



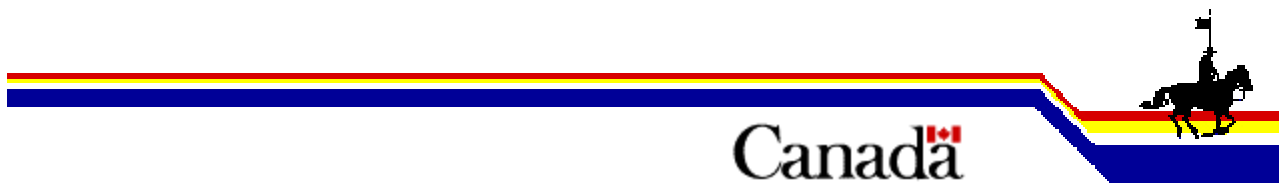
**Royal Canadian
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RIDGEOLOGY

MODERN EVALUATIVE FRICTION RIDGE IDENTIFICATION

by David R. Ashbaugh
Forensic Identification Support Section
Royal Canadian Mounted Police





10 March '99

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X S. Ashbaugh

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RIDGEOLOGY

MODERN EVALUATIVE FRICTION
RIDGE IDENTIFICATION

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INTRODUCTION TO RIDGEOLOGY

Ridgeology is an evaluative method of friction ridge identification based on scientific principles and procedures, principles and procedures that have been established and verified through years of research. The term Ridgeology refers to a forensic identification science that is associated with all of the ridges on the volar areas and not just on the finger tips as Dactyloscopy or fingerprint identification implies. Ridgeology is not only more encompassing than Dactyloscopy, but has methodologies and philosophies consistent with other forensic disciplines.

Ridgeology is an applied science. It has its origins in other sciences such as anatomy, embryology, genetics and neurology. The identification sciences of edgeoscopy and poroscopy are also a part of ridgeology as are areas of dermatoglyphics.

Ridgeology's coming of age signifies our commitment to advance into a era of evaluative identification, a process that addresses the infinite variables of friction skin and the degrees of clarity found in friction ridge prints. Ridgeology advances past the confusion of the basic laws of chance, applied to ridge characteristics alone. It addresses the whole ridge detail spectrum.

Some forensic identification investigators may feel that the science is so well established that the need to reexamine the intricacies of the identification process is redundant. The science is well developed. However, its methodology is still evolving as are the various sciences on which it is based. The need to remain current is always present.

Ridgeology can play a role in this endeavour. One of its main objectives is to identify areas in neurology, anatomy, genetics, embryology, forensic comparison methodology and scientific ethics that form a part of modern friction ridge identification. Knowledge of these disciplines in relation to friction ridge identification is a realm open to study for the scientific and inquisitive mind.

HISTORICAL REVIEW

Most fingerprint historians and text book authors do not differentiate between the early research scientists and the early fingerprint identification pioneers. They tend to coalesce all of these people into one group instead of two. During the early years it was difficult to differentiate between them. As years past the role of each became polarized and their paths separate. In this paper an effort has been made to separate the two and to follow each venue as it independently evolved.

The Early Application of Fingerprints

The earliest reference to the fingerprinting of criminals for identification purposes was reported during the rein of Hanimurabi (1792-1750 BC) in Babylon. Authors of the time are also reported to have added their fingerprints to their cuneiform writings on clay tablets and public buildings in an effort to prevent forgeries. Babylonia was an advanced civilization for its era. Sometime before 3000 BC it produced one of the first forms of writing cuneiform, a set of laws, studies in mathematics, astronomy and other sciences. After the death of Alexander the Great (356-.323 BC), last great king to rule the Babylonia area, the civilization crumbled.

Babylonian cuneiform tablets have been found as far away as Egypt. They describe mathematics, astronomy, medicine, historical information and legal processes. Fingerprinting may have spread to other countries from Babylon. This has however not been confirmed.

Historical documentation is available to establish that friction ridges were used as a means of personal identification in China from about 300 BC onward. Several Chinese historians have reported the use of finger and hand marks to authenticate official seals and legal documents. In some areas criminal fingerprints were also recorded in clay. During the Jin Dynasties (220-420 A.D.) paper and silk replaced clay and wood- based writing surfaces. Hand and finger marks from then on were recorded in ink.(Fig. 1)

From China the use of friction ridge identification spread to Japan. Japan had adopted many Chinese customs and laws, some of which were translated and adopted verbatim. Japanese historians make several references to early uses of friction ridges for identification purposes. Immigrants from China and Japan settled in neighboring countries. They are believed responsible for the spread of fingerprinting to many of these areas including India.

The British first learned of fingerprinting in India around 1858 through Sir William Herschel. Herschel noticed the locals using inked finger and palm prints on contracts. When a finger or hand print was placed on a contract, there was seldom a dispute about the authenticity of signatures. Herschel began to use the process to identify laborers in a effort to prevent impersonations.(Fig. 2) In 1877 he wrote a letter to a superior suggesting that fingerprinting was a good method to prevent impersonation and that his program should be broadened. Herschel's request was refused and he continued using friction ridge identification in obscurity for several years.

In 1880 another British subject by the name of Henry Faulds, published an article in the British journal "Nature" describing the value of fingerprints for identification purposes. Faulds had spent time working in India and working in Japan at the time he published his paper. Correspondence by Faulds reveals that he attained his fingerprint expertise in about one year. It is seldom that a completely original idea is brought forward in science. New ideas are usually spawned from previous endeavors. It is obvious in this case that both Faulds and Herschel were influenced by the practices of the natives working around them.

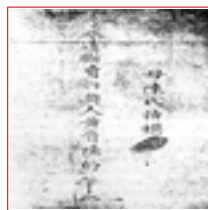
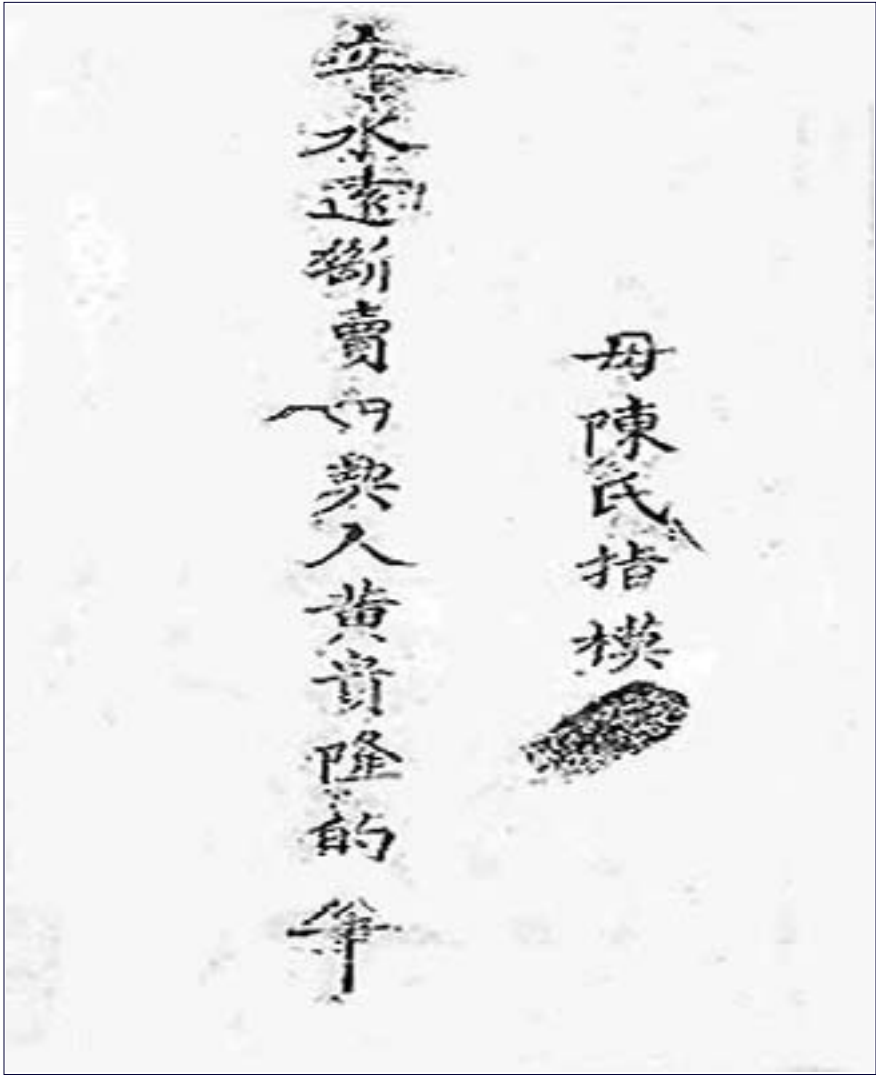


Fig. 1



Fig. 2

Fig. 1: Chinese Land Contract



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Fig. 2: Palm Print That Made Fingerprint History. The Konai Palm Print Made in 1858



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The Early Application of Fingerprints (cont'd)

Sir Francis Galton is credited with being the first scientist of friction skin identification although he played as much a role of a promoter as a researcher. Galton, a cousin of Charles Darwin, was wealthy and dabbled in various sciences of the day. He took Herschel's work and promoted it in Britain by lecturing and writing several articles on the subject. In 1892 he published a book describing the fingerprint identification and how the idea was envisioned by Herschel in India. His book refers to a symbolic use of fingerprints by locals in India and clearly indicates that he felt they had no knowledge of the value of friction ridge identification. For what ever reason, Galton ignored Faulds.

From Britain the science spread throughout Europe and to several colonial countries. In 1881 Juan Vucetich of Argentina was directed to set up an Anthropometry bureau in Buenos Aires. Once the bureau was operating, Vucetich used an article from the "Revue Scientifique" by Henry de Varigny as a guide and slowly introduced a fingerprinting system into the bureau. In 1892, Vucetich's system solved the first murder using fingerprint identification. Due to the success of friction skin identification in this case the science slowly spread throughout South America.

In 1897 two clerks working under Sir Win. Henry in Calcutta, India, overcame the largest hurdle that fingerprint identification had encountered thus far. They developed a classification system for fingerprints that had 1,024 primary classifications with secondary breakdowns for each. This classification system was named the Henry System and is still used in many countries in one form or another. The Henry system of classification overcame the problem of how to file, retrieve and search a collection of thousands of fingerprints. Its discovery established fingerprint identification as the most practical and simple personal identification method then available.

Fingerprint identification spread from Britain to Canada and the United States through Detective John Ferrier of Scotland Yard. Ferrier was at the St. Louis World's fair guarding the Crown Jewels. Constable Edward Foster of the Dominion Police was also present guarding a gold display from Canada. The two men met and Foster attended a lecture that Ferrier was giving about fingerprint identification to the International Association of Chiefs of Police. After the lecture Foster was intrigued with the possibilities fingerprinting had to offer. Upon returning to Canada he described fingerprinting to Sir Percy Sherwood the Commissioner of the Dominion Police. Sherwood shared Foster's interest in the process and supported its inception in Canada.

Early Scientific Research

Early research into Ridgeology was carried out by physicians who were also anatomists. Nehemiah Grew, M.D. (1641-1712) was an English botanist, physician and microscopist. In 1684 he published a paper in the "Philosophical Transactions" of the Royal Society of London describing his observations of the "Innumerable little ridges, of equal bigness" on the ends of the first joints of the fingers. Grew described the sweat pores, epidermal ridges and their arrangements. Included in his paper was a drawing of the configurations of the hand displaying the ridge flow on the fingers and palms.(Fig. 3) Grew didn't address the uniqueness of friction skin and apparently didn't consider it.

A year later, in 1685, Govard Bidloo, an anatomist in Amsterdam, Holland, published his book on human anatomy. In his book, Bidloo illustrated friction ridge and pore structure on the underside of the fingers. A drawing of a thumb was described in great detail with reference to the arrangement of ridges. Bidloo exaggerated the breadth of the ridges in his drawing possibly to emphasize their detail.(Fig. 4) His comments were morphological in nature and he did not refer to or mention the individuality of friction ridges.

In 1686, Marcello Malpighi (1628-1694), an anatomy professor at the University of Bologna, Italy, published the results of his friction skin research using the newly invented microscope. Malpighi has been credited with being the first to use a microscope in medical studies. His work was received with such enthusiasm that one skin layer was named in his honour. His paper dealt mainly with the function and morphology of the friction skin as a tactile organ and its use in the enhancement of friction for walking and grasping.

During the 1700's, further research papers were published by anatomists, each contributing in its own way to furthering the quantity of scientific information available about friction skin. J.C.A. Mayer, a German doctor and anatomist, published a book in 1788, which has been referred to as "an atlas of anatomical illustrations." Each illustration was accompanied by a detailed explanation.(Fig. 5) Under one of his illustrations depicting the friction skin on the fingers his comments were: "Although the arrangements of skin ridges is never duplicated in two persons, nevertheless the similarities are closer among some individuals. In others the differences are marked, yet in spite of their peculiarities of arrangement all have a certain likeness".

Mayer was the first to describe repetitiveness and similarity of friction ridge patterns in the same breath with the declaration that friction ridge arrangement is never duplicated. This is the first clear enunciation of the two basic principles that are the foundation of friction skin identification. The first being the class characteristics, which allow classification, the second being the random or accidental formation of the ridges, which ensures that duplication never occurs, even in a small area of friction skin.

Johannes Evangelista Purkinje (1787-1869), a professor at the University of Breslau, Germany, published a thesis in 1823 containing his studies on the eye, fingerprints and other skin features entitled "Commentatio de examine physiologico organi visus et systmatis cutanei". Purkinje classified nine principal configuration groups of fingerprints and assigned each a name.(Fig. 6) Although some historians credit Purkinje with drawing attention to the individuality of the friction ridges, he didn't mention personal identification or the individuality of ridge structure in his thesis.



Fig. 3



Fig. 4



Fig. 5

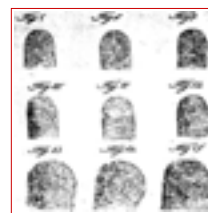


Fig. 6

Fig. 3: A drawing by Grew 1864 illustrating the ridge flow of the fingers and palm.



