7.5. Biometrics

Learning Goals and Objectives

Uniquely identifying a person for criminal and security reasons is a challenging problem that is being answered through the use of biometrics. In order to understand how biometric analysis can be used, you will need to develop an understanding of:

- the basic steps in a biometric identification;
- current and future types of biometric measurements;
- advantages and limitations of various biometric identifications.

History of Biometrics. The unique identification of a particular person has long been a significant problem in both criminal justice and security settings. In criminal applications, it is important to be able to identify a wanted person, detect someone in disguise, determine if a person is a repeat offender, or keep track of a particular person. In security applications, such as protecting sensitive information, equipment, or areas from unauthorized use, it is equally important to determine a person identity to determine if they should be allowed access to these items. In the past, solutions to these security problems have taken the form of either physical identifiers, such as keys, ID cards, driver’s licenses and badges, or through some shared secret information, such as passwords or access codes. These means of personal identification can, however, be readily lost, stolen or hacked. Besides simply losing access to the secure items when these forms of ID are lost or stolen, these personal identifiers can be used by someone else to gain unauthorized access to these secure items.

As we become more and more reliant upon electronic forms of communication and access, we are required to use increasingly complex forms of authentication. For example, in order for an electronic account password to be reliable, it must be complex enough to avoid random guessing, never be written down, and changed frequently. It is not unusual today for someone to need dozens of passwords and user IDs that are often rarely used and must be changed frequently. This is particularly problematic given the inconvenience and expense associated with forgotten or lost passwords. So, more sophisticated, reliable and intimately personal forms of personal identification are required that cannot be easily forgotten, lost, stolen or transferred. To meet this challenge, science has increasingly turned to the use of identifying features of our own bodies or personality to uniquely identify us from everyone else.

In the late 1800s, Alphonse Bertillon developed a system, called Anthropometry or the Bertillon System, that was used for a time to identify a person based upon simple measurements of body parts and other features, such as head length, the length of the middle finger, the distance between a person’s eyes, tattoos, and photographs. While this method was soon supplanted by other, far more reliable methods due to inaccuracies in the measurements when done by different individuals, the Bertillon System provides an interesting example of early biometric identification.
people, it did form the first attempt to base personal identification on body traits.

As presented earlier in this chapter, fingerprints have formed a powerful tool for uniquely identifying people for well over one hundred years. Increasingly, however, other forms of recognition based upon various aspects of the human body are being used for identification.

**Biometrics Basics**: Biometrics, the application of statistical methods to biological data, is based upon finding some individualized trait that a person has that can distinguish them from all others. These traits can be biological, such as fingerprint or iris pattern, or behavioral in nature, such as how you act or even type. But all forms of biometric identification, in order to be useful, must meet a specific set of criteria that includes: Universality, Uniqueness, Permanence, Measurability, and Ease of Use.

*Universality*. In order to be useful, the trait must be something that all people to be authenticated have in common. The analysis must be based upon common biological structures or developed behavioral patterns. For example, a biometric marker based upon how someone types on a computer keyboard makes sense only to populations where keyboard use is common and of limited use in computer-less populations. In contrast, an analysis based upon iris patterns in the eye would be generally useful for the entire human population.

*Uniqueness*. A biometric feature must be able to differentiate between all people needing authentication. An analysis based upon number of fingers on a person’s right hand is based upon a common biological trait but is not very useful in distinguished between most people. An analysis based upon fingerprints, however, is far more able to discern between two people. It is important to realize, however, that any such analysis must be based in a good understanding of the statistics involved – in other words, how probable is it that two people would randomly have the same measured value such that the test could not determine the difference between them. In the chapter on DNA, we said that the chance of two people having the same DNA profile of 14 markers is often 1 in several trillion, making it a very reliable probe of personal ID. A biometric analysis based upon ABO blood typing, however, might have a random match rate in the percent range, making it far less useful when compared to DNA as a biometric tool.

