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Heredity in finger-prints.

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HEREDITY IN FINGER-PRINTS

By

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1915
I'N E R I T A N C E O F F I N G E R - P R I N T S .

P A R T I

Finger-prints.

Introduction.-

The purpose of this investigation is to ascertain whether or not the patterns found on the tips of the fingers are inherited and, if so, to what extent. In studying the question of inheritance as applied to finger-print patterns of the parents will be compared with those of their children; those of brothers and sisters will be considered as well as the prints of twins. In addition to seeking fraternal resemblances the patterns will be studied in their relation to the Mendelian law of Heredity, whether in a given generation some patterns are dominant while others are recessive.

The subject matter of this paper consists logically of three main divisions:—Part one has to deal with a brief consideration of finger-prints with particular reference to the various classes of patterns, ridge counting and tracing, methods of identification, uses etc., The second part treats of the best methods of indexing and cataloguing finger-prints when dealing with a large collection, while the last part is concerned with the inheritance of the patterns.

HISTORY and LITERATURE:-

The employment during past times of finger-prints among various nations is discussed in the writings of Sir Francis Galton, who found the significance
attached to their use to have been partly superstitious and partly ceremonial. The existence of the superstitious basis is easily noted in children, the uneducated, and occupies a prominent place in the witchcraft of barbarians. The ceremonial significance is shown in the holding and kissing of the Bible of a modern witness, in the executant of a document placing his finger on the wafer and declaring "this to be my act and deed!"

The next grade of significance attached to an impression resembles that which commends itself to the mind of a hunter, who is practiced in tracking. He notices whether a footprint is large or small, broad or narrow, or otherwise differs from the average in any special peculiarity; he then draws his inferences as to the individual who made it. Just as, when a chief presses his hand smeared with blood or grime upon a clean surface, a mark is left in some degree characteristic of him. Such hand prints have been made and repeated in many semi-civilized nations, and have even been impressed in vermilion on their state documents, as by the sovereign of Japan. Though mere smudges, they serve to individualize the signer to some extent. And according to Sir Francis Galton no higher form of finger printing than this has ever existed in any barbarous or semi-civilized nation. The important ridges which give finger prints distinctive patterns were not discernible in such rude prints.

A good illustration of their small real value was discovered by Galton in the translation "of the China Branch of the Royal Asiatic Society, Part I, 1847, published at
Hong Kong, which contains a paper on "Land Tenure in China," by T. Meadows Taylor, with a deed concerning a sale of land, in facsimile, and its translation; this ends, "The mother
and son, the sellers, have in the presence of all the parties,
received the price of the land in full, amounting to sixty-
four taels: and five mace, in perfect dollars weighed in scales.
THE IMPRESSION of the FINGER of the MOTHER, of the maiden
name of Chin." The impression as it appears in the wood cut
is roundish in outline, and therefore was made by the tip of
the finger and not by the bulb. Its surface is somewhat
mottled, but there is no trace of any ridges.

The native clerks of Bengal give the name of "Tipsahi,"
to the mark impressed by illiterate persons who, refusing to
make either an X or their caste-mark, dip their finger into
the ink-pot and touch the document. The tipsahi is not
supposed to individualize the signer, it is merely a personal
ceremony performed in the presence of witnesses.

Many impressions are found on ancient pottery, as on
Roman tiles; while the Latin word "palmatus," is said to
mean an impression in soft clay, such as a mark upon a wall,
stamped by a blow with the palm. Nail-marks are used orna-
mentally by potters of different nations. They exist on
Assyrian bricks as signatures.

The European practitioners of palmistry and cheiromancy
did not pay particular attention to the ridges which make up
the patterns of the prints. A correspondent of the American
Journal "Science," VIII, 166, states, that the Chinese class
the striae at the ends of the fingers into,"Pots," when
arranged in a coil, and into "hooks." They are also regarded by the chiromantists in Japan. Some negroes in the United States, who, laying great stress on the possession of fingerprints in wax or dough for witchcraft purposes, are also said to examine their striae.

A brewer's sign frequently seen in England is a blood-red open hand. A similar design of some antiquity is said to be printed on tambourines and on all kinds of domestic utensils used in Arabia, it occurs also in Spain, and is supposed to be a sign of good luck. Fanciful renderings of finger print patterns occur in one or two old Buddhist or Taoist books along with the mythical imprints of the sacred foot of Buddha. These are similar to the sketches contained in Dr. L. A. Waddell's work on "The Buddhism of Tibet," p. 392.

REGECNY OF THE FINGER-PRINT SYSTEM.-

In 1823, Purkenje, a Professor of Physiology and Pathology, read before the University of Breslau a Latin Thesis on finger impressions, in which he gives nine standard types, and suggests a system of classification, but his efforts attracted no attention. He only valued the impressions as a means of knowing the ridges and furrows of the skin anatomically. Bewick, the reviver of wood-printing in England, appears to have been struck with the delicacy of the lineations, for he made engravings of a couple of his fingers, which he used as designs for his illustrated works. According to Galton, Tabor of San Francisco suggested that a system of finger-printing be used for the registration of the Chinese, during the time of the Chinese immigration.
Galton and others regard Sir W. Herschel as the first who devised a feasible method for regular use, but H. Faulds claims the honor of having published the first proposal of the method in Nature, Oct. 20, 1880, on "The Skin-furrows of the Hand." According to Faulds, Herschel considered two fingers sufficient, and it is not stated how the records were compared and classified. Sir W. Herschel finding false personation prevalent in all the courts, introduced the use of finger impressions in the district of Hooghly, in Bengal, as a means of fixing identity. He submitted a report to the Government advocating the adoption of this system throughout the Province, but it never was acted upon.

Another good instance of the practical use of finger impressions is mentioned by Galton and Faulds: Mr. G. Thompson, an American geologist, when on Government duty in 1882 in the wild parts of New Mexico, paid the members of his party by order of the camp sutler. To guard against forgery he signed his name across the impression made by his finger upon the order, after first pressing it upon his office pad. In 1883 "Mark Twain" published his "Life on the Mississippi." It contains a story of an identification by means of a thumb-print on a system supposed to be invented by a French prison doctor. Four years later Herbert Spencer wrote an account of the "Factors of Organic Evolution," (Nineteenth Century, May), in which an attempt is made to account for the ridges on the skin of the hands.

In 1888 Sir Francis Galton began to study finger-prints and, after publishing several articles upon finger-print identification and classification in 1892 he published the
results of his researches under the title "Finger-Prints." This work together with his book on "Finger-Print Classification comprises all his important writings on this subject. In addition to providing a nomenclature and types, suggesting a system of classification and examining the character and purpose of the ridges in their physiological aspect, he discussed many important features such as:- Persistence of the patterns, Inheritance, Influences of Temperament and Race. Although his system of classification is not very practical, his works, through his consideration of the subject from so many viewpoints, are the most valuable known and are most helpful to the student.

In 1889-90 Faulds attempted to interest Scotland Yard in identification by the finger-print method, but they thought the system too complex. In 1894 "Mark Twain" in his "Pudd'nhead Wilson" made the method clearer and interesting and aided much towards its final acceptance. In the same year Mr. Asquith's Committee published a Blue Book on the "Identification of Habitual Criminals." Their conclusions concerning finger-prints were very vague and indefinite. During this year the system was adopted in Bengal, and was confused with the Bertillon system of bodily measurements. In 1897 Lord Belper's Committee recommended its official adoption in England, and in 1902 the finger-print system became established as the official method of criminal identification.

In India the employment of the new system has not been confined to the Police Department, but has been introduced into all branches of public business, such as Banks, the Opium Department, Army etc.
In 1899 Sir E.H. Henry read a paper before the British Association Meeting, Dover, on "Finger Prints and the Detection of Crime in India." A year later he published a book entitled "Classification and Uses of Finger Prints," in which besides providing types, he suggested a system of indexing by which it is possible to classify any number of prints. In a collection of say fifty thousand prints, by the use of this method it is possible to find a given impression in three or four minutes. In value this work ranks second to that of Galton's; and as far as practical use is concerned, it is much more important, for Galton dealt with the subject anthropologically and his system of indexing is too complex for practical use.

The first edition of Henry's work was published at the request of the Government of India, and later three more for the Home Department. In 1910 Mr. F.A. Brayley published a work "Arrangement of Finger Prints, Identification, and Their Uses For Police Departments, Prisons, Banks, Lawyers, Secret Societies, etc.

This work is exactly similar to that of Henry's and by some it is believed to be a copy.

Since the publication of the first edition of Henry's work, his system has been adopted all over the world. In South Africa besides being used for Police purposes it is utilised for the registration of South African natives by the Labour Pass Office and of the Chinese by the Foreign Labour Department of the Transvaal Administration, which in 1905 had a collection of 50,000 sets. The system has been introduced into Ireland, Canada, and in most all of the large cities of the United States. At Pemberton Square, Boston there is a central bureau for Massachusetts under the direction of Mr. Gustaverson. The system of finger-print classification used there is.
in use here is Henry's with slight modifications.

In all of the Police Departments of the large cities
the method of identification consists of two distinct phases:—
the first process comprises the taking of the finger im-
pressions and the classifying of them, while the second part
consists of taking bodily measurements according to the Bert-
illon system, the data obtained being printed on the back of
the card containing the finger-prints together with all the
facts known of the prisoner. The name of Bertillon is
popularly confused with the finger-print method, the blunder
arising from the adoption of a combination of the two methods
and, partly from the fact that the two methods of personal
identification were proposed and expounded within a year of
each other. Bertillon's system consists wholly of bodily
measurements. In considering the respective merits of the two
systems, that of identification by the finger-print method
is far superior to Bertillon's Anthropometric system for many
reasons, but the two systems are usually combined for practical
use.

APPARATUS USED and METHODS of TAKING PRINTS——

The appliances which we use are essentially the same as
those in use at Pemberton Square consisting of:— a printer’s
roller about six inches in length and an inch and a quarter in
diameter, a quarter pound tube of ordinary printer’s ink,
ordinary white glazed paper, a glass plate about nine inches
in length and six wide, a pointer consisting of a penholder
handle with a needle let in at one end for ridge counting,
shape glass four inches in diameter and a small lens of
realitively high power, a camera lucida with an enlarging
apparatus for taking enlarged views, and gasoline.
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Example of Technique.
METHODS of TAKING PRINTS.—Impressions are taken in two ways, as "plain" and as "rolled" impressions. By "rolled" is meant the cylindrical projection of the pattern upon the paper. To take a "rolled" impression, the side of the bulb of the finger is placed upon the glass plate over which a THIN film of the printer's ink has been rolled, the plane of the nail being at right angles to the plane of the slab, and the finger is then turned over until the bulb surface, which originally faced to the left, now faces to the right, the plane of the nail being again at right angles to the slab. By this means the ridge surface of the finger between the nail boundaries is inked, and, by pressing it lightly upon the paper in the same way that it was pressed upon the inked slab, a clear rolled impression of the surface of the finger is secured. The finger must not be pressed too heavily upon the PAPER, or a blurred impression will result. A "plain" impression is secured by placing the bulb of the finger on the inked slab and then impressing it on paper without rolling the finger. Examples of rolled impressions are seen in the top two rows of impressions in Fig. 1 while those in the bottom layer represent plain impressions. To secure good prints the following details should be observed: the glass plate must be kept free from dust, hairs, etc. It should be cleaned each time after using, and when inked only a drop or two should be applied or the impressions will be blurred. Before printing the fingers should be thoroughly cleaned, xylol or gasoline being the most serviceable and convenient.

Sir, F. Galton refers to two methods of printing, each being the complement of the other. The method used in print-
ing from engraved plates, is to ink the whole surface, and then to clean the ink from the projecting parts, leaving only the spaces between the ridges filled with ink. The other method, that used in ordinary printing, is to ink the projecting surfaces only, leaving the depressed parts clear. The latter is the method commonly used and gives the best results. The right hand of the subject is taken by the operator, and the bulbs of his four fingers laid flat on the inked slab and pressed gently and firmly by the flattened hand of the operator. The inked fingers are laid flat upon the lower part of the right-hand side of the card (Fig. 1.) and pressed down firmly, and the inked thumb is placed in the small square to the left. Beginning with the thumb each finger is then rolled upon the inked plate, and the impressions transferred to the paper in the upper row. The same is then done with the left hand.

