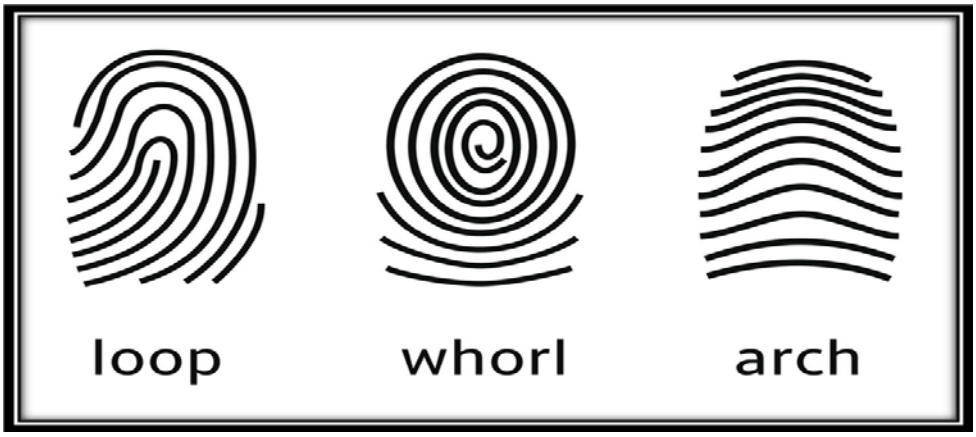

Figure 10: Basic Finger prints Patterns

Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.thoughtco.com%2Fwhy-do-we-have-fingerprints

- **Whorl:** These are circular or spiral arrangements of the ridges in the center. There are two deltas and one core in all whorls.
- **Composite:** This pattern comprises a combination of two or more of the preceding patterns such as central pocket loop, lateral pocket loop, twinned loop and accidental whorl.

Activity

Look at the terminal part of the fingers of both the hands and identify the finger print patter in all your ten digits.

According to Galton (1892), ridge characteristics may be defined as any variation from the run of the ridge as a special ridge characteristic or minutiae. For example, a ridge may end suddenly or a single ridge may divide into two ridges. Every single fingerprint has many such ridge minutiae which are distinct in their relative position, direction and orientation with respect to the delta and the core and by comparing the ridge detail in two impressions, identity can be established as combination of such minutiae does not occur at exactly same place and in same number in any two fingerprints from two different persons in the world. Different countries follow different standards for matching ridge characteristics. In India, it is between 8-12 matching points for possible conviction and the identification became firmly established on the principles of analysis, comparison, evaluation and verification (ACE-V) of friction ridge skin.

Check Your Progress 3

5) What are the fundamental principles of fingerprints?

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6) Describe various types of fingerprint patterns?

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6.5 FOOTPRINTS

The foot is considered as one of the anatomical regions that may demonstrate a high degree of individuality (Robbins, 1985; Kennedy, 1996). Identification can be established from the chance of footprints or impressions left on the foot wear or on the ground surfaces for example while stepping in the soil or in blood in the vicinity of the place of occurrence of the crime, etc. as depicted in Figure 11.

Figure 11: Foot Print

Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.alamy.com%2Fstock-photo%2Fsole-prints.html&psig

The features of the foot print such as its shape, size, angulations, depth, interspaces of toes, ball lines, inner and outer margins, heel creases, any callosities or wounds or any accidental scars and damage provide information

regarding the height of the person, length of the leg, range of body weight, gait pattern that are individualistic to that particular individual (Modi, 1977).

Dr Norman Gunn, a Canadian podiatrist, in 1972 first reported a case of identification from a foot print found on the shore of a Canadian lake and he also devised a method of comparison to demonstrate the points of individuality. Since then, there have been reports that podiatrists are involved in criminal case work such as in Australia and in New Zealand and also attempts have been taking place to develop a research database of human footprints to demonstrate the uniqueness of the human foot.

Foot identification could be especially useful in disaster situations as the foot is at an advantage over other anatomical regions through the protection offered by the encasing shoe (Smith, 1997; Robling and Ubelaker, 1997). Stature, one of the biological indicators of identification, has been shown successfully correlated with foot measurement from bare foot print impression (Kanchan et al., 2008; Sen and Ghosh, 2008; Sen et al., 2011; Hemy et al., 2013). Identification through foot print can also be performed with automated technologies with scanned images of known feet which will improve accuracy and eliminate human error.

Check Your Progress 4

7) How foot prints can help in identification of an individual?

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6.6 LIP PRINTS

Cheiloscopy or the study of lip prints deals with the furrows and grooves present on the lips. The lips can be described as two fleshy folds of reddish tissue surrounding the oral orifice and it is also denoted as the vermillion zone of the lips which is marked by the various furrows, groves and wrinkles. In 1902, the feature was first described by Fischer, an anthropologist, that the human lips have furrows on the vermillion zone. The possibility of personal identification using lip prints first mentioned in 1950 by Snyder in his book "Homicide Investigation." He reported that "the characteristics of the lips formed by lip grooves are as individualistic as the ridge characteristics of fingerprints" (Snyder, 1950).

In 1967, Santos suggested a supplementary stomatological means of identification by categorizing the features of the lips into two groups – simple and compound and further divided the group into eight subtypes. Suzuki and

Tsuchihashi (1970) first gave the anatomical name "*Sulci Labiorum Robrorum*" to the wrinkles and grooves present on the human lips and the lip prints made by these sulci as "*Figuralinearum Labiorum Robrorum*." Then, several attempts have been made by several authors to devise a classification method of lip prints. In 1971, Suzuki and Tsuchihashi, classified lip prints into five types in accordance with the shape and course of the lip grooves as depicted in Figure 12.

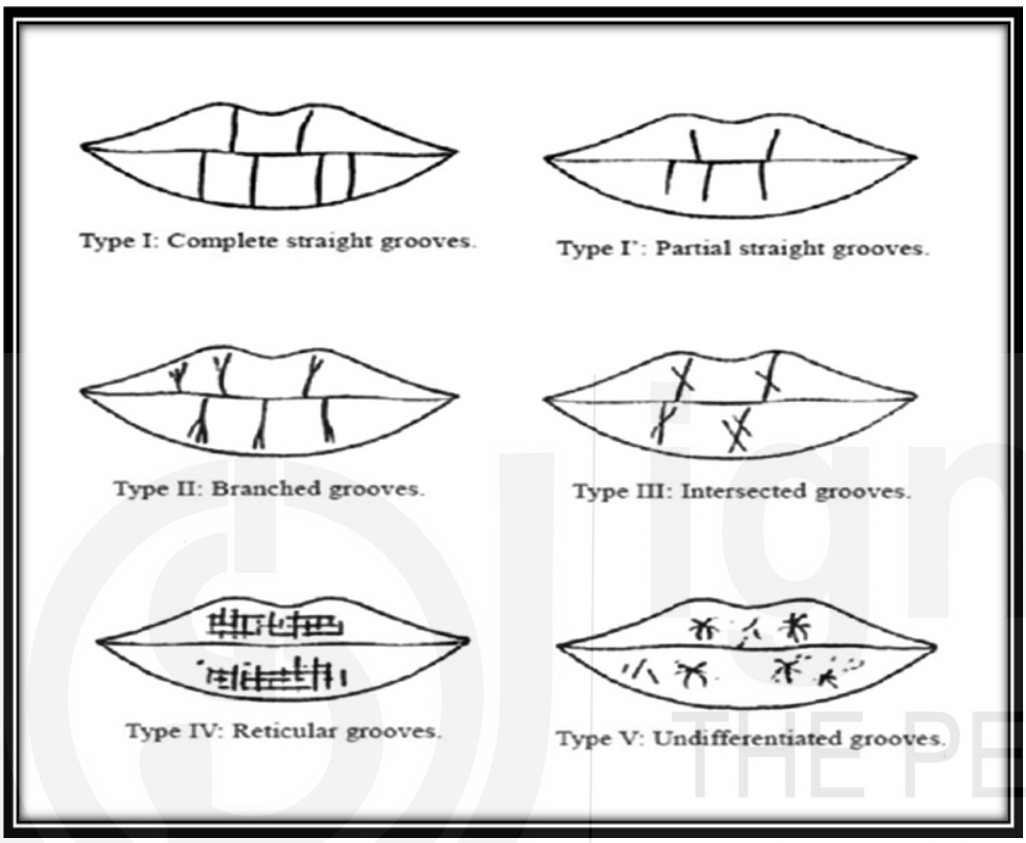

Figure 12: Tsuchihashi Classification of Lip Prints

Source:https://www.google.com/url?sa=i&url=https

Cheiloscopy is proved to be an important forensic investigation technique to conceal personal, criminal and human identification due to the fact that lip prints are unique to a particular person except in monozygotic twins (Tsuchihashi, 1974). Lip prints are considered as important evidence in cases such as sexual assault, murder, rape as the criminal unconsciously left the lip prints at the scene of crime on cups, glasses, clothes, cigarette butts, etc.

6.7 NAILS

Nails are an integral component of the human fingertip and are made up of dead keratinocytes. They perform various functions such as protecting the digits, enhancing sensations and acting like a protective tool. A fingernail is composed of several parts including the nail plate (the visible part of the nail), the nail bed (the skin beneath the nail plate), the cuticle or eponychium (the tissue that overlaps the nail plate and rims the base of the nail and provides a waterproof barrier and thus prevents from infection), the nail folds

(the skin folds that frame and support the nail from three sides), the lunula (the whitish half-moon visible at the base of the nail) and the nail matrix (the hidden part of the nail under the cuticle). Finger Nails can be classified on the basis of size (Long or Narrow or Broad), grooves – Long or Queer, and shape (Arched or watch-glass or flat shaped).

Nails are considered as one of the important tissues which can be utilised to establish personal identification. It is occasionally found in the crime scene as physical evidence especially in cases of sexual assaults and homicide etc. and if analysed properly can provide useful links to trace the identification of the victim or criminal. Nails as evidence can provide an important advantage as it is not affected or remains stable to most of the external or environmental factors and thus can remain at the crime scene for a longer time as it is non-destructive and non-invasive. Also nails are known to retail the detailed information on genetic inheritance and individualization. The term "Onychology" has been identified as the study of nails. Evaluation of human nail clippings provides useful information which helps us to ascertain the individuality of the individuals. However, the research towards the authentication of uniqueness, permanency and persistence in terms of nail striation needs to be determined.

6.8 HANDWRITING

Handwriting is considered as a neuromuscular task that requires both cognition skills and coordination of hand-eye movement and are thus individual specific with respect to unique writing features and thus can be used for personal identification. It helps in examination of forged or questioned documents in forensic investigations. Handwriting has existed as a means of communication since civilization began and the earliest record of writing came from China as far back as 5500 B.C. (International Journal of Document Examiners, 1995). Every individual has distinctive peculiarities in their formation of letters and the analysis of those peculiarities link or establish evidence of common authorship such as specific shape of letters, their sharpness or roundedness, regular or irregular spacing between letters, spacing, pen pressure, repetition of the elements or arrhythmia, analysis of inks, strokes, slants, etc.

Although it is extremely helpful in forensic identification process and used for over 100 years but with the advance of computerized technologies and proliferation of computer-aided handwriting algorithm has led to less anonymous mail and "chip and PIN" bank cards often remove the need for a signature and thus point toward the end of forensic handwriting analysis but remain the most convenient and widespread means of human identification (Stewart, 2007).

6.9 OCCUPATIONAL MARKS

Identification or investigation of either a corpse/deceased or a suspect or wounded victim or an injured person includes a careful verbal and visual record of the bodily marks, characteristics or features which every individual have on their body and a particular identification mark whether congenital, medical, accidental or artificial can be used to support in positive identification in conjunction with medical and police reports. Congenital marks can be defined as those which are present on the body since the time of birth such as birthmarks, moles, warts, white patches, congenital deformities, etc. Medical, accidental and artificial marks can be categorized as acquired marks which appear later in one's life after birth. Such acquired body marks include surgical wounds, scars, occupational marks, tattoo marks, body piercing etc.

