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Dermatoglyphic Analysis of Male Criminals

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DERMATOGLYPHIC ANALYSIS OF MALE CRIMINALS

by

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The purpose of this study was to investigate the relationship between genetics and criminal behavior. Using specific dermatoglyphic features of 100 Caucasian male criminals, comparisons were made to a comparable control group of non-criminals. Dermatoglyphics are known to be, in part, genetically determined. Differences between the non-criminal and criminal samples would support the belief that certain criminal behaviors are genetically determined.

Statistical tests were performed on the dermatoglyphic pattern types and ridge counts of the criminal and non-criminal samples. There were three tests of the total ridge counts (TRC) that were found to be statistically significant. The principal difference was that the criminal sample had a lower mean ridge count than the non-criminal sample. There were no statistically significant differences found between the pattern types of the two samples. Although not statistically significant the criminal group exhibited a higher incidence of arches than the non-criminal group.

This study is only relevant with reference to a population and not to an individual. These findings do not support the possibility of predetermining criminal intent in individuals, only that behavior may be influenced by genetics.

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CHAPTER I

INTRODUCTION

Crime and criminal behavior have existed since the earliest civilizations. Violations of personal and property rights are considered the basis of crime (Jones 1986). Since then there have been countless explanations offered as to the causes of crime, how to predict, and how to prevent crime. The modern fields of psychology, economics, sociology, and anthropology are only a few disciplines that have championed views on the motivations of crime. Only in the past twenty years have there been attempts at a collaborative effort to develop theories on criminal behavior. These efforts have yielded the most significant insight into individuals' behaviors.

It was 1764 when the current definitions of crime and punishment began to take shape in a publication by Cesare Bonesana, Marquis of Beccaria. Rights for the accused were demanded before and during any trial. The punishments imposed should be analogous to the crimes committed. The criminal should receive " just a little more pain than the amount of pleasure derived from criminal behavior" (Leps, 1992:17). England's creation of the Royal Society of Prisons in 1819 inspired debate among officials as to the proper method of incarceration and reform for criminals. Those in charge of the prisons, penitentiary scientists, were opposed to the new legislation that punished according to the crime committed. Prison officials believed that the length of punishment should be proportionate to the criminal's perversity

(Leps, 1992). This time period, which supported the belief of free will and that behavior was guided by an individual's hedonistic nature, has been called the classical school of thought (Lilly et al., 1995). The new practice of impartial punishments based on the specific crime, and not the criminal's nature or status, continued into the middle nineteenth century. As crime continued to flourish, despite the seemingly fair and equitable treatment of all prisoners, the classical school of thought suffered severe criticism. Importance was now given to the aggravating and mitigating circumstances of crime. The new positivist school began to see criminal acts as a result of multiple factors (Lilly et al., 1995). Cesare Lombroso has been attributed with this search for a multifactorial explanation for crime, with an emphasis on biological origins instead of entirely social factors.

Cesare Lombroso was trained as a physician in the mid-nineteenth century. While in the army, he began a comprehensive investigation into the range of observable human traits. Lombroso used measurements from several thousand Italian solders and six thousand prisoners (Jones, 1986). With the autopsy of a famous criminal Lombroso found several features that he thought to be characteristic of lower primates. This discovery, along with extensive physical descriptions, convinced Lombroso that criminals share certain atavistic features. Lombroso concluded that physical anomalies, with hereditary origins, could distinguish those that commit crimes from non-offenders (Jones, 1986).

With a complete classification of all relevant features, Lombroso felt that even the types of crimes a person had committed or might commit could be

determined (Gottfredson and Hirschi, 1990). Lombroso constructed an index of human anatomy with descriptions of features for criminals in relation to lawful individuals. His contention was that a criminal, any criminal, was knowable through this system based on cranial, facial, and bodily measurements and observations. The quantification of these aspects would predict to a high degree of accuracy the predisposition of an individual to crime (Lombroso-Ferrero, 1972). Some of the features that Lombroso looked for included the sense of smell, mental condition, and the shape of the head, ears, and teeth. Specifically, the incisors of criminals were often missing and, if present, are usually uniform in size with the canines and premolars. The eyebrows of criminals are considered bushy and close together. Finally, "the eyes of murderers are cold, glassy, immovable and bloodshot, the nose aquiline, and always voluminous, the hair curly, abundant, and black" (Lombroso-Ferrero, 1972:244). Lombroso created a scale by which to compare these types of measurements and observations of presumed criminals with established samples of non-criminals. The differences, or anomalies, in criminals were believed to "strongly resemble primitive races" (Lombroso-Ferrero, 1972:5). This identification of physical features, resembling those of primitive ancestors and believed to produce criminal tendencies, led Lombroso to his convictions about the role of heredity in crime. Lombroso stated that, "heredity is the principal organic cause of criminal tendencies" (Lombroso-Ferrero, 1972:137).

Although most of Lombroso's ideas on criminology have been rejected by modern science, he remains the stimulus for a multifactorial explanation of crime.

Heredity was his principal explanation, but he also examined factors of social, cultural, and economic significance. Lombroso emphasized the importance of examining all relevant clinical and historical records. Lombroso conducted his numerous studies using these ideas in an effort to further explain criminal behavior. Charles Goring, another researcher and contemporary of Lombroso, began to highlight the problems in Lombroso's emphasis on physical anomalies. Continued studies revealed that there were no obvious physical differences between criminals and non-criminals (Gottfredson and Hirschi, 1990). These ideas of biological positivism are now being reconsidered today because of our greater knowledge about the impact of genetics in determining behavior.

Today, the focus of criminal research is psychologically and sociologically based. Criminal behavior is currently considered by many to be influenced both genetically and environmentally. This interaction is now being broadly classified as a type of psychopathology. Psychopathology, in terms of criminal behavior, is any behavior of an individual which "is clearly viewed as lying outside the norm of social acceptability" (Raine 1993:8). Raine describes this population with the term psychopathology which applies to "those who repeatedly engage in nontrivial criminal behavior ... whether they are caught offenders who reside in prisons or whether they are undetected, repeat offenders residing in the community" (1993:2). While this relatively benign definition of psychopathology does not specifically reveal anything unique about criminal behavior, it does classify criminal behavior as

ignoring the possible contributing factors of genetics. Only after considering all the factors, as Lombroso attempted, can a complete understanding about the nature of criminal behavior exist.

It has only been in this century that influences of genetic and environmental factors have been isolated from one another in studies. This has been in the form of twin and adoption studies that are able to analyze the effects of either genetic or environmental factors on the behavior of individuals. From these studies it is clear that there can never be an established percentage of influence placed on these factors because they are highly variable. Raine (1993:71) states that "genetic influences are nontrivial and probably account for as much variance as environmental influences in relation to crime." Estimates for genetic influences are not always reported to be as significant as half, and in some cases are thought to have almost no effect. From a limited survey of adoption studies, Gottfredson and Hirschi (1990:60) concluded "that the magnitude of the genetic effect, as determined by adoption studies, is near zero." These differences might be a result of the samples used and might also be a direct result of the variable nature of the factors themselves.

Criminality studies involving twins are not the most sensitive test of genetic and environmental interaction. This is because the twins studied were raised together as siblings in the same household and were not separated as in adoption studies. Support for a genetic influence would be indicated with a higher concordance in criminality between identical twins than fraternal twins. Christiansen (1977) found exactly this result with a 52% concordance for identical twins compared to a 22%

concordance for fraternal twins; however, this is not definitive support for genetic influences as Christiansen (1977) noted this might be due to a greater shared experience that identical twins could be exposed to. It might have been that identical twins in these studies were treated more similarly than fraternal twins and, as such, have more similar social and environmental influences. This factor of unequal treatment of different types of twins would affect the concordance rates and would not reflect genetic effects exclusively.

The study of adoptions can better distinguish between environmental and genetic effects. Criminality rates of adoptees have been compared in categories referring to the criminality of their biological and adoptive parents. Two studies of U.S. adoptions have produced results supporting an increased rate in criminality in adoptees with criminal biological mothers. Both studies (Crowe, 1975; Cadoret, 1978) reported that antisocial behavior was a significant factor in both adoptees and parents.

Bohman et al. (1982) conducted one of the largest studies of criminality in adoptees. The authors used the information from 14,427 non-familial adoptions that took place in Denmark between 1924 and 1947. From this group came a comparison of adoptees with biological and adoptive parents who were both criminals and non-criminals. Table 1 shows that there is support for a combination of environmental and genetic factors in determining criminality of the adoptee. The biological or genetic component was shown to be the second most influential component, followed by the environmental factor that was also found to determine criminality in

individuals. This was determined because adoptive children whose biological and adoptive parents were criminals showed the highest percentage of criminality. The category of biological parent being a criminal resulted in the second highest percentage of criminality in the adoptive child. This indicates that the combined aspects of genetics and society are the most influential in determining the criminal outcome of a child, genetics alone is the second most influential, followed by social factors.

Table 1

Cross-Fostering Analysis of Adoptive Sons

Have adoptive parents been convicted?	Have biological parents been convicted?	
	Yes	No
Yes	24.5 (of 143)	14.7 (of 204)
No	20.2 (of 1,226)	13.5 (of 2,492)

Source: Mednick, S.A., W.F. Gabrielli, and B. Hutchings. 1987 Genetic Factors in the Etiology of Criminal Behavior. In Mednick, Sarnoff A., T.E. Moffitt, and S.A. Stack (Eds.), The Causes of Crime: New Biological Approaches. New York, NY: Cambridge University Press, p. 122.

Both twin and adoption studies support the theory that genetic factors are influential in the criminality of individuals. Cloninger and Gottesman (1987:107) reviewed the most relevant studies and concluded "the consistency of results from the Stockholm adoption study and the Danish adoption study ... indicate that both genetic and environmental factors are important in the epigenesis of adult antisocial behavior". Adrian Raine (1993) found only one study out of fifteen that found no

link between general crime in biological parents and crime in adoptees. Based upon his and others studies Mednick (1987:6) concludes that there is irrefutable support for "the influence of heritable factors in the etiology of some forms of antisocial acts". Numerous studies support the belief that influences for criminality can be manifested genetically (Christiansen, 1977; Cloninger and Gottesman, 1987; Mednick et al., 1987). Criminality might be a condition, similar to other medical disorders showing statistical differences in some aspects of that population's biological features, of which dermatoglyphics is one example.

CHAPTER II

HISTORY OF DERMATOGLYPHICS

The use of fingerprints as a tool for identification or authentication is not new. While methods of precise personal identification from fingerprints have only been developed in the past one hundred years, evidence of fingerprints being used for identification dates back centuries. According to Galton (1892) Roman pottery and tiles with fingerprint impressions have been found. It is believed the impressions were intentionally made to identify the makers of the items. There are Assyrian bricks where fingerprints are associated with phrases and signatures. In China, documents concerning the sale of land often included an impression of the tip of the finger (Cummins and Midlo, 1961). The oldest written material on fingerprints came from Dr. Nehemiah Grew who in 1684 presented a published report before the Royal Society in London (Cowger, 1993). In this he described the ridges and pores of the fingers and hands, which we now call fingerprints.

The first modern writings concerning fingerprints were by Johannes E. Purkenje in 1823. In his university thesis he discussed some of the anatomical features of the friction ridges as well as establishing a system of classification for fingerprints (Galton, 1892). William Herschel, in 1858, was the first to implement the use of fingerprints as a tool for individual identification for a large number of

people (Cowger, 1993). The motivation was to reduce the amount of fraud through impersonation that was occurring against the state while he was an administrator of the Hooghly District of Bengal. The fingerprints of individuals were recorded along with any signed contracts (Galton, 1892). At that time an English biologist, Francis Galton, was corresponding with Herschel while he was initiating this system of fingerprinting. In 1892 Galton published the first textbook on fingerprints. He established three main classes for pattern classification, *arches, loops,* and *whorls.* As a result of this work the English legal system, in 1894, adopted fingerprints as a supplementary means of identification.

Edward Richard Henry was William Herschel's successor in India. Using the information that was collected by both Herschel and Galton, he also developed a system of classification. Galton saw fingerprints as a means by which to measure hereditary likeness in individuals, while Henry's focus was for individual identification. Henry recognized the uniqueness of fingerprint ridges and published his own system for personal identification in 1900 (Henry, 1900). The following year, Scotland Yard implemented Henry's system of identification. By 1907 the use of fingerprints as a means of identification, and Henry's system, was practiced by the New York Civil Service Commission, United States Army, United States Navy, and the United States Marine Corps (Cummins and Midlo, 1962). Today, the clear majority of all law enforcement agencies still use the Henry system of classification with only a few modifications (FBI, 1973).