*Permanence*. Any biometric tool must persist unchanged for a very long time in a person, ideally for an entire lifetime. Most biological biometrics typically don’t change much at all over a lifetime, such as DNA, eye iris patterns, and fingerprints. Some biological and behavioral markers do change, however, with age, illness, accident, growth, or learned patterns, such as voice pattern and writing patterns. These changes do not render the method useless, however, but care must be taken to understand the possibility for change and account for it in the analysis.

*Measurability*. Any biometric tool must employ a trait that can be measured reliably and with straightforward measuring devices. If a trait cannot be measured, it cannot be used in automated ID systems.

*Ease of Use*. There are many types of probes that could be used in a biometric method that are impractical, expensive or difficult to use. Preferred methods employ measurements that are easy and quick and give highly reliable data for comparison.

*Circumvention*. The refers to how easily the biometric trait can be defeated through the use of a substitute, such as a fingerprint casting or a contact lens with a false iris pattern.

**Biometric Methods**: Biometric methods typically try establish someone’s identity by answering one of three specific questions; (1) who are you?, (2) what information do you possess?, or
what items do you own? The first question “who are you?” deals specifically with the use of physical or behavioral traits to identify a person by determining if a person’s body features be used to identify them. The second question, “what information do you possess?” involves the use of passwords, secret questions and similar information to establish your identity. Finally, the question “what to you possess?” answers the identity authentication problem through the use of physical devices such as keys. Often, however, combinations of these methods are employed to gain a higher level of reliability in establishing identity.

There are two quite distinct ways in which biometric information can be employed: identification and authentication (or verification). When we considered the use of fingerprints for identification, these two terms were first presented. Identification refers to specifically using biometric information to identify an unknown person from among a very large pool of possibilities. This could be thousands of even many millions of records through a process referred to as one-to-many matching. Authentication (verification), however, compares biometric information from one person with either just one reference or among a very small number of possibilities. This process, referred to as one-to-one matching, tries to identify a person as a match (or not) with a known biometric identity. For example, in cybersecurity systems, an iris scan can be compared to a password and user ID input by a person to prove that the person trying to gain access is the person indicated by the password. Biometric verification is usually much faster and more reliable than biometric identification since the number of data points to be compared is much smaller.

Essentially all biometric forms of identification have in common the same basic steps: (1) initial enrollment or registration, (2) characteristic information storage, and (3) a comparison process.

The first step in a biometric analysis typically begins with measuring a given biological or behavioral trait and then connecting this information with a particular person. For example, a fingerprint is first scanned and then linked directly to a person’s name and individual criminal record. This enrollment forms the basic data set to be used later linking a person to a file. The second step involves recording the data, usually in a simplified digital form, and stored in a computer database. Usually, entire images, complete scans or entire measured data sets are not stored but rather just the salient features needed to form a unique identifier for that person. Reducing the data to the smallest set necessary to obtain a unique identifier speeds up the analysis and reduces the amount of data needed to be stored. The final step usually involves a computer program that compares the new measurement with stored data to determine the similarities and differences between the two data sets. As mentioned before, a measure of the reliability of the match is key to understanding the usefulness of the comparison results.

In a typical biometric system, a sensor is used to measure the needed data. The sensor can take many forms including cameras, scanners, tablets, keyboards, microphones, and even chemical detectors.

Types of Biometric Traits. There are many biological and behavioral traits that might be useful in biometric analysis. Some, such as fingerprints, palmprints, and DNA, have already considered in detail. Others for varying levels of reliability, ease of use, and uniqueness. Some have been in use for years while others are still being

developed. A sampling of some of the more common methods is summarized here.

**Hand and Finger Geometry** – The shapes of our hands and fingers can vary enough between people to form a low-level biometric trait. For example, the relative lengths and thicknesses of our fingers and the various component shapes contained in our hand, can be used in verification of a person’s identity. The process is very simple, usually just a photograph of our hands when they are placed on a flat surface, that is then digitized in a number of key features and then compared to similar stored data for the person needing to have their ID verified. The downside of this analysis is that there is only limited variation between peoples hands and our hands can change their geometries with age, weight, accident, illness or hydration – even in the span of a single day. Nonetheless, this is a rather non-threatening and easy low-level verification technique, and has been adopted in a number of “quick-check” situations such as schools, theme parks, and businesses.