Occupation marks are the marks present on the various parts of the body due to the occupational habits and work environment at the place of work. These marks are due to the effects of a particular occupation on workers skin and body. According to Parikh (2007), bodily marks such as occupational marks indicate the identity and social position of the individual. These marks often occasionally infer the probable occupation of the person and may assist in concealing identification of the individual.

Occupational marks can be temporary or permanent. Temporary occupational marks includes paints, dyes, organic mineral matter, chemicals or grease etc. at fingertips in case of painters, dyers, coal miners, asbesters, engineers, mechanics etc (Figure 13). Microscopic examination of the debris or dust or callosities under nail bed or in clothes or in earwax proves to be an aid in the process of identification.

Figure 13: Occupational Marks

Source:https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.iloencyclopaedia.org%2Fpart-i-47946%2Fskin-diseases%2Fitem%

Permanent occupational marks are most commonly seen among manual labourers with heavy, stiff and rough hands. Those persons who are in the profession of tailoring may have needle puncture marks on their terminal phalanges of the left index fingers. In the hands of a butcher, thickening is observed in the palmer skin of fingers. Likewise, on the last joint of the right

middle finger, a callosity is generally seen or encountered where the pen or pencil usually rests among the clerks.

6.10 SCARS

The healing process of the wound results in the formation of scar which is covered by epithelium tissue. Scar is devoid of hair follicles, sweat glands and pigments. Shape of the scar usually depends upon the shape of the wound. Thus, visual examination of the scar has long been identified as a means for identification and also an indication about the weapon used for causing wounds. According to Modi (1977), the shape, size, age and type of a scar reveals a lot of information about the type, time and weapon used in injury and in crime and thus help in narrowing down the investigation process.

Figure 14: Scars

Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.lifespan.

Scars can be formed or caused as a result of trauma, incision, laceration, injuries due to electric shocks, fire explosions, radiations, burns, chemical or corrosive acids etc. Scar resulting from an incised wound would be linear in shape; Lacerated wounds produce broad irregular scars; Stab wounds produce oval, elliptical or triangular scar; scars from scalds are spotted in appearance and appear running downwards. Scars due to burns or corrosive chemicals are irregular and coarse scars; vaccination scars are circular, oval, flat or slightly elevated. Scars from bullet wounds would be circular and depressed. Striaegravidarum scars are multiple in number and usually over abdomen in females who are/were pregnant as shown in Figure 14.

If the healing of the wound occurs by secondary intention then the resultant scar would be wider and thicker in the center than periphery. Scars resulting from diseases such as smallpox may cause multiple scars at various sites of the body. Persons who are drug addicts may have scar marks at cubital fossa due to repeated injections.

Scars are permanent as it cannot be erased or removed completely but the size and shape can be altered by operative procedure such as excision and skin grafting. However, any damage to epidermis doesn't produce scar, only injuries caused to the dermis form a scar. Time required for formation of scar depends on the nature of injury, size, and site of wound over the body. A clean wound heals in 5– 6 days when healing by first intention and a definite reddish scar will be apparent in less than two weeks. However, if a scar is large and edges cannot be approximated and also there is infection then the granulation tissue forms within a few days but scar appears approximately within 2 weeks to 3 months. When first formed, the scar is red, tender and covered by scab (< 2 weeks). Then it becomes denser and brown (2 week to 2 month) and after 2 -3 months, the scar becomes whit, glistening, tough and may be wrinkled. Thus, it is not possible to determine the age of scar after 3-4 month as no further change occurred in the scar.

Scars are excellent parameters for determining the identity of the individuals. While describing a scar for identification purposes, the number of scars, shape, size and location on the body should be recorded. The consistency of the scar whether fixed or mobile and colour of overlying skin should be noted. Scars which are slightly invisible or faint can be made visible by filtered ultraviolet light or by magnifying lens.

Check Your Progress 5

8) How to describe a scar for identification purpose?

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6.11 BITE MARKS

Forensic Odontology is the application of the scientific knowledge of dentistry in medico-legal proceedings. Bite marks may be defined as "a mark created by teeth alone or along with other oral structures". It can also be defined as an injury in skin caused by contacting teeth which shows the representative pattern of the oral structure. It is generally caused due to physical alteration done through the contact of teeth or dental structures of an animal or human in a medium or object which results in representative dental

pattern left on that object or tissue. For example, bite mark impression can be recovered from the body or skin of the sexual assault victims or from criminal cases, from butt of cigarettes, pen, and pencils, on food materials like fruits, chewing gums, chocolates, cheese etc. The front teeth i.e. incisors both lateral as well as central and the cuspids are mainly responsible for the development of the bite marks.

Figure 15: Bite Marks

Source:https://www.google.com/url?sa=i&url=https%3A%2F%2Fdogtrainingobedienceschool.com%2Fbite-mark-quotes-tumblr

Bite marks are considered as 'non-human' when it is caused by animals and 'human' when caused by humans. Bite marks can be classified as criminal and non-criminal on the basis of manner of causation. Criminal bite marks are further bifurcated as defensive and offensive bite marks. Defensive bite marks are those caused by the victim upon assailant and offensive bite marks are those which are caused by the assailant upon the victim.

Bite marks can be of seven different types (Mohapatra et al., 2017). These are:

- 'Haemorrhage' – a small bleeding spot;
- 'Incision' – neat punctured or torn skin;
- 'Laceration' – puncture of skin;
- 'Contusion' – ruptured blood vessels, bruise;
- 'Abrasion' – non damaging mark on skin;
- 'Artefact' – bitten off piece of body; and
- 'Avulsion' – removal of skin.

Bite marks can also be categorised into four types based on of degree of impressions. Those bite marks which are caused due to significant application of pressure are 'Clearly defined' bite marks whereas those caused due to the effect of first degree pressure are 'Obviously defined' bite marks; 'Quite noticeable' bite marks are due to violent pressure and 'Lacerated' bite marks

are those which results when the skin is violently torn from the body. Thus, three predominant mechanisms including tooth pressure, tongue pressure and tooth scrape are responsible for production of bite marks. However, severity with which the bite marks are produced depends upon the degree of movement and duration of force applied between the tooth and the tissue/object.

Bite marks are considered a valuable identification feature and an alternative to fingerprinting method of identification because it is believed that that 'no two mouths are alike' like 'no two fingerprints are alike'. In order to identify, the dental casts of the person are prepared using dental material and are matched and compared with the recovered bite mark. Also dental model (bite mark) from a photograph or a scanned image of the dental model or that particular food possessing the bite mark can be observed for identification. The photography of the bite marks must be conducted precisely using rulers and scales to accurately depict the orientation, depth and size of the bite mark. It is suggested to capture a number of photographs which can be magnified, enhanced and corrected for distortions. Bite marks, if analysed properly, have the potential to reveal the identity of the criminal or criminals of a particular crime. Forensic odontologists while analysing bite marks first ascertain whether the bite mark is human or non-human as animals leave very prominent indicative teeth patterns. Then, the bite is swabbed for DNA which might have been left in the saliva of the assailant. After that they perform several measurements of the bite mark and carefully record it. Forensic odontologists carefully look for dental characteristics for matching and identification. Dental characteristics can be classified as:

Class characteristics: A Class characteristic, in accordance with American Board of Forensic Odontology (ABFO), refers to those characteristics or features that are able to distinguish a bite mark from other bodily marks or patterned injuries. Now, there can be 'tooth class characteristics' and 'bite mark characteristics'. In human dentition, each tooth type has specific class characteristics which differentiate it from other teeth such as two central and lateral incisors are almost uniform in size and shape while cuspids are cone shaped and thus these characteristics will be reflected in the bite mark and on the basis of such parameters identification can be established.

Individual characteristics: Individual characteristics are those characteristics which show deviations from the standard class characteristics and are individual specific such as dental pattern or feature having rotations, buccal or lingual version, fractures, missing or extra teeth, mesial or distal drifting of teeth, attrition, abrasion, erosion, restorations, injuries, chemical injuries, motor vehicle accidents biologic attacks, etc.

Bite marks are most often encountered in cases of homicides, sexual assaults, child abuse, quarrels, abduction, etc. As bite marks on the body are caused by the victim or offenders intentionally, but those recovered from food materials at the scene of crime are unintentionally and often accidentally left by the

offender and thus prove to be an excellent source to narrow down the investigation as well as identification process. Most common parts or sites of the human body where bite marks are usually encountered are face, neck, arm, ear, breasts, legs, shoulder, buttocks, waist, and genitals. However, the analysis of bite marks is extremely challenging and identification of bite marks has been done by forensic odontologists considering many parameters. As bite marks can differ if there is movement in the person's jaw and tongue than that inflicted on a still victim; depending on the location of the bite mark on the human body, it is typical to recover both upper and lower teeth's visibly clear impressions, also bite marks change significantly over time and thus any resemblance identified have to be reported immediately by the forensic odontologists.

Check Your Progress 6

9) Describe bite marks and their types?

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6.12 TATTOO MARKS & OTHER IDENTIFICATION MARKS

Tattoo marks are patterns or designs engraved in the skin through small penetrating needle like tool dipped in colouring matter and made multiple small puncture wounds that gives the appearance of tattoo. Several dyes used for tattooing are Indigo, Cobalt, Carbon, Cinnabar or Vermilion, Prussian blue, Indian ink etc. The permanency of the tattoo marks depends on the depth of deposition of the dye and also the type of dye used. The tattoo marks stay longer if the pigments of dye are deposited below the epidermis and on the body parts which remain protected by clothes than the exposed areas due to exposure and constant friction.

Tattoo marks are able to authenticate individuality and prove to be a powerful and valuable identification parameter whenever encountered. These marks not only validate the identification during once lifetime but can also be utilised for recognition of the deceased or decomposed bodies where the skin has been peeled off due to permanence and indelible features of the tattoo marks. It has its implication in identification of race, nationality as well as religion as many individuals or communities or clan members have unique and specific tattoo designs engraved on their skin and in particular location on their body such as crude designs between eye brow ridges as indication of their tribe identity; unique patterns on arms and feet or dots on the wrists may

also indicate their God of worship or some belief system to which they belong (Figure 16). Also many times, tattoo marks indicate the socio-cultural status of a person.

Figure 16: Tattoo Marks

Source:https://www.reddit.com/r/EasternSunRising/comments/64a1p0/reviving_the_art_of_filipino_tribal_tattoos/?utm_source=share&utm_medium=mweb3x

There are several complications associated with tattooing like infection, septic inflammation, erysipelas abscess, gangrene, keloid formation, syphilis, AIDS, leprosy, etc. However, if somebody wants to remove the tattoo marks, it can be done with the help of surgical method (complete excision of tattoo mark followed by skin grafting or application of carbon dioxide snow), electrolysis (by utilising 2-5 milli ampere of current with needle to remove the mark), caustic substance or laser beam (particles of dye get vaporised), etc. In order to hide or reveal identity, the tattoo marks happened to be intentionally eliminated or altered or obliterated or another tattoo superimposed. In such cases identification from the tattoo marks can still be established as the pigment can be detected under the dermis, in the nearest lymph node in case of dead bodies. On removal of epidermis, the invisible tattoo mark becomes prominent in case of decomposed bodies. It should also be remembered that due to the same professional tattooist executing the design of the tattoo, there is a possibility that the same tattoo design may be encountered in more than one individual.

Check Your Progress 7

10) List an advantage and disadvantage of using tattoo mark as a means of identification.