Dermatoglyphic patterns are formed from epidermal ridges. These are the raised configurations of skin found on the palms of the hands and soles of the feet. The ridges found on palmar and distal portion of the fingers are what commonly thought of as fingerprints. Any fingerprint consists of both furrows and ridges. Furrows are the areas between the ridges that appear between the inked lines of the rolled fingerprint. Ridges are the black lines of the ink-rolled fingers. The lines, or ridges, that appear represent an exact copy of the fingerprint ridges.

These ridges and furrows are formed by nerve endings that terminate at the dermal-epidermal junction. It is the proliferation of cells in the basal layer of the epidermis around these nerve endings that project into the superficial layer of the dermis (Babler, 1991). These projections form the primary ridges, or in total, a fingerprint. The formation of fingerprints occurs in utero between 12 and 17 weeks. At this time the primary ridges increase in number, width, and length. The permanent pattern of the fingerprint is completely formed by the fifth month of pregnancy (Hale, 1952). After the fifth month, fingerprints remain unaffected by any type of environmental influences. Only extensive physical damage of the basal layer of the epidermis could alter them after this time.

Prior to the fifth month of gestation fingerprints may exhibit effects from various environmental factors other than genetics. The taking of anticonvulsant drugs (Babler, 1991) by pregnant mothers has been shown to alter dermal ridge configurations. It has also been suggested that the intrauterine hormonal environment (Jamison, 1990) may affect dermatoglyphic features. Fingerprints are formed as the

fetus develops and so are "not free of environmental modification and might even be drastically altered during the four months or so leading to permanent primary ridge formation" (Meier 1980:155). The unchanging and unique qualities of the fingerprint after the fifth month of pregnancy make them ideal for means of individual identification. Fingerprints susceptibility to variability due to environmental and genetic factors makes them beneficial to studies concerning human diversity.

Henry System and Fingerprint Patterns

The Henry system of fingerprint classification has become the foundation for the identification of fingerprint patterns. This system is used on the level of the individual for purposes of positive identification, and on the level of a population for purposes of scientific studies. In the Henry system there are three primary divisions of fingerprint patterns, each having further subdivisions. The fingerprint divisions are arch, loop, and whorl, often referred to as A-L-W pattern types as defined by Galton (1892). The general classifications of pattern types are determined by the arrangement of the ridges on the distal joint of each finger. The further subdivisions of each pattern are as unique as the three primary classifications.

The arch pattern, often considered to be the most archaic pattern because of the lack of any triradius or delta, is identified by the complete passage of ridges across the digit. The delta of a fingerprint is the point on a ridge that is nearest to the divergences of the type lines. The type lines are the two innermost ridges that diverge and then surround the pattern area. In an arch pattern the ridges follow a

transverse path on the palmar surface of the finger. There can be no ridge that enters and then exits on the same side of the finger. Arches can be further sub-classified into plain arch and tented arch (Figure 1) patterns. The tented arch is different from the plain arch due to a spike of one or more of the ridges in the pattern. The plain arch maintains a smooth line across the volar pad. The arch pattern does not contain a core or delta. These are features found in loop patterns. An arch pattern cannot have a ridge count because of the lack of any core or delta. A ridge count is established by counting the number of ridges between the core and delta of a pattern. The arch pattern is the least common occurring pattern of the three types, usually at a rate of 5% in any population.

(a) (b)

Figure 1. (a) Plain Arch Pattern, (b) Tented Arch Pattern.

Source: Cowger, James F. (1993:38, 42) Friction Ridge Skin: Comparison and Identification of Fingerprints. Boca Raton, FL: CRC Press.

The loop pattern is defined by having at least one ridge entering and exiting the pattern area on the same side. The formation of the loop also establishes the aspects of a core and triradius, or delta, in the pattern. The core is located at the ridge ending or on the innermost recurve in the pattern area. There are complex rules

associated with establishing the position of the core and delta (Cowger, 1993). It is with the core and delta that the ridge count of the pattern is determined. The ridge count is simply a count of the number of ridges that intersect an imaginary line drawn between the core and delta. An example of ridge counting can be seen in the loop pattern shown in Figure 2. The core of the pattern is in the center of the Figure at the end of the line, the delta is at the other end of the line. The ridge counts of loop patterns are often used for classification into smaller groups based on the number of ridges. In addition, loop patterns can also be sub-classified as being either a radial loop or an ulnar loop. The radial and ulnar sub-classifications are essentially indistinguishable and are classified depending upon which side of the finger the loop pattern opens toward. A radial loop pattern is one that opens toward the thumb side of the hand, or the radius, and has the delta on the ulnar side of the hand. An ulnar loop pattern is one that opens toward the little finger, or the ulna, and has the delta on the radial side of the hand. The loop pattern occurs with the greatest frequency of the three types of patterns, usually at a rate of 65 % in any population.

Figure 2. Loop Pattern. The line shown connects the delta and core of the pattern.

Source: Cowger, James F. (1993:42). Friction Ridge Skin: Comparison and Identification of Fingerprints. Boca Raton, FL: CRC Press.

Finally, the whorl classification of a pattern is described as having ridges that encircle the core. The ridges of whorl patterns can resemble circles, rings, ovals, or spirals. The whorl pattern has similarities to both arch and loop patterns. There are ridges that pass across the fingerprint, similar to arches, as well as ridges that curve to enclose other ridges, similar to loops. What truly defines a whorl pattern is that there are at least two identifiable deltas in the pattern area. Within whorls there are four sub-groups: plain whorl, central pocket loop whorl, double loop whorl, and accidental whorl. Each sub-classification has unique characteristics that distinguish it, but all follow the rule of having at least two deltas. The whorl pattern is the second most frequently occurring pattern, usually at a rate of 30 % in any population. Figure 3 provides examples of the four primary subdivisions of whorl patterns. They are considered whorl patterns based on the identification of having at least two deltas. Further characteristics establish the subdivisions of the whorl patterns.

Dermatoglyphics in Practice

Fingerprints are used in forensic settings to prove identity or non-identity of individuals, while in anthropological settings, dermatoglyphics are used to prove similarities or dissimilarities at the population level. Cummins and Midlo (1926) proposed the term dermatoglyphics in reference to the study of all the features of friction ridged skin.

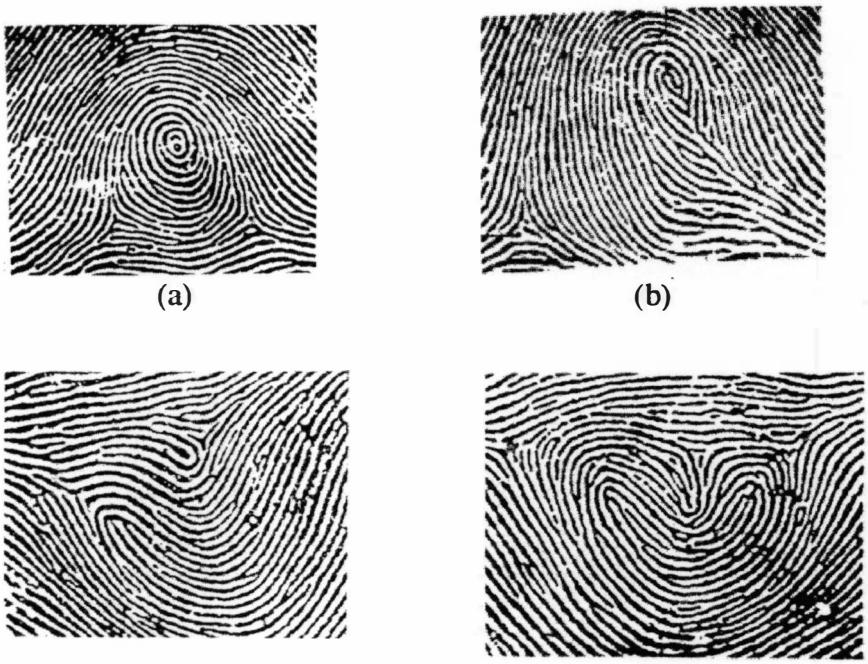

Figure 3. (a) Central Pocket Whorl, (b) Plain Whorl, (c) Double Loop Whorl, (d) Accidental Whorl.

Source: Cowger, James F. (1993:52, 54, 56, 59). Friction Ridge Skin: Comparison and Identification of Fingerprints. Boca Raton, FL: CRC Press.

The term dermatoglyphic is now in general use among all researchers in this area. The use of the term dermatoglyphic also serves to avoid confusion with the functions of fingerprints in legal settings. The use of the phrase dermatoglyphic also indicates that any statement refers to a population rather than to individual. For these reasons the term dermatoglyphic will be used through the remainder of this paper.

The purposes of population-based studies of dermatoglyphics are initially to describe a given group in an effort to discover the range of human variability, then to determine how that variation arose and what were its influences. The earliest

anthropological studies using dermatoglyphics consisted of the recording and description of patterns on a large scale (Meier, 1991). When this was being done in the late nineteenth and early twentieth centuries very little was known about the processes affecting the formation of fingerprints. These studies looked at dermatoglyphics in relation to ethnic and racial categories as well as in individuals with known medical disorders. Harold Cummins (1926, 1930, 1931, 1935, 1941, 1955, 1961) is responsible for an exhaustive study of dermatoglyphics extending over five decades. In this time, he published dermatoglyphic studies relating to aspects of non-human primates, populational variability, and medical conditions. Through these studies Cummins established the foundation for what dermatoglyphic studies can be used to investigate and what they are intended to accomplish. "These studies overwhelmingly established the use of dermatoglyphics in populational studies and anthropologists in North America have followed Cummins' lead and increasingly used this variant, invariably with Cummins' methodology" (Mavalwala, 1973:179). This allowed investigations into many aspects of human biology to legitimately use dermatoglyphics as a basis for analysis.

From the beginning, dermatoglyphics were used as possible indicators of racial classification (Galton, 1892; Cummins and Midlo, 1926; Wilder, 1922), but they were found to only establish general tendencies. This is true for all dermatoglyphic studies; conclusions can only be made in reference to the population. The statistical information that can be drawn from dermatoglyphic studies is meaningless to any one individual. In Galton's (1892:192) early study on racial

categories he looked at "English, pure Welsh, Hebrew, and Negro". The discernible differences found within these categories were based upon percentages of pattern types. Table 2 shows the differences in the occurrence of arch patterns that Galton had found. Based upon those differences, Galton (1892:192-193) made the point that "it may emphatically be said that there is no peculiar pattern which characterizes persons of any of the above races". Any differences found are only in terms of statistical frequencies and cannot distinguish differences on the level of the individual. Put simply, it is impossible to say whether an individual is male or female, or to attach a racial classification based strictly upon pattern types or ridge count information. References to pattern types and ridge counts are only applicable to specific groups or populations and are not significant on an individual level.

Table 2

Frequency of Arches on the Right Index Finger

Number of Persons	Race	Number of Arches	Percentages
250	English	34	13.6
250	Welsh	26	10.8
1332	Hebrew	105	7.9
250	Negro	27	11.3

Source: Galton, Francis. (1892:194). Fingerprints. New York, NY: Da Capo Press. The original was published in 1892. London, England: Macmillan and Company.

Galton hints at the reason for these differences in a single statement. "The only answer I can suggest is that the patterns being in some degree hereditary, such accidental preponderance's as may have existed among a not very numerous ancestry might be perpetuated" (Galton, 1892:195). This reference to heredity is correct, there is a definable genetic link to both pattern types and ridge counts (Holt, 1968). In fact, Galton began to calculate expected values of dermatoglyphic information in an attempt to compare them against the observed data he had obtained. Historically, at this time there were two differing perspectives towards the heritability of dermatoglyphics. Put simply, there were those who affirmed the inheritance of dermatoglyphics, and those who held a negative opinion of the heritability of fingerprints. Later studies would prove that Galton was on the correct side of this dichotomy.

Early studies showed that "human races did not differ in the expression of any dermatoglyphic features, but that they differed in relative frequencies of features" (Meier, 1980:161). This was beneficial because dermatoglyphics were never seriously considered for use in racial classifications. Other, more significant aspects of dermatoglyphics became the focus for researchers. This was most prevalent in the medical field. Based on these new directions in research, the influences of the environment and genetics in affecting dermatoglyphics were becoming better understood.