METHODS OF PHOTOGRAPHING AND ENLARGING PRINTS.— The prints may be made on "transfer-paper", and then transferred to stone, this process being known as "lithography." The fingers should not be printed directly upon the stone, as the print from the stone would be reversed as compared with the original impression. This is remedied by reversing the fingers on the transfer-paper. If it is undesirable to obtain a large number of impressions of a person, lithography is easier, quicker, and cheaper than photography.

WATER COLOURS AND DYES.— The pads usually used with office stamps are made of prepared gelatine, covered with fine silk, and saturated with aniline dye. If the surface be touched, the finger is inked and a good print may be made, but
there is much liability to blots. The pad remains ready for use during many days without attention, fresh ink being added at long intervals. The advantage of a dye over ordinary water colors is, that it percolates the silk without any of its color being kept back; while a solution of lampblack or Indian ink, consisting of particles of soot suspended in water, leaves all its black particles behind when it is carefully filtered; only clear water then passes through.

A serviceable pad may be made out of a few thicknesses of cloth or felt with fine silk or cambric stretched over it. The ink should be of a slow drying sort, made, of ordinary ink with the admixture of brown sugar, honey, glycerine etc. to bring it to the proper consistency.

PRINTING AS THOUGH FROM ENGRAVED PLATES.—Prof. R. Lancaster kester's method was as follows: "Take a watery brushful or two of the paint and rub it over the hands, rubbing one hand over or against the other until they feel sticky. A thin paper placed on an oval cushion the shape of the hand, should be ready, and the hand pressed not too firmly on to it." This is the process of printing from engravings, the ink being removed from the ridges, and lying in the furrows. Blood can be used in the same way.

Galton quotes the following extract from an article by Dr. L. Robinson in the NINETEENTH CENTURY, May 1892, p. 303:—

"I found that direct prints of the infant's feet would answer much better than photography. After trying various methods I found that the best results could be got by means of a soft stencil brush covered with soot, lampblack, soap, syrup, and blueohblack ink; wiping it gently from heel to toe with a..."
smoothly-folded silk handkerchief to remove the superfluous pigment, and then applying a moderately flexible paper, supported on a soft pad, direct to the foot."

SMOKE PRINTING.— A method of obtaining a very clear impression is by the smoked cylinder method, which consists of smoking a piece of highly glazed paper and then pressing the fingers upon it, and then passing the paper through a solution of shellac mixed with alcohol, and then drying. This is the method commonly used in the Physiological laboratory in obtaining tracings of blood-pressure, respiratory curves etc., Fig. 2 is a good example of finger-prints taken by the smoked paper method.

Other methods of smoke printing are well illustrated in the use of crockery, glass, or metal plates, of which the first is the most practicable, although Professor Bowditch found mica to be very serviceable. By this method the plates are smoked so as to obtain a uniform layer of soot. In all of the above methods of smoked-printing the soot comes off on the places touched by the fingers leaving a fine negative impression.

CASTS— These give the most satisfactory representation of the ridges, but owing to the variation of the heights of the ridges which are shown too plainly, they are very difficult to examine. Moreover they are easily broken, and as they are of a uniform color, the finer lines are only seen in a particular light. A sealing wax impression is the best and simplest kind of cast. A pool of blazing sealing-wax is made, stirring constantly all the while. The flame is then extinguished, and after a short interval the wax becomes cool enough for the finger to press it without discomfort.
Fig. 11.

Example of Smoke Printing.
Blood as a rule gives poor impressions, as minute clots block up the furrows, but watery blood sometimes gives excellent ones. It is incorrect to state that "sweat" causes the impressions or smudges on glass, metal etc. Sweat, is a watery liquid which evaporates quickly, and leaves no residue but a little saline material. Mr. J. Channell referred to the unsatisfactory character of a smudge which originates from sweat. Often, however, the finger may be greasy from oily sebaceous matter, which exudes from the pores of the skin, and this leaves fine traces on glass, japanned ware, and polished metal, such as a watch crystal etc. The sweat glands, or perspiratory ducts lie deep within the skin, or cutaneous structure, while the sebaceous glands occupy a different position. If sweat would leave only impression at all it would only be for the time being, and it would be but indistinct.

COLOURED SWEAT, and CHEMICAL SMUDGES:-- In a certain disorder, the name of which is CHROMIDROSIS, the sweat is coloured, and in some hysterical cases a blackish ooze is found. There is also a class of cases in which the colouring matter is derived from copper, iron etc. In the case of the copper the sweat is of a bluish colour. A red sweat has been observed in the case of lock-jaw.

DEVELOPING OBSCURE PRINTS:-- Fingerprints on glass, light woodwork, metal, and polished surfaces are usually very easily made out. Prints on dark surfaces can be detected in a various number of ways:-- O. Cromwell, Faulds and Seymour recommend
the use of a powder commonly known as "Chemist's Grey Powder". This is a whitish composition consisting of white oxide of mercury and chalk. This powder is applied in a light uniform layer where ever prints are thought to be and, if present, will be brought out clearly. A method commonly used by detectives in securing the prints of a suspected persons without their knowledge, is to take an ordinary bottle, clean the outside of it thoroughly, and then to hand it to the person. After he has taken it a more or less complete set of prints will be left upon the bottle which can be developed with the white powder. In place of the white powder, magnesia carbonate may be used. Faulds also uses a weak solution of iron perchloride to bring out impressions left by tea, gallic acid etc. He also found that, if a stain is made by a solution of iron perchloride it is brought out very clearly by the application of gallic acid. When greasy marks have been made on paper and leaves but an indistinct image Dr. Forgeot devised a method of rendering the impressions more distinct by applying a light layer of ordinary writing ink. The ink leaves the greasy lines alone and stains the untouched places where the furrows of the pattern were. The result is a negative impression, in which the summits of the ridges appear white in the pattern, while the grooves are coloured black.

If a very small quantity of cresote is added to the ink much better results may be obtained. Varnish which is nearly set gives a very good impression in relief.
The best methods for obtaining results in the photographing of prints are secured by using slow plates and making a long exposure. To photograph prints on wood the camera is placed in such a position that the right shadow will be thrown on the lens. On glass the white powder is dusted on and a piece of black paper pasted back of the fingerprint. In the case of imprints on glass bottles and tumblers, they are first filled with a black or dark red liquid in order to secure the necessary contrast. Prints on mirrors are photographed first by scraping off the silver, and then placing a black sheet behind. When prints are on the back or smooth side of corrugated glass, the reflections are removed by filling the uneven surface with black printing ink. In the case where the ridges were impressed heavily on a candle, the impression is first covered with printing ink, the superfluous ink then removed until it only lies in the furrows. Finger marks on blood or dark impressions on a light surface are photographed as if black on a white ground. Prints can be enlarged to almost any diameter desired by special enlarging cameras. To enlarge prints by hand Galton used the camera lucida to obtain the best results.

RIDGES, THEIR ORIGIN, PERSISTENCEY and USES.—The palmar surface of the hands and the soles of the feet both in man and monkeys, are covered with extremely minute ridges. These form systems which are more or less definite in appearance. On the back or crest of each ridge are sweat pores which open here and there throughout the entire length of the ridge.
There are pores where there are no ridges, but most of the ridges are punctured with pore-holes. Each ridge is characterized by numerous small peculiarities, called MINUTIAE, here divided into two, and there uniting with another; or it may divide and re-unite, enclosing a small circular or elliptical space; or the ridge may be so short as to form a small island.

Whenever an interspace is left between the boundaries of different systems of ridges, it is filled by a small system of its own, which will have some characteristic shape, and is called a "PATTERN." These are illustrated by the systems found on the tips of the fingers in Fig. III, A and B.

There are three well-marked systems of ridges in the palm of the hand marked in Fig. III-A--as TH, AB, and BC. TH is that which runs over the ball of the thumb and adjacent parts of the palm. It is bounded by the line a which starts from the middle of the palm close to the wrist, and sweeps round the ball of the thumb to the edge of the palm on the side of the thumb, which it reaches about half an inch, more or less, below the base of the fore-finger. The system AB is bounded towards the thumb by the line a, and towards the little finger by the line b; the latter starts from about the middle of the little-finger side of the palm, and emerges on the opposite side just below the fore-finger. Therefore every ridge that wholly crosses the palm is found in the system AB. The system BC is bounded by the line b on the thumbside, until that line arrives at a point just below the axis of the fore-finger; then the boundary BC leaves the line b, and skirts the base of the fore-finger until it reaches the interval which
Fig. 111, yA.
Crepases of the Hand.
Fig. III-B.

Impression of Hand on Smoked Paper.
separates the fore and middle fingers. The upper boundary of BC is the line c, which leaves the little-finger side of the palm at a small distance below the base of the little-finger and terminates between the fore and middle fingers. Other systems are found between c and the middle, ring, and little fingers; they are somewhat more valuable.

Often a small and independent system occurs in the middle of one or other of the systems AB, or BC, at the place where the space covered by the systems of ridges begins to broaden out rapidly. The small independent systems which appear on the bulbs of the thumb and fingers are much more definite in position and complex in lineation.

The three chief cheiromantic creases are made:-

1- By the flexure of the thumb.
2- " " " four fingers simultaneously.
3- " " " middle, ring and little fingers simultaneously, while the fore-finger remains extended. There is no exact accordance between the courses of the creases and those of the adjacent ridges, less still do the former agree with the boundaries of the systems. The accordance is closest between the the crease -1- and the ridges in TH; but that crease does not agree with the line a, usually considerably within it. The crease-2- cuts the ridges on either side, at an angle of about thirty degrees. The crease -3- is usually parallel to the ridges between which it runs, but it is often far from agreeing with the line c. The creases at the various joints of the thumb cut the ridges at small angles, perhaps of fifteen degrees.
Thus although the courses of the ridges are not wholly determined by the flexures, it appears that the courses of the ridges and those of the lines of flexure may be in part due to the same causes. The creases in the hand of a newly-born child are merely due to the crumpled condition of the infant's hand before birth. Prints of creases in the same hand thru different periods show a general accordance in respect to the creases, but not close enough for identification. The ridges on the feet and toes are less complex than those on the hands and digits.

DEVELOPMENT of the RIDGES.- The ridges are first discernible in the fourth month of foetal life, and are fully formed by the sixth. In babies and children the delicacy of the ridges are proportionate to the smallness of their stature. They grow simultaneously with the growth of the body, and continue to be sharply defined until old age has set in, when the beginning disintegration of the texture of the skin spoils them. They develop most in hands that do a moderate amount of work, and they are strongly developed in the foot. They are but faintly developed in the hands of ladies and idiots. When the skin becomes thin, the ridges subside in height. They may be obliterated by the callosities formed in manual labour. The ridges on the side of the left fore-finger of tailors are often destroyed by the needle. Injuries, when they are sufficiently severe to leave permanent scars, destroy the ridges to that extent. If a piece of flesh is sliced off or if an ulcer has eaten so deeply as to obliterate the perspiratory glands, a white cicatrix, without pores or ridges, is the result. Lesser injuries are not permanent. A deep clean cut leaves a permanent, thin mark across the ridges,
sometimes without any accompanying puckering, but there is often a displacement of the ridges on both sides of it. A cut or other injury that is not a clean incision, leaves a scar with puckering on all sides of it, making the ridges undecipherable or obliterating them.

In Dr. H. Klaatsch's investigations on the evolution of the ridges, he shows that the earliest appearance in the Mammalia of structures analogous to ridges, is one in which small eminences occur on the ball of the foot, through which the sweat glands issue in no particular order. The arrangement of the papillae into rows, and the orderly arrangement of the sweat glands, is a subsequent stage in evolution. The prehensile tail of the "Howling Monkey" serves as a fifth hand, and the naked concave part of the tail, with which it grasps the boughs, is furnished with ridges arranged transversely in a beautiful order.

ORIGIN OF RIDGES. - In regard to the origin of ridges Herbert Spencer in his article "ON the Factors of Organic Evolution" in the NINETEENTH CENTURY, May, 1886, endeavours to explain them. He says:- "Continuous pressure on any portion of the surface causes absorption, while intermittent pressure causes growth; the one impeding circulation and the passage of plasma from the capillaries into the tissues, and the other aiding both. There are yet further mechanically produced effects. That the general character of the ribbed skin on the under surfaces of the feet and the inside of the hands is indirectly due to friction and intermittent pressure may have proofs; first, that the places most exposed to rough usage are the most ribbed; second, that the insides of hands subject to rough usage, as those of sailors are strongly ribbed all over;
and third, that in hands which are very little used the parts commonly ribbed become quite smooth."

