Standard for Feature Selection in Friction Ridge Examination

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Organization of Scientific Area Committees (OSAC) for Forensic Science

Draft OSAC Proposed Standard

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1. Introduction

1.1. This standard has been developed with the objective of improving the quality and consistency of friction ridge examination practices.

1.2. This standard provides a comprehensive list of features and their definitions which can be used during the friction ridge examination process.

1.3. In addition to the standardized list of features and their definitions, this standard also includes information about the diagnosticity of those features. The diagnostic value of each feature is expanded upon where applicable, by recognizing shared features within a population and rarity features in the population. This information is based on the consensus opinion of the OSAC Friction Ridge Subcommittee where supporting evidence in the scientific literature is limited.

1.4. In addition to the significance of each feature, this standard provides an awareness of the relationship between features that can be used during examination.

1.5. In this standard, the following verbal forms are used: "*shall*" indicates a requirement, "*should*" indicates a recommendation; "*may*" indicates permission; and "*can*" indicates a possibility or capability.

2. Scope

2.1. This standard specifies the features that can be utilized during friction ridge examinations.

2.2. This standard does not address the examination methodology or documentation.

3. Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1. Examination: The act or process of observing, searching, detecting, recording, prioritizing, collecting, analyzing, measuring, comparing, and/or interpreting.

3.2. Examiner (Friction Ridge)/Competent Friction Ridge Examiner: An individual who has successfully completed their FSP's training program and has demonstrated to the FSP that they possess the knowledge, skills and abilities to perform the tasks required of their current position. An individual authorized to conduct friction ridge examinations for the FSP by observing and interpreting data, making decisions, forming conclusions and opinions, issuing reports and/or providing testimony.

3.3. Pattern force area: A region of friction ridge skin in which minutiae of a particular type are forced to form due to the flow of the ridges.

3.4. Rarity (of a feature type): The frequency of which a type of feature is encountered in a group of people (its prevalence), either in isolation or in conjunction with other information about its local context.

3.5. Source: an individual from which an item (e.g., crime scene impression) originates.

4. General Requirements

4.1. The following feature list contains friction ridge features and their associated attributes that examiners may use during examination of friction ridge impressions.

4.2. Only those features included on this list shall be considered during friction ridge examinations to support suitability determinations and source conclusions.

4.3. The features that can be used during friction ridge examinations include the following:

4.3.1. Ridges:

The ridges are the core feature type in the friction ridge skin. The ridges are the fully formed papillary lines on the volar surfaces of normal human hands and feet. On the skin, fully formed ridges can be distinguished from incipient ridges by the existence of sweat pores spaced somewhat evenly along the path of the ridge. If the friction ridge skin is considered a topographical map, the ridges are typically the feature at the highest elevation and are the main contact regions when the friction ridge skin touches a surface. The combination of ridge morphology and pores often impart a distinctive texture within a region of skin or within an impression. See Appendix A for definitions and examples of morphology edge shapes.

4.3.1.1. Attributes:

4.3.1.1.1. Number – count of ridges.

4.3.1.1.2. Ridge Width – distance between the sides of a ridge at a given location on the ridge.

4.3.1.1.3. Furrow Width – distance between the sides of adjacent ridges at a given location on the ridges.

4.3.1.1.4. Length – distance between two locations along the path of a ridge.

4.3.1.1.5. Spacing – distance between the midpoints of two adjacent ridges.

4.3.1.1.6. Direction – direction of the path of a ridge in relation to a fixed point in the skin or impression (e.g., a ridge that is perpendicular to an irregular crease).

4.3.1.1.7. Curvature – change in angles along the path of a ridge for a given segment of the ridge.

4.3.1.1.8. Edge Shape – contour of the edge of a ridge (straight, protrusion, and intrusion).

4.3.1.1.9. Pore Position – location of a pore with respect to the edge of the ridge or another pore.

4.3.1.1.10. Open Field – minimum of four ridges in sequence with a visible length of at least 3mm each where no minutiae are present.

4.3.2. Minutiae:

A minutia defines the end of a ridge. A ridge can end in three different manners: 1) no connection to the adjacent ridge above the level of the furrow (i.e., ending ridge), 2) completely connected to the adjacent ridge from the bottom of the furrow to the top of the ridge (i.e., bifurcation) or 3) partially connected to the adjacent ridge (i.e., ambiguous minutiae).

4.3.2.1. Attributes:

4.3.2.1.1. Number – count of minutiae within a region of skin or within an impression of the skin.

4.3.2.1.2. Density – number of minutiae within a specified surface area (e.g., high or low or per mm2).

4.3.2.1.3. Direction – angle of the path of the ridge emanating from the minutia in relation to a fixed point in the skin or impression.

4.3.2.1.4. Connectedness – extent to which the end point of one ridge is connected to a neighboring ridge.

4.3.2.1.5. Compound Minutiae – the atypical combination of multiple minutiae within a close proximity or that manifest as a single structure. Compound minutiae may include the following: short ridge, dot, break, enclosure, overlap, crossbar, bridge, spur, ending ridge and bifurcation combination, opposing bifurcations, dock, trifurcation, return, and merge point. See Appendix B for definitions and examples of simple and compound minutiae.

4.3.3. Incipient Ridges:

Incipient ridges are raised papillary ridges that are typically lower in elevation than the mature ridges (Section 4.3.1). Incipient ridges occupy space in the furrows, between the main ridges. Unlike the main ridges, incipient ridges do not have sweat pores. Incipient ridges are typically less than one half the average width of the surrounding ridges and often display numerous breaks. See Appendix C for examples of incipient ridges.

4.3.3.1. Attributes:

4.3.3.1.1. Number – count of incipient ridges within a region of skin or within an impression of the skin.

4.3.3.1.2. Density – number of incipient ridges within a specified surface area (e.g., high or low or per mm2).

4.3.3.1.3. Length – distance between two locations along the path of an incipient ridge.

4.3.3.1.4. Direction – direction of the path of an incipient ridge in relation to a fixed point in the skin or impression (e.g., an incipient ridge that is perpendicular to an irregular crease).

4.3.3.1.5. Inter-Incipient Break – distance between the ends of two incipient ridges (i.e., the gap between incipient ridges within a row of incipient ridges).

4.3.3.1.6. Edge Shapes – contours along the edges of an incipient ridge (straight, protrusion, and intrusion).

4.3.4. Dissociated Ridges:

Dissociated ridges are raised portions of the friction ridge skin that are broken into short, wavy or dotlike segments that may be completely disorganized or somewhat follow the ridge flow in a given region of skin. Dissociated ridges are typically at the same elevation as any surrounding normal ridges and may or may not contain sweat pores. Dissociated ridges are also known as dysplasia. See Appendix C for examples of dissociated ridges.

4.3.4.1. Attributes:

4.3.4.1.1. Number – count of ridge segments within a region of skin or within an impression of the skin.

4.3.4.1.2. Density – number of ridge segments within a specified surface area (e.g., high or low or per mm2).

4.3.4.1.3. Ridge Width – distance between the sides of a ridge segment at a given location on the segment.

4.3.4.1.4. Furrow Width – distance between the sides of adjacent ridges at a given location on the ridges.

4.3.4.1.5. Length – distance between two locations along the path of a ridge segment.

4.3.4.1.6. Spacing – distance between the midpoints of two adjacent ridges.

4.3.4.1.7. Direction – direction of the segment of a ridge in relation to a fixed point in the skin or impression (e.g., a segment that is perpendicular to the core of a loop).

4.3.4.1.8. Curvature – change in angles along the path of a ridge segment.

4.3.4.1.9. Edge Shape – contour of the edge of a ridge segment (straight, protrusion, indentation, and discontinuity).

4.3.4.1.10. Pore Position – location of a pore with respect to the edge of the ridge segment or another pore.

4.3.4.1.11. Connectedness – extent to which the end point of one ridge segment is joined or linked to a neighboring ridge (ridge ending, bifurcation, ambiguous).

4.3.5. Ridge flow:

Ridge flows are uninterrupted courses of ridges commonly found in specific regions of the hands and feet that reflect the stresses on the surface of the skin caused by the growth of the hands and feet and the presence of the regular flexion creases at the time the ridges are forming. These ridge flows are not defined “pattern elements,” but useful during the examination process because they are predictive for each region of the hand and foot. See Appendix E for examples of ridge flows and attributes.

In this standard, ridge flows include the fingerprint pattern traditionally classified as a plain arch. The inclusion of the plain arch as a ridge flow rather than a pattern is because the plain arch is the result of the complete or near-complete regression of the volar pad during embryological development of the skin. The lack of a volar pad permits the general growth stresses to be the primary influence on the ridge flow, causing the ridges to simply flow from one side of the finger to the

other, similar to the lower portions of the fingers and other regions of the palms and soles. The distinction between "pattern elements" and "ridge flow" in this standard is not intended to preclude the use of the plain arch to describe the ridge flow in the fingers or toes.

4.3.5.1. Attributes:

4.3.5.1.1. Curvature – change in angle along a series of parallel ridges at a given location along a ridge flow.

4.3.5.1.2. Convergence – loss of ridges along a ridge flow, causing an overall decrease in the width of the ridge flow.

4.3.5.1.3. Divergence – gain of ridges along a ridge flow, causing an overall increase in the width of the ridge flow.

4.3.6. Pattern Elements – Recurves and Triradii:

The term "pattern" is most often associated with the rules for classifying the patterns in the distal segments of the fingers. Fingerprint classification rules are inadequate when seeking a comprehensive description of the patterns across the hands and feet. For instance, the pattern in the distal portion of the finger is classified as an arch when the ridges flow transversely and lack a core or triradius. The proximal and medial portions of the fingers are not described as having an "arch" pattern, despite the ridges flowing transversely and lacking a triradius and core.