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6.13 DEFORMITIES

"Deformity is the malformation of any component or part of the body". A deformity can be defined as the quality or state of being deformed or disfigured. Deformity is a part of the body that has not developed in the usual way or with the normal shape. This malformation may be caused due to some bony distortion or alteration in the topography of soft tissues or because of some injury or illness or when someone is born with deformity. The deformity could lead to impairment or functional loss with disfiguration.

Deformities can be either congenital or acquired deformity. Congenital deformities also named as birth defects are the physical abnormalities that are present at or before birth of the child. A number of factors might be responsible for congenital deformities. These include genetics that are evident through successive generations in a particular family or may be as a result of infectious disease that affects the growing foetus or may be due to environmental factors such as exposure to toxic chemicals etc. Congenital deformities may affect the facial structure and the baby may born with cleft palate or lips, or may be skeletal or with clubbed/webbed fingers/toes or spina bifida or fused fingers, abnormally bent fingers, asymmetry in shape and size of the fingers, missing, extra or difference in alignment of fingers/toes, etc. In most severe forms of congenital deformities, the child may have neural tube defects, heart defects or have Down syndrome that causes additional health issues for the child. During pregnancy, alcohol consumption also contributes to congenital deformities including low birth weight and abnormalities in the central nervous system. Acquired deformity in contrast to congenital deformity is that which was not present at birth and has developed after birth due to injury or infection or arthritis or tumour.

Deformities or abnormalities whether congenital or acquired form an excellent indicator of individualisation and are thus used as a means of personal identification. As the identification process is based on the fact that identity of the individual should be established more precisely, the presence of some special, unique or rare type of characteristics such as deformities provides authenticity and positive identification of the person.

Check Your Progress 8

11) What is congenital and acquired deformity?

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12) Elaborate various methods of personal identification in living persons.

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6.14 SUMMARY

Personal identification refers to the determination of individuality based on certain fixed, unaltered and unique characteristics of an individual that distinguish him/her from every other individual leading to their recognition or authentication. Personal identification of the living persons can be established through somatometry; somatoscopy of skin, hair, eyes, nose, ear, hand etc.; latent prints such as fingerprints, footprints, lip prints, nails, handwriting, bodily marks such as occupational marks, scars, tattoo marks, and deformities. It might be possible to have similar five to six somatoscopic characteristics or somatometric measurements in an individual but they will definitely differ in thirty unique parameters/characteristics or more. After going through this unit you will be able to establish personal identification in the living and can also help in crime scene investigation to reconstruct the events and perform verification and recognition of the individuals or victims or criminals.

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6.16 ANSWERS/ HINTS TO CHECK YOUR PROGRESS

1) Identification can be divided into two types. Complete or Total identification and Incomplete or Partial identification. Complete or Total identification implies exact specification or the absolute fixation of the personality of an individual. Partial or Incomplete identification means to discover or determine some aspects or facts about the identity while others remain still unknown or recording certain information which will ultimately help in complete authentication of the individual.

2) An effective identification medium or trait should possess the following qualities: Universality, Uniqueness, Permanence, Measurability, and Classifiable.

3) The word 'Soma' in Somatometry refers to 'living' and the term 'metric' denotes measurement. So, Somatometry can be defined as systematic techniques for measuring living beings including head and face.

4) Human identification can be established by various means such as by anthropometry of various human body parts, somatoscopy or the descriptive analysis of the features of the human body. Somatometry involves the scientific measurement of various parts of the body with defined landmarks and using appropriate or standard protocols with respect to the measurements. However, there are certain human characteristics that are not applicable for metrical examination and can only be described through description and observation. Such human characteristics are dealt with under the domain of somatoscopy. These are Skin colour, Hair color, Hair form, hair texture, Shape of Head, Shape of Face, Cheeks, Eye orientation, epicanthal folds,, Nasal features like nasal root, nasal bridge etc.; dental pattern, ear, Lips, shape of hands, Fingers & Nails, feet, Toe & Toe Nails, etc.

5) There are three fundamental principles of fingerprints:

   - Fingerprints are unique i.e. no two persons can have exactly the same or identical fingerprint.
   - Fingerprints can be systematically classified due to definite ridge patterns or characteristics.
   - Fingerprints remain permanent and do not change throughout the lifetime of an individual.

6) There are four basic group of patterns recognized in fingerprints: Arches, Loops (ulnar loop and radial loop), Whorl, and Composite.

7) Foot prints or impressions left on the foot wear or on the ground surfaces or in blood in the vicinity at the place of occurrence of the crime can assist in concealing identity of the persons. The features of the foot print

such as its shape, size, angulations, depth, interspaces of toes, ball lines, inner and outer margins, heel creases, any callosities or wounds or any accidental scars and damage provides information regarding the height of the person, length of the leg, range of body weight, gait pattern that are individualistic to that particular individual.

8) While describing a scar for identification purposes, the number of scars, shape, size and location on the body should be recorded. The consistency of the scar whether fixed or mobile and colour of overlying skin should be noted.

9) Bite marks may be defined as "a mark created by teeth alone or along with other oral structures" Bite marks can be of seven different types. These are Haemorrhage; Abrasion; Contusion; Laceration; Incision; Avulsion; and Artefact.

10) Tattoo marks are able to authenticate individuality and prove to be a powerful and valuable identification parameter whenever encountered. These marks not only validate the identification during once lifetime but can also be utilised for recognition of the deceased or decomposed bodies where the skin has been peeled off due to permanence and indelible features of the tattoo marks. However, the drawback of using tattoo marks is that due to the same professional tattooist executing the design of the tattoo, there is a possibility that the same tattoo design may be encountered in more than one individual.

11) Congenital deformities also named as birth defects are the physical abnormalities that are present at or before birth of the child. Acquired deformity in contrast to congenital deformity is that which was not present at birth and has developed after birth due to injury or infection or arthritis or tumour.

12) Personal Identification of living persons/individuals is necessary in both civil and criminal cases. Various methods which can be utilised for establishing identification of the living persons are somatometry; somatoscopy of skin, hair, eyes, nose, ear, hand etc.; latent prints such as fingerprints, footprints, lip prints, nails, handwriting, bodily marks such as occupational marks, scars, tattoo marks, and deformities.

UNIT 7 PERSONAL IDENTIFICATION OF LIVING PERSONS-II*

Contents

LEARNING OBJECTIVES

After studying this unit, you will learn about:

- fingerprints and their role in personal identification;
- how handwriting is assisting criminal justice system; and
- parameters of personal identification like hand length, foot length, etc.

7.0 INTRODUCTION

Forensic Science includes the application of principles and techniques of various scientific disciplines. Scientific examination provides the information with scientific support. *Corpus delicti* is frequently pronounced term in forensic science that deals with the body of crime. Identification is of crucial importance for the establishment of *corpus delicti*. Over the years, various methods have been reported for the identification of living and non-living persons. Fingerprint, Handwriting, Palmprints, footprints, etc. are well established means to establish the identity.

7.1 FINGERPRINTS

The scientific study of fingerprints is known as Dermatoglyphics. Fingerprints remain constant since the birth of a child, and do not change their alignment of ridges throughout its life. Friction skin is found exclusively on the palmer and plantar surface of hand and feet. Dactyloscopy is the

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science of identification through the examination of fingerprints. Friction skin differs in structure and functions, from the skin covering the rest of the body as:

a) it contains no oil gland (sebaceous)

b) there is a lack of pigmentation

c) it is hairless, and

d) it contains higher concentration of eccrine sweat glands.

Each fingerprint consists of a distinct pattern of friction ridges and numerous ridge minutiae, which help to individualise a person. Fingerprints are useful as valuable evidence in Forensic Science; they can link victim and suspects to the crime scene.

7.1.1 History of Fingerprints

Fingerprints began to attract thousands of years before the B.C. era. Archaeologists used fingerprints on pottery to indicate the brand and maker of pottery. In 1788, J.C.A. Mayer of Germany first propounded the theory that the arrangement of skin ridges is never duplicated in two individuals nevertheless the similarities are closer among same individuals. In 1823 Johanness Purkinje, a German Professor, described friction ridge pattern and classified the fingerprint but ascribed no identification value to them. Later Sir William Herschel (1860s) submitted a request to Home Offices to use fingerprint extensively, throughout India. He required natives to affix their fingerprint as well as signature to contract but failed to establish an effective fingerprint classification system. In 1880, Dr Henry Faulds suggested the use of fingerprints not only for identification but also for criminal investigation. A British anthropologist, Sir Francis Galton (1892), described the first scientific method of classifying fingerprint patterns, a method for taking prints and providing information about ridge characteristics known as "Galton details". He also published a book *FINGERPRINTS*. World's First Fingerprint Bureau was established in Kolkata in 1897. Ten Digit classification system, also called Henry Classification System was created in 1896 by Sir Edward Henry. In 1912, Edmond Locard, Lyons France, was credited with Poroscopy – the science of identification through the position & structure of pores. In the later period of 1930s, single digit classification system was introduced by Battley, New Scottland Yard. However, now from 2000 onwards various AFISs are being used worldwide for identification, classification and searching of fingerprint through computer program.

7.1.2 Formation of Fingerprints

Fingerprints are fully developed at about seven months of foetal life and friction ridges alignment do not change throughout life except due to accidental occurrences. This characteristic feature of fingerprint makes them suitable to be used as Biometric identifier.

7.1.3 Structure of Skin

The skin is usually divided into two distinct layers.

Epidermis: It is the outer covering layer of skin, composed of stratified epithelium of five sub-layers, listed from top to bottom: -

1) Stratum Germinativum- Basal generating layer
2) Stratum Spinosum- Spinous layer
3) Stratum Granulosum– Granular layer
4) Stratum Lucidum– Transitional hyaline layer
5) Stratum Corneum- Horny cornified layer.

Epidermis bears only sweat pores and have no blood vessels, nerve ending or sweat glands. Its function is to grip and protect the delicate component of the dermis.

Dermis: It is the innermost layer of the skin composed of dense fibro elastic connective tissues. They provide strength and plasticity to the skin. The dermis contains blood vessels, arrector pilli muscles, sweat (eccrine) gland, hair follicles and determines the unique fingerprint codes.

Dermal papillae are formed by the separating boundary of epidermis and dermis. They determine the form and pattern of fingerprint on the surface.