In addition to racial categories, gender is also a factor that affects dermatoglyphic features. Before the undertaking of dermatoglyphic studies it is

important to know what human biological factors play significant roles in the determination of characteristics. In this case, there are two primary physiological differences in dermatoglyphics based on gender, ridge count and frequencies of pattern types (Holt, 1968). Again, this does not mean that the gender of an individual could be determined based on the pattern types or ridge counts of the fingerprints. What it does mean is that there are consistent statistical differences in dermatoglyphic features based on gender. This supports the idea that there are genetic differences that can be seen in dermatoglyphic features.

Differences in gender were noticed early on when Ohler and Cummins (1942) studied the ridge number per centimeter in young adult males and females. They obtained data showing a difference of 20.7 ridges per centimeter for males compared to 23.4 ridges per centimeter for females. This measurement is not the same as the ridge count, but does reflect a similar measure of pattern intensity. The more intense the ridge pattern, the higher the ridge counts would be, and this would also be reflected in a higher ridge per centimeter measure. Instead of counting ridges between two features of the fingerprint, as the ridge count does, the per centimeter measure simply counts the same ridges, but applies the restriction of reporting this information in the form of ridges per centimeter.

Sex differences are also present in the frequencies of pattern types that occur in populations. This should not be surprising given the known influence that genetics have on dermatoglyphic formation. These differences have been suggested to be due to the sex chromosomes (Jantz, 1977), however, there have not been any consistent

studies supporting this. Holt (1968) obtained the data shown in Table 3 supporting the differences in pattern types based upon gender.

Table 3 shows that women have a greater frequency of arches and a significantly lower frequency of whorls. The percentages of radial loops are the closest in percentages, but females showed a greater percentage of ulnar loops. Gender differences have also been found in ridge counts.

Table 3

Percentage of Pattern Frequencies

MALES (500 persons; 5000 fingers)		FEMALES (500 persons; 5000 fingers)	
Whorls	28.3%	Whorls	23.9%
Ulnar Loops	61.6%	Ulnar Loops	65.6%
Radial Loops	5.9%	Radial Loops	4.8%
Arches	4.3%	Arches	5.7%

Source: Holt, Sarah B. (1968:27). The Genetics of Dermal Ridges. Springfield, IL: Charles C. Thomas Publisher.

Jantz (1977) found males, on average, had a greater ridge count than females by 16.8 ridges per person. In dermatoglyphic studies known factors that affect pattern and ridge count frequencies are gender and race, or ethnicity. Our knowledge of the processes of genetic inheritance has greatly increased in the last half of this century. This is true in all aspects of biological research, including dermatoglyphic inheritance. Sarah Holt (1959, 1968) is one researcher who has been a driving force in the establishment of models of dermatoglyphic inheritance.

In order to explain patterns of inheritance we must use all we know about human genetics and the transfer of chromosomal information. As a whole it may appear to be a daunting task, but through relevant studies genetic inheritance can be understood. Dermatoglyphic studies have been important to the understanding of genetic inheritance. The goal now is to use the quantities of accumulated information from dermatoglyphic studies to answer the questions about the specific patterns of inheritance. Equally important is to identify the impact of both genetics and environment on the expression of dermatoglyphic features.

Two basic models for the explanation of inheritance patterns of dermatoglyphics have been proposed: a monogenic or Mendelian mode of transmission, and a polygenic system of inheritance. In the monogenic system of inheritance it is believed that there is a direct pattern type to gene relationship. Here, a single gene determines the pattern types and dermatoglyphic features for each digit. This concept of inheritance was supported by Anderson et al. (1979) when investigating the occurrence or nonoccurrence of arch type patterns. This study pointed to the possibility of a single locus that determines the presence or absence of arch patterns irrespective of the digit. This, however, is where support for a monogenic model of inheritance for dermatoglyphic patterns end. While a monogenic system of inheritance is quite valid with respects to other aspects of human biology Meier believes that it is implausible for dermatoglpyhics. Gene effects are not likely to be finger specific as well as pattern-type specific. Also it is

improbable that there are direct pattern-type to gene relationships, but rather controlled through indirect genetic effects (Meier, 1980:152).

The most current and prevalent view is of a polygenic system of inheritance for dermatoglyphic traits, including pattern types and ridge counts. Figure 4 shows a number of ways that genes can affect one or more biological effects. A polygenic system refers to complex traits that are controlled through the influence of multiple genes. Within this polygenic system there can exist both polygenic and pleiotropic traits. A polygenic trait is the expression of a feature affected by two or more genes on a chromosome. An example of this would be the determination of human height or skin color, which is affected by the action of a number of loci in addition to environmental factors. A pleiotropic trait is one in which a single allele has multiple effects on the biological makeup of an organism. Examples of this in nature include chickens, where one of the alleles that cause white feather color also acts to slow down overall body growth (Relethford, 1990). The human body is a biological system where many genetic effects, and their causes, are interrelated.

A correlational study is when two or more aspects of biology are compared to see if they share any genetic connection. The goal is to find possible connections between a genotype and phenotype. Dermatoglyphic studies are based upon this idea, and attempt to correlate dermatoglyphics to features of human biology. Without question, dermatoglyphic differences are the result of genetic and environmental factors. What remains to be answered is how and to what extent are these factors involved.

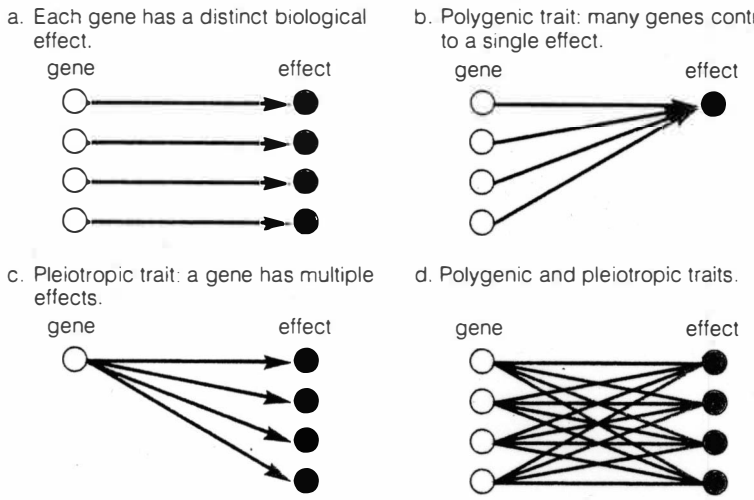

Figure 4. Relationship Between a Gene and a Biological Effect: (a) Single Gene, Single Effect, (b) Polygenic Trait, (c) Pleiotropic Trait, (d) a Polygenic and Pleiotropic Trait.

Source: Relethford, John. (1990:49) The Human Species: An Introduction to Biological Anthropology. Mountain View, CA: Mayfield Publishing Company.

Statistical studies of dermatoglyphics are the only way to distinguish which factors may be connected. Schaumann and Opitz (1991: 217) state:

> Considerable progress has been made in the understanding of the associations between dermatoglyphics and various medical disorders, as a result of which dermatoglyphic analysis has been established as a useful diagnostic and research tool in medicine, providing important insights into the inheritance and embryologic development of many studied clinical disorders.

Dermatoglyphics are an excellent tool for these types of studies because of the combination of factors described previously. All dermatoglyphic patterns can be classified within well-defined categories. Additionally, every dermatoglyphic pattern has features that can distinguish it as unique from any other pattern. Dermatoglyphic patterns remain unchanged throughout life, so factors of age or growth are not relevant. Dermatoglyphic prints are collected and interpreted with relative ease and

at minimal costs. This permits studies to use much larger sample sizes than possible with more costly genetic testing. Studies can then be accomplished with significant sample sizes and very limited funding. A significant limitation is that this reveals only correlations and not cause and effect relationships.

Studies addressing population level differences made up the majority of studies in the first half of this century. Harold Cummins (1926, 1930, 1931, 1935, 1941, 1955, 1961) was the largest contributor to this type of research. His comparisons of populations, defined by either geographic regions or general racial classifications, led to the first estimates of inheritance for ridge counts and pattern type frequencies. These studies highlighted the fact that in some cases there were real statistical differences between the groups studied. These estimates of inheritance could then be compared against any observed data. Table 4 shows the comparison of observed inheritance statistics with the corresponding expected estimates of inheritance. From these comparisons, percentages could be loosely applied to the two primary factors affecting dermatoglyphics, genetics and the environment. The correlations between relatives show both a definite pattern of inheritance as well as environmental influences. The fact that the observed correlations differ slightly from the expected genetic values indicates that dermatoglyphics may not be entirely genetically determined. Instead, inutero environmental factors in conjunction with genetics are the most likely source of dermatoglyphic determination.

Table 4

Correlations Between Relatives for Total Finger Ridge Count

Relationship	Number of Pairs	Observed Corr.	Theoretical Corr.
Parent-child	810	.40	.5
Mother-child	405	.48	.5
Father-child	405	.49	.5
Midparent-child	405	.66	.71
Sib-sib	642	.50	.5
Monozygotic twin-twin	80	.95	1.0
Dizygotic twin-twin	92	.49	.5

Source: Holt, S.B. (1968: 63). The Genetics of Dermal Ridges. Springfield, IL: Charles C. Thomas Publisher.

Further investigation into racial characteristics of dermatoglyphics continued to expand upon Cummins' earlier projects. Jantz (1974, 1977) continued to investigate both differences in sex and race in dermatoglyphics. The racial differences found in the Z scores were most significant among males, specifically digits II and III (Jantz, 1977:173). This was from a study comparing ridge count characteristics of ten different racial groups of both sexes. Jantz has suggested because racial differences between blacks and whites are greatest in males, in terms of statistical correlations, there is a possible connection associated with the Y sex chromosome. It might be possible that in addition to the developmental influences exerted through the Y chromosome, dermatoglyphic features are also affected. The effect of the Y chromosome on dermatoglyphic patterns was further investigated by Mavalwala et al. (1968) in reference to the XYY chromosome syndrome. The

motivation for this study was to develop a system for the early recognition of this genetic condition. While dermatoglyphics will likely never be used as an accurate identifier of this condition on an individual basis, the study lends insight into the possible effects that the Y chromosome could have on dermatoglyphic patterns. This study used a sample of only five individuals, not nearly an adequate size from which any conclusions could be made, but did offer some features that might show possible variations from the general population. Neither Mavalwala nor Jantz could make any significant determinations as to the effect, if any, the Y chromosome has on dermatoglyphic features.

The idea that dermatoglyphics could be an indicator of a genetic anomaly or medical condition is not unique to the XYY syndrome. dermatoglyphics have been used with relative frequency in medical research. There have been several medical conditions that have shown both significant associations between unique pattern types or ridge counts. This also means that there have been many more medical conditions shown to have no significant connection to any unique dermatoglyphic features. Some of the conditions that have shown significant connections to dermatoglyphics include Alzheimer's (Durham 1990), schizophrenia (Gyenis et al., 1990), Marfan syndrome (Krush et al., 1990), achrondroplasia (Schaumann et al., 1990), and cancer (Floris et al., 1990)

Alzheimer's disease is a presenile form of dementia. This disease has been shown to have numerous and significant dermatoglyphic differences when comparing the test and control groups. Durham (1990) found that both pattern types and ridge

counts were significantly different in females diagnosed with Alzheimer, from those who do not have this condition. Among the differences were a lesser occurrence of whorls and arches and an increased number of ulnar loops in the Alzheimer groups. With the increase in ulnar loops the ridge count would also be expected to be greater. There was found to be a higher ridge count in the Alzheimer groups affirming the differences already found among pattern types. Schizophrenia, a fairly common mental disorder, has also been subject to extensive dermatoglyphic studies. Gyenis et al. (1990) found individuals diagnosed with schizophrenia to show significant differences in dermatoglyphics, the majority of which were observed in male subjects. These differences were found in seven out of ten fingers and consisted of a decrease in the frequencies of whorls when compared to arches and loops. Gyenis et al. (1990), however, reported these results did not entirely agree with previous studies on schizophrenia. One suggestion for the difference is that there are different types of diagnosable schizophrenic disorders (DSM IV). A more comprehensive classification of schizophrenic cases might show a more accurate correlation to dermatoglyphics.

Dermatoglyphics have been studied in relation to breast and cervical cancers in an effort to establish a new method for preventative medical screening (Floris et al., 1990). This study found only one difference out of the ten features analyzed to be statistically significant. These results indicated that dermatoglyphics would not be an effective diagnostic tool for screening these types of cancers; however, there are many types of cancers with numerous causes that still might be associated with

unique dermatoglyphic features. This means that continued studies would be needed to test the correlation of the different cancers to dermatoglyphics.