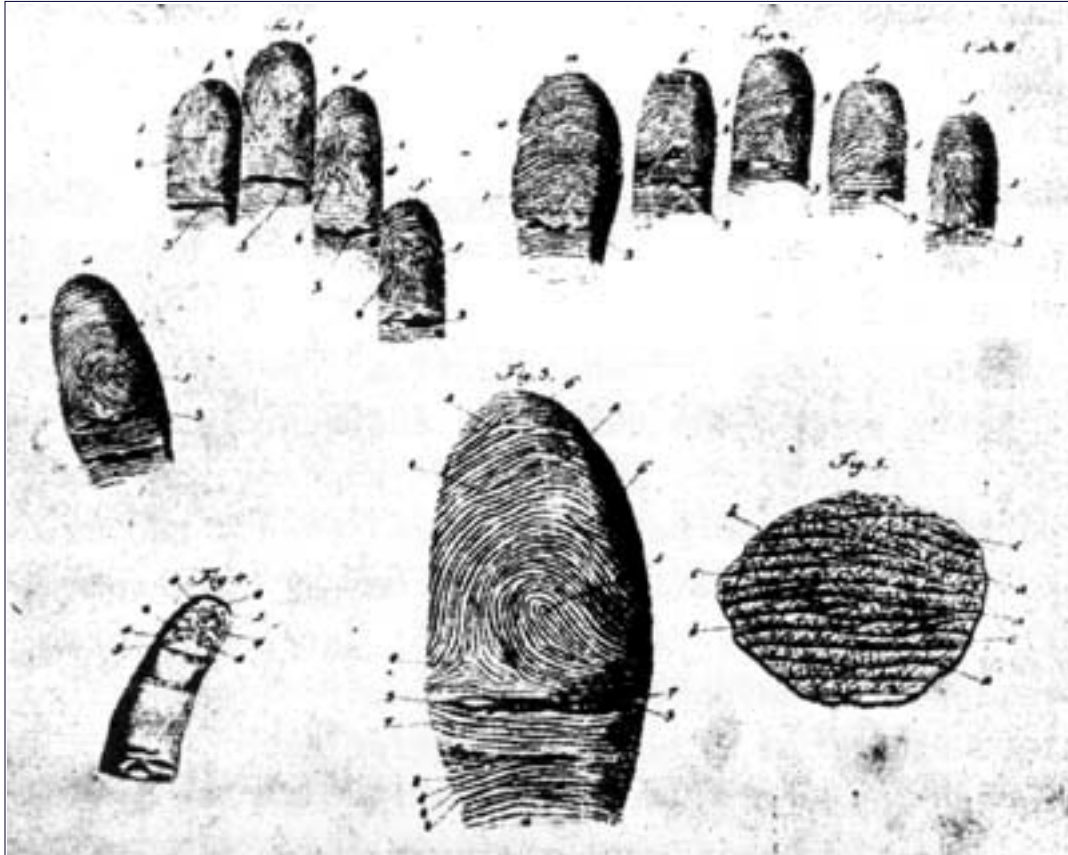
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Fig. 4: The drawing of a thumb by Bidloo 1685



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Fig. 5: Mayer's drawings of fingerprints, 1788



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Fig. 6: Purkinje's original nine types of finger print patterns. From left to right top row: transverse curves (plain arch), central longitudinal stria (tented arch), and oblique stripe (loop, ulnar or radial). Center row, left to right: oblique loop (loop, ulnar or radial), almond (whorl), and spiral (whorl). Bottom row, left to right: elliptical (whorl), circle (whorl), and double whorl.



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THE MANDATE FOR RIDGEOLOGY

Friction ridge identification methods have changed significantly since the turn of the century. At that time, fingers constituted the main volar surface that was considered for identification purposes. Since then, the discipline has grown to encompass the identification of friction ridge prints from all of the volar areas. Also, over the years, a concept slowly emerged to advance the philosophy of identification beyond just a set number of ridge characteristics.

The main reasons for the evolution of this concept was improved latent print developing techniques and the brain's natural ability to recognize and compare resulting more detailed shapes. This new evaluative process permitted an identification to be made with varying numbers of ridge characteristics. This was formally acknowledged by the International Association for Identification Standardization Committee in their 1973 report.

The accumulated quantity of scientific information about the growth of friction skin since the turn of the century is indeed prolific. Even though this literature has been readily available it has never been reported or used to establish a clear philosophy and methodology for the friction ridge identification process. The mandate of Ridgeology is to report and to apply this relevant scientific information to the current evaluative identification process.

There is concern by some that disclosing this information will somehow alter our present position in the forensic community which in turn will lead to problems in tendering evidence. The opposite is in fact true. The actual procedure used to make an identification and to present it in court, will not change. We are presently using correct methods. It is the ability to explain the process that is wanting.

Courts have accepted sufficient minutiae in the correct relative position as a basis of identification. References to clarity, rarity and uniqueness have been accepted at face value. However, in court, our duty is to also clearly explain things to others. Explaining a process is easier if the process is completely understood. This ability to explain and understand the identification process differentiates us from the lay person. Anyone familiar with friction ridges can form an opinion of identification. The forensic witness however must also be able to explain and discuss the opinion forming process in detail.

The current recognition by courts of the value of physical evidence has not gone unheeded by trial lawyers. They have become more interested in how friction ridge identifications are done and how well forensic identification investigators are trained. This interest will likely grow and challenges in court are probable. It is also probable that a large portion of the information and material related to ridgeology will seldom be entered into court. However, the knowledge and understanding of the various sciences, that gave birth to modern friction ridge identification, will provide the confidence and professionalism needed by competent forensic identification specialists in the future.

RIDGEOLOGY

The Structure Of Friction Skin

Human skin is classified as an organ. It is constructed of two main layers. The outer layer is the epidermis and the inner layer is the dermis. The epidermis is also made up of several smaller layers. The innermost layer is the generating layer. As new cells are created in the generating layer they are forced toward the surface. All cells adhere together with a special substance called desmosome. At the surface it is this substance that prevents the surface skin cells from sloughing off immediately upon arrival. The outer layers of the epidermis are basically made up of dead skin cells.(Fig. 7)

The dermis or true skin is the layer of skin in animals that leather comes from. It contains blood vessels, various glands and nerves. One of its functions is to feed the generating layer of the epidermis with nutrients. On volar areas, the surface between the dermis and epidermis is not smooth. The dermis is covered with double rows of peg like formations called papillae. Each double row of papillae lies under one of the ridges on the surface of the epidermis.(Fig. 8) Cuts that penetrate completely through the bottom layer of the epidermis and reach dermal papillae will leave a scar as new healthy skin cells cannot be regenerated due to the cell damage in the generating layer.

The dermis is in a way a template of surface ridges in that one can plot the path of the surface ridges by examining the dermal surface. This template is the result of primary and secondary ridge formation in the generating layer. Knowledge of how ridges develop is essential to recognize the various configurations found on the dermal surface.

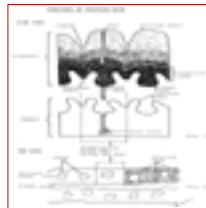
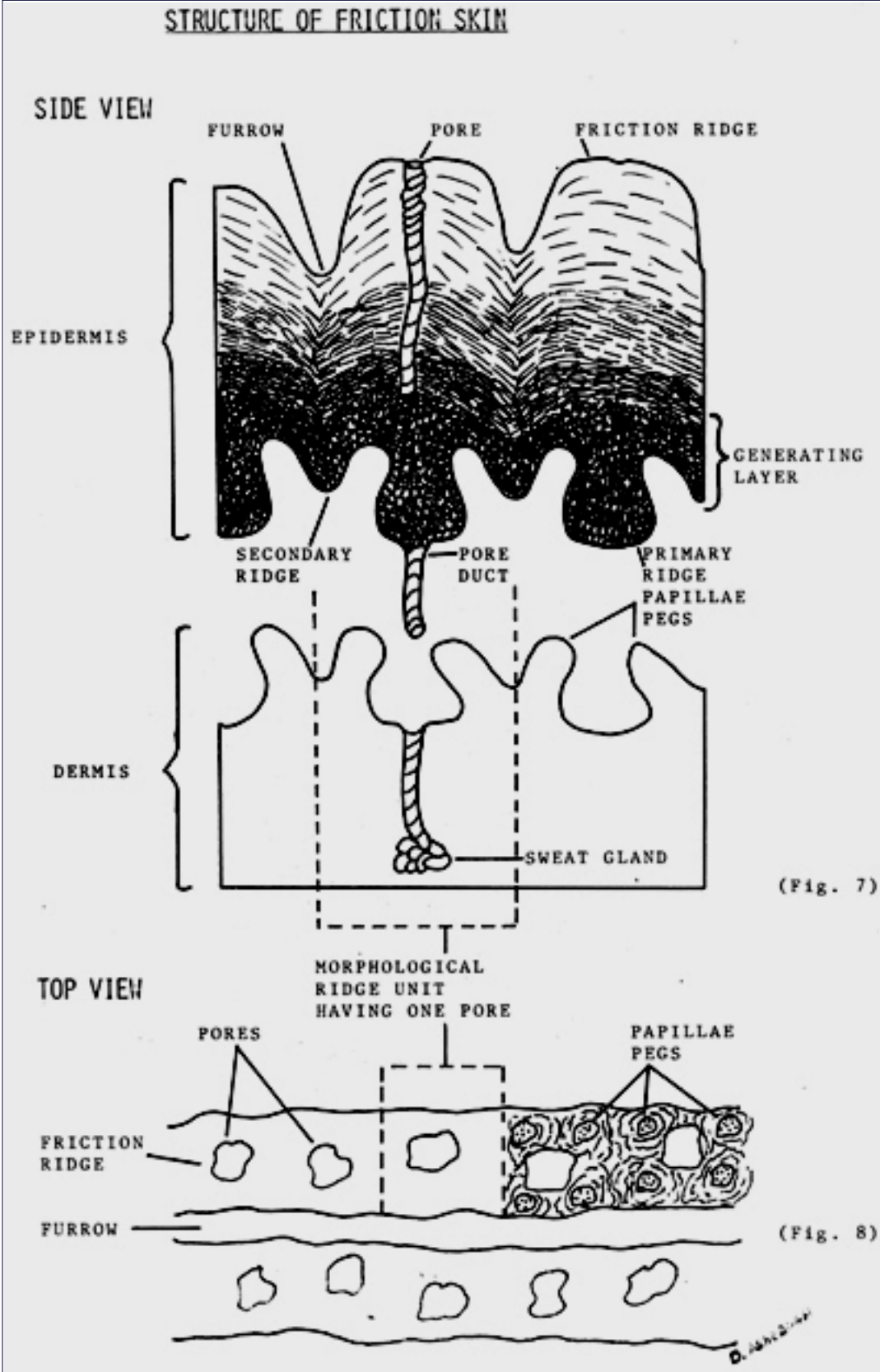


Fig. 7, 8

Fig. 7, 8: Structure of Friction Skin



Evolution of Friction Skin

Just prior to the start of this century numerous research papers were published that addressed the evolution of friction skin. (Galton 1892, Kollmann 1883, Klaatsch 1888, Reh 1894, Blaschko 1884, Hepburn 1895 and Wilder 1897) The culmination of this line of research was published in 1904 by Miss Inez Whipple in her paper entitled "The Ventral Surface of the Mammalian Chiridium." Whipple was a Zoology professor at Smith College in Northampton, Massachusetts. She collaborated with Harris Hawthorne Wilder, the author of Personal Identification and later her husband.

Whipple's paper is considered a landmark in the field of friction ridge identification and genetics. Research consisted in a review of other earlier papers and an intense study of comparative dermatoglyphics of various mammals. Whipple sums up her research with the following conclusions.

Early mammals were covered with a scale-like skin surface. Each scale had one hair protruding from it and an accompanying oil or sebaceous gland. On volar areas, which are the bottoms of the hands and feet, hairs slowly disappeared due to surface use. The pore that was related to the hair changed from a sebaceous gland to a sweat gland. Its purpose, to keep the surface skin damp which enhanced the grip of the volar surface.

Starting in all likelihood as a mutation, scales started to line up in rows and fuse together.(Fig. 9) This further assisted the grip of the skin surface by increasing friction. Through natural selection, this mutation became prevalent. Scales slowly evolved into wart-like units with pore openings near their center. The fusing of these wart formations into rows is the predecessor to the friction ridge, the individual wart being the equivalent of a ridge dot.

Whipple also reported that early mammals had walking pads on their volar surfaces similar to dogs or cats. These pads were located at the ends of what are now the five fingers or toes, four at the base of the fingers and two on each side of the palm. The pads were elevated and friction ridges formed on and around them. As the possible direction of slippage on an elevated pad is a full 360 degrees, the ridges formed around the pad in circular formation.(Fig. 10)

The circular ridge patterns radiated out from the centre of walking pads until they met ridges from an adjacent ridge system. Where three of these ridge systems met a triradius was formed. Early friction ridge patterns on the pads were believed to be whorl like in shape.

Modern friction ridge patterns on the hands and feet of humans and other primates are consistent with Whipple's walking pad locations. The pads themselves have disappeared on the adult human. However, if one examines the ridge flow of the hand or foot, most of the triradi that were originally formed between the pads are still visible. The ridges on the first and second phalanges of the fingers also slope in a manner consistent with their formation around a walking pad.(Fig. 11)

The pattern area of the foot is mainly in the ball area. This is again consistent with Whipple's conclusions. Ridges on the heel and arch area of the foot generally run across the sole from side to side. The heel was a late development in humans and walking pads did not evolve in this area. The flow of friction ridges were therefore uninhibited.

The research by Whipple and others basically explains why friction ridges developed in their present form and where they came from. It also explains the ridge configuration on the volar surfaces. Understanding the physical influences which affect the configuration of volar friction ridges is important formulating why all areas of friction skin are different.