**Writing and Typing Analysis** (Processed Dynamic Data) - For centuries, and person’s signature and their handwriting have been used for identification on legal documents. While the topic of questioned document analysis will be covered in a later chapter, it is appropriate to mention it briefly here in connection with biometric analysis since the types of information gained in the two approaches may be quite different.

In questioned document analysis, the shapes of the letters and the visual patterns of words they make on the page are very important to determining the authenticity of the document. While a signature or writing can sometimes be learned and forged, it is much more difficult to forge the way in which people write. For example, the speed, pressure, pen angle, direction changes, and rhythm that you write can tell more in terms of identification than the actual shapes of the words and letters. The physical process of typing on a keyboard can also be used to tell us apart, just as the playing of one pianist can often be told from another pianist playing the very same piece by someone attune to listening carefully – the notes are the same but the method of producing them varies. Similarly, the biometric analysis of writing and typing processes can help to identify the person making the patterns (Figure 7.5.2).

**Vein Geometry Biometric Analysis** – This method works by identifying the patterns that our veins make below the surface of the skin in our fingers and hands. The pattern from these small veins is believed to be unique to one person, such as fingerprints and DNA analysis. In addition, our vein patterns differ from left to right sides and even twins do not have identical patterns. In this method, near infrared light that shines onto our hands is absorbed by our hemoglobin. Using an infrared-sensitive detector, the pattern of the veins can be recorded and compared with a
known pattern.

**Eye Biometrics.** If you’ve ever watched a spy movie, you’ve certainly seen eye measurements for ID verification. Our eyes are complex light-harvesting and sensing organs, designed to collect light from the outside, focus it onto highly specialized cells, and convert the light signal into an electronic signal that our brains recognize as an image. Two structures of the eye, however, carry information that can be specifically used in a biometric application.

The iris of our eye is a thin membrane who’s main job is to control the amount of light allowed to enter the eye through the pupil (Figure 7.5.5). Muscles attached to the iris expand or contract the hole, or pupil, through which light enters the eye. Pigments in the iris are responsible for our eye colors. The detailed “fibrous “ridge” structure, coloration, and blood vessel pattern of the iris itself, however, is highly variable and are unique to a particular person. A detailed “picture” of the cornea and iris of a person eye can be readily taken and the patterns can be compared to a known standard for verification.

The other main type of biometric eye scan involves looking at the retina, the thin membrane that covers the back of the eye. This membrane contains specialized cells and molecules that can capture the energy of a photon, a packet of light, and ultimately convert it to electrical signals that the brain can process. The blood capillaries embedded within the retina form a very complex pattern of blood capillaries that are unique to each person. Importantly, this pattern of blood capillaries doesn’t change over the course of a person’s lifetime, although some diseases, such as diabetes and various degenerative eye diseases, can affect these blood vessels. A retinal scan can be easily and quickly done by shining a beam of infrared light onto the retina where the blood vessels absorb this light more strongly than the surrounding tissue, as shown in Figure 7.5.6. In this fashion a detailed map of the pattern of the capillaries can be generated and compared similar to other biometric data sets.

![Figure 7.5.5. Structure of the eye including the iris and retina (L) and a iris scan (R)](en.wikipedia.org/wiki/File:Schematic_diagram_of_the_human_eye_en.svg)
Voice Analysis: Our voices are different due to differences in our vocal and nasal cavities, our vocal chord properties and a number of other features where small variations can make detectable differences in the voices we produce.

In a biometric voice analysis, a voiceprint is taken that is made by having a person speak certain words or phrases into a microphone. The data is converted into a plot of sound frequency (vertical axis) versus time (horizontal axis), as shown in Figure 7.5.7. This spectrogram is then used to compare with a stored version for a particular person to complete the analysis. More on this topic will be presented in Chapter 17.