There are two studies relating to genetic disorders that cause physical deformities. Marfan syndrome is a genetic disorder of the fibrous connective tissue involving the skeletal, ocular, and cardiovascular systems of the body. There are also correlational studies that attempt to associate underlying causes of a pathology with an unrelated phenotypic trait. Krush et al. (1990) found no overall differences in pattern types or ridge count in this study. The only specific difference was the increase in whorls and fewer arches on the left thumb. In males the mean total ridge count was somewhat lower in the subjects diagnosed with Marfan syndrome. Achrondroplasia is also a genetically determined disorder that affects the limbs of an individual. A study by Schaumann et al. (1990) found that the test subjects only differed slightly in pattern types and only on two digits. The differences were an increase in loops on the right thumb and an increase in the arch pattern on the middle finger of the left hand in the test group. Overall individuals with achrondroplasia do not have any significant, identifiable aberrations associated with their dermatoglyphic features.

There have been two dermatoglyphic studies that have attempted to identify differences in the patterns of criminals. Welch et al. (1971) and Castilla (1979) both used dermatoglyphic features as a basis in an attempt to identify differences between criminals and noncriminals. Several aspects of dermatoglyphic features were compared between the criminal samples and the comparable control groups.

Significant statistical differences were found when the information was analyzed. Despite differences in geography and ethnicity of the samples, the two studies obtained similar differences.

The study by Welch et al. (1971) used a sample of white males from a Canadian correctional institution compared to a previously published (Holt, 1955) sample of non-criminal, white, British males. He found a greater number of arch patterns in the criminal sample compared to the control group. Additionally, the total ridge count (TRC) was found to be significantly less in the male criminals. In this study there was no distinction made between the two types of arch patterns. Also, there was no clarification as to which digits showed the increased occurrence of arch patterns. This type of information is important when comparing these differences to the differences found in other studies.

Castilla (1979) used a sample of male Spanish prisoners and a control group of both male and female Spanish individuals. Differences were found in both pattern types and the total ridge counts when the prisoners were compared to the control groups. There was a significantly higher occurrence of whorls and a decrease of ulnar loops when compared to both the male and female control groups. These differences were found in statistical tests of all ten digits, as well as when testing each hand independently. The frequencies of the total ridge counts were found to be significantly lower in the prisoners when compared to the male control group, but was similar to the mean of the female control group. I question the importance of the comparison using the female control group, since there are known differences in

many dermatoglyphic aspects based upon gender (Holt, 1968). The more significant differences are found between the male prison sample and the male control groups.

There are established associations that exist between dermatoglyphics and many other biological traits. These types of associations are accepted by genetic researchers and are used in many studies. In fact, it was through these associations that we gained knowledge concerning genetics before more sophisticated methods came into use. Schaumann et al. (1991:195) suggested that:

> The emerging associations between certain combinations of dermatoglyphic traits and specific chromosome aberrations quickly established dermatoglyphics as a useful diagnostic aid and an integral part of the medical diagnostic armamentarium during the early years of human cytogenic studies before completely reliable chromosome identification became possible.

This idea forms the structure for all dermatoglyphic correlational studies, including my study. These types of associative studies using dermatoglyphics have a long list of disorders that have shown both positive and negative results. These include "disorders such as mental illness, diabetes mellitus, epilepsy, leprosy, leukemia, lupus erythematosus, psoriasis, schizophrenia, tuberculosis, vitiligo, and many other disorders including single congenital malformations not involving limbs" (Schaumann et al., 1991:211). Certain criminal behaviors might eventually be added to the list of traits showing a positive correlation to certain dermatoglyphic features.

My study uses the associative nature of the many other dermatoglyphic studies to expand upon the two previous studies by Welch et al. (1971) and Castilla (1979) dealing with criminal behavior. I felt that further research could be done with this subject. I attempted to more closely define the categories of study so that any

differences found could be of more relevance to the issue of genetic involvement. Of primary importance were to have carefully selected subject and control groups based upon gender and race. In addition the criminal subject group had a defined criteria for selection that was more narrowly defined than the two previous studies. Similar statistical tests were performed so that comparisons could be made between this and the previous studies. My hypothesis is that differences found in the dermatoglyphic features of the previous studies will also be present in this study.

CHAPTER III

MATERIALS AND METHODS

The fingerprint information for this study was obtained from the records of the Kalamazoo County Sheriff's Department. The total sample consisted of 200 Caucasian males selected from the existing fingerprint records. Both the subject and control groups consisted of 100 individuals who were selected based on the criteria of racial affinity, gender, type and frequency of charged crimes. All individuals had to be Caucasian males; this restriction eliminated the two variables of gender and race from having an impact on any differences that might be found from the comparisons. The largest racial and gender category in the fingerprint records were Caucasian males. Using this group allowed the sample to be selected from the largest population.

I obtained all fingerprint information from the standard ten finger identification print cards. These cards contained the information needed to select or reject the individual for use in either the subject group or the control group. Only cards with complete sets of fingerprints were used. Any cards that had unreadable fingerprints due to missing, scarred, or mutilated digits were eliminated. Also, any cards with blurred or smeared prints were not used. The impressions had to be clear

and readable. The standard ten finger identification print cards contained the rolled impressions of each finger with clear distinctions made between each digit and hand. The impressions were all made with black printer's ink, with each finger being rolled onto the appropriate blocks of the card. I classified the fingerprint patterns and counted the relevant ridges using a standard fingerprint identification magnifying lens and pointer. All of the fingerprint information was collected directly from the original fingerprint cards.

Individuals in the subject group were selected on the basis of being Caucasian males, and having been charged with a violent crime. What I considered being evidence of violent criminal behavior was for the individual to have been charged with at least two counts of felonious assault, or charged with murder. The charges of felonious assault must have been at least one year apart with at least one other charge of some type of violent behavior on a separate occasion to show repetitive behavior and not simply a single outburst of violence. The charge of murder was also included, but only if the individual had at least one other charge associated with some type of violent behavior on a separate occasion. The inclusion of individuals on the basis of the charges described was in an effort to include only those who show repeated violent behavior and not single isolated incidents. The control group consisted entirely of Caucasian males, who were never charged with any type of violent crime. Their fingerprint records were on file because they had been involved in serious, non-felony, traffic offenses.

The classification criteria for the fingerprint patterns and methods of ridge counting were based upon descriptions and examples from Galton (1892), Cowger (1993), and Holt (1968). The type of fingerprint information I collected corresponded to what the majority of dermatoglyphic studies use for analysis. Statistical comparisons were made of all aspects of the fingerprint information that was collected. The fingerprint patterns were classified as arch, loop, or whorl. Additionally, the arch and loop categories were further sub-classified into tented arch, plain arch, radial loop, and ulnar loop categories.

The first sets of comparisons were based upon the frequencies of occurrence in fingerprint pattern types. Comparisons were made of the total pattern frequencies, pattern frequencies for each hand, and pattern frequencies for each digit. The subject and control groups were compared through the *t* test and *z* test for the difference of means between independent samples. This will test the significance of the difference between the means of the two independent samples. This is based on probability estimates calculated from the comparisons of the subject and control groups. This will determine how big a part chance plays in the outcome of an experiment. Results that are unlikely to have occurred by chance are determined to be significant.

The second sets of comparisons were made in the ridge counts of the loop patterns. The ridge counts were collected using the method outlined by Holt (1968). The ridge count is obtained by establishing an imaginary line between the core and triradius (delta) of the loop pattern. The number of ridges that either touch or cross that line is the ridge count. The ridge counts were also compared based upon total

frequencies, ridge count frequencies for each hand, and ridge count frequencies for each digit. These ridge count comparisons might be the most significant aspect because the two previous studies of similar research by Welch et al. (1971) and Castilla (1979) showed significant differences in ridge counts.

The statistical comparisons were done through the *t* test and *z* test using confidence intervals of 95% being significant and 99% being highly significant. These comparisons were done on all combinations of pattern types and finger ridge counts. All statistical comparisons were between the collected information of the subject group against the control group. The results of these statistical tests follow in the next section.

Additional pattern interpretation and ridge counting were conducted to test accuracy. These individuals were selected using the same criteria and from the same selection of fingerprint patterns as the original group. A total of 20 individuals were used for this test, 10 criminals and 10 non-criminals. The pattern types and ridge counts of the twenty individuals were recorded. The recording of this information was done three times on three separate occasions. For the three trials the fingerprint cards were given a reference number so their criminality was unknown. For each trial the order of the cards was changed to eliminate the chance occurrence of any repeatable pattern.

The pattern types were compared to see if any patterns were misidentified. The ridge counts were compared using the mean and standard deviation of the

samples. The three trials were compared to identify any possible problems with pattern identification or ridge counting.

CHAPTER IV

RESULTS

The dermatoglyphic data were analyzed through the *z* tests and *t* tests of statistical significance for the difference between two means. I used Microsoft Excel 97 spreadsheet program for the statistical test calculations. Additionally, all charts and graphs were generated from the same data through Microsoft Excel 97.

Tests of repeatability were performed for pattern types and ridge counts. These tests were to determine my accuracy in identifying pattern types and ridge counting for the criminal and non-criminal samples. For the three trials of repeatability, all pattern types were similarly identified. There were no contradictions for the identification of arch, loop, or whorl patterns. The test of repeatability for the ridge counting showed similar results. The mean and standard deviations were obtained for the three separate trials and shown in Table 5.

Table 5

Ridge Counting Test of Repeatability

	Count	Sum	μ	σ
Trial #1	156	1832	11.7	5.58
Trial #2	156	1852	11.9	5.57
Trial #3	156	1840	11.8	5.54

From the three trials it can be determined that the ridge counting and pattern interpretation methods used for this study were accurate. The close correlation of the mean and standard deviation between the three trials illustrates the precision available to ridge counting. The accurate identification of pattern types in each of the three trials also indicates the methods used for pattern identification were without error. Based on the information from the three trials, I am confident the pattern interpretation and ridge counting were also accurate for the criminal and non-criminal groups.

For the main study, the same categories of pattern type interpretation and ridge counting were analyzed. I looked at the overall frequencies and distributions of the pattern types and ridge counts to see if the criminal and non-criminal groups differed in any significant way. Based upon these categories, I performed a number of statistical tests to discover as many differences or similarities as possible.

Dermatoglyphic Patterns

None of the dermatoglyphic pattern frequencies tested showed any significant statistical differences between the criminal and non-criminal groups. All of the statistical tests that were completed and the outcomes, including the *z* score and *t* score with the P value expressed in a percentage are shown in Table 6. The percentage of pattern types can also be seen in Figure 5.

Table 6

Statistical Comparison of Criminal and Non-Criminal Samples

Pattern Tests	***t* Test**	**P**
Whorl Pattern	.38	P > .05
Combined Loop Pattern	.51	P > .05
Ulnar Loop Pattern	-.28	P > .05
Radial Loop Pattern	-.28	P > .05
Arch Pattern	.58	P > .05
Ridge Count Tests	***z* Score**	**P**
Total Ridge Count	-2.71	P ≤ .001 *
Ridge Count Right Hand	1.82	P > .05
Ridge Count Left Hand	2.05	P ≤ .05 *

* Statistically Significant

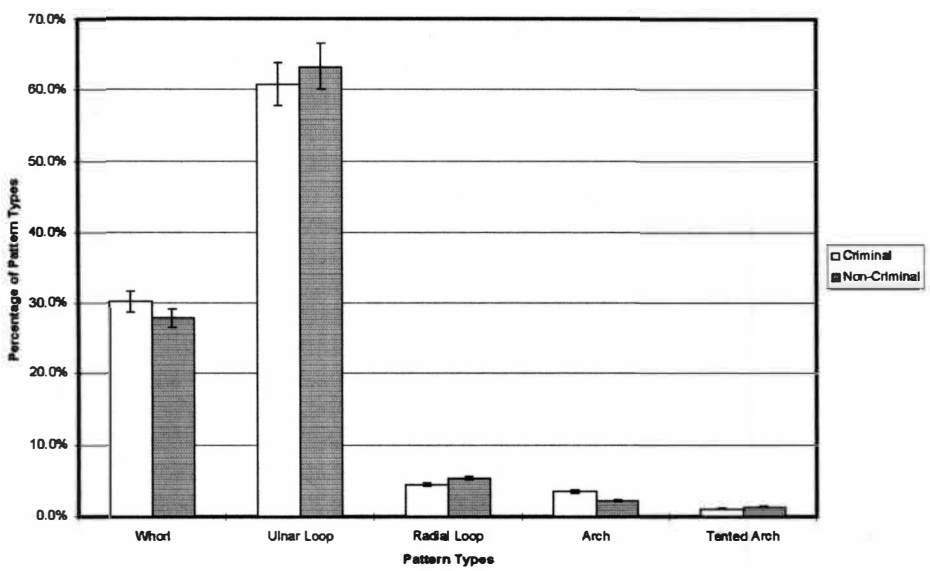

Figure 5. Percentages of Pattern Types.