Fig. 9

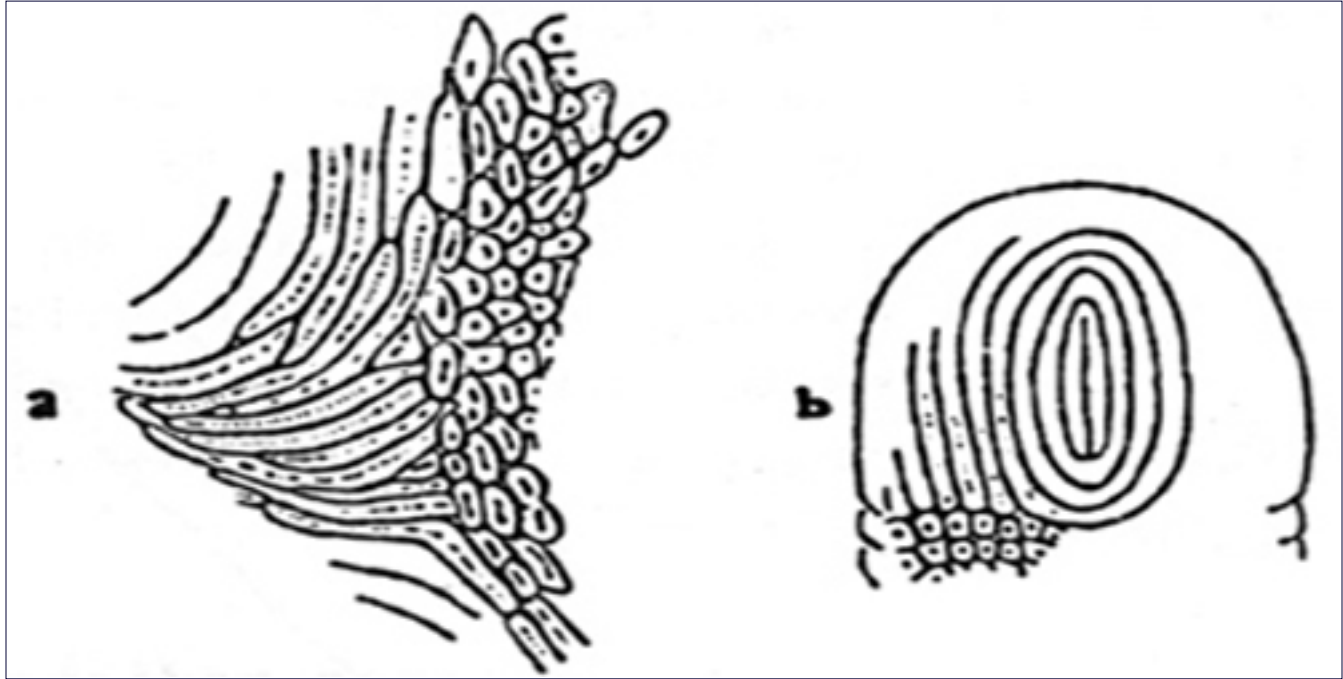


Fig. 10



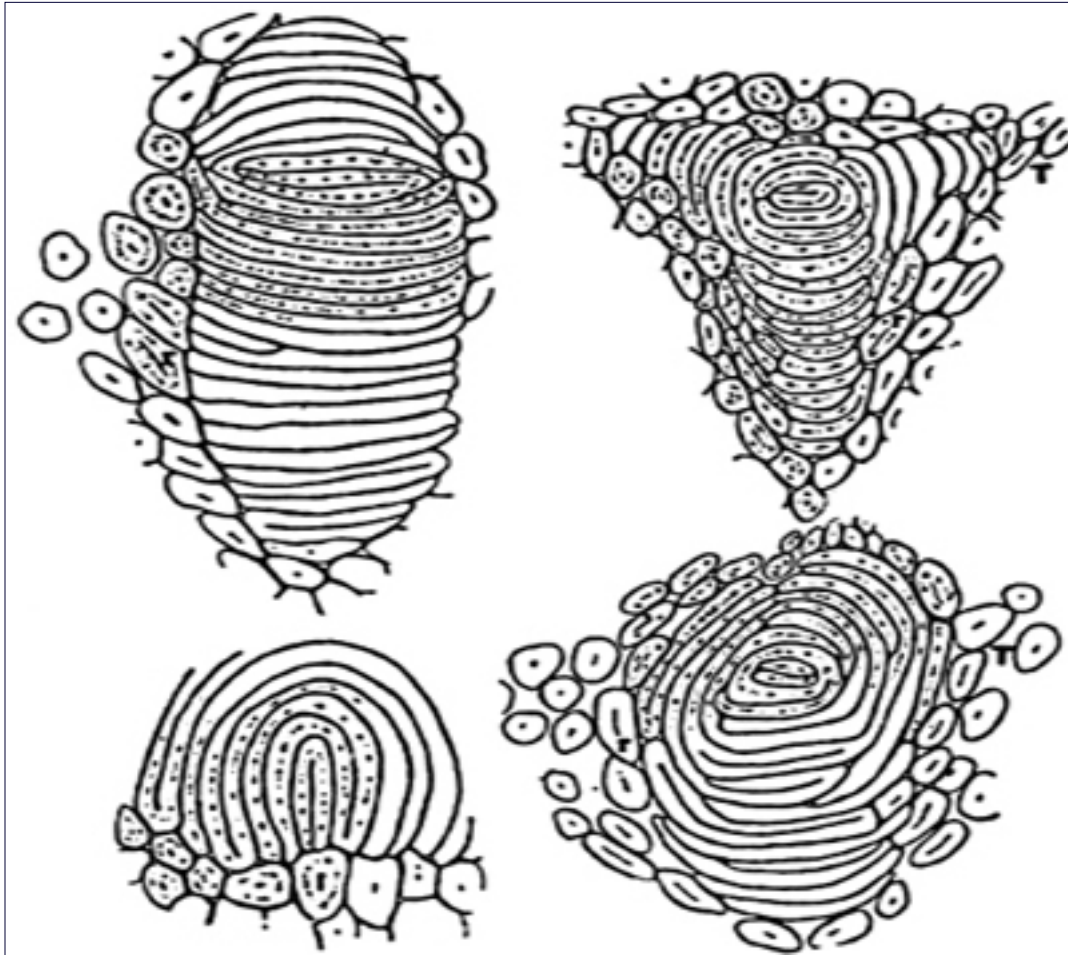
Fig. 11

Fig. 9: Drawings illustrating the relationship between epidermal warts and ridges at a triradius (a) and a pad (b). (Whipple '04)



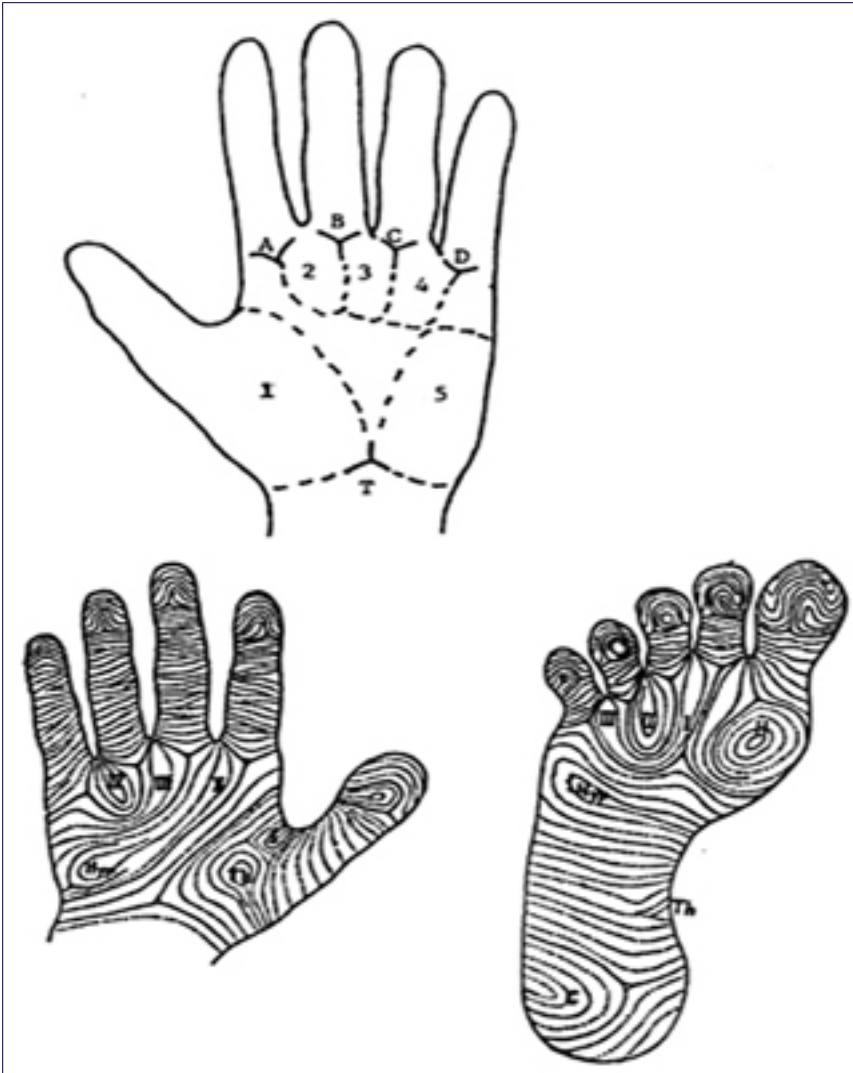
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Fig. 10: Drawings illustrating ridge pattern on various shaped pads. (Whipple '04)



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Fig. 11: The volar pad locations are centres of disturbance in the ridge configuration of the palmar and plantar surfaces.



1, 2, 3, 4 and 5 illustrate the volar pad locations in humans. A, B, C, D and T illustrate the usual palmar location of triradii.

Walking Pads On The Human Fetus

Harold Cummins Ph.D., an Anatomy professor at Tulane University School of Medicine in New Orleans Louisiana, published a paper in 1929 entitled "The Topographic History of the Volar Pads In the Human Embryo". Cummins describes the recapitulation of the volar walking pads in the development of the human fetus. He reports that the human fetus still passes through some of the stages of its' evolutionary process and this includes the appearance of walking pads.

At about the 6th week of fetal life, volar pads appear in their typical arrangement, 5 pads on the fingers, 4 pads at the base of the fingers and 2 pads on the palms.(Fig. 12) When the pads first begin to appear on the hand, the fingers are just scallops. Pads continue to develop until about the 13th week. Around this time the pads start to regress. At the same time that the pads start to regress, the friction ridges begin to form on the underside of the epidermis in the generating layer. Cummins goes on to describe how the physical aspects of the growth and size of the volar pads affects ridge development and alignment.

From Cummins paper, it can be said that the volar pads still appear on the human fetus. That the time of their appearance and regression may affect ridge formation, ridge alignment and pattern shape. Other physical disturbances such as a disease or other birth defects has also been reported to affect pattern shape and ridge formation in their initial development stage.



Fig. 12

Fig. 12: Volar pads appearing on a 17 mm. fetus (Top) and volar pads appearing on a 24 mm. fetus hand (left) and foot (right). (Bottom)



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Friction Ridge Formation

An associate of Cummins, Alfred Hale, Ph.D., also from Tulane University, published a thesis in 1952 entitled "Morphogenesis Of The Volar Skin In The Human Fetus". Hale's paper describes the formation of friction ridges. Understanding the formation of the friction ridges is the key to a comprehension of why two areas of friction skin will never be found to be the same.

Hale examined thin slices of skin, cut in cross-section to the friction ridges, from the fingers of fetuses at different stages of development. Cross sections of skin were placed on microscope slides and stained for better viewing. Various stages of ridge development were then revealed.

At about three weeks of life, the fetal epidermis is one cell thick. The epidermal cells divide and proliferate causing a thickening. Around the 12th or 13th week, ledge-like formations start to form on the bottom of the epidermis next to the dermis. The cells along the ledges proliferate rapidly.(Fig. 13A) These initial ledges are the origin of the surface friction ridges and are called primary ridges.

Primary ridges develop pores.(Fig. 13B-C) The proliferation of cells, that form the primary ridges and pore structures, expand downward into the underlying dermis similar to a carrot or beet growing into soil. Once mature, these primary ridges replenish skin cells needed to maintain surface friction ridges. Primary ridges, therefore, lie underneath surface friction ridges.

A second group of ledges also appear on the bottom of the epidermis between primary ridges.(Fig. 14) These basically develop in the same manner and are called secondary ridges.

The secondary ridges do not develop as large as primary ridges and do not form pore structures. Secondary ridges lie under the friction ridge furrows and supply skin cells to these areas.

The areas of dermis not displaced by the formation of primary and secondary ridges were left protruding up into the epidermis. These areas form the papillary pegs. They appear as double rows on the surface of the dermis and follow the path taken by the surface friction ridges.(Fig. 14)

The initial morphological formation of the primary ridges are as individual units, each developing a pore. As the ridge units are growing, they also fuse together. The units start to develop at various times and at different locations on the volar surface. This random ridge unit development creates stresses and pressures which affect ridge alignment and shape.

The overall friction ridge volar pattern is also subject to these genetic and physical factors. Heredity dictates that volar skin will form friction ridges, also that the friction ridge pattern will follow a genetic master plan which involves volar pads. The formula is carried in our genes. The degree of divergence from the master plan depends on many stimuli, the prominence and attitude of volar pads, genetic factors and other physical influences.

Closely related people have a greater chance of having a similar genetic code that controls the appearance and development of the volar pads. This results in pattern shapes that may appear to be passed from parent to child. However, even when closely related the physical and genetic variations seldom coincide to such a degree that all pattern areas display similar ridge configuration.

This can be illustrated by examining friction skin patterns of monozygotic twins. Identical twins have the greatest opportunity to have the same genetic variations and to experience the same physical variations during friction ridge formation. In some cases, the patterns from identical twins are similar; but in just as many other cases, they are not. Even though heredity may play a role in the appearance of the overall ridge configuration, it cannot and does not affect individual ridge unit alignment during growth. Ridge alignment, ridge shape, minutiae location and the location of pores openings on the ridge unit, all evolve randomly.

At about the fourth month, differentiation takes place. The ridge design is unique and immutable from this time on. Primary ridges have now proliferated enough that cells moving upward are starting to accumulate at the surface to form friction ridges. A vertical stress is evident between secondary ridges and the surface. This stress develops during secondary ridge formation and appears to secure furrow locations in the epidermis.

There are hundreds of ridge units in a small area of friction skin. The number of ridge units present can be identified by the number of pores. Each unit is approximately as long as it is wide. All ridge units have been subject to genetic and physical pressures while growing. The plethora of genetic and physical variances, during friction ridge formation, is the reason why no two areas of friction skin will ever be found to be the same, even in a small area. The variables involved are far to great.



Fig. 13A, 13B, 13C

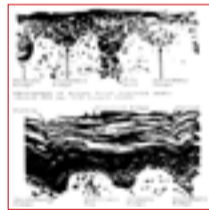


Fig. 14

Fig. 13A, B, C

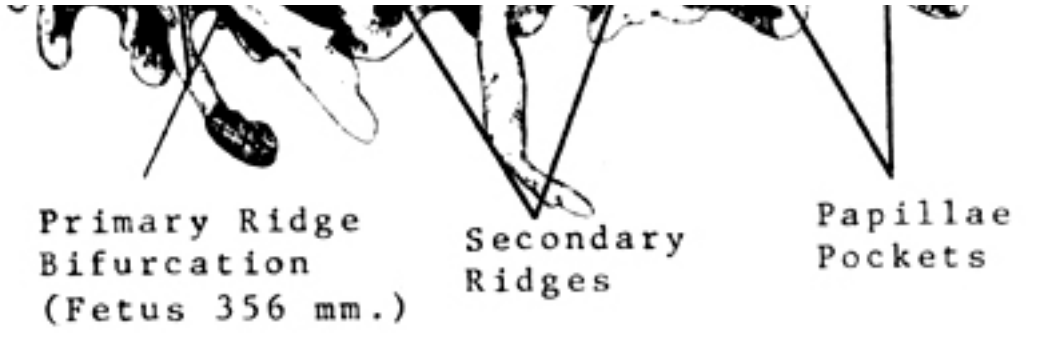


Primary ridges forming on the bottom of the epidermis.
(Fetus 100 mm. Crown/Rump length)



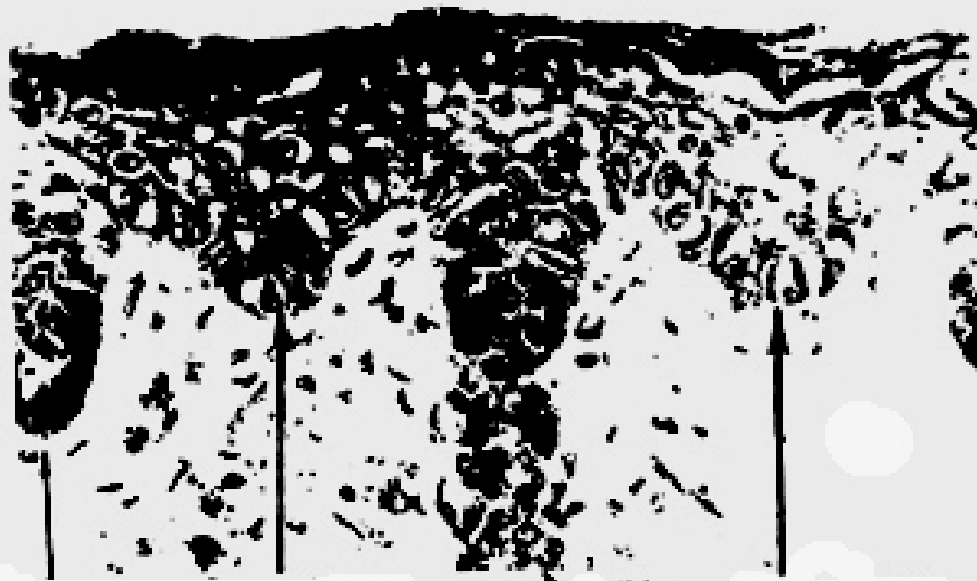
Primary Ridges with Pores. Secondary Ridges
(Fetus 120 mm.)