For this document, ridge flow will refer to the main course of a group of ridges as dictated by the general growth stresses on the friction ridge skin caused by the growth of the hand or foot and the presence of regular flexion creases during the embryological development of the skin. Pattern elements will be considered any deviation from the general ridge flow as a result of the influence of the volar pads during embryological development. For this reason, a triradius (commonly referred to as a "delta" in fingerprint classification), will be considered its own pattern element and plain arches will be described under Ridge Flow (Section 4.3.5). This distinction permits a unified approach to the entire friction ridge skin and the expansion of relationships between two pattern elements and between a pattern element and other features. See Appendix D for definitions and examples of the patterns as described in this standard. Depending on the pattern element, different attributes can be considered.

4.3.6.1. Attributes:

4.3.6.1.1. Number – count of recurves and triradii within a region of the friction ridge skin or in an impression. NOTE: For the purposes of this document, a whorl is considered a continuous recurve.

4.3.6.1.2. Triradius Angle – angle formed by two rays of a triradius.

4.3.6.1.3. Core Ridge Count – number of ridges enclosed by a recurving ridge in a tented arch, loop, or whorl; number of ridges enclosed by the two triradii of a column; number of perpendicular ridges that form a vestige.

4.3.6.1.4. Core Length – distance from the geometric center of a triradius to the innermost recurve surrounding the ray of the triradius in a tented arch. The distance between opposing innermost recurves of a whorl.

4.3.6.1.5. Pattern Element Relationships – ridge counts, distance, or angles between the cores, recurves, or triradius centers of two or more pattern elements.

4.3.7. Regular Creases:

The regular creases are those flexion creases which form prior to the friction ridges and prior to flexion of the hand or foot during embryological formation. Regular creases are tightly bound to the underlying palmar aponeurosis and ridges tend not to traverse through these creases. Regular creases are also referred to as primary creases or major creases. The five regular creases of the palm include: wrist crease, thenar crease, distal transverse crease, proximal transverse crease, and palmar digital creases. The only regular creases associated with the sole are the plantar digital flexion creases where the skin of the toe meets the sole.

Thumbs and great toes typically have a distal interphalangeal crease located at the joint between the distal and proximal phalanges (there is typically no medial phalange in the great toe or thumb). The four remaining digits of the hands and feet typically have a distal interphalangeal crease located at the joint of the distal and medial phalanges. The four fingers of the hand typically have a proximal interphalangeal crease located at the joint of the medial and proximal phalanges. In the remaining four toes, it is common for the proximal interphalangeal crease to be poorly formed or missing. See Appendix F for a schematic of the regular creases of the hands and feet.

4.3.7.1. Attributes:

4.3.7.1.1. Number – count of regular creases within a region of skin or within an impression of a skin.

4.3.7.1.2. Configuration – organization of the regular crease as a single structure or a double structure (e.g., the palmar digital crease of the

middle finger is typically a double crease while the palmar digital crease of the index finger is typically a single crease).

4.3.7.1.3. Spacing – distance between the midpoints of two adjacent creases.

4.3.7.1.4. Position – location of a regular crease within the structure of the hand or foot.

4.3.7.1.5. Width – distance between the sides of a regular crease at a given location on the regular crease.

4.3.7.1.6. Length – distance between two locations along the path of a regular crease.

4.3.7.1.7. Curvature – change in angle along the path of a regular crease for a given segment of the crease.

4.3.7.1.8. Direction – path of a regular crease in relation to a fixed point in the skin or impression (e.g., a crease that is parallel to the direction of the surrounding ridges).

4.3.7.1.9. Edge shapes – contours of the skin contained within a regular crease.

4.3.7.1.10. Branching – pattern of branching along the main line of a regular crease.

4.3.8. Irregular Creases:

The irregular creases are those flexion creases which form during or after ridge formation (ridges typically traverse through these creases). Although not as deep as the regular creases, the irregular creases also have attachments to the underlying structure of the hand or foot. The irregular creases show greater variability than the regular creases within the human population. See Appendix F for examples of irregular flexion creases.

4.3.8.1. Attributes:

4.3.8.1.1. Number – count of irregular creases within a region of skin or within an impression of a skin.

4.3.8.1.2. Density – number of irregular creases within a specified surface area (e.g., high or low or per mm2).

4.3.8.1.3. Width – distance between the sides of an irregular crease at a given location on the irregular crease.

4.3.8.1.4. Length – distance between two locations along the path of an irregular crease.

4.3.8.1.5. Curvature – change in angle along the path of an irregular crease for a given segment of the crease.

4.3.8.1.6. Direction – the path of an irregular crease in relation to a fixed point in the skin or impression (e.g., a crease that is parallel to the direction of the surrounding ridges).

4.3.8.1.7. Branching – branching pattern along the main line of an irregular crease.

4.3.8.1.8. Angle of intersection – angle(s) created by the intersection of two or more irregular creases.

4.3.8.1.9. Spacing – distance between the midpoints of two adjacent creases.

4.3.9. Wrinkles:

Wrinkles are a result of a breakdown in the skin over time. The disorganization of the various fibers and large proteins in the dermis causes the dermis to fold inward, causing a crimp in the epidermis. Unlike the regular and irregular creases, wrinkles do not have dedicated attachments to the underlying structure of the hand or foot. See Appendix G for examples of wrinkles.

4.3.9.1. Attributes:

4.3.9.1.1. Number – count of wrinkles within a region of skin or within an impression of a skin.

4.3.9.1.2. Density – number of wrinkles within a specified surface area (e.g., high or low or per mm2).

4.3.9.1.3. Width – distance between the sides of a wrinkle at a given location on the wrinkle.

4.3.9.1.4. Length – distance between two locations along the path of a wrinkle.

4.3.9.1.5. Curvature – the curvature of a wrinkle at a given location.

4.3.9.1.6. Direction – the path of a wrinkle in relation to a fixed point in the skin or impression (e.g., a wrinkle that is parallel to the direction of the surrounding ridges).

4.3.9.1.7. Branching – branching pattern along the main line of a wrinkle.

4.3.9.1.8. Angles of intersection – angle(s) created by the intersection of two or more wrinkles.

4.3.9.1.9. Spacing – distance between the midpoints of two adjacent wrinkles.

4.3.10. Scars:

A scar is a disfiguration of the skin as a result of wound healing. The disfiguration can occur in varying degrees dependent on the amount of skin contraction experienced at the site of the injury and medical intervention (e.g., stitches). Some scars are imperceptible, while others are dramatic. Additionally, scars initiated by temperature and chemical burns tend to disfigure the skin differently than cuts or punctures. Simple, linear scars tend to exist at a lower elevation than the tops of the ridges. Complex scars and scars that contain epithelial islands can exist at the same or higher elevation than the normal ridges. See Appendix H for examples of scars.

4.3.10.1. Attributes:

4.3.10.1.1. Number – count of scars within a region of skin or within an impression of a skin.

4.3.10.1.2. Width – distance between the sides of a scar at a given location on the scar.

4.3.10.1.3. Length – distance between two locations along the path of a scar.

4.3.10.1.4. Surface Area – measure of a total area of the surface the scar occupies.

4.3.10.1.5. Curvature – change in angle along the path of a scar for a given segment of a scar.

4.3.10.1.6. Direction – path of a scar in relation to a fixed point in the skin or impression (e.g., a scar that is perpendicular to the direction of the surrounding ridges).

4.3.10.1.7. Created Minutiae – new minutiae created at the border of a scar due to the misalignment of the original ridges during the healing process.

4.3.10.1.8. Edge Shapes – contours defined by the border of a scar and any epithelial islands created as a result of the injury.

4.3.11. Unstable features:

Unstable features are those features temporarily present in the skin as the result of wound healing or disease. Unstable features include, but are not limited to, warts, eczema/psoriasis, actively healing injuries, calluses, and blisters. Depending on the nature of the unstable feature, it may exist lower, equal, or higher elevations than the tops of the main ridges. See Appendix I for examples of more common unstable features found in the friction ridge skin.

4.3.11.1. Attributes:

4.3.11.1.1. Number – count of unstable features within a region in the skin or impression.

4.3.11.1.2. Width – distance between the sides of unstable feature at a given location on the unstable feature.

4.3.11.1.3. Length – distance between two locations along the path of an unstable feature.

4.3.11.1.4. Surface Area – measure of a total area of the surface the unstable feature occupies.

4.3.11.1.5. Curvature – change in angle along the path of an unstable feature for a given segment of the feature.

4.3.11.1.6. Direction – path of an unstable feature in relation to a fixed point (e.g., scrape that is parallel to the direction of the surrounding ridges).

4.3.11.1.7. Branching – branching pattern along the main line of an unstable feature.

4.3.11.1.8. Edge Shapes – contours of an unstable feature.

4.3.12. Shape of the Impression:

The surface area and border contours of a friction ridge impression.

4.3.12.1. Attributes:

4.3.12.1.1. Surface Area – measure of a total area of the surface the impression (e.g., size).

4.3.12.1.2. Outline – the contours along the border of the impression.

5. General Recommendations

5.1. Distortion factors affecting the appearance of features should be considered when conducting friction ridge examinations. Distortion factors of friction ridge features are considered from two perspectives: biological and recordability.

5.1.1. Biological distortion factors are those factors that affect the expected stability of the feature in the friction ridge skin.

5.1.2. Recordability distortion factors are those factors that can affect the appearance of the features when they are recorded in an impression.

5.2. The following distortion factors are not meant to be exhaustive of all possibilities, but reflective of common causes for features to appear different over time or due to circumstances of touch. The following definitions are meant to provide common language to describe distortion factors and provide a list of topics that would benefit from additional research.

5.2.1. Adolescent growth – growth of the hand or foot from the time the ridges form until adult size is attained (typically late teens).