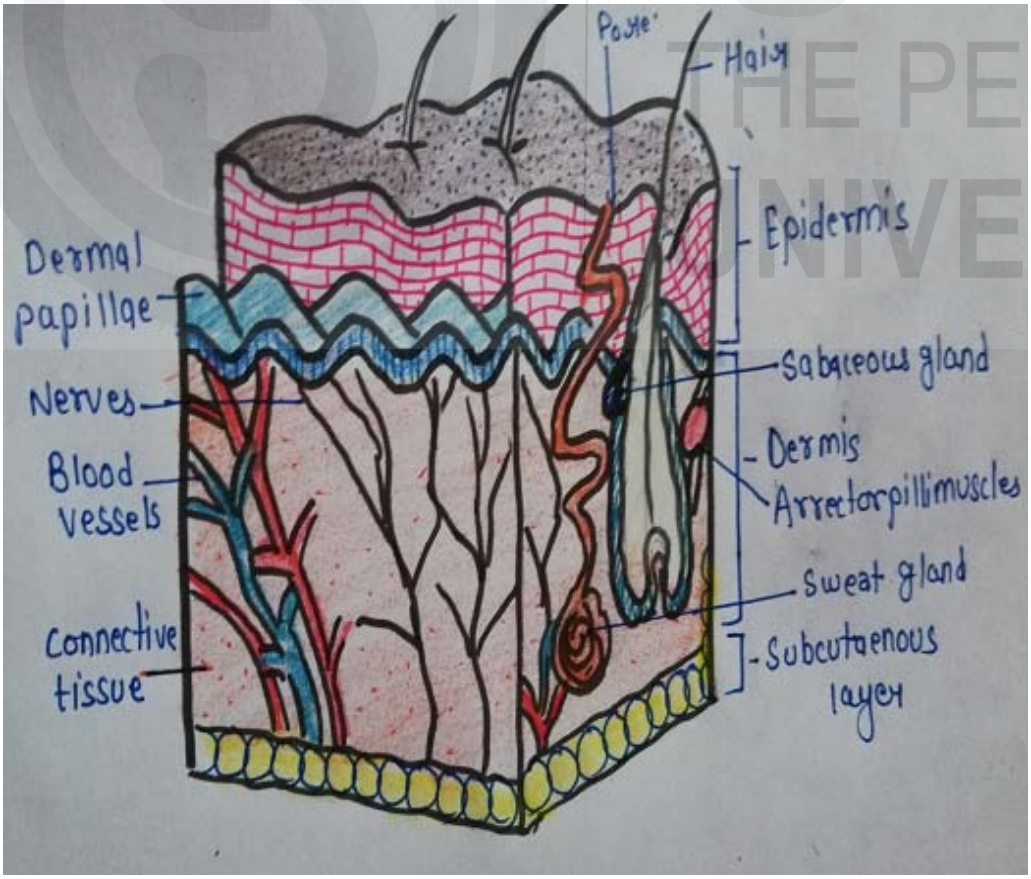

Figure 1: Structure of Skin

7.1.4 Composition of Sweat

Eccrine glands commonly referred as sweat glands are found on palms and soles in high concentration and all over the body in low concentration. They are about 2-4 million in number and their secretion is termed as perspiration.

Perspiration contains 99% water and remaining 1% consists of various organic salts, nitrogenous compound, amino acids, proteins, fatty acids, etc. When the friction ridges encounter some other objects, they leave the latent image which is the mirror image of the fingerprint.

The amount and composition of sweat residues varies greatly from person to person due to their personal metabolism, climate, and diet as well.

7.1.5 Importance of Fingerprints

Following features make fingerprint an important biometric tool:

- **Uniqueness:** No two fingers possess identical ridge characteristics. They have their own individuality even all the identical twins do not have the same fingerprint.
- **Permanency:** A fingerprint will remain unchanged during an individual's lifetime. Rare case of mutilation and skin disorder like leprosy, may affect the friction ridges. However, grafting of ridges is surgically impossible.
- **Classifiable:** Fingerprints have general ridge patterns that allow them to be systematically classified and thereby assisting the easy and early identification of a person.
- **Inimitable:** Successful simulation of fingerprint is not possible so far. This is important because no person can deny his or her fingerprints.
- **Universality:** The fingers have more intricate patterns. Fingerprints found at the crime scene are used for identification of victim, culprit, and suspects. Every individual has unique friction ridge pattern.
- **Easy recording:** They can be easily recorded by ink method or by scanning method.

They are frequently available in various crime scenes as evidence and are useful in proving and disproving the link between crime, criminal and victim.

7.1.6 Elements of Fingerprints

Following are the important elements of fingerprints:

- **Recurve:** A recurve is any ridge retracing its course, includes the bend in a loop or the circular path in whorl. Recurve is absent in arch and tented arch.
- **Delta:** When ridges converge on a point from three directions, the point is referred to as delta or triradius.

- **Friction Ridges:** The elevated portion of the skin that leaves the impression.
- **Furrow:** The Depressed portion between two ridges.
- **Type Lines:** The two innermost ridges which start parallel diverge and cover the pattern area. Type lines are absent in arch.
- **Pattern Area:** It is that part of loop and whorl pattern in which core, delta, and ridges concerned for classification are present. The pattern area of loop and whorl are enclosed by type lines.
- **Core:** The central area of the pattern contains the point of core. The type of core varies according to the pattern. There is no core found in Arch type pattern.

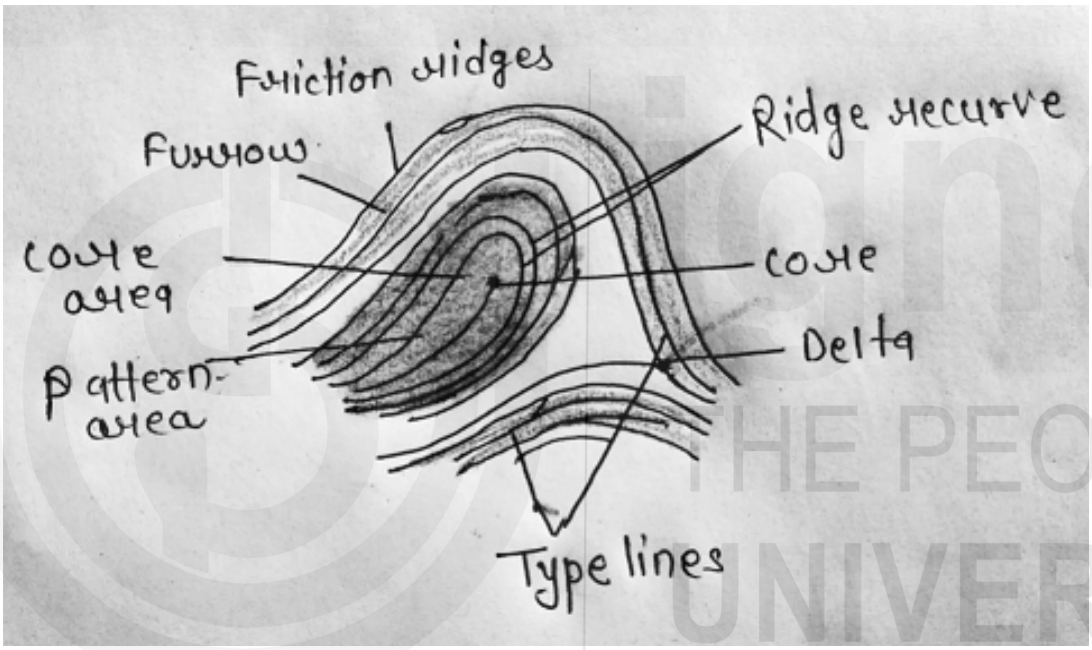

Figure 2: Elements of Fingerprints

7.1.7 Classification of Fingerprint Patterns

There are eight fingerprint patterns which are usually found on fingertip.

1) **Loop:** 60%-65% of population contains loop pattern. Loops must have one delta, one core and one or more ridge that enter or leave on the same side. This pattern is divided into two types, according to the position of radius and ulna bone of the forearm.

   i) **Radial Loop-** Loops flowing in the direction of thumb or radius bone of the forearm.

Figure 3: Radial Loop of Right Hand

ii) **Ulnar Loop-** Loops flowing in the direction of the little finger or ulnar bone of the forearm.

Figure 4: Ulnar Loop of Right Hand

2) **Whorl:** 30%-35% population contains whorl pattern. Whorl pattern contains one core, two deltas and one or more ridges that revolve around the core making a complete circle. In whorl pattern, when an imaginary line is drawn between the two deltas, it must touch or cross at least one encircling ridge.

Figure 5: Plain Whorl

3) **Arch:** 5% of the population contains arch pattern. Arch is the simplest type of fingerprint pattern that are formed by the ridges that enter from one side, slightly rise in the centre and exit on the other side. Arch contains no delta and no core. Arch is of two types:

   i) **Plain Arch-** The ridges enter on one side and exit on the other side with a rise or wave in the centre.

Figure 6: Plain Arch

   ii) **Tented Arch-** The ridges enter on one side and exit on the other side with at least one ridge(s) exhibits a sufficient upward movement.

Figure 7: Tented Arch

4) **Composites:** 1%-2% population contains composite patterns. Composites are the combination of any of the above-mentioned patterns. Composites are sub divided into following types:

   i) **Central Pocket Loop**- It has the features of both the loop and whorl. It contains at least one free recurving ridge and two points of delta. If an imaginary line drawn between two deltas, none of the revolving ridge around the core will be intersected.

Figure 8: Central Pocket Loop

ii) **Lateral Pocket Loop-** This is basically a double loop, one loop serves as a side pocket to the other loop, both the loop formations flow in the same direction with core. Lateral pocket loop contains two deltas.

Figure 9: Lateral Pocket Loop

iii) **Twinned Loop**- This is basically a double loop, one loop resting upon on encircling the other loop with core and flow towards different deltas.

Figure 10: Twinned Loop

iv) **Accidental-** Pattern consist of the combination of two or more different types of pattern. Accidental patterns contain two or more deltas. **Nutant loop** or **Nascent loop** is the combination of loop resting over plain arch.

Figure 11: Accidental Pattern

7.1.8 Ridge Characteristics: "Galton Details"

No two fingerprints are same except when obtained from the same finger of the same person due to permanency of the ridge characteristics. The minimum number of ridge characteristics for establishing the identity of a person beyond any doubt is eight. The friction ridges contain following ridge characteristics-

- **Ridge Ending or Termination**- This ridge ends abruptly between two parallel ridges and does not reappear.
- **Bifurcation**- It is formed when a ridge emerges from one side and divides into two parallel ridges.
- **Fork**- It is formed when an emerging ridge divides into two ridges and do not continue ahead.
- **Spur or Hook Formation**– When an emerging ridge divides into two ridges and only one of the dividing ridges continue ahead.
- **Enclosure**– It is formed when an emerging ridge divides into two, almost immediately converge to form a single ridge leaving a blank space within the ridges.
- **Deviated Break**- Interruption between two ridges, just before they meet, suddenly deviates from their path.
- **Point or Dot**- It is a very small fragment of a ridge which is only as long as it is wide.
- **Change Over**– It is formed when two parallel ridges change their paths.
- **Intersection –** It is formed when two parallel ridges suddenly intersect each other and continue further.

❖ **Cross Over or Bridge**– It is formed by the junction between the two ridges by a short diagonal ridge at a very acute angle.

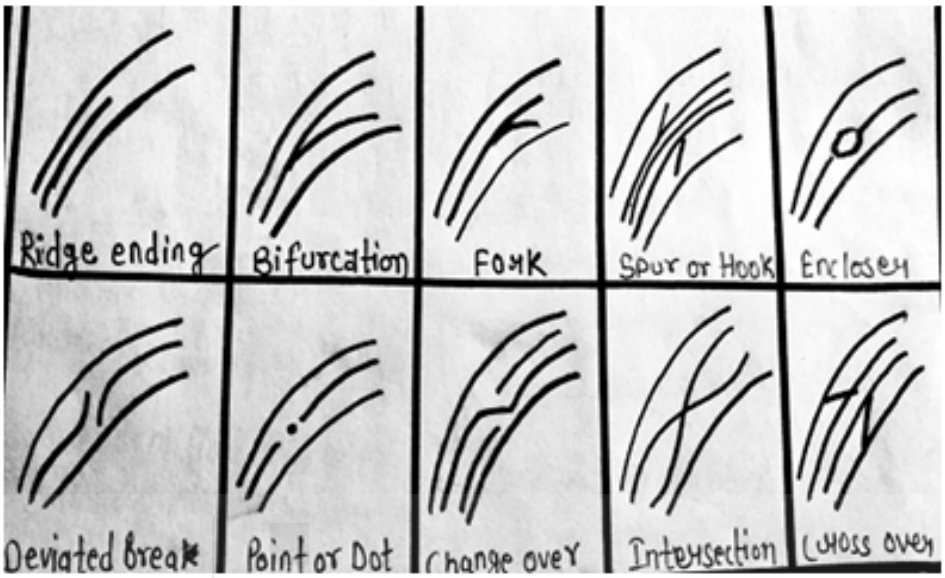

Figure 12: Different Ridge Characteristics

7.1.9 Types of Chance Prints

1) **Latent Prints-** Latent prints are invisible prints or hidden prints. They are formed due to perspiration of fingers when a perpetrator touches an object. These types of prints are enhanced or visualised by physical, chemical, and instrumental methods.