Face Image Data: Facial recognition methods are certainly one of the oldest human ways of recognizing a person. The faces of our parents are imprinted on our brains at a very early age so that we can readily recognize them. Face image data, however, is both easily obtained but difficult to use with reliability. Our faces change with age, emotion, disease, photographic conditions, and a variety of other factors. Nonetheless, the technique is being used with increasing frequency.

In a typical facial recognition process, a photographic analysis of a face is “coded” into a number of important points, such as shown in Figure 7.5.8. The size, distance, and relative orientation of these different features then form the basis for the comparison with a standard data set.

New Methods: Ear Canal Biometrics. The fine details of our ear canals vary from one person to another. This variation can be used as a biometric trait, therefore to tell us apart. For example, have you ever wondered who you were talking to when you made a phone call or wanted to be sure that you were talking to the person you intended to talk to. This could be done using ear canal biometrics. In this application, the phone could send out a very tiny pressure wave when the phone is held up to someone’s ear that could map the ear canal of the person holding the receiver. This pattern could then be used to compare with the known ear canal profile of a person on file to verify to whom you are talking.

Odor. Scientists are exploring the possible use of an “odorprint” to help establish both an individual identity and to help determine when a person is lying. This has been the basis of the use of dogs, such as bloodhounds, that have a very keen ability to detect a person’s unique odors and to track them over long ranges. Every person emits a vast array of organic chemicals that contain an odor and the ability to detect these chemical and their relative abundances could lead to sensitive new probes for biometric analysis.
**Palatal Rugae** (palatoscopy) – The palatal rugae are the ridges on the inner parts of the roof of our mouths, closest to the upper teeth. These for patterns that differ from person - and can persist after death in remains identification. There is still considerable debate, however, about the reliability of these structures for biometric identification.

**Automated Biometric Identification System (IDENT).** The US Department of Homeland Security, in cooperation with several other agencies is working to develop an comprehensive system for using biometric data to link a particular person rapidly with biographic information, such as criminal arrests, personal identification, and travel restrictions, for security and law enforcement work. The IDENT system provides verification to a wide range of government programs that collect biometric data and compile personal biographical information. Recently the IAFIS fingerprint system has been incorporated into the broader IDENT system.

Countries all over the world are faced with increasing needs for identification and authentication of people for both criminal and security threats. Thus, the use of biometric data is expected to grow rapidly in the near future as one of the best ways to rapidly connect a person with biographic information about them.
Chapter 7 References and Bibliography

FINGERPRINT REFERENCES

HAIR AND FIBER ANALYSIS REFERENCES
James Robertson, Forensic Examination of Human Hair, Taylor & Francis, Inc. (Series: Taylor and Francis Forensic Science Series), 1999.
John D. Wright, Hair and Fibers (Forensic Evidence), Sharpe Focus, 2007.

BIOMETRICS REFERENCES
GLOSSARY OF TERMS

Addition Reactions: A chemical reaction where the net result is to simply add monomers together without the loss of any portion of the monomer.

AFIS: A fingerprint database abbreviation for Automated Fingerprint Identification System.

Anagen Phase: The active growth time for hair formation.

Apocrine Gland: The scent glands.

Arch Pattern: The fingerprint pattern that has ridges beginning at one side of the fingerprint and running completely to the other side of the fingerprint without a backwards turn.

Authentication: The process of using fingerprints to compare a set of fingerprints from a person with either just one reference set or among a very small number of “standard” possibilities.

Automated Biometric Identification System (IDENT): The US Department of Homeland Security comprehensive system for using biometric data to link a particular person rapidly with biographic information, such as criminal arrests, personal identification, and travel restrictions, for security and law enforcement work.

Bifurcation: The point in a fingerprint pattern where a single ridge splits into two new ridges.