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Fig. 14



Primary Ridge Secondary Ridge Pore Duct Secondary Ridge

Photograph of actual fetal friction skin.
(Fetus 205 mm. C/R length X 600)



Secondary Ridge Papillary Peg Primary Ridge Secondary Ridge

Stress between the secondary ridge and the surface is evident below the furrows. This stress occurs at the time of differentiation.
(Fetus 200 mm. C/R length X 600)

Subsequent Ongoing Research

During the last twenty five years, there have been numerous scientific papers published about friction skin. In many cases this subsequent research confirmed and enriched the results of earlier studies. A great deal of information is found in recent scientific papers dealing with sciences such as dermatoglyphics, anatomy or genetics. They often explain many aspects of friction skin growth, heredity and friction ridge pattern development. Once surfaced, these scientific facts can be applied to friction ridge identification.

Michio Okajima, Ph.D., a professor from Japan, published one such paper in 1976 entitled "Dermal and Epidermal Structures Of The Volar Skin". Okajima describes how the dermal papillae of a young person is usually in orderly double rows under the surface of friction ridges.(Fig. 15A) However, when he examined the fingers of mature adults, he found that the papillae were no longer in orderly double rows and that they had increased in numbers. (Fig. 15B-C)

This discovery did not affect the immutability of the primary ridges or the resulting surface friction ridges due to the fact that they are generated in the epidermis and not the dermis. However, the surface of the dermis of an older person may display a more confused arrangement of papillae pegs. Knowledge of Okajima's research and of primary ridge folds on the dermal surface will help in any comparison of the dermal surface.

Okajima also examined incipient ridges, which are often called false ridges. Incipient ridges are immature ridges that have not fully formed at the time of differentiation. This fact has been established by various researchers over the years including Wilder, Cummins and Hale. The cause of incipient ridges is believed to be genetic origin.

Okajima found the dermal papillae structure under incipient ridges the same as those found under fully developed ridges, except that they are miniaturized. The size of these structures would of course depend on the stage of development at differentiation. Incipient ridges are therefore an immutable formation on the friction skin.

Numerous other related research papers on a variety of topics are available for study and research. Information describing how the volar pads affect pattern design, the dissociation of friction ridges, flexion creases, white lines and others too numerous to mention.

In an applied science, witness' expertise are in part judged by their references. An explanation of why all areas of friction skin are different is more significant if a reference to Hale's paper and its contents can be given. The pat answers, usually accepted at face value by the courts, have a solid foundation in science. It is the responsibility of all forensic identification specialists to be cognizant of that information.

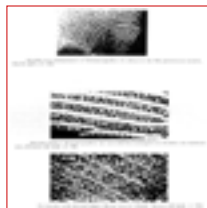


Fig. 15A, B, C

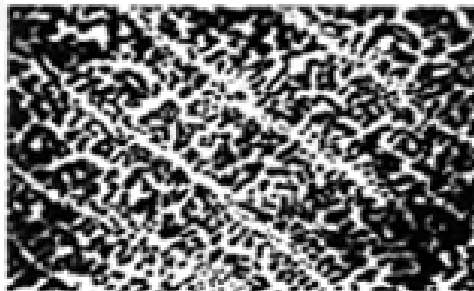
Fig. 15A, B, C



Double-row arrangement of dermal papillae of a fetus in the 8th gestational month, thumb apex. (x 20)



Dermal surface. Dermal papillae are crowded but arranged in a double row; hallucal area, 82-year-old male. (x 20)



Extremely wide dermal ridges in an area of a hand, 76-year-old male. (x 20)

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COMPARISON OF FRICTION RIDGES

Visualizing The Comparison

Friction ridge identification is an applied physical evidence science. Comparison and evaluation of friction ridge formations take place in the brain of the examiner. The medium for transporting the information from the physical realm to the mental realm are the eyes. How we see is important to forensic identification investigators because of the ease that exterior stimuli or improper procedure can affect what we see or think we see.

The eye is often described as being camera like. This is an extreme over simplification of the visual system. The eye is actually an extension of the brain. The statement "I think I see what you mean" is literally correct. We see with brain waves. Light from an object strikes the retina and creates electrical impulses which are carried to the brain by the optic nerve. The coded neural message arrives as an hypothesis. A comparison between the new hypothesis and neural coded messages already stored in memory result in an identification or recognition of the object.

The hypothesis concept can be demonstrated with the Necker Cube. A small circle on the side of the cube is first seen in one location and then another. The brain continues to organize the object after the first hypothesis has been identified. This creates several versions of the same image. There is no real answer to the puzzle. (Fig.16)

Two memory levels exist in the brain, long and short term memory. Long term is the main storage area. Short term is for thoughts we only want to remember for short periods. Friction ridge comparison usually takes place in short term memory. In instances where several hours or days are spent examining the same friction ridges, some information may trickle into long term memory. Friction ridge configuration can often be remembered months later in these cases.

Senses such as touch, smell, sound, past knowledge and subjective information assist us in identifying or recognizing things. An example of past knowledge is in the way a young child learns to recognize new objects. After neural storage, whenever the child sees that object it is identified as soon as its neural coded message reaches the brain.

Other inherent idiosyncrasies are also of interest. The brain attempts to organize all it sees. When a pattern of evenly spaced dots is examined the brain attempts to organize them into squares and vertical or horizontal lines. Concentration on one dot cannot be maintained as peripheral dots are continually included. This illustrates how the brain sees areas as opposed to specific points. (Fig. 17)

Some degree of artistic license can be taken by the brain when examining simple objects. Plain lines may be recognized as full blown figures when very little detail is actually present. This peculiarity is a cartoonist's forte. The six simple lines in, figure 18, may be seen as a person on their knees washing a floor with a bucket or as several other images.(Fig. 18)

Understanding the peculiarities of the brain ensures that we will not subject ourselves to exterior stimuli during comparison that would cause interference with our perception of things. Comparisons should be done in a stable environment and not attempted when mentally fatigued. All examiners have had the experience of leaving a difficult comparison at the end of the day feeling that an identification was remote only to reexamine the ridge detail the following day and form an opinion in minutes.

Exterior environmental stimuli such as noise distractions, investigator pressure or subjective investigative details may also affect the objectivity of the comparison. Removing or correcting these stimuli will improve the impartiality and quality of the comparison and decrease the opportunity of an error in judgment.

A common comparison procedural error often results in what is referred to as mind set. Set occurs when a clear image is examined first and its detail is stored in memory. This mental image is then compared to an unclear shape. The brain may use its organizational abilities to find the clear shape in the unclear detail, even though it may not be present.

To ensure set does not occur during the comparison of friction ridges, it is common practice to examine the

unknown ridge detail first. This ensures an uncontaminated analysis of the unknown subject and the comparison to the known can be carried out under the best conditions possible.

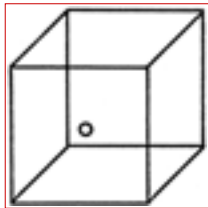


Fig. 16

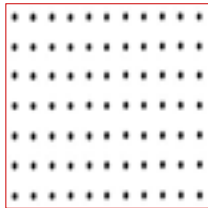
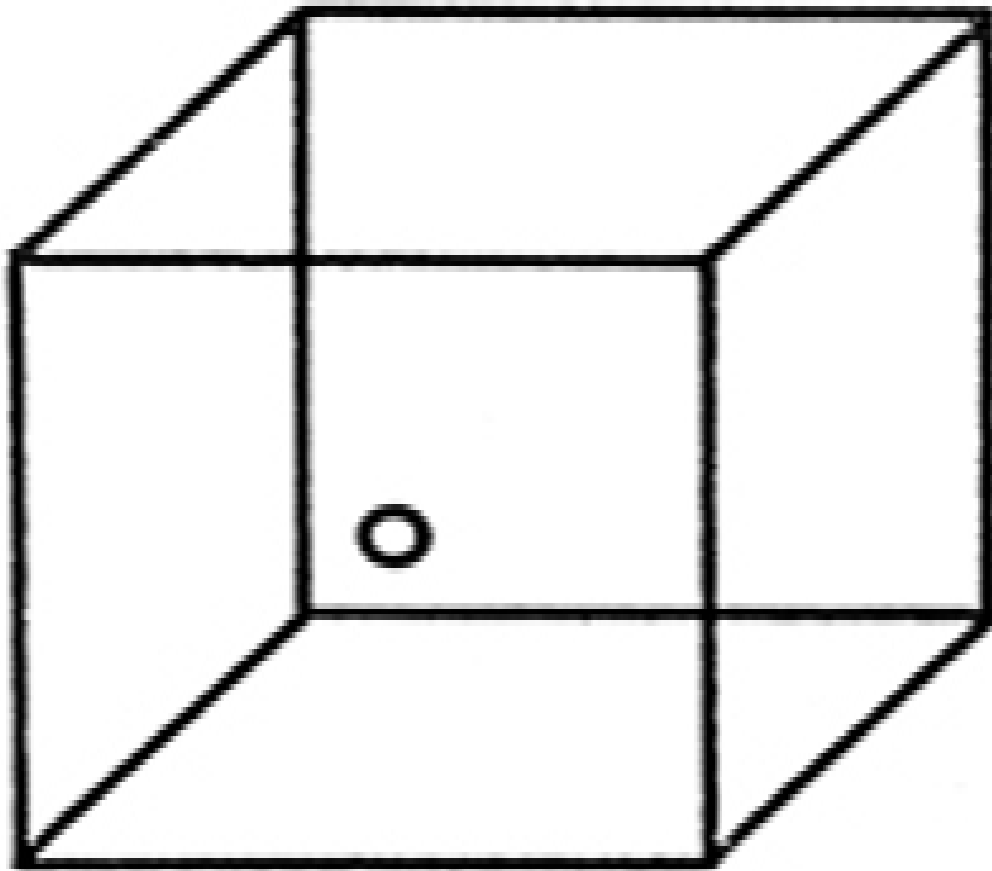


Fig. 17



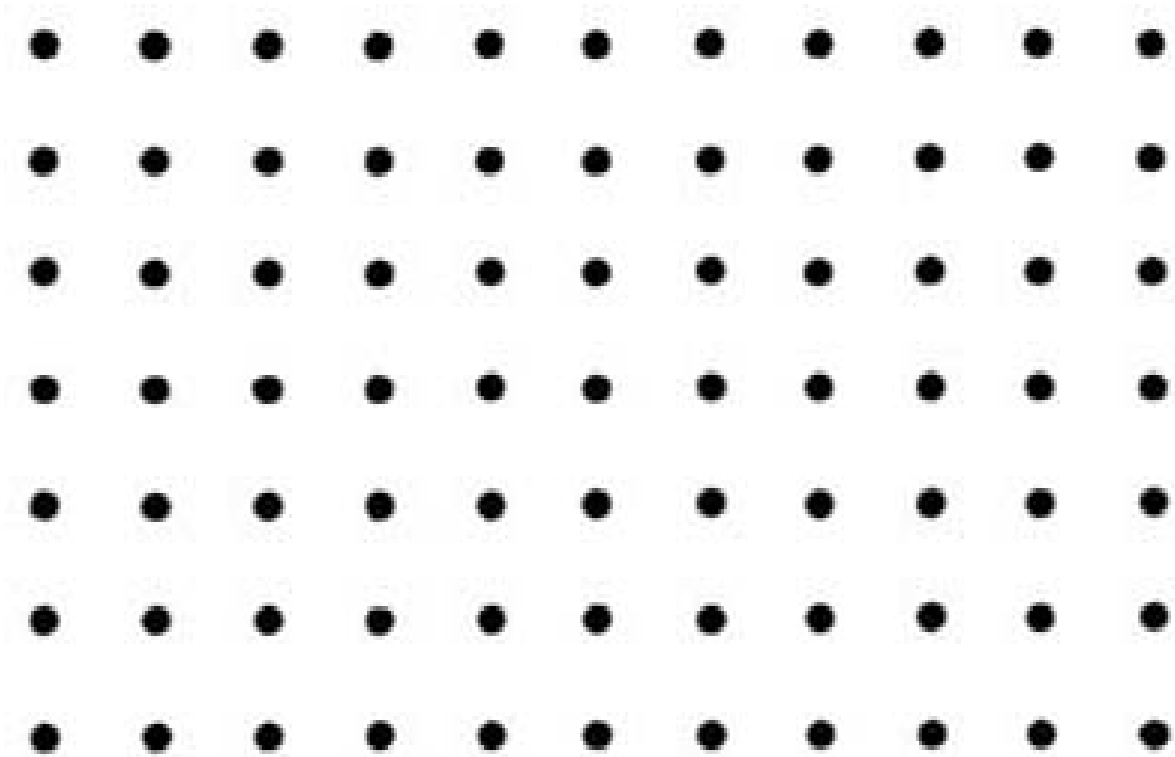
Fig. 18

Fig. 16: This figure alternates in depth: the face of the cube marked by the small circle sometimes appearing as the *front*, sometimes as the *back* face. We can think of these ways of seeing the figure as perceptual 'hypotheses'. The visual system entertains alternative hypotheses, and never settles for one solution. This process goes on through normal perception, but generally there is a unique solution.