5.2.2. Aging – changes in the friction ridge skin that take place because of the natural aging process; typically, these changes begin after the age of forty.

5.2.3. Injury – physical damage to the hand, foot, or friction ridge skin that elicits a wound healing response (e.g., cut or burn); certain injuries can result in the formation of a scar.

5.2.4. Disease – disorder in the structure or function of the skin that produces specific signs or symptoms and is not related to a physical injury (e.g., wart, psoriasis, or acquired ridge aplasia).

5.2.5. Hand flexion – the bending of the digits at the joints or the rotation of the thumb.

5.2.6. Abduction of digits – the degree to which the digits are spread apart from one another.

5.2.7. Angle of contact – the position of the hand or foot with respect to the surface during contact.

5.2.8. Compressive stress – the squeeze of the skin between the boney portions of the hand or foot and a surface (also referred to as “deposition pressure”).

5.2.9. Shearing stress – tangential force applied to the skin (also referred to as "lateral pressure").

5.2.10. Torque – rotational force applied to the skin.

5.2.11. Residue factors – any factors related to the residue on the skin that can affect the recording of the skin (e.g., initial composition of the residue, distribution of residue on the skin, or redistribution of residue in an impression due to skin moving on a surface).

5.2.12. Surface conditions – any factors related to the surface that affect the recording of the skin (e.g., texture, curvature, pliability, or contaminants).

5.2.13. Environmental factors – any factors related to the environment (e.g., temperature, humidity, UV exposure, or time) that affect the appearance of the features after the impression is recorded on a surface.

5.2.14. Post-deposition factors – any non-environmental factors that affect an impression (e.g., overlays with other impressions or smearing caused by an object touching an impression).

5.2.15. Processing technique – method used to develop the features of a latent impression; each method has a signature appearance that can vary, typically because of residue issues or surface conditions.

5.2.16. Recovery method – manner in which an impression is preserved (e.g., lift or photograph) that causes distortion (e.g., crease in tape, lens distortion, poor lighting, poor focus, low resolution).

5.2.17. Electronic capture error – inaccurate recording of a feature by an automated device (e.g., livescan stitching error).

5.2.18. Atypical anatomy – any deviation from the typical range of shape, size, or proportions of the human hand or foot or any disruption in the formation of the skin driven by genetic or epigenetic factors (e.g., syndactyly or congenital ridge aplasia). Atypical anatomy does not cause issues related to biological stability or recordability of the features; however, if it is not recognized during analysis, it can cause an examiner to underestimate or overestimate the source diagnosticity or search diagnosticity of a given feature set.

5.3. The diagnosticity of features should be considered when conducting friction ridge examinations. Diagnosticity, generally, refers to the usefulness of information to assist in a choice or decision. Diagnosticity of friction ridge features refers to the usefulness of

the feature, or attribute of a feature, for establishing search parameters[1] or the usefulness of the feature for determining source[2].

5.4. Features that exhibit low levels of variation in the population should be used for establishing search parameters. Features with generally low variation include the following: shape of the impression, creases, pattern elements, and ridge flows. Appendix J contains examples of how these features can be used to establish search parameters. Conversely, those features that exhibit higher levels of variation in the human population are useful for distinguishing one finger, palm, toe, or foot from another.

5.5. Pattern elements, ridge flows, and creases can be useful for excluding a given donor, however these features do not typically provide strong support for same source opinions.

5.6. Features that exhibit higher levels of variation in the population should be used to support same source opinions. The most variable features in the population typically include the following: ridges, minutiae, incipient ridges, dissociated ridges, and certain attributes of creases. Acquired features (wrinkles, scars, unstable features) exhibit more complex diagnosticity, depending on the feature.

5.7. The totality (number and diversity) of a specific set of features and available feature attributes ultimately determines the overall search diagnosticity and source diagnosticity for a given impression. While most formal research has focused solely on the source diagnosticity of combinations of minutiae, the remaining features and their attributes add considerable weight to the various decisions examiners make during the examination process.

5.8. The diagnosticity for each of the features include the following:

5.8.1. Ridges:

5.8.1.1. Search Diagnosticity:

5.8.1.1.1. The search diagnosticity for the ridges is generally low because all regions of the friction ridge skin are expected to have ridges.

5.8.1.2. Source Diagnosticity:

5.8.1.2.1. In general, as the surface area of an impression increases (ergo an increase in the number of ridges and the visible lengths of the ridges), the source diagnosticity of the impression also increases.

[1] Diagnosticity for search parameters refers to the usefulness of the feature to limit the comparisons to specific anatomical regions within the hands or feet, left or right hands or feet, or specific orientations. Diagnosticity for search parameters is referred to as “search diagnosticity” in this document.

[2] Diagnosticity for source determinations refers to the usefulness of the feature to include or exclude a potential donor. Diagnosticity for source determinations is referred to as “source diagnosticity” in this document.

5.8.1.2.2. In general, as an open field increases in size (more ridges or longer visible lengths of the ridges), the source diagnosticity of the open field also increases.

5.8.2. Minutiae:

5.8.2.1. Search Diagnosticity:

5.8.2.1.1. In regions where growth stresses "force" minutiae to form, there tends to be a high density of minutiae that share direction (the transition zone from the hypothenar into the mid-palm region is one such zone). This concept is called "pattern force". For example, in the outflow of a loop, many ridges are converging, which necessarily forces many ridge endings as space runs out. Because the pattern forces these minutiae to form predictably and their configurations are more common and less random, they are properly assigned less weight than more randomly distributed minutiae toward an association between two impressions. The existence of a cluster of minutiae in a pattern force area tends to increase the search diagnosticity of these minutiae.

5.8.2.2. Source Diagnosticity:

5.8.2.2.1. While the existence of a cluster of minutiae in a pattern force area tends to increase the search diagnosticity of the cluster of minutiae, it tends to decrease the source diagnosticity of those minutiae.

5.8.2.2.2. Typically, as the surface area of skin represented in an impression increases, so too does the number of minutiae present within the impression. While the source diagnosticity of a cluster of minutiae typically increases as the number of minutiae increases, the source diagnosticity ranges at a given number of minutiae until a theoretical maximum threshold is achieved (e.g., a rolled fingerprint). Beneath this theoretical maximum threshold, source diagnosticity for a given cluster depends on anatomical region, the density of the minutiae, the direction of the minutiae, the distance between the minutiae, and the population of donors under consideration.

5.8.3. Incipient Ridges:

5.8.3.1. Search Diagnosticity:

5.8.3.1.1. The search diagnosticity for incipient ridges is generally low because incipient ridges can appear throughout the friction ridge

skin and, unlike the ridges and minutiae, are not generally subject to pattern force.

5.8.3.2. Source Diagnosticity:

5.8.3.2.1. In general, as the number of incipient ridges within an impression increases, the source diagnosticity of the impression also increases.

5.8.4. Dissociated Ridges:

5.8.4.1. Search Diagnosticity:

5.8.4.1.1. The search diagnosticity for dissociated ridges is generally low because dissociated ridges can appear anywhere in the friction ridge skin.

5.8.4.2. Source Diagnosticity:

5.8.4.2.1. In general, as the number of dissociated ridges within an impression increases, the source diagnosticity of the impression also increases.

5.8.5. Ridge flow:

5.8.5.1. Search Diagnosticity:

5.8.5.1.1. The search diagnosticity of ridge flows is generally high because the ridge flows follow a predictable distribution in the human population for each region of the friction ridge skin. The search diagnosticity of a ridge flow is elevated when additional features are present (e.g., shape or regular creases).

5.8.5.2. Source Diagnosticity:

5.8.5.2.1. Generally, the source diagnosticity of ridge flows is low. Ridge flows tend to show significant left/right symmetry within a person. This symmetry is more pronounced within the corresponding hands of monozygotic twins.

5.8.6. Pattern Elements – Recurves and Triradii:

5.8.6.1. Search Diagnosticity:

5.8.6.1.1. The search diagnosticity of pattern elements is generally high because patterns follow a predictable distribution in the human population for each region of the friction ridge skin. The search

diagnosticity of pattern elements is elevated when additional features are present (e.g., shape or regular creases).

5.8.6.2. Source Diagnosticity:

5.8.6.2.1. The source diagnosticity of pattern elements is generally low. Patterns tend to show significant left/right symmetry within a person. This symmetry is more pronounced within the corresponding hands of monozygotic twins.

5.8.6.2.2. The source diagnosticity of a pattern element or group of pattern elements depends on the region of skin within which it resides. For instance, whorls are less common in the interdigital regions of palms than the interdigital regions of feet.

5.8.7. Regular Creases:

5.8.7.1. Search Diagnosticity:

5.8.7.1.1. The search diagnosticity of the regular creases is generally high because the regular creases follow a predictable distribution in the human population for each region of the friction ridge skin. The search diagnosticity of a regular crease is elevated when additional features are present (e.g., shape or ridge flows).

5.8.7.2. Source Diagnosticity:

5.8.7.2.1. The source diagnosticity of the number, configuration, and position of the regular creases is generally low. These attributes tend to show significant left/right symmetry within a person. This symmetry is more pronounced within the corresponding hands of monozygotic twins.

5.8.7.2.2. The source diagnosticity of the width, length, curvature, and direction of the regular creases is low to moderate. These attributes often show significant left/right symmetry within a person and similarity within the corresponding hands of monozygotic twins.

5.8.7.2.3. The source diagnosticity of the edge shapes and branching of a crease is expected to range from moderate to high. These attributes can show significant left/right symmetry within a person and similarity within the corresponding hands of monozygotic twins.