Biometrics: A branch of biology that analyzes statistically biological data. Forensic applications of biometrics are based upon finding individualized traits that can statistically distinguish one organism from all others.

Catagen Phase: The transitional phase in hair growth when the hair stops growing and the portion of the follicle surrounding the hair root shrinks considerably.

Catalysts: Chemical reagents that can cause a chemical reaction to occur or to accelerate without being ultimately changed itself.

Cheiloscopy: The furrows of the human lips used for individual identification.

Cellulose: A carbohydrate polymer molecule found in many plant-based fibers.

Condensation Reactions: A chemical reaction that involves the loss of a small molecule, such as water, from the reaction and couples together the two starting molecules.

Core: The feature formed where a loop pattern reaches its farthest point towards the middle of the print and begins to turn backwards and constitutes the innermost ridge of the curve.

Cortex: The inner potion of a hair fiber that makes up most of the bulk of the hair shaft and gives the hair it’s characteristic elasticity.

Cuticle: The outermost translucent protective layer of a hair shaft which appears similar to the shingles on a roof.

Delta: The point of ridge divergence in a fingerprint pattern where the upward and downward deflected ridges meet the looping ridges.

Dermis: The middle skin layer that is composed mostly collagen (protein) fibers, elastic tissue, and reticular fibers.

Disulfide Bonds: The chemical linkages between sulfur atoms (in cysteine) in difference keratin chains that hold the keratin molecules together and give rigidity and structure to the hair fiber.

Eccrine Glands: The sweat glands.

Ectoderm: The outmost of developmental germ layers of the human body that gives rise to our epidermis (skin), hair, eyes and nervous system.

Elastomers: Synthetic polymers with special elastic properties.

Ending Ridge Point: The point in a fingerprint pattern where a single friction ridge that ends.

Epidermis: The outermost layer of our skin that ranges in thickness from very thin on our eyelids (about 0.05 mm) to rather thick on the palms of our hands and the soles of our feet.

Eumelanin: The dark pigment that colors black and brown hair.
Fibers: Small structures that are defined simply as long, thin filaments in which their lengths are very much greater than its widths, at least a 100-fold longer.

Fingernails: Fingernails, composed primarily of keratin, are considered to be an appendage of the skin and are closely chemically related to the claws, hooves, and horns found in other animals.

Fingerprint: The impression made on a surface by the unique set of friction ridges found on a person’s fingers and used for the individual identification of the individual.

Fingerprint Lifting: The process of preserving fingerprints by using cellophane tape (or similar) that has been carefully placed over the print and then rubbed to ensure that the adhesive on the tape is in full contact with the print. The tape then carries the pattern of the fingerprint when it is lifted from the surface.

Friction Ridges: Raised surfaces formed from furrows in the skin that form the observed pattern of our fingerprints and serve to greatly increase the skin’s surface area and increase its gripping ability.

Fuming Fingerprint Visualization (super glue): A technique where an object suspected of containing fingerprints is placed in a closed “fuming” chamber where it is exposed to a vapor of cyanoacrylate where the fingerprints show up as a white residue.

Furrows: The adjacent lower valleys next to the ridges of fingerprints.

Hair: The complex appendage, composed largely of keratin, that grows from a follicle in the skin of only mammals and is a derivative of the epidermis of the skin and used to help regulate the body temperature of an organism by either trapping or releasing warm air near the skin’s surface.

Henry System: An early system of classifying fingerprint patterns.

Hypodermis: See Subcutaneous Layer.

IAFIS: A revised automated fingerprint database abbreviation for Integrated Automated Fingerprint Identification System.

Identification: The process of using fingerprints to identify an unknown person from a set of prints.

Impression Prints (Plastic): Fingerprints left in a soft, pliable surface, such as clay, putty, or soil.

Integumentary System: The biological system that forms the outer “boundary” of our bodies and includes our skin, hair and nails.

Iodine (I2): An element that reacts readily with the oils left behind from fingers to form a somewhat transient, observable, brown color where the finger oils were deposited.