According to Sir P. Galton the uses of the ridges are primarily to raise the mouths of the ducts, so that the excretions which they pour out may be more easily be got rid of; and secondarily to AID the sense of touch. They are said to be moulded upon the subcutaneous papillae in such a way that the ultimate organs of touch, the PACINIAN BODIES, etc, are more closely congregated under the bases of the ridges than under the furrows. The ridges must concentrate pressure that would otherwise be spread over the surface generally, upon the parts which are most richly supplied with the terminations of nerves. By their means it would become possible to neutralize the otherwise dulling effect of a thick protective epidermis.

If the ultimate organs of the sense of touch are really congregated more thickly under the ridges than under the furrows, the power of tactile discrimination would depend very much on the closeness of the ridges. Galton and Titchner proved that the fineness or coarseness of the ridges in different persons had no effect whatever on the delicacy of the tactile discrimination. The ridges may subserve another purpose in the act of touch, namely, that of enabling the characters of surfaces to be perceived by the act of rubbing them with the fingers, but there are no pure OVER-TONES of touch. In whatever way they originally began the ridges seem now to serve a useful function in enabling the hand to grasp objects firmly without slipping.

PERSISTENCY OF RIDGES.-- The evidence that the minutiae persist throughout life is derived from the comparison of
various duplicate impressions, one of each pair having been
made many years ago, the other recently. Galton studied the
digits of fifteen persons in this way, and in fact Galton is
practically the only one who has studied the question of
persistence, and given any valuable data.

The pattern in every distinct fingerprint even though
it be only a dabbed impression, contains on a rough average
thirty-five points of reference, in addition to its general
peculiarities of outline and core. They consist of forkings,
beginnings or ends of ridges, islands and enclosures.

Galton placed the enlarged prints side by side, and then
found two or three conspicuous and convenient points of re-
ference, whether islands, enclosures or distinct bifurcations,
and then identified and marked them. Finally, the position of the
prints were readjusted, so that they should be oriented exactly
alike. From each point of reference, in succession, the
lines of the ridges are then followed with a fine pencil, in
the two prints alternately, marking each new point of com-
parison with a numeral. An exact correspondence is of se-
condary importance when comparing the details of two minutiae.
The most common point of reference is a bifurcation. Now
and then the neck or point of divergence is a little low,
and sometimes fails to take the ink, so a new ridge may appear
in one of the prints to have an independent origin, and in
the other to be a branch. The apparent origin is thus of
small importance, the main fact is that a new ridge comes in-
to existence at a particular point. Also, an apparently
broken ridge may be in reality due to an imperfectly printed
enclosure. Disintegration in old age often renders the
impressions of the ridges ragged and broken. Ague in the cold or algid stage also tends to produce a somewhat similar effect. In the affection called REYNARD'S Disease the finger-tip become bloodless, cold, feelingless, and leaden blue or white. The prick of a needle will neither cause pain nor draw blood. Such diseases as typhoid and scarlet fever may have some effect in inducing alterations, but little is yet known as to their effect on the patterns.

Altogether Galton published the prints of eleven complete couplets with three hundred and eighty nine points of reference of which only one point failed. The prints cover intervals from childhood to manhood. As there is no sign of change during any one of these four intervals, which together almost wholly cover the ordinary life of man, so Galton infers that between birth and death there is absolutely no change in say 699 out of 700 of the numerous characteristics in the markings of the fingers of the same person. Neither can there be any change after death up to the time when the skin perishes through decomposition. There appears to be no external bodily characteristics, other than deep scars and tattoo marks, comparable in their persistence to these markings, whether they appear on the finger, on the other parts of the palmar surface of the hand, or on the sole of the foot. The total number of points suitable for comparison on the two hands is not less than 1000 and nearer to 2000.

Galton emphasizes the fact that it is in the MINUTIAE and not in the measured dimensions of any portion of the pattern that this persistence is observed. The pattern grows simultaneously with the finger, and its proportions vary with
its fatness, leaness etc., but the number of ridges, their em-
branchments, and other minutiae remain unchanged.

PROBATIVE SIGNIFICANCE OF EXISTENCE IN TWO FINGER PRINTS
OF DISTINCTIVE SIMILARITIES AND THEIR EVIDENTIAL VALUE.

The problem in using finger prints as a means for personal
identification according to Galton is this:—"given two
finger prints, which are alike in their minutiae, what is the
chance that they were made by different persons?"

The first attempt at comparing two finger prints would be
directed to a rough general examination of their respective
patterns. If they do not agree in being arches, loops, or
whorls, there can be no doubt that the prints are those of
different fingers, nor is there any doubt when there are dis-
tinct forms of the same general class. But even the agree-
ment in these respects goes but a short way in establishing
identity.

Galton's first attempt was to sort the prints of 1000
thumbs into groups that differed each from the rest by an
equally discernible interval. While on the whole the attempt
was not successful, it showed that nearly all the collection
could be sorted into 100 groups, in each of which the prints
had a fairly near resemblance. In addition, 12 or 15 of the
groups referred to different varieties of the loop; and as two-
thirds of all the prints are loops, two-thirds of the 1000
specimens fell into 12 or 15 groups, showing that on the
average that no great reliance should be placed on a general
resemblance in the appearance of two finger prints as a proof
that they were made by the same finger.

Galton studied the question by three main methods.—

I. The first set of tests were made upon photographic
enlargements of various thumbs to double their natural size. A six ridged-interval square of paper was clamped and laid at random on the print, the core of the pattern, as being too complex for the average test, being alone avoided. Then a sheet of tracingpaper-called No.1- was laid over all, and the margin of the square patch was traced upon it, together with the course of the surrounding ridges up to that margin. Then Galton interpolated what seemed to be the most likely course of those ridges which were hidden by the square. Number 1 was then removed, and a second sheet was laid on, and the margin of the patch was outlined upon it as before together with the ridges leading up to it. A corner only of No.2 was then raised, the square patch taken away from underneath, the corner replaced, and the actual courses of the ridges within the already marked outline were traced in. The results of comparing the two are given in the following table:-

<table>
<thead>
<tr>
<th>Result</th>
<th>Double Enlargements</th>
<th>Six-Fold Scale with Prisms</th>
<th>Twenty-Fold Scale with Chequer-work</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>12</td>
<td>8</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>Wrong</td>
<td>20</td>
<td>12</td>
<td>16</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>20</td>
<td>23</td>
<td>75</td>
</tr>
</tbody>
</table>

Interpolation of Ridges in a Six Interval System

II. In the second method the tracing papers were discarded and the prism of a camera lucida used. It threw an image three times the size of the photo enlargement, upon a card, and
there it was traced. Here the same general principle was adopted as in the first case, but the results being on a larger scale, were more satisfactory. They are given in the second column of the table.

III. A third attempt was made by a different method, upon the linesations of a finger print drawn on about a twenty-fold scale. The aim was to construct the entire finger print by two successive and independent acts of interpolation. A sheet of transparent tracing-paper was ruled into six-ridged-interval squares, and every one of its alternate squares was rendered opaque by pasting white paper upon it. When the chequer-work was laid upon the print, exactly one-half of the six-ridged-interval squares were masked by the opaque squares, while the ridges running up to them could be seen. When the chequer-work was moved parallel to itself, thru the space of one square, whether upwards or downwards, or to the right or left, the parts that were previously masked became visible. The object was to interpolate the ridges in every opaque square under one of these conditions, and finally, by combining the results, to obtain a complete scheme of the ridges wholly by interpolation. The results are indicated in the third column of the table.

The three methods give roughly similar results, and the ratio of their totals, 27–75 or 1–3, represent the chance that the reconstruction of any six-ridged interval square would be correct under the given conditions.

When the reconstructed squares were wrong, they had none the less a natural appearance, especially seen in the method by chequer-work. The ridges rarely run evenly flowing lines but may be compared to foot-paths in a broken country.
In comparing finger prints which are alike in their general pattern, the proportion of the patterns may differ; one may be that of a slender boy, the other that of a man whose fingers have been broadened by work etc., and only one of these prints is divisible into an exact number of squares.

These six-ridged interval squares are to be regarded as independent units, each of which is equally liable to fall into one or other of the two alternative classes, when the surrounding conditions are alone known. Thus the chance of an exact correspondence between two different finger prints, in each of the squares into which they may be divided, and which are about 24 in number, is at least as \( \frac{1}{24} \) times \( \frac{1}{24} = \frac{1}{24^2} \), that is as 1--10,000,000,000.

Galton next combined the above enormously unfavourably chance, which he called \( A \), with the other chances of not guessing correctly beforehand the surrounding conditions under which \( A \) was calculated. These later are divisible into \( B \) and \( C \); the chance \( B \) is that of not guessing correctly the general course of the ridges adjacent to each square and \( C \) that of not guessing rightly the number of ridges that enter and issue from the square. Thus \( B \) might be taken as \( \frac{1}{2} \) for two-thirds of all the patterns, or \( \frac{1}{2} = \frac{1}{24} \). As to \( C \) with which \( A \) and \( B \) have to be compounded, Galton gave no observations. Let the chance against guessing each and every one of these data correctly be as \( \frac{1}{250} \), or \( \frac{1}{250} = \frac{1}{250} \).

The result is, that the chance of lineations, constructed by the imagination strictly according to natural forms, which shall be found to resemble those of a single finger print in all their minutiae, is less than \( \frac{1}{24} \times \frac{1}{2} \times \frac{1}{250} \), or \( \frac{1}{64,000,000,000} \). The inference is, that as the number of
the human race is reckoned at about 16,000,000,000, it is a smaller chance than 1-4 that the print of a single finger of any given person would be exactly the same as that of the same finger of any other member of the human race.

When two fingers of each of two persons are compared, and found to have the same minutiae, the improbability of 1-236 is squared, when three fingers the chance is cubed, etc.

Henry studied the question from a different viewpoint. He made a drawing similar to that of Fig.4, and assumed that there were three chances against one of the bifurcation B occurring casually in this particular limb of a "staple" and at this particular point of it in another impression selected at random, the probability of such occurrence is \( \frac{1}{4} \). The degree of probability here assigned is not excessive, for there might be no bifurcation, or if so, it might be in some other position of the limb. In the same way, the probability of bifurcations at D and E occurring by chance is \( \frac{1}{4} \) for each; the probability of a ridge beginning abruptly at G may be put at \( \frac{1}{4} \); of its ending abruptly at H at \( \frac{1}{4} \); of ridges beginning abruptly at K, M, N, each at \( \frac{1}{4} \); the chance of another impression being an ULNAR \( \text{L} \& \text{P} \) with a "staple" for core at \( \frac{1}{4} \); and, finally, the probability of a second impression having just 17 ridges intervening between its "inner" and "outer terminus" at 7 and so on. The probability of all ten occurring by chance in the impression of any other digit is \( \frac{1}{4} \) mul-
multiplied by $\frac{1}{4}$ nine times, or $\frac{1}{4}^{10}$. In other words, the odds against all these similarities being found in two impressions, not those of the same digit, is over a million to one.

Galton figured that the chances were $64,000,000,000$ against there being two alike, but L. Seymour on Page 63 of his "Finger Print Classification" states that M.M.V. Balthazard recently addressed a report to the French Academy of Science, and in that report computed the chances to be only a fraction of Galton's figure.

M. Balthazard wrote that if any finger print be divided into 100 squares - Fig. 5 - each square will contain some distinctive mark, rarely two marks, and in some cases three or none. By distinctive marks he referred to bifurcations of ridges or terminations. Fingerprints differ from each other either in the arrangement of the ridges in the different squares or in the character of the ridges in a particular square. The total number of combinations possible is the hundredth power of four, which is $1,000,000,000,000,000,000,000,000,000,000,000,000,000$. This means that there are just so many different combinations and that the chances are the above number to one that any combination will not happen more than once.

In order to compare this chance with human chances generally, it is necessary to consider the population of the world, which is, in round numbers, $1,500,000,000$. As there are three generations per century, the total number of persons per century would be fifty thousand million. To have enough people to realize all the possible combinations of fingerprints
would require a period of $2,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000$ years, and the chance of there being any two finger prints alike would be once in that many years.