2) **Plastic Prints (3-D Prints)-** These types of prints are produced when the friction skin touches softer surface like soap, wax, butter, paint etc. Plastic impressions need not to be dusted with fingerprint powder.

3) **Visible Print (Patent Print)-** Fingerprints which are visible to naked eye are called as visible print. Visible prints include inked print, bloody print, dirt print, etc.

7.1.10 Fingerprint Development Techniques

Various physical and chemical methods are employed for the easy detection and development of latent prints on different types of surfaces like porous, non-porous and wet surfaces.

1) Powder Methods (Physical Methods)– The enhancement of print relies on the mechanical adherence of powder with oil or moisture component of perspiration. Powder method is suitable for non-porous surface. For example, ferric oxide powder, black charcoal powder, white fingerprint powder, etc.

Figure 13: Fingerprint developed by Black Powder

2) **Chemical Methods–** Components such as protein, amino acids, lipids and oils, salts, etc. react with different chemical to reveal the latent prints. Chemical methods include Iodine Fuming method, Ninhydrin method and Silver Nitrate methods, which are usually applied for the development of fingerprints on porous surfaces such as paper, cardboard, etc.

Check Your Progress 1

1) Explain the different layers of skin and formation of fingerprints.

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2) What do you understand by ridge characteristics?

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7.2 HANDWRITING

Handwriting is a highly complicated motor skill which involves together neurological, physiological, and sensory impulses. Usually, people learn the art of writing by copying the letter designs from a copybook at a very young age. Since each person has a different skill regarding reproduction of the

designs of letter, as it depends on the writer's perception of image and his/her ability (motor skills) to regenerate that visual perception. This act of handwriting is gradually mastered by repeated practice. Once this act is mastered, writers start focusing on the subject matter rather than the physical act of writing and this is the point when they start deviating from the learned copybook forms by inculcating such characteristics which are peculiar to them. The writing gradually becomes a pattern of habitual, subconscious formations that are repeated over from one writing to next.

7.2.1 Development of Handwriting

In the initial stages, the process is slow. But with passage of time and with the goading and guiding, this process speeds up. Modifications of the copy form and individual idiosyncrasies continue to create an individualistic handwriting till the person acquires graphic maturity, usually after the adolescent age for most of the writers.

7.2.2 Handwriting Characteristics

Handwriting features called characteristics are used to identify handwriting. The characteristics of writing that occur in handwriting include the appearance of the writing and the method of construction.

Characteristics that are mutually shared by many writers are called **Class Characteristics**. Class characteristics of natural writing are those characteristics which the writer shares with a group of persons who happen to learn the same system of writing forms and models, from the same teachers, from the same or similar schools or institutions. The school or the teacher teaches a particular letter design (style), slant, size, placement, etc., to hundreds of pupils.

In contrast to this, **Individual Characteristics** are those that are highly peculiar or unique to writer. Individual characteristics are created by an individual consciously or unconsciously by modifying the copybook writing forms of letters, digits, etc. It is a combination of both the class as well as individual characteristics that are used to identify an individual's handwriting.

Following twelve handwriting characteristics should be considered while analyzing a handwriting match:

1) **Line Quality:** The smoothness of the line of writing represents the line quality or line value. It is the strength, thickness, and rhythm of the letters. It could be shaky, flowing, or very smooth and fine.

Figure 14: Different Types of Line Qualities

2) **Letter Spacing:** It is referred as the quantity of space left between two adjacent letters. The letters could all be connected or spaced drastically.

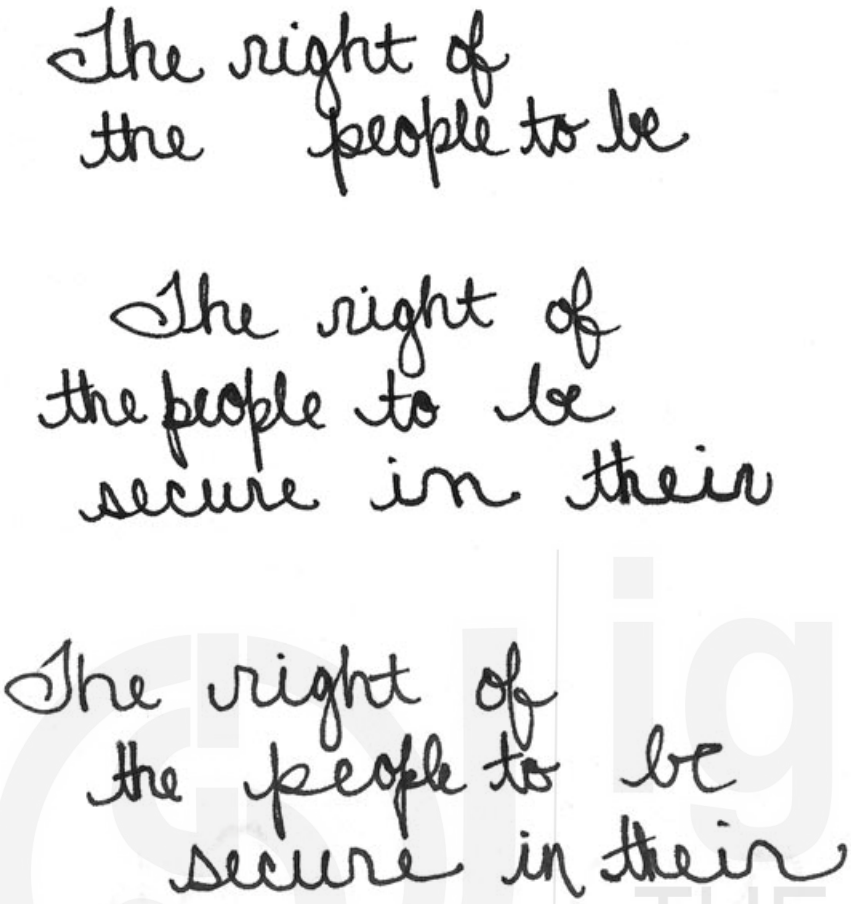


Figure 15: Different Letter Spacing Habits

3) **Size of Letters:** The relative sizes of letters and words become almost fixed with passage of time with a writer. This simply analyzes the proportions of the handwriting. As it is a general assertion that relative proportion of all the letters remains fairly constant in a developed handwriting.

Figure 16: Different Sizes of Handwriting

4) **Pen Lifts:** Pen Lift is the lifting of pen during or after the formation of any stroke/letter. People usually tend to use similar pen lifts, if all the

letters are well separated even when the real signature connects them, so a forgery may easily stand out.

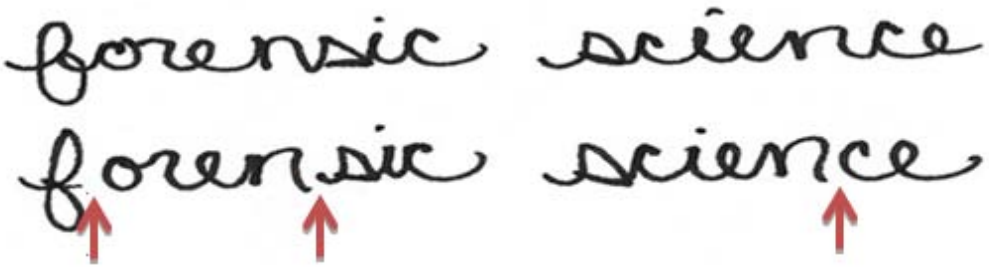


Figure 17: Pen Lifts in Handwriting

5) **Connecting Strokes:** Connecting strokes joins the letters in words. These strokes are also known as ligatures. Connectors can consist of arcades, garlands, thread connections or angular connections.

Figure 18: Connecting Strokes of Handwriting

6) **Initial and Terminal Strokes:** Initial strokes are the initial placement of pen to begin letter form. These are highly personalized strokes that have a high value in identifying a writer. Contrary to this, terminal strokes are ending strokes on letters and words. They also may be straight, curved, or hooked, long or short and are consistent with writers.

Figure 19: Initial and Terminal Strokes of Handwriting

7) **Letter Formation:** Any peculiar and unique capital or lowercase letter is highly individualistic and could give an indication as to the authorship of the writing.

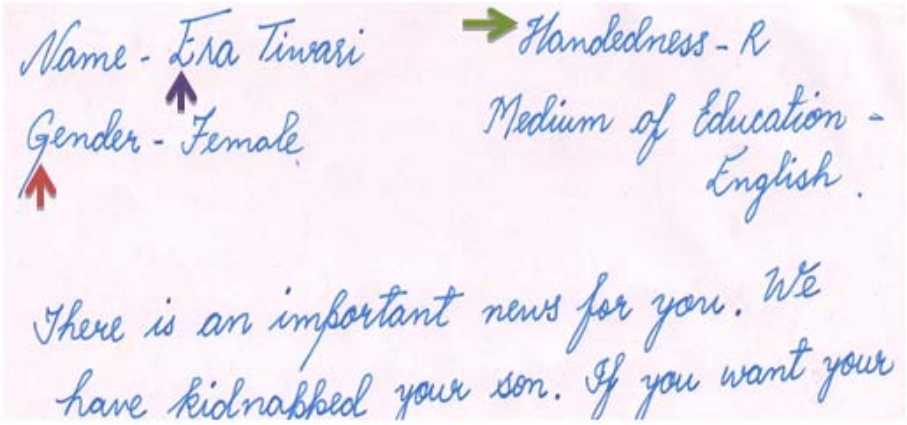


Figure 20: Specific Letter Designs

8) **Pen Pressure:** There are two types of pressure in handwriting: grip pressure, which refers to the hand's grasp on the writing instrument, and the pressure that is used to push the pen across the paper. It varies for different writers from light to heavy.

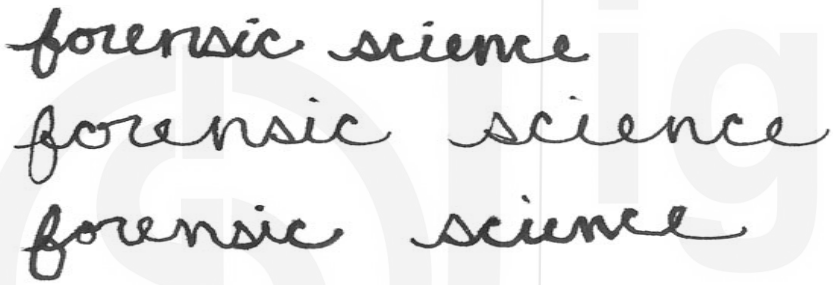


Figure 21: Different Pressures exerted during Writing

Source: slideplayer.com

9) **Slant/ Slope:** The inclination of written strokes w.r.t. actual/imaginary line is called as slant. The slant can be studied by the prediction of degree of angle. The inclination of written strokes in relation to perpendicular with respect to actual/imaginary line is called as slope. Slope may be towards left or right.

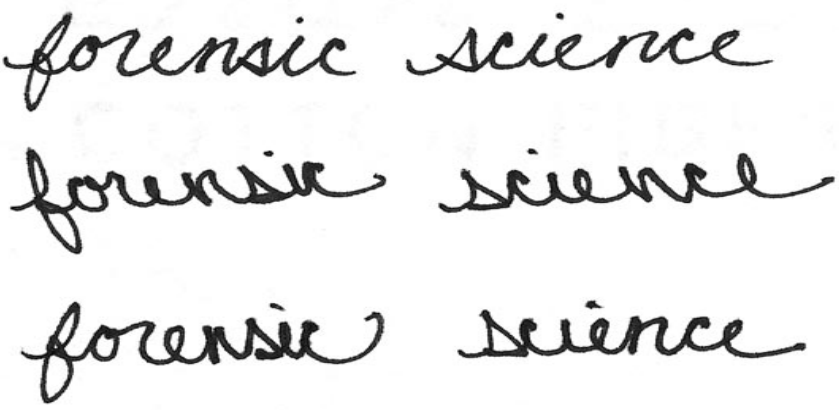


Figure 22: Different Slants of Handwriting

10) **Baseline Habits:** Baseline is that imaginary or real line on which the letters of lower-case rest. It is the tendency of writer that where he tends to write. It could be on the line, below the line or above the line.