Keratin: A tough, durable, fibrous protein composed of long chains of amino acids typically found as a structural component of hair, nails, horns and claws.

Latent Fingerprints: Fingerprints are not observable to the naked eye but are present in oils and amino acids that have been left behind on a surface when touched by a finger. These may later be developed to become visible.

Loop Pattern: The fingerprint pattern that contains ridge lines that enter on one side of the fingerprint, run towards the middle of the print, and then curve backwards to exit on the same side that they entered the pattern.

Medulla: The part of the hair at the center of the fiber that is characterized by either very spongy cells or no cells at all, forming a canal-like structure in the center of the shaft (medullary canal).

Medullary Canal: See medulla.

Medullary Index (MI): The ratio of the diameter of the shaft to the diameter of the medulla.

Melanin: A pigment polymer derived mostly from the amino acid called tyrosine that imparts the color to a hair sample.

Minutiae: The fine details of fingerprint patterns.
Monomers: the small building blocks that make up polymers.
Natural Fibers: Fibers come from many different naturally-occurring sources including plants, animals and inorganic sources.
Ninhydrin: A chemical that reacts with the amino acids found in a fingerprint and, upon gentle heating, forms a typically purple/blue-colored pattern of the fingerprint.
Palmprint: Patterns left by the complex ridge patterns of flexion creases found in the palm of the hand or sole of the foot.
Pheomelanin: The pigment that is the main coloration chemical found in red hair.
Pinnascopy: The patterns of the ears used for individual identification.
Polymers: Long chain molecules that are composed of smaller units, called monomers, strung together.
Principle of Persistency: The principle states that once our fingerprints, once formed during prenatal development, remain unchanged throughout our lives and often last even well beyond death to the latter stages of decay.
Regenerated Fibers: Fibers that are made by chemically processing naturally occurring materials into fibers of desired shape and structure.
Ridge: The top of the fingerprint ridge pattern on our fingers.
Ridge Count: The number of ridges between these two features in a fingerprint pattern.
Sebaceous Glands: Glands in the skin that produce sebum, an oily material that protects, lubricates, waterproofs, and helps to inhibit the growth of microorganisms on the hair.
Stratum Basale: The lowest layer of the skin’s epidermis.
Stratum Corneum: The topmost layer of the skin’s epidermis.
Subcutaneous Layer (hypodermis): The lowest layer of skin that is composed largely of fat and connective tissue that contains larger blood vessels and nerves.
Synthetic Fibers: Fibers that are prepared from chemical feedstocks and are typically formed through polymerization reactions that lead to long chain molecules.
Telogen Phase: The resting period for the follicle in the hair growth cycle.
Thermoplastic: Synthetic fibers that melt or soften easily.
Trace Evidence: Evidence that includes fingerprints, hair, fiber, glass, soil, and explosives, among others. Trace analysis often involves the comparison of small pieces of evidence with a standard in an attempt to see if the origin or use of the evidence can be identified.
Vellus Hair: The fine short hairs that covers the majority of the body.
Visible Fingerprints: Fingerprints are readily observable by the naked eye.
Whorl Pattern: The fingerprint pattern that contains ridges that complete at least one 360° “circuit” in the pattern, although not always forming a regular circular pattern.
QUESTIONS FOR FURTHER PRACTICE AND MASTERY

7.1. The fingerprint pattern class-type shown at right displays a(n):
   (a) arch
   (b) whorl
   (c) loop
   (d) bifurcation
   (e) double loop

7.2. Which of the following types of fingerprints require dusting powder or a chemical like ninhydrin or iodine in order to see them?
   (a) visible
   (b) plastic
   (c) latent
   (d) hidden
   (e) None of the above.

7.3. The middle, often hollow, portion of a human hair is called the
   (a) cuticle.
   (b) cortex.
   (c) root.
   (d) follicle.
   (e) medulla.