5.8.8. Irregular Creases:

5.8.8.1. Search Diagnosticity:

5.8.8.1.1. The search diagnosticity of the number, density, width, length, curvature, and direction of irregular creases depends on the region of skin under consideration. The search diagnosticity of these attributes is higher for thenars of palms, proximal and medial phalanges of the fingers, and the arches of the feet because a high density of creases is expected in these regions. Elsewhere in the friction ridge skin the irregular creases are more variable, and consequently less useful for search diagnosticity.

5.8.8.2. Source Diagnosticity:

5.8.8.2.1. The source diagnosticity of the number, density, width, length, curvature, and direction of irregular creases depends on the region of skin considered. The source diagnosticity is lower for palm thenars, proximal and medial phalanges of the fingers, and the arches of the feet because a high density of creases is expected in these regions. Elsewhere in the friction ridge skin the irregular creases are more variable, and consequently displaying higher source diagnosticity.

5.8.8.2.2. The source diagnosticity of the branching and angles of intersection of irregular creases is expected to range from moderate to high. These attributes can show significant left/right symmetry within a person and similarity within the corresponding hands of monozygotic twins.

5.8.9. Wrinkles:

5.8.9.1. Search Diagnosticity:

5.8.9.1.1. The search diagnosticity for wrinkles is generally low because wrinkles can appear anywhere in the friction ridge skin.

5.8.9.2. Source Diagnosticity:

5.8.9.2.1. In general, as the number of wrinkles within an impression increases, the source diagnosticity of the impression also increases.

5.8.10. Scars:

5.8.10.1. Search Diagnosticity:

5.8.10.1.1. The search diagnosticity for scars is generally low because scars can appear anywhere in the friction ridge skin.

5.8.10.2. Source Diagnosticity:

5.8.10.2.1. In general, as the number or complexity of a scar within an impression increases, the source diagnosticity of the impression also increases.

5.8.11. Unstable features:

5.8.11.1. Search Diagnosticity:

5.8.11.1.1. The search diagnosticity for unstable features is generally low because unstable features can appear anywhere in the friction ridge skin.

5.8.11.2. Source Diagnosticity:

5.8.11.2.1. In general, as the number or complexity of an unstable feature within an impression increases, the source diagnosticity of the impression also increases.

5.8.12. Shape of the Impression:

5.8.12.1. Search Diagnosticity:

5.8.12.1.1. The search diagnosticity of size and outline of an impression is generally high because the size and contours of human hands and feet are generally shared in the population. The search diagnosticity of an impression's shape is elevated when additional features are present (e.g., ridge flows or regular creases).

5.8.12.2. Source Diagnosticity:

5.8.12.2.1. The source diagnosticity of the shape of an impression is low. Hands and feet tend to show significant left/right symmetry within a person and similarity within the corresponding hands of monozygotic twins.

6. Appendix A: Edge Shapes

The images below highlight the edge shapes on normal ridges; however, these shapes can also occur on segmented ridges (dysplasia) or incipient ridges.

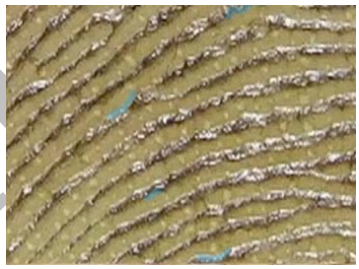
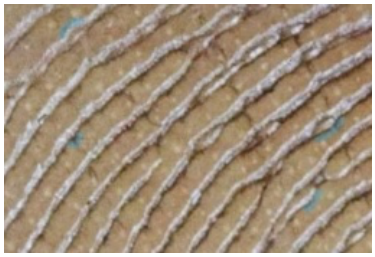
Edge Shape	Description	Example
Straight	Where the edge of the ridge is defined by a smooth line.	
Protrusion	Where the edge of the ridge protrudes into the furrow (causes a widening of the ridge at that location).	
Intrusion	Where the edge of a ridge intrudes into the main body of the ridge (causes a narrowing of the ridge at that location).	

Table 1 - Examples of edge shapes (images not to scale)

7. Appendix B: Minutiae

Simple Minutia Types

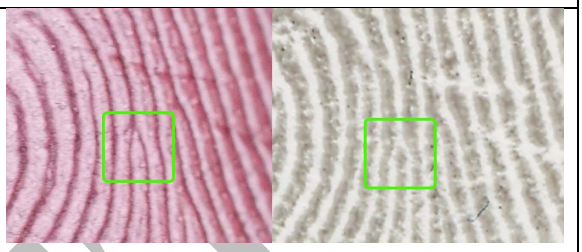
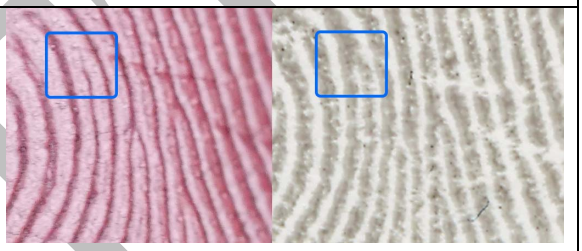
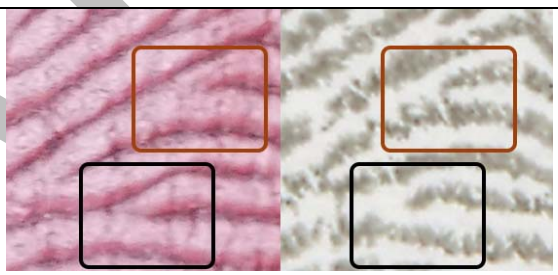
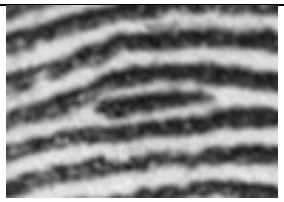
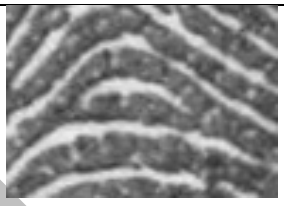
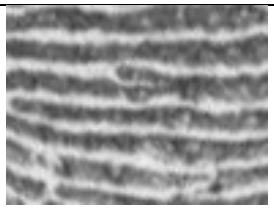
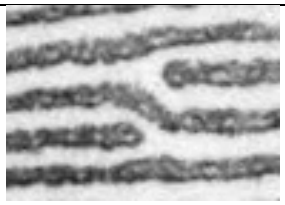
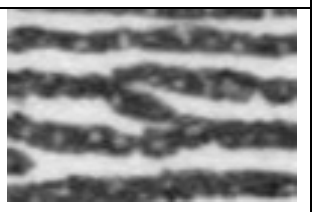
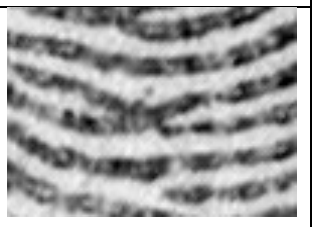
Minutia Type	Definition	Example
Ending Ridge	The end of a ridge with no connection to the adjacent ridge above the level of the furrow.	
Bifurcation	The complete connection of an end of a ridge to the adjacent ridge from the bottom of the furrow to the top of the ridge	
Ambiguous Minutia	The partial connection of the end of a ridge to the adjacent ridge (connected above the level of the furrow, but below the level of the tops of the ridges)	

Table 2 - Examples of simple minutiae (images not to scale)

Compound Minutia Types

Minutia Type	Definition	Example
Short Ridge	An independent ridge (defined by two ending ridges) with a length that is less than ten times the average width of the ridge.	
Dot	An independent ridge with a length that is less than two times the average width of the ridge.	

Minutia Type	Definition	Example
Break	A site along the ridge where the course of the ridge is interrupted, like a sink hole in the ridge. This length of the discontinuity is at least the width of the ridge, but no longer than twice the width of the ridge.	
Enclosure	A minutia defined by the merger of both ends of a short ridge with a neighboring ridge (defined by two bifurcations directed toward each other). The distance between the bifurcations is less than ten times the average width of the ridges.	
Overlap	Where two ridges meet and overlap. The length of overlap is less than ten times the average width of the ridges.	
Spur	A minutia defined by the merger of one end of a short ridge with a neighboring ridge (defined by one bifurcation and one ending ridge). The distance between the ending ridge and bifurcation is less than ten times the average width of the ridges.	
Crossbar	A ridge that alters its course to zig-zag around other minutiae, similar to a train switching tracks. The transfer zone is less than ten times the average width of the ridges.	
Bridge	A minutia defined by the merger of a short ridge with two neighboring ridges. The path of the bridge tends not to be parallel to the neighboring ridges and the length of the bridge is no longer than five times the average width of the ridges.	
Opposing Bifurcations	A minutia defined by two bifurcations directed away from each other. The distance between the two bifurcations is less than five times the average width of the ridges.	

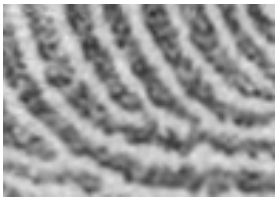
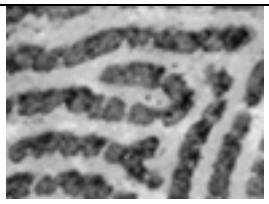
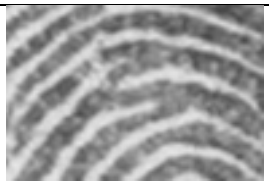
Minutia Type	Definition	Example
Dock	A minutia defined by an overlapping cluster of three ridge endings where the center ridge ending is in the opposite direction of the other two ridge endings and the length of overlap on each side of the center ridge is less than ten times the average width of the ridges.	
Ending Ridge + Bifurcation Combination	A minutia defined by the end of a ridge leading to a bifurcation. The distance between the end of the ridge and the bifurcation is less than five times the average width of the ridges.	
Trifurcation/Double Bifurcation	A minutia defined by the merger of three ridges into one. This minutia type can appear as a trifurcation when the three ridges emanate from a common vertex or a double bifurcation when one ridge is not centered on a vertex with the other two ridges. The merger of the three ridges is contained within a distance less than three times the average width of the ridges.	 
Return	The location along an independent ridge where the ridge makes a 180° turn and the return is not part of a recurve associated with a tented arch, loop or whorl pattern.	
Merge Point	The merger of the legs of two bifurcations into one ridge. The mergers (the points of the "M") are contained within a distance less than five times the average width of the ridges.	