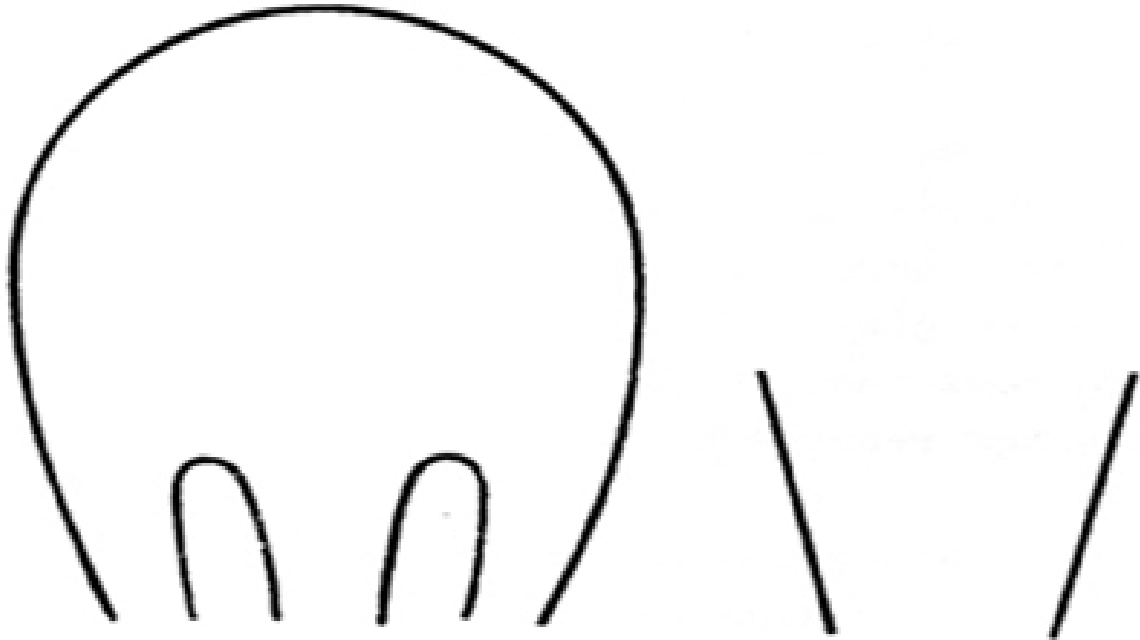
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Fig. 17: This array of equally spaced dots is seen as continually changing patterns of rows and squares. We see something of the active organising power of the visual system while looking at this figure.



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Fig. 18: A joke figure-what is it? When you see an object, not merely meaningless lines, it will suddenly appear almost solid-an *object*, not a pattern.



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Scientific Basis

Friction ridge identification is based on the fact that ridge structures do not change from birth to death, except with injury or disease and that they possess an infinite variety of detail that is not repeated in other areas of friction skin. The information supporting this was discussed in the sections dealing with the Historical Review, the Mandate For Ridgeology and The Friction Skin.

The seasoned forensic identification investigator not only requires knowledge in these areas of science and but also experience. Experience or practice is gained initially from a formal training course. Exposure after training perfects the ability to recognize and evaluate unique ridge structures. Knowledge of this type can only be acquired by examining thousands of friction ridge prints. The scientific facts, established by researchers and early pioneers, are confirmed through personal observation. It is our responsibility to be aware, understand and apply that knowledge.

Philosophy

The purpose of the identification process is to individualize. This is done by comparing the similarities of details between an unknown person, thing or mark to a known person thing or mark. The details examined during the comparison will either be a class characteristic, which may be common to others of the same strain, or a unique or randomly placed characteristic, which is unique to the single person or thing. At times class characteristics, when encountered in the aggregate, can create a unique formation.

The source of the class and unique characteristics can be either biological or manufactured. Class characteristics found in the friction skin are the result of genetic programming while the class characteristics of metal are man-made. Unique characteristics of friction skin are created due to the random growth of the friction ridges, while unique characteristics of metal, during a physical match, are the results of an accidental break or damage. In either case, the presence of unique characteristics or formations is a requirement for the comparison to result in individualization.

This philosophy of identification was addressed by Chief Superintendent R.A. Huber, B.Sc. in R.C.M.P. Gazette (July/August 1972). In his article entitled "The Philosophy of Identification," Huber stated, "When any two items contain a combination of corresponding or similar and specifically oriented characteristics of such number and significance as to preclude the possibility of their occurrence by mere coincidence, and there are no unaccounted for differences, it may be concluded that they are the same, or their characteristics attributed to the same cause.

During the comparison more individualizing power is allotted to the smaller detail found in agreement. It is the tiny details that cause similar objects to be different. The closer an object can be examined the less chance there is of finding similar details. In monozygotic or identical twins, large features are basically the same, but comparison of smaller features differentiates between them. This is especially true when friction skin is compared. Friction skin is the most variable area of the human body and the difference between the twins becomes immediately apparent.

Comparison of friction ridge prints however adds another dimension that must be looked at during examination. Unlike examining broken objects or the friction skin itself, friction ridge prints are found in varying degrees of clarity. Clarity of the print dictates the quantity of detail present for comparison and evaluation.

Three levels of detail exist that may be found in a friction ridge print with today's developmental technology. The first level of detail is pattern or ridge configuration which is a class characteristic.(Fig. 19A) The second level is type and position of minutiae which are a unique formations.(Fig. 19B) The third level is shape of minutiae, shape of individual ridges, presence and location of pores.(Fig. 20)

A print found at a crime scene may have one, two or all three levels of detail, depending on its clarity. Often the various detail levels are present to varying degrees in different parts of the same print. Clarity, quality and quantity of unique detail dictates the friction ridge area size required for individualization.

When an opinion has been reached that the unknown and known print have a common origin, the conclusion must also include the fact that the print could not have been made by any other area of friction skin. When this

has been established, it can be said that the friction ridge print has been identified to an individual. The opinion of identification is therefore reached when two criteria are satisfied. The unknown and known prints have detail that indicates they have a common origin and there is sufficient uniqueness about the detail that prohibits any chance another area of friction skin could have made the print.

During comparison areas of friction ridge are compared and evaluated as individuals and in a group. The comparison must be carried out in sequence to allow the individual values to be accumulative. Should sequence be broken, another comparison starts. When comparing friction ridges it can therefore be said, **THAT IDENTIFICATION IS ESTABLISHED BY THE AGREEMENT OF FRICTION RIDGE FORMATIONS, IN SEQUENCE, HAVING SUFFICIENT UNIQUENESS TO ESTABLISH INDIVIDUALITY.**

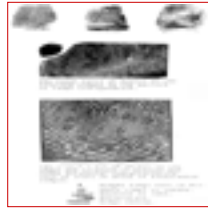


Fig. 19A, 19B

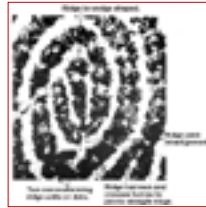


Fig. 20

Fig. 19A, B

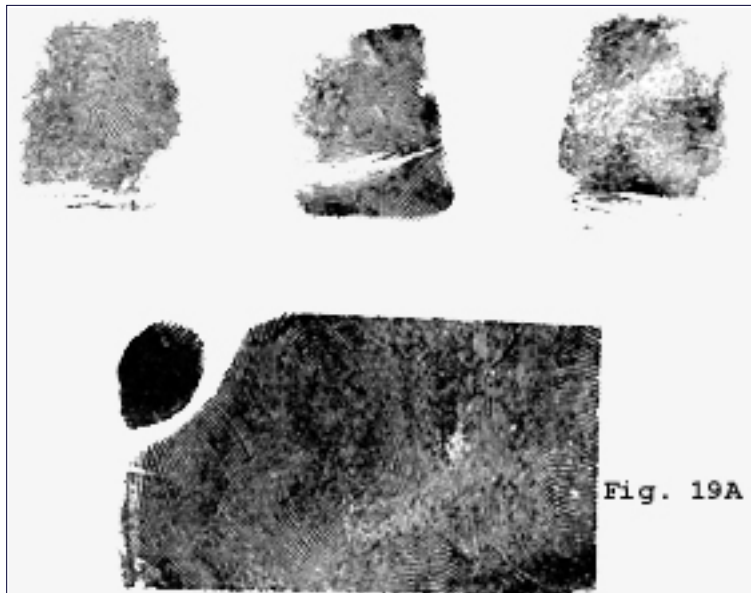


Fig. 19A

The first level of detail on the friction ridges is the pattern or ridge configuration.

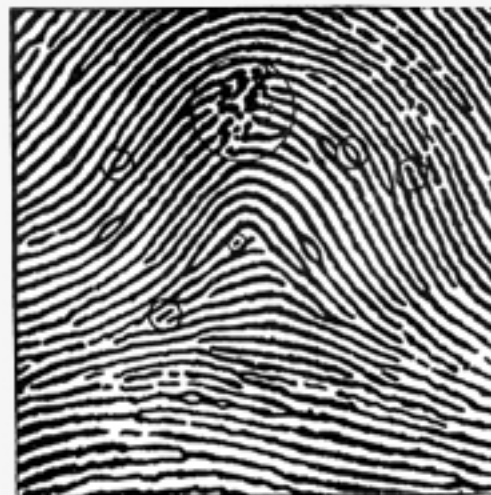
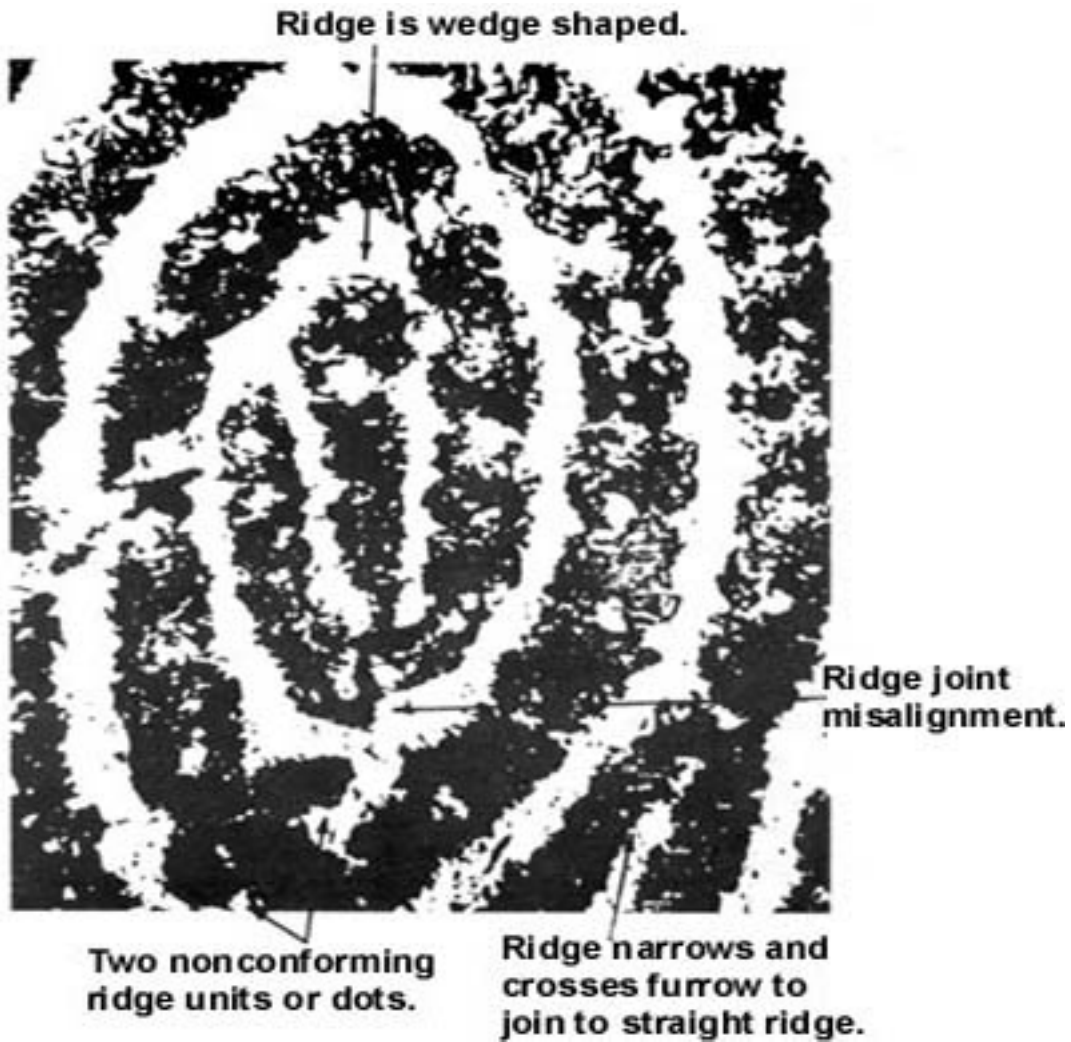


Fig. 19B

The second level of detail is the shape and location of minutiae and other accidental characteristics such as scars or areas of dissociated ridges.

- Single ridge unit or dot.
- 1 Short ridge or island.
- o Encloser or lake.
- Y Bifurcation
- | Ridge ending.

Fig. 20



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Methodology

The identification process, regardless of the subject matter, passes through three stages during the course of an examination. Analysis, Comparison and Evaluation.

ANALYSIS - The unknown area of friction ridges must be examined and reduced to its basic components.

The analysis of an unknown area of friction ridges establishes specific comparison information about them. The digit or area of volar surface suspected of making the print is determined. The prints clarity and the number and variety of details present are established. Only after the unknown friction ridges have been fully examined does the comparison to the known friction ridges take place. You must know what detail is there.

COMPARISON-The properties or basic components of the unknown area of friction ridges, established during analysis, are compared to the known area of friction ridges.

The comparison starts at a common location in the unknown and known prints. Pattern centres, triradii or minutiae are commonly used. Areas of ridge formation around the minutiae are compared as to their location, shape and relative position to each other. The comparison progresses unknown to known, systematically and sequentially until all available ridge detail has been compared.

EVALUATION - Similarities or dissimilarities in the ridge structure will each have a specific value or weight that is applied toward establishing the individuality of the area of friction ridges.

The evaluation of friction ridge detail takes place during comparison. Various evaluations are taking place at the same time. The first is the rarity of the overall pattern or class characteristic. Next an evaluation of unique characteristics on the ridges, such as the minutiae. Ridges between minutiae, which do not contain specific minutiae, are called open fields and must also be considered.

Open fields are compared and evaluated the same as minutiae. A lack of a ridge characteristic at a specific ridge unit does not mean it has no value. Ridge units within open fields formed in the same atmosphere of random possibility as those within minutiae. Open fields are unique due to a lack of minutiae, especially conspicuous are very large ones.

In clear prints, smaller details may be visible along the ridges for comparison. Alignment, misalignment or shape of individual ridge units, create discernable formations. These formations are immutable and unique but are not minutiae. Improvements in development technology very often provides this level of detail for our scrutiny.

The clearer the friction ridges available for comparison, the greater the opportunity there may be to compare and evaluate minute detail. The more minute detail found in agreement, the greater the individualizing power of that area of friction ridge. The more obscure and undetailed the ridge structures the less individualizing power it has. It is therefore possible for an opinion to be formed on differing areas of friction ridges due to the quality of the friction ridge structures and the quantity of the ridge details present.

Evaluation of ridge detail may also be affected by the Forensic Identification Investigator's level of knowledge and experience. With the recognition that clarity affects the value of ridge details comes the problem of establishing just how clear a particular print is? This assessment skill is enhanced by ones experience and knowledge of the science.