**TYPES OF PATTERNS:**

The patterns on the 'thumb and fingers were first discussed at length by Purkenje in 1823, in a University Thesis. The thesis is an ill-printed small pamphlet of fifty-eight pages, written in poor Latin. It has a great historical interest, and there are only one or two copies of it in existence.


Translation page 42. - "Our attention is next engaged by the wonderful arrangement and curving of the minute furrows connected with the organ of touch on the inner surfaces of the hand and foot, especially on the last phalanx of each finger. Some general account of them is always given in every manual of physiology and anatomy, but in the organ of such importance as the human hand, used as it is for very varied movements, and especially serviceable to the sense of touch, no research, however minute, can fail in yielding some gratifying addition to our knowledge of that organ. After numberless observations I have thus far met with nine principal varieties of curvature according to which the tactile furrows are disposed upon the
the inner surface of the last phalanx of the fingers. These are as follows.

1. **TRANSVERSE FLEXURES.** - The minute furrows starting from the bend of the joint, run from one side of the phalanx to the other; at first transversely in nearly straight lines, then by degrees they become more and more curved towards the middle, and finally they are bent into arches that are almost concentric with the circumference of the finger.

2. **CENTRAL LONGITUDINAL STRIA.** - This configuration is nearly the same as in I, the only difference being that in this case a perpendicular stria is enclosed within the transverse furrows, as if it were a nucleus.

3. **Oblique Stria.** - A solitary line runs from one or other of the two sides of the finger, passing obliquely between the transverse curves in I, and bending near the middle.

4. **OBlique SINUS.** - If this oblique line recovers towards the side from which it started, and is accompanied by several others, all recurved in the same way, the result is an oblique sinus, more or less upright, or horizontal, as the case may be. A junction at its base, of minute lines proceeding from either of its sides, forms a triangle. This distribution of the furrows, in which an oblique sinus is found, is by far the most common, and may be considered as a special characteristic of man; the furrows that are packed in longitudinal rows are, on the other hand, peculiar to monkeys. The vertex of the oblique sinus is generally inclined towards the radial side of the hand, but it must be observed that the contrary is more frequently the case in the fore-finger, the vertex there tendi
ing towards the ulnar side. Scarcely any other configuration is to be found on the toes. The ring finger, too, is often marked with one of the more intricate kinds of patterns while the remaining fingers have either the oblique sinus or one of the other simpler forms.

5. Almond.- Here the oblique sinus, as already described, encloses an almond-shaped figure, blunt above, pointed below, and formed of concentric furrows.

6. Spiral.- When the transverse flexures described in 1 do not pass gradually from straight lines into curves, but assume that form suddenly with a more rapid divergence, a semicircular space is necessarily created, which stands upon the straight and horizontal lines below, as it were upon a base. This space is filled by a spiral either of a simple or a composite form. The term 'simple' spiral is to be understood in the usual geometric sense. I call the spiral 'composite' when it is made up of several lines proceeding from the same center, or of lines branching at intervals and twisted upon themselves. At either side, where the spiral is contiguous to the place at which the straight and curved lines begin to diverge, in order to enclose it, two triangles are formed, just like the single one that is formed at the side of the oblique sinus.

7. Ellipse, or Elliptical Whorl.- The semicircular space described in 6 is here filled with concentric ellipses enclosing a short single line in their middle.

8. Circle, or Circular Whorl.- Here a single point takes the place of the short line mentioned in 7. It is surrounded by a number of concentric circles reaching to the ridges that
Fig. 6.

THE STANDARD PATTERNS OF PURKENJE.

The Cores of the Above Patterns
bound the semicircular space.

9. Double Whorl.- One portion of the transverse lines runs forward with a bend and recurves upon itself with a half turn, and is embraced by another portion which proceeds from the other side in the same way. This produces a doubly twisted figure which is rarely met with except upon the thumb, fore, and ring fingers. The ends of the curved portions may be variously inclined; they may be nearly perpendicular, of various degrees of obliquity, or nearly horizontal.

In all of the forms 6, 7, 8, and 9, triangles may be seen at the points where the divergence begins between the transverse and the arched lines, and at both sides. On the remaining phalanges, the transverse lines proceed diagonally, and are straight or only slightly curved."

Evidently Purkenje valued the impressions as a means of knowing the ridges and furrows of the skin anatomically only. Neither Purkenje, nor his age for that part, had yet felt the need for a trustworthy scientific method of identification.

Following Purkenje, Galton appears to be the next one who attempted to formulate a system of classification. He first endeavoured to sort them according to Purkenje's standards, but was not successful. He then attempted to sort the patterns into groups so that the central pattern of each group should differ by a unit of "equally discernible difference" from the central patterns of the adjacent groups, proposing to adopt those central patterns as standards of reference. He also failed in this trial. To quote from page 66 of his work "Finger Prints," - On considering the causes of these failures, different influences were found to produce them, any one of which was sufficient by itself to give rise to serious un-
certainty. A complex pattern is capable of suggesting various readings, as the figuring on a wall-paper may suggest a variety of forms and faces to those who have such fancies. The number of illusive renderings of prints taken from the same finger, is greatly increased by such trifles as the relative breadths of their respective lineations and the differences in their depths of tint. The ridges themselves are soft in substance, and of various heights, so that a small difference in pressure applied, or in the quantity of ink used, may considerably affect the width of the lines and the darkness of portions of the prints. Certain ridges may thereby catch the attention at one time, though not at others, and give a bias to some false conception of the pattern. Again it seldom happens that different impressions of the same digit are printed from exactly the same part of it, consequently the portion of the pattern that supplies the dominant character will often be quite different in the two prints. Hence the eye is apt to be deceived when it is guided merely by the general appearance. A third cause of error is still more serious; it is that patterns, especially those of a spiral form, may be apparently similar, yet fundamentally unlike, the unaided eye being frequently unable to analyse them and to discern real differences. Besides all this the judgement is distracted by the mere size of the pattern, which catches the attention at once, and by other secondary matters such as the number of turns in the whorled patterns, and the relative dimensions of their different parts. The first need to be satisfied before it could become possible to base the classification upon a more sure foundation than that of general appearance, was to establish a well-defined point of reference in the patterns.
This was done by utilizing the centers of the one or two triangular plots which are found in the great majority of patterns and whose existence was pointed out by Purkinje, but not the remote cause, which is as follows:

The ridges, as was shown in Fig. 3A, of the palm of the hand, run athwart the fingers in rudely parallel lines up to the last joint, and if it were not for the finger-nail, would apparently continue parallel up to the extreme finger-tip. But the presence of the nail disturbs their parallelism and squeezes them downwards on both sides of the finger. Consequently, the ridges that run close to the tip are gradually arched, those that successively follow are gradually less arched until in some cases, all the signs of the arch disappear at about the level of the first joint. Usually, however, this gradual transition from an arch to a straight line fails to be carried out, causing a break in the orderly sequence, and a consequent interspace. - Fig. 7, 2 - The topmost boundary of the interspace is formed by the lowermost arch, and its lowermost boundary by the topmost straight ridge. But an equally large number of ducts exist within the interspace, as are found in the adjacent areas of equal size, whose mouths require to be supported and connected. This is affected by the interpolation of an independent system of ridges arranged in loops.

Fig. 7.

Formation of Interspace and Enclosed Patterns.
- Fig. 7, 3, or in Scrolls -Fig. 7, 4- and this interpolated system forms the pattern. Now the existence of an interspace implies the divergence of two previously adjacent ridges-Fig. 7, 2- in order to embrace it. Just in front of the place where the divergence begins, and before the sweep of the pattern is reached, there are usually one or more very short cross ridges. Their effect is to complete the enclosure of the minute triangular plot in question. Where there is a plot on both sides of the finger, the line that connects them -Fig. 7, 4- serves as a base line whereby the pattern may be oriented, and the position of any point roughly charted. Where there is a plot on only one side of the finger -Fig. 7, 3- the pattern has almost necessarily an axis, which serves for orientation, and the pattern can still be charted, though on a different principle, by dropping a perpendicular from the plot on to the axis, in the way there shown.

These plots formed corner-stones to Galton's classification. He placed great stress upon marking the outlines of the different patterns. In drawing the outline each of the two diverging ridges that start from either plot is followed in succession by a pencil, pen, or brush, and if the ridge bifurcates the branch that trends towards the middle of the pattern is followed. If it stops short, the outline is stopped and the nearest adjacent ridge is followed. As an illustration of the method of outlining patterns Galton gave those of eight persons; -Fig 8-. Colour was used to distinguish between the ridges that originate from the inner and outer sides of the hand. Galton used the terms INNER and OUTER; or thumb-side and little-finger side.

The system of ridges in Fig. 8 that come from the inner side "1" are coloured blue; those that originate from the
Fig. 8.

OUTLINES of the PATTERNS of Eight Persons, Taken at RANDOM

<table>
<thead>
<tr>
<th>LEFT HAND</th>
<th>M.F.</th>
<th>P.F.</th>
<th>R.F.</th>
<th>I.F.</th>
<th>( \text{R.F.} )</th>
<th>( \text{T} )</th>
<th>( \text{T} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>
outer "0" are coloured red.

MIRROR PATTERNS.— The impressed or printed pattern, as in ordinary printing, shows just the reverse arrangement existing in the actual ridges and furrows of the skin. A loop or a whorl veering to the left in print actually in nature veers to the right, and so on throughout.

In Fig. 9, the actual ridge pattern a may be that of Henry Smith, while b is that of John Smith. By a slight mistake in photography John's fingerprint may assume the form of the "mirror pattern" c, and then be mistaken for that of Henry's.

Mirror patterns of a complex kind do not often occur, for many apparently such will under close examination prove to be of a non-mirror nature.

REVERSIBLE PATTERNS.— The print is a reversed picture of the pattern upon the digit that made it. The pattern is a reversed picture of a similar pattern as it shows on the other. In the various processes by which prints are multiplied, the patterns may be reversed again and again. If the finger is impressed on a lithographic stone, the impressions from that stone are reversals of the same finger impression made upon paper. If made on transfer paper and then transferred to stone, there is a reversal. In photography there are more possibilities. Galton points out the fact that there are twelve capital letters in the English alphabet which, if printed in block type, are unaffected by being reversed. They are A, H, I, M, O, T, U, V, W, X, Y, Z. Some symbols do the same, such as ≠ + – : =. These and the letters H, O, I.
X. have the further peculiarity of appearing unaltered when upside down.

**SYMmetrical and Unsymmetrical Sets of Fingers.**—In many hands the whole ten fingers show this quality, five pointing one way with the main loop and just reversing the direction on the other hand, though the details of lineation may differ.

What might be taken perhaps as the normal type would show in nature, each loop on the left fingers pointing upwards to the left, and on the right each pointing upwards to the right:

![Symmetrical Loops](image)

**Fig. 10.**

**Symmetrical Loops**

**Right Hand**

**Left Hand**

**Fig. 11. Unsymmetrical Loops**

**Right Hand**

**Left Hand**
In selecting standard forms of patterns Galton disregarded a great many of the more obvious characteristics. Thus the size of generally similar patterns in Fig. 8 will be seen to vary greatly, but the words large, medium, or small may be applied to any pattern.

CLASSIFICATION OF PATTERNS.- Innumerable trials have been made with a view to fixing standards or types according to which all impressions can be readily sorted; Purkenje proposing nine, Galton three. According to the system proposed by Sir. E. Henry, which is used now all over the world, there are four main types. These four types are: ARCHES; LOOPS; WHORLS; COMPOSITES.

FIXED POINTS IN IMPRESSIONS.- In impressions of the LOOP, WHORL, and COMPOSITE types there are fixed points which have several important uses. These fixed points are:

1. The "Delta" or "Outer Terminus."

2. The "Point of the Core" or "Inner Terminus."

DELTA; "OUTER TERMINUS".- The "Delta" here referred to may be formed either -a- by the bifurcation of a single ridge, or -b- by the abrupt divergence of two ridges that hitherto had run side by side.

a. Where the upper and lower sides of the "delta" formed by the bifurcation of a single ridge, the point of bifurcation forms the "outer terminus", marked X in Fig. 12. Where there are several such bifurcations, the one nearest the core is taken as the "outer terminus."

b. The upper and lower sides of the "delta" may be formed by the abrupt divergence of two ridges which up to this point, had run side
by side. The nearest ridge in front of the place where the
divergence begins, even though a märse point, and whether it is
independent of or sprung from the diverging ridges or not,
is the "outer terminus", marked Y in Fig. 13.

CORE; POINT OF CORE; INNER TERMINUS.— The core of a
LOOP may consist either of an even or an uneven number of
ridges— termed RODS— not joined together thus:

\[ \text{Fig. 14.} \]

or it may consist of two ridges formed together at their
summit— termed STAPLE—, thus:

Where the top of the core consists of
an uneven number of rods, the top of the
central rod is the "point of the core". If the core is a
staple, the shoulder of the staple that is farthest from the
delta is taken as the "point of the core", the nearer shoulder
counting as a separate ridge. Where the core consists of an

\[ \text{Fig. 15.} \]
even number of rods, the two central ones are considered as
joined at their summits by an imaginary neck, and, of these
two, the shoulder farthest from the delta is the "point of the
core." In WHORLS circular or elliptical in form, the center
of the first ring is the "point of the core". Where the WHORL
is spiral in form, the point from which the spiral begins to
revolve is the "point of the core". "POINT of the core" is
synonymous with "inner terminus." In the above figures the
first ridge that envelopes the core is dotted.
ARCHES.— In arches the ridges run from one side to the other, making no backward turn; there is ordinarily no delta, but, when there is the appearance of a delta, no ridge must intervene between the "inner" and "outer terminus." Figs. 17 and 18 present no difficulty. In Figs. 19 and 20 there are one or two ridges which have the appearance of recurving, and it might be contended that these impressions are of the type of both the LOOP and the ARCH; but when the above definition is applied, it will be seen that as no ridge comes into count between the two terminal points, they fall within the class of ARCHES. But according to Galton if the majority of ridges are of the arch type the impression is classed as an arch. He lays down the following rules for differentiating between ARCHES, ARChES and LOOPS:—

1. When the loop is formed by NOT MORE THAN ONE complete loop, which, however, may be perfectly distinct and may even enclose a rod, the pattern is an ARCH. 2. When there are two, or even three, imperfect bends, especially if they converge and unite, the pattern is an ARCH.

3. Offsets at acute angles from the same ridge do NOT rank as loops.

4. When two symmetrically disposed loops are enclosed in the same curved ridge the pattern is called a form of TENTED ARCH.

Seymour follows Galton's rules, but there is no universal rule upon this point.
Fig. 21

ARCHES.—PLAIN and TENTED.

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Fig. 22
ARCHES and LOOPS.
Fig. 23

LOOPS.—Ulnar and Radial.
Fig. 21

LOOPS.- Ulnar and Radial.

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**Fig. 25**

LOOPS.- Ulnar and Radial.

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Fig. 26

LOOPS.—ULNAR, RADIAL, and CENTRAL POCKET.
**Fig. 27**

**LOOPS. - CENTRAL POCKET.**

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**Images:**
- Image1: ![Image1](image1.png)
- Image2: ![Image2](image2.png)
- Image3: ![Image3](image3.png)
- Image4: ![Image4](image4.png)
- Image5: ![Image5](image5.png)
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- Image48: ![Image48](image48.png)
Fig. 28

TIWINED and LATERAL POCKET LOOPS, and WHORLS.
### WHORLS

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**Fig. 30**

WHORLS
The impressions given in Figures 21 and 22, 1-25 inclusive are Arches.

TENTED ARCHES.— In patterns of the Arch type, the ridges near the middle may have an upward thrust, arranging themselves as if were on both sides of a spine or axis, towards which adjoining ridges converge. The ridges thus converging give to the pattern the appearance of a tent in outline, thus the name TENTED ARCH—Fig. 21, 11 and 12. In order to distinguish clearly the line which separates Tented Arches from those Loops whose ridges have a more or less vertical trend, it is held that, if ON EITHER SIDE OF THE AXIS EVEN ONE RIDGE RECURES, the impression is a LOOP—Fig. 31, A and B. The meeting of two ridges at a sharp angle resulting from their running into each other thru not maintaining their parallelism of direction, is not to be confused with recurving. The recurving ridge must be wholly on one side of the axis.

LOOP.— In Loops some of the ridges make a backward turn but without twist;

there is one DELTA. The ridges are enclosed in a bay-like form, looping towards the center of the finger. The loop must be continuous and without a turn or twist. Fig. 32— The Illustrations 25 to 88 inclusive represents many varieties of Loops.
ULNAR and RADIAL.— When seen in a looking-glass, the right hand appears as a left hand, the right eye as a left eye, the right half of the body as a left half.

Similarly, the print of a finger is a reversal of the pattern on the finger; if this pattern on the finger be a Loop with slope from left to right, it will appear in the print as a Loop with slope from right to left. If a finger print impressed on transparent paper be held in front of two persons facing each other, the pattern as seen by the one will be a reversal of the pattern as seen by the other; all the details of the print will correspond, but to one observer the ridges which lie to the left of a central line will to the other observer appear to lie to the right.

This is exactly what occurs when the same pattern exists on corresponding fingers of the two hands, as may be seen by taking prints from the two fingers, when it will be noticed that one print delineates a pattern which is a reversal of the pattern delineated by the other. This must be considered in determining whether a Loop is ULNAR or RADIAL. A Loop is ULNAR—U when the downward slope of the ridges about the core is from the direction of the thumb towards that of the little finger. It is RADIAL—R when the downward slope is from the direction of the little finger towards the thumb. Fig. 33, A and B.

The following rule may always be applied. When the print under examination is that of a right hand digit, place the right palm on the table; if the downward slope of the ridges about the core is from the thumb side towards the little finger the Loop
is ULNAR, if the slope is from the direction of the little finger towards that of the thumb it is RADIAL. If the print is that of a left hand digit, place the left palm on the table, and apply the rule. Using the symbol \ for ULNAR in the right hand and / for RADIAL in the right hand, these symbols will be reversed for the left hand, where / - ULNAR and \ - RADIAL.

The terms ULNAR and RADIAL are borrowed from anatomy, the ulna and radius being the two bones of the fore-arm.

WHORLS.- In whorls some of the ridges make a turn thru at least one complete circuit; there are two deltas. Whorls are single cored or double cored.

Fig. 35
In Fig. 34 the ridge or stream AY bifurcates at Y, the stream YB making an upward turn before descending, while the stream YC passes away towards the right side, this bifurcation causing the appearance of a delta at Y. On the right side of this same diagram the stream DZ, which flows from right to left, bifurcates at Z, causing the appearance of a delta there; the stream ZE at first flows upwards before taking a downward direction, while the stream ZF, continuing in the same direction of the parent stream DZ, passes away to the left.

In Fig. 35, A, B, C, D, E, F, G, and H represent some characteristic types of Whorls, other illustrations of Whorls are represented by 121-160 inclusive. Among some of the principal varieties of Whorls are the Spiral, Elliptical and Circular Whorls. In Loops the ridges double back upon themselves and return approximately to the place where they started from, leaving an open mouth at the side, but the ridges do not make a complete circuit or circle around. In Whorls, however, the ridges always make at least one complete circuit.
The skeleton drawing, Fig. 36, illustrates four forms of loops. In Fig. 37 are skeleton drawings of Whorls, showing both and deltas.

**COMPOSITES.** Under Composites are included patterns in which combinations of the Arch, Loop, Whorl are found in the same print, also impressions which might be considered Loops in respect to the majority of their ridges and Whorls in respect to a few ridges at the center or side. These are subdivided into Central Pocket Loops, Lateral Pocket Loops, Twinned Loops, Accidentals.

**CENTRAL POCKET LOOPS.** Often in patterns of the Loop type the ridges around the center deviate in course from the general course of the other ridges. These impressions are therefore Loops in respect to the majority of their ridges and Whorls in respect to the appearance of the few ridges directly about the center, a delta more or less faintly defined in evidence. This space so occupied by ridges whose course deviates from the course of the ridges surrounding them is spoken of as a "pocket," and the impression as a Central Pocket-Loop-Fig. 38 and 39.

All varieties of the Central Pocket type can be arranged under one or other of the forms of core shown in Fig. 40. These four standards overlap; II. is a modification of I., and III. a more complete form of IV. The arrow marks the position of the axis or line of exit of the ridges. If this arrow is prolonged it will meet at least one recurving ridge at right angles. This characteristic determines in doubtful cases whether an impression is a Loop or Central Pocket. Illustrations 88 - 113 represent forms of the Central Pocket type.
LATERAL POCKET LOOPS.—When the ridges constituting the Loop bend sharply downwards on one side before recurving, thereby forming on that side an interspace usually filled by the ridges of another Loop, such an impression is a Lateral Pocket Loop.

In Fig. 41 compare 1, 2, 4, 5; the outline of the Loop whose ridges bend down sharply, is shown by the dotted lines, the thick dark line a—represents its central ridge, the dark line b—representing the central ridge of the Loop where ridges occupy the pocket. Fig. 42 represents an impression of the Lateral Pocket type.

TWINNED LOOPS and LATERAL POCKETS COMPARED.—In the Twinned Loop there are two well-defined Loops, one superincumbent on or surrounding the other. Many of these Twinned Loops appear identical with the Lateral Pocket in so far as the ridge grouping is concerned. Fig. 41 contains patterns which show clearly the essential differences. The dark lines a and b, are the central ridges of the two Loop systems, the ridges which contain the "points of core". In I, 2, 3, 4, 5, Fig. 41, these ridges a, b have their exits on the same side of the right hand delta. In 6, 7, 8, 9 these ridges have their exits on different sides of the right hand delta. Thus in Lateral Pockets the ridges containing the "points of the core" HAVE THEIR EXITS ON THE SAME SIDES OF THE RIGHT DELTA; in Twinned Loops the ridges containing the "points of the core" HAVE THEIR EXITS ON DIFFERENT SIDES OF THE RIGHT DELTA.

Illustrations of these forms are seen in Fig. 28, 113–120.
LATERAL POCKET & TWINNED LOOP PATTERNS.

Fig. 41.
ACCIDENTALS.- Under Composites are included the very small number of patterns too irregular in outline to be grouped under Central Pockets, Lateral Pockets, or Twinned Loops; they are termed ACCIDENTALS.

Galton classified the patterns according to the following forms.-

**Fig. 43.**
ARCHES

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<tbody>
<tr>
<td>Plain Arch</td>
<td>Forked A.</td>
<td>T.A.</td>
<td>T.A.</td>
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<tbody>
<tr>
<td>W</td>
<td>A</td>
<td>W</td>
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**Fig. 44.**
Loops.

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<tr>
<td>A or L?</td>
<td>Nascent L.</td>
<td>Plain L.</td>
<td>Invaded L.</td>
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<tr>
<td>Tented L.</td>
<td>Crested L.</td>
<td>Bevelled L.</td>
<td>C.P.</td>
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<td>Twinned L.</td>
<td>Nascent Curl</td>
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Fig. 45.

WHORLS.

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<td>Spiral in L</td>
<td>Circlet in L</td>
<td>Ring in L</td>
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<tr>
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<td>Ellipses</td>
<td>Spiro-rings</td>
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<tbody>
<tr>
<td>Simple Spiral</td>
<td>Duplex Spirals</td>
<td>Banded D.S.</td>
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</table>

Fig. 46.

Cores to Loops.

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Cores to Whorls.

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PECULIARITIES of DIGITS. - Galton found that from the examination of 5000 prints that the relative frequency of the three several classes was as follows. -

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<thead>
<tr>
<th>Class</th>
<th>Relative Frequency</th>
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<tr>
<td>ARCHES</td>
<td>6.5 per cent</td>
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<tr>
<td>LOOPS</td>
<td>67.5 &quot;</td>
</tr>
<tr>
<td>WHORLS</td>
<td>26.0 &quot;</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
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</tbody>
</table>

From this it appears that on the average out of every 15 or 16 digits, one has an arch; out of every 3 digits, two have loops; out of every 4 digits, one has a whorl.

Seymour states the proportion is as follows. -

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<th>Class</th>
<th>Relative Frequency</th>
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<tbody>
<tr>
<td>ARCHES</td>
<td>5. per cent</td>
</tr>
<tr>
<td>LOOPS</td>
<td>60. &quot;</td>
</tr>
<tr>
<td>WHORLS &amp; COMPOSITES</td>
<td>.35. &quot;</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

RIDGE COUNTING. - As two impressions out of every three are Loops, the subdivision into ULNAR and RADIAL fails to split them up into groups small enough for a thorough classification.

Fig. 47 represents the ridges of an ordinary Loop. The line SB joins the two terminal points, "inner" and "outer" terminus. If the ridges which cut the line SB are counted they will be found to number 17, so this Loop is specialized as a Loop with 17 ridges.
or COUNTS, and if it is an impression of a right hand digit it
would be further specialized as an ULNAR; if of a left hand
digit as a RADIAL Loop.

In ridge COUNTING the TWO TERMINAL POINTS ARE EXCLUDED
FROM COUNT, and ridges like G, which run close up to without
touching the line SB are also excluded, and when two ridges result from a bifurcation as at D, close to the line SB, both are counted?

RIDGE CHARACTERISTICS.— The "core" is a "staple" whose
right limb bifurcates at B, and whose left limb bifurcates at
D and again at E. In the ridge surrounding the core ridge is
a small island to the left of D, and another in the third
surrounding ridge directly above A. These islands appear clearly in the diagram, but in actual impressions they
might appear as a bulging out or thickening of the ridge, due to the ink running. At G the ridge begins abruptly
and ends abruptly at H, at K another ridge begins abruptly,
at L another ridge bifurcates, at O another ridge begins abruptly. These abrupt beginnings and endings, islands, bifurcations, etc., are known as ridge CHARACTERISTICS.

Whorls and Composites show such endless varieties of CHAR
ACTERISTICS that when two whorls are compared it is easy
to determine whether they are impressions of the same or of different fingers.

RIDGE TRACING.— In all impressions of the above two
types there are two deltas, one to the left and the other to
the right. These deltas are formed either by the bifurcation
of a single ridge, or by the divergence of two ridges that up
to this point had run side by side. Taking the lower limb or lower ridge of these two, its course is followed, and it will be found either to meet, to go inside or go outside the corresponding ridge of the right delta. When the ridge whose course is being TRACED stops short, the course of the ridge next below it is followed; when the ridge bifurcates, the TRACING proceeds along the lower line of bifurcation. When the ridge whose course is TRACED meets the corresponding right delta ridge the WHORL is specialized as M; when this ridge goes inside, it is specialized as I, when outside as O.

To secure an even distribution of I, M, O Whorls it is necessary to provide that if the ridge whose course is TRACED goes inside or outside the right delta ridge with not more than two ridges intervening between them, such ridge is considered as though it actually met the corresponding ridge. I then means that the left delta ridge goes inside the right delta ridge, there being between them not less than three intervening ridges; 0 means that the left delta ridge passes outside the right delta ridge, not less than three ridges intervening; and M means that the ridge whose course is TRACED actually meets the corresponding ridge, or that they are not apart by more than two intervening ridges.

\[ \text{Fig. 48.} \]
SYMBOLS USRD. - The symbols used are A-Arch; T- Tented Arch; L- Loop; W- Whorl; C- Composite; LP - Lateral pocket; TL - Twinned Loop; CP - Central Pocket; Ac - Accidental; IT - "inner terminus"; OT - "outer terminus"; U - ULNAR in right hand; R - RADIAL in right hand; U - ULNAR in left hand; R - RADIAL in left hand.

A BRIEF SUMMARY OF PART I.

The palmar surface of the hand and the soles of the foot are traversed by countless ridges, forming many varieties of pattern, and by creases. The ridge patterns and the ridge CHARACTERISTICS persist throughout the whole period of human life, and are so distinctive as to differentiate each individual from all others. An accurate reproduction of these ridges is obtained by inking the finger bulb and pressing it on paper, the impression thus recorded being a reversal of the pattern on the finger. All impressions may be arranged under one of four types, namely, Arches, Loops, Whorls, Composites. Arches subdivide into Arches and Tented Arches; clear definitions demarcate Arches from Tented Arches; and both from Loops. Loops may be ULNAR or RADIAL, and are further differentiated from each other by ridge COUNTING and by their ridge CHARACTERISTICS. Whorls are single or double cored; impressions of this type differ conspicuously from each other, owing to the innumerable varieties of pattern they present, but further demarcation is provided by ridge TRACING. Composites include Central Pockets, Lateral Pockets, Twinned Loops, Accidental Accidentals; the definitions given are sufficient for the accurate differentiation of these subclasses. In impressions there are fixed points, the "inner" and "outer terminus".
PART II

METHOD OF INDEXING PRINTS
Primary Classification.- The "rolled" impressions of the digits are recorded in their natural order of thumb, index, middle, ring, and little finger- those of the right hand being in line above, immediately below them the impressions of the corresponding digits of the left hand. At the bottom of the slip the "plain" impressions of the index, middle, ring and little fingers are taken, of both hands. It is very necessary to correct classification that the digits should be printed in their proper sequence; and as it could happen, thru carelessness on the part of the operator, that the impression of the, say, right index might appear as that of the middle or ring finger, the following check is provided. After the "rolled" impressions have been taken, the index, middle, ring and little fingers of each hand are dabbed down on to the paper so that the imprints of their phalanges are simultaneously made and they must of necessity appear in their proper sequence. When slips are being classified their "plain" prints are compared with the "rolled" impressions.

The impressions are then read off in the following order: RIGHT THUMB and RIGHT INDEX; RIGHT MIDDLE and RIGHT RING; RIGHT LITTLE FINGER and LEFT THUMB; LEFT INDEX and LEFT MIDDLE; LEFT RING and LEFT LITTLE FINGER.

The proportion of arches and composites being relatively small, Arches in primary classification are included under loops, and Composites under Whorls. In primary classification an impression must be either a Loop -Arches included- or a Whorl- Composites included-. Taking the first pair, the arrangements possible among them are: right thumb a Loop and right index a Loop; right thumb a Loop and right index a Whorl; right thumb a Whorl and right index a loop; right thumb a whorl and right index also being a whorl.
The above exhausts all possible arrangements, and may be thus set out-- the numerator letters referring to the thumb or first of the pair, the denominators to the second of the pair or index:

\[
\begin{array}{c}
L; L; W; W \\
\hline
L \quad W \quad L \quad W
\end{array}
\]

There is the same number of combinations for the second pair, and, as each of these can be combined with each arrangement of the thumb and index, the total number of combinations of the two pairs taken together is 16. The third pair has similarly four arrangements, which, taken together with those of the preceding two pairs, raises the number of combinations to 64; adding the fourth pair the number rises to 256, and with the fifth pair to 1024. The number 1024 is the square of 32, so a cabinet containing 32 sets of 32 pigeon-holes arranged horizontally would provide locations for all combinations of Loops and Whorls of the ten digits taken in pairs.

**ARITHMETICAL RULE FOR DETERMINING PRIMARY CLASSIFICATION, ETC.** The digits are taken in pairs, as before, the first of the pair being shown as numerator and the second as denominator, the formula thus obtained being as follows:

\[
\begin{array}{c}
L; W; L; W; L \\
\hline
W \quad L \quad L \quad W \quad W
\end{array}
\]

When a Whorl occurs in the first pair it counts 16, in the second pair it counts 8, in the third 4, in the fourth 2, and in the fifth 1; no numerical value is given to a Loop.

The above formula can then be expressed as:

\[
0; 8; 0; 2; 0
\]

\[
16 \quad 0 \quad 0 \quad 2 \quad 1
\]
Numerators are added together, also denominators, and the totals form a new fraction \( \frac{10}{19} \). To both numerator and denominator I is added, making \( \frac{12}{20} \), and this fraction inverted gives the primary classification number \( \frac{20}{12} \), which represents that the impression slip will be found in the twentieth pigeon hole of the eleventh horizontal row.

Given the primary classification number, it is easy enough to work backwards and determine the type of each digit. Taking the primary classification number \( \frac{20}{12} \), it is seen that 20 falls short of 32 by 12, which is equivalent to \( 8 + 4 \), thus Whorls are wanting in the second and third pairs and in the denominator, for, \( \frac{20}{12} \) is the inversion of \( \frac{12}{20} \). Also II falls short of 32 by 21, which is the equivalent of \( 16 + 4 + 1 \), and therefore Whorls are wanting in the first, third, and fifth pairs - numerator-. Where Whorls are wanting, Loops must take their place, and so we come back to the formula:

\[
\text{L; W; L; W; L; W; L; W; W}
\]

Classification numbers run not from 1 to 1024 consecutively, but from 1 to 32 of each horizontal row. Thus \( \frac{4}{5} \) represents the fourth pigeon hole or division of the first horizontal row; \( \frac{10}{5} \) the tenth division or pigeon-hole of the fifth horizontal row; \( \frac{31}{32} \) the thirty-first or last but one pigeon-hole of the last horizontal row.
SECONDARY OR SUBCLASSIFICATION.

Owing to the occurrence, under certain primary classification numbers, of large accumulations secondary classification is required to break them up into groups of convenient size.

The fingers are impressed in their natural sequence, the thumb first, then the index, middle, ring, and little finger those of the right hand being above and below each of its digits, the corresponding digit of the left hand. The index finger of each hand is taken as the FULCRUM, the mark specialising it being the capital letter of its symbol, the mark specialising the thumb being the small letter of its symbol placed to the left of the FULCRUM, the marks specialising the remaining fingers being the small letters of their symbols to the right of the FULCRUM. Arches, Tented Arches, and RADIAL Loops being of relatively infrequent occurrence are utilised in subdividing, and their presence noted in the subclassification formula. This formula is in the form of numerator and denominator, the numerator referring to the right, the denominator to the left hand. Formula $\frac{I_{aAr}}{I_{rRa}}$ indicates that the slip containing the impressions will be found under classification number 1, and will there be found included in the collection specialised by having an Arch in the right thumb, an Arch in the right index, and a RADIAL Loop in one of the remaining digits of the right hand, while the left thumb and index are RADIAL Loops, one of the other digits of this hand being an Arch.

SUBCLASSES FORMED BY ARCHES AND RADIAL LOOPS.- Classification number $\frac{I}{I}$ contains the slips of all the impressions $\frac{I}{I}$.
which are Loops as distinguished from Whorls - Loops including Arches, Tented Arches, RADIAL and ULNAR Loops--; Arches, RADIAL and ULNAR Loops may occur in one or both index fingers in nine combinations, and when they occur they provide for the formation of nine subclasses. The letters arranged horizontally refer to the right, those vertically to the left index.

Under subclass A will be found accumulated the slips with an Arch in both index fingers; under R, those with an Arch in the right and RADIAL Loop in the left index. Similarly there are subclasses:

\[
\begin{array}{cccccc}
R & R & R & U & U & U \\
\hline
A & R & U & A & R & U
\end{array}
\]

these nine subclasses representing the nine combinations.

In subclass A, as Arches may occur in one, two, three, four, or five fingers, the number of groups created by utilising them may be as follows:

\[
\begin{array}{ccccccc}
1 & 2 & 3 & 4 & 5 & 1 & 2 & 3 & 4 & 5 \\
\hline
A & - & a & - & - & a & A & - & a & - \\
A & a & - & - & a & a & A & - & a & - \\
A & a & a & a & a & a & A & a & a & a
\end{array}
\]

where 1 denotes the position of the thumb, 2 of the index,
3 of the middle, 4 of the ring, and 5 of the little finger. There will be a like number of groups for the fingers of the other hand, and, as both hands are utilised in splitting up subclasses, the total number that may be created by this device is 16 times 16 - 256. An equal number of groups will be created by the occurrence of RADIAL Loops in both hands, or of RADIAL Loops in one and arches in the other. In subclasses A; A; R; R; 256 such groups can be made.

A R A R

As this is a number in excess of requirements, a smaller number are employed, formed upon deciding whether there are one, two, or three Arches to the right of the index or PULCRUM. These groups are A; aA; Aa; aAa; A2a; aA2a; A3a; aA3a; they are arranged amongst themselves in the above order. This substitutes 53 for the possible 256 groups.

When Tented Arches take the place, of Arches, they are placed below the slips containing Arches to the same number. When RADIAL Loops occur they are disposed below the groups containing the same number of Arches and Tented Arches.

In subclasses A; R, the numerators provide 16 combinations and the denominators a number of combinations formed by ridge COUNTING.

In subclass U, although both index fingers are ULNAR

\[ \frac{U}{U} \]

Loops, Arches or RADIALS may occur in the remaining digits. This subclass splits into two, the first denoted as \[ \frac{U}{U} \]-lettered, of which instances are \[ aU; \frac{U}{aU} ; \frac{Ua}{U} \], etc., the term "lettered" referring to the appearance on either side of numerator or denominator of the letters a, r, or t. The other subclass is \[ \frac{U}{U} \]-unlettered.
SUBDIVISION BY RIDGE COUNTING. - These methods of selection for the separates subclasses leave the residuum under subclass U in which all the impressions are ULNAR Loops. The number of ridges which intervene between the "inner" and "outer" termini can, with the aid of a reading glass and a pointer, be counted correctly. Trials made with many thousands of impressions which have from one to nine ridges between the inner and "outer terminus" both these fixed points being excluded from count equals the number of impressions with ten or more than ten ridges. In the middle finger, the number

\[
\begin{array}{cccc}
11 & 10 & 01 & 00 \\
10 & 10 & 10 & 10 \\
01 & 01 & 01 & 00 \\
00 & 00 & 00 & 00 \\
\end{array}
\]

with from one to ten ridges equal the number with eleven or more. Calling the lower limit I and the higher limit 0, taking both index and middle finger of each hand, the number of arrangements possible may thus be set out, the letters horizontally placed referring to the right index and middle, those vertically to the index and middle of the left hand. This represents 16 groups:

\[
\begin{array}{cccccccccccccccc}
11; & 10; & 01; & 00; & 11; & 10; & 01; & 00; & 11; & 10; & 01; & 00; & 11; & 11; & 10; & 01; & 01; & 01 & 00 \\
10; & 01; & 00 \\
00; & 00 & 00 \\
\end{array}
\]

The advantage of this method is that in most instances it is possible to determine on view whether the ridge COUNTS fall within the lower or upper limit.
PART III

INHERITANCE OF FINGERPRINTS.
LITERATURE.—On the subject of the transmission of finger marks by descent there has been no definite conclusion reached as yet. Some of those who have written on finger prints affirm that they are inherited, others assert the direct contrary.

Henry Faulds admirably sums up the modern views upon this subject as follows: "The subject of heredity is hardly yet ripe for scientific treatment in this connection, nor would this be the place for such a discussion. Likenesses of the prints of children to those of the parents are often striking, but while close resemblances occur in the general trend of the lineations, and often marked correspondence in a general way, of finger with finger, yet the evidence of individual differences in detail and in measurement, is usually quite secure. I have not yet encountered a case of heredity which would present any practical difficulty in the ordinary identification of old offenders. The patterns of son and sire might, indeed, be strikingly similar at first sight, but when particular ridges or furrows were carefully followed up each by each, the two individual patterns were seen to diverge, just as the points and sidings at similar stations on the same railway system would be found to present variety of detail."

In an interview with Mr Gustafferson, who is at the head of the Finger-print Department of the Massachusetts Criminal Bureau, Pemberton Square, Boston, he stated that as far as he knew Galton has been the only investigator, who dealt with the matter on a large scale. In regard to his own personal experience in the Finger-print Department, he stated that neither he nor his subordinates had ever found any two finger prints which were identical, either among brothers, cousins, or twins.

After a thorough investigation of many prints Galton was convinced of the reality of an hereditary tendency. In order to test out this belief he studied the patterns of
a hundred or more families paying particular attention to the
the following relationships:— Filial Relation, Fraternal Re-
lation, and Regression. In studying the relationships be-
tween twins, he investigated the patterns of seventeen sets
of twins.

Before considering the results of this investigation it
might be well to examine some of the salient features of
inheritance. There are various definitions of Heredity, but
defined in brief: — Heredity is the organic relation between
successive generations. It is a truism that like tends to
beget like. Heredity consists of more than a bare relation-
ship between parent and child, but it includes that which con-
nects children of the same parents. The connection between
fraternal and the filial relations is to a great extent
interdependent. Galton stated that a simple algebraical
equation must exist, that connects together the three elements
So far as Regression may be treated as being constant in value
the Filial and Fraternal relations become reciprocally con-
ected.

Modern advance in the knowledge of Heredity has been
almost wholly due to the application of the MENDELIAN Law,
which is the law of the PURITY OF THE GERM CELLS. Quoting from
the example given by Dr. A. W. Weisse in his textbook on Zoo-
logy:— "Let us take two animals of the same species, which
differ in some one striking characteristic, such as color in
the gray mouse and the albino, white mouse; crossed with one
another they will produce offspring all of which will be gray,
and the gray characteristic is said to be dominant " the
white " recessive." Now the germ cells which these gray
mice of the second generation produce will bear the gray
characteristic or the white, and the two in equal numbers, but
no no germ-cells will have both characteristics; this is the
principle of the purity of the germ-cells and we see its
effect in the next generation, for the gray mice of the second
generation, when bred with one another, will give rise to the
third generation which will consist of both gray mice and
white mice in the proportion of three to one. These white
mice, if bred to together, will produce only white offspring,
for all subsequent generations. These gray mice, although
all apparently alike, are really of two kinds; one third will
produce only gray mice forever, but the other two-thirds are
precisely like the gray mice of the second generation, and
like them produce both gray and white offspring in the pro-
portion of three to one. The reason for this is simple.
The gray mice of the second generation possess germ-cells, half
of which have gray characteristics and half white, — to
represent it graphically, G+W; the crossing of two such in-
dividuals affords the following possible combinations, G G
+ 2 GW + WW. The combination GG will naturally be gray
and can only produce gray offspring; the same law is true for
the combination WW; but in the combination GW, the W is
recessive as we saw in the second generation, and hence these
mice will all be gray, but will produce gray and white off-
spring in the proportion of three to one; since in the com-
bination GW the W is recessive, it is best written G- W-. The
whole matter may be graphically represented as follows:

\[
\begin{align*}
G \quad & \quad \quad \quad G \quad \quad \quad \quad G \quad \quad \text{ad infinitum.} \\
G \quad & \quad \quad \quad G \quad \quad \quad \quad G \quad \quad \text{ad infinitum.} \\
G \quad & \quad \quad \quad G \quad \quad \quad \quad G \quad \quad \text{ad infinitum.} \\
W \quad & \quad \quad \quad W \quad \quad \quad \quad W \quad \quad \text{ad infinitum.}
\end{align*}
\]

In his investigations upon the subject of inheritance
Galton found that there were more or less similarity be-
tween patterns of brothers and sisters, this similarity much
more pronounced in the case of twins—especially those of the
same sex. Galton concludes from the results which he ob-
tained that there IS A DECIDED TENDENCY TO HEREDITARY TRANS-
MISSION, but the number of his cases was too few to justify
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## Table II.

### Right Hand

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<td>W</td>
<td>W</td>
<td>U.L.</td>
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<td>35 Greenleaf Mr.</td>
<td>U.L.</td>
<td>A</td>
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<td>U.L.</td>
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<td>A</td>
<td>A</td>
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<td>U.L</td>
<td>U.L</td>
<td>R.L</td>
<td>U.L</td>
<td>C.P</td>
<td>U.L</td>
<td>C.P</td>
<td>U.L</td>
<td>C.P</td>
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<tr>
<td>&quot; R.W + W</td>
<td>A</td>
<td>A</td>
<td>W</td>
<td>U.L</td>
<td>L.P</td>
<td>A</td>
<td>U.L</td>
<td>U.L</td>
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<td>W</td>
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<td>C.P</td>
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Table IV.

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<td>A</td>
<td>A</td>
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<td>A</td>
<td>A</td>
<td>U.L</td>
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<td>R.I</td>
<td>R.M</td>
<td>R.R</td>
<td>R.L</td>
<td>L.T</td>
<td>L.I</td>
<td>L.M</td>
<td>L.n</td>
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<td>U.L</td>
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<td>U.L</td>
<td>W</td>
<td>W</td>
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<td>W</td>
<td>UL</td>
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<tr>
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<td>W</td>
<td>W</td>
<td>W</td>
<td>W</td>
<td>W</td>
<td>U.L</td>
<td>W</td>
<td>UL</td>
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<td>&quot; F.V.</td>
<td>W</td>
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<td>W</td>
<td>W</td>
<td>W</td>
<td>W</td>
<td>CP</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 49.–A. The Palmer Twins.

A. Elmer D./Palmer.
Fig. 49.- The Palmer Twins.

B. Elwin T. Palmer.
Fig. 50. - The Peterson Twins.
A. - N.P. Peterson.
Fig. 50. - The Peterson Twins.

B.-R.H. Peterson
Fig. 51. - The Elliott Twins.
A. - Miss E. Elliott.

<table>
<thead>
<tr>
<th>Right Thumb</th>
<th>Left Thumb</th>
<th>Right Ring</th>
<th>Left Ring</th>
<th>Left Index</th>
<th>Right Index</th>
<th>Left Pinky</th>
<th>Right Pinky</th>
</tr>
</thead>
</table>

Four Fingers

<table>
<thead>
<tr>
<th>U.R.</th>
<th>L.R.</th>
<th>U.L.</th>
<th>L.L.</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.F.</td>
<td>L.F.</td>
<td>U.F.</td>
<td>L.F.</td>
</tr>
</tbody>
</table>
Fig. 51. - The Elliott Twins.

B. - Miss M. Elliott.

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<td>W</td>
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</tr>
</tbody>
</table>

R. Four fingers
L. T.
quantitative conclusions. Mr Collins suggested to Galton that there was a decided preponderance of maternal influence in the hereditary transmission of finger prints, but as yet there have been no supporting facts to that conclusion.
In order to establish and formulate new truths and definite laws in such a phase of Biology as Heredity, great masses of data and information must be accumulated which deal with the question under consideration from every possible aspect. Even after some new and great truth has been discovered and clothed in the form of a law such as the Mendelian law, which now serves as a nucleus around which all the known facts of Heredity and Genetics cluster, such a law, although apparently sound and reliable, is by no means infallible. Thus to take the concrete example of Mendel's law, which is really one of the most wonderful discoveries in Modern Biology. This law when tested out by careful and conscientious investigators is found to abound in exceptions. But in the formation of a general rule which is to be a working hypothesis for a new field of study these various discrepancies and apparent deviations from the normal must be ignored.

Thus to state definitely, beyond the shadow of a doubt that the patterns found on finger-tips are inherited would require the examining of at least 500 families. With this number of units to work with, by studying the various relationships, such as the Filial, Fraternal etc., it would be possible to derive and formulate some specific laws which could be applied universally.

To go a step further, and to attempt to show or state that Mendel's Law of "Recessive & Dominant" holds true or does not, would require in addition of from 500 to 1000 families, the examining of the grand-parents on both sides of the family. For to apply Mendel's Law to the transmission of a given unit-character, the following units are absolutely essential: First the father and mother of both parents; next the grand-children, and if possible their children.

In the pursuit of this particular line of research there are several obstacles to be considered. In the first place there is the question of time, for the actual securing of the requisites number of prints would at the best take from one to
three years. The time required for the actual examination must also be taken into account.

The next and most important impediment is the actual taking of the prints, which require considerable technical skill. In order to apply Mendel's Law, it is necessary to collect several members from a family; to examine the Filial relationship, the parents and at least one child are necessary, and if possible two; to observe the fraternal correspondence, if any.

The actual process of the securing of a finger impression is in itself the greatest obstacle, for it involves the smearing of the digits in printer's-ink, which causes considerable inconvenience. This difficulty although of apparently trifling nature proves to be a real one when it becomes necessary to request prints from a group of strangers. It is even difficult to secure good prints from friends for this slight reason alone.

Then again it is often difficult to secure the members of a given family at one time, and two or three journeys are necessary which consume time.

There are several other inconveniences and difficulties attending the collection of patterns which cause no small trouble.

The observations and deductions in this section are based upon impressions taken from members in some thirty odd families. Owing to several difficulties the working material is rather meagre, but suffices for fairly definite data.

The impressions obtained are arranged in tabular form, and classified. Following these tables are the prints of the three sets of twins which were secured.

When comparing the impressions of the first few groups, whenever the ulnar Loop occur more than once on the same digit, the ridges were counted and the result printed in above the classification. The differences in sex are represented by: + referring to male, and - to the female member of the group, the parents are indicated by add
Mr. or Mrs. to the names, respectively.

Before considering the deductions here derived it might first be well to examine the patterns secured paying particular attention to the relative frequency of the different types. Then if the results obtained are similar to those computed by Galton and other investigators we are justified in assuming that our patterns under consideration are typical and therefore whatever deductions are arrived at will be valid.

The relative frequency of the various types of patterns as determined is as follows:

1. Galton stated the proportion as.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6.5%</td>
</tr>
<tr>
<td>L</td>
<td>67.5%</td>
</tr>
<tr>
<td>W</td>
<td>26.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

2. The ratio as determined by modern investigators is.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5%</td>
</tr>
<tr>
<td>L</td>
<td>60%</td>
</tr>
<tr>
<td>W&amp;C</td>
<td>35%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

3. Our results are.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>L</td>
<td>50.0%</td>
</tr>
<tr>
<td>W</td>
<td>18.5%</td>
</tr>
<tr>
<td>A</td>
<td>25.0%</td>
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Upon comparing the determinations with those tabulated under 1 and 2, we see that the tables agree as to the order in which the patterns predominate:—The Loops being most numerous, W next, and Arches last. But upon examining the proportions in which the patterns occur they are seen to differ. But this deviation is only natural and to be expected, and may be explained
as follows:

I. Biometry, the science dealing with statistical math methods as applied to biology, is the only means by which variations and fluctuations from the normal can be studied. But even biometry, although a branch of science concerned directly with mathematical determinations, is at its best but approximate and uncertain, and its rules by no means infallible. Thus values and their tables obtained from different groups of individuals will be found to fluctuate in varying degrees from the theoretical mean.

Thus we see that even the determinations as recorded by galton[,] who was one of the most eminent of the biometricians and those of the modern investigators disagree in their actual numerical proportion.

2. Again our deviation, if apparently , may be explained when we consider the working material. Thus Galton and others drew their determinations from say the examination of 1000-10,000 individuals and thus obtained more nearly accurate results, as statistical methods in biology necessitate extensive data. On the other hand our results are merely drawn from a hundred or more characters, and the fact that they compare favourably with those of others indicates that the other deductions and conclusions will be sound and reliable.

3. If the patterns are inherited to any extent we should expect that the relative frequency of the patterns would be altered to some extent.

Upon considering now the chief conclusions obtained from the analysis of our data, our first and by far the most
important deduction is that the patterns are inherited to a
greater or lesser extent, and that the resemblance in families
is much more marked than among individuals at large.

This conclusion can be substantiated by the examination
of the tables- Pages 76 to 81-. Let us consider the cases of
a few families taken at random, beginning first with that of the
Billings. Here there are only two units present, the mother
and daughter. The patterns here consist not merely of loops,
but all are L.L., with the exception of a single deviation in
the L.I. where a R.L. occurs in the child, but even here
the nature of the pattern is the same, that of a Loop.

Thus the patterns are strikingly similar and apparently
are nearly identical- See I , page 9/2-. But when viewed
through a lens the loops are found to differ in the number of
their component ridges, respectively. Thus, for example, the
Loop of the R.T. of the mother is distinguished by possessing
16 ridge counts, while the corresponding digit of the daughter
contains 12 etc.

Turning now to the next family, that of the Blacketts,
we have here the patterns of the parents and of several child-
ren. In the case of the father we see that the ARCHUS pre-
dominate, while those of the mother consist chiefly of U.L.

We come next to the patterns of W.C.B.- Here the majority
are loops, with one C.P., thus corresponding with those of the
mother. The two noticeable deviations occur in the R.T. and
R.R. where the patterns are Ws, and these are found in neither
parent.

The following impressions are those of S.W.B.- That of
the R.T. is an U.L. with 5 ridge counts thus resembling that of the father, which has 2, while that of the mother has 10 ridge counts; in the next digit we find an arch, which also occurs in the corresponding digit of the father; in the R.L. an U.L. is present which probably corresponds with that of the mother; in the R.R. we find the A again resembling that of the father; in the R.L. an U.L., similar to that of the mother. In the left hand all the digits are those of A., and thus are similar to those of the left hand of the father.

Upon considering the case of the next member, G.H.B., the last member of this group, the U.L. of the R.T. is nearest that of the mother as it contains 9 ridge counts. The A on the R.I. goes back to that of the father; the next five and then the last digits are loops similar to those of the mother, while the intervening two, the L.M. and L.R. are As as in the father.

As there are 18 loops of various kinds among the children in this group and but 10 arches, the MATERNAL influence predominates here.

Thus in this group the patterns of all the children tend either to resemble those of the father or the mother, with but two deviations, where 2 Ws are found. These Ws are probably "recessive" unit characters and refer back to one of the grand-parents.

Let us now consider another group chosen at random, say that of the Carlsons. Here in their father all of the impressions are Ws, with the exception of a C.P. found on the R.M. In the case of the mother, there are 5 Ws and 5 Ls, U.L. present. In their three children the R.L. and R.T. are ALL Ws.
Table of Patterns referred to in this section.

I. The Billings Family.
   A. Mrs. B. - 10 U. Loops.
   B. M. B. - 9 U. Loops and 1 R. L.

II. The Blackett Family.
   A. Mr. B. - 9 Arches and one U. L.
   B. Mrs. B. - 6 U. Loops and one C. P.
   C. W. C. - 2 Whorls; 6 U. Loops; 2 C. P.
   D. S. W. - 3 U. Loops; 7 Arches.
   E. G. H. B. - 6 U. Loops; 3 Arches; 1 R. L.

III. The Carlson Family.
   A. Mr. C. - 9 Whorls; 1 C. P.
   B. Mrs. C. - 5 Whorls; 3 U. Loops; 1 R. L. & 1 C. P.
   C. E. C. - 2 Whorls; 7 C. P.; 1 U. L.
   D. N. C. - 6 Whorls; 4 U. Loops.
   E. L. C. - 5 Whorls; 4 U. Loops & 1 C. P.

IV. The Rogers Family.
   A. R. R. - 10 Whorls;
   B. Mrs. R. - 4 U. Loops; 6 Whorls.
   C. B. R. - 8 Whorls; 1 U. L; 1 C. P.

Taking the Print of E. C. we find that there are 7 C. P. loops and 1 M. 2 while in N. C. besides the 2 W already mentioned there are 4 more and the remaining are U. 2

Again in the daughter there are 5 W. 4 U. 2 and 1 C. P.

Thus in this group we see that there is not a single deviation in patterns from those of the parents. Insomuch as we are found in both parents it is difficult to ascertain whether the maternal or paternal influence predominates.

Since we have now examined cases where there were the on parent and one child, cases where there were several children and both parents; we will now consider the patterns where both parents and one child are present, as for instance the case of the Rogers family.

There all of the patterns of the father are W. and in those of the mother 6 W and 4 U. 2. The patterns of the child contain 8 W and 2 L.

Here again the patterns have a definite family
resemblance. Thus as these families hitherto considered were taken at random from our data, and give typical results, we can safely assume that there is a resemblance between patterns of a given group or family again that is similarity is quite pronounced.

We now naturally raise the question, "But is this resemblance hereditary; can it not be assumed between individuals at large?"

To answer these questions we come to the laws of probability and chance, here we come again to the question of the probature significance of 2 similar F. P. already threshed out by Galton, Page and later in his work in a Biometric discussion he shows conclusively how slight the chances are of a close resemblance between individuals chosen at random.

For that matter we can pick out say 4 or 5 individuals some of our own collection and compare their patterns and we find there to be a great diversity and but little or no actual resemblance.

Another question now rises, namely how far does this family resemblance or heredity go? Are any of the transmitted patterns identical in every respect with those of the parent? Our answer derived from material on hand is no, the prints even in the case of the closest twins are not absolutely identical, although to the unaided eye they appear so. With the use of a lens of moderate power slight variations in the ridge characteristics, ridge counts etc, are easily noted.

Upon comparison our deductions upon the family
resemblance with those of Galton they are found to agree, for the ultimate conclusion that the patterns are transmitted is the same.

The next logical subject which arises is that of the relative influence of the parents in transmitting patterns. According to Galton the maternal influence predominates. As far as the data on hand is concerned the preponderance is found to fluctuate first to one and then to the other and sometimes neither.

Then as to the question whether the Fraternal resemblance is closer than that of the Filial we are justified, in stating that there is no apparent difference. Thus although we may find a pair of twins whose patterns are almost identical, we can just as close resemblances between father and son or mother and daughter, etc.

Upon turning back to Galton's statements upon this aspect we find that he asserted that the relationships were reciprocally connected with one another.

To assume that the Mendelian principle holds in the transmission of finger patterns it is essential if possible to find some patterns which are "dominant" and others which are "recessive". Upon referring again to the tables and in specific to the case of W. C. Blackett whose R. T. and R. R are W. the presence of these 2 W nowhere else found upon the patterns of the family, may be explained by assuming that the W here is one of the Mendels Unit Characters c a Recessive; and goes back to one of the grandparents.

Again on page 77 in the case of N. G. Dawson we find
several Arches, which insomuch as there are no Arches in the parents, must be Recessive and refer back again to the Grandparents.

Somuch then for the Recession aspect of Mendelism and now if we can find any of the so-called "Dominants", we are fairly justified in stating that the Mendelis law holds.

The most conspicuous cases of Dominants noticed are those of the W. most noticeable in the Family of Carlsons, page 76. Here the R. S. and R. I. in both parents are W. and so the R. S. and R. I. in the children should be W. as we find to be the case. Further inasmuch as the W. tend to predominate in both parents, we should expect to find that the number of patterns in the children to be W. which is the case. For there are 13 W and 16 L. The fact that there are 3 more L is to be explained by the relative frequency of patterns for when both L and W are present as is the case, the L will predominate.

Taking one more example let us look at the case of the H. Family—p78— here all of the patterns of the parents are L. with the exception of one W. found on the L. R. finger of the father. There as to be expected of the patterns of the child are L and the fact that the rest are W. is due to the presence of the fathers influence and to the influence of the Grandfather.
SUMMARY OF DEDUCTIONS.—

Sufficient resemblance was found to justify the conclusion that the patterns present on the fingertips are inherited, and that the resemblance between the patterns of a given family is much more marked than between individuals chosen at random.

The patterns inherited resemble those of the parent very closely, but though often apparently identical, upon microscopic examination they are found to differ with respect to their ridge counts, characteristics etc.

The data on hand furnishes enough examples of "dominants," "recessives" to support the deduction that a pattern is one of the so-called "unit-characters" of Mendell.

As to the question of the influence of the parents in transmitting a given pattern, neither parent can be said to predominate. While in the case of the relative resemblance in the filial relationship as compared with that of the Fraternal they are found to be interdependent and may be reciprocally connected.
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   B. "Decipherment of Blurred Finger Prints". -1893-
   C. "Fingerprint Directories". -1895-
   PUBLISHER. Macmillan and Co.

II. In his work "Finger Prints" Galton gives a translation of an article taken from a University Thesis. This Thesis which was written by Purkeme in 1823 has the following title: "Commentatio de Examine physiologico organi visus et systematis cutanei quam pro loco in gratioso medicorum ordine rite obtinando die Dec. 22, 1823 H.X.L.C. publice defendit Johannes Evangelista Purkeme, doctor, Phys. et Path.

III. In 1883 "Mark Twain" published his "Life on the Mississippi", which contains a story of an identification by means of a thumb-print, on a system supposed to be invented by a French prison doctor.

IV. In 1894 "Mark Twain" in his "Pudd'n-head Wilson" made the Finger-print method much clearer and more interesting.

V. In 1900 Sir. E.H. Henry published a work entitled "Classification and Uses of Finger Prints." - The edition used is the Fourth

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VII. "Arrangement of Finger Prints, Identification, and Their Uses." By F.A. Brayley. -1910-

VIII. "Finger-Print Photography". By O. Cromwell, -1907-


IX. "Finger Print Classification". By Lee Seymour, -1913-

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PART II. SOME OF THE MORE IMPORTANT PERIODICAL ARTICLES DESCRIBING FINGER PRINTS.

Articles by Sir F. Galton.-


4. "Identification by Finger Tips". - Nineteenth Century, August, 1891.

II. The following Accounts were published between 1897-1902.


III. In 1911:-


IV. In 1912:-

1. "Afternoon with Bertillon". K. M. Blackford. ll. Out-
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V. In 1913:-


RELATIVE IMPORTANCE OF THE ABOVE REFERENCES:- Of the above mentioned sources by far the most important for both a theoretic and practical consideration of the subject the works of Sir P. e. Galton are of the most value. Of his writings that entitled "My Finger Prints" is of the most value to the student. Apart from Galton, Henry's "Finger-print Identification" gives a standard method of classification. The study of Finger-prints in relation to crime is admirably and concisely by O. Cromwell. The remaining works and articles merely treat different aspects chiefly from the standpoint of their value for identification.