While none of the tests for pattern types showed a significant difference, there were several points of interest. The criminal sample had an increased number of arches and whorls compared to the non-criminal sample, which can be seen in Figures 6 and 7. In particular, the criminal sample had 13 more plain arch patterns than the non-criminal group. This difference is most marked on digit 7 where the non-criminal sample did not have a plain arch pattern. The arch pattern is the least frequently occurring of all patterns, usually at a rate of only 5% when compared to the other pattern types. Differences between the criminal group (4.6%) and non-criminal groups (3.6%) exist, but are not significant. This is not necessarily important in terms of this study; rather the relationship between the loop patterns and ridge counts is more consequential.

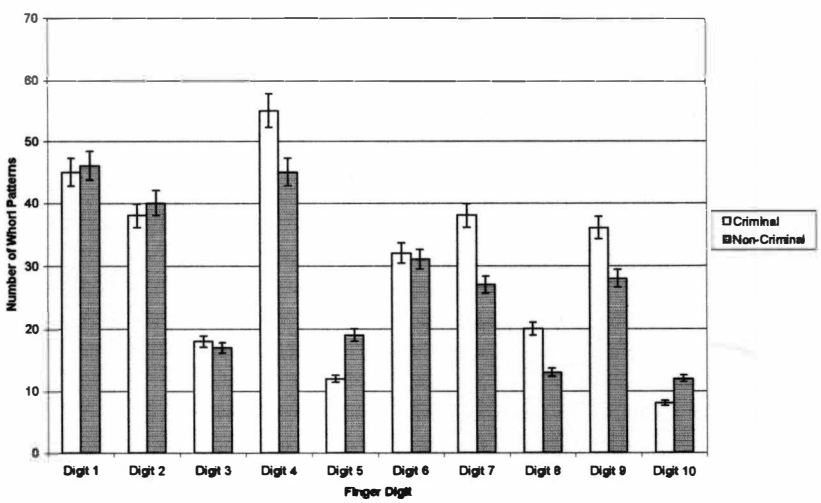

Figure 6. Whorl Pattern Distribution.

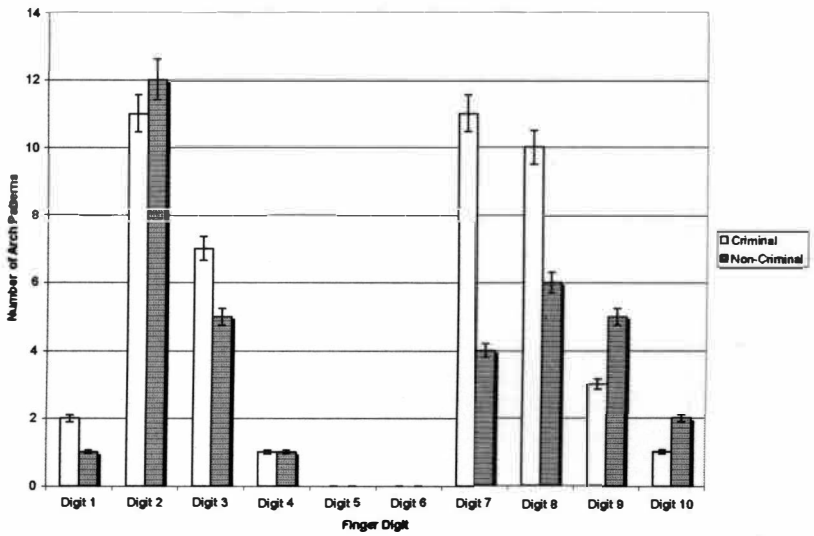

Figure 7. Arch Pattern Distribution.

The total number of pattern types for each digit is shown in Table 7. An aspect of this table that will be of greater importance after the presentation of the ridge count data is that the loop patterns did not differ in any significant way. If there were significant differences found in the frequencies of the loop patterns it would be assumed that the ridge counts would also differ. The ridge count data would then not yield any additional information. The loop pattern tests included ulnar loops, radial loops, and combined totals. The criminal group had only 34 fewer loops than the non-criminal group, a total of 652 compared to 686 that can be seen in Figure 8. This is important because it is the loop pattern that yields the ridge counts. With a similar number of loop patterns in each group it would be expected the two groups would exhibit similar ridge counts. The fact that the loop pattern frequencies were similar make any differences found in the ridge counts more meaningful.

Table 7

Number of Individuals Displaying Pattern Types on Each Digit

Finger	1	2	3	4	5	6	7	8	9	10	Total
Number of Plain Arches											
Criminal	2	8	6	1	0	0	7	8	2	1	35
Non-criminal	1	6	4	1	0	0	0	5	4	1	22
Number of Tented Arches											
Criminal	0	3	1	0	0	0	4	2	1	0	11
Non-criminal	0	6	1	0	0	0	4	1	1	1	14
Number of Ulnar Loops											
Criminal	53	33	71	42	88	65	35	68	61	91	607
Non-criminal	53	25	76	54	81	65	41	81	69	87	632
Number of Radial Loops											
Criminal	0	18	4	2	0	3	16	2	0	0	45
Non-criminal	0	23	2	0	0	4	23	1	1	0	54
Number of Whorls											
Criminal	45	38	18	55	12	32	38	20	36	8	302
Non-criminal	46	40	17	45	19	31	27	13	28	12	278

In conclusion, the comparisons of the pattern frequencies and distributions showed no statistical differences. The arch patterns were shown to differ slightly but not in a significant way. From these results there can be no definitive differences found to exist between the criminal and non-criminal groups, in terms of pattern types.

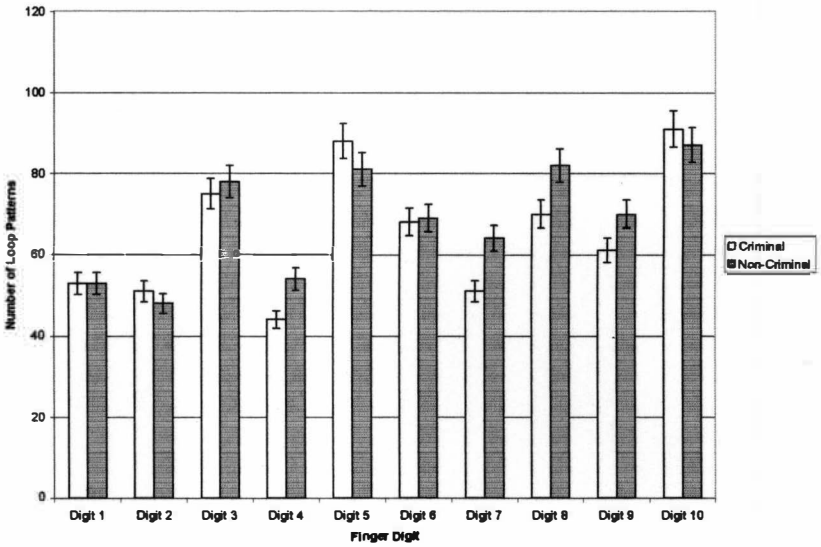

Figure 8. Loop Pattern Distribution.

Ridge Counts

Three of the statistical tests with respect to differences in ridge counts were found to be statistically significantly. The first two and probably most notable are shown in Table 6 and refer to the total and left hand ridge counts. The third test found to be statistically significant can be seen in Table 8 and refers to digit 6, the left thumb. The lower ridge counts found in the criminal group corresponds with the results of the previous two studies that found substantially lower ridge counts in the criminal populations.

Table 8 shows the breakdown for each digit, the mean, standard deviation (SD), *z* score, and the probability calculation. Again, the probability calculation indicates whether any difference is actual, or simply due to random chance. The lower the percentage, the less likely any observe difference was due to random chance; a higher percentage indicates that there isn't enough of a difference to be

significant and the discrepancy could easily be the result of random chance. Figure 9 shows a chart of the total ridge counts for each digit, comparing the criminal and non-criminal groups. As Figure 9 displays, the non-criminal group exceeded the criminal group in average ridge counts on all digits except digit 9. The only digit that was found to statistically significant was digit 6, the left thumb. The total ridge count and ridge count of the left had were found to be statistically significant, shown in Table 6.

The differences found in the ridge counts have increased significance, since the loop patterns showed no differences between the groups. If the loop patterns were different, in that there were fewer loops in the criminal group, the ridge count would be expected also to be less than the non-criminal group. Since there was no difference found in the loop pattern types between the groups, the variance in ridge counts cannot be attributed to dissimilar pattern distributions.

Table 8

Summary of the Average Ridge Count for Each Digit

Finger Digit	Groups	Mean	SD	*z* score	Probability
Digit 1	Criminal	17.1	5.73	.76	P > .05
	Non-criminal	18.0	6.86		
Digit 2	Criminal	9.8	6.25	1.07	P > .05
	Non-criminal	11.1	5.30		
Digit 3	Criminal	10.9	5.60	-1.29	P > .05
	Non-criminal	12.0	4.77		
Digit 4	Criminal	13.2	7.56	.077	P > .05
	Non-criminal	13.3	6.22		

Table 8-Continued

Digit 5	Criminal	12.6	6.08	-1.11	P > .05
	Non-criminal	13.6	5.43		
Digit 6	Criminal	14.5	5.33	-2.26	P ≤ .05 *
	Non-criminal	16.7	5.75		
Digit 7	Criminal	9.3	5.59	-1.79	P > .05
	Non-criminal	11.0	4.93		
Digit 8	Criminal	11.0	5.93	-1.49	P > .05
	Non-criminal	12.2	4.50		
Digit 9	Criminal	14.4	6.27	.30	P > .05
	Non-criminal	14.1	5.73		
Digit 10	Criminal	12.9	5.45	-.44	P > .05
	Non-criminal	13.3	4.90		

* Statistically Significant

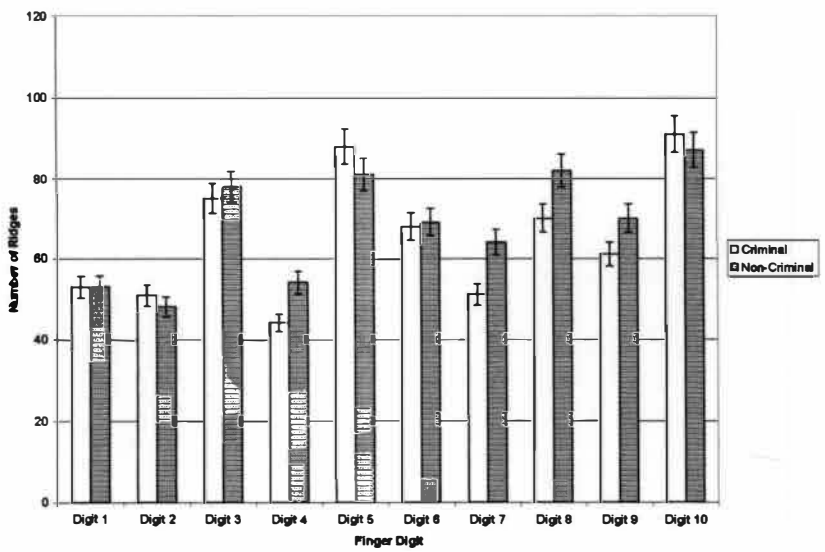

Figure 9. Total Ridge Count Comparison.

The statistical tests for ridge counts generally showed no statistical differences. The three tests that were statistically significant showed fewer ridges

between the core and delta of the criminal group compared to the non-criminal group. The remaining tests even though they were not significant tended to support this tread of the criminal group having fewer ridges than the non-criminal group. These results correspond to those of Castilla (1979), and Welch et al. (1971) who also found, on average, the criminal groups to exhibit fewer ridges than the non-criminal group.