Inexperienced forensic identification investigators may have difficulty assessing clarity. When one starts making identifications, all fingerprints are evaluated as though they are at the unclear end of the clarity spectrum. Unclear prints display large accidental formations with little intrinsic shape. In these instances identifications are based more on quantity. The recognition of quality develops with experience. Forensic identification investigators, having varying degrees of knowledge and experience, perceive the comparison differently. This also affects the size of friction ridge area required for individualization.

Different levels of knowledge and experience coupled with available quality and quantity of ridge detail dictates that a preset number or size of ridge detail cannot be established as a basis for identification. Examiners of

equal experience and training should arrive at an identical conclusion when comparing the same area of friction ridges.

VERIFICATION - The opinion of the forensic identification investigator must be verified by another equally qualified examiner.

Verification is not a part of the identification process. It is a very important part of the scientific process. The friction ridge identification science has prided itself on the fact that errors are not acceptable. To ensure this high standard of excellence is maintained, the Royal Canadian Mounted Police verify in writing, one identification for each form of evidence and each person identified.

EDGEOSCOPY

Edgeoscopy first came to light in 1962 with a paper by Salil Chatterjee of India. Chatterjee envisioned an identification process where characteristics along the ridge edge would be compared and evaluated for identification purposes. He listed various characteristics that he suggested be used for this purpose.(Fig. 21) These characteristics are the result of the alignment and shape of the individual ridge units as well as pores close to the edge of the ridge which appear as notches. These shapes are only evident when the friction ridges are very clearly reproduced.

This type of ridge shape has already been discussed earlier in this paper. The brain's natural ability to compare shapes includes these details when comparing the areas of friction ridge detail. Isolating the edge shapes and evaluating them by themselves would be counter productive to the philosophy of evaluating ridge shapes in the aggregate.(Fig. 22)

Even though edgeoscopy is already considered during the comparison and evaluation of friction ridges, a Forensic Identification Investigator should be aware of the principals behind Chatterjee's philosophy. This knowledge will assist the specialist in the evaluation of friction ridges and with establishing one's credentials before the courts.

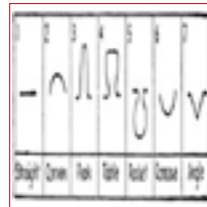



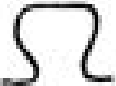





Fig. 21



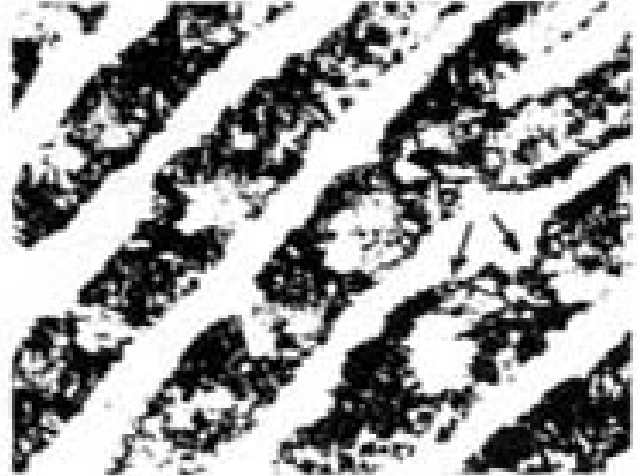
Fig. 22

Fig. 21: Chatterjee felt that the shapes found in sufficient numbers along the edge of the friction ridges could be used for identification.

1	2	3	4	5	6	7
						
Straight	Convex	Peak	Table	Pocket	Concave	Angle

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Fig. 22: These shapes are already addressed by the brain during comparison. If sufficient clarity is present these small shapes give the ridges a distinct character (below).



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POROSCOPY

The science of Poroscopy was established by Dr. Edmond Locard of Lyons France in 1912. Locard was of the opinion that friction ridges could be identified by comparing pores. Locard suggested identification could be based on the size, shape, relative position, and frequency of appearance of pores. In his opinion agreement of between 20 to 40 pores was sufficient for a positive identification.

Studies by myself and others have found pore structure does not record accurately enough in inked or crime scene prints to facilitate this type of absolute comparison and evaluation. Locard presented one case in court in which he stated that identification was based on pores. The print that Locard illustrated contained a large number of minutiae detail which would have been sufficient for an identification.(Fig. 23) In my opinion Poroscopy, as Locard envisioned it, is not a practical identification science at this time.

The technology used today to develop friction ridge prints has improved to the point where pores are appearing frequently in ridge detail from crime scenes. This phenomenon has cleared the way for the use of one of Locard's ideas. The comparison of relative pore locations along friction ridges is now a feasible method of evaluating ridge detail in conjunction with minutiae.

Scientific information available to us clearly establishes the immutability of pore position along ridges of friction skin. When comparing pore position in a friction skin print the examiner will have to address fill in or failure to record and some pressure distortion of the pores. Locard felt an occasional filled in pore could be overlooked as long as the pore location was not obviously situated elsewhere on the ridge segment. From my research and experience I have found pressure distortion is not a factor in altering pore location as long as the area compared is confined to a small segment of ridge.

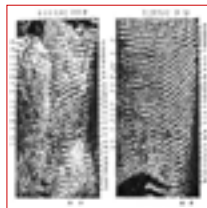
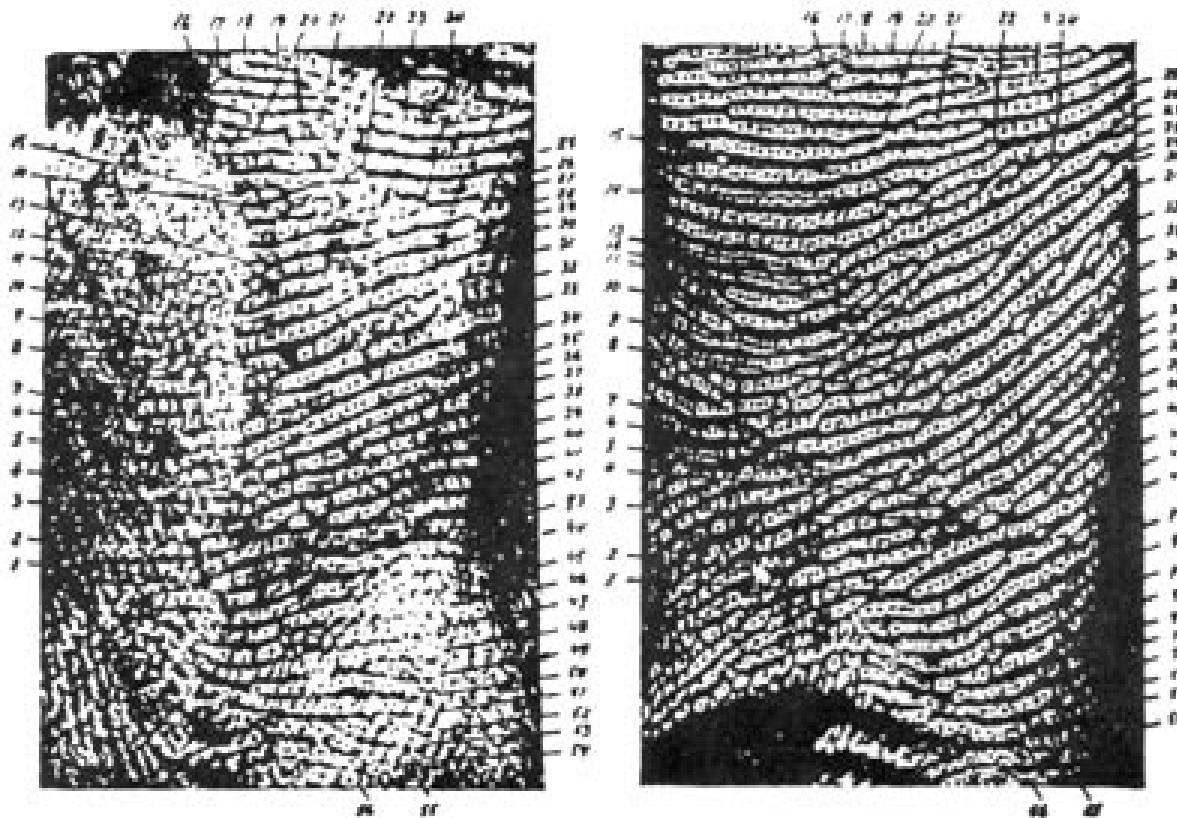


Fig. 23

Fig. 23: Locard's chart from his one court case. Many minutiae are present within the ridge detail .



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Poroscopy (Cont.)

I followed two procedures during ridgeology research when comparing relative pore position. The first was used when pore locations were being compared on or next to a minutiae. I found that relative position of the pores on minutiae could be assessed at the same time that the minutiae was being evaluated for ridge shape. Pores situated very close to the minutiae focal points were compared visually. Ridges immediately adjacent to the minutiae were also compared in a similar manner.(Fig. 24)

In open fields pore locations were compared in a different way. In these areas I used an overlay method. With the overlay process, photographic enlargements of the prints are systematically examined ridge segment at a time. Each segment compared was related to a minutiae, directly or indirectly, by moving across furrows at known locations and along ridges pore at a time, to maintain sequence. Ridge configuration, pattern, minutiae type, minutiae shape and relative location, as well as the correct number and shape of intervening ridges or open fields, has already been established by the agreement of level one and level two detail. Establishing that relative pore location is also in sequence permits the evaluative weight to be accumulative.

During comparison a piece of clear plastic is placed over each enlarged unknown and known photographs securely. Clear document protectors work well. A starting point is marked on the plastic above a ridge to be examined on the unknown photograph. Each segment of ridge compared is numbered starting at number 1. A second piece of overlay plastic is placed over the unknown photograph. The number, location of a nearby minutiae, pore locations and other various shapes along the selected ridge are marked onto the overlay plastic.(Fig. 25)

The overlay plastic is then placed over the known photograph. The ridge being compared is located by the minutiae. A corresponding number is marked on the unknown plastic. The relative pore locations are then compared and evaluated.

Thus far, a corresponding number has been marked on the unknown and known plastic coverings in a common location and on the overlay plastic sheet. Surrounding the numbers on the overlay sheet are the symbols representing pore locations and any other information recorded in that segment of ridges. The process is repeated until all the available pore structure has been compared. The completed overlay would have consecutive numbers down the sheet with symbols clustered around each.

Various symbols can be used to indicate what type of detail, pressure or fill was encountered at pore locations and along the ridges. I use circles to mark pores, slash marks to indicate ridge breaks and mark ridge notches according to their shape. I combine minutiae location and number by putting the number in a triangle.

The agreement of relative pore position has considerable value in establishing the individuality of an area of friction skin. This is an example of the significance of the principle that the more minute the characters relied upon the greater becomes their individualizing power. The issue is not whether a specific sequence of pores can be found in another location or print. The issue is can this sequence of pores be found in the same location in another print that has the same ridge configuration, same type of minutiae in the same relative positions, having similar ridge shape all in the correct relative position this specific pore sequence.

There are numerous pores in a very small area of friction skin. Each pore location in agreement adds to the improbability of duplication ever happening in another print. All randomly formed details are considered not only for their relative position to each other but also in the overall aggregate. (Fig. 26)

Comparing relative pore position is a new technique that requires further practical application to establish an acceptable manner to illustrate the comparison. There is ample scientific basis to support its use but the availability of pore detail in crime scene prints and the logistics of the comparison process will limit its use to specific cases. When clear ridge detail is present and there is a need to examine all of the available formations on the friction ridges, relative pore position will represent the last level of detail that can be compared on friction ridges within the physical realm.

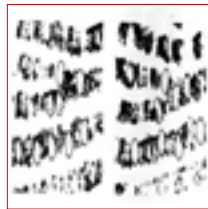


Fig. 24



Fig. 25

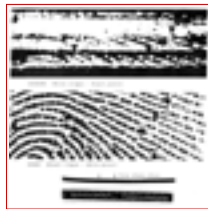
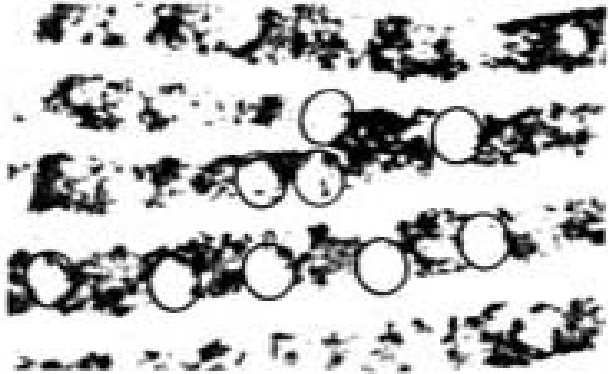


Fig. 26

Fig. 24: These two bifurcations were found in the same location on a similar pattern. Normal examination would find them in agreement, however, their pore location differs.



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Fig. 25: Copy these symbols on to a document protector and examine the relative pore locations on the illustration at the end of this section. Fig. 26. Examine the areas around the minutae left to right.