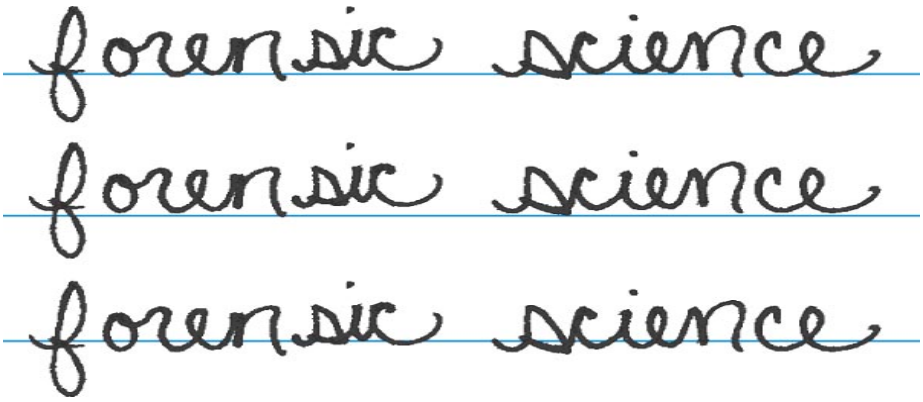


Figure 23: Different Baseline Habits

11) **Flourishment and Embellishment:** These are formations added to the writing to improve the aesthetic appearance of the writing. Usually these are in terms of large loops and swirls in handwriting.

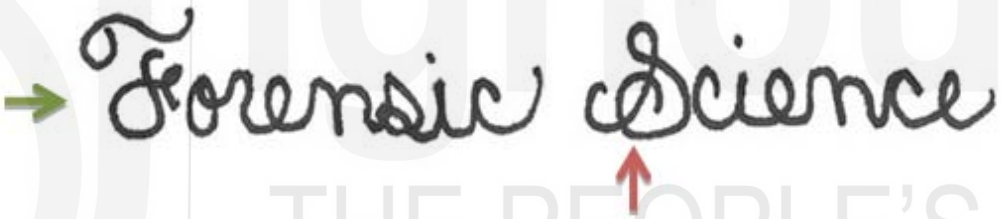


Figure 24: Different Flourishment of Handwriting

12) **Placement of Diacritics:** Diacritics are the modifications that are made by the writer in the design of any letter like the way in which writer put dots over j and i.

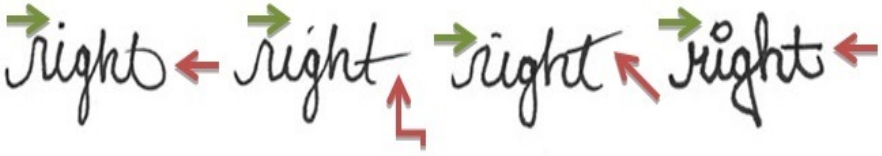


Figure 25: Diacritics Placement in Handwriting

A writer's identity, however, cannot be established through a single individual feature in the writing. Rather, it is established by the combination of various significant features among the writings, with no significant differences.

7.2.3 Factors Affecting Handwriting

Handwriting being an acquired art is affected by several internal and external factors. Some of these are:

- **Writing material:** Paper, pen, ink, pencil, writing support, seat etc. can contribute to variations in handwriting.
- **Mechanical factors:** These include the writing surface, position of writer i.e., whether writer is standing, sitting, or trying to write under adverse conditions. Poor lighting conditions can also affect handwriting.
- **Physical or psychological disturbances:** Excitement, illness, fear, pain, injury to the hands, and influence of drugs or alcohol can adversely affect the writing characteristics.
- **Age:** As time advances some of the old characteristics are modified or dropped and a few new characteristics are acquired. Old age may set in deterioration in strokes and poor form of letters.
- **Natural variations:** Two writing specimens prepared by the same person cannot be identical in all the aspects. Variation is an integral and inherent part of a natural writing.
- **Education:** The initial training of the person has a great impact on his or her handwriting. Besides this, it also depends on power of observation, capacity of graphic expression and technical execution of the writer.

7.2.4 Handwriting Analysis: The Scientific Foundation

7.2.4.1 Individuality

The principle of individuality, which is also known as the principle of uniqueness, lays down the foundation of handwriting analysis. No two writers can share the exact combination of handwriting characteristics, provided there should be sufficient quantity and proper quality of writing to compare.

7.2.4.2 Natural Variation

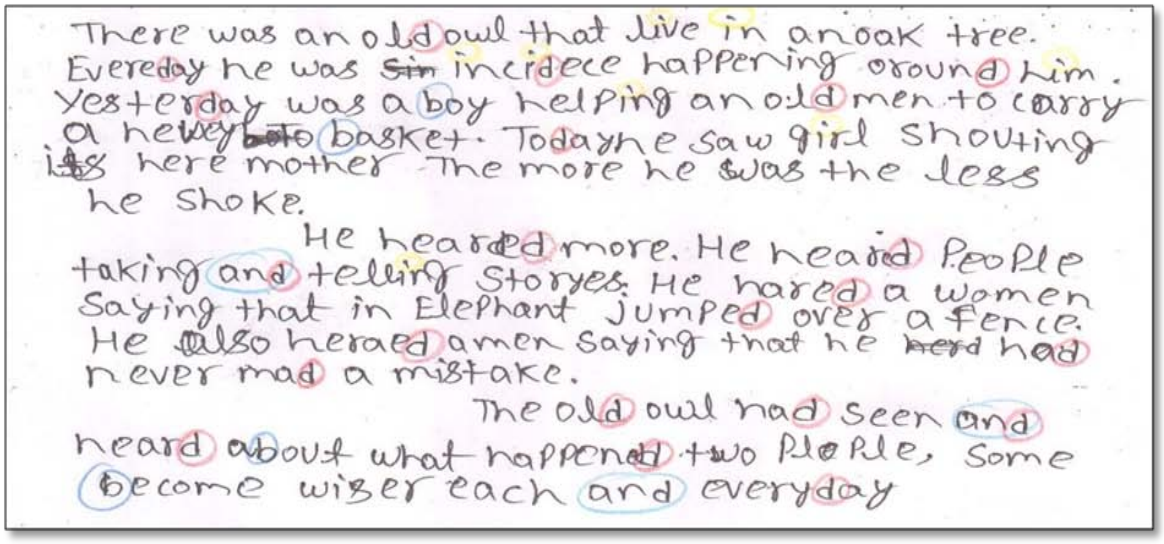
No person can write exactly in the same way, even within number of repetitions of writings. This is called intra-writer variation or more precisely natural variation, which enunciates the next important principle employed in handwriting analysis.

Machine-like repetition and precision could never be achieved by human beings. Neuromuscular process always results in some variations in style (formation). Variations have always been an integral part of an individual's writing.

7.2.4.3 Writing Skill

A writer has his own writing skill that can never be dramatically improved in short time span while maintaining all appearances of natural writing. Individuals can write *at or below* their skill level but not *above* their skill level. Figure 26 and Figure 27 show two writing samples to demonstrate

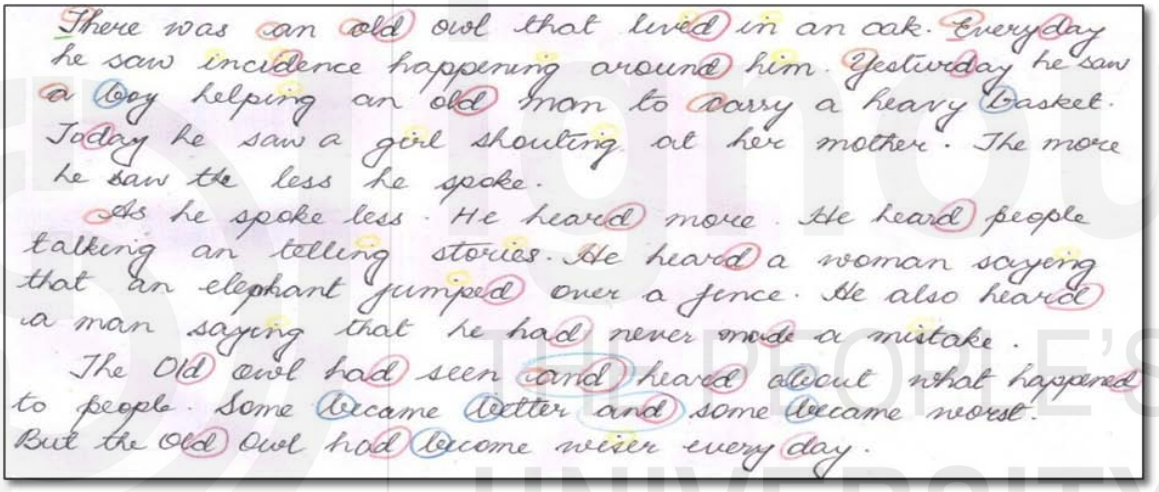
clear cut discrimination between the writing skills of their writers.


There was an old owl that live in an oak tree. Evereday he was ~~sin~~ incidece happering around him. Yesterday was a boy helping an old men to carry a heavy ~~bo~~ basket. Todayhe saw girl shouting ~~is~~ here mother The more he was the less he shoke.

He hearded more. He heard People taking and telling Storyes. He hared a women saying that in Elephant jumped over a fence. He also herad amen saying that he ~~herd~~ had never mad a mistake.

The old owl had seen and heard about what happened two PleRle, Some become wiser each and everyday

Figure 26: Low Skilled Writer


There was an old owl that lived in an oak. Everyday he saw incidence happening around him. Yestirday he saw a boy helping an old man to carry a heavy basket. Today he saw a girl shouting at her mother. The more he saw the less he spoke.

As he spoke less. He heard more. He heard people talking an telling stories. He heard a woman sayeing that an elephant jumped over a fence. He also heard a man saying that he had never made a mistake.

The Old owl had seen and heard about what happened to people. Some became better and some became worse. But the old owl had become wiser every day.

Figure 27: High Skilled Writer

Check Your Progress 2

3) What is handwriting?

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4) Discuss various characteristics of handwriting.

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7.3 NAILS

Forensic Onychology (Greek word, Onukus=nails, Logia=study of) deals with the study of fingernails and toenails to improve the administration of justice in court. Nails have been utilized for human identification. Benefits of utilizing nail in comparison to alternative tissues is that sample size and sampling methods are comparatively non-invasive and non-destructive, nevertheless every nail retains a separate record of genetic inheritance, drug use, pathology, diet, and history of exposure to explosives residues or other pollutants.

7.3.1 Nail Unit

Nail unit comprises of

- a nail plate,
- four specialized epithelia (which includes the proximal nail fold, the nail matrix, the nail bed, and eponychium) and
- lateral nail folds.

The nail bed is underneath the nail, it connects the nail to the finger. The nail matrix situated at the base of the nail, is the place nail development begins. The cuticle serves as the connection between the top of the nail plate and the skin behind it. The lunula is the half-moon shape at the bottom of the nail. The nail folds are the folds of hard skin along the edges of the nail plate where the nail and the skin meet. The main function of nails is to protect the underlying tissue of nail bed.