CHAPTER V

DISCUSSION

This study was conducted to test the possibility that two seemingly unrelated aspects of human biology might share an association. This is referred to as a correlational study, where there is an attempt made to associate two elements in some meaningful way, or to determine that no connection can be made. My study used dermatoglyphics and criminal behavior in an effort to find such an association. In order to establish an association there has to be a common genetic factor that influences the expression of two or more unrelated phenotypes.

Holt (1968) has established the genetic inheritance of dermatoglyphics. Continued research has attempted to identify specific chromosomes that are associated with certain dermatoglyphic features. Most often, looking at the different chromosomal trisomy conditions does this. Trisomy describes a condition when a chromosome, normally one of a homologous pair, is present in triplicate and the extra chromosome is indistinguishable from the normal pair. Linkage studies have identified differences in the following trisomy conditions 13, 14, 15, 17, 18, 21, and 22 (Penrose, 1963). "By comparison of a patient's ridge configurations with those of known chromosomal abnormalities, a decision can be made as to whether or not a particular chromosome is likely to be involved" (Holt, 1968:167). These findings indicate that dermatoglyphic features are not controlled by a single chromosome but

are associated with a number of different chromosomes. This supports the idea that there is polygenic control for the inheritance of dermal prints. This implies that the phenotypic expression of other biological conditions can be linked to genes on chromosomes that also affect dermatoglyphics.

Criminal behavior, like any human behavior, is not completely understood. There are many social and environmental variables, in addition to genetics, that affect any individual's behavior (Raine, 1993). From this, emphasis has been placed on the results of twin and adoption studies (Christiansen, 1977; Crowe, 1975; Cadoret, 1978). These studies can have more control over the influence of social and environmental factors helping to isolate the genetic effect. While these efforts have emphasized the significance of genetics on behavior, this does not mean that genes are the major factor for behavioral determination. The belief that individuals are ultimately controlled by their genetic makeup is called biological determinism. This concept states that the "shared behavioral norms, and the social and economic differences between human groups–primarily races, classes, and sexes-arise from inherited, inborn distinctions and that society, in this sense, is an accurate reflection of biology" (Gould, 1981:20). This idea of biological determinism completely ignores the environmental and social factors that also affect human behaviors (Raine, 1993). Marks (1995:244) agrees, "it seems quite naive to seek an organic basis for something that is in part defined culturally." Any one factor must be recognized and considered in reference to all other factors that can affect human behavior. An analysis of crime is especially difficult because there are so many influential

circumstances. Factors influencing crimes include but are not limited to genetics, environment, and society,

The methodology for twin studies uses concordance rates of criminals to non-criminals in the estimation of heritability. The concordance was usually measured between monozygotic (MZ) twins, who are genetically identical and dizygotic (DZ) twins who share, on average, 50% of their genes. To date there have been 10 studies which have produced 13 analyses of the genetics of crime in twins (Raine, 1993). A genetic influence is indicated through higher concordance rates in MZ twins when compared to DZ twins. Raine (1993) reports that all 13 analyses show greater concordance rates for criminality in MZ twins than in DZ twins, at an average of 51.5% for MZ twins and 20.6% for DZ twins.

Adoption studies may even be able to separate genetic and environmental factors more clearly than twin studies. In these studies the crime rates of individuals are compared in terms of the criminal or noncriminal status of their foster parents and biological parents. Table 1 shows how these studies work and that the results were as conclusive as the twin studies. As expected when the biological and adoptive parents were criminals the children have the highest percentage of criminality. Alternatively when the biological and adoptive parents were not criminals the children have the lowest percentage of criminality. When the criminality was different for the adoptive and biological parents, children were more often criminals when their biological parents were criminals. This indicates that the genetic association, in terms of criminality, is more influential than certain social and environmental factors. In a

survey of 15 studies, Raine (1993) found that only one of the 15 studies did not find some degree of genetic influences in crime causation.

While precise values on the influence of genetics on any behavior cannot be established there are estimates of heritability that make it difficult to deny that genetics does have some significance. Raine (1993:66) concludes "given the current evidence, it would seem erroneous to deny the fact that genetic factors play some role in the etiology of criminal behavior". This may have been and still is difficult to accept because of the convoluted interaction between the variables involved. "We are biosocial animals, each influenced both by genetic and environmental factors active and interacting in complex ways" (Eysenck et al., 1989:108).

There have been few studies that have looked at a possible correlation between dermatoglyphics and criminality. Studies by Welch et al. (1971) and Castilla (1979) did attempt to find an association. Each used dermatoglyphic features to identify differences between criminals and noncriminals. Several aspects of dermatoglyphic features were compared between the criminal samples and the comparable non-criminal groups. The two previous studies found significant statistical differences in dermatoglyphics when the information was analyzed. Despite differences in geography and ethnicity of the samples, the two studies obtained similar results.

Welch et al. (1971) found a greater number of arch patterns in the criminal sample compared to the control group. Additionally, the total ridge count (TRC) was found to be significantly less in the male criminals. The sample consisted of male

criminals from the U.S. compared to the control group of white British males from a previously published study (Holt, 1955). Castilla (1979) found differences in both pattern types and the total ridge counts when comparing prisoners to the control groups. There were a greater number of whorls and fewer ulnar loops when compared to both the male and female control groups. The frequencies of the total ridge counts were found to be significantly lower in the prisoners when compared to the male control group, but was similar to the mean of the female control group. My study found a greater number of arches and a lower, average total ridge count in the sample group when compared to the control group, although these differences were not statistically significant.

There was a common difference found in both published studies and this thesis, that the total ridge count (TRC) of the test population was less than the comparable control groups. Welch et al. (1971) and this study both showed a higher number of arch patterns in the test group compared to the control group. Castilla (1979) did not find this difference. The differences found in total ridge counts (TRC), and not pattern types, can be expected when considering the established heritability estimates for certain dermatoglyphic features. The total finger ridge counts have been found to have "one of the highest heritabilities of any anthropometric traits in humans" (Schaumann et al. 1991:197). Holt (1968:64) adds "we may conclude, therefore, first that total ridge-count is an inherited metrical character; secondly, that a number of perfectly additive genes are concerned; and thirdly, that environment plays a comparatively small part".

There are numerous statistical tests that can be performed on dermatoglyphics, and any one 'significant' result may simply occur from chance. This appears to be the case when considering the differences found in the pattern types. Only Welch et al. (1971) and I found disparities in the percentages of arch patterns, approaching significance. This is the most infrequently occurring pattern and such small differences in the number of patterns can yield misleading significant statistical differences. Larger size samples in either case might have shown that these differences were not significant. The differences in total ridge counts (TRC) were found to be similar in all three of the studies. These studies all showed that the criminal populations had a lower total ridge count than the control populations. While this could have been the result of random variation, it more likely indicates a biological variation.

Those differences found in the criminal populations may indicate a genetic association between certain dermatoglyphic features and the biological factors that produce antisocial behavior. Often, these antisocial tendencies are associated with criminal behaviors. This means that there are certain dermatoglyphic features that might share a genetic connection to heritable antisocial behaviors, not to specific criminal behaviors; however, there may be crimes more likely to be committed by those diagnosed with antisocial tendencies. Crimes committed by individuals exhibiting antisocial behaviors should show more significant disparities in dermatoglyphic features.

The results of the three studies show meaningful agreement in the total ridge counts of the criminal samples. This along with the evidence of the total ridge count being strongly genetically controlled supports the assumption that certain criminal behaviors may share a genetic connection to dermatoglyphic ridge counts. Castilla (1979:415) acknowledged the similarity in the results of her study to that of Welch's but would only go so far to say "another possibility is that the results indicate a biologic difference in the tendency to antisocial conduct". The other possibility was simply because of random variation due to geographic or ethnic differences in the studies, or between the sample and control groups. While my study did not any conclusive evidence I feel more comfortable in supporting the possibility that a biologic difference may exist between certain criminal and noncriminal individuals. Additionally, these differences might be linked to the differences found to exist in the total ridge counts of criminals. This would support the inclusion of antisocial criminal behavior within the list of other biological genetic disorders that have been shown to share some type of association with certain dermatoglyphic traits.

Even with the evidence of genetic influences on human behavior it must be stressed that this is only one component of many that are involved in influencing behavior. The criminality of an individual could not be determined from any particular dermatoglyphic, or genetic trait. Only in combination with the other factors that affect behavior can we begin to understand the causes of crime. The single most important reason that genetics must be considered in conjunction with all other factors is because the "causes of crime are not monolithic" (Marks, 1995:245).

Genetics may be shown to affect certain human behaviors, but will never be as important as an individual's societal environment (Raine, 1993).

CHAPTER VI

CONCLUSION

The results of this and the two previous studies indicate there is a chance that a genetic association exists between certain dermatoglyphic traits and some criminal behaviors. The strongest support for this conclusion is the similarity in results between the three studies. All have shown similar differences between the criminal and the non-criminal groups. While the data is compelling, it is far from definitive.

These results were all subject to factors that may affect the validity of the information obtained. Some items include statistical methodology, definition of criminal behavior, and impartiality of the control group. All three studies used different ethnicities in the criminal and non-criminal groups and Castilla (1979) even used both genders for the non-criminal group. There are also a number of different ways to interpret pattern types and ridge counts. All studies used systems based upon Henry's original system for fingerprint identification, but there can always be observational error.

This research does not provide absolute proof for the connection of dermatoglyphics to certain criminal behaviors, but does add support for this hypothesis. This and previous studies encourage further research in this area. The

question of whether dermatoglyphics share a genetic connection to criminal behaviors can be answered only after additional studies continue to show similar results. It is important that these future studies only compare criminal samples to appropriate control samples. This means groups of similar ethnicity and gender. It is also important to consider what criminal behaviors to include as the test group, and an equally appropriate control group. There also must be standardization as to the methods of dermatoglyphic identification used.

To conclude, based on this study and previous studies, there appear to be differences in the total ridge counts (TRC) of criminals when compared to noncriminals. The pattern types of these groups do not differ in any meaningful way. The ridge counts of dermatoglyphic patterns are strongly genetically determined and share a genetic connection to antisocial behaviors, which are commonly attributed to criminal behaviors.

Appendix A

Protocol Clearance From the Human Subjects Institutional Review Board

Date: 13 June 1997

To: Robert Sundick, Principal Investigator
Jeremy Matyas, Student Investigator

From: Richard Wright, Chair

Re: HSIRB Project Number 97-06-04

This letter will serve as confirmation that your research project entitled "Dermatoglyphic Analysis of a Prison Population" has been **approved** under the **exempt** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: 13 June 1998

Appendix B

Data for Pattern Types in Subject and Control Groups

Dermatoglyphic Pattern Types – Subject Group

Subject	Digit 1	Digit 2	Digit 3	Digit 4	Digit 5	Digit 6	Digit 7	Digit 8	Digit 9	Digit 10
1	W	R	\	W	\	W	R	/	W	/
2	\	\	\	\	\	/	T	/	/	/
3	W	W	\	W	\	W	W	/	W	/
4	\	R	\	\	\	W	/	/	W	/
5	\	W	\	\	\	W	W	/	/	/
6	\	R	\	\	\	/	A	R	/	/
7	W	R	R	\	\	/	W	/	/	/
8	\	W	\	W	\	/	/	/	/	/
9	W	W	\	\	\	W	W	/	/	/
10	W	\	\	\	\	/	R	/	/	/
11	W	W	\	W	\	W	W	/	/	/
12	\	\	\	W	\	/	R	/	W	/
13	\	\	\	\	\	/	/	/	/	/
14	\	W	W	W	\	/	/	W	/	/
15	W	W	\	W	W	W	/	/	W	W
16	\	W	\	W	\	/	W	W	W	/
17	\	\	\	W	\	W	/	W	/	/
18	\	W	\	\	\	/	R	/	/	/
19	W	\	\	W	\	/	/	/	/	/
20	W	W	W	W	\	W	W	W	W	/
21	\	R	\	\	\	/	A	/	/	/
22	W	W	\	W	W	W	W	W	W	W
23	W	W	\	W	\	/	R	/	/	/
24	\	\	A	W	\	W	/	A	/	/
25	\	\	\	\	\	/	/	/	/	/
26	W	R	\	W	\	/	R	/	W	/
27	\	A	\	\	\	/	/	/	/	/
28	\	A	A	R	\	A	/	/	/	/
29	\	\	\	\	\	/	T	R	T	/
30	\	W	\	W	\	/	W	/	W	/
31	\	\	\	W	\	/	/	W	/	/
32	\	\	\	\	\	/	/	/	/	/
33	A	A	A	A	\	A	A	A	A	A
34	W	\	\	W	\	/	W	/	W	/
35	W	\	\	\	\	W	/	/	/	/