Glossary of Symbols

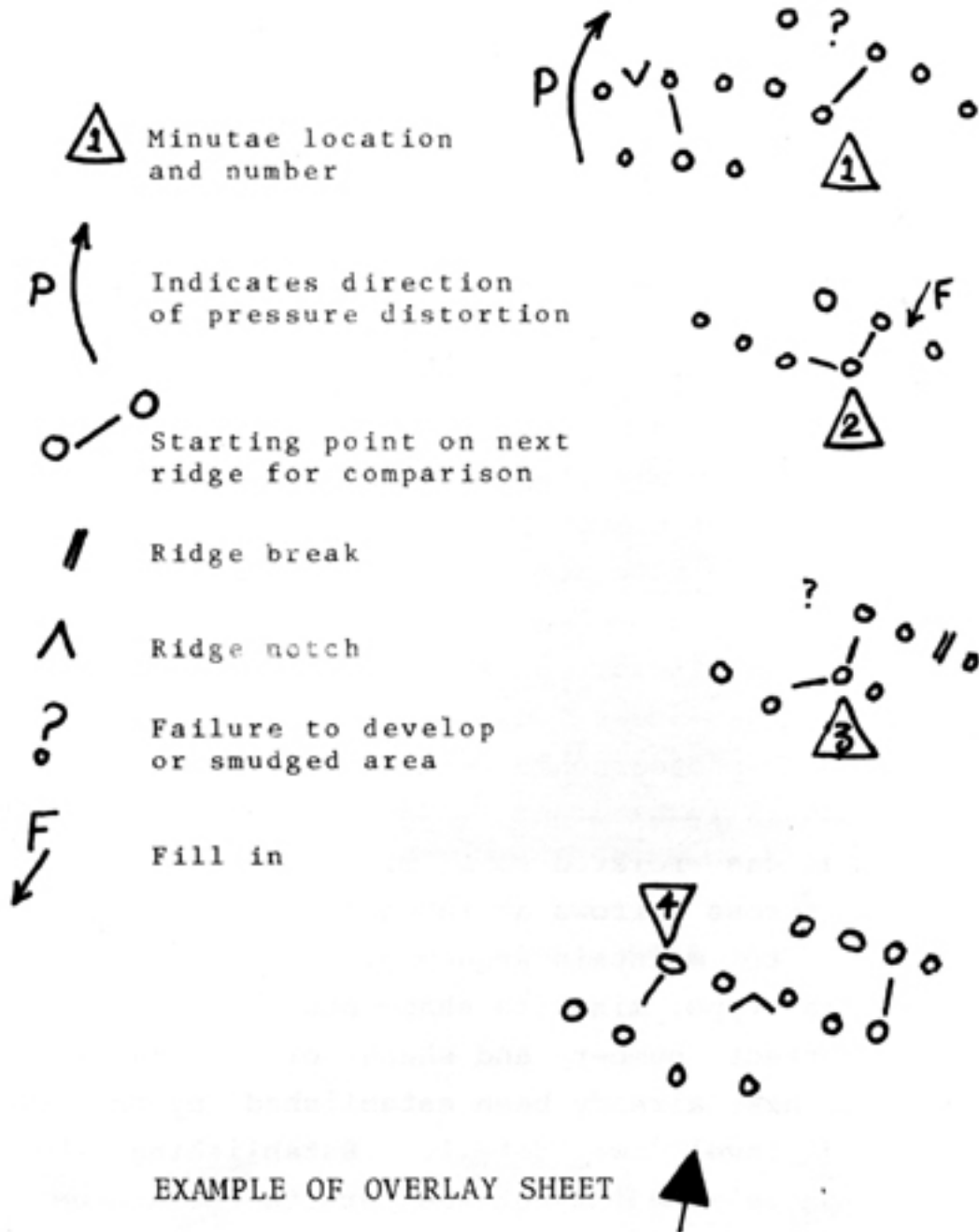
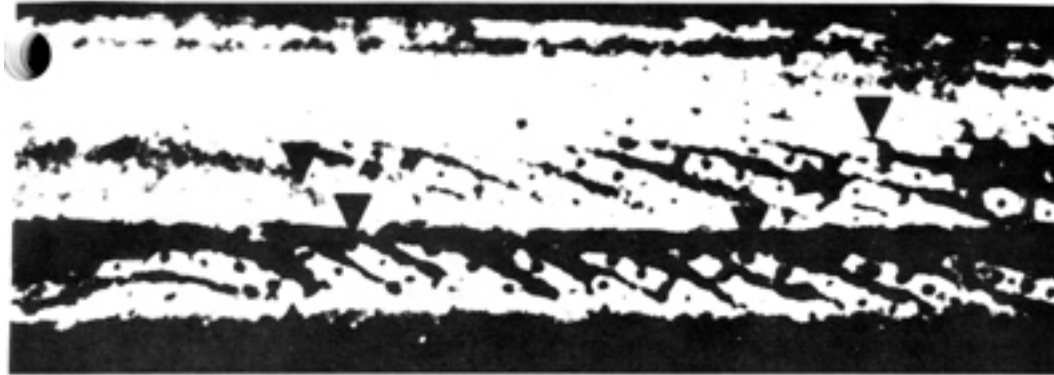


Fig. 26: The print below was developed on a telephone wire with cyanoacrylate after it was cut by a suspect during an armed robbery. Some pressure distortion is present. (Courtesy of Cst. F. Barclay, Thunder Bay Police)

Comparison of relative pore location across the bottom of the print, between the marked minutiae, can be compared using the visual or overlay method.

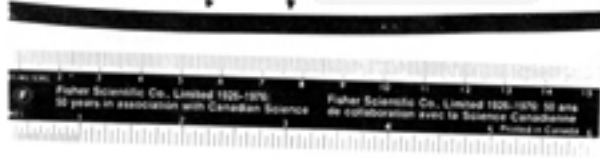


UNKNOWN (White ridges - black pores)



KNOWN (Black ridges - white pores)

↓ ↓ Area shown above



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CLOSING

Forensic identification has become more dynamic during the last few decades than at any other time in its history. The latest of technology is currently employed in various methods for developing friction ridge prints and searching fingerprints is now computerized. With all the improvements taking place within the science, it is only natural for forensic identification investigators to increase their awareness and understanding to address these changes.

Physical evidence is moving to the forefront of crime scene investigation. The value of physical evidence has not been overlooked by the judiciary. Their interest will certainly be reflected in courts of the future. Having a clear and concise explanation readily available to describe the philosophy, methodology and scientific basis of modern friction ridge identification will ensure we are prepared to meet any challenge.

Ridgeology reaffirms the status of friction ridge identification as a modern forensic science. The pursuit of understanding through continual inquiry and research will ensure the science is prepared to meet challenges of the future.

- Adams, M.S., : Palm-Prints And A Ring-D Chromosome, The Lancet, London, 1965 PP494-495
Ashbaugh, David R., Edgeology, RCMP Gazette, Vol.44, No2, 1982
----- : Poroscopy, Identification Canada, Vol9, No1, Jan 1986 P3
----- : Fingerprint Identification Today, Identification News, VolXXXIII, No9, Sept 1983
----- : Ridgeoscopy - The Time Is Now, Fingerprint Whorld, Vol8, No30, October 1982
----- : The Key To Fingerprint Identification, Fingerprint Whorld, Vol10, No40, April 1985
----- : Identification Specialist And Trainer, RCMP Gazette, Vol44, No6, 1982
----- : Ridgeology : Our Next Evaluative Step, RCMP Gazette, Vol45, No3, 1983
Bade, Win. F., : Fingerprints On Pottery Aid In Tracing Past, Science News Letter, Oct 27, 1934 PP 261-262
----- : A Manual of Excavation In The Near East, University of California Press, 1934
Bansal, I.J.S, and Shobha Rani Dhiam and Harminder Kaur, : A Study Of The Inheritance Of Palmar Mainlines, Ind.J. Phys, Anthrop. & Hum. Genet. Voll3, No3, Lucknow, 1987 PP201
Bassett, C. Andrew L., : Biologic Significance of Piezoelectricity, Calcified Tissue Research, Vol 1, PP252-272, 1968
Blake, Lieut. James W., :Identification Of The New-Born By Flexure Creases, Ident. News, Vol9, No9, Sept 1952
Blank, Joseph P., : The Fingerprint That Lied, The Reader's Digest, Sept. 1975, PP81-85
Bridgewater, B.R., : Fingerprints : The Basic Facts
Brodie, J.M., : Skin Creases And Their Value In Personal Identification.
Califana, Anthony L. and Jerome S. Levkov : Criminalistics For The Law Enforcement Officer, McGraw - Hill, New York, 1978
Canadian Police College, Fingerprints, 1977
Cassidy, Michael J., Footwear Identification, RCMP Pub. 1980
Castellanos, Israel M.D., : New Techiques Of Skin Impressions, Ident. News PP13-14
Caton, H.E., : Physical And Chemical Aspects Of Latent Print Development, F.B.I. Pub.
Chatterjee, Salil K. and Richard V. Hague : Finger Prints or Dactyloscopy and Ridgeoscopy , Calcutta, 1988
Chatterjee, Salil K., : Finger Palm and Sole Prints, Calcutta, 1967
----- : Speculation In Fingerprint Identification, Calcutta, 1983
Cherrill, Frederick R. : The Finger Print System At Scotland Yard, London, 1954
Clements, Wendell W. : The Study of Latent Fingerprints, Thomas, Springfield Illinois, 1987
Cohen, Stanley A. B.A.,LL.B,LL.M, : The Role Of The Forensic Expert In A Criminal Trial, Crim Reports, 3rd Ser Vol 1
Cooke, T.G., : Hands Of Mystery, Finger Print Mag.,Vol 31 No7, Jan 1959, PP 4
----- : Famed French Criminologist Throws Some Light On Bertillon's Use Of Finger Prints, Finger Print and Ident. Mag., May 1950
Cowger, James F., :Friction Ridge Skin, Elsevier, New York, 1983
Cummins, Harold, : Finger Prints - Normal and Abnormal Patterns, Fingerprint and Identification Mag., Nov 1967 Vol49(5) PP3
----- : Epidermal-Ridge Configurations in Developmental Defects, With Particular Reference To The Ontogenetic Factors Which Condition Ridge Direction, American Journal of Anatomy, Vol.38, No1, PP89.
----- : The Fingerprint Carvings Of Stone Age Men In Brittany, Science Mon., Vol 31, PP 273-279, 1930
----- : Ancient Finger Prints In Clay, Science Mon., Vol 52, PP 389-402, 1941
----- : Finger Prints Of Phantoms, Finger Print and Ident. Mag., Dec., 1960.
----- : Dermatoglyphics : An Introductory Review, The Interne, Nov 1949
----- : The Configurations Of Epidermal Ridges In A Human Acephalic Monster, The Anatomical Record, Vol26, No1, Aug, 1923
----- : The Skin And Mammary Glands, Morris "Human Anatomy" 10th Ed., The Blakiston Co. 1942
----- : Some Members Of N.Y. Family Lack Usual Ridge Patterns, Finger Print and Ident. Mag., March 1970
----- : Why Takeshita Lacks Patterned Friction Skin, Finger Print and Ident. Mag., May 1950
----- : Loss Of Ridged Skin Before Birth, Cummins Collection, Tulane University, New Orleans Louisiana
----- : Skin, Cummins Collection, Tulane University, New Orleans, Louisiana
----- : Underneath The Finger Print, Cummins Collection, Tulane University, New Orleans, Louisiana
----- : The Anatomy Of Research, Cummins Collection, Tulane University, New Orleans, Louisiana

----- : The Topographic History Of The Volar Pads (Walking Pads; Tastballen) In The Human Embryo, Contributions to Embryology, Carnegie Inst., Wash, Pub No 394 PP103-126 1929

----- : Harold Cummins Explains Some Mighty Curious Ridge Patterns, Finger Print and Ident. Mag., Oct 1960

----- : Dermatoglyphics : A Brief Review, The Epidermis - Chapter 10, Academic Press, New York, 1964

----- : Harold Cummins Describes Dissociated Ridges In A Letter To A Colleague, Cummins Collection, Tulane University, New Orleans, Louisiana

Cummins, Harold and R.V. Platou, : Mongolism : An Objective Early Sign, Southern Medical Journal, Vol39, No 12, Dec 1946

Cummins, Harold and E.E. Dudley and Hereward Carrington and Arthur Goadby and Walter Franklin Price, : The "Walter - "Kerwin" Thumb Prints, Boston Society for Psychic Research, Bull.XXII, April 1934

Cummins, Harold and Charles Midlo, : Finger Prints, Palms and Soles, Research Pub.,South Berlin Mass., 1976

Cummins, Harold and Charles Midlo, : Palmer And Plantar Epidermal Ridge Configurations (Dermatoglyphics) In European-Americans, Am. J. Phys. Anthropol., 1926, Vol 1X, No4.

Cummins, Harold and Walter J. Waits and James T. McQuitty, : The Breadths Of Epidermal Ridges On The Finger Tips And Palms : A Study Of Variation, The American Journal Of Anatomy, Vol68, No1, Jan 1941

Cummins, Harold and Edwin A. Ohler, : Sexual Differences In Breadths Of Epidermal Ridges On Finger Tips and Palms, American Journal of Physical Anthropology, VolXXIX, No3, Sept, 1942

Cummins, Harold and Rebecca Wright Kennedy, Purkinjes' Observations (1823) On Fingerrpits And Other Skin Features, Amer Jour of Police Science (J. of Crim Land and Crim Vol XXXI No 3, Sept-Oct 1940)

Davis, John E., : Further Thoughts On Finger Print Comparisons, Finger Print Mag.,July 1955.

Dermatology In General Medicine, McGraw-Hill Book Co., Toronto, 1971

De Varigny, Henry, : Anthropology - The Finger Prints According to M.F. Galton, Revue Scientifique, May 1891

Encyclopaedia Britannica, : History, Fingerprints PP 671, Skin, Human PP838, Eye And Vision PP91 Vol 14

Federal Bureau Of Investigation, : The Science Of Fingerprints, U.S. Dept. of Justice

----- : An Analysis of Standards In Fingerprint Identification, FBI Law Enf Bull, June 1972

----- : Fingerprints, U.S. Gov., Washington, 1937

Feng, Xu, and Huang Li, and Guo Renqiang, : On The Development Of Dermal Papillae And Epidermal Ridges Of Human Skin, Acta Zoologica Sinica, Vol34, No3, Sept 1988, Nanking, China

Forbes, Anne P. M.D., : Fingerprints And Palm Prints (Dermatoglyphics) and Palmar-Flexion Creases In Gonadal Dysgenesis , Pseudohypoparathyroidism and Klinefelter's Syndrome, New England Journal of Med. June 1964

Fraser, F. Clarke Ph.D and James J. Nora M.D., : Dermatoglyphics, Genetics of Man, Sec Ed. ,Lea and Febiger, Philadelphia 1986

Galton, Sir Francis RS : Finger Prints, MacMillan and Co., New York, 1892

Ge, Liu Chun and Zhao Xiang Xin, : The Historical Application Of Hand Prints In Chinese Litigation, Journal of Forensic Ident., Vol 38(6) PP277-284, 1988

Gregory, R.L., : Eye and Brain, The Psychology of Seeing, World University Library, McGraw-Hill, New York and Toronto 1981

Grieve, David L., : The Identification Process : Attitude And Approach, J. For. Ident, 39(5), 1988 PP211

----- : Reflections On Quality Standards, Unpublished.

Gupta, Sia Ram, :Statistical Survery Of Ridge Characteristics, International Police Review, May 1968

Hale, Alfred R., : Morphogenesis Of Volar Skin In The Human Fetus, The Amer. J. Of Anatomy, Vol9I, No1, July 1952

Headrick, A.M., : The Vulnerability Of Scientific Evidence, RCMP Pub.

Heindl, Dr. Robert, : Sir Edward Henry, Archiv Fur Kriminologie, Vol 88 (May-June) 1931

----- : Sir William Herschel, Archiv Fur Kriminologie, Vol 70 (May) 1918

Henry, E.R., : Classification And Uses Of Finger Prints, London, 1900

Hepburn, David, : The Papillary Ridges On The Hands And Feet Of Monkeys And Men, The Scientific Transactions of the Royal Dublin Society, Vol5, Series 2, Sept, 1895

Hill, S. Casey, : The Right To Fingerprint, Unpublished.

Hirsch, W. and J.U. Schweichel, : Morphological Evidence Concerning The Problem Of Skin Ridge Formation, J. Ment. Defic. Res., 1973, 17, PP58.

Holt, Sara B., : The Genetics Of Dermal Ridges, Charles Thomas Pub., Illinois USA, 1968

----- : The Morphogenesis of Volar Skin, Developmental Medicine and Child Neurology, 1979, 12, PP369-371.