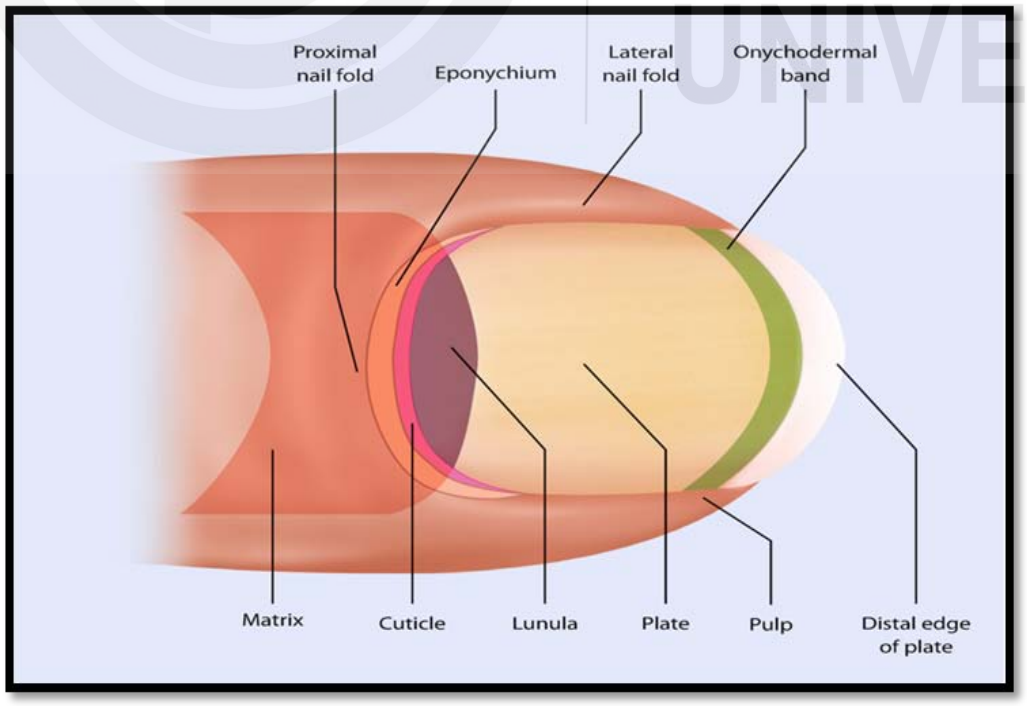

Figure 28: Fingernail Unit (Surface View)
Source: kkforensics.com

7.3.2 Various Features of Nail

- Nails grow at an average rate of 3mm per month. Nail growth is impacted by disease, nutrition, medications, trauma, chronic sickness, fever, and the aging process, chemical effects, pollution absorption, etc.
- Nails can reveal the general state of health. The deformities and abnormalities in nails give clues about the medical problems of an individual.
- The nail plate has longitudinal ridges like texture which are distinctive and are useful in identification.
- Finger- and toenail matrices can accumulate drugs during long term exposure to them.

7.3.3 Various Nail Deformities and Dystrophies

Nail deformities refers to the change in nail shape and Nail Dystrophies refers to the change in nail texture.

	Nail Deformities/ Dystrophies	**Causes**	**Images**
Associated with Diseases	Spoon shaped nails (koilonychia)	Iron deficiency	
	Pigmented nails (half white half pink)	Kidney Failure	
	Beau Lines	Infection, injury, chemotherapy	
Associated with Drugs	Nail bed blue-black	Chloroquine drug	

	Dark blue-gray nails	Silver	
	Horizontal white lines or brown nails	Arsenic poisoning	
	Brown-black longitudinal streaks	Zindovudine	
	Onycholysis	Drugs: Doxorubicin, Bleomycin, Captopril, practolol, 5-fluorouracil, and retinoids	
	Photo-onycholysis	Drugs: doxycycline, psoralens, and fluoroquinolones	

Figure 29: Various Nail Deformities and Dystrophies

Source: *msdmanuals.com*

7.3.4 Forensic Importance of Nails

In Forensic Science, diagnosis of nail plate serves as an important tool. In many cases, broken fingernail plates have been used for associating a suspect with the victim by comparing pattern of nail ridges. In forensic toxicology, nails can provide good matrix for detection of drugs of abuse. Nails are also the source for DNA which further makes it helpful in identification purpose. The longitudinal ridges on nail plate, which can be evaluated by computational analysis even in low-resolution images, proved to be unique and stable biometric identifier.

Check Your Progress 3

5) What do you understand by Forensic Onychology?

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6) Explain forensic significance of nail.

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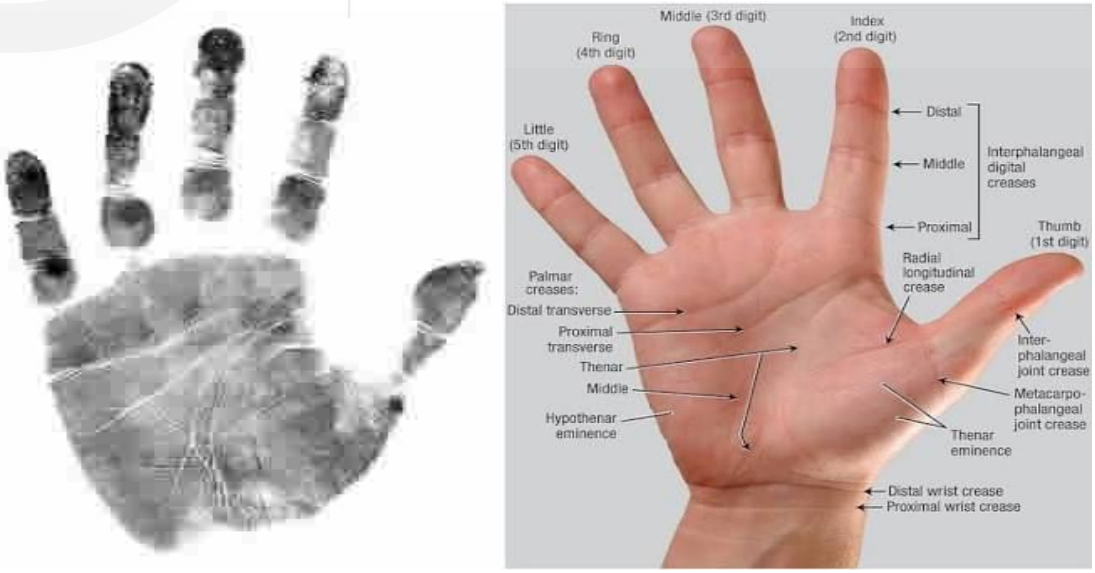
7.4 PALMPRINTS

Palmprints are the impressions of dermal friction ridges present on the palmer surface of the hand. When a person touches the surface, the impressions are left behind. Like fingerprints, palmprints also remain unaltered until death. Palmprints play vital role in identification of a suspect. According to the study of Jain and Feng (2008), about 30% of the latent prints recovered from crime scenes are from palms. They are found in latent form on almost every surface like documents, wall, dead body, handle of knife, bottles of beverages, etc.



(a) **(b)**

Figure 30: (a) Inked Palmprint (b) Labelled Palm
Source: *biometricupdate.com*

7.4.1 Different Regions of Palm

The palm of a human hand is divided into three regions:

- **Hypothenar-** It is the largest area located on the ulnar side of the palm. Three creases separate the region from the other two regions – the distal transverse crease, radial longitudinal crease and carpal crease located above on radial side and below the hypothenar region respectively. This region also contains variety of patterns just like fingerprint pattern.
- **Thenar-** It is located on the radial side of the palm. It is separated by the radial longitudinal crease and carpal crease, on the ulnar side and below it respectively. It contains a unique pattern- the vestige. A vestige is a ridge flow that runs opposite to the main flow of the ridges. A vestige can be small and independent, or it may be quite large and accompanied by loops, columns, or whorls.
- **Interdigital Area-** It is located under the fingers with the metacarpophalangeal crease above and the distal transverse crease below it. This region contains highest frequency of patterns.

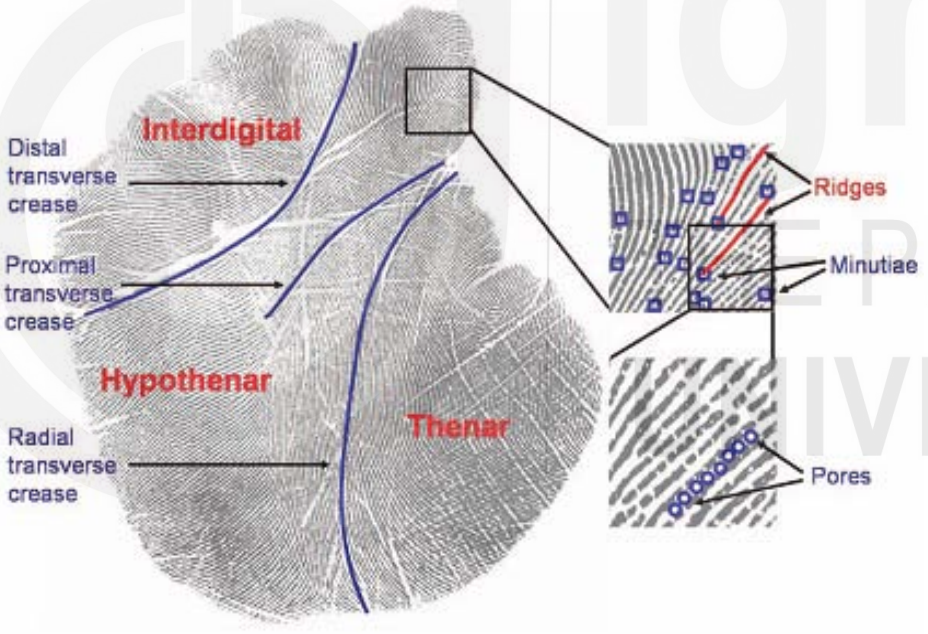


Figure 31: Regions of Palm Print and Creases Separating the Regions
Source: Ali et al. (2016)

7.4.2 Advantages of Palmprints over Other Biometric Techniques

Palmprints have following advantages over other hand based biometric technologies:

- ❖ Palmprints have larger area as compared to fingerprints, which enables the extraction of more features for comparison purpose.
- ❖ An individual is less likely to damage palm than fingers.

- ❖ Presence of dirt or grease on the finger may interfere in extraction of features accurately but in palmprints this problem does not arise, as a low-resolution palmprint is used for extracting features.

7.4.3 Characteristics of Palmprints

Human palmprint is rich in features. Some of features are discussed below:

Principal Lines: There are three principal lines on palms, named as heartline, headline and lifeline. They are also called as flexion creases. These are the most important physiological features for individual recognition as they vary little over time, their shapes and location on palm serves great importance in recognition.

Regions: Palm is divided into three regions, which include finger-root region (I), inside region (II) and outside region (III).

Datum points: End points across the palm and their mid-points.

Geometry Features: This defines the width, length, and area of palm.

Wrinkle Features: Other than the principal line, there are some thinner and more irregular lines termed as wrinkle lines. They are classified into two types- coarse wrinkles and fine wrinkles.

Delta point Features: The centre of delta like region in the palm prints. There are always some delta points located in the finger root region and outside region. Delta point determination is helpful in locating endpoints of the principal lines.

Minutiae Features: Palm prints are composed of ridges, similar to fingerprints.

7.4.4 Process of Palm Prints Identification

Like fingerprints, palm prints also play crucial role in identification of suspect. They are unique, universal, stable, and permanent. The lower part (Hypothenar area) of the palm print has a large area in comparison of fingerprints which are left over the object/surface because of which probability of identification is higher of such prints. The thenar area of palm has wrinkles and folds of skin which also play vital role in identification.