36	\	R	\	\	\	/	R	/	/	/
37	W	A	\	W	\	/	A	/	W	/
38	W	W	W	W	\	/	W	W	/	/
39	\	\	\	\	\	/	/	/	/	/
40	\	\	\	W	\	/	/	A	/	/
41	\	\	\	\	\	/	R	/	/	/
42	\	R	\	\	\	/	W	/	/	/
43	W	R	\	W	\	W	/	A	W	/
44	\	\	\	\	\	/	/	/	/	/
45	W	T	\	W	\	/	/	/	/	/
46	W	\	\	\	\	W	W	/	/	/
47	\	A	A	\	\	/	A	/	/	/
48	W	W	W	W	\	W	W	/	W	/
49	W	\	\	\	\	/	R	A	/	/
50	W	R	W	W	W	W	W	W	W	W
51	W	W	\	\	\	/	W	/	/	/
52	W	W	W	W	W	W	W	W	W	W
53	W	\	\	W	W	/	R	/	/	/
54	\	W	W	W	W	W	W	W	W	W
55	W	W	W	W	\	W	W	W	W	/
56	\	\	\	W	\	/	/	/	W	/
57	\	\	\	W	\	/	/	/	/	/
58	\	W	W	W	\	/	W	/	W	/
59	\	W	\	\	\	/	R	/	/	/
60	W	W	R	W	W	/	/	W	W	/
61	W	W	W	W	\	W	W	W	W	/
62	\	\	\	\	\	/	R	/	/	/
63	W	A	\	\	\	/	A	A	A	/
64	\	\	\	\	\	/	R	/	/	/
65	\	W	\	W	\	/	W	/	W	W
66	W	\	\	\	\	W	W	/	/	/
67	\	R	\	\	\	/	/	/	W	/
68	\	R	R	W	\	/	W	/	/	/
69	W	A	A	W	W	W	A	A	/	/
70	\	T	\	R	\	/	T	/	/	/
71	W	R	\	\	\	W	/	/	/	/
72	W	W	\	\	\	W	W	/	/	/
73	W	R	R	W	\	W	/	/	/	/

74	\	\	\	\	\	/	R	/	/	/
75	W	W	\	\	\	W	W	/	/	/
76	\	\	\	W	\	A	/	/	W	/
77	W	R	A	W	W	/	/	/	/	/
78	\	W	T	\	\	/	R	T	/	/
79	W	W	\	W	\	/	/	/	/	/
80	W	W	W	W	\	W	W	W	W	/
81	\	\	\	\	\	W	W	W	W	/
82	\	\	\	W	\	/	/	/	/	/
83	\	\	\	W	\	/	/	/	/	/
84	W	R	\	\	\	/	/	/	/	/
85	\	\	\	\	\	/	T	T	/	/
86	\	W	\	\	\	/	W	/	/	/
87	\	A	\	\	\	/	/	/	/	/
88	W	W	\	\	\	W	W	/	W	/
89	W	\	W	W	\	W	W	W	W	W
90	\	W	\	W	\	/	W	W	W	/
91	W	W	W	W	\	/	W	/	W	/
92	W	W	W	W	W	/	/	/	/	/
93	W	W	W	W	\	W	W	W	W	/
94	\	T	\	W	\	/	R	/	/	/
95	\	\	\	\	\	/	/	A	/	/
96	\	W	\	W	\	/	W	/	/	/
97	A	R	W	W	\	/	/	/	W	/
98	\	W	W	W	W	/	W	W	W	/
99	\	R	\	W	\	/	W	/	W	/
100	W	W	W	W	W	W	W	W	W	W

W – whorl pattern
A - arch pattern
R – radial loop pattern
\ or / - ulnar loop pattern

Dermatoglyphic Pattern Types - Control Group

Subject	Digit 1	Digit 2	Digit 3	Digit 4	Digit 5	Digit 6	Digit 7	Digit 8	Digit 9	Digit 10
1	W	\	\	\	\	W	W	/	/	/
2	\	\	\	\	W	/	/	/	/	/
3	W	R	\	W	W	W	/	/	W	/
4	W	R	\	\	\	W	R	/	/	/
5	W	R	\	\	\	W	R	/	/	/
6	W	W	\	W	\	/	W	/	/	/
7	\	\	\	\	\	/	/	/	/	/
8	\	\	\	\	\	/	/	/	/	/
9	\	W	\	W	\	/	/	/	/	/
10	\	W	\	\	\	/	/	/	/	/
11	W	W	W	W	W	/	W	/	W	/
12	\	W	W	W	\	/	W	W	W	/
13	\	\	\	\	\	/	/	/	/	/
14	W	W	W	W	W	/	W	W	W	W
15	\	A	\	A	\	/	A	/	/	/
16	W	R	\	\	\	W	R	/	/	/
17	\	R	\	\	\	/	T	/	/	/
18	W	W	W	W	W	/	W	/	W	W
19	W	A	\	\	\	/	A	A	/	/
20	W	W	W	W	W	W	W	W	W	/
21	\	\	\	\	\	/	/	T	R	T
22	\	R	W	W	W	/	R	W	/	/
23	W	W	W	W	\	/	W	/	W	/
24	\	W	\	W	\	/	W	/	/	/
25	W	R	\	\	\	/	R	/	/	/
26	\	R	\	\	\	/	R	/	/	/
27	\	\	\	\	\	/	/	/	/	/
28	W	A	\	\	\	/	R	/	/	/
29	W	W	\	W	\	W	W	W	W	/
30	W	R	W	\	\	/	W	/	/	/
31	\	W	\	W	\	/	/	/	/	/
32	\	\	\	\	\	A	/	/	/	/
33	A	R	\	W	\	/	R	/	/	/
34	W	W	\	W	W	/	/	/	/	/
35	\	W	\	\	\	/	/	/	/	/

36	\	T	T	\	\	W	R	/	/	/
37	\	\	\	W	\	W	W	/	W	W
38	W	R	R	W	W	/	/	/	/	/
39	\	\	\	\	\	W	W	/	/	/
40	W	W	\	\	\	/	R	/	W	/
41	W	W	\	\	W	W	W	A	W	W
42	W	\	\	\	\	W	T	/	/	/
43	\	A	A	\	\	A	A	A	T	/
44	\	R	\	\	\	/	/	/	/	/
45	\	R	A	W	\	A	A	/	/	W
46	W	W	\	W	\	W	W	/	W	/
47	\	\	W	W	\	/	/	W	W	/
48	\	\	\	\	\	/	/	/	/	/
49	W	W	\	W	W	/	/	/	W	W
50	\	\	\	W	\	/	R	/	W	/
51	W	\	\	\	\	/	/	/	/	/
52	W	W	\	W	W	W	/	/	W	W
53	W	W	\	W	W	W	W	/	/	/
54	\	R	\	\	\	A	/	/	/	/
55	W	T	\	W	\	W	R	/	/	/
56	\	\	\	W	\	/	/	W	W	/
57	\	R	A	W	\	/	R	/	/	/
58	\	W	W	W	\	/	W	W	W	/
59	\	\	\	\	\	W	/	/	/	/
60	\	W	\	\	\	/	W	/	/	/
61	\	W	\	\	\	/	R	/	/	/
62	\	R	\	\	\	/	/	/	/	/
63	\	R	\	\	\	/	R	/	/	/
64	\	\	\	\	\	/	/	/	/	/
65	\	W	W	W	\	/	T	W	W	/
66	\	W	\	\	\	W	R	/	/	/
67	W	\	\	\	\	/	/	/	/	/
68	W	W	W	W	W	W	W	/	W	/
69	\	\	\	W	\	/	/	/	/	/
70	W	\	\	\	\	W	R	/	W	W
71	W	W	\	W	\	/	W	W	W	/
72	\	W	W	W	\	/	/	/	/	/
73	\	W	W	W	\	/	W	W	/	/

74	\	R	\	\	\	/	/	/	/	/
75	\	W	\	W	\	/	/	/	/	/
76	W	W	\	W	\	W	W	/	/	/
77	W	\	\	\	\	/	/	/	/	/
78	W	\	\	\	\	/	/	/	/	/
79	W	W	W	W	W	W	W	W	W	/
80	W	W	\	\	\	/	/	/	/	/
81	W	T	\	W	\	/	/	/	/	/
82	W	W	\	\	\	W	/	/	/	/
83	\	W	\	\	\	W	W	/	/	/
84	\	W	\	\	\	W	/	/	/	/
85	W	A	\	\	\	W	W	/	/	/
86	W	\	R	W	W	/	R	R	A	/
87	\	R	\	\	\	/	T	/	W	W
88	\	R	\	\	\	/	R	/	/	/
89	W	R	\	W	W	/	R	/	/	/
90	W	T	A	\	\	W	R	/	W	W
91	\	W	W	W	W	W	/	/	/	/
92	W	R	\	W	\	/	/	/	W	W
93	W	T	\	\	\	W	/	/	/	/
94	W	W	W	W	W	/	/	/	/	/
95	\	A	\	\	\	W	W	W	W	W
96	W	W	\	W	\	/	A	A	/	/
97	\	T	\	W	\	W	/	/	W	/
98	\	\	\	\	\	/	R	/	/	/
99	\	W	\	\	\	/	R	/	/	/
100	\	R	\	\	\	/	W	/	/	/

W – whorl pattern
A - arch pattern
R – radial loop pattern
\ or / - ulnar loop pattern

Appendix C

Data for Ridge Counts in Subject and Control Groups

Dermatoglyphic Ridge Counts - Subject Group

Subject	Digit 1	Digit 2	Digit 3	Digit 4	Digit 5	Digit 6	Digit 7	Digit 8	Digit 9	Digit 10
1		21	14		15		19	14		16
2	20	10	2	16	16	14		3	9	16
3			20		21			21		20
4	25	2	15	10	6		2	8		14
5	28		15	19	19			16	19	17
6	19	5	2	4	7	8		2	9	4
7		22	2	20	17	16		10	15	18
8	21		11		11	15	10	12	12	13
9			16	18	18			17	15	18
10		2	3	10	15	20	2	4	15	11
11			14		21			15	22	19
12	21	3	7		8	16	3	13		16
13	19	11	10	17	7	11	8	9	12	7
14	20				19	20	16		21	17
15			16				15	15		
16	22		12		12	20				12
17	23	18	14		13		14		22	13
18	18		12	19	14	18	13	13	21	14
19		17	14		20	16	15	14	16	13
20						15				16
21	9	2	2	7	5	11		1	10	5
22			18							
23			21		20	26	12	20	21	20
24	17	5			6		4		17	15
25	18	8	7	18	4	14	7	17	14	8
26		2	4		8	16	3	2		7
27	14		2	5	4	8	8	12	11	3
28	5			1	6		3	4	4	8
29	13	6	5	10	6	12		1		3
30	7		9		14	12		10		16
31	10	10	11		9	11	13		12	9
32	20	18	13	27	20	24	15	14	25	27
33					2					
34		2	13		15	24		16		12
35		4	2	3	5		4	4	4	3
36	20	1	5	15	8	12	2	2	12	7

37			5		7	14		5		10
38					16	15			16	17
39	19	2	6	9	6	10	2	3	4	5
40	15	10	10		4	4	4		11	6
41	10	13	13	15	7	14	17	14	11	11
42	11	6	6	11	11	10		3	13	9
43		15	13		12		11			17
44	10	8	8	11	4	10	8	12	10	4
45			10		17	17	5	12	18	16
46		19	17	17	16			13	18	16
47	11			12	6	7		4	6	3
48					24			13		13
49		5	2	3	15	22	6		2	12
50		17								
51			14	37	36	22		13	27	22
52										
53		12	5			21	1	2	14	10
54	32									
55					16					19
56	24	18	12		19	20	18	17		15
57	19	13	13		15	14	15	12	16	17
58	16				14	21		17		16
59	22		16	14	10	19	13	17	18	7
60			10			9	11			12
61					18					16
62	15	6	11	14	7	14	5	14	13	10
63			6	5	8	13				8
64	16	6	9	2	6	10	3	7	4	4
65	18		21		18	17		21		
66		17	15	12	9			18	16	10
67	19	15	15	22	14	18	18	14		12
68	23	23	18		15	21		8	22	17
69									24	25
70	15		3	8	5	9		4	14	13
71		7	8	12	13		7	1	14	12
72			17	18	19			16	14	18
73		1	2		8		8	8	13	11
74	18	11	10	4	14	15	10	5	5	19
75			9	13	12			2	5	16