Table 3 - Examples of compound minutiae (images not to scale)

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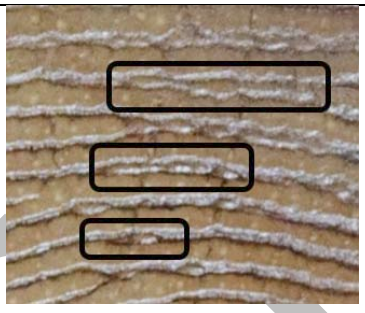
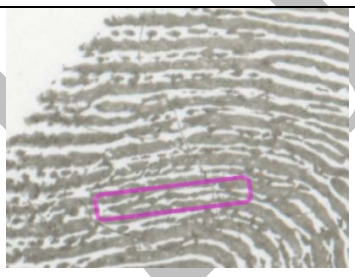
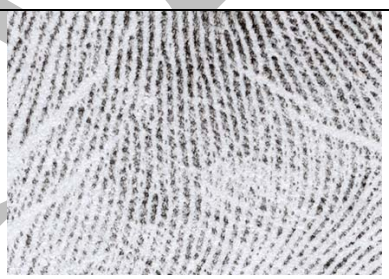
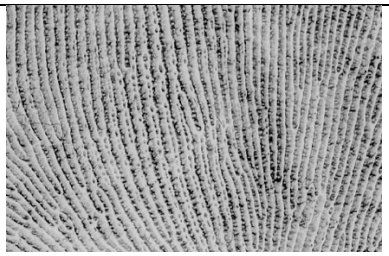
896 8. Appendix C: Incipient Ridges and Dissociated Ridges

Feature	Example
Incipient ridges in the friction ridge skin of a finger	
Incipient ridges in an impression of a finger	
Incipient ridges in an impression of a palm	
Incipient ridges in an impression of a foot	
Dissociated ridges (severe case) in an impression of a palm	

Feature	Example
Dissociated ridges (severe case) in an impression of the distal and medial segments of the fingers	
Dissociate ridges (mild case) in an impression of a thumb	

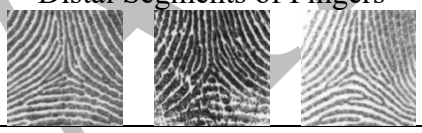
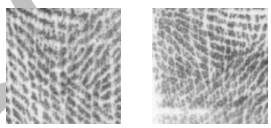
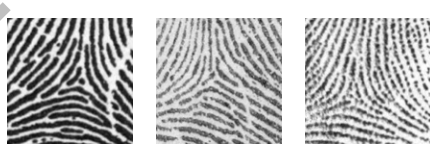
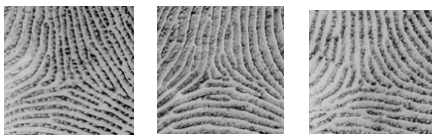
Table 4 - Examples of incipient ridges and dissociated ridges (images not to scale)

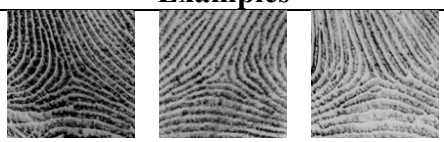
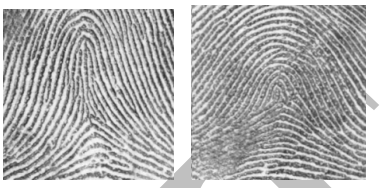
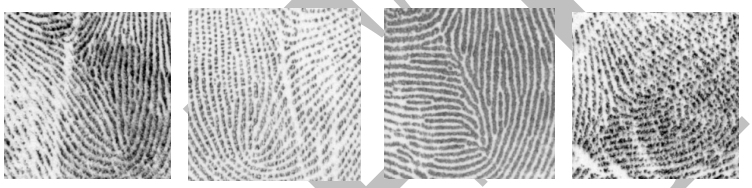
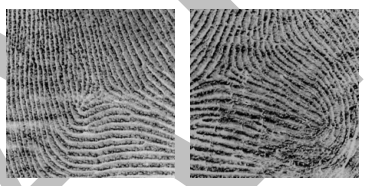
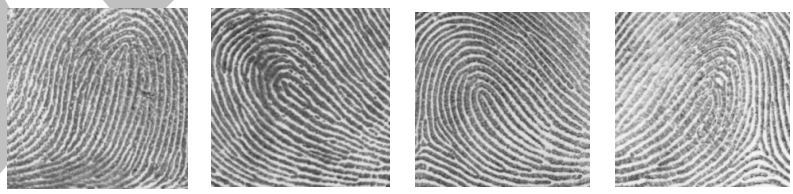
9. Appendix D: Pattern Elements

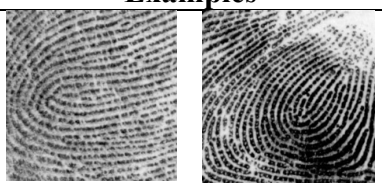
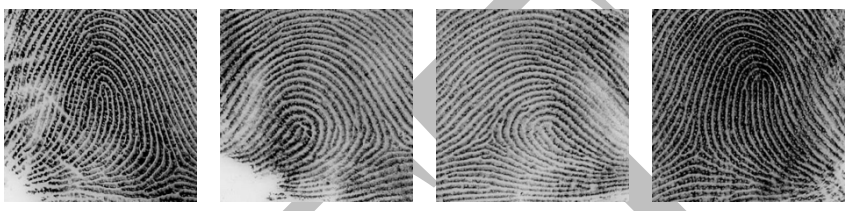
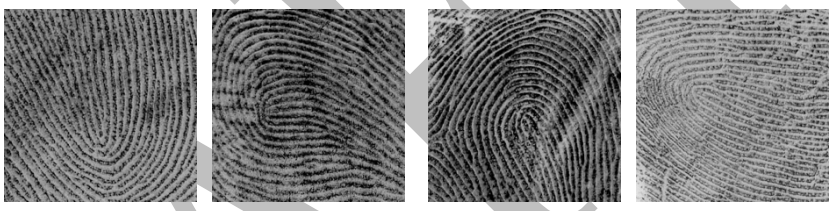
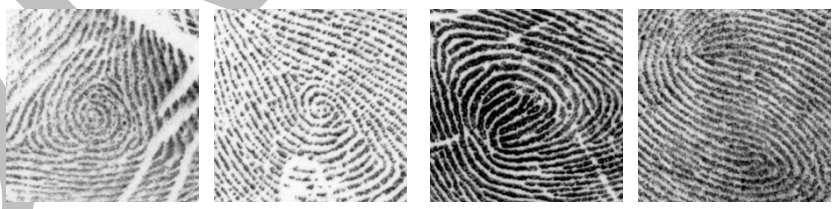
The patterns below are defined at a very rudimentary level to permit the use of pattern definitions across regions of the friction ridge skin. It is recognized that there are various classification schemes, with different rules, related to each region of the friction ridge skin.

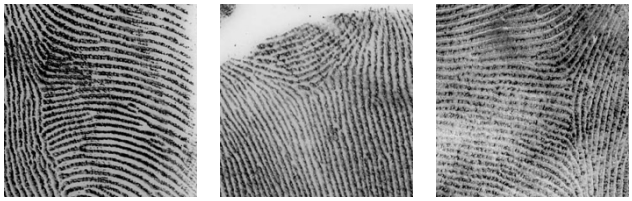
In partial impressions of the friction ridge skin; however, it is not always possible to determine if a given pattern (e.g., a loop) is from a specific anatomical region. If the anatomical region cannot be determined, it is impossible to know which classification scheme to apply or the specific rarity of the pattern (i.e., a triradius is rarer in the hypothenar than the interdigital of a palm). It is recognized that some patterns on the skin do not easily conform to the below categories and this standard will not attempt to catalog each permutation of the patterns that are possible in the friction ridge skin.

In this table, all impressions are oriented distally. Isolating each pattern and providing examples from each region of the skin highlights the importance of relationships between the patterns (e.g., position of the triradius in relation to the recurve of a loop) and other features to assess the anatomical region and orientation.

Pattern	Examples
Triradius Three rays of ridges (convergence of three ridge fields) that converge on a geometric center point. The core of a triradius is the geometric center point.	Distal Segments of Fingers 
	Medial and Proximal Segments of Fingers 
	Palms 
	Soles 
	Toes

Pattern	Examples
	
Tented Arch A triradius with a recurve over one of the rays (the ray can be one or more ridges). The core of the tented arch is the geometric center point of the triradius.	Fingers 
	Palms 
	Soles 
	Toes 
Loop A pattern defined by a single recurve in the ridges that does not arch over a radius. The core is generally positioned on the sharpest curve along the innermost recurve.	Distal Segments of Fingers 
	Palms 

Pattern	Examples
	
	Toes 
	Soles 
Whorl A pattern defined by two or more recurves, making a roughly circular pattern of ridges. While biometric systems may have specific rules for indicating the core of a whorl in fingers, these rules do not apply for palms and feet. Consequently, friction ridge examiners can use alternative or multiple cores when considering whorls.	Distal Segments of Fingers 
	Palms 
	Toes 

Pattern	Examples
	Soles 
Column Two triradii flanking 3 or more ridges that are parallel to the rays of the triradii. The core of the column is the center-most ridge between the two triradii.	Medial and Proximal Segments of Fingers 
	Palms 
	Soles 
Vestige	Thenars of Palms

Pattern	Examples
A complex pattern associated with the distal portion of the thenars of the palms.	 