----- :Polydactyly And Brachymetapody In Two English Families, Journal of Medical Genetics,(1975)12,355

----- : Dermatoglyphics In Mongolism, Annals of The New York Academy of Sciences, Voll7I,Art2, PP602-616 Sept 1970

----- : Palm-Prints And Their Uses In Medical Biology, Cerebral Palsy Bull., Vol3, No4, 1961, PP333-347

Hough, Walter, : Thumb Marks, Science Mag, Vol Viii, NoI8S PP166 1886

Huber R.A., : The Philosophy Of Identification, RCMP Gazette, July/Aug 1972

----- : Expert Witness, Criminal Law Quarterly, Vol2 1959-60

Huberman, Marvin J., : Anatomy Of A Problem : Proving The Identity Of Fingerprints In Limiting Situations, The Advocate, Vol4I, Pt2, Mar 1983

International Association For Identification, : Report Of The Standardization Committee, 1973

Interpol Symposium Report of First Meeting, : Fingerprinting Problems, International Criminal Police Review, Mar 1968

Jevons, W. Stanley and Ernest Nagel, : The Principles Of Science- A Treatise On Logic And Scientific Method, Dover Publications, New York.

Jungbluth, William O., : Knuckle Print Identification, Journal of Forensic Ident., 39(6) 1989 PP375.

Kikuchi, Syozo, : Concerning The Appearance Of Linear Dots In Fingerprints, Fingerprint and Ident. Mag., Jan 1977

Kimura, Sumiko and Tadashi Kitagawa, : Embryological Development Of Human Palmar, Plantar And Digital Flexion Creases, The Anatomical Record 216, 1986, PP191.

Kingston, Charles R. and Paul L. Kirk, : Historical Development And Evaluation Of The "12 Point Rule" In Fingerprint Identification, International Criminal Police Review, Mar 1965

----- : The Use Of Statistics In Criminalistics, Vol55 1964

Klen, Rudolf Dr., : Purkinje - A Man Of Science, Finger Print Mag., Mar 1950

Kloepfer, H. Warner, : Kloepfer Collection, Louisiana State University, New Orleans Louisiana.

Krush, Anne J., Blanka A. Schaumann and Hagop Youssoufian : Arachnodyctyly And Unusual Dermatoglyphics : Study Of A Case, American Journal of Medical Genetics,31 :57-62, 1988, Alan R. Liss, Inc.

Lambourne, Gerald : The Fingerprint Story, Harrop, London, 1984

Laufer, Berthold, : The History Of The Fingerprint System, Smithsonian Institution, Annual Report, 1912

----- : Concerning The History Of Finger Prints, Science Mag., Vol XLV No 1169, May 25, 1917

Loesch, Danuta, : The Contributions Of L.S. Penrose To Dermatoglyphics, Journal of Mental Deficiency Research, Voll7, Ptl, Mar, 1973

Lohnes, R.C., : Infant Footprint Identification By Flexure Creases, Internation Forensic Symposium, Quantico, Virginia, July7 - 10, 1987

Ludy, John B., : Congenital Absence Of Fingerprints, Transactions of the Atlantic Dermtologic Conf., Philadelphia, Mar 1943

MacArthur, J.W. and Dr. Ernest McCullough, : Apical Dystrophy An Inherited Defect Of Hands and Feet, Human Biology, Vol4, No2, May 1932

MacArthur, J.W., : Reliability Of Dermatoglyphics In Twin Diagnosis, Human Biology, VolIO, No1, Feb 1938

MacArthur, J.W., and O.T. MacArthur, : Finger, Palm and Sole Prints Of Monozygotic Quadruplets, Journal of Heredity, Washington, VolXXVIII, No4, April 1937

Mairs, G. Tyler, : A Study Of The Henry Accidentals With An Analysis Of The Distinction Between Deltas and Triradii, Finger Print and Ident Mag., Vol25, No2, Aug 1943

----- : Identification Of Individuals By Means Of Fingerprints, Palmprints And Soleprints, The Scientific Monthly, October 1918

----- : Supplement To "Digi-Print" Evolution Chart

Mairs, G. Tyler, : Can Two Identical Ridge Patterns Actually Occur - Either On Different Persons Or On The Same Person, Finger Print and Ident. Mag., Vol27, No5, Nov 1945

McDougall, Patrick S., : Different Fingerprint Types Provide A Clue To Mentality, Cummins Collection, Tulane University, New Orleans Louisiana, 1937

----- : Expert Asserts Fingerprints Can Be Forged Successfully, Cummins Collection, Tulane University, New Orleans Louisiana

----- : Dionnes Cause New Problem, Cummins Collection, Tulane University, New Orleans Louisiana 1937

Mavalwala, Jamshed, : Dermatoglyphics : Looking Forward To The 21st Century, Progress In Dermatoglyphics Research, 1982, Alan R0 Liss, New York, N.Y.

McLaughlin, Glen H., : The Case Of Robert James Pitts, Texas Department of Public Safety, Austin 1941

Meier, Robert J., : Anthropological Dermatoglyphics : A Review, Year book of Physical Anthropology 23 :147-178, 1980

Midlo, Charles, : Form Of Hand And Foot In Primates, Amer. Journal of Physical Anthropology, VolXIX, No3, Oct 1934

----- : A Comparative Study Of Volar Epidermal Ridge Configurations In Primates, Louisiana Academy of Sciences, VolIV, No1, Nov 1938 PP136-141

----- : Dermatoglyphics In Tupaia Lacernata Lacernata, Journal of Mammalogy, Voll6, No1, Feb 1935

Midlo, Charles and Harold Cummins, : Dermatoglyphics In Eskimos, Amer. Journal of Physical Anthro., Vol XVI, No1, July 1931

Miller, J.R. : Dermatoglyphics, Journal of Investigative Dermatology, 1973, 60, PP435-442

----- : Dermal Ridge Patterns Technique For Their Study In Human Fetuses, Journal of Pediatrics, Vol 73, PP614-616, Oct 1968

Miller, James R. PhD. and Joan Giroux B.Sc., Dermatoglyphics In Pediatric Practice, Amer. Journal of Human Genetics, Vol 69, August 1966

Misumi, Yuko and Toshio Akiyoshi, : Scanning Electron Microscopic Strucure Of The Finger Print As Related To The Dermal Surface, The Anatomical Record, 208 :49-55 (1984).

Moenssens, Andre A., : Poroscopy - Identification By Pore Structure, Finger Print and Ident Mag., July 1970

Montgomery, Geoffrey, : Seeing With The Brain, Discover Mag., Dec 1988.

Montgomery, Robert B., : Sole Patterns - A Study Of The Footprints Of Two Thousand Individuals, The Anatomical Record, Vol33, No2, June 1926

----- : Sole Prints Of Newborn Babies, American Journal Of The Medical Sciences, VolCLXIX, No6, June 1925, PP830

----- : Sole Patterns Of Twins, Biological Bulletin, VolL, No4, April 1926

----- : Classification Of Foot Prints, Journal of Criminal Law and Criminology, Vol XVIII, No1, May 1927

Mukherjee, Deba Prasad, : A Brief Note On Use Of Dermatoglyphics In Medical Genetics, Applied Physical Anthropology, India 1963

Mulvihill, John J., : The Genesis Of Dermatoglyphics, The Journal of Pediatrics, Oct 1969, Vol 75, No4, PP579-589

Myers, Harry J. II, : The First Complete And Authentic History Of Identification In The United States, Finger Print and Ident. Mag., Vol20, No4, Oct 1938

----- : Supplemental History Of Identification In The United States, Finger Print and Ident. Mag., Vol 25, No6, Dec 1942

----- : A Third History Of Identification In The United States, Finger Print and Ident. Mag., Vol29, NoIO, April 1948

----- : The Henry System Semi-Centennial, Finger Print and Ident. Mag., Vol31, Nol2, June 1950

----- : Psychic Finger Prints, Finger Print and Ident. Mag., Voll5, Nol3, July 1934

----- : A Note On Tabor, Finger Print and Ident. Mag., Vol46, NoIO, April 1965

Newman, H.H., : Palmar Dermatoglyphics Of Twins, American Journal of Physical Anthropology, VolXIV, No 3, July 1930

----- : Aspects Of Twin Research, The Scientific Monthly, VolLII, Feb, 1941, PP99-112

----- : Methods Of Diagnosing Monozygotic And Dizygotic Twins, Biological Bulletin, VolLV. No4, Oct 1928

----- : Asymmetry Reversal Or Mirror Imaging In Identical Twins, Biological Bulletin, Vol LV, No4, Oct 1928

----- : Differences Between Conjoined Twins, The Journal of Heredity, VolXXII, No7, July 1931

----- : The Finger Prints Of Twins, Journal Of Genetics, VolXXIII, No3, Dec 1930

----- : Dermatoglyphics And The Problem Of Handedness, The American Journal Of Anatomy, Vol5S, No2, Sept 1934

----- : Palm Print Patterns In Twins, The Journal of Heredity VolXXII, No2, Feb 1931

Okajima, Michio, : Frequency Of Forks In Epidermal Ridge Minutiae In The Finger Print, American Journal of Physical Anthropology, Vol32, No1, Jan 1970

----- : Development Of Dermal Ridges In The Fetus, Journal of Medical Genetics (1975) 12, 243.

----- : Dermal And Epidermal Structures Of The Volar Skin, March of Dimes Birth Defects Foundation, VolXV, No6, PP179-198 1979

----- : A Methodological Approach To The Development Of Epidermal Ridges Viewed On The Dermal Surface Of Fetuses, Progress in Dermatoglyphic Research, 1982, PP175-188.

O'Hara, Charles E. and James W. Osterberg, : An Introduction to Criminalistics, MacMillan Co., New York, 1949

Osterburg, James W., : Fingerprint Probability Calculations Based On The Number Of Individual Characteristics Present, Identification News, October 1974

----- : An Inquiry Into The Nature Of Proof, The Journal of Forensic Sciences, Vol9 No4, October 1964

Olsen, Robert D., : Scott's Fingerprint Mechanics, Thomas, Springfield Ill. , 1978

Ontario Police College, : The History Of Fingerprinting, Aylmer, Ont., 1987
----- : Fingerprint Identification, Aylmer, Ont. 1982
----- : Seeing And Perception - The Psychology Of Seeing, Aylmer
Penrose, L.S., : Dermatoglyphics, Scientific American, Dec 1969 PP72-84
Penrose, L.S. and P.T. O'Hara, : The Development Of The Epidermal Ridges, Journal of Medical Genetics (1973) 10, PP201.
Philipps, K.A., : Testifying As A Forensic Scientist, Journal of Forensic Science
Plato, Chris C. and Wladimir Wertelecki, : Changing Trends In Dermatoglyphic Research, Progress In Dermatoglyphic Research, 1982 Alan R. Liss, PP1, New York, N.Y.
Pun, Dewan K., : Further Thoughts On Fingerprinting, Intern. Crim. Pol. Rev. Vol178, P130, May 1967.
----- : Thoughts On Fingerprinting, Intern. Crim. Pol. Rev., Nol6O, P225, Aug 1962.
RCMP : Fingerprint Textbook, RCMP Pub. 1966
----- : Scenes Of Crime, RCMP Pub.
Robinson, Dr. Victor, : Johannes Evangelista Purkinje, Scientific Monthly, Sept 1929 Vol XXXIX, No 3, PP217
Schaumann, Blanka and Milton Alter, : Dermatoglyphics In Medical Disorders, Springer-Verlag, New York, 1976.
Singh, Parduman, : Is This A Contribution To The Science Of Fingerprints?, Identification News, Mar, 1975
Singh R.D., : Digital Ridge-Count Variations In Some Castes Of India, Progress In Dermatoglyphic Research, 1982, Alan R. Liss, New York, N.Y.
Slatis, Herman M. and Mariassa Bat-Miriam Katznelson and Batsheva Bonne-Tamir, The Inheritance Of Fingerprint Patterns, The American Journal of Human Genetics, Vol28, No3, May 1976
Soderman, Harry and John J. O'Connell : Modern Criminal Investigation, 5th Edition, Funk and Wagnalls, New York, 1962
Steinwender, Ernst, : Dactyloscopic Identification, Finger Print and Ident. Mag., Vol4l(10)., April, 1960
Stoney, David A. and John I. Thornton, A Systematic Study Of Epidermal Ridge Minutiae, Journal of Forensic Sciences, Sept, 1987
----- : A Method For The Description Of Minutia Pairs In Epidermal Ridge Patterns, Journal of Forensic Sciences, Oct, 1986
----- : A Critical Analysis Of Quantitative Fingerprint Individuality Models, Journal of Forensic Sciences, Oct, 1986
Svensson, Arne and Otto Wendel. : Crime Scene Investigation, Elsevier Pub., New York, 1972
Temtamy, Samia A., : Diagnostic Significance Of Dermatoglyphics In Certain Birth Defects, Progress In Dermatoglyphic Research, 1982, Alan R, Liss, New York, N.Y.
Taylor, Richard A., : Flexure Creases - Alternative Method For Infant Footprint Identification, Identification News, Sept, 1979
Thompson, James S. M.D. and Margaret W. Thompson, Ph.D., Genetics In Medicine, W.B. Saunders Co. Pub., Phil. 1989
Thornton, John I. ----- : The One-Dissimilarity Doctrine In Fingerprint Identification, Intern. Crim. Pol. Rev. No306, P89, Mar 1977.
Thorwald, Jurgen, : The Century Of The Detective Harcourt, Brace and World, New York, 1965
Tiller, C.D., : Identification Of Fingerprints - How Many Points Are Required?, RCMP Gazette, Vol39, No11
----- : That's Him But, RCMP Pub.
----- : Are You A Professional?, RCMP Pub.
----- : Identification By Fingerprints - The Real Anatomy, Advocate, Vol4l, Pt4, July, 1983
Tsuchihashi, Yasuo, : Studies On Personal Identification By Means Of Lip Prints, Forensic Science, 3(1974) PP233-248
Updegraff, Howard L., Changing Of Fingerprints, The American Journal of Surgery, VolXXVI, No3 PP533-534, 1934
Van Der Meulen, Louis J., : False Fingerprints - A New Aspect, Journal of Criminal Law, Criminology and Police Sciences, Vol40, No1, May 1955
Walker, Norma Ford Ph.D., : The Use Of Dermal Configurations In The Diagnosis Of Mongolism, The Pediatric Clinics of North America, May 1958
Wentworth B. and H.H. Wilder, : Personal Identification, Second Ed., Chicago, T.G. Cooke, 1932
Werrett, David J. and Joan E. Lygo, : The Role Of DNA Profiling In The Courts, Home Office, London 1988
Whipple, Inez L.(Mrs Inez Whipple-Wilder) : The Ventral Surface Of The Mammalian Chiridium, Zeitschrift Fur Morphologie Und Anthropologie, Vol 7, PP 261-368, 1904
Wilton, George, : Fingerprints, Wm Hodge and Co., London, 1938
Wilton, George Wilton, : Fingerprints : Home Office And Henry Faulds, Tantallon Press, North Berwick Scotland, 1960
Xu, Feng; Huang, Li and Guo, Renqiang, : On The Development Of Dermal Papillae and Epidermal Ridges Of Human Skin, Acta Zoologica Sinica, Vol 34, No3, Sept, 1988.