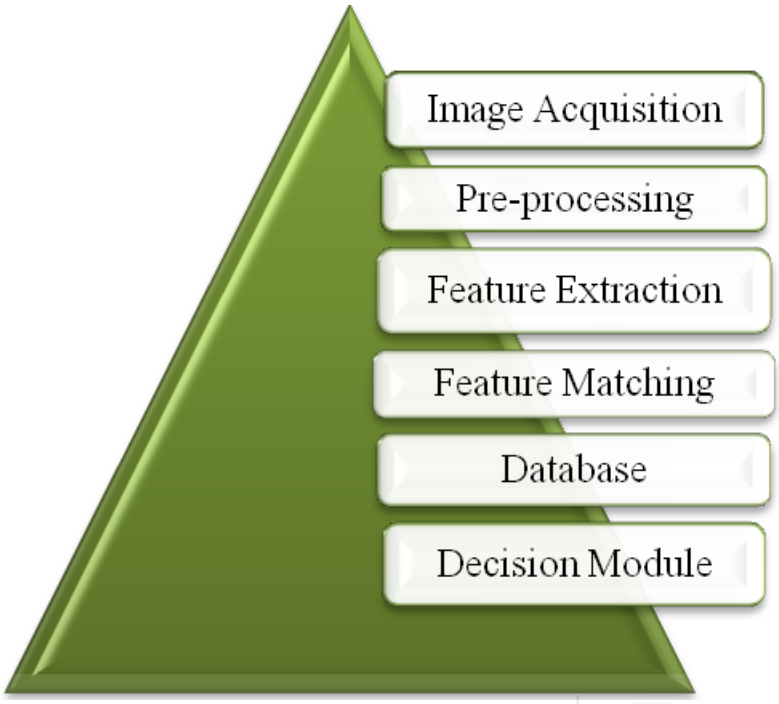


Figure 32: Stages in Palmprint Verification

1) **Image Acquisition:** Palmprints are captured widely by using CCD based palmprint scanners and digital cameras.

Figure 33: CCD based Palm Print Scanner

Source: Krishneswari, and Arumugam (2010*)*

2) **Pre-processing:** This defines the coordinate system that is used to align different palmprint images, correct distortion, key point identification and crop the region of interest for feature extraction.

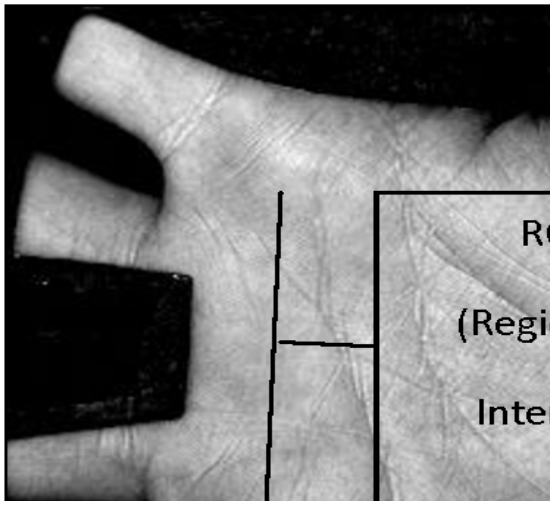


Figure 34: Region of Interest on the Palm Print
Source: Krishneswari, and Arumugam (2010*)*

3) **Feature Extraction:** Palmprint features are extracted for matching purposes. The feature extraction methods used are- Gabor filter, elimination of creases and discrete finger and palmprint extraction.

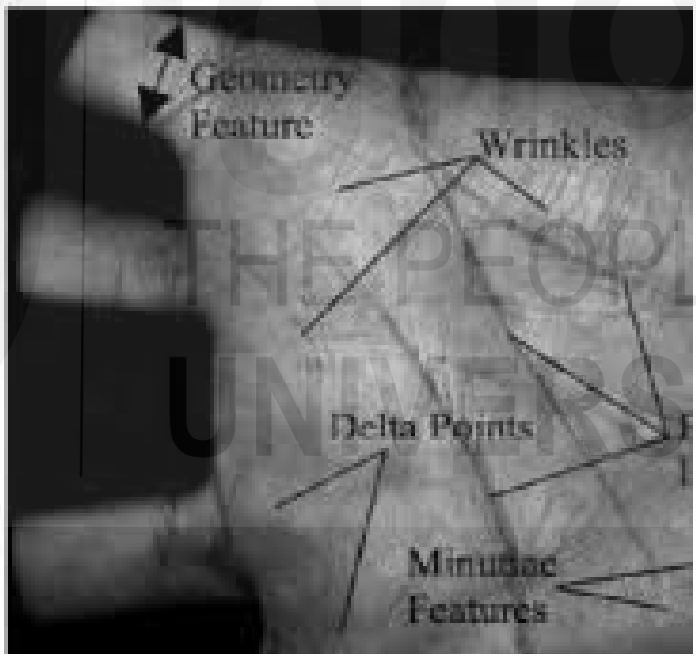


Figure 35: Features on Palm Print
Source: Krishneswari, and Arumugam (2010*)*

4) Feature Matching: This establishes the similarities between the two prints. The palmprint matching approaches are classified into two type-

i) Geometry based matching, uses geometry objects such as points, orientation, principal lines, and coarse wrinkles.

ii) Feature based matching, using Euclidean distance, Hamming distance, Hausdroff distance and using skeletal lines.

5) Decision Module: Based on scores obtained in matching, decision is made whether the two palm prints are same or different.

Check Your Progress 4

7) Discuss various features of palm prints that contribute for the identification purpose.

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8) Discuss various steps in forensic palm print identification process.

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7.5 HAND DIMENSIONS

In anthropometric research, hand geometry is widely used for biometric recognition systems, personal identification, verification, and recognition. Stature of a person could be ascertained by using these dimensions.

Stature: The vertical distance between the highest point on the vertex and platform of stadiometer (instrument used to measure vertical height of the subject).

Hand Length: The projected distance between the middle point of a line joining the styloid process of radius and ulna bones of forearm and the tip of middle finger.

Hand Breadth: The distance between the prominent point on the lateral aspect of hand of second metacarpal and the most prominent point on the medial aspect of the hand of fifth metacarpal.

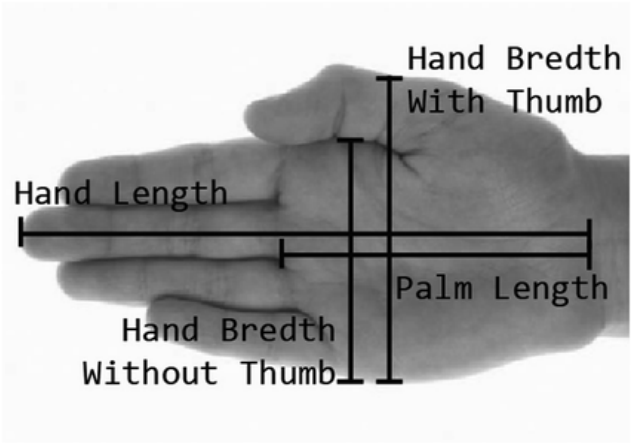

Figure 36: Hand Dimensions
Source: Krishneswari, and Arumugam (2010*)*

Check Your Progress 5

9) Discus the anthropometric significance of the various hand dimensions.

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7.6 FOOTPRINTS

Footprints are the impressions or prints formed on any surface by the foot or footwear of a person.

7.6.1 Type of Footprints

1) **Surface Footprints**: These are 2-D footprints found on the hard surfaces.

2) **Sunken Footprints:** These are 3-D footprints found in mud, clay, sand and snow and other soft surfaces.

7.6.2 Location of Footprints

Footprints can be located at various crime occurrence places i.e., at the crime scene itself, the areas surrounding the crime scene, pathway of arrival and departure of the culprit i.e., line of entry and exit, secondary and tertiary crime scenes, floors of the room, walls, lower part of doors, mats, rugs, chairs, tables, staircases, boxes, drainpipes, papers, wooden logs, etc.

7.6.3 Collection of Footprints

Footprints are collected by some of the methods discussed below.

1) Photography: Photography is the first and the most significant step of collection of any evidence in the forensic field because it provides us with long duration evidence without any tampering in it. Photographs of the footprint evidence should be taken with scale and by keeping the camera parallel to the footprint impression.

2) Tracing: A glass sheet or celluloid sheet should be kept on the footprint impression in such a way that the sheet does not touch the impression and then the counter outlines are drawn on the sheet with a thin glass marking pencil or oil-based pen. This glass sheet is then sent to the laboratory.

3) Lifting: When it is difficult to clearly identify the impressions on hard surfaces or the print is present on clothes, mats etc., in such case photo bromide paper is used to lift the footprint impressions.

4) Casting: Sunken footprints are lifted by making its cast of Plaster of Paris, wax, resin, plastic powders, modelling clay Sulphur and various other materials.

Plaster of Paris is most used for the cast. Plaster of Paris mixed with water in ratio 3:7 to prepare its solution and then is poured from a corner of the frame so the fluid slowly fills and covers the impression to a uniform thickness of about ½ inch.

Figure 37: Cast of a Footwear Impression
Source: http://www.forensicsciencesimplified.org/

7.6.4 Examination of Foot Impressions

Examination of footwear impression is done by identifying the following individual characteristics:

1) Dimension i.e., length, breadth, and height.
2) Ridge pattern of the prints.
3) Inner and outer marginal line of the footprint.
4) Shape of the heel i.e., it may be oval or rounded.
5) Toe marks i.e., their shape, size, alignment, inter distance between two toes, missing toes, extra toe, long or short toe etc.

7.6.5 Forensic Significance of Footprints

Like fingerprints, no two individuals have the same palm and footprints. Footprints obtained from the scene of crime and analysis of footprints help in the estimation of stature, weight, sex, holding weight, number of perpetrators, direction of movement and the speed at which an individual was moving.

Check Your Progress 6

10) Discuss the forensic examination procedure for the footprints.

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7.7 SUMMARY

The scientific study of fingerprints is known as Dermatoglyphics. Fingerprints remain constant since the birth of a child. No two fingerprints are same except when obtained from the same finger of the same person due to permanency of the ridge characteristics. The minimum number of ridge characteristics for establishing the identity of a person beyond any doubt is eight. Various physical and chemical methods are employed for the easy detection and development of latent prints on different types of surfaces like porous, non-porous and wet surfaces.

Handwriting is a highly complicated motor skill which involves together neurological, physiological, and sensory impulses. Handwriting features called characteristics are used to identify handwriting. The characteristics of writing that occur in handwriting include the appearance of the writing and the method of construction. Characteristics that are mutually shared by many writers are called Class Characteristics. In contrast to this, Individual Characteristics are those that are highly peculiar or unique to writer.

In forensic toxicology, nails can provide good matrix for detection of drugs of abuse. Like fingerprints, palmprints, footprints and hand dimensions also play crucial role in identification of suspect. They are unique, universal, stable, and permanent.

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7.9 HINTS TO CHECK YOUR PROGRESS

1) The skin is usually divided into two distinct layers- Epidermis and Dermis. Sweat glands are found on palms and soles in high concentration. When the friction ridges encounter some other objects, they leave the latent image of the fingerprint.

2) The minimum number of ridge characteristics for establishing the identity of a person beyond any doubt is eight.

3) Handwriting is an acquired neuro- muscular activity.

4) Handwriting features called characteristics are used to identify handwriting. These are of two types.

5) Forensic Onychology is the study of fingernails and toenails for the purpose of justice.

6) Nails could be used for toxicological analysis as well as for personal

identification.

7) Principal Line, Minutiae are among important features of palm prints.

8) Process of palm print identification is usually performed in 6 steps.

9) Hand geometry is widely used for biometric recognition systems, personal identification, verification and recognition.

10) Foot-wear/ foot prints are compared on the basis of various individual characteristics.