76	15	4	13		14		5	14		15
77		9				15	10	6	11	11
78	13			4	5	10	6		13	8
79			22		19	11	20	19	30	21
80					18					17
81	18	13	18	13	14					20
82	8	6	14		14	8	9	13	16	13
83	20	7	19		18	19	16	21	21	19
84		12	15	17	17	18	11	16	14	17
85	11	5	19	17	8	18			20	14
86	29		19	27	20	24		17	27	21
87	17		9	13	8	4	5	8	13	14
88			17	25	25			16		21
89		9			14					
90	17		10		7	21				14
91					8	12		14		11
92						18	16	16	17	17
93					18					15
94	13		2		4	8	2	7	10	5
95	7	9	3	7	6	14	4		4	3
96	14		13		17	10		12	19	16
97		21			13	5	18	19		14
98	19				16					11
99	24	14	11		13	5		14		6
100			9					2	12	4

Dermatoglyphic Ridge Counts - Control Group

Subject	Digit 1	Digit 2	Digit 3	Digit 4	Digit 5	Digit 6	Digit 7	Digit 8	Digit 9	Digit 10
1		18	3	6	8			6	11	10
2	18	10	9	18		19	17	16	24	20
3		10	14				10	15		16
4		4	6	9	7		5	11	6	10
5		4	6	9	8		6	11	5	7
6			15		17	16		14	25	14
7	16	12	14	10	12	4	18	13	14	13
8	12	12	15	14	6	11	10	14	17	8
9	24		15		16	21	14	15	20	16
10	26		16	24	16	20	15	18	20	14
11						21		13		16
12	16				14	11				14
13	24	13	12	11	9	18	13	12	9	9
14						17				
15	3		5		2	4		2	3	5
16		17	15	18	15		22	15	19	18
17	21	8	10	19	17	12		11	15	12
18						22		17		
19			11	6	9	10			7	3
20										18
21	26	11	12	7	4	24	3		12	
22	23	18				20	18		18	17
23					21	27		16		16
24	21		9		13	17		14	12	14
25		6	13	14	12	19	8	15	12	17
26	19	19	12	22	20	19	3	14	18	18
27	27	7	5	7	11	18	11	12	6	5
28			11	9	14	12	17	6	11	11
29			24		21					23
30		13		18	17	22		14	19	17
31	15		16		18	11	16	21	15	15
32	5	4	8	4	3		8	5	4	4
33		2	4		20	9	5	12	21	17
34			17			22	16	15	18	23
35	15		15	18	14	14	9	14	18	14
36	15			5	7		7	4	5	8

37	21	14	15		13			18		
38		8	5			23	15	14	25	16
39	28	12	15	14	18			15	15	15
40			10	20	20	21	19	14		19
41			12	16						
42		16	14	14	16			12	11	15
43	3			4	5					2
44	19	5	8	11	8	9	2	10	13	10
45	2	2			3			2	10	
46			16		17			8		16
47	25	16			11	20	13			9
48	20	15	15	17	14	18	6	14	16	9
49			18			13	13	16		
50	11	6	10		16	13	9	13		16
51		14	12	18	17	20	11	13	14	16
52			16				11	16		
53			8					17	19	18
54	9	9	2	10	8		6	11	5	5
55			16		26		15	10	25	20
56	26	18	16		15	29	17			14
57	17	4			16	13	4	9	11	13
58	18				17	19				14
59	24	17	16	22	18		15	3	13	18
60	5		3	2	3	4		9	2	3
61	22		11	20	17	19	11	14	16	15
62	22	21	9	14	13	22	15	15	14	17
63	18	5	11	13	11	20	10	11	11	10
64	23	10	5	3	5	22	5	7	4	3
65	23				24	23				15
66	20		14	13	11		11	12	10	9
67		15	10	16	17	23	17	14	12	16
68								12		16
69	24	16	18		13	12	14	12	12	16
70		2	10	20	14		5	5		
71			23		22	23				23
72	16				13	11	7	12	14	13
73	21				15	19			18	13
74	7	4	14	16	14	10	12	9	11	20
75	13		13		15	7	12	13	17	15

76			14		21			4	18	16
77		13	12	14	11	17	11	15	15	13
78		8	11	14	13	15	10	14	16	13
79										15
80			13	18	8	17	6	13	17	7
81			13		11	18	6	14	16	7
82			18	16	19		13	13	21	12
83	19		18	25	22			18	15	14
84	21		17	26	25		9	22	21	19
85			4	3	5			23	19	18
86		8	1			18	3	4		5
87	17	18	13	19	14	14		11		
88	19	11	17	11	13	16	17	13	23	15
89		18	11			15	10	12	11	12
90				4	5		17	2		
91	13						3	4	4	5
92		10	21		21	18	16	17		
93			8	8	12		14	17	24	21
94						8	5	9	9	12
95	19		7	5	13					
96			17		12	15			12	11
97	27		11		14		19	18		16
98	31	16	13	21	16	20	8	11	15	12
99	13		11	11	13	31	13	13	14	15
100	14	13	7	13	15	13		12	14	8

Appendix D

Data for Ridge Counts in Test for Accuracy

Dermatoglyphic Ridge Count Data Trial 1.

Subject	Digit 1	Digit 2	Digit 3	Digit 4	Digit 5	Digit 6	Digit 7	Digit 8	Digit 9	Digit 10
1	11	12	10	9	8	10	7	2	10	8
2	20	13		14	16	20	3	10	16	21
3	20	16	12	9	10	12	9	7	14	17
4					17		9	16		16
5	9	9	6	6	9	8	12	11	8	6
6	20	13				17	19	16		15
7		3	11	11	14	20	3	1	9	14
8	17	2	2	6	3	10	1	3	7	7
9			8	19	18	17		11	16	12
10	22	5	9	11	3	9			10	3
11		16	16				9	15		
12			13				12	12		11
13	22	1	3	14	6		4	5	15	14
14	7	8	8	8	10	3	6	5	3	14
15	24	13	16	15	15	17	9	14	15	13
16			22		22			22		16
17	23	17				13	10	13	10	12
18	12	9	11	18	11		3	11	13	13
19	12		12		6	10	5	12		13
20	28		15	19	14	25	16	18	17	13

Dermatoglyphic Ridge Count Data Trial 2.

Subject	Digit 1	Digit 2	Digit 3	Digit 4	Digit 5	Digit 6	Digit 7	Digit 8	Digit 9	Digit 10
1	11	11	11	9	8	10	7	2	9	8
2	19	13		15	20	19	3	10	16	20
3	19	16	12	16	11	12	11	9	15	17
4					16		10	17		17
5	10	10	7	6	9	8	10	11	9	6
6	21	12				20	18	16		15
7		3	10	11	14	21	3	1	9	14
8	16	3	2	6	3	11	1	3	8	7
9			9	19	17	17		12	17	13
10	22	6	9	11	3	9			10	3
11		16	16				9	16		
12			14				12	12		12

13	22	1	3	13	6		3	6	14	13
14	8	8	8	8	11	3	6	5	3	14
15	25	13	14	14	14	19	9	14	14	14
16			23		23			20		15
17	23	16				13	10	13	9	12
18	12	9	10	18	12		3	11	13	13
19	11		12		6	10	5	12		12
20	28		15	18	14	25	16	18	18	12

Dermatoglyphic Ridge Count Data Trial 3.

Subject	Digit 1	Digit 2	Digit 3	Digit 4	Digit 5	Digit 6	Digit 7	Digit 8	Digit 9	Digit 10
1	11	11	11	9	8	10	7	2	10	8
2	19	14		14	17	17	3	10	16	18
3	19	16	12	11	11	12	10	8	12	17
4					19		10	17		17
5	8	9	7	6	8	8	9	9	9	6
6	20	12				20	19	16		16
7		3	10	11	14	21	3	1	10	15
8	16	3	2	5	3	10	1	4	8	7
9			8	19	17	17		13	14	13
10	22	6	9	11	3	9			10	3
11		16	16				9	16		
12			15				12	12		12
13	22	1	3	14	6		3	6	14	14
14	8	8	8	8	11	3	6	5	3	14
15	25	13	16	14	14	18	9	13	15	14
16			24		22			19		16
17	23	16				13	10	13	10	12
18	12	9	11	18	12		3	11	13	13
19	11		12		6	10	5	12		13
20	28		15	18	14	25	16	18	19	13

Appendix E

Data for Pattern Types in Test for Accuracy

Dermatoglyphic Patterns Type Trial 1.

Subject	Digit 1	Digit 2	Digit 3	Digit 4	Digit 5	Digit 6	Digit 7	Digit 8	Digit 9	Digit 10
1	L	L	L	L	L	L	L	L	L	L
2	L	L	W	L	L	L	L	L	L	L
3	L	L	A	L	L	L	L	L	L	L
4	W	W	W	W	L	W	L	L	W	L
5	L	L	L	L	L	L	L	L	L	L
6	L	L	W	W	W	L	L	L	W	L
7	W	L	L	L	L	L	L	L	L	L
8	L	L	L	L	L	L	L	L	L	L
9	A	L	L	L	L	L	A	L	L	L
10	L	L	L	L	L	L	A	W	L	L
11	W	L	L	W	W	W	L	L	W	W
12	W	W	L	W	A	W	L	L	W	L
13	L	L	L	L	L	W	L	L	L	L
14	L	L	L	L	L	L	L	L	L	L
15	L	L	L	L	L	L	L	L	L	L
16	W	W	L	W	L	W	W	L	W	L
17	L	L	W	W	A	L	L	L	L	L
18	L	L	L	L	L	W	L	L	L	L
19	L	W	L	W	L	L	L	L	A	L
20	L	W	L	L	L	L	L	L	L	L

Dermatoglyphic Patterns Type Trial 2.

Subject	Digit 1	Digit 2	Digit 3	Digit 4	Digit 5	Digit 6	Digit 7	Digit 8	Digit 9	Digit 10
1	L	L	L	L	L	L	L	L	L	L
2	L	L	W	L	L	L	L	L	L	L
3	L	L	A	L	L	L	L	L	L	L
4	W	W	W	W	L	W	L	L	W	L
5	L	L	L	L	L	L	L	L	L	L
6	L	L	W	W	W	L	L	L	W	L
7	W	L	L	L	L	L	L	L	L	L
8	L	L	L	L	L	L	L	L	L	L
9	A	L	L	L	L	L	A	L	L	L
10	L	L	L	L	L	L	A	W	L	L
11	W	L	L	W	W	W	L	L	W	W

12	W	W	L	W	A	W	L	L	W	L
13	L	L	L	L	L	W	L	L	L	L
14	L	L	L	L	L	L	L	L	L	L
15	L	L	L	L	L	L	L	L	L	L
16	W	W	L	W	L	W	W	L	W	L
17	L	L	W	W	A	L	L	L	L	L
18	L	L	L	L	L	W	L	L	L	L
19	L	W	L	W	L	L	L	L	A	L
20	L	W	L	L	L	L	L	L	L	L

Dermatoglyphic Patterns Type Trial 3.

Subject	Digit 1	Digit 2	Digit 3	Digit 4	Digit 5	Digit 6	Digit 7	Digit 8	Digit 9	Digit 10
1	L	L	L	L	L	L	L	L	L	L
2	L	L	W	L	L	L	L	L	L	L
3	L	L	A	L	L	L	L	L	L	L
4	W	W	W	W	L	W	L	L	W	L
5	L	L	L	L	L	L	L	L	L	L
6	L	L	W	W	W	L	L	L	W	L
7	W	L	L	L	L	L	L	L	L	L
8	L	L	L	L	L	L	L	L	L	L
9	A	L	L	L	L	L	A	L	L	L
10	L	L	L	L	L	L	A	W	L	L
11	W	L	L	W	W	W	L	L	W	W
12	W	W	L	W	A	W	L	L	W	L
13	L	L	L	L	L	W	L	L	L	L
14	L	L	L	L	L	L	L	L	L	L
15	L	L	L	L	L	L	L	L	L	L
16	W	W	L	W	L	W	W	L	W	L
17	L	L	W	W	A	L	L	L	L	L
18	L	L	L	L	L	W	L	L	L	L
19	L	W	L	W	L	L	L	L	A	L
20	L	W	L	L	L	L	L	L	L	L

A – arch
L – loop
W – whorl

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