Table 5 – Examples of patterns in the hands and feet.

10. Appendix E: Ridge Flows

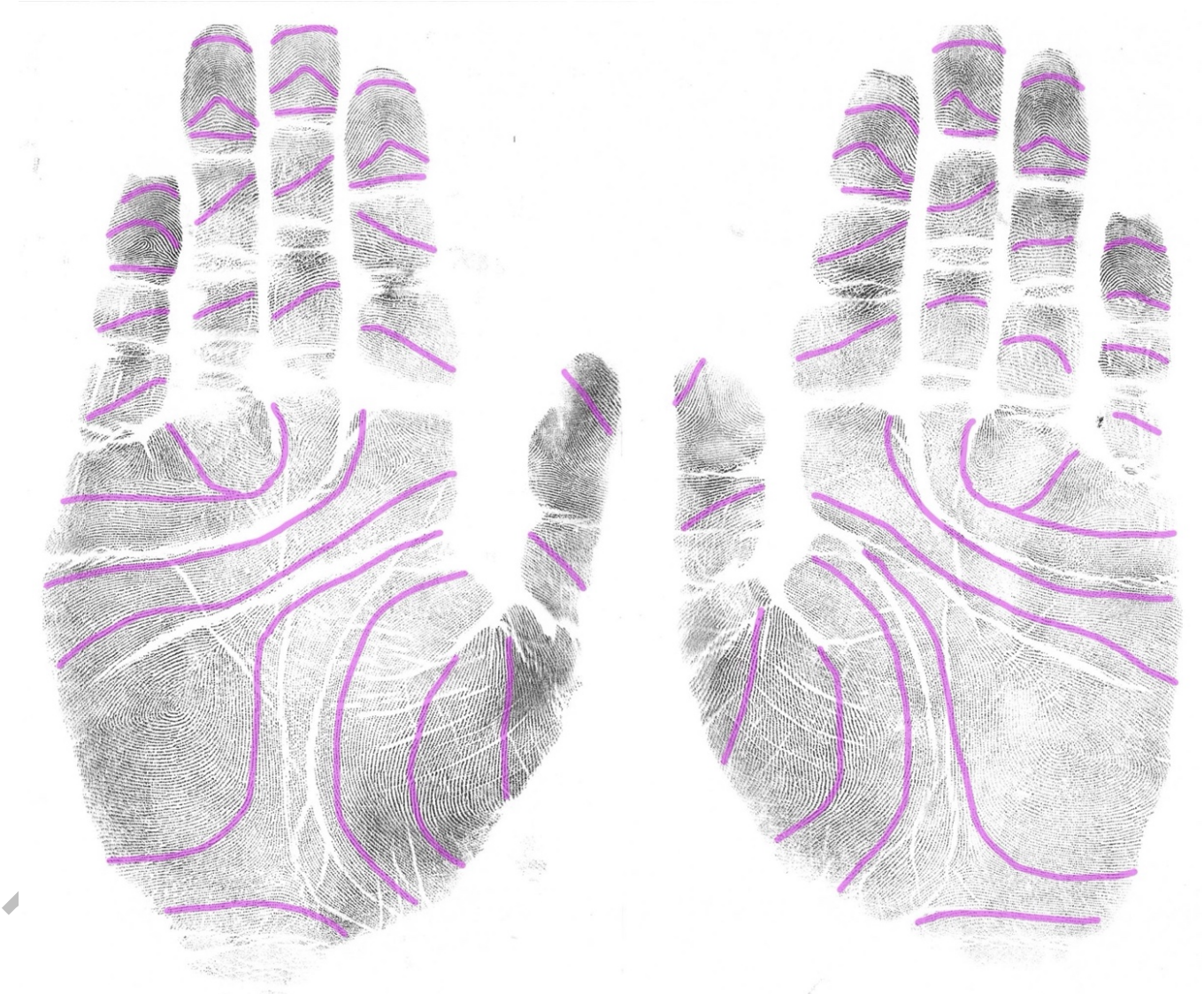
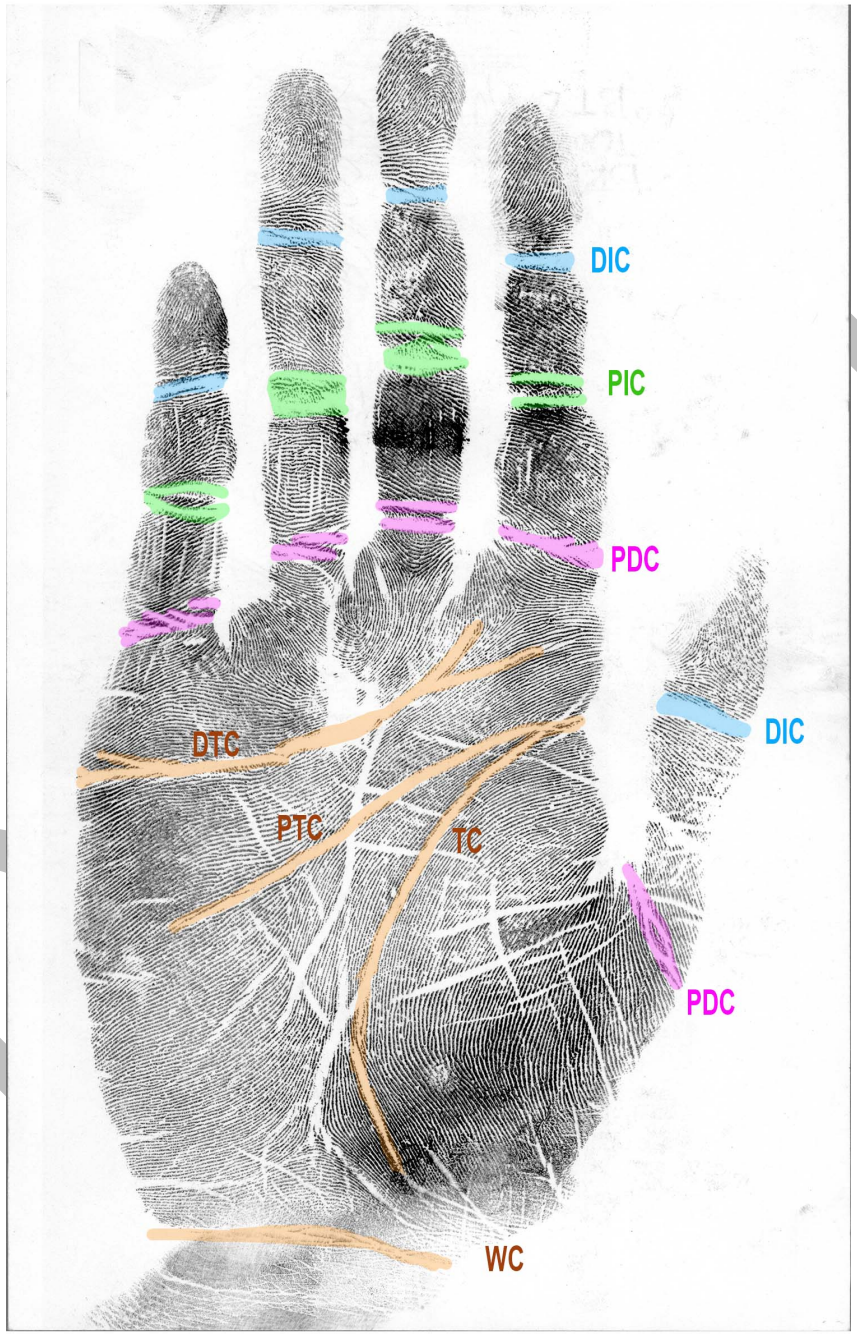


Figure 1 - Hand Ridge Flows. Hands not to scale.

Figure 2 - Foot Ridge Flows. Feet not to scale.

926

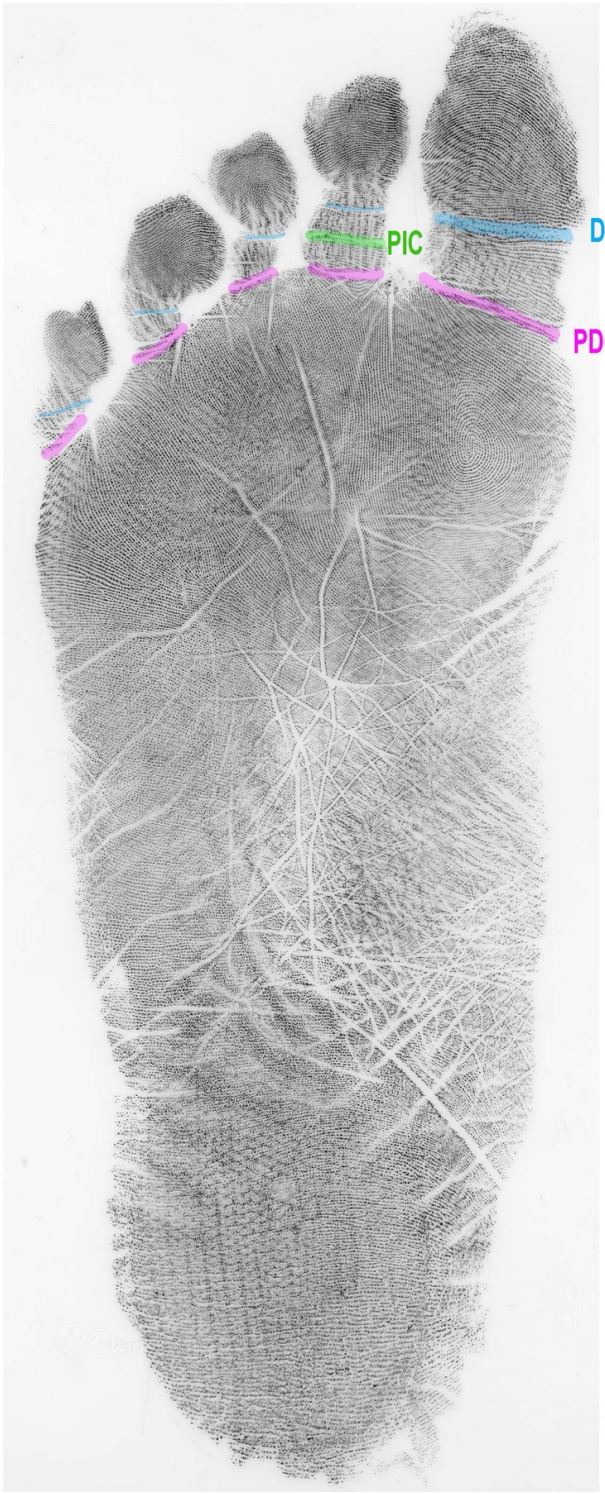
927 11. Appendix F: Regular and Irregular Creases of the Hands and 928 Feet



929
930 Figure 3 - Regular and irregular creases of the palm (image not to scale).