7.4. The minutae detail shown at right (black lines) is a:
   (a) bifurcation
   (b) trifurcation
   (c) delta
   (d) island
   (e) crossover

7.5. The outermost portion of the hair that resembles scales is the
   a) cortex
   b) cuticle
   c) medulla
   d) root
   e) follicle

7.6. The fingerprint pattern class type shown at right displays a(n)
   a) arch
   b) whorl
   c) loop
   d) bifurcation
   e) double loop

7.7. Which of the following types of fingerprints will most likely be found impressed in soft wax?
   a) visible
   b) plastic
   c) latent
d) hidden
e) molded

7.8. A polypeptide is
(a) a polymer of composed of amine monomers
(b) a polymer of amino acid monomers
(c) a polymer of sugar monomers
(d) a part of nucleic acid monomers
(e) none of the above

7.9. Which feature in the following list does not directly effect the properties of polymers?
(a) length of chain
(b) 3D arrangement of chains
(c) branching of chain
(d) composition of monomer units
(e) formation temperature

7.10. Hair can most often be characterized as originating from an animal by examining
(a) its thickness
(b) the cortex
(c) both medulla and cortex
(d) it’s color
(e) its scale (cuticle) structure

7.11. In the micrographs below, which picture shows an animal fiber?

7.12. Nylon is classified as a
(a) regenerated fiber
(b) animal fiber
(c) natural fiber
(d) synthetic fiber
7.13. In what stage of a hair’s growth cycle is the hair actively growing?
   (a) anagenic
   (b) telogenic
   (c) catagenic
   (d) analgesic
   (e) none of the above

7.14. Which part of the hair shaft is most resistant to chemical decomposition?
   (a) medulla
   (b) cortex
   (c) follicle
   (d) cuticle
   (e) shaft

7.15. The central canal running through many, but not all, human hairs is known as the:
   (a) medulla
   (b) shaft
   (c) cortex
   (d) cuticle
   (e) shaft

7.16. Hair, fibers and fingerprints are examples of what classification of evidence?

7.17. Who is considered the “father of fingerprinting”?

7.18. What is IAFIS?

7.19. Define the following terms used in fingerprint identification: core, delta, bifurcation, ridge line and island.

7.20. What is the current minimum accepted number of matching points needed to place a reasonable level of trust in deciding two fingerprints are a match?
   a) 6 b) 8 c) 10 d) 12 e) 14

7.21. What is the difference between identification and authentication methods?

7.22. What are some of the legal questions that have arisen in the use of latent prints in court cases?

7.23. What are the three general scale patterns on a hair shaft?

7.24. What are the three layers in a hair?

7.25. In order for a hair dye process to be effective (last longer than a rinse), what must the hair stylist do to the cuticle layer of the hair shaft?

7.26. How does a “perm” work?

7.27. What forensic information may be gathered when examining a dyed or ‘permed’ hair shaft?

7.28. What are the three main groupings of fibers?

7.29. Plant fibers are typically ____________ based while animal fibers are typically ____________ based.

7.30. What is a regenerated fiber? What is a synthetic fiber?

7.31. What property do thermoplastics have that make them desirable polymers?

7.32. What are the two main polymer synthesis reactions?

7.33. What are the criteria that any biometric identification must satisfy?

7.34. Which of the following could not be used as a means of biometric analysis? A) fingerprints B) vein geometry C) iris scan D) face imaging E) right hand digit count

**EXTENSIVE QUESTIONS**
7.35. Explain the basis for classifying a fingerprint as an arch, a loop or a whorl.

7.36. Explain the difference between visible, latent and plastic fingerprints.

7.37. Describe the anagen, catagen and telogen phases of hair growth.

7.38. Describe the fundamental difference between mongoloid, Caucasian and African hair.

7.39. What are the important forensic questions that are asked when examining a fiber found at a crime scene?

7.40. Explain the following biometric criteria: universality, uniqueness, permanence, measurability and ease of use.

7.41. Using the examples in the inset box, classify each of the following fingerprints:

7.42. Identify the following hair cuticle patterns and give an example of the animal it may have come from: