INTRODUCTION
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PREAMBLE

"Dermatoglyphics" (derma-'skin' glyphe-'carve') - the term introduced by Cummins and Midlo (1926) is concerned with studies of dermal configurations including the quantitative and qualitative aspects, population variation, hereditary transmission, disease implication, forensic application and personal identification.

The history of dermatoglyphics has had long association with the Indian sub-continent (Mukherjee 1990) and like the Chines, the ancient Indians also were struck by the uniqueness of individuality of dermal configurations. It was William Herschel, the district administrator of Hooghly, Bengal, who wrote a letter in the Nature in the year of 1880 in response to Fauld's (1880) article published in the same journal, demonstrating that the individual dermal configurations are the most reliable tool for personal identification. Again in Bengal in 1887 Edward Richard Henry, the then chief of Bengal Police opened a separate cell for recording the finger prints of criminals which was the first finger print bureau in the world (Mukherjee, 1990).

The foundation stone of this subject was laid by Sir Francis Galton who not only first classified finger patterns but also devoted his greater part of scientific life in the quest of many truths including the inheritance of dermatoglyphic traits.
The dermal ridges first appear around 6-8 weeks and are fully differentiated during the third and fourth foetal months (Cummins 1929; Mulvihill and Smith 1969).

Dermatoglyphic features once formed are free from environmental influence and for this reason they have been found extremely useful for genetic and developmental studies.

INHERITANCE PATTERN

The dermatoglyphic characters of man are excellent markers for genetic analysis because of their being stable in regard to postnatal age, sex and environment. In contrast to most other traits they are less susceptible to alteration and some times they do appear more superior even to serological markers (Mondol and Kumbnani 1994).

More than a century ago Galton (1892) initiated genetic studies of dermal characters to probe their hereditary mechanism. Since then, a host of genetic researches have been carried out by dermatoglyphisists throughout the world and the results of these studies have confirmed that the dermatoglyphic characters are heritable. Today, two modes of inheritance are widely accepted - the first is the simple single factor inheritance for epidermal patterns and the second is polygenic transmission of quantitative dermatoglyphic traits (Mavalwala 1983).
A) FINGER RIDGE COUNT

Long back it was established from the observed correlation coefficient between relatives (Bonnevie 1924; Newman 1930), deviations from the population means of parents and their children (Mueller 1930) and on the basis of mean differences within twin pairs (Gruneberg 1928; Essen-Moller 1941; Geipel 1941) that the finger ridge count has a substantial genetic basis. Holt undertook a series of studies (1952, 1953, 1954, 1955, 1956, 1957 a, b, 1958, 1960) which included correlation analysis of the total ridge counts as well as ridge counts on individual fingers and confirmed a strong genetic base for the finger ridge counts. Holt (1968) proposed a single genetic factor for total ridge counts, while Weninger (1964, 1965, 1976) claimed that ridge counts on each finger were an independent trait. Penrose (1969), Matsunaga (1972) and Matsuda (1973) indicated the multifactorial mode of inheritance for the genetic variation of dermal ridge counts. Holt (1958), Knussman (1967) and Spence et al., (1973) advocated that major genes contribute to finger ridge counts. However, Karlin et al., (1983) propose a multifactorial mode of transmission for the digital ridge counts as well as the pattern intensity index.

PATTERN

The genetic endowment of finger pattern particularly for right thumb was first reported by Galton (1892). Later
in the beginning of the twentieth century Bonnevie (1924) suggested that individual fingers were not independent characters but that each digit represented a part of a common genetic complex. Gruneberg (1928) did not accept this view and in his opinion pattern types were governed by two pairs of epistatic factors (alleles). A number of researches (Elderton 1920; Mueller 1930; Geipel 1937, 1954; Weninger 1938; de Wilde 1953 a, b; Lazaro et al., 1963; Gladkova 1964; Slatis et al.; 1976) carried out since then have suggested recessive or dominant inheritance, with many, few or single pairs of alleles controlling each type of patterns particularly, whorls and loops. The studies have suggested also that whorls and ulnar loops may be more influenced by hereditary factors than the radial loops or arches. A relatively higher concordance in terms of digital pattern types has been noticed among monozygotic rather than the dizygotic twins (Bonnevie 1923 a, b; Gruneberg 1928; Newman 1930; Geipel 1937, 1942; de Wilde 1955; Parisi and Di Bacco 1968; Pena et al., 1973) which suggests a strong genetic predisposition for finger pattern inheritance. A very high genetic component for the whorls and ulnar loops and a relatively low one for radial loops and arches has been reported also by Loesch (1974). The estimated familial correlation coefficients values for all fingers for pattern types was found higher 0.28 between mother and son than between father and daughter 0.20 (Knussman 1973). Loesch (1979) reported that the thumb and index finger have relatively large genetic component while
the little finger has the lowest whereas Reed et al., (1975) reported that the thumb is the only digit which shows non-significant genetic component. A high heritability for total pattern intensity (0.92) among twins was also found (Loesch et al., 1982). Anderson et al., (1979) reported ninety five percent penetrance of a dominant gene which controls the inheritance pattern of digital arches. However, Chakraborty et al., (1982) have not confirmed this.

B) PALM

RIDGE COUNT

The inheritance pattern of palmar interdigital ridge count has been extensively studied by several workers (Fang 1950; Pons 1964; Mitra et al., 1966; Rogucka et al., 1971; Pateria 1974; Borecki et al., 1985) and the results indicate an additive mode of inheritance rather than the presence of a major gene, with appreciable influence of a non-genetic component as well, which is relatively most pronounced for the a-b ridge counts.

PATTERN

Weinandt (1937) and Geipel (1950) made an attempt to trace the mode of inheritance of palmar patterns. Bansal and Rife (1962) proposed single-gene dominant inheritance with incomplete penetrance of the gene for patterns in areas II and IV whereas Singh et al., (1976) reported for the same trait a dominant mode of inheritance with 75-80
percent penetrance. The hypothenar triradius \( t^b \) or according to traditional method, the hypothenar radial arch follows single-gene recessive mode of inheritance (Holt 1975). Loesch (1971, 1974) reported a dominance for thenar loops and for the fourth interdigital loop, recessivity for a distal loop in the second interdigital area and an intermediate type of inheritance for distal loop on interdigital area III. Loesch (1974) again reported that distal loop II and axial triradius \( t \) may be determined by single (major) gene. The results obtained by Mukherjee (1966) and Loesch (1971, 1974) show that up to some extent the palmar pattern intensity is also determined by genetic factors.

**RIDGE ALIGNMENT**

The results of a number of studies (Meyer-Heydenhagen 1934; Weinandt 1937; Csik and Malan 1938; Baitisch and Bauer 1954; Mitra 1968) based on data on twins or the similarities within families have shown that the courses of main lines are inherited. Although the way of approach of several authors (Glanville 1965; Rogucka 1973; Knussman 1973) to find out the substantial genetic mechanism behind the main line exists were different but it is accepted that the course of main lines probably follow a polygenic mode of inheritance (Pons 1954, 1959).
ASYMMETRY

Only in a very general way the bilaterally distributed traits of all the living creatures of universe are symmetrical. A closer observation and comparative study of bilaterally distributed traits revealed, that each and every paired structure whether it is a floral character of plants (Sakai and Shimamoto 1965), sternopleural chaetae of Drosophila (Reeve 1960) or cranial traits of rhesus macaques (McGrath et al., 1984) is fairly and distinctively asymmetrical. This characteristic phenomenon of nature is equally true for human bodily traits such as lung or kidney which shows unlikeness in form, size and position between the two halves of the body. It is a very amazing fact that though the developmental mechanism is intrinsically same on either side of the body of an individual (Waddington 1942; Mather 1953; Lerner 1954; Randel 1967) the paired organs or tissue system are seldom exactly symmetrical. Apart from the functional asymmetry of man such as handedness or footedness, size and shape of limb muscles; structural asymmetry is also present in almost all bilaterally distributed phenotypically expressed minute traits such as dermatoglyphic configurations of hands and feet.

TYPES OF ASYMMETRY

Van Vallen (1962) while dealing with the fluctuating asymmetry discussed various types of asymmetry at length. According to him the deviation of an organism or part of an organism can conveniently be grouped into three classes:
1. Directional Asymmetry:

Frequently asymmetry is biased, that is one side of the body shows a marked tendency to have a larger organ or to be favoured for the expression of a defect more often than would be expected by chance. An asymmetry can be termed as directional when the asymmetry in all subgroups of the population studied favour the same side of the body. It occurs when there is normally greater development of a character on one side of the plane or planes of symmetry than on the other. It is supposed to be the result of normal development and is thus genetically predetermined (Leary and Allendorf 1989).

2. Fluctuating Asymmetry:

Fluctuating asymmetry (Ludwig 1932) occurs when symmetry is in the normal state and there is no tendency for one side to have a larger value than the other and the population distribution of signed differences between the two bilaterally distributed phenotypical traits is approximately normally distributed with a mean of zero (Van Vallen 1962, Leary and Allendorf 1989). Waddington's (1957) "developmental noise" or fluctuating asymmetry (FA) develops whenever there is a gross failure to carry out genic instruction responsible to develop symmetrical expression of paired character. Thus the FA reflects the degree of developmental perturbations which an individual gained during the course of its ontogenic development.
One of the unique characteristic features of all living being is their ability to maintain the constancy of their internal milieu despite the changes in the chemical composition of an organism or changes in the surrounding environment. Whenever the magnitude of changes or 'stress' overshadows the individual canalization process (self regulatory mechanism), there is a possibility of fluctuating asymmetry.

The 'canalization' mechanism as described by Lerner (1954) is a self regulatory mechanism of the organism which permits it to stabilize itself in fluctuating inner and outer environment. This individual self regulatory mechanism or canalization process was first introduced by Waddington (1957) as "developmental homeostasis" and thereafter is being used to refer to the phenomenon whereby the development of phenotypic trait is buffered against environmental influences. As a consequence, these traits proceed towards a highly predictable genetically determined endpoint in the mature individual. It has been demonstrated that the trait expressing highest degree of deviation from normal expression or symmetry are least canalized (buffered) against the stress which incorporates a multitude of extrinsic factors such as heat, cold, protein deprivation, disease infection, self inflicted biohazards like cigarette smoking or alcoholism etc., intake of certain drugs or social factors such as consanguinity, inbreeding or some times genetical factors
like selection pressure or chromosomal anomalies. It has been stated that the nature and the degree of fluctuating asymmetry differ from individual to individual depending upon the magnitude of stress or the individual's capacity to resist local upset which itself is under genetic control (Mather 1953).

3. Antisymmetry

It refers to the apparently less common situation where asymmetry is normally present but it is variable which side has greater development. The example of this kind of asymmetry is the handedness of human population where right and left handed individuals are frequent but a significant number of ambidextrous individuals are also present.

IMPORTANCE OF ASYMMETRY STUDY

Among all asymmetries, fluctuating asymmetry which reflects the developmental disturbances or the canalization process is perhaps the major unsolved problem of biology (Palmer and Strobeck 1986). Far back Darwin (1868) remarked that it might have been anticipated that deviations from the law of symmetry would not have been inherited. Darwin's initial hunch was later confirmed by the genetic studies (Purnell and Thompson 1973; Potter and Nance 1976; Chakraborty and Rayman 1983; Leamy 1984; Mitton and Grant 1984; Leary et al., 1985) which stated that where only small, random deviations from bilateral symmetry exist the deviations in a particular direction have little or no measurable heritability. On the contrary the results of
several other studies (Mather 1953; Reeve 1960; Hagen 1973; Mackay 1980; MacGrath et al., 1984, Leamy and Atchley 1985, and for dermatoglyphic traits Singh 1970, Loesch and Martin 1982, Martin et al, 1982, Jantz and Webb 1982 ) unequivocally showed that asymmetric expression of certain dermatoglyphic traits are influenced by genetic factors. Asymmetry particularly FA is also an important tool to understand the other unsolved problems of biology. Study of FA is immensely important because it provides an appealing measure of developmental noise. The second reason is that, over the last few years a repeated observation of statistically significant result between FA and heterozygosity: the more heterozygous the individual (Leary et al., 1983, 1984) or the population (Soule 1979; Kat 1982; Vrijenhock and Lerman 1982; Biemont 1983; Leary et al., 1983, 1985; Allendorf and Leary 1986; Palmar and Strobeck 1986) the lower the fluctuating asymmetry, has been reported.

In other words, for reason yet not clear, increased heterozygosity appears to provide increased buffering against environmental disturbance during development (Lerner 1954; Mitton and Grant 1984). However, a somewhat reverse result, that is, an increased asymmetry closely linked with hybrid population (Adams and Shank 1959; Zakharov 1981; Grahm and Felley 1985; Leary et al., 1985) or a correlation between low level of FA and inbred group (Mukherjee 1985; 1989) also is reported. The third
important aspect of FA, if the level of FA reflects the degree of canalization (Mather 1953; Waddington 1957; Soule and Cuzin-Roudy 1982), is that it could be used to test for the evolution of increased canalization ability within taxa over the several million years of evolution. Fourth, fluctuating asymmetry could be a useful diagnostic measure to estimate the selection pressure in different populations as it is well understood from the fact that the pressure of natural selection is relatively greater among those who possessed extreme deviation from the fit value; mean value of bilaterally distributed quantitative traits, due to a higher degree of asymmetry.

Finally, again assuming fluctuating asymmetry reflects the degree of canalization, comparison of levels of fluctuating asymmetry among the traits within single species may reveal differences in the strength of selection for canalization of different traits. Presumably, characters of greater functional significance to the organism would be subject to stronger selection for canalization.

INDICES OF ASYMMETRY

A number of indices have been used to measure the degree of asymmetry of quantitative traits of dermatoglyphic characters particularly finger ridge counts. Holt (1954) used right minus left difference as a measure of asymmetry for finger ridge count. Another measure of
asymmetry (A) is the summed absolute difference between finger ridge counts of homologous fingers used by Parsons (1964). Singh (1968, 1970) used the mean of the squared finger ridge count differences between homologous digits, whereas Jantz (1975) proposed a measure taking the square root of squared difference between homologous fingers.

However, bilateral asymmetry can conveniently be measured by other indices such as signed right minus left difference, the mean of which represents unidirectional asymmetry and the variance of the difference evaluates the magnitude of fluctuating asymmetry as proposed by Jantz (1979). Non-signed difference between right and left variables provides a measure of ambidirectional or absolute asymmetry as suggested by Loesch and Martin (1982).