931 Regular Creases: DIC – Distal Interphalangeal Crease; PIC – Proximal Interphalangeal Crease;
932 PDC – Palmar Digital Crease; DTC – Distal Transverse Crease; PTC – Proximal Transverse

933 Crease; TC – Thenar Crease; WC – Wrist Crease. The remaining "white lines" in the hand
934 impression are irregular flexion creases.
935



936

937 Figure 4 - Regular and Irregular creases of the foot (image not to scale).

938 Regular creases: DIC – Distal Interphalangeal Crease; PIC – Proximal Interphalangeal Crease;
939 PDC – Plantar Digital Crease. The remaining “white lines” in the foot impression are irregular
940 flexion creases.
941

12. Appendix G: Wrinkles

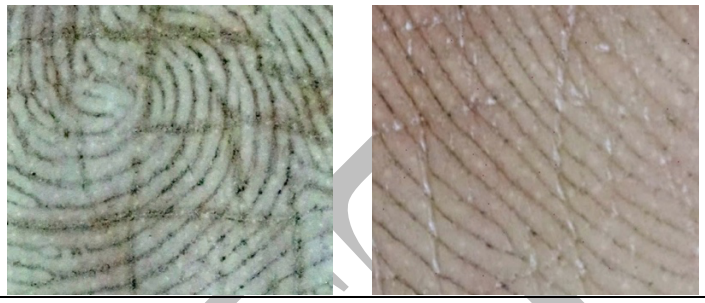
Feature	Example
Wrinkles in the friction ridge skin	

Table 6 - Examples of wrinkles (images not to scale)

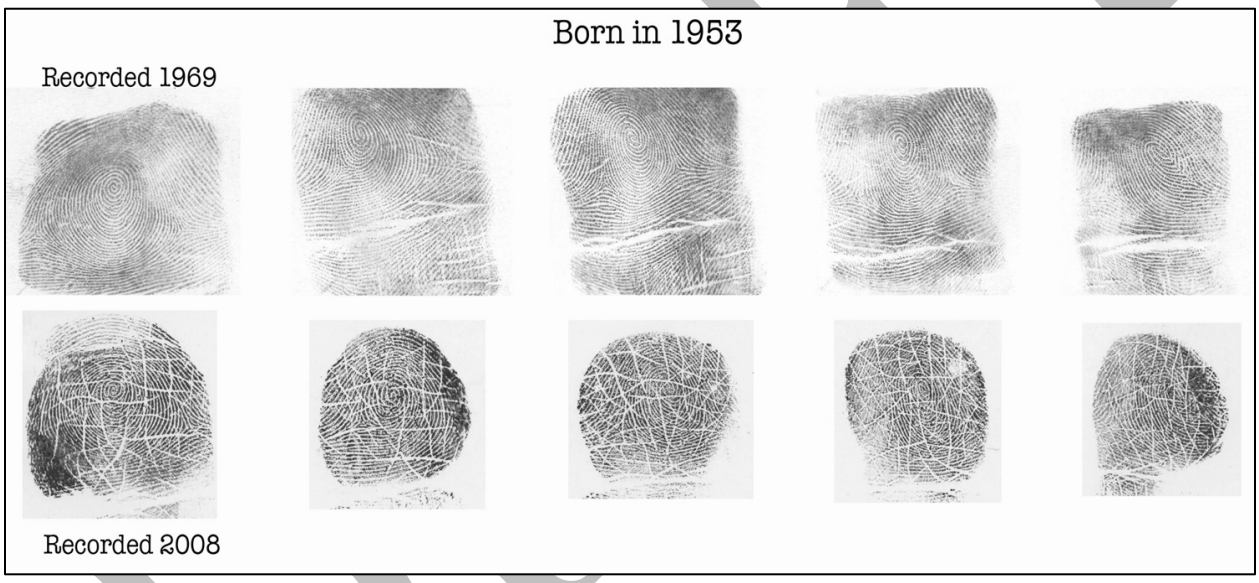


Figure 5 - The right thumb and fingers of a subject taken 39 years apart (images not to scale). The additional "white lines' in 2008 impressions are wrinkles acquired over the 39-year period.

13. Appendix H: Scars

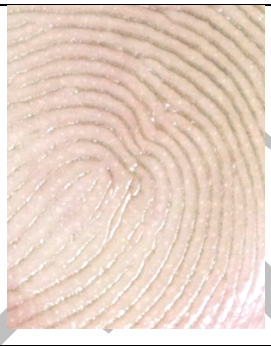
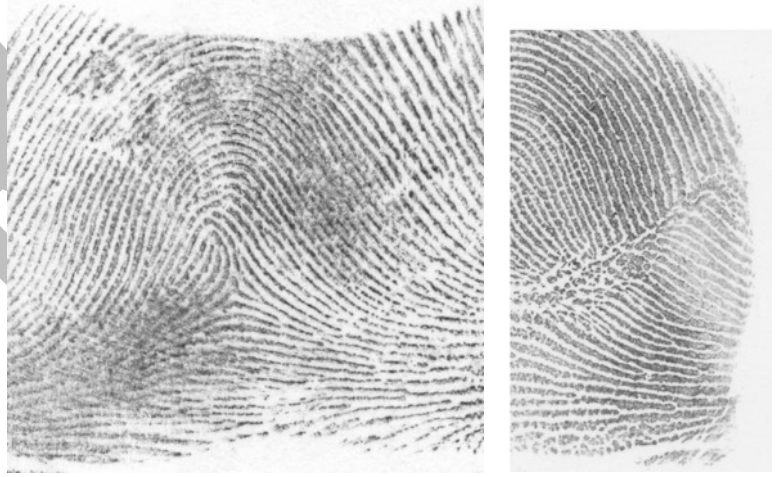
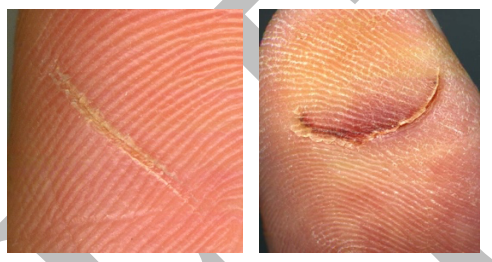
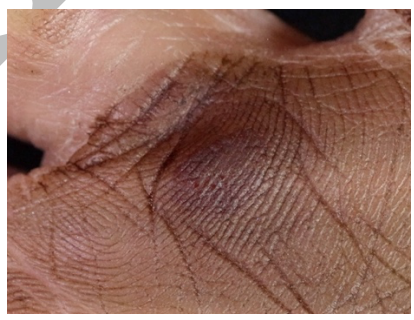
Feature	Example
Simple scar in the friction ridge skin	
Burn in the friction ridge skin	
Impressions of the same finger before and after the formation of a complex scar with epithelial islands	

Table 7 - Examples of scars (images not to scale).

14. Appendix I: Unstable Features

The examples below are not an exhaustive list of unstable features, but those unstable features seen most commonly in the friction ridge skin.

Feature	Example
Actively healing cuts on the friction ridge skin (this feature is considered unstable until the healing process is complete and it may, or may not, result in a detectible scar)	
Actively healing scrapes in an impression of a finger taken in 2007 and the recovery of the skin in 2008 (two stable scars highlighted in yellow)	
Callus in the interdigital of a palm	
Calluses in an impression of a right interdigital palm	

Feature	Example
Wart in the friction ridge skin	
Wart in an impression of a finger	
Eczema/psoriasis in an impression of a finger	

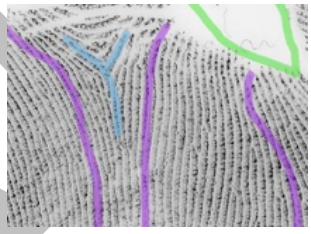
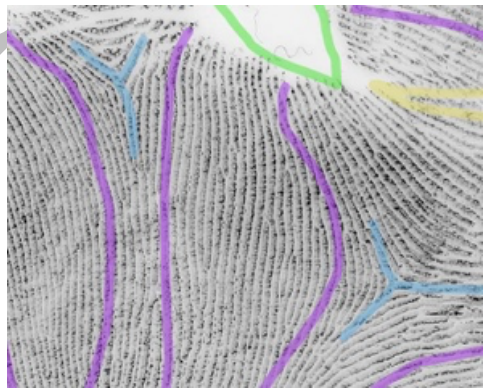
957 Table 8 - Eczema/psoriasis in an impression of a finger

958

15. Appendix J: Relationship of Features

Throughout the descriptions of the various features in this standard, reference is made to the impact of feature attributes, and relationships between features, on the search diagnosticity and source diagnosticity. This section provides examples of relationships and their potential impact on the examination process.

Example 1: In the series of images below the colors signify the following features: green is the relevant outline of the impression, blue indicates patterns (including triradii), purple indicates ridge flow, yellow indicates regular crease. In each image, more of the impression is revealed to demonstrate the importance of the relationships of these features and how these relationships guide decisions. The feature discussion illustrates the thought process, it is not an example of expected documentation for the impression.

Feature Discussion	Impression
The relationship of the size and outline of this impression and the position of the triradius within the surrounding ridge flow rule out fingers and toes but include the palms and feet as a possible donor region. The shape of the impression and the triradius angles further indicate the impression is in the most likely distal orientation and most likely from an interdigital region of a palm or foot.	
The shape (size and outline) indicates the interdigital region of a palm or foot. The pattern relationships between the two triradii (ridge count and angle), the curvature of the ridge flows, the divergence and convergence (going from top to bottom) of the ridge flow between the triradii, and the presence of the palmar/plantar digital crease also indicate interdigital region of a palm or foot. The triradius angles of the two triradii and their respective relationships to the perimeter of the impression and palmar/plantar digital crease indicate possible left interdigital palm under the index and middle fingers or a left foot under the great toe and index toe. A right interdigital palm under the little and ring fingers and a right interdigital foot under the little and ring toes cannot be ruled out.	

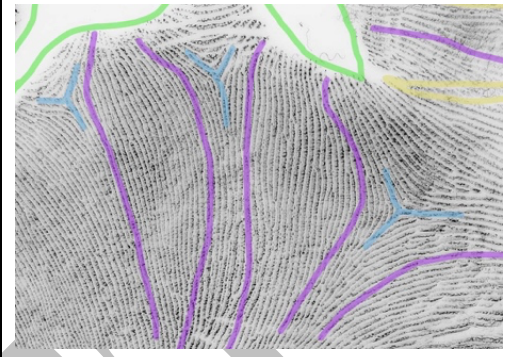
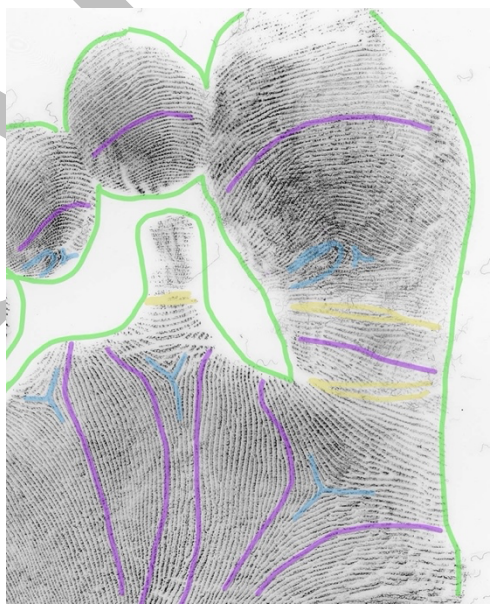
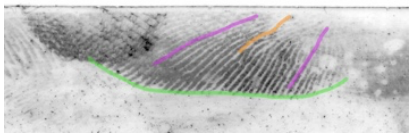
Feature Discussion	Impression
The shape (size and outline) indicates the interdigital region of a palm or foot. The relationships between the three triradii, the ridge flows (curvature, divergences and convergences), and palmar/plantar digital crease also indicate interdigital region of a palm or foot. The triradius angles of the left and middle triradii and the surrounding ridge flows indicate these patterns are positioned under the middle and ring digits of a left interdigital palm or the index and middle digits of a left interdigital foot. The triradius angles of the right triradius and the surrounding ridge flows indicate this pattern is located under the index finger of a left palm or the great toe of a left foot. Given the size of the impression, the lack of a visible distal transverse crease indicates this impression is more likely from a left foot rather than a left palm.	
The following features and their various relationships to each other are consistent with an impression from a left foot and toes: shape (size and outline), regular creases, patterns (including triradii), and distinct ridge flows.	

Table 9 – Examples of the diagnosticity of feature relationships (images to scale).

Example 2: This example describes two impressions of the friction ridge skin, each with a different subset of features present. The colors signify the following features: green is the relevant outline of the impression, blue indicates patterns (including triradii), purple indicates ridge flow, yellow indicates regular crease, and orange indicates a possible irregular crease. The discussion below each image illustrates the thought process and the importance of the friction ridge examiner's understanding of the distribution of the features and feature relationships in the human population. The feature discussion illustrates the thought process, it is not an example of expected documentation for the impression.

Impression A	Impression B
	
The shape (size and outline) of impression A in combination with the ridge flow indicates this impression could have originated from any region of the friction ridge skin; however, the distal portion of any of the digits is unlikely. The combination of the limited features also indicates multiple orientations would have to be considered and fully recorded friction ridge impressions of both the hands and feet would be required to exclude a given person. The source diagnosticity of the ridges and minutiae (and their attributes) should be impacted by the inability to pinpoint the anatomical region and orientation of Impression A. In other words, is this cluster of ridges and minutiae (and their various attributes) sufficient given the unknown anatomical region and orientation of this impression?	The following features, attributes, and relationships indicate Impression B should be oriented as indicated above and represents a right interdigital palm below the middle and ring fingers and the proximal segment of the right middle finger: shape (size and outline), patterns (including triradii), ridge flows, and regular flexion crease. The ability to pinpoint the specific hand and region of the hand is dependent on the friction ridge examiner's understanding of the distribution of these features in normal human hands and feet. The combination of features in Impression B could be considered so diagnostic for source; however, that the inability to pinpoint anatomical region and orientation (which indicates many more possible donor regions) may not significantly influence the source diagnosticity of the impression.

979 Table 10 - Examples of the diagnosticity of feature relationships.

980

16. Appendix K: Quick Reference Summary Table

	Attributes	Search Diagnosticity	Source Diagnosticity
Ridges	▪ Number ▪ Ridge Width ▪ Furrow Width ▪ Length ▪ Spacing ▪ Direction ▪ Curvature ▪ Edge Shapes ▪ Pore Position ▪ Open Field	Low	▪ In general: surface area increases, source diagnosticity increases ▪ In general: open field increases in size, source diagnosticity of the open field increases
Minutiae	▪ Number ▪ Density ▪ Direction ▪ Connectedness ▪ Compound Minutiae	Cluster of minutiae in a pattern force area generally increases search diagnosticity Cluster of minutiae in a non-pattern force area generally decreases search diagnosticity	▪ In general: number increases, source diagnosticity increases ▪ Minutiae in a pattern force area can decrease source diagnosticity ▪ For a given cluster: depends on anatomical region, density of the minutiae, direction of the minutiae, distance between the minutiae, population of donors under consideration
Incipient Ridges	▪ Number ▪ Density ▪ Width ▪ Length ▪ Direction ▪ Inter-Incipient Break	Low	▪ In general: number increases, source diagnosticity increases

	Attributes	Search Diagnosticity	Source Diagnosticity
	▪ Edge Shapes		
Dissociated Ridges	▪ Number ▪ Density ▪ Ridge Width ▪ Furrow Width ▪ Length ▪ Spacing ▪ Direction ▪ Curvature ▪ Edge Shapes ▪ Pore Position ▪ Connectedness	Low	▪ In general: number increases, source diagnosticity increases
Ridge Flows	▪ Curvature ▪ Convergence ▪ Divergence	High, elevated in combination with additional features (e.g., shape or regular creases)	▪ Low
Pattern Elements: Recurves and Triradii	▪ Number ▪ Triradius Angle ▪ Core Ridge Count ▪ Core Length ▪ Pattern Element Relationships	High	▪ Low ▪ Value depends on the region of skin
Regular Creases	▪ Number ▪ Configuration ▪ Spacing ▪ Position ▪ Width ▪ Length ▪ Curvature ▪ Direction ▪ Edge shapes	High	▪ Low (number, configuration, position) ▪ Low to moderate (width, length, curvature, direction) ▪ Moderate to high (edge shapes, branching)

	Attributes	Search Diagnosticity	Source Diagnosticity
	▪ Branching		
Irregular Creases	▪ Number ▪ Density ▪ Width ▪ Length ▪ Curvature ▪ Direction ▪ Branching ▪ Angle of intersection ▪ Spacing	Depends on the region of skin (higher in the thenars of palms, proximal and medial phalanges of the fingers and arches of feet)	▪ Lower in palm thenars, proximal and medial phalanges of the fingers, arches of the feet ▪ Higher in other regions of skin
Wrinkles	▪ Number ▪ Density ▪ Width ▪ Length ▪ Curvature ▪ Direction ▪ Branching ▪ Angles of intersection ▪ Spacing	Low	▪ More wrinkles, higher source diagnosticity
Scars	▪ Number ▪ Width ▪ Length ▪ Surface Area ▪ Curvature ▪ Direction ▪ Created Minutiae ▪ Edge shapes	Low	▪ The more complex and frequent, the higher the source diagnosticity
Unstable Features	▪ Number ▪ Width ▪ Length	Low	▪ The more complex and frequent, the higher the source diagnosticity

	Attributes	Search Diagnosticity	Source Diagnosticity
	▪ Surface Area ▪ Curvature ▪ Direction ▪ Branching ▪ Edge shapes		
Shape of the Impression	▪ Surface area ▪ Outline	High	Low

982 Table 11 – Quick Reference Summary Table

983

17. Appendix L: References

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18. Appendix M: Change Log

Version	Date	Change
1.0	09/06/2022	Original Issue